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PHYSICOCHEMICAL STUDIES OF NICKEL DOPED ZnO NANOPARTICLES

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Abstract

The physicochemical properties of zinc oxide (ZnO) nanoparticles (NPs) doped with nickel, $Zn_{1-x}Ni_xO$ (x= 0%, 2%, 4%, 6%) have been investigated. Thermal gravimetric analysis (TGA), powder x-ray diffraction (XRD), Fourier transform infrared (FT-IR), and ultra violet visible (UV-Vis) spectroscopy were used to characterize the samples, which were fabricated using the co-precipitation technique. The materialization of ZnO as well as its phase stability temperatures were determined using TGA. The formation of wurtzite and the substitution of Ni in the ZnO lattice were verified by powder XRD. With increasing Ni replacement, the average crystallite size decreased and ranged between 41 and 29 nm. The existence of vibrational modes at different energies revealed the modifications in ZnO nanostructures with Ni substitution using FT-IR spectroscopy. By increasing the Ni content in ZnO, UV-Vis spectroscopy confirmed that the bandgap decreases.

Keywords: Crystal structure; Nano particles; Optical materials and properties; X-ray techniques.

1. INTRODUCTION

Zinc oxide is a non-toxic, semiconductor-type material with tunable properties and chemical stability. It has a stable hexagonal wurtzite structure at ambient conditions[1, 2]. Because of fundamental chemistry and numerous applications of ZnO in capacitors, storage systems, and biosensors [3], their nanoparticles are important. The addition of Ni^{2+} to nanostructured ZnO boosts AC conductivity by six to eight orders of magnitude, which is beneficial for solar cell applications [4]. Zinc oxide NPs (ZnO) are multifunctional and versatile materials that may be used in a variety of applications, including photovoltaic, electronics, thermo-electrics, neutron detection, biomedicine, and spintronics [5, 6]. ZnO NPs have excellent thermal and power stability, significant exciton binding energy (60 meV at RT), and a spectrum of absorption with a wide radiation range because of a direct bandgap of 3.3 eV. ZnO is a suitable candidate for solar cells and photo detectors because of its configurable absorption and emission properties in blue light/ ultraviolet, as well as its high electron mobility and carrier concentration [7]. ZnO can be used as a substrate and active material, passivation or an interfacial surface, an anti-reflection coating, or a photovoltaic module [8]. Absorption across a wide range of wavelengths is required to enhance the power conversion efficiency of solar cells. This needs materials with different bandgaps configured in a tandem array [7, 8].

As a result, modifying the bandgap of ZnO with the goal of improving solar cell performance is desired. Doping ZnO with transition metals (TMs) such as Fe, Cu, Mn, Co, and Ni allows for such bandgap tunability and, as a result, optical absorption shift [9]. Smaller bandgap ZnO-based materials are required in the applications of photo electrochemical (PEC) and solar cells and this is dependent on the use of synthesis process and type of dopant. The doping of ZnO with TM sources, Ni doping has the potential of shifting the optical bandgap to the region of red wavelengths [10]. Ni^{2+} is one of the most effective dopant TMs in ZnO

due to its chemical stability while inhibiting Zn^{2+} sites. The electrical and optical properties of ZnO improved due to unpaired electrons in Ni's d-orbitals, which have the ability of carrier's interactions [11]. The effect of Ni doping in ZnO is greatly influenced by the synthesis method employed. With increasing the Ni content from 2% to 15%, the bandgap of Ni-doped ZnO decreased from 3.43 to 2.87 eV, synthesized via spray pyrolysis deposition on quartz substrates [12]. Also, observed the reduction in the bandgap from 3.2 to 1.4 eV up to 7% of Ni-doped ZnO, fabricated by DC/RF magnetron-sputtering technique [13]. At the same time, the bandgap of Ni-doped ZnO NPs produced by the sol-gel method increased from 3.29 to 3.32 eV [14].

In this manuscript, the synthesis, thermal, structural, and optical properties of pure and Ni-doped ZnO NPs, demonstrating the structural transformation caused by Ni are reported.

The co-precipitation method was used to synthesize un-doped and doped Ni-ZnO NPs ($Zn_{1-x}Ni_xO$, x = 0.00, 0.02, 0.04, and 0.06), following the previous reports [4, 15], and the sample fabrication steps are depicted in Fig. 1.

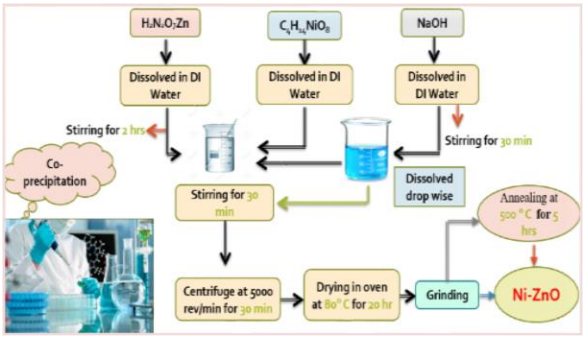


Fig. 1. Synthesis route for $Zn_{1-x}Ni_xO$ NPs.

A simultaneous thermal analyzer was used to perform the thermal analysis in the air atmosphere at a heating rate of 10 °C per minute. A two-stage weight loss is indicated by a TGA transformation from 60 °C to 550 °C, as shown in Fig. 2. Since the evaporation temperature of nitrates is about 130 °C, weight loss in the first stage is due to dehydration on zinc nitrate hydrate, where 2% weight loss occurs above the 102 to 165 °C limits. In the second step, zinc nitrate hydrate decomposes into zinc oxide, resulting in a 7.5% weight loss before 310 °C. Although the decomposition of nitrate ions begins at 312°C, nitrogen peroxide, as well as a line attributed to the N_2O^{-4} radical, can be seen at temperatures ranging from 240 to 550 °C. Up to 310 °C, an absolute weight loss of 9.5% occurs; after this temperature, no significant weight loss occurs. The temperature at which ZnO achieves phase stability is 310 °C. This finding is consistent with previous research [16-18].

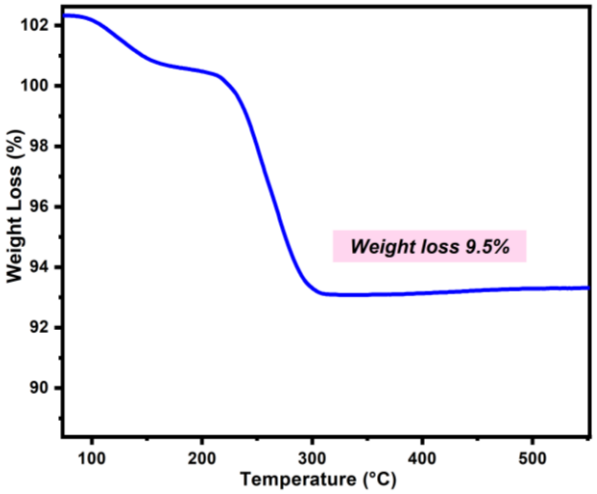


Fig. 2. TGA trace of pure ZnO NPs.

An X-ray diffractometer with CuK_α (λ =1.5406 Å) was used to perform X-ray diffraction (XRD) of the annealed samples at room temperature. Fig. 3a shows the indexed XRD patterns of all the samples. JPCDs card no. 89-1397 matches with all the peaks perfectly. The indexed patterns correspond to reflections from the hexagonal wurtzite structure of ZnO [19, 20]. The diffraction patterns of $Zn_{1-x}Ni_xO$ for x = 0.02, 0.04, and 0.06, display XRD characteristic lines like those for un-doped ZnO NPs when Zn atoms are partially replaced by Ni atoms in the crystal lattice and conform the single-phase hexagonal wurtzite structure of ZnO is preserved for all the Ni substitutions. Fig. 3b shows an enlarged view of the peaks shifting towards the higher diffracting angle in the XRD characteristic lines for $Zn_{1-x}Ni_xO$ NPs (x = 0.00, 0.02, 0.04, and 0.06), demonstrating the non-uniform stresses generated in ZnO. As a result of XRD analysis, slight changes in the values of lattice constants can be predicted and estimated using standard relations [21]. The *a* and *c* values decrease slightly when Ni is substituted in the $Zn_{1-x}Ni_xO$ lattice due to the smaller ionic radius [22] of Ni^{2+} (0.69 Å) compared to Zn^{2+}(0.74 Å), but the *c/a* ratio remains nearly the same. The average crystallite sizes for nickel-doped ZnO nanostructures estimated by the Scherrer equation [21] range from 41 to 29nm; the decrease in crystallite size is due to the mismatch of Ni^{2+} and Zn^{2+} ionic radii [16]. The specific surface area [22] increases as the crystallite size decreases. The values of various parameters corresponding to different concentrations of Ni substituted in ZnO are tabulated in Table 1.

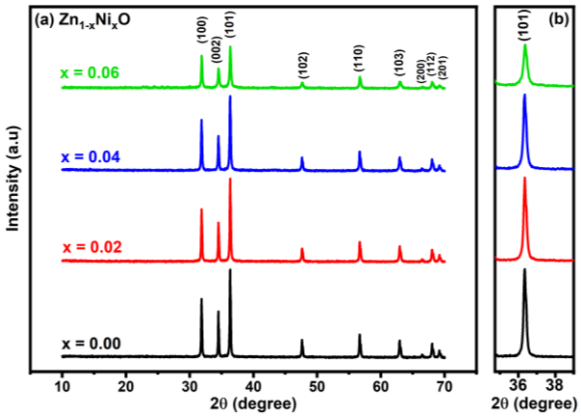


Fig. 3. (a) X-ray diffraction patterns (b) Enlarged view of the (101) peak shifting for $Zn_{1-x}Ni_xO$ nanostructures.

FT-IR measurements have further confirmed the formation of the Wurtzite structure of $Zn_{1-x}Ni_xO$. FT-IR spectra observed in the 400- 4000 cm^{-1} are shown in Fig. 4. The band around 522 to 505cm^{-1} corresponds to the vibrational energies of zinc oxide bonds that may have hexagonal vibration mode characteristics, indicating that ZnO was formed [4, 23]. By comparing the FT-IR spectra of pure and Ni-doped ZnO nanostructures, the effect of Ni doping on structural modification of ZnO nanostructures was investigated. The Ni-O bond is detected with a peak at 625 cm^{-1} in 6 % Ni-doped ZnO spectra, suggesting active Ni substitution in ZnO lattices, which is due to vibrations of Zn-O-Ni local bonds and modes from defect states, which involves increased Ni substitution in ZnO [15]. The vibrations of C-O stretching due to the accumulation of carbon monoxide from moisture in samples are represented by the band at 1099-1086 cm^{-1} [24]. The peaks at 1618 and 1648 cm^{-1} for 4 % and 6 % Ni-doped ZnO are associated with O-H bending vibrations of water molecules (H_2O), a small amount of moisture in ZnO NPs. H-bonded O-H stretching can be seen in the 3428 to 3471 cm^{-1} zone [25].

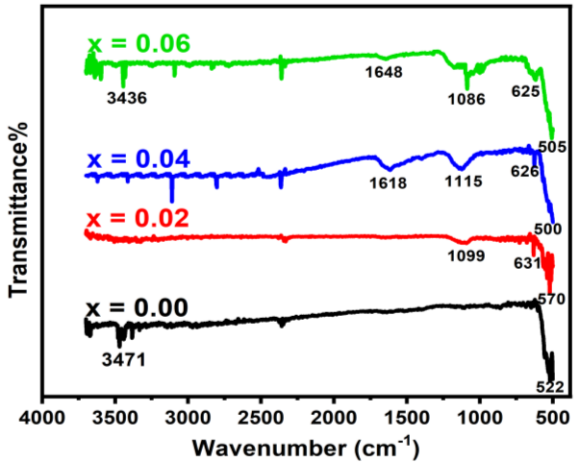
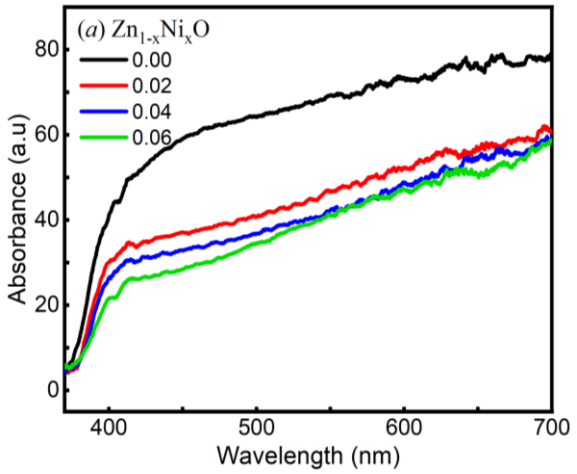


Fig. 4. FT-IR spectra for $Zn_{1-x}Ni_xO$ NPs.

The diffused reflectance distribution of ZnO and $Zn_{1-x}Ni_xO$ is shown in Fig. 5a. When Ni is substituted, the signature shoulder becomes red-shifted, implying a reduction in the bandgap [18]. The narrowing of the band edge also indicates that Ni has been incorporated into the ZnO crystal structure [19, 20]. Gao et al. [18] found the same redshift in Ni-doped ZnO. As Ni is incorporated, the reflectance edge redshifts, which may be due to the formation of a faulty Ni energy level. Zn causes a shallow donor level below the conduction band as a donor impurity, lowering the bandgap of ZnO.



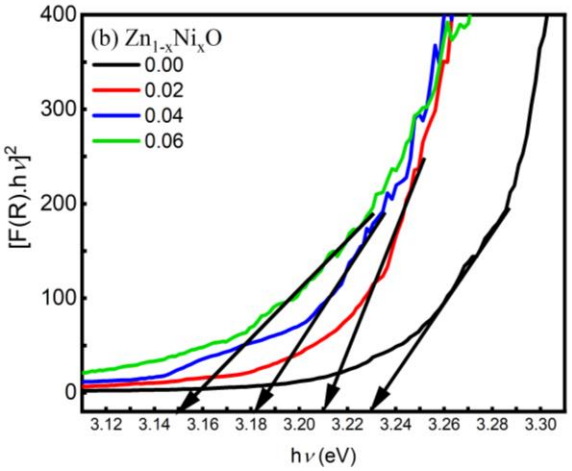


Fig. 5. (a) Reflectance as a function of wavelength at room temperature (b) Tauc plots as a function of energy for different concentration of Ni in ZnO.

The bandgap decreased from 3.23 eV to 3.15 eV as Ni concentration increased, as tabulated in Table 1. The decrease in bandgap may be attributable to sp-d exchange interactions of substituted divalent ions between band electrons and localized d electrons [15].

Table 1. Lattice constants, c/a ratio, average crystallite size, density, specific surface area, FT-IR data and optical bands of Zn_{1-x} Ni_xO.

Composition (x)	**0%**	**2%**	**4%**	**6%**
Lattice constant, a (Å)	3.24(±1)	3.241(±1)	3.24(±1)	3.23(±1)
Lattice constant, c (Å)	5.19(±1)	5.19(±1)	5.19(±1)	5.18(±1)
c/a ratio	1.602	1.602	1.602	1.602
Volume ($Å^3$)	47.30	47.22	47.11	46.94
Crystallite size (nm)	41	38	36	29
Density (g/cm^3)	5.72(±1)	5.716	5.72	5.75
Specific surface area(m^2/g)	25.38	27.50	28.89	35.95
Zn-O bond (cm^{-1})	522	570	500	505
Ni-O bond (cm^{-1})	-	631	626	625
C-O bond (cm^{-1})	-	1099	1115	1086
H-O-H bond (cm^{-1})	-	-	1618	1648
O-H bond (cm^{-1})	3428	-	-	3436
Bandgap (eV)	3.23	3.21	3.18	3.15

It is concluded that the co-precipitation method was used to prepare $Zn_{1-x}Ni_x$ O (x = 0, 2, 4, 6%) samples successfully. Thermo-gravimetric analysis indicates that 310°C is the phase stability temperature for zinc nitrate hydrate decomposition into zinc oxide. All the samples have the hexagonal wurtzite form with a slight peak shifting in the diffraction angle with doping of Ni are established from the XRD analysis. The crystallite size decreases as the Ni content in the ZnO lattice increases. The formation of the ZnO phase and Ni^{2+} substitution is confirmed by the absorption peaks at 522 and 625cm^{-1} in FT-IR analysis. The optical bandgap narrowed as the concentration of Ni increased in the samples.

NOMENCLATURE

ZnO	Zinc Oxide
Zn	Zinc
Ni	Nickel
O	Oxygen
TGA	Thermal Gravimetric Analysis

XRD	x-ray diffraction
FT-IR	Fourier Transform Infrared
UV-Vis	Ultra Violet visible
NP	Nanoparticle
AC	Alternate current
RT	Room Temperature
eV	Electronic Volt
TM	Transition Metals
Cu	Copper
Mn	Manganese
Co	Cobalt
Fe	Iron
α	Alpha
λ	Lamda (wave length)
Å	Angstrom
H	Hydrogen
H2O	Water

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US-RUSSIA CONFLICT IN MIDDLE EAST

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Abstract
The study concentrated on the key areas of Russian influence which Russia sought to safeguard against American hegemony and attempted to pinpoint the areas in which the United States and Russia contended in the Middle East and the Arab world. System analysis in international relations was utilized in this study since it is pertinent to the subject. The primary subject the study seeks to address is, "What are the internal and external variables that directly promote Russia's increasing position in the global system?" The study came to the conclusion that Russia was able to retain its zones of influence without the help of American hegemony because of its reforming efforts.

Keywords: US, Russia, Middle East, Rivalry

2. INTRODUCTION

The basic argument behind Russia's foreign policy is that the Middle East's geostrategic position prevents the World Order from developing independently of the region. Russia views the Middle East as a key region for maintaining the balance of power. Maintaining the proper pace of peace and stability, Russia strives to avoid directly interfering in the internal affairs of those nations via its Middle East policy. In an effort to get the maximum reputation and respect, this is done. In actuality, Russia wanted to protect its spheres of influence against invasion. In opposition to the US domination over the Middle East, especially the Arab area, by developing closer ties with nations like Iran, it fights the US by enlarging its spheres of influence in the Middle East. Russia started upholding the ideas of non-intervention and the fight against terrorism after the upheavals of the Arab Spring. Adopting such a policy is a strategy for regaining its active duties alongside the American presence, as well as for gaining support and legitimacy to keep its place in vital sectors [1].

3. LITERATURE REVIEW

The research by Andrej Kreutz looks at the objectives and plans that the former Soviet Union and Russia had for the vast majority of the Arab Middle Eastern nations. Before the fall of the Soviet Union in the early 1990s, the author claims that Russia had been a prominent player in the area for more than a century and had made efforts to reassert its influence in a number of nations2]. Kreutz claims that Moscow has no desire to wage war against the US or other nearby Western countries. Due to its proximity to its borders, Russia is particularly concerned in ensuring peace and stability in the region. In addition to wanting to see a just and reasonable resolution to the Arab-Israeli and Palestinian-Israeli conflicts that takes into account the interests of both the Arabs and the Palestinians, Moscow wants to see improved ties with Israel. In his research for a significant position in the globe, Mohammed Majdan focused on Russia's proactive role in crisis management and containment As Russia supports a multi-polar world, it also rejects the domination of one pole [3]. The study focused on Putin's substantial role in the development of Russia's internal political structure and his initiatives to develop a foreign strategy that would enable Russia to regain its preeminence. Russian Policies towards the Middle East is the title of a study by Ahmed Saied. Sayed examined the nation's overall foreign policy, which updated the objective of creating a safe world order based on international law as well as the Russian position in the region. He also emphasized Russia's involvement in other regional issues including the Syrian war and Iran's nuclear programme.

In his research, Nourhan Alsheikh examined several problems in the Arab area and emphasized Vladimir Putin's accomplishment in creating a strategy that allowed him to get Russia out of the instability and upheaval it was experiencing [4].

Karim Mufti argued in an analytical research that attention should be paid to the rise of strong regional

actors like China and Russia. He also emphasized the geopolitical goals behind Russia's steadfast return to the Middle East, and he illustrated its stance on the Iranian nuclear problem and the Syrian conflict

4. FOREIGN POLICY OF RUSSIA

Russia has a prestigious place on the global stage. Its powerful military capabilities and strategic position have greatly impacted its economic standing, which is shown by its advancements in technology and science. Since 2000, Putin's reforming measures have allowed Russia to firmly re-enter the world political scene and grow into a significant player in shaping international affairs. These strategies have enabled Russia to successfully overcome all of its challenges, including the threat of disintegration and secessionist movements. Particularly in the age of globalization and technical advancement, Russia was allowed to adopt stances in world affairs that benefited its objectives [6]. Putin was able to implement a policy that intended to increase the authority of the central state, increase its strategic skills and influence on political and economic institutions. He also embraced a strategic strategy to make the most of the nation's resources, notably its oil and gas, in an effort to revitalize the Russian economy and improve the standard of living for its population. Russian foreign policy, which progressively restored Russian prestige in an effort to increase security, directly mirrored this [7].

- The following are the major characteristics of Russian foreign policy:
- The effort to reverse unilateral polarity and start the multi-polarity trend.
- Encouragement of democratic practices has been the main goal of improvements to the nation's foreign policy and the tactics used to support and strengthen democracies.
- Join the Commonwealth of Independent States in dialogue.

In order to combat terrorism and keep an eye on the proliferation of WMD, President Putin emphasized Russia's dogged pursuit of constructive collaboration. This goal would be reflected in measures to prevent political conflicts from occurring, which would harm the goals of the new Russian policy. President Putin emphasized once more that in order to set the rules of the game, powerful countries could not exclude Russia from global politics and the economy [8].

With the assistance of this strategy, the nation will be able to compete with the world's superpowers and aim to join a number of international political organizations. The Asia-Pacific Economic Cooperation Forum and the Group of the Major Industrialized Countries are two examples of this. Although Russia has achieved tremendous economic gains, it now has to speed up economic development via indicators if it wants to regain control over the price of oil and gas. Russia is regaining her former splendour and has been able to completely capitalize on all of the opportunities by taking on more responsibility in international affairs and convincing the world that she has been able to overcome her fragility and instability. Russian foreign policy should be seen as national, and Russia should be given back its former stature.

- Improve strategic ties with long-standing allies including China, Iran, and India as well as friendships with those powerful nations in world affairs; Increase Russian influence, achieve strategic plan, and reestablish political and economic stability.
- Reach agreements with neighbouring nations that will help bring about peace and make a peaceful policy appealing.
- Co-operate with Commonwealth of Independent States members.

Through its management of some crises, like the Georgian conflict, Crimea's recovery, and eastern Ukraine, Russia has significantly increased its political presence. It is evident that the notion of "priority interests," or, to put it more specifically, that Russia's interests come first, is the cornerstone of Russian foreign policy in the Middle East, particularly in the Arab world. The relationships between various Arab nations and Russia may be used to illustrate this. Several people do not see relations with Russia as a secure option to connections with the United Governments, and as a result, some Arab states maintain complicated relations with Russia while also forging ties with the US, which would place constraints on Russian activities in the region13. Based on these fluctuations and inconsistencies in ties, one can get the conclusion that Russia's position on the

issue is vague and that the country's interests could lead it to make a different decision than what is expected. Russian regional expansion is influenced by US policies and the dynamics of regional internal exchanges. No matter how hard Russia tries, it is unable to stray from some aspects of its relationship with the United States. The two sides' views may converge, changing everything, and the Arab nations would then adopt a denunciation-only stance [9].

5. US-RUSSIA STRATEGIC RIVALRY

Russian policy aims to coordinate its foreign policy including its domestic goals in light of the perceived notion and realization that the world has evolved and that foreign policy may change in a way that enables major countries to work cooperatively to actually solve their internal problems—especially financial ones, which are directly linked to other problems—at the expense of other stakeholders through peaceful means. The US strategy and Russian policy share many of the same objectives. Russia is attempting to position its navy in the Mediterranean as a result. We could see a significant Russian entry into regions where the United States has failed with the help of a Syrian military base. The distinctive features of Russian strategy in the Middle East include;

Russian policy is now again active and prominent in world affairs, particularly since it was able to overcome its economic crises. Given that a substantial return was anticipated and that this return carries messages, it is possible that Russia would use every tool at its disposal to retain its spheres of influence, particularly given the Syrian situation [10].

Fill the void, especially given that the majority of analysis points to the likelihood that the United States is about to end its presence in the region after being on the verge of abandoning its presence in some areas, and that the Middle East's issues have not been resolved by the US, which has approved of Russia's robust presence to fill the hole after its departure.

After the turmoil and instability that the so-called Arab Spring caused, it is imperative to guarantee that the area is stabilized as quickly as possible. Saudi Arabia set the example for this development, demonstrating a keen interest in the Syrian issue in order to avoid having a significant negative impact on the region. As a result, Saudi Arabia is prepared to make up for Russia's loss in Syria in an effort to prevent the region from further disintegrating. Many rumours surround the possibility of Saudi Arabia providing financial support for the so-called Arab Spring. Russia opposes a number of US actions in the area, including the building of the missile shield, this it claims is aimed entirely at Russia and not at any other region since it feels that these regions are under Russian influence [11].

Although they have different dimensions, some people think that the US's objectives in the region and the increased activity of Russian foreign policy in the region and the achievement of some Russian strategic interests—which do have political overtones that frame Russia's relations with its allies—are essentially comparable. First, it seems that Russia wants to preserve the current situation in the Middle East, which was formed following the Arab Spring upheavals. Russia also believes that the US is supporting colored revolutions in the region, which may be a sign of the end of the Cold War. Both the forces in favor of and against the colored revolutions make up its parties. The belief that American interests are threatened by Russian interests is the second factor. The advice is for Russia's partners to avoid the United States. All of the area's active players, including States and non-State entities, are covered by the third dimension. Examples include think tanks, civil society groups, and the US's instruments for sowing unrest across the targeted region [12].

6. ROLE OF RUSSIA IN ARAB WORLD

Politicians in Russia see the Middle East as a crucial geostrategic region that can contribute actively and significantly to world affairs. Due to Iran's geostrategic and geopolitical significance, Russia has obviously taken on a role in the Middle East by backing its nuclear program. Russia now intends to establish a strategy in the region by turning Iran into a strategic ally. Along with Syria20, Georgia, Ukraine, and the Crimea are other crisis zones where Russia is attempting to increase its involvement. Russia wants to take advantage of chances and use its political know-how. Given the US's betrayal of its partners, it believes that the results of the Arab Spring may be utilized to further its own objectives [13]. A prominent example of this is how it has handled President Bashar al-Assad in the present situation in Syria. Russia

actively participated in the conflict. , backed military operations, kept up its Tartus naval station, and built air bases in Latakia in order to earn the respect of its allies. For instance, the United States' reputation with its allies was weakened when it abandoned Egyptian President Hosni Mubarak. In order to achieve military deals on weapons and other energy-related activities, it tried to develop these relationships. Because Iran and Russia cooperate closely, the latter had a better chance of strengthening its economic links with Iraq (in exchange for the American failure). Along with its policies toward Iran, which reflect its positive ties with other nations like Iraq, this was also the case (in exchange for the American failure). These positions refute the idea that Russia has lost the ability to protect its allies and use force to influence international affairs [14]

7. FUTURE PRESPECTIVE OF US-RUSSIA RELATIONS

Due to a well thought-out plan for its reappearance in the Middle East, Russia has been able to make a significant comeback on the global stage. It was highlighted that Russia has made enormous strides in the previous 10 years in terms of its connections with critical regions including Central Asia, East Asia, the Brix Group, and the influence of international choices. Also apparent is Russia's persistent stance on the Syrian problem and its strong ties to American failures like Iraq. Thus, it is feasible to see the scope of Russia's vision for intensifying Russia's involvement in international events and expansion of its influence in the Middle East are in its best economic and military interests [15].

It is hard to avoid the American presence in the Middle East given all these shifts in Russian views toward the area, particularly the Arab world. Even if the United States were to allow Russia some wiggle room, their rivalry would still be driven by how the world is changing and intensify to suit the various interests of each nation. Although Russia has undertaken diplomatic efforts, fiercely criticized the US stance, and disagrees with US policy on a number of issues, the US presence and influence in nations like Iran and Syria cannot be diminished. Russia's foreign policy has not fundamentally changed in reaction to the US confrontation or full challenge, whether in respect to the Middle East or other matters. Several things support this, but the most significant one is that the Russian leadership sees American activities as endangering Russian interests. In order to actively engage, Russia is well aware that doing so will allow it to reclaim some of the positions of power that it has lost in the area [16].

Despite Russia's increasing desire to reclaim its global stature, The United States cannot relinquish key spheres of influence and may do so at any time. Instead, it chooses to remain silent in the face of Russia's expanding dominance. Alliances that accomplish shared objectives may be seen as a result of changes in global circumstances. The interests that cause foreign policy to vary its direction, rather than constants, determine whether foreign policy is successful. Regardless of its reason for action, Russia is acting strategically and diplomatically in ways that serve its interests and those of the United States in the area, according to developments and world events. Therefore, regardless of how Russia attempts to take advantage of the opportunity, American goals collide with them, taking into consideration the many ways that each party maintains its interests. Russia positions itself as a state that does not aim to intervene militarily or violently in the affairs of other nations via crises and revolutions [17].

As a result, individuals have different perspectives on Russia than they do on the US. As we know it based Russia thought the movements of Arabs are being influenced by outside groups that the United States has sponsored. As a consequence, in the case of ongoing and widespread loss, which necessitate the appearance of supportive teams in opposition to the rejection powers and exacerbate tension. Contrarily, the Middle East is marked by balance, which underscores the legitimacy of its friends. As a result, the region's political history and allies' positions increase the likelihood that America will be seen as a threat to the region's stability, which presents another chance for Russia to boost its self-assurance and uphold its interests. Russian hostility to US policies extends beyond only the Middle East.

NATO expansion on the Russian border was opposed by President Putin, showing his disapproval of American hegemony or a single pole. Russian positions in the Arab world may benefit from this.

Additionally, in order to enhance its position and improve its performance in international affairs, Russia is expanding its diplomatic efforts to China, India, and the major Asian nations. Given that these alliances may push Russia in a number of ways, notably economic ones, Arab states see Russia as a competitive ally to the United States as a result of such Russian acts [18].

As a result of abandoning its regional friends in times of crisis, this division may have an impact on American ties with them. Furthermore, others believe that Russian policy is practical, particularly after restructuring, and that it has made greater progress in terms of advancing national interests, therefore its influence on world affairs is growing. After losing faith in its friends and governments, the Arab Spring area lends legitimacy to this claim. As part of its efforts to combat terrorism, Russia has also signed several agreements and deepened its ties with allies in the Arab world. These agreements include the sale of Israeli drones to Russia moreover, the establishment of contact lines among Russian Intel. Agencies and their Middle Eastern counterparts. In the Arab world, Russia has grown more and more competitive with the US. Due to its power to alter the rules of the game, it won't give up the leadership position it has in international affairs, which has sparked a huge weapons race. The nation has a different approach to crisis intervention than the United States, which favours using military force and direct action.

No matter how far along their ties have gotten, Russia and the US relationship is characterized by a need to exercise caution. Russian efforts to retake the top rank in the international arena have been persistent, especially after Russia abandoned its ideology and started to believe that the world is dominated by the interests of a few nations. As a result, this change in global politics now serves interests in control and power. Their history has been defined by this competition. Putin has chosen to use a combination of strong and soft power to achieve its objectives.

8. CONCLUSION

Unprecedented volatility in the US-Russian relationship with respect to the Middle East has recently emerged. Patterns and structures have endured despite the Middle East's long history of infamous volatility brought on by wars, revolutions, civil unrest, military coups, and regional and international competition. There were state structures, connections among Arab countries, and interactions between the Arabs and Israel. Disputes between the US and the USSR during the Cold War. Putin's declaration of the new foreign policy tenets of Russia aims to eliminate one-pole dominance. , build a multipolar international order, and restore Russia's leadership engagement in global events and developments, signaled the start of a new era for Russian foreign policy. In an effort to alter public impressions of the new Russia—one that has attempted to regain its old dominance while demonstrating via the management of crises and its foreign policy that it has no desire to be a hegemon—Russia has altered its foreign policy, particularly in the Middle East. Instead, its participation aims to establish a mutually advantageous strategic relationship with regard to the economic and development aspects. Given the issues brought on by the Arab Spring and the US military's missteps in Iraq, Afghanistan, and the Caucasus, the world is ready to reject uni-polarity. Throughout these crises, it changed the balance of power and opted for a more gentle strategy rather than one that included using force.

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EMERGING TRENDS OF CONTEMPORARY WARS IN SOUTH ASIA

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Abstract

Since ancient times, wars have been embedded in societies as the human civilization evolved. Even though the nature of war remained same throughout the human history, its character has always evolved with the evolution of technology. Every time a new technology enters the international arena, it had an impact on warfare. In modern times, the technology has a significant influence on how wars were fought during the 1950s especially in South Asia. However, the emergence of hybrid warfare has become a new trend in South Asia specifically in recent times. This research aims to understand the emerging trends of warfare in South Asia with a special focus on hybrid war as a growing phenomenon in the region. It will rely more on qualitative research methodology. Since every technological advancement has affected warfare differently, the study will predict the potential future of hybrid warfare in South Asia. The study concludes that the conflicts in South Asia would likely to remain hybrid in their conduct and may further intensify with the emergence of new technologies.

Keywords: Contemporary Wars; Emerging Trends; Hybrid Warfare; Emerging Technologies; South Asia.

1. INTRODUCTION

Since the beginning of mankind's history, wars have been ingrained in societies as a necessary component of society. As civilizations evolved, humans began to participate in activities that were intended to eliminating their opponents. Over the period, people modernized the role of combat, making it even more complicated than it had been in the past. This seems to be consistent with earlier studies, which described how the emergence of military tendencies coincided with shifts in cognitive processes and how the development of both peace and conflict was facilitated by the same thinking [1]. The notion of warfare changed with technological advancements, yet combat has stayed the same throughout history. Every time a new technique to fight a war was invented, it had an impact on the strategies and tactics being used. In each era of war that has occurred across civilizations, innovative war plans have been crucial. The technology used to have a significant influence on how the wars were fought during the 1950s, notably in the South Asian region. Later on the overt nuclearization of South Asia in 1998 also had a significant impact on the character of warfare in the region. However, since the use of nuclear weapons may be catastrophic for mankind and can only be employed for deterrence, the likelihood of a large scale war has significantly reduced in South Asia. Both India and Pakistan have switched their focus to unconventional warfare tactics. The term "Hybrid-Warfare" refers to an idea in warfare that has emerged since the start of the twenty-first century and involves both technological and human involvement to outpace the opponent. The idea has transformed every aspect of combat since its emergence in the South Asia.

The concept of hybrid warfare has become increasingly popular in South Asia in recent times. With the utilization of different tactics, for instance, misinformation, economic harm, political unrest, extremism, coercive diplomacy, domestic conflicts, and proxies against the enemy, hybrid warfare aims to damage the enemy state from within and bring it into disrepute at the international arena. The adversaries in South Asia label nearly every occurrence that provokes conflict among both states as a hybrid war. The research seeks to comprehend the modern conflict tendencies in South Asia. It will specifically examine the hybrid war as a growing phenomenon in South Asian warfare by differentiating it from traditional warfare. Since advancements in technology may affect the conduct warfare in any way, therefore, the study also explore the impact of these technologies on the future of hybrid warfare in South Asia especially between India and Pakistan. Even though emerging technologies have been considered in this paper as a new instrument for warfare, it is more likely that conflicts will continue to be hybrid despite their introduction.

2 PRINCIPLES OF MODERN WAR

2.1 Information Domain:

It's not a novel strategy to obtain information from multiple sources to utilize against opponents. Romans were among those who used embassies for spying in different states. Similarly, spies were used to collect information in WW1 and American civil war. The domain where data is gathered, processed, changed, and distributed is known as the information realm. Among the most notable cases are psychological manipulation, information warfare, and the media [2].

2.2 Social Domain:

Politicians base their assessments of the will of people on religion, society, ethnicity, customs, beliefs, and behaviors. It also refers to the area of human activity where individuals and groups of different cultures interact, share ideas, and come to mutually acceptable decisions [3].

2.3 Cognitive Domain:

It refers to the field where fundamental ideas like purpose, doctrine, strategies, procedures, security norms, and war plans first appear. Kinetic and non-kinetic aspects are combined in this field. The objectives, plans, and tactics used in non-kinetic warfare are what define the cognitive realm [4].

3. HYBRID WAR AS AN EMERGING TREND IN SOUTH ASIA

Hybrid warfare is among the most debated phenomena of the twenty first century. As the term "hybrid" indicates, it is a combination of prior conflicts, including; both military and non-military operations. In hybrid warfare, a variety of elements are combined to wage war on the opponent. Hybrid warfare has origins in earlier war-fighting strategies, therefore it is not entirely new as a classification of war, but it has the power to influence how a battle is perceived in the future. There have been several conflicts throughout history in which several state and non-state actors, have used a mix of irregular, conventional, and non-conventional tactics to achieve political and military goals. It is a military strategy that employs both kinetic and non-kinetic tactics of combat to advance political goals. In the military realm, the techniques utilized in hybrid warfare get an ancient legacy of productive operations. Risks and actions of warfare are defined and identified using hybrid warfare. [5] In recent years, hybrid warfare refers to irregular and conventional operations that also include cyber-attacks and escalating domestic proxy conflicts. Attacks are carried out by states against other states, with non-state entities also taking part. Given that hybrid warfare incorporates all of the earlier forms of conflict, the idea is not new. It also uses strategies employed in conflicts from centuries past, such as the use of awe and shock, and espionage. [6] Due to unfamiliarity with the term or the fundamentals of hybrid warfare or any other developing tools and approaches, it is frequently assumed as a newer concept. Due to a lack of understanding, a confusion still exists about the concepts of hybrid warfare, fourth-generation warfare, and fifth-generation warfare. By targeting a state's weak areas, hybrid conflicts are forced upon it, and the targeted government only realizes the threat after it has been completely waged against it [7]. These wars are conducted to exacerbate state identity conflicts and exploit historical cultural, religious, and geographic fault-lines that, in the end, cause a state's destabilization, and ultimately strategic stability of a specific region.

The three primary forms of warfare that make up hybrid warfare could also be further divided into different categories [8].

1. **Asymmetric Warfare-**This also covers unconventional and non-kinetic forms of combat
2. **Irregular Warfare-**encompasses guerrilla warfare, terrorist, and other irregular attacks
3. **Compound Warfare-**a quick deployment of regular forces with an irregular group using guerilla tactics against the adversary

The UK Ministry of Defense characterized hybrid warfare as;

“Hybrid warfare can be characterized as a comprehensive strategy based on a broad, complex, adaptive, and often highly integrated combination of conventional and unconventional means. It uses overt and covert activities, which can include military, paramilitary, irregular, and civilian actors, targeted to achieve (geo) political and strategic objectives. Hybrid warfare is directed at an adversary’s vulnerabilities, focused on complicating decision making, and conducted across the full spectrum (which can encompass diplomatic, political, information, military, economic, financial, intelligence, and legal activity) whilst creating ambiguity and deniability. Hybrid strategies can be applied by both state and non-state actors” [9].

Another way to define hybrid warfare is "warfare that involves a blend of irregular forces and ground forces are employed to target the enemy, by leveraging means like media, economics, political unrest, extremism, coercive diplomacy, domestic conflicts and proxy strikes, to internally weaken and globally embarrass any state."

Owing to the hybrid character of the term itself, hybrid warfare is seen as a vague and poorly defined notion. Similar to many other phenomena, hybrid warfare lacks a generally accepted definition. It is often described in accordance with the way how an institution understands it. From 2002 till 2015, the idea grew in acceptance, notably after the Russian Hybrid War in Ukraine [10]. The idea spread throughout South Asia only when military leaders of Pakistan and India began discussing it. Military leaders in South Asia were the first to promote the idea of hybrid warfare, followed by policymakers [11].

One of the main characteristics of hybrid warfare which makes it even more successful is the opponent's ability to simultaneously attack the ideology and kinetic centers of gravity, reducing a state's available physical and mental space. The aim of hybrid warfare is to shake up ideologies, alter a country's identity, and even bring about regime change rather than to achieve a decisive conquest [12].

Here are a few indicators of hybrid warfare in South Asia. The attack on the Sri Lankan cricket team in Lahore in 2009 resulted in the suspension of international cricket matches and events in Pakistan, the rejection of Pakistani players' visas for Asian competitions [13], and economic coercion in the FATF (Financial Action Task Force. The 2008 Mumbai attacks, the January 2016 Pathankot attack, and the Uri incident all ultimately ended in a blame game, further putting strain on India-Pakistan relations. Terrorist attacks on several important military institutions, which include GHQ, Mehran Naval Air Base, and Kamra Air Base, have also undermined national morale. The 2014 Army Public School Incident, the involvement of RAW (Research and Analysis Wing) in exacerbating security issues in Karachi and Baluchistan, generating economic and political upheaval in Pakistan, and have risen in recent times. During the past 20 years, countless Pakistani websites have been hacked.

3.1 Fifth Generation Warfare

In the fifth generation, non-state entities conduct hostilities without any defined goal, which shapes the perception that these forms of unconventional warfare are driven by hatred. This may restrict future generations' access to contemporary joint arms forces. Rather than employing physical combat techniques, this novel notion in warfare develops the fight for ideas and curbs extremism internationally.

Fifth-generation warfare has already been waged against Pakistan through the media, cyber-attacks, money laundering, bank account hacking, etc. [14]. Electronic and social media are the firing line of fifth-generation conflict. The primary goal of the fifth generation is to use various techniques to target the audience to have a psychological influence. India has been active in conducting psychological operations against Pakistan through terrorist attacks, deploying spies to Baluchistan, and campaigns on social media with the help of local and international news outlets [15]. These agencies have contributed to the propagation of anti-state agendas. In 2016, the arrest of Indian Spy Kalboshan Yadav, an Indian Navy officer, in Baluchistan is evident of the fact that India has waged an active hybrid campaign against Pakistan. He revealed the Indian government's intentions for hybrid warfare, including the use of Baluchistan's territory for political purposes. He confessed that by instilling a criminal mindset that encourages murder and disrupts the operations of Gwadar port-hybrid assaults on CPEC (China-Pakistan Economic Corridor), he has contributed to the unrest in Pakistan [16]. Then, in March 2020, a second RAW agent was captured at Karachi University for carrying out criminal, terrorist, and anti-state propaganda-making operations [17].

3.2 Information Warfare

Information warfare is a term for fifth-generation warfare. Both nations are emphasizing information warfare, obtaining the enemy's data through spies and exploiting it against them. States are focusing on information warfare, media warfare (which encompasses social media and electronic media), and psychological warfare in this area. It concerns information gathering as well as information that may be changed and presented to the public incorrectly. In information warfare, the media is a key player. The fight to manage perceptions is fifth-generation warfare. Disinformation is an essential part of almost every military doctrine, with the main objective having to be to intimidate the enemy [18].

The formation of narratives is greatly influenced by the media. Media is one of the main tools used in contemporary information warfare to target the population of the enemy. The Indian government is using the media as a battleground to ensure the success

of hybrid war against Pakistan. By propagating false information and concentrating on the public, the media is employed as a weapon in hybrid warfare to accomplish a specific goal. Certain people have extremist beliefs; the narrative cultivated by the media directly targets them, and they can be misused to spread chaos and instability in a nation. The Magic Bullet theory by Harold Lasswell proposes that media messages are directly fired like a gunshot into the targeted viewers' minds. The audience is influenced by whatever the media broadcasts. As a result of the efficiency with which youth might be targeted by social media, the Indian government is investing billions of dollars in propaganda campaigns on Pakistan. People were easily misled by such agendas supported by the enemy state through the media since the general population was unaware of the notion and growing threat of conflict [19].

3.3 Fake News

The Indian government supports yellow journalism internationally because it presents Pakistan to the world as a state that supports terrorism and uses the media to broadcast false information. The Indian government spends $7 billion on media efforts against Pakistan [15], which include the use of print media, television, movies, plays, and literature. The Indian government released numerous applications supported by RAW as part of their media campaigns. RAW officials broadcast the radio station in the Balochi language, making it one of the tools used to incite hatred for Pakistan among the Balochistan people. India is making similar attempts to destroy Pakistan's national identity under the name "ZEE SALAM" [15]. To further pursue its agenda, the Indian government is spending a significant amount of money to help journalists and overseas news organizations, notably Pakistani journalists and social activists. Also, revealed in the EU Dis info Lab report of 2020 [15]. On social media, Indian RAW has set up some 350 phone identities with Balochi names, with which they post, share, and give speeches against Pakistan. These fictitious personas quickly spread any post or comment made by journalists or media organizations. In terms of electronic media, one of the well-known Pakistani networks already features morning shows and dramas that reflect Indian culture [20].

The largest dis info network in the world was revealed in a study released in end of 2020 that exposed Indian chronicles. In a 15-year campaign against Pakistan, an EU-based Dis info Lab based in Brussels exposed India for using hundreds of fictitious media outlets operating in various nations to disseminate false information and advance India's anti-Pakistan agenda. India made an effort to malign Pakistan through the network by portraying a tolerant attitude toward the rest of the world. The Indian agenda has been supported and promoted in the world community by the Indian news organization ANI (Asian News International).

3.4 Diplomatic Isolation

The Indian government is trying to harm Pakistan by distributing fake information through utilizing its diplomatic channels. Given the aforementioned facts, it is admirable that India is humiliating Pakistan to manipulating the international community from coming closer to Pakistan. Pakistan is being isolated to limit its relations with other countries and halt import and export deals. To isolate the adversary state, media campaigns that circulate false information are created. In his speech, Indian Prime Minister Narendra Modi stated that his country has isolated Pakistan and expects China and the rest of the world to stand behind India, providing further evidence of India’s intentions against Pakistan [21].

3.5 Religion and Extremism

Creating tensions between a state's ethnic, religious, and cultural groups is another strategy used in modern warfare and for that matter hybrid war. The South Asian region is based on a variety of religions, but India and Pakistan, which have hostile relations, have two more notable religions with rigid ideologies. When it comes to their faith, both sides have fanatical attitudes. The religious and cultural traditions of both states are being taken advantage of. The internal conflicts of each other's states are being made as dramatic as possible by both India. By supporting the insurgent organizations and paying them to commit the killings throughout the nation, India has contributed to exacerbating the internal identity crisis in Pakistan [22].

The most typical strategies used in contemporary hybrid conflicts include; attacking the opponent's ideology, emphasizing the state's internal identity conflicts, and exploiting cultural roots, religious views, and geographic concerns. States launched covert attacks on the identity pillars of other states by utilizing geography, socioeconomic values, ideology, history, and religion. External forces may undermine this identification by taking advantage of internal factors or by preying on a state's weaknesses through fabricated conflicts. Due to religious differences, the South Asian region is dealing with multifaceted identity challenges [23]. The conventional military has little bearing on the enemy state in this type of conflict,

instead, what is more important are the strategies employed against the opponent to obstruct his capacity for independent thought and decision-making. It is a tool for starting a campaign against the enemy to pursue political goals through the use of kinetic and non-kinetic warfare tactics. The populace is misled by the ongoing internal conflicts, which include using them against their country by focusing on underdeveloped or neglected areas and fueled by outside forces like separatist movements, a faltering economy, and fanaticism. To isolate a state from the rest of the world and create political instability, non-state actors utilize proxy wars to assault state infrastructure and corruption is highlighted, as it is in the case of Pakistan. These are a few of the conflicts that have been fabricated to undermine a state's sense of identity.

The Pakistani territory has frequently been used by the Indian intelligence agency (RAW) to wage hybrid warfare against Pakistan. The spy who is supported by RAW is typically apprehended by Pakistani forces while agitating against the government there. Another instance of a planned non-state act of violence is the arrest of Kalboshan Yadav and another RAW agent at Karachi University in March 2020 for propagandizing, anti-state, and illegal actions like terrorism and anti-nation narrative construction [24].

3.6 Economic Warfare

The principles of modern economic warfare are also a part of hybrid warfare since it entails export restrictions and sanctions. This is what has happened in the FATF; a case of a false impression presented to the international community is carried out, by utilizing the fake news network as exposed in the EU Dis info Lab report of 2020.

The hacking of bank accounts and even banks been used in economic warfare and has caused significant financial damage to a state. Economic sanctions and money laundering are also part of economic warfare. South Asia is also experiencing a smaller-scale economic conflict. The competition between the nations of South Asia can also be viewed as economic warfare. India and Pakistan are attempting to influence a state's decisions to strengthen their economic position. Regional states are not the only ones engaging in economic warfare; larger countries also play a significant role in this area. By building the Gwadar port in Baluchistan, China is helping Pakistan advance the China-Pakistan Economic Corridor (CPEC). For Pakistan, CPEC is seen as a game-changer and an economic booster. It is also seen as a factor in the nation's rising employment rate. By supporting rebel criminal activities around the CPEC route and Gwadar port, the Indian government and intelligence agencies are exploiting the CPEC project as a weak spot in Pakistan to strike it. By launching terrorist attacks, targeting the Chinese embassy, attacking Chinese residents across the nation, and supporting the separatist activities in Balochistan, the Indian government and military are attempting to undermine the CPEC using all available tools of modern warfare. Most recently, in April 2022, a woman blew up a bomb at Karachi University, killing three Chinese citizens. The Balochistan Liberation Army (BLA) reportedly claimed responsibility for the attack. The attack was intended to frighten the Chinese people and government into leaving Pakistan and ending the CPEC project.

"The cowardly incident is a direct attack on the Pakistan-China friendship and ongoing cooperation. Pakistan and China are close friends and iron brothers. Pakistan attaches great importance to safety and security of Chinese nationals, projects, and institutions in Pakistan"—*Ministry of Foreign Affairs, Pakistan*. [25]

3.7 Cyber Warfare

Pakistan is the target of Indian waged fifth-generation and hybrid warfare, including cyber-attacks and bank account hacking. Pakistan has been compelled to establish its cyber defense forces and related institutions, given the in the growing role of cyber warfare. India is also working on creating propaganda to damage Pakistan's interests, especially vis-à-vis Afghanistan. India has established a Defense Cyber Agency near its border with Pakistan, which directly reports to the National Cyber Security Advisor. The Indian cyber agency is capable of taking both offensive and defensive measures [15]. A cyber-attack by India on Bank Islami in 2018 cost the company 2.6 billion rupees [26]. India has frequently been active in the hacking Pakistani government and educational institutions websites. The state bank has already been the victim of an electronic robbery. The infrastructure for the country's power is being disrupted by hacking. The air traffic control at the airports in Karachi and Islamabad has been attacked and shut down. A large demoralizing campaign is launched on social media to disturb the public [27].

3.8 Separatists Movement- Proxy War

Terrorism is referred to as being centered in South Asia, and it has a long history in the region. Most separatist organizations have their roots in India and Pakistan, two major actors in the region that are

constantly threatened by terrorism. Terrorism and non-state actors have been fully utilized by India, like other tactics, to undermine Pakistan's stability, which has a direct impact on the strategic stability of South Asia. Several separatist organizations, including Mukti Bahini, the Tehrik e Taliban Pakistan (TTP), and the BLA, have been born and raised by India.

Global powers have a significant impact on South Asia's power transition and other political issues. Proxy wars are waged by international forces using Pakistani citizens.

3.9 Political Turmoil

India has sponsored political parties in Pakistan and used them as weapons against that country. A political faction in Pakistan called the Muttahida Qaumi Movement (MQM), which has been active in causing turmoil in the port city of Karachi, was revealed to be backed and funded by India. British authorities discovered evidence of money laundering, informed Pakistan of the activities, and assisted Pakistan in reducing the funding of terrorism in Karachi. Another significant problem in Pakistan is the money laundering of politicians, which the country is unable to address owing to inadequate institutional governance. The political unrest in Pakistan has given rivals like India the chance to finance political parties and utilize them against their nation.

4. FUTURE OF HYBRID WARFARE IN SOUTH ASIA

Considering the basics of modern warfare and the escalating patterns of conflicts in South Asia, it becomes clear that both Pakistan and India are actively engaging in hybrid warfare. The genesis of warfare encompasses many other elements that affect the changes in warfare and requires hundreds of years to modify the trends in warfare. The application of technology and techniques has an impact on how war is fought, and technology always advances in this race. With the emergence of new and disruptive technologies, conventional weapons have become relatively less significant to be used in a conflict. It might be deduced that the development of technology has altered the old notion of war, but it cannot be affirmed that the employment of conventional weapons has completely ceased. Warfare still involves conventional weaponry, but how those weapons are used on the battlefield has evolved [28].

It wouldn't be incorrect to expect that the range of conventional weapons will be reduced with the increasing relevance of hybrid warfare techniques in contemporary warfare discourse. Unconventional and conventional weaponry would remain relevant in any future confrontation between India and Pakistan. Nuclear weapons won't push India and Pakistan into a conventional conflict, but they won't eliminate the deterrent factor either. India and Pakistan would likely place unconventional strategies ahead on their priority lists if they wanted to avoid a full fledge war under nuclear overhang. Even when new military technologies will be developed, hybrid warfare would likely continue to remain relevant in South Asian context [29]. The conflict would still have a hybrid nature in South Asia. India and Pakistan would not rely on unconventional weapons, but they would rather actively try to expand their traditional military range of influence.

Future conflicts will use a mix of conventional and unconventional weapons of war, as predicted by Frank G. Hoffman in his book. States try their utmost to employ new technologies against their adversaries whenever they enter battle.

Although its application would be limited, nations still utilize these technologies alongside other types of warfare. Similar to other regions around the world, South Asia is expected to have seen the advent of emerging technology. India is also gaining these technologies in anticipation of a future confrontation with Pakistan.

5. ROLE OF EMERGING TECHNOLOGIES IN FUTURE WARFARE

Likewise, disruptive technologies and their role in warfare are currently a hot topic of discussion in the domain of warfare. The future generation of warfare is predicted to be shaped by these technologies and might revolutionize how war is fought. Emerging technologies like Artificial Intelligence (AI), cyberspace, anti-satellite (ASAT) weapons, robots, drones, and hypersonic weapons have the potential to transform warfare, and their use in upcoming wars poses grave challenges. Due to the capacity of some of these weapons to carry nuclear warheads, the advent of these disruptive technologies poses a risk to the use of nuclear weapons in military conflicts [30].

One of the most important disruptive technologies is artificial intelligence (AI), which consists of several tools that let machines monitor various activities, including military actions, around them and behave following the intelligence that has been given to them. AI is useful in cyberspace for detecting and blocking malicious cyber-attacks. Similarly, airborne drones may quickly recognize and attack enemy forces on a

battlefield by using sensors to locate and recognize them. AI and cyber-attacks are the most challenging weapons to restrict through arms control agreements since it is hard to measure them [31].

Unmanned weapons, autonomous weapons, or 'Lethal Autonomous Weapons' (LAWs) that jointly find and strike an adversary's assets using drone and AI technology are also a part of cyber-warfare. Another name for autonomous weapons that can be used to track the adversary without a person directly involved is killer robots. According to the US Department of Defense, autonomous weapons are "weapon systems that, once triggered, may choose and attack targets without additional human operator engagement" [32]. It would be catastrophic for global standards and prosperity if all these weapons are frequently deployed.

Hypersonic weapons, which travel at minimum five times speed of sound, can transport nuclear and other types of weaponry.

They are employed for both quick reactions and nuclear delivery systems. They are used to swiftly attack the enemy's targeted areas while the adversary is not even prepared and does not even contemplate being attacked. These non-nuclear weapons also pose a danger to strategic stability, perhaps raising the probability of an unavoidable response.

ASATs, or anti-satellite weapons, are responsible for the disintegration of outer space. ASAT weapons are making it riskier to conduct operations in outer space, especially those near the earth's orbit. For instance, when China performed an ASAT test in 2009, there were concerns all around the world.

India is investing in emerging technologies to secure its interests as a state. The goal of India's acquisition of disruptive technologies is to secure its national policy objectives against external challenges [33]. History proves that anytime India gained technology with the intention of using it peacefully, it subsequently turned that technology into a military realm. The same applies to the acquisition of emerging technologies. The Indian strategy is based on a hegemonic ambition since the country aims to be a regional hegemon and be seen as one of the world's great powers. India, on the contrary hand, is attempting to compete China technologically, particularly in the field of defense. India is working very hard to acquire emerging technology and the potential to deploy them against its adversaries. India also has the opportunity to utilize its strategic alliance with the US, since the latter wants India to be a competitive state against China and to contain China's increasing influence in the region. The US has backed India in gaining more technology and military equipment. India has been part of several international agreements, treaties, and strategic partnerships by the US [33].

"Modern technologies like 5G, AI, block chain, virtual reality, machine learning & deep learning, robotics, and NLP are presently being prepared by India. All of this will play a vital part in both industry and government, whether it's strategy or decision-making, boosting development or reviewing deployment, problem-solving or product creation, or discovering new patterns or correlations" [34].

India is investing heavily in hypersonic cruise missile defense research and development, becoming the fourth nation to do so [30]. All the tri-services are currently working together with DRDO and Russia to build hypersonic missiles [35]. With the help of the DRDO and NPO, the Russian company Mashinostroyenia built the Brah Mos Aerospace firm to manufacture cruise missiles in New Delhi. The powered, air-breathing hypersonic cruise missiles (HCMs) can be launched from rocket boosters, where they float autonomously across the upper atmosphere until crashing into their destinations. Hypersonic weapons with nuclear or non-nuclear warheads can be used to selectively target nuclear weapons and command-and-control facilities, as well as to demolish mobile missiles, anti-satellite weaponry, radars, and missile-defense systems, warships, and other vital targets. India is also building HCMs, notably the Brahmos-II, to increase strategic deterrence over China and Pakistan [36].

South Asia is currently prone to a new arms race as a result of Indian ambitions to modernize its military by acquiring emerging technologies. Owing to the military's deployment of such technologies and the potential use of nuclear weapons, South Asia's strategic stability is once again in trouble. Modern technology advancements have increased the risk of full-scale war and the possible use of nuclear weapons by enabling warfare more viable. For instance, AI-controlled drones may find and take out hostile weapons like surface vessels, radars, and submarines. Hypersonic missiles offer first strikes during a conflict along with the deployment of cyber-attacks and nuclear warheads right at the start of the conflict. All of these strategies make it challenging for the targeted state to immediately conduct a counter strike or even a nuclear strike in retaliation.

Role of AI is likely to be increased in future Chinese and Indian military operations. Publicly accessible evidence reveals that Pakistan has not yet adopted an official policy on the application of artificial intelligence (AI) in defense, although it has just begun to work on research and development in the area of emerging technologies. However, the existing strategy might be insufficient to deal with the enemy's increasing threat. At the moment, Pakistan has no plans to apply these technologies to its military; instead, it is trying to advance research in these fields to assist the research community and other specialists in applying these technologies to the advancement of the nation. To strengthen the economy, such technologies are increasingly used in the agricultural sector. However, it is tough to deny the growing hostile regional environment. The security of the region is seriously threatened by India's pursuit of such disruptive new technologies. As India poses a significant challenge to South Asia and Pakistan is now unable to bridge the conventional gap, Pakistan has taken the position to restrict the disruptive application of these developing technologies.

It is difficult to forecast with any certainty whether Pakistan and India would use nuclear weapons in the future. The only thing that could be done is to draw out a few possible situations and offer policy recommendations [36].

6. CONCLUSION

While it seems impossible to predict a peaceful South Asia, one may forecast future wars thereby studying past conflicts and current patterns of conflict. The research confirms that hybrid warfare is an effective form of conflicts in South Asia going forward [12]. Due to the wide usage of this term by military officials and politicians, the concept of hybrid warfare has become more popular in South Asia than ever before.

One might say that upcoming wars would be hybrid if we understand the principles of modern warfare. Therefore, neither of the South Asian nations would completely rely on their military nor even their unconventional or non-military spheres. States are not allowed to compromise their conventional military capabilities. Given that India is acquiring emerging technologies that enables quick war fighting without even requiring the actual movement of its military troops, it may be assumed that future conflicts would be non-contact [28]. In order to avoid using extensive conventional military forces, deterrence will be essential considering the existence of nuclear weapons. Non-contact warfare, particularly economic strategies that attempt to undermine a state's financial stability, will exacerbate the security problems that need to be resolved.

In South Asia, there are less likely possibilities for the deployment of disruptive technologies in warfare. Conflicts in South Asia are distinct and are based on unchangeable truths that might never be resolved. In pursuit of its regional hegemonic and great power ambitions, and to threaten Pakistan India is acquiring emerging technologies. Even if Pakistan necessitates a great deal of effort in the area of emerging technologies, it is unlikely that Pakistan would prevail in these disruptive technologies. Pakistan already faces considerable economic difficulties. Pakistan won't be able to purchase such costly military technologies due to its slow economic growth. It also has very limited resources to carry out research and development in the domain of disruptive technologies. India would have accomplished two of its national goals once it will possess these technologies. The first is to compete with China, and the other is to threaten Pakistan.

The research showed that both Pakistan and India might indulge in hybrid warfare which has already begun in the past few decades. However, the war strategies will differ from one another in nature, as do the technology and tactics. Warfare trends may be headed in the same direction, but technological advancements in hybrid warfare is happening at a different rate.

Considering that today is a digital generation with rapid and easy access to facts from a diverse range of sources, it is difficult to regulate and restrict the usage of media among the people and even a state. . In the contemporary era, social media is a real weapon, and there's no way to restrict public usage, particularly among young people. Countering cyber-attacks both inside and outside of a state is very challenging. India is making progress in the domain of cyberspace, while Pakistan stands far behind and is unable to readily counteract Indian cyber-attacks. To combat the propaganda and false information spread by the enemy, it is necessary to fight hard and act quickly.

NOMENCLATURE

FATF	Financial Action Task Force
RAW	Research and Analysis Wing
CPEC	China-Pakistan Economic Corridor
ANI	Asian News International
BLA	Baluchistan Liberation Army
TTP	Tehrik e Taliban Pakistan

AI	Artificial Intelligence
ASAT	Anti-Satellite Weapons
LAWs	Lethal Autonomous Weapons

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ENERGY STRATEGY OF RUSSIA AND ITS IMPACT ON EUROPE

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Abstract

This article explains the energy strategy of Russia and its impact on Europe. The disintegration of the USSR resulted in a weak military and defense industry which is fundamentally critical for regaining the status of global super power. To substitute the weak defense industry, energy sector was the alternate option that could ensure collecting enough revenue to finance the country achieve regional and then global dominance. The monopoly of the state over production and distribution of its natural resources providing energy helped Russia dominate the region and the regional policies pertaining to energy. The significant gas pipelines between Russia and European Union passes through countries previously part of the Russia that makes the country intensely reliant on these states as energy transportation arbitrators. To guarantee a consistent energy supply and diminish Russia's dependence on travel nations, Russia is looking for alternative approaches to expand the gas supply lines entering into the European Union. The federation is prepared to take any steps that could result in bypassing these states and provide energy directly to Europe. The monopolistic control of Russia on gas supplies to Europe could help achieve regional dominance. Compromising a chance of unexpected energy disturbance and cost dictation can be a productive apparatus of state power to accomplish Russia's political targets.

Keywords: Russia, European Union, Energy, and Transportation Routes.

1. INTRODUCTION

Since the demise of the USSR, Russia has been preparing to retake the glory it once had as a global player. To do so, the country is looking for ways to attain dominance in the global markets and control the region as a major power. One of the pathways to restore the previous glory is by dominating the European markets and becoming the region's biggest energy supplier. The article analyzes how Russian control over gigantic energy potential affects the formation of the country's present international strategy, especially vis-à-vis the E.U and the individual nations of Europe which are vigorously reliant on Russia to fulfil their energy needs. The article will build up a notion that a customer's overwhelming reliance on a provider's energy assets may transform the last into a financial instrument of political compulsion and evaluate the energy market of Europe and the level of its dependence on the energy supplies of Russia. The disintegration of the USSR, trailed by financial as well as administrative disturbance, left the country with weak defense and military sector that is fundamentally essential for its regional and global dominance. The impediment is attainable if the military reliance is substituted by energy distribution that could help raise finance for the country which is essential for achieving its strategic objectives. Accordingly, the state control of energy production and distribution network can help Russia take control of activities in the region that interest

Russia and its interests and act as a tool of power for the state [1].

The significant gas pipelines between Russia and European Union passes through countries previously part of the Russia that makes the country intensely reliant on these states as energy transportation arbitrators. To guarantee a consistent energy supply and diminish Russia's dependence on travel nations, Russia is looking for alternative approaches to expand the gas supply lines entering into the European Union. The federation is prepared to take any steps that could result in bypassing these states and provide energy directly to Europe. This led Russia to look for options that enhance the supply of energy courses to Europe, specifically via the South and the North Stream ventures, which bypass the current routes without entering into previously controlled states by Russia. Such an approach to connecting customers and providers directly propelled by political motives of the country instead of financial [2].

Russian federation is willing to invest in projects that can bypass the current supply line and supply through an independent pipeline that the country controls even if there is a high price for the venture.

This will reduce its reliance on the previous Soviet nations, specifically on Ukraine, through which majority of gas is supplied throughout Europe. The new energy supply pattern will pave the way toward less reliability in a single state for its distribution network. Russia will have alternative routes for its distribution network if there is a disruption of energy supply through the existing passage [3]. Compromising the chance of unexpected energy disturbance and value control, Russia could raise its political dominance in the region by dictating its terms to beneficiary states. As such, economic influence could become a proficient device of state capacity in accomplishing its political goals [4].

2. METHODOLOGY

The primary technique for assessment of the research is the use of Realism and Constructivism theories on global associations that Russia seeks towards the individual beneficiary states in European Union, and the post-Soviet region.

3. ECONOMIC DIMENSION

Since the demise of the USSR, Russian ambitions of becoming the global superpower have taken a new dimension. The focus of Russian international and economic strategy shifted from the military to the energy sector. The shift was motivated by Russian fast economic development and stability subsequently following the confusion and strife of post-cold war era. The general sentiment is that it became conceivable, given the presence of another age of leadership that are receptive and liberated from the Soviet mindset, and that to regain the previous glory, they develop a unique strategy apart from military might [5].

One significant factor driving the current Russian international strategy is presenting economic courses of action. The economy of Russia is export oriented. Around 85% of its income originates from exporting crude materials, for example, metals, timber, gas, and oil. Russia has around 30% of the global gas stores and oil reserves of around 6%. Moscow's primary mineral buyers are the previous Soviet nations and lucrative E.U states. Since it acquired advanced gas and oil pipeline frameworks from the Soviet Union, Moscow didn't need to put resources into developing energy transportation courses [6].

Economic and Political dimensions of Russia are linked. In Putin administration, the country recaptured authority over major companies and the people closely associated with Putin were selected to maintain those business properties and enterprises (Dawisha, 2011). The inner circle of Putin and Russian oligarchs turned out to be his colleagues in the Saint Petersburg city and KGB administration. Consequently, the individuals selected for high administrative and business places had similar ideas and values that had been formed during the Soviet period. The clearest instance of interlaced economic-political relationship is Medvedev (previous president of Russia), who worked in Saint Petersburg with Putin. In 2012, the country revisited the energy policy and devised a plan till 2035 to be acted upon in two phases; one from 2012 till 2020 and another till 2035, which both optimistic and pessimistic strategies (Alexander, Alekseev et al., 2019). The strategy is based on achieving economic goals and setting up a European monopoly so that Russia can dominate the regional market and dictate its terms to the member states [7].

4. ENERGY REPLACES MILITARY POWER

Even though the political leadership of Russia figured out how to solidify the populace behind the modern foreign strategy, Moscow is probably not going to satisfy its global dominance desires by utilizing its defense sector as the method for power projection. The military of Russia is in decay in the course of the most recent two decades since the disassembling of the Soviet Union (Hedlund, 2011). Reliance on the atomic weapons arsenal will not help propel national interests abroad. The best way it could be utilized for military prevention is to keep up the state of affairs with hard powers. Help the idea of political that foreign strategy effectiveness relies upon the level of power inclusion, a viable replacement for a hard power plan could be found in controlling energy supplies that not only have significant financial repercussions yet likewise an authoritative political device (Goldman, 2010) [8].

If Moscow's regular hard power can be utilized to extend capacity and bolster its state benefits outside borders, as was seen in 2008 during the Tbilisi-Moscow unrest, at that point, its gigantic resources, current pipeline framework, and geographical landscape gave the former USSR a preferred position. Russia can get an advantage from these resources and use as weapons to expand itself. (Zimmerman, 2009), particularly in Europe, which as of now, is the biggest lucrative exporter of hydrocarbons, particularly gas (Closson, 2009). Europe has few choices to fulfill its energy demands other than Moscow, which makes it hard not to rely on Russia as the biggest energy provider [9]. These circumstances offer leeway to Russia concerning price control (Hedlund, 2011). Besides, energy supply could be interrupted for any reason, which would seriously harm customers' need and pay the price in its domestic strength, as it occurred when the Russia-Ukraine gas emergency during 2009. Consequently, concerning E.U. nations, "the leaders of the West would need to reconsider before opposing the political requests of the provider" (Goldman, 2010) [10].

Russia local real-political strength come from financial assets, specifically, its natural assets compared to military methods, comes from the present political administration. Putin has made it clear that the state has the right to develop and direct the energy in the way it deems suitable to fulfill the wider national interest. The Russian economy has been isolated for quite a long time compared to other developed markets to have the option to rapidly make up for technologically and contend successfully on a global level. Even though foreign financial specialists were invited, Putin confirmed that the legislature must hold working control of the assets instead of privatization of the energy sector of the country [11].

5. EUROPE AND RUSSIA INTERDEPENDENCE

A straightforward clarification of monetary relations between market players is that a customer and a provider are commonly keen on exchanging products to expand trade (Wheelan, 2010). In this regard, energy trade or reliance between Europe and Russia should be advantageous to providers and purchasers. The mutual benefits for both nations come in the form that Europe needs energy supplies to fulfill their needs, and Russia needs finance to sponsor its global dominance. The primary revenue generation source of Moscow is hydrocarbons export, and the main to connection is that lucrative of Russia's clients are Italy and Germany (Closson, 2009). Russia "gets" itself "monetarily rely on Europe" (Ericson, 2009), and Europe intensely depends on cleaner energy [12].

The least expensive approach to supply the gas from pipeline, when it has been built. Pipeline development requires gigantic funding which take normally takes as long as 25-year promises from purchasers/clients of the energy to buy enough to legitimize improvement costs. A pipeline "genuinely" associates the dealer and the purchaser, it gives a provider "colossal market power" over its customer because of the structure price for a pipeline for a low minor cost per unit of energy shipped (Ericson, 2009). For the situation of Europe-Russia energy relations, the current gas transportation framework was worked during the Soviet times; and Moscow, having stayed away from the need for significant ventures contribution to pipelines development, showed up in a place of the compelling imposing business model over energy assets spilling from Asia to Europe as a result of an absence of other significant elective courses interfacing the previous and the latter [13].

Every European nation looks for the ideal ways that could be available to ensure its national advantages. That additionally applies to energy security. Monetary

imbalance in European Union and each state's extraordinary topographical location influence how much to acquire energy assets to run their markets proficiently. Verifiably industrialized E.U. economies, for instance, Italy, France, and Germany require large quantities of energy supply to cover their demands compared to industrially smaller states. For example, after the 2011 Fukushima tragedy, the German political administration chose to close down its atomic plants before 2023 (Spiegel Online, 2012) and, step by step, replace them with "green" gas, principally from Russia. On the other hand, countries like Poland and France are reducing their reliance on external energy providers and concentrating on in-house atomic power-production facilities. In this manner, prioritization of the monetary interests by the E.U. nations over combined ones unavoidably sabotages the E.U.'s ability to act viably as a solitary voice to manage any difficulties that this political substance may confront [14].

To ensure demand of energy in the E.U. gas market, Russia has signed long-term energy contracts with various European nations on a "take-or-pay" premise. Any change in plan will cost heavily**.** Former Soviet knows to landlock E.U. is dependent on its energy because they will not find any solution to overcome its energy need in a short period of timing LNG could be a choice, yet its monetary reasonability is dicey now, given the significant expense of LNG transportation and terminal development. Russia appreciates a "natural imposing business model" on gas supply to certain E.U. nations for at least 10–15 years, implying that they would stay dependent upon the energy assets of Russia in the close term until a powerful replacement is viable. The fundamental worry of the**.** The strategy of E.U is provide energy and it security. Enhancement of supplies as a key component of the energy security strategy (Closson, 2009) can be accomplished distinctly through the realization of "market rules and rivalry standards," (Aalto, 2009) permitting different players reasonable access to the energy market resources, including Gazprom [15].

Russia has entered into long-term contracts with European Union member states via Gazprom to take hold of the energy supply throughout Europe. It is also investing directly in other energy-related projects in Africa, Latin America, the Caspian Basin, and the Middle East (Closson, 2009). To keep up the energy supply and meet the consistently expanding Russia is purchasing gas from the Caspian Sea and its neighbors because of the high demand from the E.U. and it cannot fulfill the current demand (Overland, 2009). Additionally, while various gas fields of Russia stay undiscovered, foreign financial specialists are not invited to upgrade new fields without local partnerships. Russia demands collaboration in these ventures with state-controlled organizations, especially Gazprom. In any case, the Putin regime overwhelms investors, forcing impediments by specific utilization of the enactment (Pleines, 2009). Traditional arguments against the inclusion of foreign investments are the dispute that "foreign investment has frequently been viewed as giving outside unjustified investor impact within one's nation" and could be deciphered as an "infringement of sovereignty" (Quester, 2007). In this regard, investor commitment in the market of Russia would mean its progression and, as a result, a debilitated state restraining infrastructure over distribution, and transportation the basic energy source that may be utilized as an instrument of compulsion [16].

6. KEY CHALLENGES FOR EUROPE

6.1 Diversifications prospects

To reestablish its reputation for being a solid energy provider to Europe after the 2009 cut-offs**,** Moscow reliably convinced the E.U. concerning the need to accelerate the development of the Southern project that is to associate Europe and Russia, bypassing Kyiv, which is at present the significant travel nation for the Former Soviet energy supply to Europe. Moscow did not force its stance by criticizing Kyiv as being inconstant in satisfying assumed travel commitments (Pirani, 2009). Hence, Russia demands that the energy supply through "antagonistic" transit countries should unquestionably stay away from it. Cost assessment of the pipeline development over the base of the Black Sea, around €24 billion (Socor, 2009), sensibly questions the financial capability of the project: it would not supply any additional gas to E.U.; to sidestep Ukraine, 63 billion cubic meters would be redirected from the transit structure of Ukraine (Aseeva, 2010) [17]. Altogether, the South Stream supplemented by the North Stream with 55 bcm of gas transportation limit per annum would have the option to annul noteworthiness of the Ukrainian pipeline,

which at present records for transportation of around 120 bcm of gas to E.U. purchasers yearly [18].

The Nabucco pipeline project aims do not depended on Moscow gas. With an assessed yearly supply limit of 31 bcm, the Nabucco project additionally falls into a system of the Solidarity and Energy Security Action Plan of the E.U. that proposes the "building up a southern gas way for the supply from Caspian and Middle Eastern region" (Europa, 2009) and became "leader project" of the E.U. energy security strategy.[19] Even though its development is less expensive than the South project, despite everything, question whether in advance investments would provide a prompt yield as Nabucco faces significant problems in running the channeling if sufficient assets are found to meet the pipeline with gas. At first, Teheran was viewed a significant energy supplier for Nabucco. Yet, because of continuous questions on the Iranian atomic program, Iranian natural gas will probably not be utilized until the emergency is finished. The elective approach to get the essential volume of gas for the Nabucco pipeline would be an entrance to the fossil assets of previous Soviet republics in Central Asia. [20] Up until this point, that choice is not practical for two reasons. Initially, the contradiction over the authentic status of the Caspian between its coastal nations, regardless of whether it should be considered as an ocean or a lake – is as yet uncertain, which does not permit the development of a pipeline on the base of the Caspian. The last is that Moscow "tied up accessible and future gas supplies in long-period Gazprom agreements" (Ericson, 2009). Therefore, even though Nabucco's expansion alternative bodes well, it will probably not be actualized in the near future because of the absence of obvious solutions for afforested troubles rapidly [21].

Africa and the Middle East are some of the other energy stations. These alternative stations of energy are achievable and as expensive as others. LNG projects are very expensive and require significant advanced investment and duties by the consumers and producers. Supplying regular LNG depends upon liquefaction and de-gasification facilities. The arrangement of long-period contracts and their steady restoration should be set up to guarantee the security of interest. Both matters of supply and security are key factors that specify the certainty of high-fixed expenses for the LNG decision [22]. Other than that, if LNG is economically practical for the nations with the sea to get quick, this alternative barely makes economic logic for the land-bolted nations, specifically for the central states of Europe, which now acquire energy supplies from Moscow by means of pipelines. Along these lines, because of the high expense required to build the LNG framework**,** predicted that the gas market of the EU which is now at around 20%, would stay modest for what it's worth throughout the following couple of decades. To be sure, somewhat LNG would lessen developing reliance on Russia's gas, particularly for the West E.U. nations. Yet, it will probably not adjust the existing uneven relationship in the Russia-European Union energy cooperation [23].

6.2 Common Energy Strategy

The energy triangle of Russia, the European Union, and European states needs to work together to manage the energy crisis in the region (Aalto, 2009). The E.U. endeavors to work an "integrator motor" to implement the shape of a typical gas and oil security strategy in inward and outer measurements, expecting to make a one-sided approach by the E.U. nations to withstand simultaneous heterogeneous energy reliance on Russian fossil fuels assets. In reality, Russian-European energy cooperation throughout Europe increased certain novel qualities after the appearance of another player, specifically the E.U that progresses a unified energy strategy for the benefit of the E.U. nations without importing gas (Solanko, Laura and Pekka, 2009) [24]. Simultaneously, implementing the bound together methodology towards combining the security of energy is frequently in strife with these types of energy partnerships, especially with Russia and European nations. After the disintegration of the USSR, a significant revisit on the E.U. political chart, alongside the arrival of fresh players perceive for energy transit nations and the formation of E.U., called for the amendment of the current energy strategy. This amendment aimed for new courses of action for energy collaboration between the E.U. and different nations. Toward the start of the 1990s, the E.U. propelled an activity with a reason to "build a legitimate establishment for oil and gas security, in light of the standards of open, modest markets and maintainable development. The idea has been revealed in ECT (Energy Charter Treaty) with an essential accentuation on the improvement of normal principles

to give a more adjusted and proficient structure for global collaboration than is offered by reciprocal understanding**.** In 1994 treaty was signed by fifty-one nations, most of them from the E.U. nations, Russia and other countries (Moldova Turkey, and Ukraine) [25].

The disappointment of dealings with former USSR over substance of the Energy Charter Treaty incited E.U. to look for some types of energy collaboration with Russia. At the "Summit of E.U-Russia in 2000," it was consented to start a separate Russia-E.U. Energy Dialog (Ferran, 2009). The E.U. Commission, as an international authority, was commanded by the E.U. nations to offer the Russian government a true reciprocal type of energy cooperation. Moreover, to "financial, technical, and institutional help" provisioned by the Charter Agreement, the E.U. offered Russia to "take an interest in the improvement of the E.U.'s joint market" (Closson, 2009). Simultaneously discussion in the structure of the Russia-E.U Energy Dialog is consistently intense when the matter of fossil assets is raised. While Moscow looks for "long-period agreements for gas, technology and investment, cooperation in the E.U. Investment Bank, and evacuating limited ban on imports of items related to energy," the E.U., to improve the security of delivery, tries the "opening energy market of Russia" and reasonable circumstances for investments [26].

To additionally build up a consistent multilateral methodology towards combining energy security, in 2008, the E.U. followed a combined action plan highlighting the inadequacy of "explicit national arrangements" according to "the coordination of energy markets and frameworks in the E.U." and the need to "build up a plan for 2050" (Europa: Please Releases RAPID). Simultaneously, a consistent increase in energy utilization throughout the E.U. raised genuine environmental worries highlighted in the energy and climate package of E.U." The package predicts a decrease of 20% in greenhouse emissions," "20% of E.U. energy utilization starts from renewable energy," and a decrease by 20% "in essential energy use contrasted and anticipated levels by refining energy proficiency" [27].

6.3 European and Central Asia Energy Security

With the present policy to control the E.U. energy market (Ericson, 2009), Moscow also searches eastbound for broad energy participation with energy needing East Asian and Chinese economies (Poussenkova, 2009). Key components of the energy policy of eastern fixed in "Eastern Gas Program" by the Russian Federation Industry in 2007. The program predicts the advancement of energy fields and gas production development in Russian Eastern Siberia to fulfill requirements for gas by potential East Asian clients and Chinese (Gazprom) [28].

China's economic boom set the most adaptable and exceptionally monetarily position for Russia to develop energy links with China. Similarly, Beijing also sees Moscow as a significant future energy partner for a few significant reasons. To begin with, the strategic importance of their topographical nearness allows for associating upstream and downstream ventures with lower costs and evading dependence on mediators. Second, Beijing is worried about broadening energy sector and its use. China is blame for its CO_2 producer due to local energy production from coal; subsequently, it facing worldwide pressure on environmental matters (Indra and Kyrre, 2009). As of now, no choice has been made after the development of gas pipelines [29]. The primary issue is that both sides cannot agree on the price of natural gas. China wants lower prices accentuating the need to keep up a rivalry with the elective source of local energy production, specifically coal. Russia then again endeavors to help China through "long-period agreements for the gas supply." As the government of Russia brought up, such a long-period promise is "the reason for the choice on the construction of a pipeline" (Poussenkova, 2009) [30].

The absence of agreement over the price of gas with Russia and uncertainty over future power of gas collaboration with Moscow induced Beijing to depend more on elective sources of energy, incorporating those in the nations of Central Asia, to be specific Turkmenistan and Kazakhstan (Xuanli, 2006). Right now, Turkmenistan has the world's fourth-biggest gas reserves (Reuters, 2012) "; it is the main in the region which supplies its hydrocarbons to Beijing, (Bloomberg News, 2011) with an anticipated export yearly limit of 40 bcm (Gorst, Isabel, and Geoff, 2009). At the same time, China is discussing gas

supply with Turkmenistan and Kazakhstan. In 2011, Kazakhstan and China agreed to propel a pipeline development that would connect the gas fields of Kazakhstan with the current transportation system, which begins in Turkmenistan and passes Uzbekistan and Kazakhstan, and ends in China (Reuters, 2012), and include another 15 bcm of gas for China. Normally, Kazakhstan could expand yearly export volumes to around 40 cm (Financial Times, 2011) [31].

Key ramifications for the E.U. security strategy in extending energy participation among Central E.U. energy suppliers and China are that the volumes of gas would be sufficient for different consumers, explicitly Beijing. Even though Moscow would lose "its higher position as the purchaser of neighbors gas" (Ericson, 2009), it would hold its syndication over transportation from Asia to E.U. and enjoy staying solid over E.U dependence on Russian petroleum. One more problem face by E.U. energy security may show up if Russia connects East and West Siberia energy fields and if China and Russia would solve the gas price. Moscow would not rely solely on E.U. for its energy deals (Nanay, 2009), and demands for the fossils of Russia and income would be safe in case of politically persuaded disruptions of energy flow to the E.U. market [32].

7 FUTURE POSSIBILITY FOR EUROPEAN INTEGRATION

The foreign Strategy of Russia toward Europe weaves together numerous strands of Putin's strategy of arrangement with the Euro-Atlantic group to foster global consistency and support the modernization of Russia. Russia's links with Europe show up fundamentally positive. Europe is not unfriendly to Moscow, nor is it a conceivably undermining military-political organization, similar to NATO. Russian-E.U trade relations are imperative for the economy of Russia, and Brussels offers substantial assistance and expertise for the economic reforms of Russia. Moreover, as Europe becomes more dependent on Russian energy supplies, Moscow is not the only reliant party in the relationship. Relations between the E.U. and Russia can satisfy Russia's requirement for outer interlocutors that accommodate a Russian voice on the worldwide stage and back Russia's inner transformation.

The mix of E.U. development and the association's rise as a security player, in any case, raises problems for Russia, the first being doubt. The leadership of Russia is unsure of Europe's future part and its strategies toward Moscow. In the long term, is a coalition in Europe taking shape? By what method will the new nations influence the E.U.'s strategy toward Moscow? Will Europe make more efforts to meddle in Russia's local matters? To what degree will Russia have the option to exploit links with the old partners? There are no suitable and clear answers to these questions [33].

The second problem is psychological, even though Putin does not want to be isolated on the E.U.'s periphery, subject to growth beyond its ability to control. Europe extension obscures the distinction between the E.U. and the possibility of "Europe"; the two ideas are combined. For all his realism, Putin has constantly confirmed Russia-European work and attached Russia's new Federation's destiny to that of Europe. Collaboration between a previous domain in retreat and a growing force cannot be required come without problems. The border areas between Belarus, Ukraine, and the Caucasus will probably include friction as lines of influence and power become clearer. This was clear in Moscow's reactions to the discussions in Brussels (2003) when Europe discussed an ESDP operation to supplant the Russian-drove peacekeeping operation in Moldova (Dov, 2003). In public, Russia responded calmly against the thought; in private, Moscow's reactions were a mix of concern, anxiety, and astonishment.

Putin started his presidency seeking more unsurprising and pleasing universal partners for Russia's state consolidation. The E.U. had pride of spot in his vision. The E.U. remains capricious, and Russia is minimal more locked in. Indeed, Russia finds itself pushed to the sidelines, confronting the truth that a unified Europe is being worked at the beginning of the twenty-first century—however, without Russia [34].

The recent Russo-Ukrainian conflict has also changed the region's dynamics and regional coordination. As Russia is highly reliant on Ukraine to supply gas to Europe through its pipelines, the future of the conflict will determine the outcome of energy supply in the region. As reported by the European Commission Quarterly, the Russian energy supply was over 41% of the total revenue. On the other hand, the dependence of Europe on Russian gas has also increased because of the dependence on green fuels and the stoppage of

greenhouse emission sources like coal (Boehm, 2022). The war's outcome could be anything but will deeply affect the trade relationship and energy reliance between Russia and the European Union. Both sides will be looking for new markets, new collaborations, and new strategies to fulfill their needs and also dominate the market at the same time.

8 EUROPEAN ENERGY PROBLEM AFTER UKRAINE CRISIS

The Ukraine crisis brings about a crisis in the energy sector in Europe and the rise in the prices of gas and oil on the European continent. Europe imposed a gas and oil embargo on Russia, which was done purposefully to reduce the dependence on Russia. No more depending on Russian gas and oil in next couple of years. Europe is the second largest importer of oil. Russia is the world's largest oil exporter, and Europe is the second largest oil importer. US pressures Saudi Arabia and UAE to extract more oil as they are one of the largest exports. Qatar is also a good venue for Europe for gas. The energy minister of Qatar, Saad al-Kaabi, said that Qatar could not fulfill the gap with Russia. Another Middle East nation Iran has the world's largest oil and gas reserves. The US and European Union do not have friendly relations which can overcome the current energy crisis. The Iran nuclear program is a major bone of contention between them. Now, if the US and Europe Union make any deal that will favor Iran. Israel, UAE, and Saudi Arabia are strategic partners in the Middle East and will not welcome any breakthrough. Because Iran's economic condition will improve, Iran will come closer to US and European Union, and it can fast the process of making nuclear bombs, which is not acceptable to Israel, Saudi Arabia, and the UAE. Algeria openly offered to supply gas; the CEO announced the Algeria state energy firm [35].

Russian energy is cheaper for Europe due to the near short distance of the direct pipelines. Now they will not get cheaper and cannot be sold cheaper to the consumer. Which will increase commodity prices, and the political party in power will face its effects in elections. Europe energy is facing challenges for new energy stations, domestic use of energy and supply and demand challenges, rise in the price of energy and its political drawback for political parties in power, the production of items, short-term solutions, the European Union common purchase of gas and storage. Energy divided the European countries on the import of energy from Russian due to the consumption and need. The ban former USSR was to hit hard its main sources of income. The solution is that Europeans need a common energy policy as they have a common agricultural policy [36].

9 CONCLUSIONS

The foreign strategy of Russia can be clarified by using the theory of political authenticity that portrays world as a radical domain where states use different techniques to survive. As the defense sector of Russia is not stable enough to dominate the global dynamics, there needs to be another tool that the country can take advantage of in order to dominate the regional politics according to the theory. Phenomenal shorts of energy flow from Moscow to E.U. in 2009 led to the utilization of another economic weapon by the country aimed at the European Union that placed its impact on the economic collateral in the region. This served as an economic weapon launched towards Europe that affected the region without any use of military force that affected the region economically rather than from loss of lives in traditional warfare. The reason behind the energy dominance of Russia in the region is that the states in Europe are dependent on the single supplier to fulfil its needs. Russia used its legislative power to control the energy supply organizations that are responsible for the production, storage and transportation and state institution Gazprom established its monopoly in the region as a result. The transactions of energy supply from Russia to European states has empowered the country to dominate the economic conditions of the region and hence its decision making powers are influenced by the dependence of energy supply on Russia. There are, as of now, current and operational energy-transportation courses that associate European consumers and Russian energy fields. Europe needs to devise policies that could result in reducing the dependence on Russian energy and looking for alternative suppliers and methods to fulfil their energy needs. All choices are either capital-escalated and require huge forthright investment or could place the E.U. customers into a more profound energy reliance on Russia, which provides the opportunity to Russia to dominate the decision making of these countries. Improving the

southern energy corridor is considered the main economically and politically feasible choice for the E.U. to differentiate its energy supplies; however, its future is dubious. Certain impediments coming from uncertain issues over the Atomic program of Iran, the agitated issue of the legitimate position of the Caspian sea that doesn't permit interfacing Europe and Central Asia while sidestepping Russia, and as of late, increased energy participation in Asia make it muddled who will give enough energy to legitimize the pipeline development cost. The outcome of the newly developed conflict between the Russians and Ukraine and the role of NATO and the European Union will also determine the future of the Russian energy supply. The new alliances and regional changes resulting from the conflict will affect the Europe-Russia relationship regardless of the war's outcome. In this manner, by supplanting the military as an instrument of national power with economic methods, Russia could depend on the energy substance as dealing tool to seek its goals.

NOMENCLATURE

E.U European Union

USSR Union of Soviet Socialist Republics

LNG Liquefied Natural Gas

ESDP Enterpreurship Skill Development Programme

NATO North Atlantic Treaty Organization

ECT Energy Charter Treaty

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THE CONFLICT IN SYRIA AND ROLE OF KEY ACTORS: THE FUTURE SCENARIO

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Abstract

In light of the involvement of several parties, including state and non-state organizations on a national, regional, and international level, this study seeks to examine the complex dynamics of the Syrian conflict. The Syrian Crisis' potential future is examined, along with the people involved, their viewpoints, and their worldviews. Following the study of the documents, a qualitative approach was used to assemble a plethora of data on the topic as well as all the players and components that contributed to the Syrian conflict. Pro-Assad, Anti-Assad, and Non-aligned players are found to be divided into these three groups. Islamic State has a unique position in the conflict by engaging in combat with both pro- and anti-Assad factions. According to the report, the intricate interaction between multiple state and non-state players in the Syrian war on all scales, from the regional to the global, will continue for the foreseeable future.

Keywords: Syrian Civil War, Assad Regime, Middle East, Proxy, Conflict.

1. INTRODUCTION

The Middle Eastern rebellion, often known as the "Arab Spring," started in Tunisia in the latter days of 2010, continued through 2011, despite the utter instability of the nation, and continued until March 2020, when it entered its tenth year. The "Arab Spring" has had a significant influence on both regional and global politics [1]. For a variety of causes, including dictatorial control, corruption, People in the region rebelled against the long-standing authoritarian authorities due to issues such as a lack of democracy, a lack of accountability, a less free society, falling economic well-being, religious differences, etc.[i]Middle Eastern nations experienced sociopolitical unrest as a result of the rebellion in the area. The turmoil is quite evident in all of its cross-border sociopolitical expressions. The region's long-standing governments changing is one of the most notable expressions [2]. The demonstrations led to the toppling of the regimes of Tunisia, Egypt, Libya, and Yemen. The significant protests that cast doubt on the legitimacy of the countries were so large that not even the governments that survived could put an end to them.[ii]In an effort to defend their separate countries, the regimes responded elsewhere by striking back hard against the demonstrators. The use of force by state officials turned the protests into violent, protracted battles. As civil conflicts broke out in Middle Eastern nations including Syria, Iraq, Libya, Egypt, and Yemen, the situation got increasingly dangerous. Millions of lives in the area are at danger due to the power struggles between many stakeholders and the stark socio-political differences, which has created a worrying human security scenario. With the spread of a deadly phenomenon like Islamic State, the conditions in the area continue to deteriorate. With regard to resolving the dilemma, the civil unrest and insurgency in the area, together with the participation of foreign players, have made the situation more complicated [3]. In this sense, the Syrian crisis, in which there are more than a dozen players in the war ranging from internal state (non-state actors) to international level, may be

considered the most important example to comprehend constantly increasing complexity in the lethally unstable area (regional and international actors). [4].

2. LITERATURE REVIEW

The principal subject of discussion about Assad was the tyrants' plans to respond decisively in the aftermath of the toppling of the dictatorships in Tunisia and Egypt. Particularly the Assad regime presented the protests as terrorist actions conducted by radical Islamists. Bashar al-Assad used a tiny military squad to carry out his offensive operations against his foes. Additionally, the Syrian military exploited pro-Assad militants well to expand their authority across the nation.[iii] The opposition's involvement in this vital circumstance was essential, and given that it is composed of individuals from various ethnic, political, and religious backgrounds, it might help transform the variety into a sense of national identity. The disagreement cannot be fully addressed without creating a solid political system or structure, and the opposition is capable of managing the situation. The collapse of the Free Syrian Army prompted the emergence of several new organizations, according to a thorough review of Syria's dispersed opposition. The division of Sunni sympathizers into two regional groups, the Pro-Muslim Brotherhood (Qatar and Turkey) and the Anti-Muslim Brotherhood, further exacerbated the issue (Saudi Arabia) [5].

Hokayem repeatedly emphasized the significance of regional powers, especially Iran, which backs the regime, and Saudi Arabia and Qatar, which support the opposition.[iv] The United States' hypocrisy was highlighted by Yassin-Kassab and Al-Shami in their book Burning Country since they only publicly intervened after ISIS struck Syria. Along with attacking ISIS, the US also targeted another anti-Assad Islamist organizations. The Syrian crisis was gradually and continually changed by both internal and exterior influences, although the capacity of Assad was consistently challenged more by domestic or internal politics [6].

The crisis in Syria should not just be understood from a single, personal perspective; rather, it is important to take into account deeply ingrained historical patterns.

The European Union has continued to play a role in resolving this situation and has even sanctioned Syria and ended its alliance with that country. However, it was discovered that by adopting such measures, EU diminished its influence in the area, and that Europe's withdrawal from the region worsened the problem, especially as it related to the refugee crisis and extremism [7].

2.1 The conflict actors who support Assad

A diverse combination of local, regional, and extra regional entities make up the Pro-Assad. The majority of the pro-Assad troops are made up of local Shiite, regional, extra-regional, and Syrian government forces.

2.3 State of Syria

With the help of its friends both within and outside the country, the Assad administration has managed to survive among all the turmoil by using an exceptionally harsh policy against the rebels. Indeed, the Assad regime's supporters' unwavering backing made the possibility of the regime's survival on all fronts viable. In truth, the Assad regime's alleged use of chemical weapons caused hesitation among its allies in giving the crucial backing.[v] However, against all chances, the Assad administration has received significant assistance from Russia, Iran, and the tenacious Hezbollah in the political, economic, and military spheres. Actually, each side is working with the Assad administration to further its own strategic goals in light of local, planetary, and global dynamics. While the allies' assistance has helped the Syrian government retain some degree of territorial integrity, the phenomena of reliance has also grown [8].

2.4 Iran

One of the most ardent supporters of the socialist-secular-nationalist state of the Arab world is the Islamic Republic of Iran, which has a theocratic background. The coalition really

represents a distinct regional political trend in the Middle East. Both countries have certain common strategic objectives as well as difficulties posed by regional and international entities. Both nations have successfully engaged one another in order to achieve their respective goals. Syria and Iran have a close strategic alignment on issues like Palestine and Lebanon even before the Syrian crisis started. Both Syria and Iran provide a difficult and convoluted nexus for Israel and other regional and international organizations due to the strategic depth provided by Hamas and Hezbollah. Historical studies demonstrate that Iran often enters Syria to help Hezbollah, a big opponent of the Israeli military [9].

Iran has backed the Assad administration in its fight against the opposition forces from the very beginning of the war. To protect the Assad government, it has stationed soldiers on Syrian territory. It has also extended its assistance by routinely sending supply planes to Damascus. As the battle develops, several armies from the area and beyond have joined it to further their own strategic objectives Iran put in a lot of effort to assist the Assad government in the face of any opposition. For the Iranian state to have a strong enough hand to counter the aggressive opposition being led by Saudi Arabia in regional geopolitics, a friendly Damascus government would be quite beneficial at this moment. In addition to sending its regular military personnel and providing heavy military support to defend the Assad regime, Iran has used its influence to persuade Shiite non-state actors and fighters from the Middle East, South Asia, and other regions of the world to travel to Syria in order to further their objectives [10].

2.5 Hezbollah

Hezbollah, one of the most potent non-state actors, with Iran's assistance has bolstered the Assad regime's resistance against Sunni troops and their supporters. Hezbollah, a predominantly Shiite movement, once enjoyed great popularity in the Arab world for its armed struggle against Israel, but this popularity has since declined due to its involvement in the Syrian conflict, as the Arab world now views it as a party to the Sunni-Shiite conflict due to its active support for Iran and Syria. In reality, the alliance between Iran, Syria, and Hezbollah was clear even before the Syrian crisis began, when Syria served as a conduit for the transfer of Iranian weapons to Hezbollah for use against Israel. Hezbollah is now engaged in combat against the opposition groups in Syria with Iran and Russia. The willingness of Iran and Russia, in the framework of a potential alternative for peace building, is, nevertheless, a determining factor in the future existence of the dynamic non-state actor in the nation [11].

2.6 Lebanon

Lebanese social services are understaffed and underfunded as a result of the crisis in Syria, which has also had a significant effect on Lebanon. a circumstance for which the nation is inadequately prepared. Additionally, it has exacerbated the standoff between Hezbollah and the Free Movement and stoked Sunni-Shi'a tensions at the local and national levels. Due to its support for the Syrian government, the latter is in a precarious position. On the other hand, Hezbollah fears that a complete victory by the Syrian opposition may result in President Bashar al-ouster. Assad's. It is worried about the possibility of a post-Assad Sunni-dominated period that supports Hezbollah in Lebanon. As a result, some groups in Lebanon are concerned that Syria may one day develop into a powerful Sunni state [12].

2.7 Israel

Israel has decided not to become involved in the Syrian war. Regardless of this, any political agreement that permanently establishes Iran as a prominent player would unavoidably raise concerns. Sunnis in Iraq may become less concerned and re-align with the Baghdad government if Iran is unable to threaten Israel's northern borders, which would destabilize Lebanese and Jordanian affairs [13]. Given the likelihood of an Iran-dominated Syria and a future weapon transfer to Hezbollah through Damascus, Israel should tread cautiously. Israel fears that Hezbollah-created asymmetric battles may result in significant civilian casualties for its people.

2.8 The United States

Despite American claims to have no direct interests in the Syrian crisis, maintaining Syria is crucial to the country's national security. ISIS being able to launch attacks from safe havens in Syria is something that worries everyone that there would be a worldwide refugee crisis, and that the war may spread to other nearby nations. Despite its previous diplomatic failures, a political agreement led by the US would be perceived as the US making up for its lack of credibility in the area. However, the United States' robust participation without taking into consideration the regional political circumstances might cause more issues [14].

Today, two US approaches to Syria may be outlined: the Obama administration's strategy and potential effects of Trump's presidency on Syria and the Middle East. The US has not militarily involved in the crisis, in contrast to Russia. However, Salafi radicalism has always been its main source of worry. Obama's presidency saw a significant shift in US strategy against ISIS while maintaining a feigned interest in Assad's ouster. Compared to his predecessor, Donald Trump seems to give fighting extreme organizations a higher priority. This might serve as evidence to support an agreement with other nations. It is to be expected that the American administration will be more understanding of the Assad regime [15].

2.9 Russia

Since the start of the conflict, Russia has taken on a dual role that sometimes contrasts with it and other times enhances it. Russia backed the Assad regime and participated in the conflict on the one hand, while also serving as a mediator for almost every imaginable diplomatic accord. Syria's military presence in the Mediterranean, in particular the Tartus naval station, is known to Russia. Syria's location in relation to the gas pipeline is presumably another consideration. Given that it is home to over 20 million Muslims, Russia views radical Islamist organizations as a danger to the stability of its own internal politics. Furthermore, according to Russia, Syria runs the danger of degenerating into a failed state if President Bashar al-Assad is ousted without a universally agreed-upon replacement. ISIS will be able to cement its positions thanks to these safe havens. In September 2015, the Assad administration started an intensive military operation against the opposition in addition to giving him military equipment [16].

According to the Syrian Observatory for Human Rights, hundreds of civilians have died as a result of airstrikes since that time, including children. However, the balance of power in Syria was significantly impacted by Russian air assistance, Iranian participation on the ground, and the limited engagement of the US and many European nations. Without Russian balancing measures, the government would have had a difficult time surviving the civil war and regaining the areas it had earlier lost. However, Russian Federation really backed a political solution that mostly benefited the government. The ceasefire that was established in Astana in late December 2016 and is still in effect today is thanks in large part to Russia. A 85-article draught constitution was also submitted by Russia in Astana in January 2017, albeit it was unofficial and rejected by all parties involved, including the government [17].

2.10 The UN and the EU

On June 16, 2012, the UN halted its operations in Syria due to an uptick in violence. Since then, it has played a significant role in both diplomatic attempts to broker peace via the "Geneva Process" and humanitarian aid to Syria. In December 2015, it also approved Resolution 2254 of the UN Security Council, which supports a timeline for the Syrian peace process. A peaceful political resolution that enables the nation to rebuild is welcomed by the UN. On the other hand, the Syrian war has a significant impact on the European Union due to the issue surrounding the refugee crisis. Federica Mogherini, the High Representative of the Union for Foreign Affairs and Security Policy, has worked tirelessly to change this, but despite consistently condemning attacks on civilians, supporting a diplomatic resolution, enacting sanctions against the offenders, and being a sizable donor to

the international community, it has had little impact on politics [18].

2.11 Other Non-State Actors

Shiite militias from all throughout the area back Iran and Hezbollah in their conflict with Sunni troops. The pro-Assad troops see the Shiite militias as a key asset, and they have been instrumental in giving them the upper hand against the opposition forces. Shiite militias' protection of the area's sacred sites was one of their primary goals, and in doing so, they provided the Assad government with essential and all-encompassing support. By waging a ferocious battle throughout Syrian land against the Sunni forces supported by the US, These foreign Shiite combatants more than made up for the massive material and non-material losses suffered by the Assad troops [19].

2.12 Assad regime opponents

The Assad regime's adversaries include a complex amalgam of local, regional, and extra regional groups. The majority of the resistance troops are made up of local and regional Sunni fighters who are assisted by western friends. The opposition is made up of liberal elements who want a pluralistic Syria on the one hand, and extreme religious organizations that want a nationalistic fundamentalist state on the other. It's interesting to note that the US and its Western allies support the diverse character of the opposition groups, whether they are fighting the brutal IS or the Assad dictatorship [20].

2.13 Qatar and Saudi Arabia

Saudi Arabia and Qatar have both seen a decline in their once significant influence on the dispute in recent years. In the early years of the conflict, they all financed different rebel combat organizations and were ardent supporters of the anti-al-Assad opposition. By supporting many competing organizations rather than one, they contributed to the rebels' frailty. Qatar, in particular, used a "scattergun" strategy. The rivalry between these two Gulf States has also split the opposition, with Doha supporting the Syrian Muslim Brotherhood (MB) together with its ally Turkey and Riyadh supporting the MB's foes. When Saudi Arabia took over the SOC from Doha in 2013, it effectively put a stop to Qatar's significant engagement in Syria. But soon, Saudi influence also diminished. Some of this was beyond of Saudi Arabia's control; once Russia interfered, Riyadh saw the changing terrain. Saudi Arabia was also preoccupied with the conflict in Yemen, which began in 2015, and the embargo of Qatar, which began in 2017. Riyadh finally ended its backing for the armed rebels shortly after Donald Trump did as a result of rising friction with its former partner Turkey, which replaced the monarchy as the primary backer of rebels [21].

Since 2013, Qatar has mostly replicated and supported Turkish policies in Syria, playing a limited role. But Saudi Arabia has revised its strategy. The UAE, a close friend, stated in late 2018 that it was restoring its Damascus embassy, which had been shut down in protest along with other Arab embassies in 2011. Bahrain and Kuwait, two further Saudi allies, said they would soon follow. This was also a trial run for Saudi Arabia to reestablish relations, even if the UAE had its own objectives. Even the possibility that Saudi Arabia would consent to al-reinstatement Assad's into the Arab League after his suspension in 2011 has been floated. Saudi Arabia and the UAE are driven by the desire to diminish Damascus' dependence on Riyadh's arch-enemy, Iran, by re-engaging al-Assad and investing in rebuilding. They could also want to outwit Turkey, whose continued backing for the MB and Qatar has enraged it. At a time when Ankara seems to be becoming more helpless outside its borders, strengthening its influence in Syria may have some benefits. Al-Assad is unlikely to leave Iran, however, and his government has a long history of receiving funding from the Gulf without providing anything in return [21].

3 FUTURE POSSIBLE SCENARIOS

While there is increasing agreement that multi-party elections are inevitable, the key topic that has generated several discussions is the nature of the new government's "power distribution." The methods of "horizontal and vertical power distribution" have both been taken into account as potential futures for Syria.[vi]

Federalism has not come up in the talks between the parties so far. On the premise of administrative decentralization, there seems to be broad agreement in how to run a country's affairs. In accordance with Article 8 of the HNC's Executive Framework for a Political Solution, which was published in September 2016, it underlines its commitment to "give the people of each governorate and district a role in governing their local affairs." The same declaration also pledges to take efforts "to protect their ethnic, linguistic, and cultural rights" and acknowledges "the Kurdish struggle" (Article 6). However, all of these privileges and local autonomy will be granted "within the framework of the state and people's unity" (Article 8) [22]. On the other hand, local councils as grassroots groups, successfully expressing the democratic participation concept even today in Syria, are also anticipated to play a significant role in Syria's future (Article 50). Planning, industry, agriculture, economy, commerce, education, etc. are all covered by their responsibilities as outlined in Article 51 of the Executive Framework, but security is not mentioned in any way [22].

Federalism is not mentioned or even suggested in the UN Special Envoy's Paper on Points of Commonality. The Social Contract of the Rojava in northern Syria is the lone exception. Despite having the name "Social Contract of Rojava," It smells like separatism. Despite its questionable democratic credentials, it is essentially ready-made material that might be deployed in the event that any vision of self-determination came to pass. Fundamentally valuable is the fact that, other from the "social compact," all other debates about Syria's future have been focused on a united nation that recognizes Syria as a sovereign state and protects its geographic integrity.

According to the idea of a united Syria after the war, there should be a significant amount of decentralization and strengthening of the local government infrastructure. Additionally, ethnic and sectarian groups must to have political representation at the federal level. Even while a two-chamber system could be the best option in this case, the Russian suggestion to choose representatives based on their religious or ethnic identities would only serve to exacerbate existing tensions. Therefore, planting the seeds of political inaction. The job of monitoring the prevention of discrimination might be given to an upper house. However, no official positions at the executive level should be distributed based on sectarian or ethnic preferences. Additionally, there are certain ambiguous provisions in the same upper chamber known as the Constituent Assembly in the draught Syria constitution issued in January 2017 that might be read as allowing for federalism (Article 40) [23].

Due to Syria's pre-war centralized character, the nation urgently needs decentralization and a new administration system. As a consequence of the nation's fragmentation and the exclusion of many areas from central government power, there has been a de-facto decentralization. Significantly, local governments were established in these areas to guarantee the population's access to basic amenities like electricity and water, and some even started Sharia courts. These decentralizations, however, were chaotic and illegitimate; they were managed and funded by warlords using forced levies and extortion, smuggled money, and money from outside backers. Only half of Syria's landmass, or around 15 million people (65%), is now governed by the government [24].

In terms of promoting a better governance framework for Syria post-conflict, an all-inclusive decentralization that addresses the political, administrative, and fiscal spheres could be a suitable scenario. This would improve participatory governance, improve service delivery, and lead to the realization of balanced development [25]. Decentralization should encourage local council participation, guarantee that the local population's voice is heard in the process of development and reconstruction, and ensure that essential services are provided to affected areas as envisioned in the Executive Framework of the HNC. Despite this, decentralization still has a difficult task ahead of it due to the emergence of warlords in rebel areas, the fear of local political and social strife, the confluence of internally and externally displaced people, the global fight against ISIS, and

divisions within regional and global powers. All of these regional difficulties and global conflicts converge in Syria [26].

4 CONCLUSIONS

The sociopolitical dynamics of Middle Eastern countries in particular and the international system in general have changed as a result of the "Arab Spring." This also applies to the Syrian war, which is altering its patterns in accordance with the periods as well as the alliances between the many state and non-state entities participating in the battle. The actors may be broadly categorized into two groups: those who support Assad and those who oppose him. In actuality, the conflict's various regional and extra regional actors are pursuing their individual strategic goals. Because it is waging war on every participant in the Syrian conflict, IS's role has continued to be quite unique. Additionally, the situation is changing due to recent events in which IS has lost the majority of its control as well as the senior leadership and Turkey has been more outspoken in its opposition to Kurds. The pro-Assad forces, particularly those from Iran, have made tremendous progress in establishing their power and influence in Syria. On the other hand, Iran's own citizens have begun to voice concerns about the nation's hegemonic and regional influencing policies as a result of the ever-increasing pressure of US economic sanctions. It is crucial to start an extensive dialogue about the situation in the entire region with the participation of local, regional, and international actors. Without addressing the strategic and structural factors that facilitate these organizations' existence, ad hoc solutions that target, engage, or assist them are unlikely to have any long-term possibilities for success. The EU nations might act as facilitators in this respect by considering all the parties and their constant roles in the overall regional context.

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A SURVEY OF THE OPTIMIZATION TECHNIQUES FOR THE DESIGN AND MANUFACTURING OF BALLISTIC PROTECTION

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Abstract
In this research, a brief survey of the techniques used for the optimization of ballistic protection are discussed. Moreover, this paper focuses on the modelling techniques of the blast/explosions from an IED or a suicide bombing. The study focuses only one single aim i.e design of a highly efficient ballistic protection. Ballistic Protection is a major concern when there exist high level threats of terrorism targeting security personnel and military patrol vehicles. Land Mines do pose a significant threat to military operations. Two types of impacts that are the major cause of lethality of Improvised Explosive Devices and other Suicide Bombings are the shockwaves and the shrapnel. Similarly, law enforcing agencies often do tackle situations where law-breakers often use arms against them. In all these situations there is a high urge to briefly elaborate and discuss the effect of explosions and blast and how to develop a protection that can mitigate the effect of the bomb partially or completely. In this regard, the contribution of composite structures for the design and manufacturing of ballistic protection is surveyed. Evaluation of materials with different behaviors used in the development of ballistic protection was discussed. The technique and approach for solving the problems associated with explosion/ blast modelling in LS-Dyna was briefly elaborated in one of the publications surveyed.

Keywords: ballistic protection, Improvised Explosive Devices (IED), Kevlar, Dynamic Explosions, Blast Simulation, NIJ-National Institute of Justice

1. INTRODUCTION

In late 1960s new fibers were discovered and research was started to find light weight body armor. DuPont's Kevlar ballistic fabric was one of the most significant discoveries in body armor research, the intended purpose of the fiber was to replace the steel belting in vehicle tires. The bullet proof vest had also become a part of metropolitan police department. The anti-ballistic proof jackets were used in world war-II which is also known as Flak jacket. The designed jacket did not prove effective for the pistols and the rifle threats. The heavy weight of the jacket was a main reason behind the low demand of the jacket in the armor market.

Meanwhile, the creation of Kevlar armor protection by National Institute of Justice was based on four phases that spanned several years. The very initial phase determined if Kevlar fabric could stop a bullet. The next phase covered estimation of the numeral of sheets of material sufficient enough to stop the bullet from penetration at various speeds with different calibers, as well as constructing a prototype vest to defend officers from the most common threats: 38 Special and 22 Long Rifle rounds.

The movement's third phase included thorough medical examination and inspection to assess the amount of body armor performance required to preserve police officers' lives. For the very final case, armor's method used to measure the effectiveness were monitored. The vest was found to be comfortable, prevented any undue generation of stress or pressure on the shoulders, and allowed typical body movement required for police duties in a preliminary test in three cities with ease. Adaptability in variations of temperature, comfort level during a complete working day, and durability over long years of use were all the necessary considerations for the design. Designers worked out to make a body armor which could bear the 38-caliber bullet which had the velocity of 800 ft/s. The design proved very effective as it demonstrated extremely low penetrations from bullets. The novel protective material proved as an effective solution in delivering a bullet protective jacket that was lighter in weight and comfortable for long shift/time duties, according to a report finalized in 1976.

For many years, the main goal of body armor development was to provide increased levels of protection. This process appears to have reached a nadir, as modern body armor offers less protection than that of the 1970s, owing to the belief that increased mobility comes after a compromise on the level of offered protection.

2. LITERATURE REVIEW AND ANALYSIS

2.1 Study of methods of development for improvement in ballistic protection of vehicles using the concept of composites and sandwicthed panels.

Stiavnicky with Adamec [1] proposed a comparative study of composite materials for safety required by military patrol

vehicles in terms of ballistic protection. They designed three different composite armors and analyzed it via LS dyna software package and their individual performances were evaluated against a sub-caliber round. Stiavnicky and Adamec further concluded that the that from the comparison of a homogenous ballistic protection plate from SSAB (Swedish Steel Group Company), a Silicon Carbide plate inserted between two armox 500T plates, a several layer woven Kevlar fibers sandwiched between two Armox 500T plates and the same Kevlar layer combined with two Toolox 44 material, the Toolox and Kevlar combination was clearly the most effective as it absorbed the most impact energy.

2.2 Evaluation of explosion resistance of ballistic polymeric materials

Skalicky, Komenda, Vitek, Jedlicka and Vlhova [2] published the results of an experimental comparative study of different materials subjected to a highly explosive blast for ballistic testing. They used fabric from two different manufacturers, three laminated and three woven and therefore conducted six sample tests. Their experiment was primarily based on the exposure of the specimen to the effects of blast from a reference charge. The testing conditions were maintained the same for each of the six fabrics. Test samples with similar constraints were extracted from the set of fabrics chosen. Their experiment proved different explosion resistances and proved the claim of the manufacturers about their impact absorption values.

2.3 The Damage Analysis from Ballistic Threats on Transparent Armor

Chaichuenchob and his team [3] had carried their research in transparent armors comprising of transparent. They laminated various soda lime panes of glass using polyvinyl butyral as reinforcements. The testing of the designed armor was done using a 7.62 mm FMJ armor fired at different speeds. They realized that the total of cracks generated on the 12 mm strike plate was greater when compared with a 19 mm strike plate tested under the same conditions. They calculated the surface areas for these two plates and further deciphered that the same amount of energy (kinetic) was absorbed during the impact. The bifurcation of the cracks was observed when the velocity surpassed 838 ms^{-1}. Ultimately, they concluded their research with the recommendation that their study can be used for the optimization and improvement in the field of transparent armor.

2.4 Evaluation of various Textiles for high performance as ballistic protection

Agrawal [4] proposed a detailed analysis on high performance textiles essentially significant in ballistic protection. They explored the use of several textiles such as Nylon, Carbon fibers, Ceramic fibers, Aramids and Glass Fibers, Ultra High Modulus Polyethylene (UHMPE), Thermoplastic Liquid Crystal Polymer (TLCP), p-Phenylene -2,6-Bezobisoxazole (PBO). He further proposed an approach for the construction of ballistic protection such as woven textiles, non-woven, Composites and laminates, moreover he proposed the recent development in the field of ballistic safety particularly in bullet proof pocket square and Soldier exoskeleton.

2.5 Prefabricated Steel Stud Wall as Bulletproof protection

Ngamjarungjit, and others [5] investigated the behavior of a bullet proof steel stud wall. They had initially described their purpose of research that was to design a rapidly installable wall. They used cold-formed 10-cm thickness steel that served as the cladding for the external surface. This insulation was extracted from concrete mixed with foam that made the design lighter in weight and weather resistant. Results of the 0.5 mm thick sandwiched steel stud wall showed the level of protection provided by the wall system. The firing took place on a firing range with a standard range between the rifle and the test subject of 15 meters. 5.56x45mm ammo and an M16Al rifle were used for the tests. They, concluded their research after claiming that their product satisfied and met the requirements essential for the level III protection.

Table 1: Results of experiments performed [2]

No.	Style	Areal density ($kg.m^{-2}$)	Number of layers (ks)	Thickness of one layer (mm)	Sample thickness (mm)	Total areal density ($kg.m^{-2}$)	Number of punched layers (mm)	Areal density of punched layers ($kg.m^{-2}$)	Relative punched thickness (%)	Relative number of punched layers (%)
1	UD-42	0.246	20	0.23	4.6	4.92	0.92	0.98	20	20
2	Microflex	0.216	23	0.26	6	4.96	1.3	1.08	21.74	22
3	CT 714/2	0.203	25	0.22	5.4	5.07	1.08	1.02	20	20
4	Sp Sa-3118	0.173	29	0.17	5	5.01	1.21	1.21	24.14	24
5	CT 709/2	0.122	41	0.12	5	5	0.73	0.73	14.63	15

2.6 Simulations of the aftermath of Suicide-Bombing via Blast-sim

Zeeshan, Usmani and others [6] proposed their research in Blast-Sim. Blast-Sim refers to the physics associated with stationary multi-agent computational model of blast-waves. The effect of the blast on human body was also an integral part covered in their research. The agents were constrained by mechanics of the blast wave and its physical characteristics. The simulations were designed to capture the effect of human group formation and patterns on the scale of wounds and number of fatalities in case of a bomb attack particularly a suicide attack.

2.7 Emergency 101 – Suicide Bombers, Crowd Formations and Blast Waves

Zeeshan and Kirk [7] again investigated the impact of suicide bombing in another paper they published. They declared Suicide bombing as the most effective method for terrorist organizations worldwide. They showed the significance of the impact crowd density on the effectiveness of the suicide bomb. They developed a virtual simulation tool which had the capacity of analyzing the effect of human formation and crowd layouts on the magnitude of wound and number of expiries during the madness.

2.8 Study of the testing method of aerial blast point based on shock wave overpressure.

Sheng, Hao and Xue-Lin [8] showed their interest in the analyses of the examination technique of aerial blast points primarily reliant on blast wave over pressurization. They began their research by initially describing the problem associated with low positioning accuracy that poses a great threat to the workers in traditional method of the aerial blast point, a built a model to locate the point. They investigated the peak over pressure information for incident shock wave along with newtons method that are capable of solving the problem described initially. Finally, they verified positioning accuracy of the model through experiments.

2.9 The Simulation Analysis on the Numerical Destructiveness of different wall materials Under the Explosion Overpressure Shock Wave

Jiang and others [9] presented the idea of analysis via simulations of the numerical destructiveness of various wall materials when exposed to an explosion overpressure shock wave. The paper they published includes the modeling and analysis of the dynamic response of the common wall, blast wall and shear wall under blast loading. The models were simulated using ANSYS\LS-DYNA as software for simulations and analysis. By the analysis of the stress changes and overpressure peaks of wall under the blast loading, they were able to achieve properties of the wall material against over pressurization.

2.10 Research of Dynamic Response Numerical Simulation Technology about Underground Chamber with Blasting Load in Deep Environment

Dynamic Response of Numerical Simulation Technology (NST) in Relation to Underground Chamber with Blasting Load in Deep Environment was addressed by Hu and Yang [10]. They used the general (FEA) finite element analysis program ANSYS/LS-DYNA for their investigation. They used a conversion function and combined static and dynamic response in the methodology they adopted. They introduced nodal displacements as IC's (Initial Conditions. An extensive dynamic analysis was done to simulate the terrible effects that the blasting load would have on the next chamber. They offered the enthusiastic readers to further investigate the respective field.

2.11 Investigation and Application of Parallel Method for Blast Wave Interaction and Detonation

Application of Parallel Methods Essential for Blast Wave Contact and Discharge was explored by DENG and colleagues [11]. They proposed a similar strategy for the investigations through simulations of flow fields with moving and deforming pieces or chemical non-equilibrium explosion. The idea was built on an environment with multiple concurrently operating jobs. They provided two examples to demonstrate the speed increment of the parallel computation. Finally, they concluded that the results indicated the parallel algorithm, they implemented is effective and effectual and encouraged to further explore the relative field.

2.12 Computational Simulation of Shock Tube and the Effect of Shock Thickness on Strain-Rates

Laksari, Assari and Darvish [12] discussed about the computational Simulation of Shock Tube. They further brought along the impact of Shock Thickness on Strain-Rate into consideration. They looked into the high rates of loading involved in the development of explosive devices as well as the blast-induced neuro damage, which is a significant worry. On the basis of current investigations, they asserted that brain tissue experiences brief and rapid displacements under blast loading circumstances after studying recent publications. When modeling the reaction of tissues in shock tube situations, Laksari and colleagues investigated the effects and significance of shock front thickness. They showed in their research that the precautions they had made might significantly imply damage and causation hazards in computer models.

2.13 Damage modeling of ballistic impact in woven fabrics:

In this case study, S.D. Rajan and B. Mobasher [13] had made the structural system structural by dry woven and it was subjected to ballistic impact. The finite element analysis was main key which was used in modeling. They used fabric woven as it was having high strength to weight ratio in addition to it had the capability to fight from high-velocity piece impact. A continuum model was

made at macro scale level instead of tale geometry at musicale level for analysis of ballistic influence. Friction and tension test were used for this experiment. Friction test was used to determine the static and dynamic coefficient. In order to calculate the distortion, damage and catastrophe reply of polymer matrix. It used the influence condition and it required the accurate material model. The changes could come in this model as well to make it more efficient and worthful.

2.14 Ballistic impact response of Kevlar reinforced thermoplastic composite armors:

In this Aswani Kumar Bandaru, Vikrant V Chavan, Suhail Ahmad R Alagirusamy, and Naresh Bhatnagar [14] used thermoplastic composite made by Kevlar of propylene composite armors. The performance of ballistic impact was observed by using this material. Kevlar fabrics of many architectures which are named as, 2D plain woven, 3D orthogonal and 3D angle interlock fabrics, were generated which made the panel of composite armor. The main technology which was used was compression molding. They used the coupling agent called maleic anhydride in order to make the interfacial property between Kevlar and propylene more efficient.

2.15 Ballistic Impact Behavior of thermoplastic Kevlar composites: Parametric studies:

In this research paper, Aswani, Kumar, Bandaru and Suhail Ahmad [15] observed the ballistic impact behavior by using Kevlar and propylene through Ansys software by doing hydrocode simulations. The investigational and mathematical results were investigated of ballistic impact reply against the Kevlar. The mathematical model was validated by scoring the presentation of Kevlar's ballistic impact under the simulated impact of a SATANG-2920 fragment. The shear plugging was main failure mechanism in thermoplastic composites. A body armor was made which was a good object in protective piece of clothing. The shear plugging was seen near the impact zone in terms of energy absorption method. The impact velocity was directly proportional to residual velocity. The increased residual velocity showed steep ballistic limit.

2.16 A ballistic material model for continuous-fiber reinforced composites:

To facilitate computational studies of advanced damage/failure in plain-weave composite coverings under high velocity ballistic impact circumstances, Chian-Fong Yen [16] created a ply-level material constitutive model for plain-weave composite laminates. In order to account for failures brought on by tensile, compressive, punch shear, and crush loads, they employed failure starting criteria and harm development regulations in their model. These fiber and matrix failure mechanisms were caused by the ballistic event. The Ansys software's and LS Dyna dimension was used to predict the plain weave composite layers' progressive failure performance. In the impact of ballistic in composite panels, the damage development and progression occur could be seen through this composite material.

2.17 Modelling of composite materials behavior for blast and ballistic impact:

C.F.Yen [17] developed the robust computational constitutive model. The failure behavior of composite laminates was investigated under explosion and ballistic circumstances. The LS-dyna program, which is a component of the Ansys software, was used to simulate the blast and ballistic impact on composite panels. In blast loading of light weight composite material, the damaged development and progression happened which could be seen through this composite models. The prophesied panel damage was related with tested panel. The current ballistic assessment approach yielded results for the value of V50 and projectile residual velocities for composite laminated panel with a precision of 13%, according to a comparison of repeated results with investigational data for composite panels

2.18 A computational analysis of the ballistic performance of light weight hybrid composite armors:

Basically, M. Grujicic and his team [18] determined strength of hybrid light weight fiber strengthened polymer matrix composite laminate armor so as to know that how much it could bear with impact of fragment simulating projectiles. It was supervised by using the non-linear dynamic transient computational analysis. They used carbon fiber reinforced epoxy which had high strength and high toughness. It was used in different combinations and stacking sequences. The ballistic performance of the armor was greatly hit because of using the assembling sequence and number of the laminates. The ballistic performance of the hybrid armor was increased by using the Kevlar fiber reinforced epoxy laminates which was the outer face of the armor.

2.19 Ballistic impact simulation of an armor-piercing projectile on hybrid ceramic/fiber reinforced composite armors:

In this Daniel Bürger and his team [19] made the composite of the model were alumina plates and ultra-high molecular weight polyethylene composites. The explicit finite element code was used for the three different constitutive models which were made for testing. The investigational and mathematical results were compared so as to cater the damage shape. Then the composite and ceramic materials were used to make it more efficient and useful. It enhanced the performance of the armor materials. The commonly used fiber for the armors is aramid and ultra-high molecular weight poly-ethylene. The alumina, silicon carbide and boron carbide were the commonly used ceramics. It was important to develop more efficient tolls to make the price low.

2.20 Fragment ballistic performance of homogenous and hybrid thermoplastic composites:

S.B. Sapozhnikov, O.A. Kudryavtsev and M.V. Zhikharev [20] had done many extensive ballistics tests on various protective composite structures. The speed had been reached up to 900 m/s. they used 6.35mm steel ball. The V50 threshold as well as the post V50 limit were used to evaluate the ballistic performance. It was seen that the effect of temperature was negligible. In high velocity impact condition, the absorbed energy and indicators of V_{50} of UHMWPE fibers were good than by using other fibers. However, as the projectile's velocity reached the ballistic limit,

their energy absorption capability dropped significantly. The ballistic limit, which establishes the incident impact velocity at which there is a 50% likelihood of damage, was one of the important variables.

2.21 Measurement of ballistic impact properties of woven kenaf-aramid hybrid composites:

In this case study, R. Yahaya, S.M. Sapuan, M. Jawaid, Z. Leman and E.S. Zainudin [21] made the two arrangements of woven kenaf Kevlar composite materials by varying the volume fraction of the composite material. The different impact and residual velocities were performed by using fragments simulating projectiles since the ballistic measurement test of hybrid composites was done. The failure modes were investigated by invigilating the damaged sample of hybrid composites. In comparison to other fiber composites, the 14 layers of Kevlar and the 2 layers of kenaf exhibited better characteristics and demonstrated higher ballistic performance. The hybrid composite had good thickness a areal density due to which the ballistic properties are increased.

2.22 Ballistic impact of a KEVLAR helmet: Experiment and simulation:

C.Y. Thama, V.B.C. Tanb and H.P. Lee [22] experimented and simulated the ballistic impact of Kevlar helmet. The experiment that was done was a light gas gun fired the spherical projectile which was hit the Kevlar helmet at the speed of 205 m/s and at the mean time when projectile was hit the helmet, it was detected through high-speed photography. The investigational and replicated results were compared. The simulation was compatible with the response that the helmet had bear. By getting the experimental and simulation results, it was seen that projectile could not penetrate through helmet.

2.23 An experimental investigation on the impact behavior of hybrid composite plates:

In this, Metin Sayer, Numan Bektas and Onur Sayman [23] had performed the behavior of hybrid composite plates that how they act. The two hybrid composite pates were used. The plates were tested by increasing the impact energy. They kept on increasing the impact energy until it caused the hole into the specimens. As to get the relationship between absorbed energy and impact energy, they used the energy profile method. When load deflection curve was added then they got about three things which were penetrations, rebounding and holes. The hybrid composite had good fatigue life and corrosion resistance. When impact load was applied on the composites material s it had more importance in engineering field.

2.24 Composite materials with the polymeric matrix applied to ballistic shields

In this paper, M. Rojek, M. Szymiczek, J. Stabik , A. Mężyk , K. Jamroziak E. Krzystała and J. Kurowski [24] made an alternative armor plate by using the composites paper. It was capable to resist against caliber bullets of 7.62 and 5.56. in this epoxy matrix composite was used which was strengthened with the glass fiber and the glass fiber was in the state of steel mesh, fabric or mat. The three sheets were attached with the ceramic panel. This composite fiber was used for the light weight armed vehicles in the ballistic protection. The steel mesh was connected with glass mats in order to strength it and by doing this, it would reduce the destruction of the composite material. The defragmentation was also reduced decreased by strengthening the ceramic panel with inter layer of steel mesh.

2.25 An Experimental and Numerical Study of Fracture Toughness of Kevlar- Glass Epoxy Hybrid Composite.

J. Maheswaran and his colleagues [25] used experimental methods and finite element analysis to study the behavior of a Kevlar and Glass Epoxy Hybrid Composite during fracture. The tension test was used with fixtures in accordance with ASTM guidelines. The Fracture Toughness for both across the direction of the fiber and along the direction of the fiber of the test material was obtained experimentally. It was observed from the results that the cracked sample was tougher along the direction of the fiber as relative to across the direction of the fiber. The elastic modulus for both cases had a difference of 417 MPa, more for along the fiber case, same behavior was observed for critical stress intensity factor.

3. BEST THREE METHODOLOGIES

3.1 Ballistic Analysis of 14.5 AP Bullet on Armor Material

In the very first significant methodology, a 14.5 mm AP bullet was tested to analyze the impact on armor. Furthermore, ballistic resistance numerical simulation was performed. In order to properly define and monitor the strength of metallic material Johnson-Cook strength model was used. The conditions under which the material was tested involved large and high strains, strain rates and temperatures.

$$Y = [A + B\varepsilon^{n}_{p}] [I + C \log e^{*}_{p}] [I - T^{m}_{H}\}] \quad (1)$$

Here the term ε_p can be defined as the effective plastic strain with e^*_p as the rate of the normalized effective plastic strain and the term T_H is the homologous temperature.

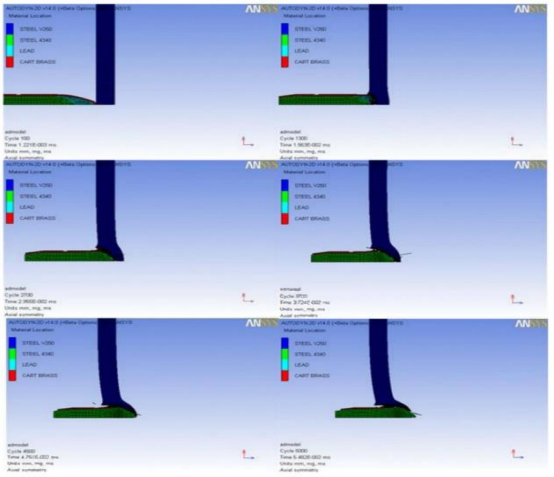


Figure 2: V250 steel (Simulation result,thickness 11.0 mm, steel core) [26].

On ANSYS commercial software, the research progressed with explicit dynamic code on AUTODYN. The study found that a 14.5 mm AP bullet could not be stopped by a single layer of

10mm V250 steel, the simulation was done using explicit dynamic method with non-liner finite element. The simulation consisted of two parts a bullet and the target, the bullet was made of three components, a steel core made with AISI 4340 hardened steel, Lead and brass were used for jacket and cartridge. A circular shape of steel V250 was used for the target. The bullet made impact on the center of the target. Because of restricted computational resources the analysis was done with plain strain condition in 2-D manner, the components were set up into frictionless pullies.
The study was carried out in two cases in case 1 the armor was made of V250 only and in case 2 a layer of alumina was also added. The following results were obtained from simulations of case 1.

The maximum plastic deformation was observed at 0.55 millisecond but at that time the bullet had perforated the target and still had a velocity of 650 ms^{-1}, adding a second layer of alumina ceramic increased the resistance of V250 steel to ballistic impact. The bullet hit the target with an impact velocity of 911 ms^{-1}.
The simulations done for case 2 got the following results.

$2.2x10^8$ and $5.5x10^8$ mj were plastic work of V250 steel and alumina respectively, at 0.055 ms. In case of double layer, the plastic work of V 250 steel was significantly less than that for the single layer.

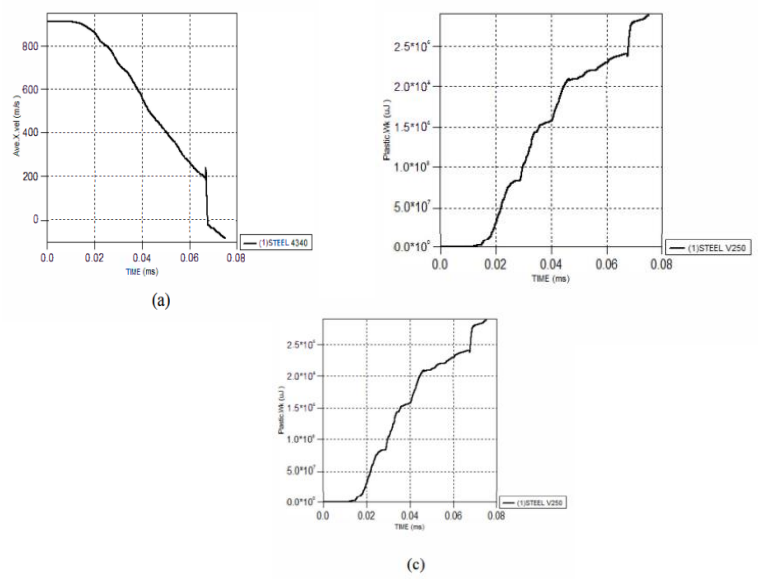


Figure 3: Result of simulation of 10 mm V250 steel (a) Plastic work of the sheet vs. time (b) Velocity of the projectile vs. time [26].

The ceramic layer increased the ballistic response as the V 250 could not stop the bullet but adding alumina proved helpful. The mathematical model of the material used for simulation assumed that the strain rate of a material is independent of the temperature sensitivity, which is contrary to what happens in real life. Due to lack of computational resources only 2D analysis was done.

3.2 Modeling and Simulation of a Shock Absorbing Shell for Ballistic Vests and Helmets to Achieve Optimal Protection

By using modeling and simulation-based study of shock-absorbing shells, Suciu, Fukui, and Kimura's research was published with the intention of enhancing the design of helmets and vests for ballistic protection [27]. When a colloidal pad was positioned on the exterior of the shell, up against the bullet, it was discovered that the back-face signature was reduced by 10%. However, when the colloidal pad was positioned on the inside of the shell, up against the striking bullet, the back-face signal was diminished by 25%.

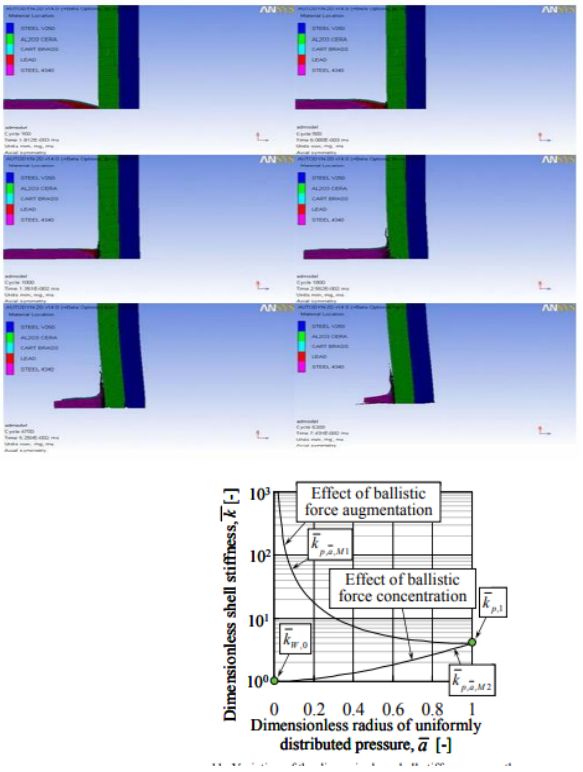


Figure 4: V250 steel (Simulation result, thickness 10.0 mm additional alumina) [26].

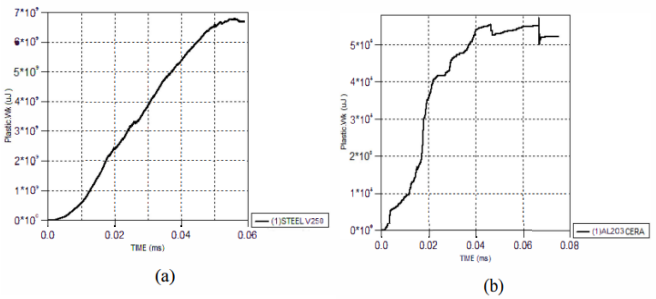


Figure 5: The result of the simulation of l0 mm alumina added with V250 steel (a) Velocity of steel core vs. time (b) Plastic work of alumina vs. time and (c) Plastic work of V250 steel vs. time [26].

The following equation can be used to calculate a membrane's transverse out-of-plane displacement, w:

$$\nabla^2 D \nabla^2 w = p \tag{2}$$

Or for constant flexural rigidity throughout the plate

$$\nabla^4 w = \frac{p}{D} \tag{3}$$

Where the bending or flexural stiffness of the plate is D, defined as: where Pressure, acting in the same direction as z and w, is

represented by p, ∇^4 is known as the bi-harmonic differential operator, and ∇^2 is Laplace's differential operator.

$$D = Et^3/12(1-v^2) \quad (4)$$

Here, E stands for the Young's modulus of elasticity, v for the Poisson's ratio of the material used to make the plate, and t for the plate's thickness.

∇^2 is the Laplace's differential operator and can be written as

$$\nabla^2 = \frac{\partial^2}{\partial r^2} + \frac{1}{r}\frac{\partial}{\partial r} + \frac{1}{r^2}\frac{\partial^2}{\partial \theta^2} + \frac{\partial^2}{\partial z^2} \quad (5)$$

For a pressure that was evenly distributed across the surface of a shell with a clamped edge, the equation shown below was found. With the origin at (r = 0) and the clamped edge at (r = R) and the following boundary conditions:

$$w_{p,1}(r=R) = \frac{dwp,1}{dr}(r=R) = \frac{dwp,1}{dr}(r=0) \quad (6)$$

The shell displacement $w_{p,1}$

$$w_{p,1}(\bar{r}) = \frac{3(1-v^2)}{16\pi}\frac{WR^2}{Et^3}\left(1-\bar{r}^2\right)^2 \quad (7)$$

Where the W is the force and $\bar{r}$ is the dimensionless radius, both can be expressed as.

$$\bar{r} = \frac{r}{R} \quad , \quad W = \pi R^2 p \quad (8)$$

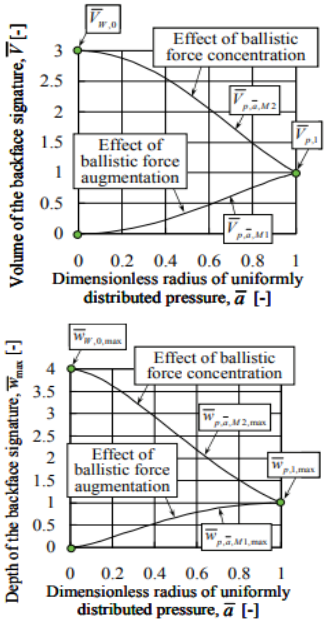
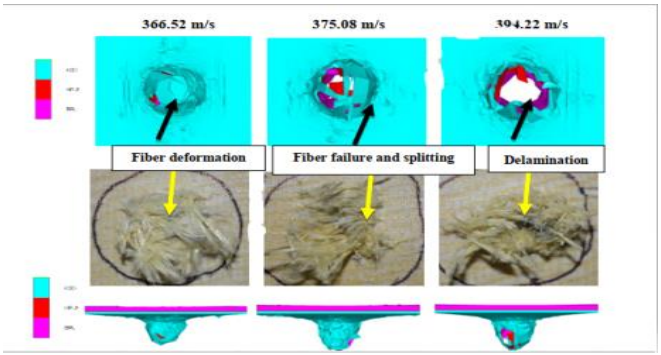


Figure 6: Fig graphical representation of the entire results [27].

At the center of the shell the back face signatures depth is

$$w_{p,1max} = w_{p,1}(\bar{r}=0) = \frac{3(1-v^2)}{16\pi}\frac{WR^2}{Et^3} \quad (9)$$



ms) [28]

The volume of the back face can be calculated from the equation

$$V_{p,1} = 2\pi R^2 \int_0^1 \bar{r}\, w_{p,1}\bar{r}.\, d\bar{r} = \frac{(1-v^2)}{16}\frac{WR^4}{Et^3} \quad (10)$$

The shell's stiffness

$$_{p,1} = \frac{W}{wp,1max} = \frac{16\pi}{3(1-v^2)}\frac{Et^3}{R^2} \quad (11)$$

For the modeling of a circular ballistic shell with a clamped edge that has been evenly loaded throughout.

$$Q_r = -\frac{W}{2\pi r} \quad (12)$$

The shell displacement;

$$W_{W,0}(\bar{r}) = \frac{3(1-v^2)}{16\pi}\frac{WR^2}{Et^3}\left(1-\bar{r}^2+2\bar{r}^2\, ln\bar{r}\right) \quad (13)$$

The volume of the back face signature;

$$V_{W,0} = 2\pi R^2 \int_0^1 \bar{r}\, w_{W,o}\bar{r}.\, d\bar{r} = \frac{3(1-v^2)}{16}\frac{WR^4}{Et^3} = 3V_{p,1} \quad (14)$$

The shell stiffness;

$$k_{W,0} = \frac{W}{w\, w,o\ max} = \frac{4\pi}{3(1-v^2)}\frac{Et^3}{R^2} = \frac{kp,1}{4} \quad (15)$$

For the modeling of a circular shell with clamped edge, loaded by eccentric focused force, the dimensionless depth of the back-face signature is given by:

$$\overline{w}_{w,\bar{b},max} = \overline{w}_{w,\bar{b}}(\bar{b}=\bar{r}, \Theta=0) = 4(1-\bar{b}^2)^2 \quad (16)$$

They investigated the impact of the force eccentricity in more detail and came to the conclusion that ballistic vests and helmets could not provide the highest level of protection. This was so that they could make the biggest back face autographs the majority of the time. They discovered that when the bullet impacted the unit cell at a specific eccentricity and caused the impact force to spread over a larger area, it was able to boost the protection of the helmets and vests. They conducted an experiment to see the armor strengthening and added silica colloidal pads to either the exterior or inner face of the shell unit.

3.3 Ballistic impact performance of hybrid thermoplastic composite armors reinforced with 2D/3D Kevlar and basalt fabrics

The composite thermoplastic material is used in which it includes the Kevlar with basalt fabrics of 2D plain woven as well as 3D interlock angle was also viewed through simulations and experiment to check the ballistic protection performance. Random stacking sequence (H-1) was used as well as symmetric stacking sequence (H-2) as hybrid armors types. The 9mm full jacket impact was targeted on H-1 as well as H-2 armor. H-2 resisted perfectly but H-1 armor was

Perforated for velocity between 365 ms^{-1} to 395 ms^{-1}. The material and method they used to test the armor was similar to our working process for the Kevlar based ballistic protection for military armor vehicle. The aim of the working of this paper is to develop polypropylene-based Kevlar/basalt composite armors to check the performance of ballistic protection. The hybrid 3D fabric is implemented for the composite armors.

The Defense Metallurgical Research Laboratory is used to the ballistic protection. The software which was used for the ballistic protection performance of hybrid composite material is ANSYS-AUTODYN -3D. The equivalent pressure is given as:

$$P = -\frac{1}{3}(\sigma_{11} + \sigma_{22} + \sigma_{33}) \quad (17)$$

Whereas the effective bulk modulus is given as:

$$K = \frac{(C_{11}+C_{22}+C_{33}+2(C_{12}+C_{23}+C_{31}))}{9} \quad (18)$$

It was seen that there is linear relation in pressure and volumetric strain.
The following equation enables the connection of an orthotropic

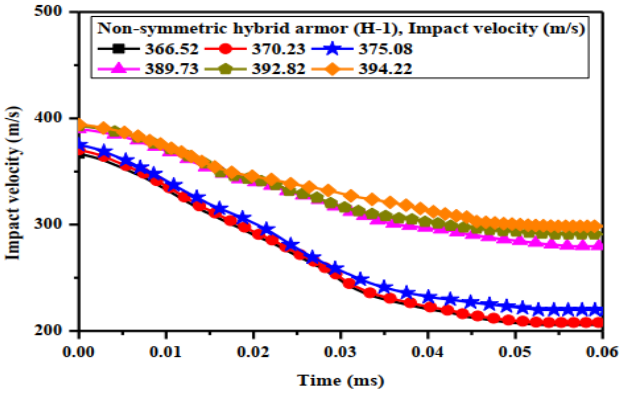


Figure 8: Full Perforation (Velocity time history for H-1 armor) [28]

material toughness with a nonlinear equation of state.

$$C_0 = \sqrt{\frac{k}{\rho}} \quad (19)$$

where k denotes the effective bulk modulus, C_0 is the bulk acoustic speed of sound, and ρ is the material density.
The following graph depicts that the ballistic limit velocity is less than these velocities. In order to predict he ballistic impact velocity further simulations were made at lower velocity

4. Conclusion

- Through the implemented material models, researchers were able to foresee thermoplastic hybrid armors can effectively withstand a variety of failure modes, such as matrix cracking, fiber failure, shear plugging, and delamination.
- The symmetric stacking sequences was able to meet the requirement of the experimental performance as it showed good resistant against the 9 mm full metal jacket.
- The non-symmetric stacking sequences have absorbed very small amount of energy of projectile, it shows that the implemented model was capable.
- The stacking sequence has a strong impact on back face damage pattern instead of the front face damage pattern.
- Materials reinforced with strong materials had a lower rate of failure compared to those that were not reinforced.
- Coating of Impact Resistant Materials with different binding and tough agents also contribute positively in the determination of level of protection offered by an armor.
- Bullet impact is an intense phenomenon. The process needs to be analyzed with modern tools and specialized equipment.
- Crowd formations and the human pattern/layouts are a deciding factor in terms of lethality of IEDs.
- Textiles including Nylon, Carbon fibers, Ceramic fibers, Aramids and Glass Fibers, UHMPE, TLCP, and PBO are quite effective in the ballistic protection design.
- The orientation/ angle of approach and the distribution of pressure are some but not all the key factors responsible for damage during a ballistic impact.
- The impact of the bullet at a certain eccentricity on the unit cell causes even force distribution and minimizes the effect of bullet shots on a helmet or other protective equipment.
- Lamination of soda lime panes of glass using polyvinyl butyral as reinforcements increases the level of protection from 7.62 mm FMJ armor shots.

Recommendation

- Designers associated with ballistic sciences should collect data to understand the impact of different factors as the composite ballistic performance solely dependent on the nature of fabric.
- The research on applied technology of polymerization is not enough for advancement at a faster pace so the research on sintering technology should be considered.
- Use of latest materials in the development of ballistic protections is an essential and crucial phase, further investigation needs can reveal interesting behaviors of these materials.
- Lamination of protective materials with strong materials to reinforce their strengths should be explored.
- Kevlar based strong protective materials are the most stable in terms of bullet impact. Therefore, further research needs to be pursued in Kevlar fabrics.
- Human bodies are very sensitive to shrapnel. A safe and secure protection needs to be developed to lower the threat level for soldiers.
- Back face signature of protection plates is the most crucial field to study in terms of ballistic impacts.

Nomenclature

- ACH = Advanced Combat Helmet
- AISI= American Iron and steel institute
- ASTM= American society of testing and material.
- BP = Ballistic Protection
- CNF = Carbon nano fibers
- E = Modulus of elasticity
- ECH = Enhanced Combat Helmet
- FDM = Fused Deposition Modelling
- FEA= finite Element Analysis
- IC = Initial conditions
- IED = Improvised explosive device
- MS = Mild Steels
- NRL = Natural Rubber Latex
- PASGT = Personnel Armor System Ground Troops
- PBO = p-Phenylene -2,6-Bezobisoxazole
- PTFE = hybrid poly tetra fluorethylene fabric
- RP = Rapid Prototyping
- TLCP = Thermoplastic Liquid Crystal Polymer
- TPO = Thermoplastic Polyolefin
- TS = Tensile Strength

- UDF = Uni Directional Fabric
- UHMPE = Ultra High Modulus Polyethylene

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DYNAMIC RESPONSE STUDY OF HARTNELL GOVERNOR

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Abstract
The function of the governor is to minimize the fluctuation in the mean speed, which mainly occurs from load variation. It controls the speed when torque is changing due to load variation. It senses the engine's speed, automatically supplies more fuel when speed decreases, and limits the fuel supply when it increases. This study aims to find the equation of motion of the Hartnell governor for vibrational studies and present the dynamic behavior of the Hartnell governor for different speeds

Keywords: Mechanical Governor, Hartnell governor, vibration, natural frequency, dynamic behavior.

9. INTRODUCTION

Hartnell governor is a spring-loaded centrifugal governor used to regularize the fuel flow to reduce speed fluctuations. A flywheel which minimizes the variation of speed in one cycle cannot reduce the fluctuations due to variation in load. The average speed of the engine is not under the control of the flywheel in any way. The introduction of governors helps to smooth out the peaks and valleys at the average speed [1]. The governor is responsible for maintaining a constant average speed regardless of the changing demands on the engine over an extended time. The governor readjust the amount of fuel supplied to changes in the vehicle's speed. When the speed is low, the governor increases the fuel supply; when the speed is high, the governor reduces the fuel supply [2].

The governors are mainly classified into two categories, one category consists of inertia governors, and the other category consists of centrifugal governors [1].

In governors characterized by inertia, the controlling force counterbalances the force of inertia. In contrast, in governors characterized by centrifugal motion, the controlling force counterbalances the force of centrifugal motion. The centrifugal governors see a lot of applications and come in various varieties [1].

The working principle of the Hartnell governor is the same as that of other centrifugal governors [1], [3].

- The bell crank lever is pivoted to the frame. It has a fly ball mounted on the vertical arm, and the horizontal arm is connected to the sleeve.
- Fly balls are mounted onto the vertical arm of the bell crank lever.
- Spring is enclosed into the frame. This spring applies a load on the sleeve in the downward direction.
- The sleeve is the main part of the governor that is installed on the spindle.
- The horizontal part of the bell lever is linked to the sleeve using a roller. The movement of the sleeve is used to change the fuel supply.
- The frame holds and safeguard the bell crank levers and springs.

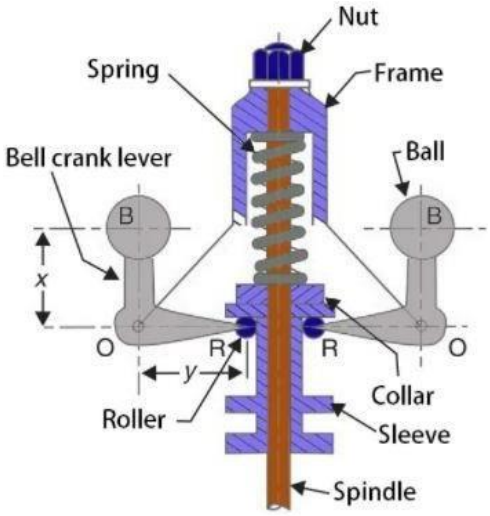

Fig.1. Hartnell governor construction

When the engine load increases, the engine's speed decreases. The decrease in engine speed decreases the rotational speed of the spindle, and as a result, the centrifugal force on the fly balls decreases. The fly balls move inside, and in result the force on the spring decreases; therefore, the length of the spring increases. The sleeve is lowered on the spindle; hence the fuel supply increases, and the engine's speed increases to the mean speed. The same principle is repeated when speed is high, the fly balls move outside due to centrifugal forces, and the sleeve is compressed

against the spring, which decreases fuel supply and the engine's speed is reduced [4]. The balls moves away from the spindle axis, the crank levers adjust around pivot point, and the sleeve lifts opposing spring load as the force on the engine reduces. The sleeve's movement is transferred to the engine's throttle, and the fuel supply to the engine is reduced, resulting in a reduction in engine speed. When the engine's load diminishes, the speed drops, the balls move closer to the spindle axis, and the sleeve descends. The sleeve's movement is transferred to the engine's throttle, and the fuel flow to the engine is increased, resulting in increased engine speed. Using a screw cap nut, the spring force may be modified.

10. DESIGN CONSIDERATIONS

2.1. Sensitiveness. The governor's sleeve movement must be large to maintain a constant rotational speed, and the accompanying adjustment in equilibrium speed should be as modest as possible. The more sensitive the governor is, the sleeve is adjusted quickly and detect more accurately small changes. A more accurate definition of sensitivity would be the ratio of the difference in equilibrium speed between the highest and lowest speeds to the speed at which the equilibrium is maintained on average. An overly sensitive governor will significantly adjust the amount of fuel supplied whenever there is even a slight variation in the rotational speed. This results in significant shifts in the engine speed, which drives the governor into a state of constant hunting. [2].

Nmax = maximum equilibrium speed
Nmin = minimum equilibrium speed

$$\text{Sensitiveness} = 2(N_{max}-N_{min})/(N_{max}+N_{min})$$

2.2. Stability. It is possible to determine whether or not a governor is stable by determining whether or not there is only one distance of the balls at which the governor is in equilibrium for each speed that falls within the operating range. If the equilibrium speed were to increase, the governor balls' radius would also need to grow for the governor to remain stable. [5].

2.3. Isochronism. Isochronous is the behavior of a governor in which the equilibrium speed remains the same over the whole operating range for a given set of radii of rotation for the balls. A governor based on isochrones theory will have unlimited sensitivity. [6].

2.4. Governor effort. The amount of load that a governor can put on the sleeve of the mechanism that regulates the amount of fuel supplied to the engine is referred to as its "effort." The term "effort" refers to the average amount of load applied throughout the specified change in speed. The standard definition of an effort accounts for a one percent chance of speed. [7][8].

2.5. Advantages of Hartnell governor

- The Hartnell governor has the following advantages.
- Operational speed is very high
- Compact in size
- Precise regulation
- For required equilibrium speed the compression of spring can be adjusted.

2.6. Dynamics of Machinery Laboratory's Hartnell Governor Experiment. The purpose of the work that will be done is to analyze the performance characteristics of a Hartnell governor mechanism available to our undergraduates, postgraduates, and research scholars in the dynamics of machinery laboratory and compare those results with the theoretical one that the manufacturer provided. Researchers, scientists, and design engineers would be able to select the fly ball's precise spring length and mass to execute the specific duty per specific needs based on this study. This paper examines not just the theoretical features of the Hartnell governor but also its practical applications. When beginning the conceptual design stage for their research projects, researchers and scientists may find this study useful as a reference tool to help them carry out their job.

2.7. Review of centrifugal governor design and analysis. When there is a change in the amount of work being done by the engine, it is the governor's job to keep the speed constant within a predetermined range. This device is suitable for use in virtually all types of motor vehicles. When the governor is rotated around its axis, our inquiry aims to discover the stress concentration places and the areas most prone to failure and measure the value of these stresses. This investigation is carried performed with the assistance of PRO E. In addition to this, the distance from each component of the SPINDLE is moved away from the base is computed, and graphs are drawn to represent the results. The effect of the "Weight Of the Arms" is the primary focus of our research, and the calculations that are carried out take into account this factor. The weight of the arms acts on the centroid of the arms, and when the governor assembly spins, centrifugal force starts working on the centroid of the arms and tends to bend or deflect the arms; however, this deflection or bending needs to be kept to a minimum. Within the scope of our service, we have performed the Stress study on a specific configuration of the

governor. Assembly, after which various materials are offered on a theoretical basis.

2.8. Hartnell Governor Design and Fabrication. A governor's job is to maintain the speed of an engine within set limits, and it also increases the sensitivity of an engine whenever there is a difference in load. Our study aims to produce a prototype of a product called "Hartnell Governor." It is a clever piece of equipment used in manufacturing technology. It is not very pricey and can be used in any car. The governors control devices and operate according to the feedback control concept. Their primary purpose is to maintain a constant speed within predetermined parameters regardless of the load the prime mover carries. They are powerless to influence the fluctuation in the cycle's speed. Within the cycle, the flywheel controls the speed at which the cycle rotates. As a result, the governor plays a vital part in controlling the speed. It assures that the speed will be regulated under any

Circumstances to investigate what happens when the mass of the sleeve in the middle of the porter governor is changed.

2.9. ANSYS design, multi-rigid body dynamic, and modal analysis of the centrifugal governor. When there are fluctuations in the load, such as when the load on an engine increases, its speed decreases, and as a result, it becomes necessary to increase the supply of working fluid; the function of a governor is to regulate the mean speed of the engine so that it remains constant. This is accomplished by controlling the flow of working fluid. On the other hand, if the engine's load is reduced, then its speed will increase, and as a result, you will need less working fluid. The governor is a device that automatically regulates the flow of working fluid to the engine in response to changing load conditions. It also ensures that the average speed remains within predetermined parameters. And maintains the average speed within a predetermined range by a radial force equal and opposed to it, referred to as the regulating force. It is made up of two balls of the same mass, sometimes called governor balls or fly balls. The engine turns the spindle, which in turn causes the balls to revolve, using bevel gears as the transmission mechanism. Because the top ends of the arms are hinged to the spindle, the balls can ascend higher or descend lower as they circle the vertical axis of the device. The links attach the arms to a sleeve, which is keyed to the spindle. The spindle is the central component. This sleeve rotates around the spindle simultaneously with the spindle itself, but it also can glide up and down the balls. Additionally, the sleeve rises when the spindle speed increases and descends when the speed drops.

In this project, we model centrifugal governor individual parts and assembly of parts of Centrifugal governor using Catia V5 and import into ANSYS WORKBENCH 14.5 for Multi Rigid body dynamic Analysis and Modal Analysis. In this Multibody dynamic analysis, we investigate how the deformation, spring probe, and mode shapes vary depending on the natural frequencies. In modal analysis, velocity is a factor that considers the structure.

2.10. Hartnell governor's construction and operation. The Hartnell governor is loaded with a spring. When the spring is first installed, it is done so in a compressed state so that a force can be exerted on the sleeve. It is constructed out of two bell crank levers hinged to the frame. Because it is coupled to the governor spindle, the frame rotates in the same direction. Each bell crank lever has a mass attached to one end and a roller attached to the opposite end. If there is less load on the engine, the speed will go up; the balls will move away from the spindle axis; the bell crank levers will move on the pivot, and the sleeve will be lifted in opposition to the force of the spring. The movement of the sleeve is then transferred to the engine's throttle, which reduces the fuel supplied to the engine and, consequently, a slower engine speed. The speed will also drop if the load being placed on the engine is reduced.

This will result in the balls moving closer to the spindle axis, which will cause the sleeve to slide downward. The movement of the sleeve is transferred to the engine's throttle, which results in an increase in fuel supply to the engine and, consequently, an increase in engine speed. With the use of a screw cap nut, the amount of force generated by the spring can be altered.

2.11. Hartnell governor: working, diagram, parts. One variety of spring-loaded centrifugal governors is known as the Hartnell governor. The Hartnell governor utilizes a spring to exert a downward force on the sleeve of the governor. Adjusting the nut on the frame will compress the spring, resulting in a different amount of downward force. In this particular style of governor, the sleeve is loaded using a spring, as opposed to other styles, such as the porter and propeller governors, which employ a dead weight instead. When using a governor of this kind, the load placed on the spring is altered to adjust the engine's average speed. We can alter the mean speed of the engine because the governor is equipped with a spring; however, in the case of governors loaded with dead weight, it is impossible to adjust the mean speed. When compared to previous governors, this one has a more compact design. Compared to another

governor, the flyballs produced by this governor are significantly smaller due to the adjustable spring load. Because it is spring-loaded, it may return to its original place when its speed has been reduced, even without the assistance of gravitational pull. As a consequence of this, it can be mounted in either a vertical or horizontal orientation. The presence of rollers on the surface of the sleeve contributes to a reduction in the amount of resistance caused by friction.

2.12. Structurer design and Hartnell governor analysis to improve speed sensitivity. This work will modify the structure design of the Hartnell governor to improve the sensitivity within the alteration speeds by reducing the friction between the sleeve and the spindle. Additionally, this work will analyze the structure of the Hartnell governor after it has been modified. It is possible to change the dimensions of the sleeve without changing the dimensions of the other parts of the governor assembly by introducing ball bearings between the sleeve and the spindle of the governor assembly. This will reduce friction and allow for the dimensions of the sleeve to be changed. When the newly designed governor is rotating at maximum speed about its axis, determining the stress concentration places most prone to failure and measuring the maximum value of these stresses, the goal is to do both of these things simultaneously. The governor's design will be altered in response to the measured values of the stress. The software known as solid works is utilized in the process of carrying out this analysis. The current experiment involves modifying the Hartnell governor to raise the level of sensitivity and lower the friction between the spindle and the sleeve. Ball bearings are inserted in this modification's new location between the spindle and the sleeve. The stress values were measured at various parts of the governor, and the structure of the Governor was modified to lower the amount of stress concentration. This was done to show a graph between the alteration speed and the friction.

Table 2. Summary of Findings

Author	**Method**	**Results**
Trupti J. Navathale, 2017 [2]	Governor's axial deflection	axial displacement rises with angular velocity.
Ramavath Suman, 2019 [5]	Isochronism	It regulates speed under any circumstances
Vanga Padmasri, Padmasri, 2018 [1]	ANSYS	Vibration analysis improves accuracy.
M.Tech , Shaik Munny, 2020 [8]	Analysis of Hartnell Governor	Governor with bearing reduces friction and change speeds.

3. MATHEMATICAL MODELING

The mathematical equation is derived from studying the Hartnell governor's dynamics. The following assumptions are made while deriving the equation of motion for the Hartnell governor.

- Only the mass of the ball is considered
- The mass deflection is small due to high sensitivity, and the angle is ignored.
- Levers are considered rigid elements

All these assumptions are made to derive the equation for a single degree of governor's freedom.

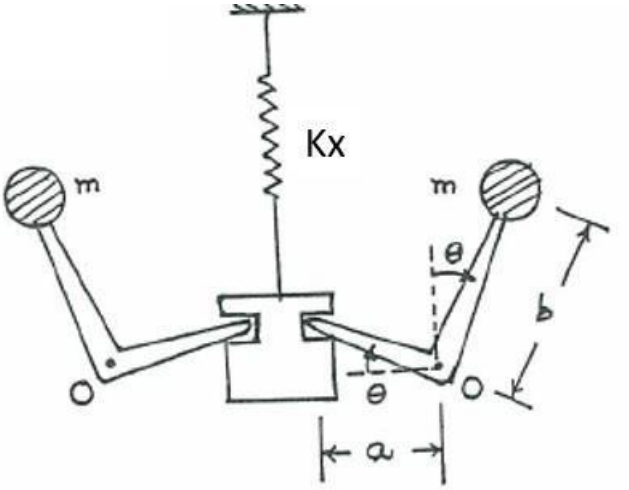

Fig.2. Freebody diagram of Hartnell governor

m = mass of the ball

b = vertical distance between ball and pivot point O.

a = horizontal distance between the pivot point and roller centre

Kx = stiffness of the spring

Considering a small displacement of the ball arm about the vertical position. Equilibrium about point O gives;

….. (1)

Equation (1) represents equilibrium about point O

For small values of Θ, sin (Θ) = Θ, cos (Θ)=1. The equation is reduced to the following form in Equation (2)

$$M \cdot b^2 \cdot \ddot{\theta} + k \cdot a^2 \cdot \theta = 0 \quad \text{..... (2)}$$

For this, the natural frequency is derived below in Equation (3)

$$w_n := \left(\frac{k \cdot a^2}{M \cdot b^2}\right)^{\frac{1}{2}} \quad \text{..... (3)}$$

3.1. A general equation for the free and undamped system. The general equation for the free and undamped system is represented in Equation (4)

$$x(t) := A \cdot \cos\left(w_n \cdot t - \phi\right) \quad \text{..... (4)}$$

Where A is the vibration amplitude and Ø is the phase difference. The following formulas are used for calculating the amplitude and phase differences.

$$A = \sqrt{x_o^2 + \left(\frac{\dot{x}_o}{w_n}\right)^2} \quad \text{..... (5)}$$

$$\phi = \operatorname{atan}\left(\frac{\dot{x}_o}{x_o \cdot w_n}\right) \quad \text{..... (6)}$$

3.2. The general equation for the free and damped system. The general equation for the free and damped system is

$$x(t) = X_o \cdot e^{-\zeta \cdot w_n \cdot t} \cdot \sin\left(w_d \cdot t + \phi\right) \quad \text{..... (7)}$$

X_0 is the vibration amplitude, wd is the damped natural frequency, ζ is the damping ratio, and Ø is the phase difference. The following formulas are used for calculating the amplitude and phase differences

$$X_o = \frac{\sqrt{x_o^2 \cdot w_n^2 + \dot{x}_o^2 + 2 \cdot \zeta \cdot w_n \cdot \dot{x}_o \cdot x_o}}{w_d} \quad \text{.....(8)}$$

$$\phi = \operatorname{atan}\left(\frac{x_o \cdot w_d}{\dot{x}_o + \zeta \cdot x_o \cdot w_n}\right) \quad \text{..... (9)}$$

3.3. The general equation for the forced and un-damped system. The general equation for the force and un-damped system ignoring the natural response, is

$$x_p(t) = X \cos \omega t \quad \text{..... (10)}$$

Where the value of X can be calculated using the following equations

$$x_p(t) = \frac{X}{k - m\omega^2} \cos \omega t \quad \text{..... (11)}$$

$$X = \frac{F_0}{k - m\omega^2} \cos \omega t \quad \text{..... (12)}$$

Equation 11 is for the unit force and equation 12 is for the sinusoidal force.

3.4. The general equation for the forced and damped system. The general equation for the force and un-damped system ignoring the natural response is

$$x_p(t) = X \cos\left(\omega t - \phi\right) \quad \text{..... (13)}$$

The value of X and Ø can be calculated using the following equations.

$$X = \frac{F_0}{[(k - m\omega^2)^2 + c^2\omega^2]^{1/2}} \quad \text{..... (14)}$$

$$\phi = \tan^{-1}\left(\frac{c\omega}{k - m\omega^2}\right) \quad \text{..... (15)}$$

C is the damping coefficient, and w is the force frequency.

The force can be calculated using the following formula

$$F_o := M \cdot r \cdot w^2 \quad \text{..... (16)}$$

4. DYNAMIC RESPONSE

PTC Mathcad Prime 4 is used to plot the dynamic response of the Hartnell governor. The following values are used to calculate different parameters in the governing equations

Gravitation acceleration g=9.8m/s2, spring stiffness Kx=104 N/m, length a=0.12m, length b=0.20m, initial speed w=20 rpm, damping C=5N*s/m, mass of the ball M=2.548kg, central distance r=c=0.16m.

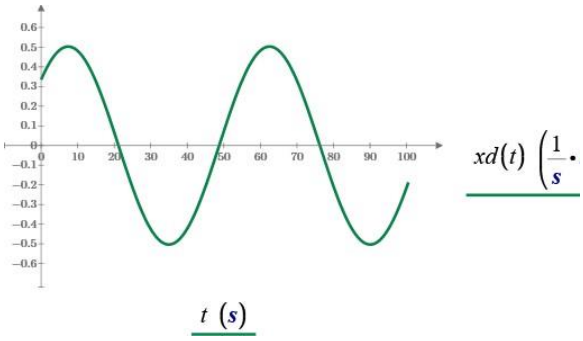

Fig.3. Displacement vs time (un-damped, free)

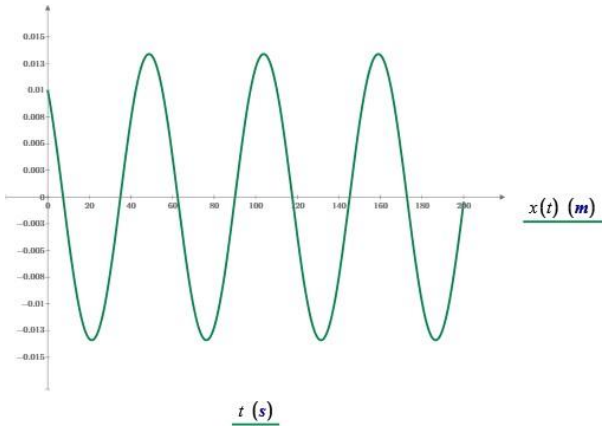

Fig.4. Velocity vs time (un-damped, free)

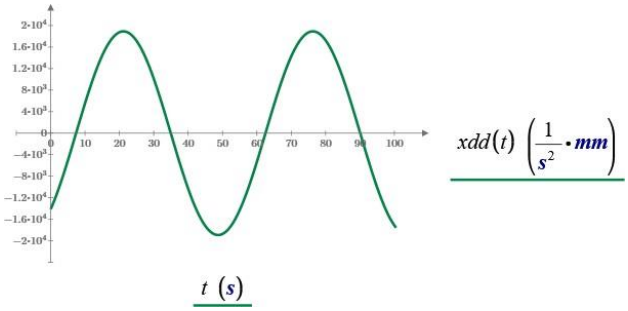

Fig.5. Acceleration vs time (un-damped, free)

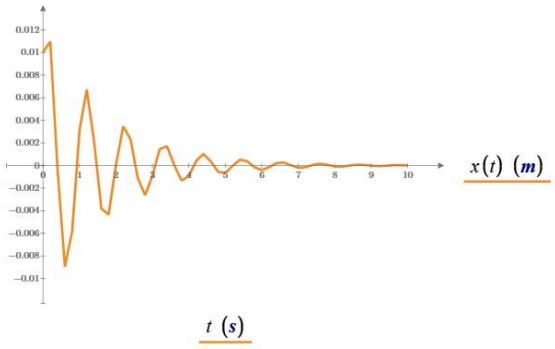

Fig.6. Displacement vs time (damped, free)

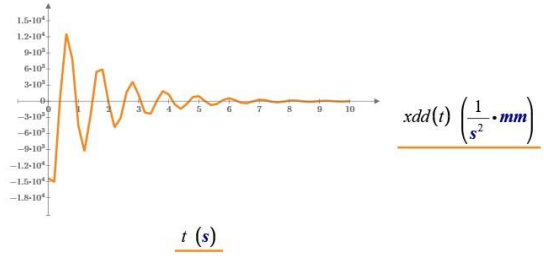

Fig.7. Velocity vs time (damped, free)

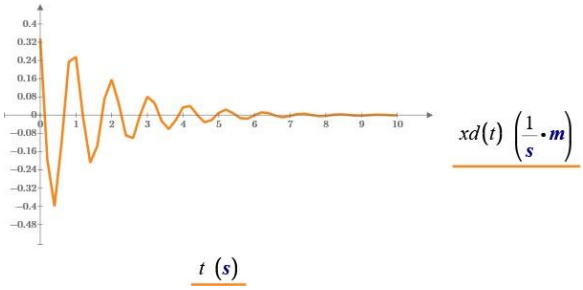

Fig.8. Acceleration vs time (damped, free)

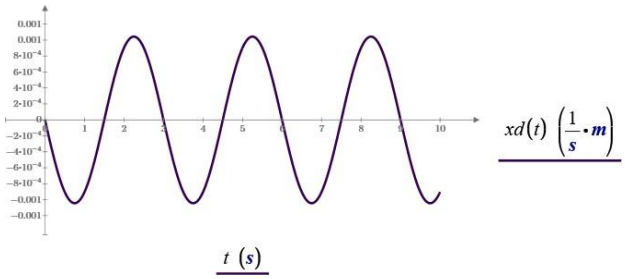

Fig.9. Displacement vs time (un-damped, forced)

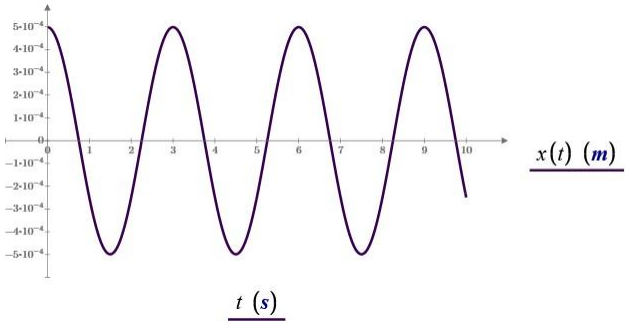

Fig.10. Velocity vs time (undamped, forced)

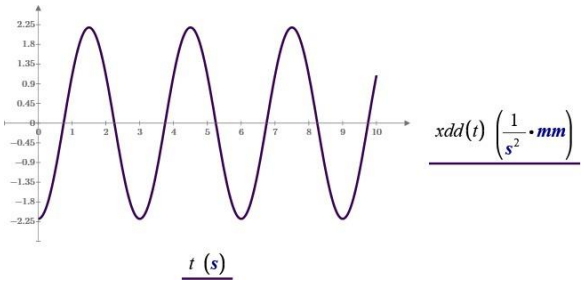

Fig.11. Acceleration vs time (undamped, forced)

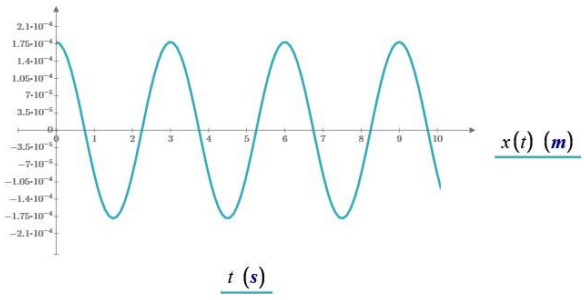

Fig.12. Displacement vs time (damped, force)

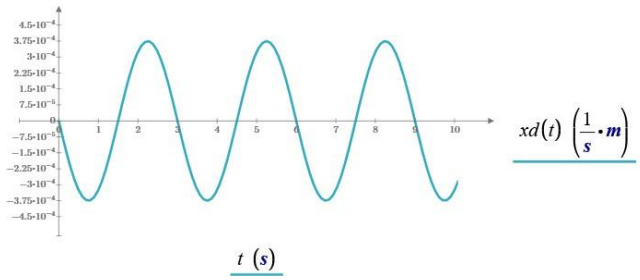

Fig.13. Velocity vs time (damped, force)

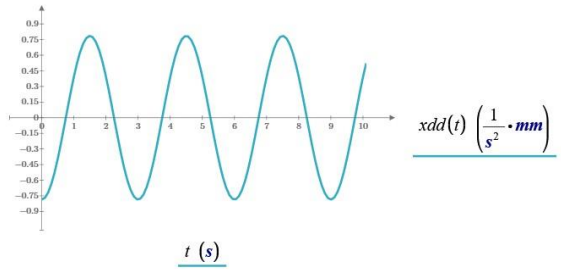

Fig.14. Acceleration vs time (damped, force)

5. RESULTS

The dynamic response or behavior of Hartnell behavior for a different situation is shown in the previous section by taking some parameters constant. This section explains the graphs presented in section 4.

5.1 Un-damped and free vibration. First, the natural frequency is calculated using equation 3. The natural frequency of Hartnell governor for the given data is 37.58 rad/s. Figure 3 shows the displacement vs time graph where the maximum amplitude is 0.013m. Figure 4 shows the velocity vs time graph, and figure 5 shows the Acceleration vs time graph. The amplitude is different for each graph, but the frequency is the same. Another difference is phase difference. The difference between the respective graphs is 90 degrees.

5.2. Damped and free vibration.

Figure 6 shows the displacement vs time graph for the damped and free system. The amplitude reduces over time because of damping. The damping causes the loss of energy and vibrations to vanish over time. Figure 7 shows the velocity vs time graph, and figure 8 shows the acceleration vs time graph. There is a phase difference in each graph from the other, but the damping behavior is almost the same.

5.3. Un-damped and forced vibration.

Figure 9 shows the displacement vs time graph for the un-damped and forced system. The force is applied in repetitive sinusoidal form. The natural response is ignored because it dries out quickly, and the response under force is shown. Figure 10 and figure 11 shows the velocity and acceleration graphs for time. The amplitude for these graphs is different, but the frequency is the same as that of applied forces.

5.4. Damped and forced vibration.

Figure 12 shows the displacement vs time graph for the damped and forced system. The vibrations do not die over time because of the constantly applied force. The damping changes the phase of the vibration, and this is how the response of the system lags the applied force and resonance is prevented. Figure 13 shows the velocity vs time graph, and figure 13 shows the acceleration vs time graph. There is a phase difference in each graph from the other, but the damping behavior is almost the same.

6. CONCLUSION

The main aim of this study was to present the mathematical model and behaviour of the Hartnell governor. The study is based on assumptions, and calculations are done using a single degree of freedom approach. The mathematical models are presented for four different scenarios, and then these mathematical models are presented on graphs for each case. This calculation can be used if any manipulation is required in the governor for different inputs and loading conditions.

The natural frequency of the Hartnell governor depends upon the stiffness, dimensions of the lever arm and mass of the ball. If the natural frequency lies in the range of operational forces, then the natural frequency of the Hartnell governor can be changed by changing these parameters. Suppose the range of the forces is large, and it is impossible to change the natural frequency. In that case, suitable damping should be added to the Hartnell governor, which is always tricky because of the sensitivity of the governor. Damping decreases the sensitivity of the governor. Therefore, an optimum solution should be found for scenarios where both phenomena should be interconnected, and suitable damping is used.

7. RECOMMENDATIONS

This study details the single degree of freedom where the weights and stiffness of different parts are ignored. Multi-degree studies will give a detailed picture of the dynamic response of the Hartnell governor. The effects in 3 dimensions and inherent damping and stiffness's of the part will affect the dynamic response. Such detailed studies can be carried out using FEM (finite element method). Dynamic mode analysis gives the natural frequencies range and directions in different possible directions. The response spectrum density analysis shall be used to find the system's response under the applied loads and damping. This will ensure that the governor is stable and strong in different forces.

ACKNOWLEDGEMENTS

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DESIGN, DEVELOPMENT AND FABRICATION OF WINGS EMBEDDED WITH MORPHING TECHNOLOGY

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Abstract

Morphing aircraft and unmanned aerial vehicles (UAVS) are expected to have a multirole capacity, allowing them to adapt to changing mission environments. A UAV model is required to efficiently and quickly calculate the attributes of numerous wing variants. Unmanned Aerial Vehicles (UAVs) are increasingly being used in unconventional and asymmetric military missions, as well as in a variety of civic situations. With dynamic onboard reconfiguration capabilities, UAVs are designed to accommodate conflicting mission objectives. The ability to accomplish a wide range of missions is severely limited by the traditional fixed-wing aircraft configuration. Wing morphing has been offered as a method to modify a flying vehicle's aerodynamic features while it is in flight. A morphing aircraft is a type of aircraft that may morph/ change geometry while in flight to boost efficiency. Traditional aircraft wings are a sacrifice that enables the plane to fly in a wide range of conditions while offering sub-optimal performance in each of those. Morphing shows potential as little more than a future enabler technology for next-generation aircraft. Wing morphing technologies seek to make the aircraft increasingly energy and aerodynamically efficient by actively changing the wing configuration during flight. Morphing offers hope as a future facilitator innovation for next-generation aircraft. Wing morphing technologies strive to make airplanes more power and aerodynamically efficient by actively changing the wing form during flight. These wing and tail form variants may be used to facilitate rapid directional changes, slow flight without crashing, and minimize drag during high-velocity flight. This study's overarching goal is to investigate the effects of readily adjustable wing sweep and wingspan on aerodynamic and flight stability characteristics.

Keywords: Morhphying, UAV, performance, characteristics, wing sweep, wing span

1. INTRODUCTION

The word morphing in the Oxford language dictionary means a smooth gradual transition from one phase to another. In the field of smart structures, the word has a somewhat similar topology meaning gradual transition of structure with respect to externally applied conditions. Wing transforming is the streamlining of the optimal design of an airplane by effectively changing the wing state of the airplane during flight. Not just that transforming gives decrease fuel utilization it additionally further develops mobility, extend the section of ideal flight speeds, decrease in vibrations, and vacillate is likewise accomplished because of the disposal of pivoted control surfaces like ailerons and folds. Advancing optimal design in the field of flight controls has been there from the absolute first day when the Wright siblings presented wing wrapping for the purpose of roll control. Biological mimic is in close proximity to

wing morning technology. The observation of flight drove man to fly, and we still have a lot to learn from nature today. Birds can perform Avian morphing even in urban environments, allowing them to efficiently Cruise perform powerful manoeuvres and accurate descents. Each wing arrangement is tailored to a specific flight requirement. A falcon, for example, waits for prey in a high aspect ratio arrangement before scooping down to attack as soon as prey is found. Traditional flaps, slates, and ailerons have compromised geometry that only allow for restricted functions in a wide variety of flight circumstances.

There are primarily three distinct categories of wing morphing. The three types of morphing are called "In plain morphing," "Airfoil morphing," and "Out of plane morphing".

2. LITERATURE REVIEW AND ANALYSIS

Birds have long influenced man's desire to soar. Nature has revolutionized them into this as a result after millions of years. Although an aero plane and a bird appear to be extremely similar at first glance, the morphology of a bird is not as rigid as that of an aero plane. They can fluidly modify the shape of all of their body components to provide optimum performance in a number of flight conditions, such as elevated dash and small hovers, as well as increased maneuverability. Morphing technique attempts to simulate aircraft ability to adapt to various flight conditions by altering the shape of the aircraft at different phases of flight, much like birds do. This allows for a larger flight path, higher flight quality, and numerous operation characteristics to be executed by the same aircraft.

Airplane wings are a concession that allows the plane flying in a wide range of conditions while giving it semi functionality in each. Engineers and designers have long been intrigued by the ability of a wing to change shape during flight, as it reduces the amount of design compromises required. Morphing technology can modify certain geometry parameters such as the shape which includes (chord, sweep and span), morphing out of plane which includes span bending, span twist etc. airfoil modification (camber and thickness). Altering the wing's structure or shape is nothing unusual. Previously, morphing approaches have always cost money, complication, or weight penalty, although these have been somewhat mitigated by system-level advantages.

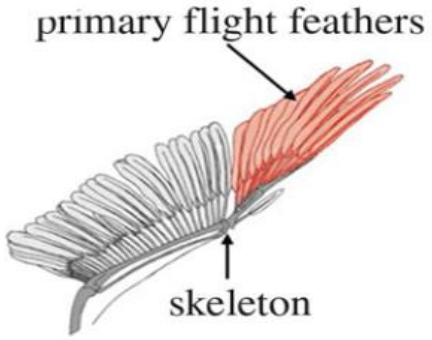

Fig 1: Birds feathers attached to internal skeleton

Fig2: replication of bird feathers

Such compromises are becoming less acceptable with the prevailing situation to exceptionally economical and "ecofriendly" aircraft, forcing the development of revolutionary morphing designs capable of giving greater benefits with fewer drawbacks. Recent advancements in "smart" materials may be capable of overcoming these limitations and enhance the

The manufacture of different aircrafts either civil or military have been done with different flight capabilities. Nevertheless, fuel consumption and distribution change all through the journey, and the aircraft may be compelled to fly in much less conditions due to air controlling traffic constraints. Because airliners are more versatile than military aircraft, the resulting sub-optimal performance is more significant, and fuel efficiency is a far more important performance metric.

The motivation to have airplanes go through transforming is to expand their exhibition at various flight conditions. Quickest speed, energy utilization, taking care of, most extreme burden, perseverance, dependability, and adjustment can be in every way improved with the transforming wing idea. The airplane's overall performance can be improved by increasing some or all of these parameters. For example, altering the wing area and airflow net shapes can help enhance performance measures.

Flights have different stages and the outcome of morphing is to expect better performance by the aircraft at these stages. Top speed, fuel usage, maneuvering, payload capacity, range, durability, and stability can all be improved using the morphing wing concept. Improving one or more of these factors will increase flying efficiency and allow the aircraft to undertake more missions. Changing the design of the wing section and the air net, for instance, can significantly promote performance metrics.

Communier et al [1] have presented a working model for morphing and also have carried out its testing in the wind tunnel. The morning in this mechanism is being achieved by carving slits at the leading and trailing edges of the aero foil which are actuated by the arm rods mechanism. Small angular deformation in each slit produces at large a change in the shape of the airfoil and hence morphing is achieved. The leading and the trailing edge are dealt with as separate systems that are combined to produce the same overall effect. In figure 3 leading and trailing edge, slits are shown along with their actuating mechanisms. Drag reduction is achieved due to a smaller angle of attack in camber morphing as compared to that of ailerons or other control surfaces. Results show that wings morphed by the above-explained mechanism give better aerodynamic performance but the limitation is that only small changes in angle can be achieved.

A double rib sheet (DBS) structure has been proposed by Zhao et fir changing the camber of the wing. The DRS structure constituents are having a semicircular on one end and a circular ear at the other end. The individual constituents are coupled as shown in figure the relative motion of the DRS structure is realized by actuators that are distributed along the chord of the wing. The method presents no other additional weight penalty other than the weight of adhesives and actuators. As a result, the wing's structural weight is well within the limit. Experimental analysis has been carried out on Talon UAV an increase in efficiency of 14.1% is observed in comparison to that of fixed-wing Talon UAV. In addition, the critical angle obtained is 18 degrees and distortion in performance is observed at 4 degrees which is due to the laminar-turbulent transition.

Chanzy et al. have shown a 15 kg load bearing capacity morphing UAV wing. The morphing wing's supports are made of carbon fibre bracings and glass fibre covering, styrofoam covering, and SLS nylon inlays. SLS fabric male and female sliders, as shown in Figure 5, enable the wing's top and lower surfaces to slide over each other. To complement the experimental verification, we used the highest capability CFD code with MATLAB and ABAQUS for mathematical modelling. The servo motor is attached to an SLS nylon rib in the actuation mechanism. The fully autonomous thread is another crucial factor that allows the wingspan to maintain its shape while consuming no energy. The aforesaid technique produces slowly but enough roll control for the UAV learner, according to experimental data.

Multi-unit flexible rib mechanism has been presented by Meguid et al. the overall assembly consists of basic subunits that are connected by revolute joints attached over a flexible rib system driven by onboard servo motors. A functional prototype has been designed which is cranked by a flexible servo motor actuated mechanism or simply rocker slider system. The design can alternate between two distinct states indefinitely. The aero foil leading edge and trailing are capable of changing shape independently while the central point has a constant geometry. The structural integrity of the flexible rib system has been analyzed by finite animal element analysis by discretizing with quadratic hexahedron elements along with quadratic wedge elements. Aerodynamics of the maximum Camber has been analyzed for a velocity value of 20 m per second and results for lift coefficient to drag coefficient have been calculated. At the conclusion of the design stage perimeters for the maximum lift to drag ratio were recorded by repetitive alterations.

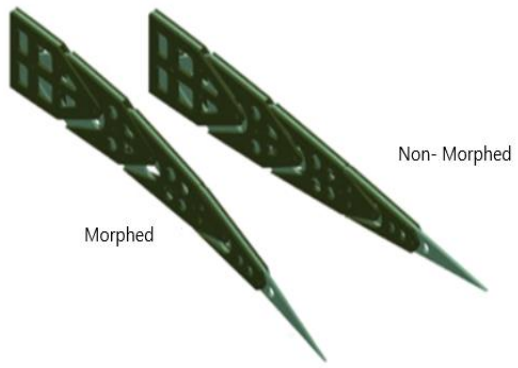

Fig 3 multi-unit flexible rib structure [4]

Morphing mechanism by the application of corrugated structures at the core of wing has been proposed by Yokozeki et al [5] which fosters the an-isotropic character of corrugated geometry. The corrugated structure is composed of identical C-shaped round portions and identical transverse sections. Chord-wise tension is created via a strain wire coupled to a servo motor assembly, which can achieve the requisite morphing ability by varying the pressure in the line. The proposed design is only capable of producing downward motion because of design restrictions tension wire is attached to the lower wing surface only. The corrugated structure along with tension wires as shown in Figure 7 has been only applied to the trailing edge while the Leading edge has a constant geometry. A prototype has been manufactured from carbon-reinforced plastics and results show that the proposed design can be used in place of flaps for low-speed maneuvers such as landing and take-off but high-speed maneuvers such as role motion are not possible.

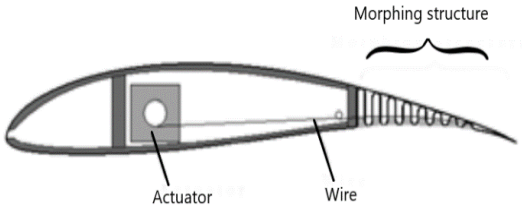

Fig 4 Corrugated structure at trailing edge [5].

A camber morphing technique based on a compliant composite structure and an electromechanical actuator is presented by Yokozeki [6]. Recent progress in material engineering material topology optimization is becoming increasingly popular to exploit material anisotropy in the best favor of required features. Continuous fiber composite materials are one such example where the manufacturing of complex structural members can be done. The concept design as shown in figure 8 consists of a structural morphing rib in combination with an actuating mechanism. The global actuation system is a motor speed control actuator in conjunction with an activator tube attached towards the wing skin. The rib is made of nylon polymer and polyester 12 sequentially created morphing structure. Pushing and pulling of the actuator rod by the servo motor produces morphing in the trailing edge of the wing. The study shows that rib structure exploiting anisotropy and strength of composite material provides superior maneuverability and plays an instrumental role in achieving maximum control.

Kota et al [7], who use a mission adaptable compliant wing, address adjustable curvature trailering at cruising elevation on protracted aircraft (MACW). The flap system's topology has been optimized by taking into account the actuation force, morphing movement error, transforming shape error, system external circumstances, buckling forces, fatigue damage, and lift capability. During flow acceleration, while maneuvers the trailing edge gets affected by flow separation which has a strong adverse effect on the pressure gradient of the wing. To increase the aircraft's durability in different types of manure, an optimization was performed to achieve minimal flow separation and a maximum laminar boundary layer throughout a broad range of lift coefficients. Possible provision of differential deflections along span provides better load distribution and mean wing bending moment to give efficient lift force distribution hence providing fuel savings and better structural stability. Experiment set up showed that energy required to elasticity deform the wing in the case of MECW is 33% less than the actuation force in a conventional wing flap.

Hybrid camber morphing concept has been presented by Zheng et al [8] which fosters the benefits from both the worlds of material and structural sciences. A monolithic compliant mechanism has been introduced for the transmission of forces from the actuator to the

morphing mechanism. To achieve massive deformations, hyper-elastic topology optimization has been utilized, while a combination of the meshless approach in the leading and trailing edges of the wing has been used to decrease computing resources. A spring steel plate manufactured using electron discharge machining EDM and fiberglass-reinforced skin, aluminium stringers with a lead screw, and an actuator are all parts of the Assembly. Lead screwed actuator with linear stepper motor converts rotational inputs to a straight-line movement. Polylactic acid was used to 3D print additional mechanisms (PLA). A maximum of 27 degrees can be achieved at the leading edge which is a result of 48 mm displacement of complaint mechanism whereas at the trailing edge minus 8 degrees to 40 degrees can be achieved for minus 9.74 mm and 37.83 mm displacements respectively. Aerodynamic load testing simulation was carried and the load-carrying capability of the wing was found to be permissible. Analysis needs to be tested or cross-checked with experimental results the setup for which has been explained in the research paper.

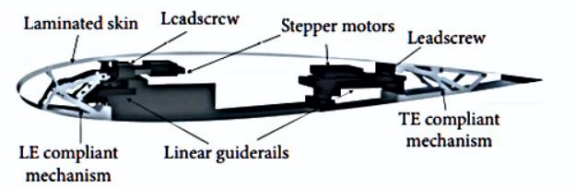

Fig. 5 Laminated skin and variable camber morphing wing [8]

To increase fighter aircraft capabilities, this article concentrated on their stability. The dissymmetric varied span system, or VSMW, was used to do this (Variable Span Morphing Wing). This technology is advantageous not only while the plane is cruising, but also during flight operations procedures [17].

Now the plane can be made to undergo two types of stabilities.

a) Static stability: When the aircraft is in the air while it is cruising its net forces acting on it are zero neglecting the thrust i.e. at constant acceleration. In this state the plane is in equilibrium. The static stability focuses on the planes equilibrium position that if the plane withdraws this equilibrium state it helps it return to the equilibrium. For this to happen it requires some counter forces or moments which help it stabilize back. Static stability deals with this stabilization.

b) Dynamic stability: The dynamic stability focuses more on the plane's motion when it undergoes disturbances which can be done either by damped or un-damped oscillations or non-oscillatory motions Nonetheless, it is important to note that even if an aircraft is constant, it can be dynamic unstable; Static consistency, on the other hand, is essential if a plane is dynamically stable.

Therefore the aircraft's lateral and longitudinal stability is comprised of the control surfaces constituting the forces and moments that help it stabilize during in flight conditions.

Fig 6 Variable Sweep Morphing in a Bell X-5 [17]

Table 1: Summary

Authors	Year	Findings	Type
Q. Chanzy	2018	Experimental verification and analysis of morphing UAV wings	Camber
Dan Xu	2019	Deep Reinforcement Learning for the Control of a Bionic Morphing Unmanned Aircraft System	Camber
Tuba Majid	2021	Modular Camber Transformation Mechanisms: Design and Construction	Camber
David Communier	2020	Conception and Verification of a Subsonic Wind Tunnel-Based Morphing Camber System	Camber
Anmin Zhao	2019	Structure development and validation of a novel entire adaptive variable camber wing	Camber
Tomohiro Yokozeki	2019	Creation of a Corrugated-Structure, Variable-Camber Airfoil	Camber
U. Fasel	2019	Aerospace composite additive fabrication for form-shifting structures	Camber
Yaqing Zhang	2019	Incorporating nonlinear big deformation into the design of a variable camber morphing wing using a compliant mechanism	Camber
C. Soutis	2016	An adaptable aerofoil whose aerodynamic properties may be fine-tuned	Camber
Matthew G. Good	2003	Structural Optimization for the Development of a Tail for a Variable-Camber Aircraft	Camber
Chawki Abdessemed	2018	3D Stability Analysis of a Transforming Wing's Continuous Side-to-Side Edge Transition	Trailing Edge Flap
Sérgio João Monteiro	2016	Analysis of an Aeronautical Morphing Structure	leading edge
Hafiz Muhammad Umer	2020	Wing Span and Sweep Morphing for Small Unmanned Air Vehicle	Span and Sweep
Frédéric Moens	2019	The Effects of Morphing Technology on the Flight Performance of a Turboprop Regional Aircraft Wing	Span and Sweep
Luis P. Ruiz-Calavera	2021	The advantages of a semi-morphing wing idea are investigated	Semi-Morphing
Amit Geva	2019	An Investigation into a Morphing Wing That Can Adjust Both Its Airfoil and Its Span Using a Folding Mechanism That Can Be Retracted	Span

To avoid the elastic deformation of an aircraft wing its wing structure is designed such as to be semi morphed i.e. deflecting a large number of redundant and complementary control surfaces. The most modern transport aircraft's wing dynamics can be still improved by two methods. First is to reduce induced drag by increasing aspect ratio of the wing area while the second is to reduce the friction drag by using the laminarity. Now both these methods are effective but hard to achieve. Wing Morphing is an additional possibility alternate to these in modifying the design of the wing. This area is under a lot of research but practically it has not been achieved most of the work has only been simulated and performed in laboratories. This particular paper [18] focused on the morphing wing and its effects on the improvements in drag, aircraft control and load alleviation.

3. RECOMMENDED APPROACH

We have already discussed the basic idea about using corrugated structures inside the core of morphing sections which provide flexibility to the airfoil in the morphing direction while maintaining the ability of carrying dynamic loads along the span. The concept defined by Yokozeki et al can be classified as structure-based camber morphing. The overall assembly consists of a corrugated structure at the leading and trailing of the airfoil while there is a fixed section in the center. The central fixed section is used for placing servo motors and pulleys that are meant for controlled activation of morphing sections.

FX03-137 airfoil has been taken as the reference shape the parameters for morphing where parameters to range a value of maximum thickness ratio 13.7% and a maximum camber ratio of 5.97%. The chord length of the airfoil understudy is 800 mm and the corrugated structure responsible for morphing is present at 69% of the chord length position while the corresponding equivalent system aileron hinge is present at 77% of the portion. There has been some thought given to using tension wire attached to the underside of the wing and a servo motor to shape uniform C-sections of the corrugated structure.

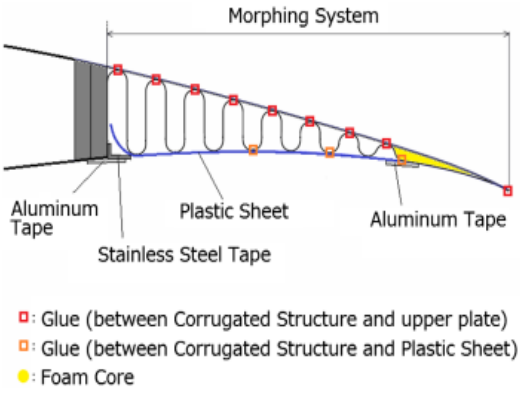

Fig 7 Perspective of the morphing section as seen via a cross-section [5].

Figure 7 shows the take up length of the wire and tension on the vertical axis against the morphing angle of the wing taken on the horizontal axis. A linear trend between the set of variables is observed where take up length and tension in the wire increases linearly with the applied angle of morphing. The relationship developed here plays an important role towards defining fabrication parameters.

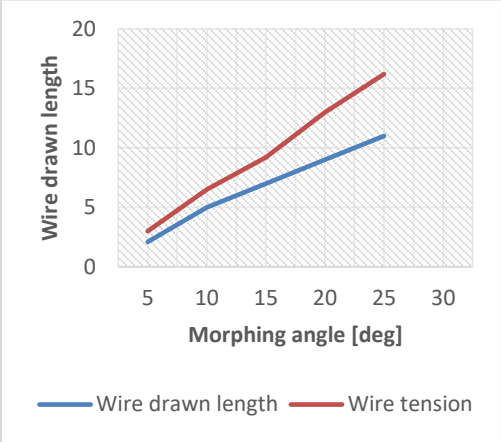

Fig 8 Wire tension as a function of morphing [5].

The FEM analysis for corrugated structure has been carried out on MSC Marc which is a commercial software for structure analysis. MSC marc has its specialty in dealing which situations where a large amount of deformations are to be analyzed and used in applications involving nonlinear material behavior with crack propagation. Now because wire penetrates through the corridor structure and so its motion is constrained along with the thickness of the airfoil so sliding contact is assumed for the FEM analysis. The material of the corrugated structure has been

considered linearly elastic. The Locus for the trailing edge and deformed shape of upper and lower surfaces have been simulated for deformation angles of 10 and 20°. A slight discrepancy between simulated results and experimental prototypes was found but morphing was still efficiently possible. The models discussed till now have been fabricated to demonstrate aerodynamic forces for morphing motion. The test was acted in Japan investigation organization and the air stream was of Gottingen type. Engine and pulley get together for initiation of the transforming segments were associated with a regulator that was please outside the air stream. Since the viewpoint proportion of the wings was low so mind boggling airstream was normal at the edges of the wing, to alleviate this impact ellipsoid wingtip boards were connected to the two edges of the fundamental wing. The model was upheld by three structs out of which two are associated with the forward portion and another was associated with the intriguing streamlined powers saw by balance under the swaggers. The general test arrangement for a particular transforming point and a speed should be visible in figure 16 where we can see two swaggers connected to the forward portion and one joined to the back piece of the wing.

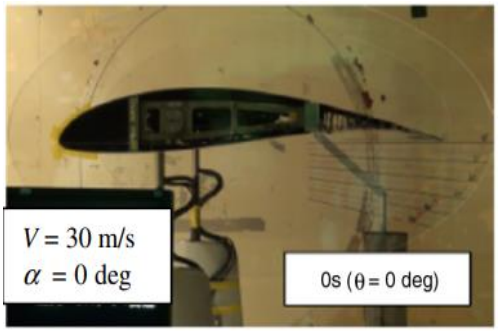

Fig 9 Test setup in wind tunnel [5]

Corrugated structure and upper skin have been fabricated from carbon fiber reinforced polymer along with a layer of fabric and epoxy.

Following formulation has been adopted to find the lift and drag coefficients for morphing wing:

$$C_L = \frac{L}{\frac{1}{2\rho V^2} * S} \qquad (3)$$

$$C_D = \frac{D}{\frac{1}{2\rho V^2} * S} \qquad (4)$$

In the above equations, lift force L and drag force D.

The known geometrical parameter that is 0.64 m square.

Figure 18 shows the relationship of lift coefficient with the flap or morphing angle. Solid lines in the graph show lift coefficient behavior for our morphed wing while the dotted lines are for reference geometry it can be seen that for lower values of angle of attack alpha and intermediate values of morphing angle best results are obtained.

The figure also shows that our initial observation about a discrepancy in the shape of morphing wings at higher morphing angles is playing the role here and is causing deterioration of wing Lift performance.

4. CONCLUSIONS

Aero elastic behavior is one of the areas that need to be explored in more depth. While designing of morphing wings we come across a paradox between rigidity and flexibility where on one hand we want a wing to be augmented with elasticity and on the other, the load-bearing capacity of the wing shouldn't suffer as well. Embedded servo motors in case of pure mechanical solutions are sensitive to aero elastic issues has caused many failures as discussed in the literature review where in some cases slight discrepancy was observed whereas in others deformation angles were totally disturbed.

Because of its benefits, the morphing idea has been popular research topic in the aerospace industry. The slider crank mechanism was discovered to be the best mechanism for achieving the wing sweep motion in this study. Wing actuation kinematics is investigated. For in plane wing shape, the mechanism alters the span and wing area change.

In the third technique, the twisting happens on a specific area of the wing and is accomplished on a UAV-sized wing, the concept for twist morphs has already been illustrated. This is the first model to exhibit a twisting distortion limited to a single wing section. This was accomplished by combining an SSC framework with SMA wires for actuation. This type of

notion is beneficial in instances when maintaining flying at low speeds is required.

5. RECOMMENDATION

The main error in the approach of corrugated structures appeared due to the surface shape of morphing wing not being able to match up with the reference shape. The error is partially coming from fabrication of the corrugated geometry and in addition there can be some error from the modeling part as well because the authors were dealing with non-linear geometry. The results can be improved by modifying and optimizing corrugation geometry to achieve more smooth and seamless morphing. One of the approaches to mitigate the above problem is to introduce calculated eccentricity about the central line of the corrugated structure.

NOMENCLATURE

- UAV: Unmanned Aerial Vehicle
- DRS: Double Rib Structure
- CFD: Computational Fluid Dynamics
- EDM: Electron Discharge Machining
- VSMW: Variable Span Morphing Wing
- FEM: Finite Element Modelling.
- FDM = Fused Deposition Modelling
- CNF = Carbon nano fibers
- RP = Rapid Prototyping
- TLCP = Thermoplastic Liquid Crystal Polymer
- CNF = Carbon nano fibers
- E = Modulus of elasticity

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MODELING, DESIGN AND ANALYSIS OF AUTOMOTIVE ENGINE PISTON LUBRICATION AND DAMPING SYSTEM

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Abstract
In internal combustion engines the piston reciprocates due to the combustion forces. It reciprocates having a clearance between cylinder liner and the piston skirt and this clearance causes the piston to move laterally as well. In this work a mathematical model have been developed to find the response of reciprocating motion as well as the lateral or secondary motion with total of two degrees of freedom. For this purpose the combustion force have been transformed using Fourier transform method. The forces acting in both direction such as primary direction and secondary direction (lateral) have been plotted along with the response of the piston under the influence of these forces. For this purpose a 127 cc motorcycle piston have been considered, while modeling the damping the viscous properties of SAE 30 motor oil have been used, also the motor oil lubrication is assumed hydrodynamic and also as a Newtonian fluid. Similarly the stiffness of the system have been derived using rotational work energy principle. The equations have been solved and plotted using Matlab.

Keywords: secondary motion; piston; vibration; Fourier transform; response; Mathematical Modeling; two degrees of freedom; damping

1. INTRODUCTION

Piston converts the energy from combustion and expanding gases to reciprocator motion. But there are some energy losses due to frictions and the frictional losses in piston accounts for almost 50% and in some cases 30 – 45%. The piston has two types of motion while it works such as linear reciprocator motion and secondary motion. The linear reciprocator motion is essential but the secondary motion which is mainly the lateral motion of the piston because of the clearance between the piston skirts or in some cases piston rings and the cylinder liner. This clearance also allows the piston to rotate around the piston wrist pin. Hence there are two types of secondary motions which cannot be avoided because the piston to operate there must be some amount of clearance between the cylinder liner and the piston skirt and the clearance ultimately allows the secondary motion.

The piston is contained in the sleeve and the rings of the piston which are assembled to the piston at its respective grooves helps in the sealing of the combustion chamber. Basically the three types of rings are termed as ring pack, the top ring is called compressing ring the second scraper ring and the third is called oil control ring, these rings as well as the piston skirt are connected to the cylinder liner by hydrodynamic contact.

And for the purpose of the reduction of the friction between the two mating surfaces the engine oil is used as lubricant. Piston is a part which experiences the pressure of the expanding gases and compressing gases and these forces either makes the piston move and also produces some stresses in the piston. The main concern in case of the piston is that the processes in the problems of piston repeat at varying frequencies and so is the secondary motion of the piston. Even if the surfaces are lubricated the secondary motion allow the surfaces to come in close contact and even Elast-hyro-dynamically which give rise to the noise, friction and even elastic deformation of the mating surfaces.

When solving problems like this it needs the knowledge of fluid mechanics, theory of elasticity, vibrations and tribology. First the model of the lubrication is decided first and then the coupling of piston lubrication and the cylinder liner are modeled. The Literature review suggest that the partial elasto-hydrodynamic lubrication model is more realistic approach in solving Tribological problems because it includes the wear phenomena, the elastic deformation of the mating surfaces and the hydrodynamics principles are still not violated and there is a constant

flow into the film of oil maintained by the lubrication system.

There is an active lubrication system working in the automotive engine which serves to lubricate the crank shaft, piston and every mating surface and this lubrication is made possible without the influence of external pressure and a hydrodynamic lubrication is thus made possible by continues supply of the lubricating oil into the mating surface to maintain film of oil. The pressure that is acting on the surfaces is due to the fluid shear and the pressure due to hydrodynamics of the film.

2. LITERATURE REVIEW

There have been large sum of research carried out on the tribology of the piston and cylinder and the lubrication problem has been modeled with Hydrodynamic Lubrication (HL), Elasto-Hydrodynamic Lubrication (EHL), Partial Elasto-Hydrodynamic Lubrication (PEHL) and Mixed Lubrication (ML) The engine oil has many other functions as well but in our peace of work three functions of the lubrication engine oil have been considered such as lubrication, cooling of the mating surfaces by convection and damping of the secondary motions. In these functions according to the studied

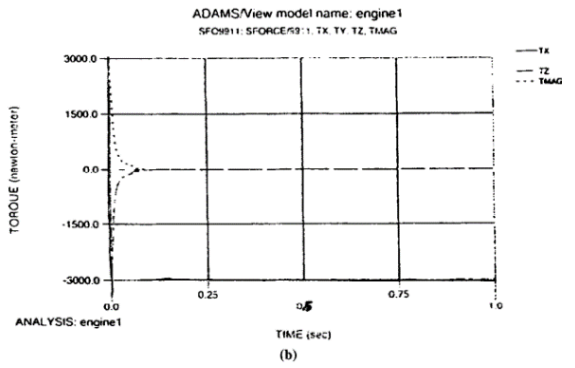


Fig. 4. Torque of starter motor to start the engine [1]

Fig. 4 shows the torque of starter motor to start the engine and process of reciprocation. Harmonic analysis using commercial engineering software Ansys has been done in three dimensions as well as in two dimensions for Aluminum material such as HF 18 for different compression pressures of 40-75[2] bar of range in Variable Compression Ratio (VCR) cylinder liner of diesel engine

Using FUNGILAB SMART series V210003 rotary viscometer[3] the kinematic viscosity over different

died literature the lubrication and the Tribological performance have been thoroughly studied but the damping of the secondary motion by the engine oil still need attention and that is why it has been considered. The torsional vibration analysis were carried out for Multibody single cylinder internal combustion engine model comprising inertial rigid bodies, bearings for support, damping components , connections and couplers between some of the engine components. Using this model[1] some of engine designs prototypes can be tested. This model also investigates noise and vibration. The new approach numerical analysis of dynamics problems which are Multibody and complex nonlinear has been brought up. Fig. 3 shows the combustion force behavior over time

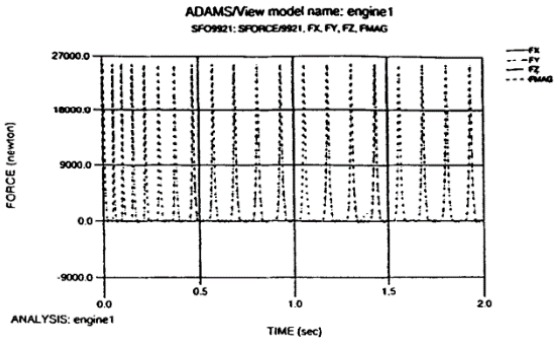


Fig. 3. Combustion Force behavoiur over time [1]

temperatures of engine oils has measured for two types of oil such as new oil and used oil of a passenger car and in this work Citroen Berlingo car[3]. The viscosity of oil selected is 5w30. Engine oil is used both in internal combustion engines of both diesel and petrol or gasoline fueled. And viscosity is the major property of lubricating oil as it is the internal friction of moving oil particles, kinematic viscosity decreases with increasing temperature[3]. The dynamics and lubrication of piston are analyzed using a developed method in finite Element Method. First numerical modal has been developed for Multibody dynamics including for piston connecting rod and crack. LaGrange multipliers [4] and constraint Jacobean matrix has been created for solving the Multibody dynamics equations. And the dynamics and lubrication model have been coupled[4]. They also investigated that how some of the piston design parameters affect the noise from slap and the lubrication performance. Some parameters including bore clearance, curvature parameter of skirt profile and bulge position. The results suggest that if the clearance is small than the smaller would be piston secondary motion due to less space, and hence it results in high slap noise and wear. Also it produces higher oil film shear stress. And the piston skirt position of barrel peak have effect on the

characteristics of piston skirt-liner lubrication and dynamics[4].

The lubrication performance of piston skirt has also been worked out by [5] through some design parameters. The computer code used for this analysis is called Friction and Lubrication Analysis of reciprocating Engines (FLARE) .The type of lubrication selected is Mixed Elasto-hydrodynamic lubrication [5]. And thermal and elastic deformations have been considered for skirt also for the fine model the effect of piston tilt and piston load and variation in speed also been considered. The lubricant pressure has been calculated using the Reynolds equation. The film thickness is decided by the magnitude of clearance between the piston and the cylinder liner. As the model developed include three type of piston and cylinder liner interaction such as in which there is a lubricant film between the surfaces and other solid to solid hydrodynamic contact and one with no contact and a cavity is present between the two surfaces. For those regions where the solid to solid contact comes into play the pressure has been find out by using elasticity equations. And the combined effect has been find out by using Murty's method. Further where Reynolds's number has to be solved Newton-Raphson (NR) method has been used. And in each step of NR method the pressure of the oil film, pressure from contact and secondary motion of the piston are solved simultaneously.

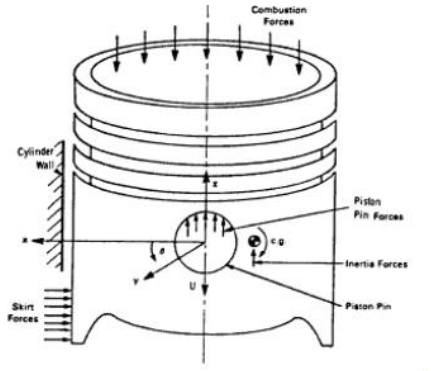


Fig. 5. Applied and reaction forces on the piston [5]

The Fig. 5 shows the applied and reaction forces in the model such as the combustion forces and its reaction at piston pin, the restraints by cylinder wall, skirt forces, inertial forces in the piston and moments along y direction which tends to tilts the piston [5].

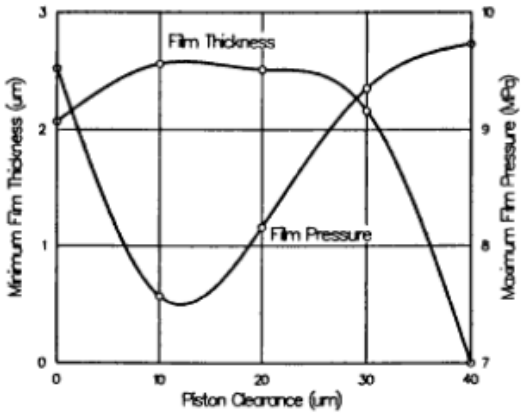


Fig. 6. Film thickness, Pressure vs piston clearance [5]

Fig. 6 shows film thickness first increases with clearance to 10 um[5] and then start decreasing abruptly after 25 um and the pressure decreases at first and then start increasing with increasing the clearance. The force of viscous damping of MR damper prototype increases slowly[6] as compare to bobbin-in-piston configuration and thus results in great dynamic range. It has the ability of greater stroke while in hydraulic cylinder. Using solid works a CAD model is developed for an internal combustion engine reciprocating piston and at the speed range of 600 rpm to 3000 rpm[7] the model is simulated for certain results like the reaction forces, linear velocity against the different times of combustion, thermal stresses and equivalent strains in the piston and the piston displacements are being determined. The geometrical features of the piston is shown in Fig. 7.

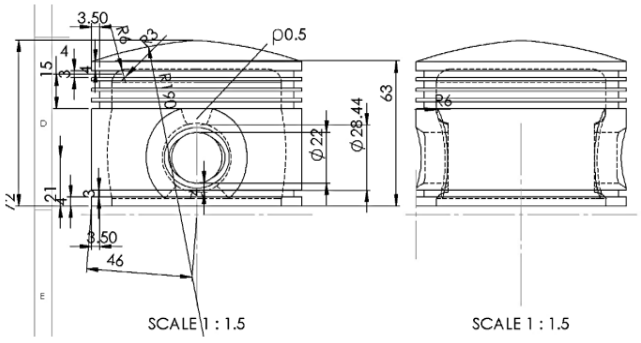
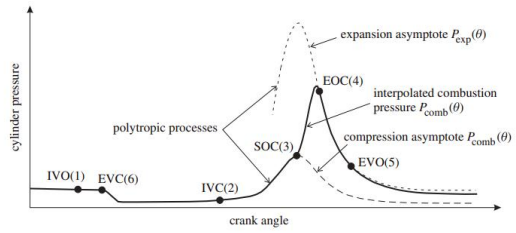


Fig. 7. Piston Dimentions [7]

Importance of textured surface of Tribological surfaces has been discussed by [8] as the textured piston ring reduce the friction by 20 percent to 50 percent as compare to the un-textured [8] ring and decreases 4 percent of the total fuel consumption. In

another work [9] Finite Element structural and thermal analysis has done using five different types of materials such as Al-sic Graphite, AL-GHY 1250, A7075, A4032, and A6082[9]. The analysis is done using Ansys 15 static and a piston from four stokes and single cylinder engine has been selected. The results for total von misses stresses, Equivalent Strains and Total deformation have been obtained for all of the five materials. On the basis of these results Al-sic graphite has been suggested to be used for piston material. [10] using the gas pressures with in the cylinder the piston motion has been determine of the internal combustion engine and not just assuming the uniform constant rotation of the crank, for the secondary motions the damping have been determine in lubrication condition of fully flooded. The variations in pressures can be modeled by Mass Fraction Burnt (MBF) [10] profile of the mixture of both air and fuel. The MBF nonlinear interpolation in the two pressures traces such as asymptotic pressure traces P_{comp} and asymptotic pressure traces P_{exp} which is illustrated theoretically as in the following figure. Also the pressure has been measured and that calculated are also shown in Fig. 8.



Cylinder pressure model based on non-linear MFB interpolation between expansion and compression asymptotes [**20**]

Fig. 8. Non Linear MFB interpolation model for cylinder pressure [10]

In 1982 Steve M. Rohde, Dennis F. LI and Hazem A. Ezzat in general motors research laboratories Michigan conducted a classical analytical study on piston dynamics in a reciprocating engine. [11] studied that how the clearance and other properties and parameters changes the piston secondary motion such as piston secondary translation and rotation on piston pin axis, and also how the piston skirt frictional power loss[11] behave. Other parameters have also been analyzed for the effect on the secondary motion and frictional loss like the lubricant viscosities and more significantly the piston pin location. The approach that has been developed by [11] can be used to select the parameters for designing the engine and operating conditions. And the piston slap effect on the vibration and noise of engine can be assessed easily[11][12]. have developed a new mathematical model for the dynamics of piston in the mathematical modal the connecting rod and crack shaft dynamics are also been considered which are mainly ignored in many models for analyzing the secondary motions of the piston.

Cristiana Deplete, Abbas Razavykia and Paolo Baldissera [13] developed an analytical model to study the contact behaviors of piston skirt and the cylinder liner. They have selected the hydrodynamic lubrication and packed lubrication using piston ring. And for determining the friction forces for the piston ring pack and its respective moment in the axis of wrist pin the nonlinear equations system have been solved and the governing equations is Reynolds equation and Force equilibrium. Three types of boundary conditions have been used to determine the change thickness of minimum film of oil at the interface of piston ring and liner [13].

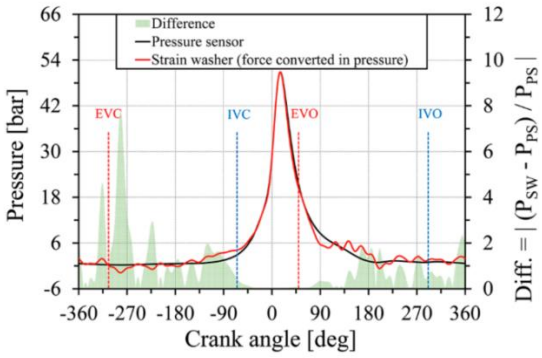


Fig. 9. variation of pressure in cylinder against Crank angle [14]

The in-cylinder pressure has been measured using piezoelectric sensor and that measured using the strain washer are shown in Fig. 9 which are in close agreement with relative error at certain crank angle. And further the method has also been applied to conditions such as misfiring, knocking and pre-ignition. And the method developed can be used for multiple cylinders[14] as well.

S.d'Ambrosio, A. Ferrari, L.Galleani [15] presented his work to compute in-cylinder pressure and the essential combustion features such as start and end of combustion and the angle of crack shaft corresponding to half burned mass. The pressure has been recorded using piezoelectric[15] transducer. For diesel combustion the time and frequency analysis are also been applied. Using different values of crankshaft angular velocities and different types of engines running on gasoline, methane and other fuels are considered. For an internal combustion engine a design such as on-line estimator has purposed by Ibrahim Haskara and Larry Mianzo [16] which has the

purpose of indicating torque and each cylinder pressure of combustion. FFT analyzer [16] is used and with accelerometer is used to measure the vibration which is important aspect of finding the valid reason for vibrations in the engine. The natural frequency and the characteristics of the motion have been mapped. Using Matlab and Simulink [17] established complete simulation model to study the complete features of motion. And the results thus obtained from free piston system shows that the system is forced vibrated with the effect of damping and stiffness. And the response in steady state with periodic excitation is converging thus representing the stability of the combustion in periodic manner. The simulation model includes thermodynamic, dynamic and thrust force models [17]. Md Wasim, Abhishek Bhandari [18] applied Taguchi method to determine what the best settings for a diesel engine piston are and the method is used in other fields of engineering as well. And it has done by the optimization of temperature and stresses using Minitab Software. And the piston shape, butanol fumigation, EGR[18], injection pressure, and injection timing affect the performance[18] The optimization strategy is effective in lowering operational costs and the streamlining of the processes used in design. For high temperature conditions Ansys 15 has been used for thermal analysis. The engine used is Light Duty DI diesel engine and the fuel used is diesel jatropha methyl ester (JME)[18] twenty percent of volume. A mathematical model including mixed lubrication for piston. The work done suggests how the friction, lubrication and piston motion is affected by the thermal distortion, elastic deformation, the profile[19] of the piston skirt, roughness and waviness of the surface of the cylinder bore and piston skirt.

And it is suggested by [20] that improvements are required in the structure of the test rig for accurate and cleaner measurements when the engine operates at higher speed such as above 800 rpm[20]. The experimentation token place for two types of piston configurations. And it is reviled from the results that the compression ring adds most of the fraction to the total friction all over the cycle of the piston. A subtraction method used suggests[20] using slightly oversized piston.

Xun Zhang, Hui Liu, Mahmoud Taha of Beijing institute of Technology [21] investigated the vibrations under the influence of active damping and these vibrations are produced by the engine ripple torque in power split hybrid electric vehicles (HEVs)[21]. Furthermore a simple model for dynamics of transmission is developed which simplifies the analysis of the transmission and makes the control of active vibration possible. And the active vibration controller which is basically works on the basis of filtered-x lead mean square (FxLMS) [21] type algorithm, this algorithm deals the vibration that is produced in the power split of hybrid electric vehicle. The results thus obtained for the steady-state conditions from the simulation and when the active damping algorithm is applied so the fluctuation of torque in the driveline shafts is decreased by 60 %[21] over various velocities and different types of modes of driving which shows the effectiveness of the demonstrated strategy.

The literature reviewed by [22] indicates that the piston skirt dynamics and also the Tribological performance which is basically the performance of the lubricant oil is supposed to be a complex engineering problem[22]. [23] used an algorithm NSGA 2[23] to optimize more than one objective function and in this case the objective function were for temperature for which the maximum value was required at piston top ring groove and second objective function was the equivalent maximum stress in upper part of the piston, for temperature and stress the best results are obtained when cooling gallery is close as possible to the top of the piston crown[23][24] carried out computational study on piston using Ansys and performed static and modal analysis of the piston of the engine. The engine specifications were WP10.290 Diesel engine, water cooled and four strikes engine additionally it is high pressure and electronically controlled common rail and supercharged intercooling, with 126 mm cylinder head, 213 W rated power, 2200 rpm rated speed[24], 600 rpm of idle speed and 1160 N-m maximum torque, maximum speed is 1200 rpm - 1600 rpm and this analysis involved only one piston and in static analysis has applied fixed constraints to model at inner wall of piston pin pedestal holes. And as far as loads are concerned instead of maximum burst pressure the average effective pressure has been used with value of 1.182 MPa. Using Ansys first sixth natural frequencies are found out and the mode shapes are shown in the figures[24].In 1950 IBM developed a programming language for scientific and engineering applications called Fortran the Fortran cones from formula testing system and ADAMS stands for Automated Dynamic Analysis of Mechanical systems is a simulation software and its solvers works on Fortran as well as C++. The general purpose of ADAMS is solving complex Multibody dynamics and the research carried out by 1 consist of establishment of dynamic model of piston cylinder system of an internal combustion engine (ICE) and their model has two parts, first is hydrodynamic lubrication and second part is the dynamics of Multibody system for that of piston cylinder system both parts are coupled together by ADAMS [25] and FORTAN subroutine. The

deliverable of this work is that how the length of clearance between pistons sleeve and piston skirt dictates the lubricating characteristics of piston geometric parameters. Basically this is solving tow equations such as system dynamic equation and secondly average Reynolds equation and they are solved simultaneously with the help of ADAMS solver and FORTRAN subroutine[25]. [26] with critical loads of 300 N, 400 N and 500 N the change in friction coefficient with varying loads have been find out then spectrometric analysis has been carried out, for each case of critical loading and it has been observed that the amount of ferrum has increased dramatically above the critical load. The spectrometry results also contain the small particles (Ds) and large particles (D_l) in the lubricating oil and a trend has been shown how these two types of particles varies such as increasing critical load increases Ds relative to Dl[26] Then Friction between surfaces and quality of lubrication oil have been studied such that three groups with same surface roughness like 0.6 um -6.2 um have chosen for group 1 CD40 lubrication has been use in second group CD40[26] lubrication oil with MoS2 have been used and finally special running-in lubricant has been chosen and each group have critical load of 300 N, 400 N and 500 N respectively. Hence it has been concluded for [26] that spectrometric analysis on lubricating oil can work effectively to monitor the friction process in diesel engine, further it has showed that the type of quality of lubrication oil matters while formation of film and affects the friction process, and the experiments performed in this work are by Pin Pan[26] experiment machine. [27] mapped analytical model to find out the minimum film thickness of lubricating oil between piston ring and cylinder liner. This model is based on partial elastohydrodynamic lubrication (PEHL) which accounts for surface roughness. According to author previously used different types of lubrication like Elaso-Hydro_dynamic lubrication (EHL) and mixed lubrication (ML) didn't account for surface roughness and oil pressure, when these two factors are considered such as in (PEHL) [27]the minimum film thickness at (dead top center) of the cylinder liner becomes smaller then that calculated for EHL and greater then ML. The work done by [28] concentrates over the creation of tool for the study of the hydrodynamic lubrication for the rings and an experimental portion of this work using sensors for the measurement of the thickness of the lubrication film has also presented[28,29].

3. METHODOLOGY

As the reciprocating of the piston involves rotation of crank shaft and the reciprocation and rotation of connecting rod and reciprocation of the piston itself. In this vibrational analysis of piston two degree of freedom have been considered such as motion of the piston in x axis which is also called lateral motion of the piston and the motion along the y axis as shown in Fig. 10.

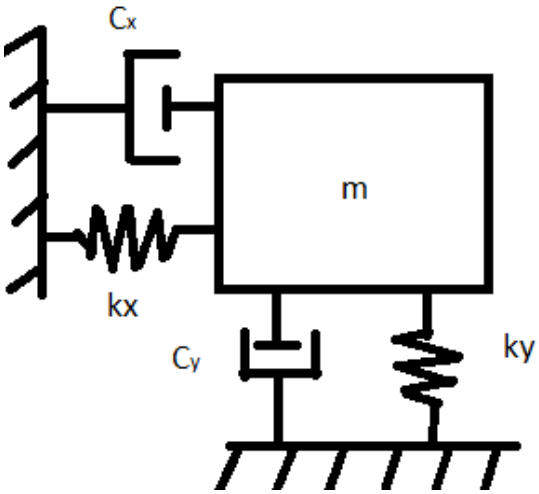


Fig. 10. Spring mass damper system

4. STIFFNESS:

To find the restoring force which causes the piston to restore to its mean position has been find out from the rotational energy of the crank shaft. In this approach during the expansion of gases in the cylinder work is done both on piston and crank shaft, the crank shaft stores some of the work in form of rotational energy which then helps the piston to restore to its mean position. And two components have been find out such as one for reciprocating and other for lateral motion of the piston.

$$\text{work done} = RF\theta \tag{1}$$

$$\text{change in rotational energy} = \frac{1}{2}I_c\omega^2 - \frac{1}{2}I_c{\omega_o}^2 \tag{2}$$

$$equevlent\ stored\ energy\ for\ restoring\ of\ piston \quad E = \frac{1}{2}kx^2 \tag{3}$$

$$k = \frac{RF}{y^2} \tag{4}$$

$$k_y = k\cos\alpha \tag{5}$$

$$k_x = k\sin\alpha \tag{6}$$

5. DAMPING COEFFICENT

In this analysis only the viscous damping due to engine oil have been taken such as for x direction and y direction of the piston in the sleeve. The lubrication is hydrodynamic and Newtonian lubricant fluid has been used. The damping coefficient have find out using law of continuity and flow rate. As the piston during lateral motion displace the lubricant tangential to the piston dimeter and the shear force between the piston and cylinder is given by

$$Shear\ force = F = \pi rl\ d\tau \tag{7}$$

Where πrl half the area of the piston skirt, and this area is experiences the shear force due to the viscosity of the lubricant.

$$\tau = -\mu \frac{dv}{dy} \tag{8}$$

$$F = -\mu \pi rl\ \frac{d^2v}{dy^2} dy \tag{9}$$

$$pressure\ force\ on\ end\ elements = 2pl\ dy \tag{10}$$

$$where\ p = \frac{P}{\pi rl} \tag{11}$$

$$F = \frac{2P}{\pi r} dy \tag{12}$$

$$\frac{2P}{\pi r} dy = -\mu \pi rl\ \frac{d^2v}{dy^2} dy \tag{13}$$

$$\frac{d^2v}{dy^2} = -\frac{2P}{\pi^2 r^2 l\mu} \tag{14}$$

$$v = -\frac{2P}{\pi^2 r^2 l\mu} y^2 + y\left(\frac{Pd}{\pi^2 r^2 l\mu} - \frac{v_o}{d}\right) + v_o \tag{15}$$

Where d is the clearance and v_o is letral velocity of the piston and also

$$Q = \int_0^d 2lv\ dy \tag{16}$$

$$Q = \frac{2Pd^3}{3\pi^2 r^2 \mu} + v_o dl \tag{17}$$

$$also\ Q = Av_o = \pi rlv_o \tag{18}$$

$$P = \frac{v_o(\pi rl - dl)3\pi^2 r^2 \mu}{d^3} \tag{19}$$

$$also\ P = Cv_o \tag{20}$$

$$C_x = \frac{3(\pi r - d)\pi^2 r^2 l\mu}{d^3} \tag{21}$$

Using the same principles the translatory damping coefficient have been find out

$$C_y = \frac{A\mu}{d} \tag{22}$$

6. FORCES

Step force have been taken to find the two motions of the piston. This step force is a piece wise function of time which is zero for half rotation of the crank shaft and have a step value for the other half rotation of the crank shaft. This force has also two components for the two type of motions. The friction forces and inertia of the crank shaft have been ignored only the masses of connecting rod and the piston have been considered.

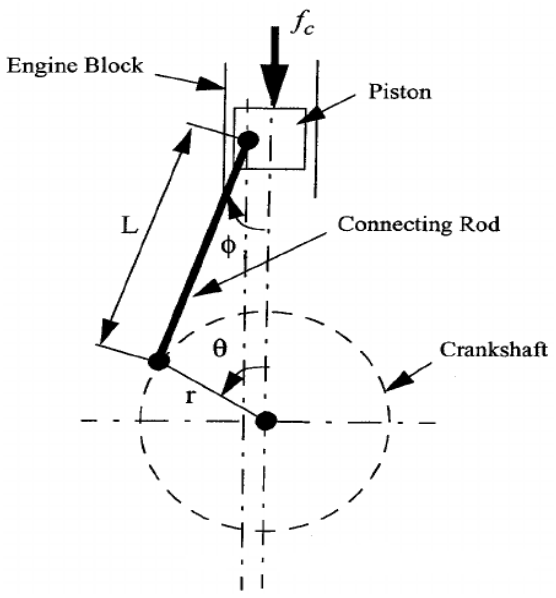


Fig. 11. Different Parameters of Piston Dynamics

$$Lsin\phi = r_c sin\theta \tag{23}$$

$$\phi = sin^{-1}\left(\frac{L}{r_c}\ sin\theta\right) \tag{24}$$

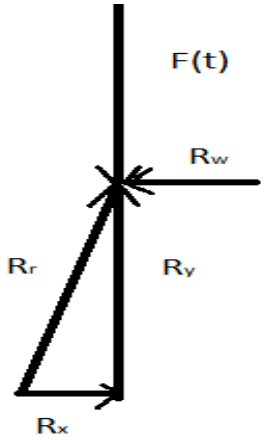


Fig. 12. Combustion forces and reaction from connecting rod and the cylinder wall.

$$R = \frac{T}{r} sin\theta \quad (25)$$

$$Rx = Rsin\ \phi \quad (26)$$

$$Ry = Rcos\phi \quad (27)$$

$$Rx = \frac{T}{r} sin\theta \sin\phi \quad (28)$$

$$Ry = \frac{T}{r} sin\theta \cos\phi \quad (29)$$

$$Fx(t) = Rx \quad (30)$$

$$Fy(t) = -Fy + Ry \quad (31)$$

7. EQUATION OF MOTION:

$$\begin{bmatrix} m & 0 \\ 0 & mp \end{bmatrix} \begin{bmatrix} \ddot{x} \\ \ddot{y} \end{bmatrix} + \begin{bmatrix} Cx & 0 \\ 0 & Cy \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} + \begin{bmatrix} kx & 0 \\ 0 & ky \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} Rx \\ Ry \end{bmatrix} \quad (32)$$

These are uncoupled equations and can be solved independently using Fourier Transform.

8. INPUT PARAMETERS

Table 3, List of Input parameters

Parameter	Symbol	Value
Crank Shaft inertia	I_c	1.3e-3 kg m^2
Ratio of connecting rod length	j	0.4
Connecting rod length	L	0.15m
Piston and piston pin mass	m_p	0.2kg
Connecting rod mass	m_r	0.35kg
Total mass of piston, piston pin and piston rings	M	0.33kg
Crank shaft radius	r_c	25mm
Piston skirt and cylinder liner clearance	d	0.5mm

9. IMPLIMENTATION

The response of each degree of freedom have been find out using Fourier transform because this problem include forcing function which is piece wise defined and Matlab have been used to code program for solutions. First of all the 127 cc motorcycle piston geometrical dimensions have been selected for the analysis and the values are fed into the stiffness mass and Damping coefficient equations find earlier and have been incorporated into the equation of motions and solved with Matlab.

$$a_j = \frac{2}{\tau} \int_0^{\tau} F(t) cosj\omega t dt, \ \ j = 0,1,2 \ldots . \quad (33)$$

$$b_j = \frac{2}{\tau} \int_0^{\tau} F(t) sinj\omega t dt, \ \ j = 1,2 \ldots . \quad (34)$$

$$x_p(t) = \frac{a_o}{2k} + \sum_{j=1}^{\infty} \frac{(\frac{a_j}{k})}{\sqrt{(1-(jr)^2)^2 + (2\xi jr)^2}} \cos(j\omega t - \phi_j) + \sum_{j=1}^{\infty} \frac{(\frac{a_j}{k})}{\sqrt{(1-(jr)^2)^2 + (2\xi jr)^2}} \sin(j\omega t - \phi_j) \quad (35)$$

These equations are used to find two solutions for each type of motion

10. RESULTS

For the step force of 5 N and time period of 0.1 sec there is major deflection of piston in lateral direction at 0.05 sec of time period and when force is

zero at time period of 0.1 the piston regain its mean position.

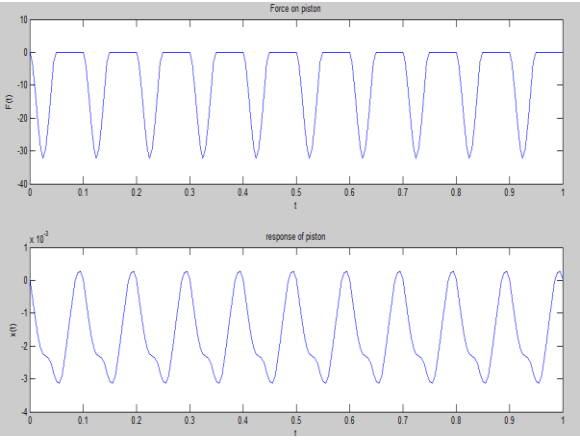


Fig. 13. Force on the Piston in x direction and its Piston Secondary/lateral response

The reciprocating response in y direction is shown in the following figure with the R_x component shown as F (t).

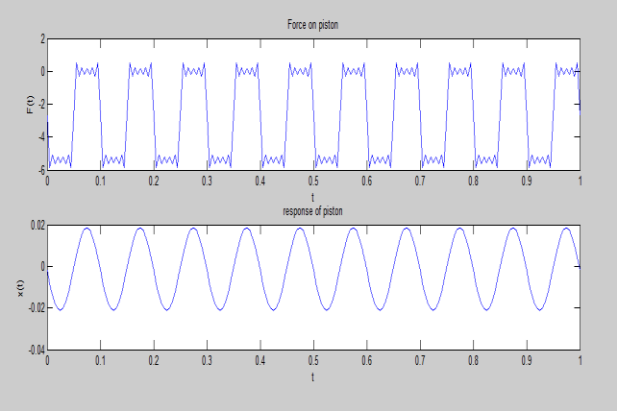


Fig. 14. Reciprocating force and piston response in y direction

11. CONCLUSION

This work shows that a secondary motion exists between tribological surfaces in which the surfaces move relative to each other and having hydrodynamic lubrication. As in piston cylinder arrangement, in which the reciprocatory motion is the primary motion along with this motion the lateral or secondary motion does exist as shown in Fig. 13.

The primary and secondary response of the piston have been obtained by modeling the piston as a system with two degrees of freedom and for both types the response have obtained independently using Fourier transform method.

The stiffness and damping due to the lubrication have been modeled and incorporated into the furrier equations and the response have been generated using Matlab with n = 10, T = 0.1.

The reciprocating or primary response is harmonic as in Fig. 14 while lateral or secondary response is different as in Fig. 13.

When two surfaces have clearance, having hydrodynamic lubrication and moving relative to each other the lateral response can be find out using the same model by changing the parameters governing the areas.

12. RECOMMENDATIONS:

A more realistic approach could be used to model the mechanism by including the inertia of crank shaft and there will be more accuracy in damping coefficient if we include the real piston skirt area and piston rings in modeling the lubrications.

NOMENCLATURE

Capital

P_{comp}	pressure during compression
P_{exp}	pressure during expansion
I_c	rotational inertia of the crank shaft
F	shear force
P	force causing hydrodynamic pressure
Q	rate of flow through the clearance space
C	damping coefficient
L	length of the connecting rod
R	reaction force
T	torque
M	total mass

Lowercase letters

k	stiffness of the system
r_p	radius of the piston
l	length of the piston
p	hydrodynamic pressure in the thin oil film
d	clearance between piston and cylinder
r_c	radius of the crank shaft
m_p	mass of the piston
m_r	mass of connecting rod
j	ratio of L and r_c
$\ddot{x}$	acceleration in x direction

$\ddot{y}$ acceleration in y direction

Greek capital symbols

ϕ angle of connecting rod with y axis
θ crank shaft angle

Greek lower case

μ oil viscosity
τ shear stress
ω angular velocity of crank shaft

Abbreviations

HL hydrodynamic lubrication
EHL elasto-hydrodynamic lubrication
PEHL partial elasto-hydrodynamic lubrication
ML mixed lubrication
VCR variable compression ratio
FLARE friction and lubrication analysis of reciprocating engines
NR newton-raphson
CAD computer aided design
MBF mass fraction burnt
JME jatropha methyle ester
HEVs hybrid electric vehicles
FxLMS filtered-x lead mean square
ADAMS automated dynamic analysis of mechanical systems
ICE internal combustion engine

ACKNOWLEDGEMENTS

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MATHEMATICAL MODELING AND VIBRATIONAL ANALYSIS OF HELICOPTER SLING-LOAD MECHANISM

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Abstract

Of the best machines that are employed worldwide for transporting or carrying heavy load over large distances, helicopter is the one. If we talk about the mechanism(s) used for the very job, there are the suspended cables below the helicopter. In response, disturbance forces such as wind coupled, with the helicopter motion the suspended load oscillates. The oscillations load carried by the suspended cables below the helicopter is not only dangerous but also affects the control of helicopter, and that too adversely. In the aerospace community the application of helicopter carrying external suspended loads is of significant focus owing to the stability problems in such systems. In the past, most of the work was focused on determining the favorable wire length, helicopter load ratios for stability analysis. In addition, the design of techniques that could augment stability in the slung load systems had also been the focus of past researches. In addition, a few of the researches focused on situation specific and simple models; however, most work in the past was focused on more general models that were suitable for control and simulation. The literature review, along with generic approaches to modeling slung load, discusses input shaping method to helicopter's flight controller in order to gain stability. So far as this paper is concerned, it includes mathematical modeling of the sling load in single degree of freedom. Additionally, in this paper we discusses different conditions to model sling load such as: un-damped free vibrations, damped free vibrations, vibration under harmonic forces and vibration under general forcing conditions. The finding of our paper presents the response of the sling load modeled in single degree of freedom under certain conditions. In this article we will learn as to how helicopter sling-load can be modeled and mathematically in single degree of freedom, and what is the response of the sling load under different conditions.

Keywords: Sling-Load; Mathematical Modeling; Single Degree of Freedom; Vibrations; Damped; Un-damped; Harmonic Excitation.

1. INTRODUCTION

We witness the employment of cranes for lifting heavy objects. Such cranes are designed for this purpose. However, when loads are to be carried over a large distance i.e. from tens of miles to hundreds of miles then helicopters do such job. So, keeping in view such a functionality, helicopters can rightly be termed as flying cranes. What makes helicopter a flying crane? It is the load suspended underneath aided by slings or cables. And, it is due to this very mechanism flying cranes or helicopters are very versatile; for it can transport almost anything i.e. from logs to power transmission towers; from rescuing people from remote areas to delivering food supplies for them. A few of the helicopter transport operations are shown in the figures 2,3, and 4 respectively. Now the question arises here as to what kind of helicopters do such jobs. One such example in this regards is the Kaman K-MAX R© Aerial Truck. Figure 5 is a manifestation of the utility of flying crane helicopters. If we talk about the utility of these flying crane helicopters, a couple of K-MAX helicopters have been employed for transporting over one million pounds of cargo to US Marine Corps deployed in Afghanistan over a span of 16 weeks.

Bisgaard et.al [1] presented a generic approach for modeling slung load systems that could aid the design engineers to handle not only wire slacking and tightening but also multi-lift systems. The model presented by Bisgaard et.al [1]gave an intuitive and easy-to-use approach to not only modeling but also simulating various slung-load suspension systems. It

is not limited to but inclusive of response to, and detection of the tightening and slackening of wire. Moreover, the research also provides its readers with an intuitive approach to aerodynamic coupling between the slug-load and the helicopter.

2. MODESLING APPROACHES

There exist two distinct modeling approaches concerning the modeling of slung-load system under helicopters. The approaches include: the embedded formulation and the augmented formulation. The advantage of embedded formulation is that it formulates the problem in terms of degrees of freedom coupled with generalized. The advantage of such a formulation is that there are minimum set of equations; and moreover, constraint forces on the system are not revealed by such set of equations [2]. On the contrarys, the second type of formulation that is augmented formulation articulates the system in the form of redundant forces[3].

Glauert [4] was the first amongst all who considered the dynamics of the object carried by helicopter through sling, and he discovered all the problems that were involved in such a task. In addition, he identified that the two main causes leading to the instability of any such system included low load masses and short wires. His research was divided into three part wherein the first part dealt with wire system and subsequent determination of three periods of oscillations i.e. two in planar symmetry and third one being perpendicular to the first two. In the part two and three of his research the criterea for the longitudinal and lateral stability was developed respectively coupled with the introduction of two more periods of oscillations.

Moreover, Luscassen and Sterk [5] were the first ones who performed a thorough study on the helicopter slung load system. Although, the analysis performed by Luscassen and Sterk [5] were limited to three degrees of freedom; however, they were the first ones who considered the coupling between helicopter and slung load. The researchers in the following decades carried out research on the stability of slung load systems with the help of analytical models coupled with experimental testing of those analytical models. In a nutshell, almost all of the work was focused on determining a stable flight region vis-à-vis the parameters of slung load in order to avoid instabilities during the flight. A few of the researchers carried out analysis on certain parameters like the shape and geometry of the load to be carried in order to minimize the instabilities. Additionally, some other parameters were also considered that included fins, gyroscope, and drogues in order to reduce the instabilities in the system.

If we talk about the limitations in such model(s) devised by the early researchers, they were limited to or focused at stability analysis in the bounced region. In addition, a linearized model was also considered and studied that assumed no coupling between longitudinal and lateral motion [6]. Linearized model only dealt with forwarded flight and single-point suspension, and it also proposed that a long wire was needed for the stability. This model, by all means, proved to be beneficial for the later work that considered the utilization of gyroscope and fins to gain stability.

In addition, experimental testing using forced oscillations in a wind tunnel were also performed by Cicolani et.al [2]. And, it concluded that a two wire suspension system solved a few stability problem revealed in a single wire suspension system, and provided with an adequate suspension system with more stability. During the experimental testing in a wind tunnel, the flow filed and dynamics of the helicopter were ignored. Apart from the models that has been discussed above briefly, Newton-Euler equations can also be used to describe another suspension system for lifting heavy objects with helicopter. And, that specific system is inverted V-shaped suspension system Bisgaard et.al [1]. Moreover, this system also includes helicopter model based on stability derivatives. The basis of the model are inflexible and inextensible wires coupled with embedded system that reduces the constraining 12 degrees of freedom to 9 degrees of freedom. This system also incorporates the difficulties faced by engineers in order to obtaining an adequate model reaction to yaw-motion of the helicopter.

3. HELICOPTER MODELING

The design of flight control systems are assisted by helicopter dynamic models. Input shapers can be designed with the help of those models in which suspended load dynamics exist. This is done through the provision of estimates of the damping ratio and

natural frequency of the load oscillation. The purpose of designing input shapers can be achieved substantially through these estimates. For obtaining measurements of the suspended load natural frequency, the need for reliance on a vision system which is a conventional method for designing input shapers – would be reduced. Usage of such models for designing input shapers will be investigated in this thesis. A simple model of the suspended load oscillation was verified by Potter et al. [21] and this model was put into use for testing how robust and effective different kinds of input shapers are and this was done by simulation. Conversely, control of the helicopter is affected by the suspended load oscillation in an adverse manner. This is due to coupling between the helicopter motion and the load swing. The model investigated by Potter et al. [21] did not incorporate this particular coupling effect into consideration. In this thesis, load-attitude coupling effects and load-back driving of the helicopter will be included in the models which are to be investigated. The design and subsequent testing of helicopter flight control systems for operations of suspended load can be done through relatively more sophisticated models that take into account more of the helicopter dynamics. In this thesis, such a sophisticated model will be employed to examine the combination input shaping with a flight control system for usage during suspended load operations.

3.1 Dynamic Modeling of Helicopter

James [11]addressed the dynamic modeling of helicopter carrying suspended load. The main goal of the dynamic modeling was to come up with such a model that yields estimated damping ratio coupled with natural frequency of the suspended load swing for load configurations and range of helicopters[25]. Dynamic modeling of the helicopter carrying suspended load was an effort to producing sufficiently accurate damping ratio and natural frequency estimates that could be employed in designing input shapers. Moreover, the dynamic modeling helped to identify the dynamic effects that are important to helicopter-suspended load operations. Following the design of dynamic model, it was employed for designing and simulation testing of flight controllers that were proposed for suspended-load operations.

Several researchers carried out a research on the design on the design oy dynamic modeling of helicopter carrying suspended load. Dukes [24] studied helicopters carrying suspended loads using simple models consisting of only a few degrees of freedom. The models studied by Dukes [24] were used to analyze such methods that could damp the pendulum mode of the swing load for different maneuvers performed by the helicopters. Moreover, Potter et al. [21] embarked on translational model, and his motivation towards studying such a model was to approximate the suspended load dynamics by studying the similarities between cranes and helicopters carrying suspended load

Lucassen and Sterk [5] jumped on the same bandwagon and proposed in their work that a helicopter carrying a suspended load near hover is similar to the double pendulum, albeit mechanically. Additionally, Bisgaard et al. [1] contributed to the cause in such a manner that he modeled distinct slug load suspension types that included multi-lift configurations. The results were also verified experimentally, albeit on a small scale helicopter.

It has also been established that the dynamics of the crane payloads and the loads suspended from a helicopter are similar to each other [11]. In fact, the dynamic modeling of both of the systems can be as simple as the dynamic modeling of a pendulum. So, it was justified that the modeling of helicopter load suspension system which is quite complex could be simplified by employing same techniques that were used to model cranes coupled with the complex dynamics that includes load-vehicle coupling [26]. Simple dynamic models of the helicopter load suspension system was derived by relaxing a few assumptions that were employed in deriving the dynamic models of cranes.

Potter et al. [21] embarked on a similar approach i.e. coupling a first order model with a simple but second-order underdamped model of the swing or payload swing. This coupling helped to approximating transnational dynamics with helicopter attitude. James [11]presented a planar model where suspending payload was allowed to back-drive the suspension point. This back-drive effect is common in heavy sling loads.

Cao et.al [28] presented a dynamic model of helicopter slung-load system under the flexible sling hypothesis. The model was comprehensive base and physics based that was established via Kane's method[29]. The first model of the dynamic model for flexible sling-external laod system was developed on the basis of spring-point

mass-damper model. The slung-load system of the helicopter with flexible sling can be seen in Fig. 1.

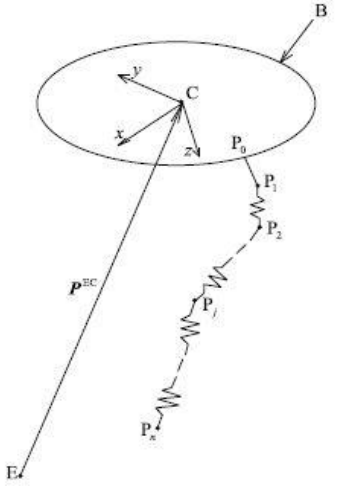

Fig. 1 The slung-load system of the helicopter with flexible sling.

Rigid body "B" is the manifestation of helicopter, and "C" illustrates the mass center. Point P0 is the hook point on the helicopter. As far as the modeling of sling is concerned, it is modeled as n-1 mass points i.e. P1, P2,….., Pn-1 where (n>1). These points are connected via spring chains. The gravity force was considered concerning the flexible sling; however, the aerodynamic force was neglected. As the aerodynamic force was neglected, the sling was divided into "n" parts and the portion in the figure i.e. P0, P1 is a rigid pole. As far as the remaining parts are concerned, they were taken as spring dampers. The aerodynamic force and gravity of the slung-load was considered and it was simplified as point mass Pn. Point "E" was taken as fixed reference point the ground. If we talk about helicopter, x-axis, y-axis, and z-axis in the figure above are the body axis system of helicopter and are taken in positive direction. The unit vectors b1, b2, and b3 were defined for the x, y, and z- axis respectively. The formula given was: b3= b1 x b2. A space vector was introduced to define the hook point. Lastly, forces on the hook point that represents the pull of the sling were also defined.

In another research carried out by Cao and Wang [30] another dynamic model of helicopter and slung load was presented which was based on rigid body rigid body slung-load hypothesis. The model presented by Cao and Wang [30] included 19 DOF that incorporated rigid body slung-load and helicopter full motions. A thorough analysis of helicopter stability and with rigid body slung-load was carried out based on the trimmed results. The trimmed results were established following the calculation of trimmed values of state variables at distinct velocities; and the method that was used for this, was continuation method. The paper established that the introduction of slung-load not only exert external forces but also effects the dynamic stabilities of the helicopter.

4. MATHEMATICAL MODELING

In this section, helicopter sling load will be modeled in different conditions in single degree of freedom and two degrees of freedom. As far as the free body diagram of concerned, it is manifested in the picture below. However, prior to discussing different conditions for mathematical modeling, it is necessary to define certain parameters that will be used to study the response of the system are listed in the table below:

Table 1. List of Parameters Used in Mathematical Modeling.

PARAMETR	FORMULA	VALUE
CABLE MASS	N/A	80 Kg
MASS ATTACHED	N/A	2000Kg
EQUIVALENT MASS:	$m_{eq.} = M +(33/140)(m)$	2019 Kg
CABLE DIAMETER	N/A	0.038 m
CABLE LENGTH	N/A	10 m
CROSS-SECTION AREA	$\pi/4\ (D^2)$	1.134×10^{-3} m^2
YOUNG'S MODULUS	N/A	2.1×10^{11} N/m^2
CABLE STIFFNESS	k= EA/L	2.3814×10^{7} N/m
NATURAL FREQUENCY	$\sqrt{k/m_{eq}}$	108.6 rad/sec
DAMPING RATIO	C/C_c	0.5
DAMPING FREQUENCY	$w_d = \sqrt{1-\zeta^2}\, w_n$	94.05 rad/sec
EXCITATION FREQUENCY	N/A	70 rad/sec
FREQUENCY RATIO	$r = w/w_n$	0.64
FORCE	N/A	2000 N
STATIC DEFLECTION	F_o / k	8.399×10^{-5} m

In the following section there will be a discussion about as to how sling load mechanism can be modeled mathematically in different conditions in single DOF i.e. Un-damped free vibrations, damped free vibrations, Un-damped vibrations under harmonic

force, damped vibrations under harmonic force, and vibrations under general forcing conditions (particularly constant force). So, we will discuss all these conditions and their response equations one by one.

4.1 **Un-damped Free Vibrations** In this condition, it is assumed that system that consists of sling load is vibrating freely. Free body diagram of the system is shown in figure 2.

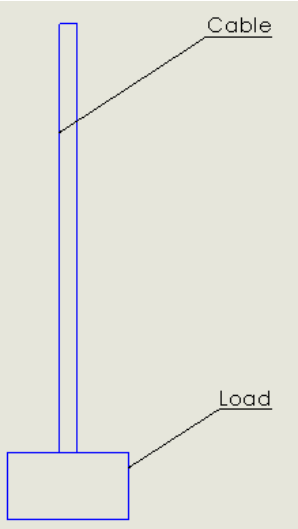

Fig.2 Free Body Diagram of Helicopter sling load in single degree of freedom

The response equation of the system is given by:

$$x(t) = X_o \cos(w_n + \emptyset) \quad (1)$$

Whereas the values of Xo and ɵ for the un-damped free vibrations are as follows:

$$X_o = [\, x_\circ + (\frac{x_o}{w_n})^2 \,]^{1/2} \quad (1.1)$$

$$\emptyset_\circ = \tan^{-1}[\frac{x^\circ_o \, w_n}{x_o}] \quad (1.2)$$

As far as the initial conditions are concerned, they are taken as follows:

$$Displacemen\ (x_\circ) = 0.25 \text{ m at (t=0)} \quad (E1)$$

$$Velocity\ (x^\circ_o) = 0\,\frac{m}{s} \quad (t=0) \quad (E2)$$

4.2 Damped Free Vibrations In this conditions, a damper will be introduced in the system and the damping ratio ζ is taken as 0.5 that means the damping co-efficient "C" of the damper is on half of the value of critical damping "Cc ", as it can also be seen in the table 1 above. The free-body diagram of the system is given in figure 12 below:

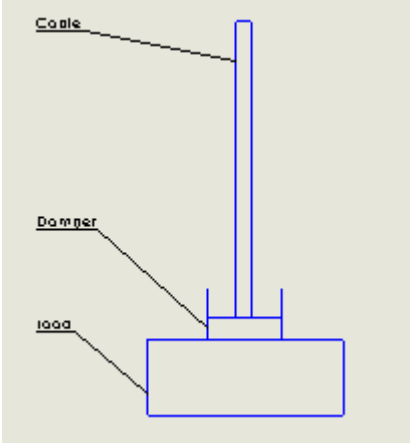

Fig.3 Free Body Diagram of Helicopter sling load with damper in single degree of freedom

The response of the system can be defined by the following set of equations:

$$x(t) = X_o\, e^{-\zeta w_n t} \sin(w_d t + \emptyset) \quad (2)$$

$$X_o = [x_\circ^2 w_n^2 + (x^\circ_\circ)^2 + 2\,\zeta x_\circ x^\circ_\circ\,]^{1/2} / w_d \quad (2.1)$$

$$\emptyset_\circ = \tan^{-1}\frac{x_o\, w_d}{x^\circ_\circ + \zeta w_n x_\circ} \quad (2.2)$$

4.3 System Under Harmonically Excited Damped Vibrations In this condition, the system response will be modeled under harmonic excitations through the following set of equations:

$$F(t) = F_0 \cos wt \quad (A)$$

In the above equation "w" represented excitation frequency and its values can be taken as 70 rad/sec as mentioned in Table 1 above. So far as free-body diagram is concerned, it is same as shown in the figure 12 above. The only difference is that harmonic force is acting on the system as manifested in the (A). The

response of the system is given by the equation written below:

$$x(t) = X_o e^{-\zeta w_n t}\cos(w_d t - \emptyset_\circ) + X\cos(wt - \emptyset) \quad (3)$$

$$X_o = [x_\circ^2 w_n^2 + (x_\circ^\circ)^2 + 2\zeta x_\circ x_\circ^\circ]^{1/2} / w_d \quad (3.1)$$

$$\emptyset_\circ = \tan^{-1}\frac{x_0\, w_d}{x_\circ^\circ + \zeta w_n x_\circ} \quad (3.2)$$

$$X = \delta_{st} X \frac{1}{\sqrt{(1-r^2)^2+(2\zeta r)^2}} \quad (3.3)$$

$$\emptyset = \frac{2\zeta r}{(1-r^2)} \quad (3.4)$$

4.4 Vibrations Under General Forcing Conditions In this condition the system will be modeled in such a way that constant force of 2000N is acting on the system. The free-body diagram of the system is same as manifested in figure 12. Moreover, the initial conditions will remain same as manifested in (E1) and (E2) above. The response of the system under constant force (Fo = 2000N) can be given by the equations given below:

$$(t) = \delta_{st}\,[1 - \frac{1}{\sqrt{(1-\zeta^2)}} e^{-\zeta w_n t}\cos(w_d t - \emptyset_\circ)] \quad (4)$$

$$\emptyset = \tan^{-1}\frac{\zeta}{\sqrt{(1-\zeta^2)}} \quad (4.1)$$

5. IMPLEMENTATION

In order for the above response equation to be solved or implemented, MATLAB serves the purpose quite efficiently. If we talk about the pros and cons of employing MATLAB for solving response of the system through the equations discussed in previous section then they are as follows:

5.1 **Pros** The pros of using MATLAB for calcylating the system response are as follows:

I. It has a huge built-in library for functions and tools, so it is simple to utilize Matlab when used properly.

II. Due to the built in functions of ODEs it was easy to use MATLAB to solving for the system response.

III. One of the best advantages of using MATLAB is that it uses intuitive approach and helps the user a lot when it comes to matrix manipulation.

IV. As far as plotting and graphing is concerned, it is quite simple in MATLAB for unlike excel, one needs not change the scale from normal to logarithmic which in some cases is difficult when the output value is negative.

5.2 **Cons** The cons are listed as follows:

I. One cannot use MATLAB sans prior practice.

II. Unlike MS Excel, one must learn coding technique of MATLAB in order to solve the problems.

III. The picture quality of the graphs is not as good as in case of other plotting programs.

IV. Sometimes it is hard to locate syntax error, if any, which prove to be cumbersome for the user.

6. RESULTS

In this section, results are discussed one by one in the form of graphs that we obtained following the solution of the response of our system in the conditions mentioned above.

6.1 Un-damped Free Vibrations Un-damped Free vibrations are oscillations where the total energy stays the same over time. This means that the amplitude of the vibration stays the same. Un-damped free vibration happens at the natural frequency of the body. This natural frequency plays an important role in damage mechanics. It is called “free” because there is no external energy source driving the movement (after the sudden blow that starts the movement).

As far as our case is concerned, the response of system concerning un-damped free vibrations was solved through MATLAB. The response is shown in the figure 4 below:

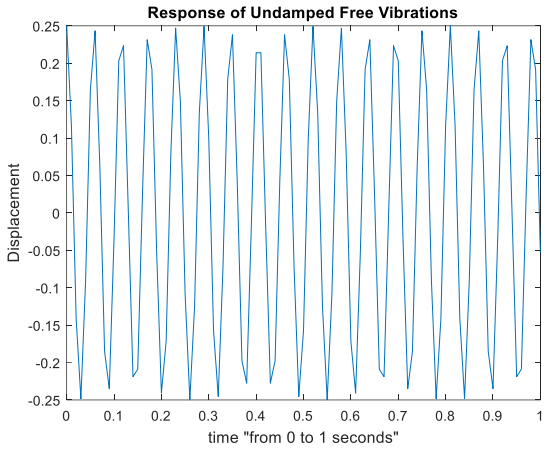

Fig.4 Response of Un-damped Free Vibrations

The plot in the above picture shows that the system will keep on oscillating with natural frequency unless and until resistive force i.e. damping is applied on it. Moreover, free vibrations are practically not possible; and the reason is that such systems neither lose energy nor gain energy during this process. Vacuum can only render free vibrations of sound, and such vibrations are said to be ideal. Practically, it is impossible to apprehend the phenomenon of free vibrations. However, the above picture only shows that how the system will behave vis-à-vis un-damped free vibrations.

6.2 Damped Free Vibrations When a body vibrates with its natural frequency and the amplitude decays with time and finally the body comes to rest at its mean position. Such vibration is called damped vibration. So far as the damping the system is concerned, the system is underdamped i.e. the damping "C" is less than "Cc". Now, the question arises here that why underdamped systems are desirable. Underdamped systems are the most practical and most commonly used. An underdamped system ensure the system always reaches the desired end state with some overshoot. Even though there is overshoot the damping eventually brings the system to the desired state. The response of the system for damped free vibration is shown below in the figure 5

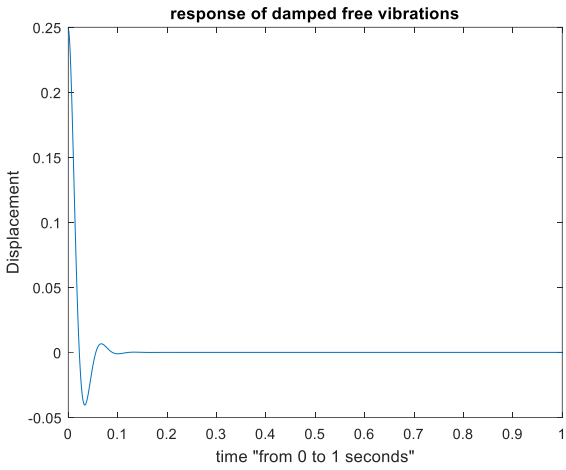

Fig. 5 Response of Damped Free Vibrations

As it is evident from the above graph that system comes to normal state after a very short period of time i.e. 0.1 seconds. This is because the higher value of stiffness and corresponding high value of critical damping. As far as the damping is concerned, it is one half of the critical damping.

6.3 Damped System under Harmonically Excited Vibrations in this condition, the system under harmonically excited vibrations will be discussed. As far as the solution of such systems are concerned, they are of the form x(t) = xh (t) + xp (t) i.e. the solution consists of homogenous part and the particular part. The homogenous solution xh (t) is due to the natural frequency of the system whereas, xp (t) occurs due to the excitation frequency or forced frequency. Due to damping the oscillations due to the natural frequency will die out as discussed in previous section (Figure 6), and the system will come to it steady state i.e. the oscillations due to the excitation frequency or forced frequency. However, it must be taken care of that the ratio of forced frequency to natural frequency i.e. r = w/w n is never equal to 1. Because, in such a case the system will experience resonance and could fail or damage catastrophically. So far as the response of such a system is concerned, it as shown in the figure 6 below.

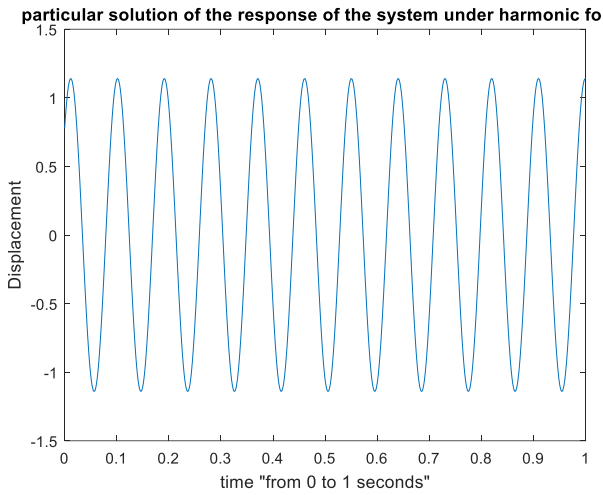

Fig. 6 Particular Solution of the Response of the System Under harmonic Force

The response only captures the particular solution because due to damping the oscillations due to natural frequency will die out. The above figure manifests the steady state response i.e. after the natural is vanished, this is how the system behaves under forced frequency which, of course, is less the natural frequency.

6.4 Vibrations Under General Forcing Conditions (Constant Force)

In this condition, the response of the system under the step input or constant force is discussed. As we can see in the figure 7 that system response dies out after 0.1 seconds. This is due to the introduction of damper in the system. As we know that the degree of damping indicates the nature of transient system. There will be no damping at all if the ratio is equal to “Zero”, and the system will continue to oscillate indefinitely. The ratio when increased from 0 to 1 (0 to 100%), will reduce the oscillations, with exactly no oscillations and best response at damping ratio equal to 1. On further increasing the damping ratio, the degree of damping has been overdone, this will cause sluggish performance/longer transients in the system.

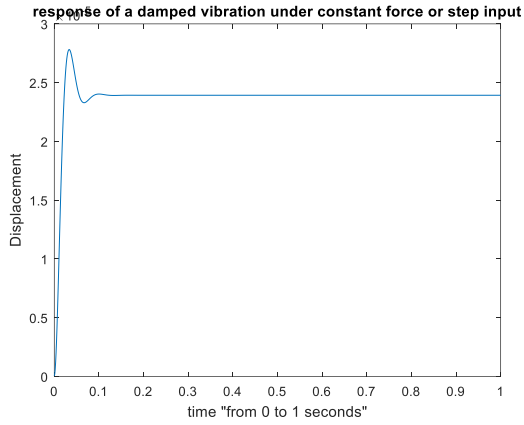

Fig. 7 Response of a Damped Vibrations under Constant Force or Step Input

7 CONCLUSION

The response of the system under different conditions was studied. Only the free vibrations were discussed without damping and, all the other cases were studied and discussed with damper. It is because the dampers are inevitable in the vibrating systems. Otherwise, the oscillation with natural frequency will damage the system. Moreover, the oscillations die out very rapidly in our case because the stiffness is very high and corresponding value of the critical damping is also very high. So, it was inevitable to use with damping ratio of at least half. Damping ratio describes how rapidly the Amplitude of a Vibrating system decays with respect to time. If damping ratio is less than 1 then the system is called Under Damped. Vibratory system is critically damped if the ratio of the damping equates 1 and system is called over damped if the ratio of damping is greater than 1. Under Damped system, when excited by a force, oscillates and comes to rest gradually with decaying amplitude. Over Damped system doesn't vibrate at all. In case of Critical Damping the system gets displaced from its equilibrium position and in return the system does not overshoot the equilibrium position immediately and comes to rest in a very short interval of time. Mostly the systems are underdamped because the ratio of damping for such system will always be less than 1.

8 RECOMMENDATIONS

In order for system to be modeled more accurately, it is recommended that system be modeled in two degree of freedom system. Two degrees of freedom system will further refine the response of the

system in different conditions. Moreover, it is also recommended that vibration produced the helicopter movement, its rotor RPMs etc. must also be considered for better understanding of the system. In this system, all the responses were studied for only material; so, in future it is recommended that at least two materials of the sling cable be tested in different condition with at least two sets of the parameters shown in the Table 1. If we talk about the implementation of the mathematical model of the system discussed in this paper, it is good for understanding the fundamentals of the oscillations in the helicopter sling cable. However, there is a room for further refinement in terms of mathematical models for understanding and studying the response of the system.

NOMENCLATURE

M	Mass attached to the string
D	Cable Diameter
L	Cable Length
A	Cross-section Area
E	Young's Modulus
W_d	Damping Frequency
F_o	Force
m	Cable mass
$m_{eq.}$	Equivalent Mass
k	Cable Stiffness
w_n	Natural Frequency
w	Excitation Frequency
r	Frequency Ratio
ζ	Damping Ratio
δ_{st}	Static Deflection

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TO EXPERIMENTALLY ANALYSE THE IMPACT OF BIOSYNTHETIC FUEL ON PERFORMANCE AND EMISSION CHARACTERISTICS OF AN IC ENGINE

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Abstract
Conventional fuels such like gasoline and diesel are used in most car sectors but constant increases in demand and environmental degradation due to recent rise in population, urbanization, scientific and technological advancements. Through use of renewable energy, such as biofuels and biosynthetic fuel, seems to be the only solution for humanity's growth and achievement. For this environmental degradation, Climate act of UK was passed in 2008. Later Paris Agreement 2015 on Climate Goals came into existence. USA clean air agreement also played its part. With the passage of time demand for energy is constantly increasing but the resources are getting limited so a new fuel known as Biofuel is introduced to the world. They refer to fuels that derive their energy from biomass i.e. organic materials. This is considered to be one of the most efficient alternate energy source in modern times. Biofuels can be divided into three generations. The first generation, second generation and third generation. Third generation biofuels are the advanced ones. The biggest concern about fuel in the future will be its depletion and the negative environmental impact of increasing greenhouse gas emissions. We must identify alternate routes that are both renewable and capable of replacing petroleum-based products. These alternative renewable fuels will reduce the demand for fossil fuels, which are diminishing at an alarming rate, while also improving engine emission and performance aspects. The primary goal of this research project is to produce new biosynthetic renewable fuels and evaluate their effects on engine performance and emissions.

Keywords: fossil fuels, biofuels; renewable fuels; alcoholic fuels; UK act; Paris agreement act; emissions; IC engine refining; biosynthetic.

1. INTRODUCTION

The importance of fossil fuels, which include gasoline or diesel, natural gas, and coal, which meet 90% of our energy requirement, cannot be emphasised. However, their all-purpose utility comes with a price. The gases released during the combustion of fossil fuels, particularly CO2, which of the following are the biggest factors as a due to climate change [1]. Furthermore, with the passage of time, fossil fuels are diminishing at an alarming rate [2] of time .These reasons are causing countries to exert pressure in the form of new laws and regulations. Legislation aimed at ensuring the environment's and people's safety. England was the very first country to pass the Climate Act of 2008, which aims to cut emissions by approximately 80% by 2050 compared with 1990 levels [3]. Additionally, the US Environmental Agency has enacted the Clean Air Act, which attempts to limit air pollution [4]. The only option for humanity's survival, success, and development is to adopt alternative renewable energy sources to address this worldwide crisis. [5]. This research project's primary purpose is to examine the stability, ignition, and emission characteristics of novel biosynthetic fuels, as well as their effects on regulated, unregulated, and GHG emissions, to enhance engine productivity and deliver a complex decrease in exhaust emissions. Biofuels are viewed as appealing alternative fuels with the potential to decrease GHG and pollution emissions. As a result, biofuels constitute a viable renewable and sustainable energy source. Biomass had already long been emerged as a

potential substitute for fossil fuels, and attempts have been undertaken all over the world to transform renewable organic matter into biofuels. The technologies developed thus far to convert agricultural wastes for energy purposes have resulted in solid, liquid, and gaseous fuels. resources for energy purposes [6]. A summary of the research on the use of various biomass-based solid fuels in diesel engines, like coal, charcoal, carbon, and carbon black-based sludge's, was also published. [7]. The literatures contain information on the application of both gaseous and liquid biofuels. [8] , [9].

Generation	Feedstocks	Biofuels produced
1st	Sugar crops, starch crops	Bioethanol, SVO[a], biodiesel
	Vegetable oils, animal fats	Biosyngas
2nd	Nonfood crops, wheat straw solid	Bioalcohols, DMF[a], BTL[a] diesel
	waste, energy crops	Biohydrogen, bio-oil
3rd	Algae, see weeds	Bioalcohols, biodiesel
		Biohydrogen
4th	Vegetable oil, biodiesel	Bio-gasoline

Table 15: Classification of biofuels obtained from feedstock [9]

Through the use of computational tools and system metabolic engineering, some microorganisms have recently been used as a biosynthetic platform to effectively create both non-natural and natural biofuels [11], [12].

2. LITERATURE REVIEW

2.1 Fossil fuel limitations and climate change: Most of the energy is coming from fossil fuels. But two more problems comes with it which are limited resources of fossil fuels and climate effect of fossil fuels [13]. The desire for more efficient modes of travel led to the railroad, but then to steam locomotives. In the eighteenth century, a need for power in coalfields helped lead to the invention of the steam engine. [14] According to the World Energy Outlook (WEO) 2007, energy generated from fossil fuels [15]. The combustion of fuel emits so-called greenhouse gases, which are harmful to the planet's ecology and continue to be a major contributor to global warming and thus climate change. [16]

2.2 Climate act UK 2018: At the end of November 2008, the UK Parliament approved the world's first Climate Change Act (henceforth 'the Act,' constructing a legally enforceable greenhouse gas reduction aim of an 80% reduction from 1990 levels by 2050. The Act has now become central to the UK's image as a ruler in climate change. During its movement through Parliament, the rules was largely viewed as a historic step.[17]

2.3 Paris agreement 2015 on climate goals: Over the next century, the Mediterranean basin is likely to generate ecosystems that have no derivative in the world, even if temperature goes up by 1.5 ° Celsius above pre - industrial times. A temperature increase of 2 °C, on either hand, is unsupportable. Different climate-change circumstances Holocene observations of greenery and land act as a base upon which to try comparing climate models and grasses suppositions.[18]

2.4 USA clean air act: A governmental tactic in which a benchmark is indicated that cannot be met with available systems, or at least not at an affordable fee, is known as technology trying to force. Using the 1970 U.S. Clean Air Act for attempting to control automobiles emissions as a benchmark example, we demonstrate the importance of governmental project delivery if policies and guidelines are to nurture technological change. [19]

2.5 Advantages of biofuel: Biomass is the production of biofuel and biomaterials, and enhancing its use will indeed assist in meeting a variety of social concerns. The advantages of biomass conversion into fuel sources were among the first motivation factors for physiological and biological research.[20]. Biofuels have the potential to be a reduced energy source, but this depends on how they are produced [21]. The use of corn for ethanol increases the price of beef, chicken, pork, eggs, breads, cereals, and milk in the United States by 10% to 30% [22]. New market opportunities and aids in agricultural expansion Products, resulting in increased income for farmers. Another advantage is that when sugar and starch-bearing plants are fermented, co-products such as necessary supplements are produced in large quantities. [23] The effects of a variety of energy-related emissions, such as suspended fine particles and precursors of city's air pollution and ecosystem degradation are exacerbated by ozone and acid deposition. [24] Furthermore, no gum formation is associated with. There is no need for ethanol, anti-oxidants, or detergent additives. [25].

2.6 Biofuel generations:

2.6.1 First generation biofuel: These biofuels are obtained from edible crops like sugarcane and corn crop. The first-generation biofuels are in market in a very large quantity and it is the most matured generation of biofuels because a great work has been done on this.

2.6.2 Second generation biofuels: These are basically the upgraded version of first generation biofuels. These are the advanced biofuels and the

positive thing which is different from the first-generation biofuels is that they are derived from biomass.

2.6.3 Third generation biofuel: Algal biomass is basically a feasible and renewable feedstock for biofuel production. These algae are the photosynthetic organisms which have the natural ability to accumulate carbohydrates which is in most of the cases in the form of starch. These products are further used as a substrate for the sugar-based biofuels like bioethanol and biobutanol. Third generation biofuels are derived from algal biomass.

2.7 Blending biofuel: Instead of completely replacing the traditional fuels with these biofuels, a median can be adopted, known as blended fuel. The blending biofuels such as ethanol with traditional fuels means mixing them in specific ratios.

2.8 Biomethanol: Methanol is regarded among the most engine-friendly energy sources. Adding a specific amount of methanol to fuel enhance the effectiveness of ICEs in all conditions. Some countries are already using methanol-gasoline blends commercially.

2.9 Bioethanol: Properties of bioethanol: The higher octane number of bioethanol prevents engine knocking and early ignition, resulting in a high antiknock value.

2.10 Biobutanol: Bio-butanol is yet another clean alternative fuel with a number of benefits for usage in ICEs. Butanols, such as n-butanol, iso-butanol, and tert-butanol, can be utilized as gasoline additives since they have straight-chain or branched architectures. Some of its advantages are: Butanol has a volumetric energy density that is roughly 50% higher than ethanol. In reality, this means that reduced fuel consumption and higher mileage are possible.[44]

2.11 Economic approach towards advanced biofuels: Biomass energy already has a key role in the global energy market, and its increased use is a vital component of future low-carbon scenarios, where it may help reduce greenhouse gas (GHG) pollution from the transportation sector in particular. However, their manufacture alone has reached a small scale so far. However, these advanced biofuels are significantly more expensive than the fossil fuels they can replace, as well as more traditional biofuels like ethanol from sugar or corn or biodiesel. As a result, it's critical to explore what might be done to lower the manufacturing costs of a variety of advanced biofuels, as well as the conditions under which they might become feasible [46] , [47].

3. METHODOLOGY

3.1 Internal combustion engine alternative fuels: Acetylene (C_nH_{2n2}), when formed from calcium carbide, the first member of the alkynes is a colourless and odourless gas with a garlic-like odour. Although acetylene gas is seldom found in great quantities in nature, it is frequently created by mixing calcium carbide with water. Calcium carbide (CaC2) is created by heating a mixture of quicklime and coke to a high temperature. 2000–2100 °C in electric arc furnaces. Calcium carbonate ($CaCO_3$) is heated to roughly 900 °C to make quicklime (CaO). Production of calcium carbide is given by chemical equation as:

$$CaCO_3 + \text{heat} \rightarrow CaO + CO2 \quad (1)$$

$$CaO + 3C \rightarrow CaC_2 + CO \quad (2)$$

Load (%)	Gasoline (g/h)	Acetylene (g/h)	Acetylene (%)	Peak Pressure (bar)	Spark Advance (CA BTDC)
25	1877	0	0	16.6	21
	1320	500	27.5	16.5	13
	840	1000	54.3	15.6	2
50	2805	0	0	25.4	18
	2145	500	18.9	26.5	11
	1800	1000	35.7	20.9	1
75	3730	0	0	31.5	15
	3250	500	13.3	24.6	3
	2750	1000	26.7	23.8	0
100	4265	0	0	40.6	11
	3890	500	11.6	30.9	1
	3390	1000	22.8	29.0	-2*

Table 2: Mass flows of fuels, peak pressure and spark advance [53]

At all loads, hydrocarbon emissions were greatly decreased. Working with gasoline resulted in lower nitrogen oxide emissions at full loads.

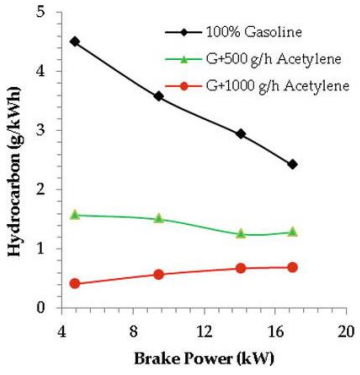

Figure 1: Variety of HC with brake power [53]

With SI engines, acetylene enhances the poor combustion limit in partial loads. With gasoline-

acetylene mixes, the engine can run under leaner conditions.

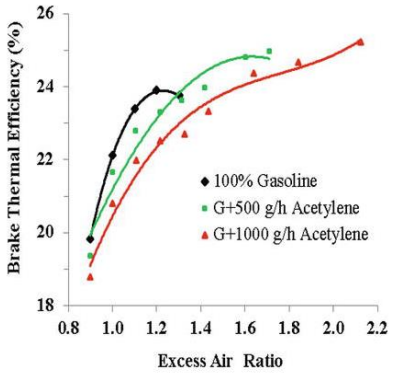

Figure 2: The variation of Brake thermal efficiency with excess air ratio [53]

So we can conclude that Acetylene offers a number of desirable characteristics, including a high energy density, a high flame temperature, a high flame speed, and a low emission rate. It improves brake thermal efficiency while lowering fuel consumption and overall emission levels. However, some research should be done to improve acetylene's knock resistance. A well to tank analysis should be undertaken to assess whether acetylene is cost-effective. [53]. Experiments observations of various fuels like petrol, acetylene gas, acetylene +methanol are represented in following tables.

Speed (rpm)	Dead weight(kg)	Spring balance Reading (grams)	Torque (N-m)	Break Power (W)
730	2	250	1.422	108.74
700	4	600	2.76	202.5
670	6	950	4.103	288
610	8	1450	5.322	340.1
570	10	1950	6.541	390.6

Table 3: Only acetylene gas [54]

Speed(rpm)	Dead weight(kg)	Spring balance Reading(grams)	Torque (N-m)	Break power (W)
420	2	350	1.341	58.987
410	4	650	2.722	116.911
390	6	1050	4.790	195.693
370	8	1450	5.332	206.286
360	10	1850	6.622	249.739

Table 4: Only petrol [54]

The performance tests are done by the following equations.

$$T = (W\text{-}S) * (\frac{D+d}{2}) \quad (3)$$

$$BP = (22/7)*(WS)*(D+d) * N/60 \quad (4)$$

$$BHP = BP/746 \quad (5)$$

Equation (3) is for torque. Equation (4) is Brake Power of engine. Equation (5) shows the Brake Horse Power of engine.

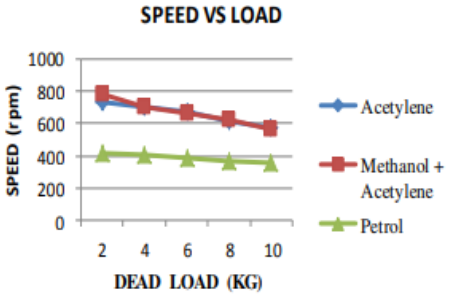

Figure 3: Speed vs dead load graph [54]

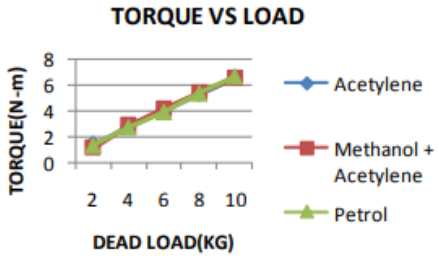

Figure 4: Torque vs dead load [54]

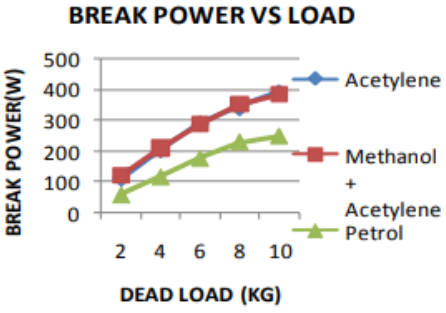

Figure 5: Break power vs dead load [54]

So we can conclude here that Acetylene, like petrol and gasoline, is easily produced and relatively inexpensive. Numerous safety precautions must be taken when storing petrol due to its low flash point and fire point, whereas acetylene can be produced in the amount required by adding water to the petrol. The graphical solution obtained are as following which include comparison of Physical-Chemical Characteristics of bio-butanol Important for Biofuels, with Bioethanol and Other Types of Fuels.

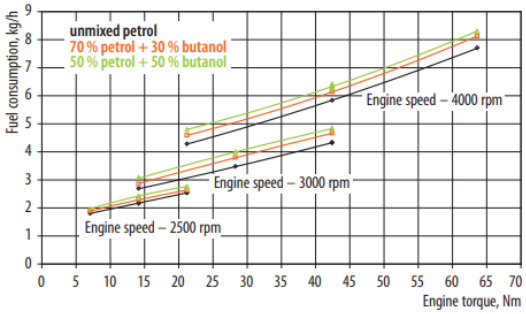

Figure 6: The relationship between fuel consumption and the engine torque [55]

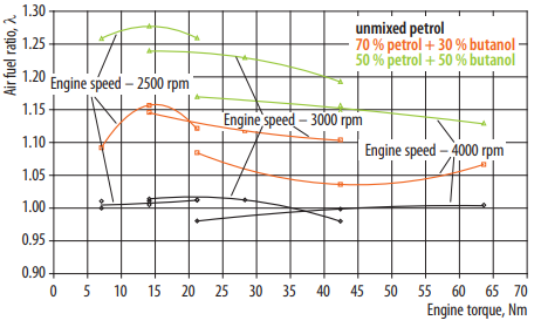

Figure 7: The relationship between air fuel ratio and the engine torque for the engine using various fuel mixtures [55]

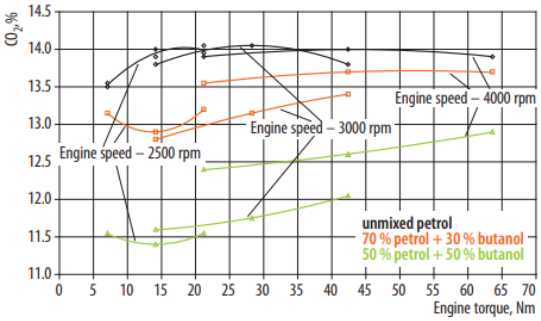

Figure 8: The relationship CO_2 and the engine torque for the engine using various fuel mixtures [55]

Engine parameters are very crucial for experimental analysis. The equations for these parameters is discussed below. In an IC engine, work is obtained as a result of combustion of gases in the cylinder's chamber.

$$W = \int F\, dx \tag{6}$$

$$W = \int P \times A_p \times dx \tag{6.1}$$

$$W = \int P \times dV \tag{6.2}$$

Equations (6), (6.1), (6.3) shows the work done in one cycle.

In specific terms (per unit mass), work can be expressed as in Equation (7), (7.1).

$$w = \int P \times dv \tag{7}$$

$$w = \int mep \times \Delta v \tag{7.1}$$

Mean effective pressure can be expressed as:

$$mep = \frac{w}{\Delta v} \tag{8}$$

$$bmep = \frac{w_b}{\Delta v} \tag{9}$$

$$imep = = \frac{w_i}{\Delta v} \tag{10}$$

$$(imep)_{gross} = \frac{(imep)_{gross}}{\Delta v} \tag{11}$$

$$(imep)_{net} = \frac{(w_i)_{net}}{\Delta v} \tag{12}$$

$$pmep = \frac{w_{pump}}{\Delta v} \tag{13}$$

$$fmep = \frac{w_f}{\Delta v} \tag{14}$$

Toque is another parameter that shows the ability that how much an engine work.

Equation (15) is for two stroke engine.

$$\tau = (bmep) \times \frac{V_d}{2\pi} \tag{15}$$

Equation (16) is for four stroke engine.

$$\tau = (bmep) \times \frac{V_d}{4\pi} \tag{16}$$

If the engine speed is between 4000-6000 revolution per minute, the maximum torque that is produced is about 200-300 N-m. Maximum torque speed term is used for maximum torque point. If we compare torque of CI engine with SI engine, CI engine produces more torque. Power of engine is expressed as:

$$\dot{W} = \frac{W \times N}{n} \tag{17}$$

For two stroke engine power is expresses as:

$$\dot{W} = \frac{(mep) \times A_p \times \bar{U}_p}{2} \tag{17.1}$$

For two stroke engine power is expresses as:

$$\dot{W} = \frac{(mep)\times A_p \times \bar{U}_p}{4} \quad (17.2)$$

Air fuel or fuel air ratio tells us about how much ratio of fuel and air is present.

$$AF = \frac{m_a}{m_f} \quad (18)$$

$$FA = \frac{m_f}{m_a} \quad (19)$$

Actual Fuel Ratio(φ) is expressed as:

$$\varphi = \frac{(FA)_{actual}}{(FA)_{Stiochiometric}} \quad (20)$$

$$\varphi = \frac{(AF)_{actual}}{(AF)_{Stiochiometric}} \quad (20.1)$$

Specific fuel consumption is the fuel consumption per unit of thrust. It is expressed as:

$$sfc = \frac{\dot{m}_f}{\dot{W}} \quad (21)$$

The fuel efficiency of any prime mover that consumes fuel and generates rotational, or shaft, power is measured by brake-specific fuel consumption. It is expressed as:

$$bsfc = \frac{\dot{m}_f}{\dot{W}_b} \quad (22)$$

Brake specific fuel consumption has an inverse relation with speed of engine. By increasing the engine speed, brake specific fuel consumption will decrease.

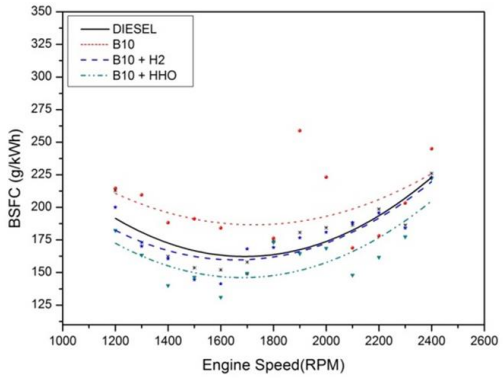

Figure 9: BSFC as a function of Engine speed (RPM) [56]

There is indicated specific fuel consumption which indicates power of engine.

$$isfc = \frac{\dot{m}_f}{\dot{W}_i} \quad (23)$$

Mechanical efficiency of engine, η_m is expressed by:

$$\eta_m = \frac{\dot{W}_b}{\dot{W}_i} \quad (24)$$

$$\eta_m = {(isfc)}\Big/{(bsfc)} \quad (25)$$

Thermal efficiency of engine is expressed as:

$$\eta_t = \frac{W}{Q_{in}} = \frac{\eta_f}{\eta_c} \quad (26)$$

For mechanical efficiency:

$$\eta_m = \frac{(\eta_t)_b}{(\eta_t)_i} \quad (27)$$

Also fuel conversion efficiency:

$$\eta_m = \frac{1}{(sfc)\times Q_{HV}} \quad (28)$$

[56]

4. CONCLUSION

After studying all the above research papers our main focus was on working the acetylene and bio-butanol as a biosynthetic acetylene fuel on IC engine. That Acetylene offers a number of desirable characteristics, including a high energy density, a high flame temperature, a high flame speed, and a low emission rate. It improves brake thermal efficiency while lowering fuel consumption and overall emission levels. It is also easily produced and relatively inexpensive. Acetylene and methanol with acetylene have a stronger breaking force than petrol. Break Horsepower is better than Petrol when utilising acetylene and methanol plus acetylene. The engine's power is higher when methanol and acetylene are used together than when acetylene is used alone. The experimental results of the novel biosynthetic fuel butanol shows that exiting engine can be run using small concentration of n-butanol blended with gasoline without any hardware changes because the rise in peak pressure and temperature is very small. Better performance was observed while using iso-butanol because it improves the octane number that leads to better combustion. When the concentration of N-pentanol is increased, the oxygen content increases, resulting in tidy and clean burning. As a result, CO_2 emissions are on the rise, whereas CO and HC emissions are on the decline. Throughout the 200 hp operation, the power remained steady. Engine torque

levels were found to be higher with mixes than with pure diesel operation.

5. RECOMMENDATIONS

Some of the errors that were present in these experiments were many much research work is still left to increase the efficiency of fuel. The experiment should be done on multiple engines to check the result. Mainly torque and power parameters were discussed in these researches. Mean effective pressure, thermal efficiency and specific fuel consumption can also be calculated. In future we will also discuss power consumption of engine using different isomers of butanol other than n-butanol and iso-butanol.

NOMENCLATURE

Capital

T	torque transmitted by the engine
W	dead load
S	spring balance reading
D	diameter of the wheel
N	speed of the engine shaft
P	combustion chamber's pressure
N	speed of the Engine Shaft
dV	differential volume
W	work done in one cycle
$\dot{W}$	power of engine

Lowercase letters

x	piston's distance as it moves
w	specific work done in one cycle
d	diameter of the rope
n	number of revolution per cycle

Greek capital symbols

Δ	change
φ	actual fuel ratio

Greek lower case

η	efficiency
τ	torque

Subscripts

A_p	area against the piston face
m_a	air's mass
m_f	fuel's mass
$\dot{m}_f$	fuel flow rate's ratio
$\bar{U}_p$	average speed of piston
η_m	mechanical efficiency
η_t	thermal efficiency
Q_{HV}	heating value of fuel

Abbreviations

BP	break power
BHP	brake horse power
TDC	top dead centre
BDC	bottom dead centre
mep	mean effective pressure
$bmep$	brake mean effective pressure
$imep$	indicated mean effective pressure
$(imep)_{gross}$	gross indicated mean pressure
$(imep)_{net}$	net indicated mean effective pressure
$pmep$	pump mean effective pressure
$isfc$	friction mean effective pressure
$fmep$	indicated specific fuel consumption
AF	air fuel ratio
FA	fuel air ratio

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DESIGN AND FABRICATION OF HEAVY LIFT DRONE

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Abstract

Unmanned Aerial Vehicles (UAVs) are transmitted into multirotor UAVs having the capability of lifting the payload and are also being used for the surveillance of unapproachable areas. The payload and programming capabilities of quadrotor UAVs are frequently limited. Unmanned aerial vehicles have recently piqued the curiosity of the research community (UAVs). Different multirotor UAV configurations were investigated in this study to determine the ideal configuration for a compact but heavy-lift multirotor which can sustain a payload of 50 kgs. It has been discovered that coaxial/overlapping designs can boost payload while maintaining a modest dimension. With the right selection of rotor plane angles, thrust might be boosted by up to 90% for overlapping systems. The rotor thrust in a coaxial configuration was determined to be 76 percent that of an independent rotor. The ability to develop a highly maneuverable and reliable vertical take-off and landing (VTOL)-UAV is a significant contribution to the field of aerial robotics because the possibilities are endless in practical applications, an operator controls the UAV's position in space using a remote server using sensory cues from an image acquired, while the angle is automatically stabilized using an onboard controller. The attitude regulator is critical when the pilot executes the desired movements because it allows the vehicle to maintain the appropriate orientation and so avoids the vehicle turning over and crashing.

Keywords: Aluminum; Analysis, Carbon fiber, design, Frames, Multirotor, Payload.

1. INTRODUCTION

Diverse wireless drones are commonly used for various purposes. Blades on multirotor are typically fixed pitch. Due to the unavailability of flight controls in ancient times, work on proving the concept could not be completed due to the instability of the multirotor. Multirotor development advanced with the introduction of MEMS sensors, motors, electronic speed controllers (ESCs), and Li-Po batteries. These are radio-controlled drones that can carry up to two kilograms of cargo during flight. A multirotor is now employed for a variety of purposes. Surveillance, rescue operations, and other tasks are among the multirotor applications. Due to developments in inflight controls and ESC, multirotor drones are more stable. The current research platform is Multirotor. When it comes to multirotor configurations, the quadcopter configuration UAV has a strong frame structure that is also simple in dynamics. When used in the media, hex copters and octocopters lift huge payloads for aerial photography or broadcasting. The above UAV designs were examined, and it was discovered that the hex copter configuration is superior in terms of rescue and surveillance activities.

Drones and quadcopters have a fascinating history. With the aid of superior computer engineering and technology, they have progressed in incredible ways. Armed forces were the first to employ drones. These vehicles were first developed for military use by the Austrian army. In 1849, the Austrians attacked Venice with explosive-filled air balloons. A few of these balloons operated, while others were blown back into Austrian land by the wind, indicating that they had potential. After WW1, unmanned aircraft began to appear. One of these airplanes was Larynx. It was a

small monoplane that could fly 2 on autopilot after being fired from a battleship. The US and British armies quickly created plenty of other automatic planes. Reginald Denny, a well-known Hollywood actor, designed the first mass-produced aircraft. He founded Reginald Denny Company to pursue his passion for remote-controlled drones. This firm created the radio plane, which he later refined for the US army during WWII. The US military experimented with drones and built a variety of airborne torpedoes as a result. During the Cold War, the US army utilized these planes as target drones. These drones could also collect radioactive information. The Quadcopters were one of the first vertical take-off and landing (VTOL) aircraft. Previously, tail rotors were employed to offset the torque created by a single main rotor. This was a waste of money and time. Engineers developed quadcopters to tackle the challenges that helicopter pilots had when making vertical flights. The Omnichen 2 was the very first quadcopter. Etienne Omnichen invented it in 1920. This airplane performed over 1,000 successful trips and flew a distance of 360 meters. In 1956, the Convert a wings Model A quadcopter was released. George E. Bothezat designed this quadcopter. Convert a wings' Model A quadcopter was the first to use propulsion to control a plane's yaw, spin, and roll. This same Curtis Wright V27 had been designed by Curtis Wright Company in 1958. In terms of technology, Multicopters and drones had already come a long way. In the last ten years, companies such as Heli-Max, Blade, Walker, Parrot, as well as DJI it has devised micro and nano drones with cutting-edge computer media for aerial photos and flight management.

Multirotor are categorized and called based on the number of motors or blades they have. A quadcopter refers to a drone with four motors. Because there are so many different combinations, the performance of the motors varies as shown below:

Figure 16: Bi-copter Configuration[1]

Figure 17: Tri-copter Configuration[2]

Figure 18: Quadcopter Configuration[3]

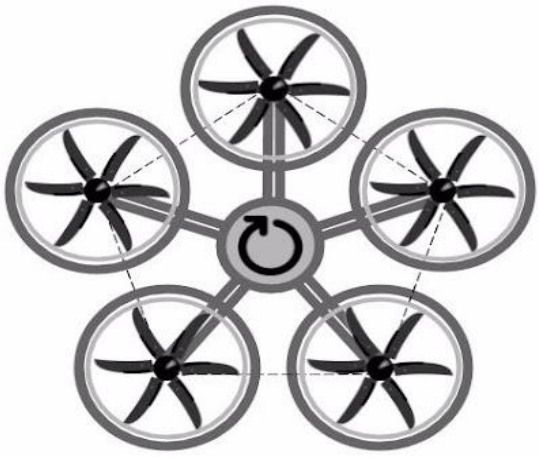

Figure 19: Penta copter Configuration[4]

Figure 20: Hex copter Configuration[5]

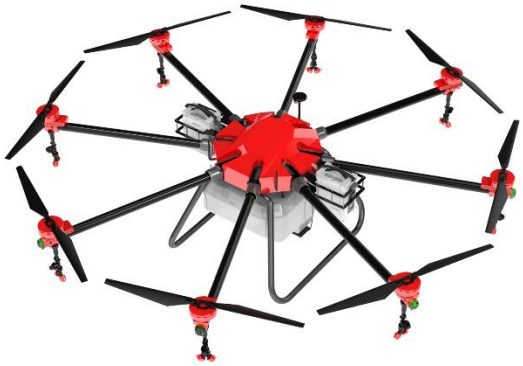

Figure 21: Octocopter Configuration[6]

2. Literature Review

Quadcopters or simple quadrotors are rotorcraft having four lift-producing propellers. Two propellers rotate in a clockwise manner and the other two rotate in an anticlockwise direction. Propeller speed is an important factor in controlling rotorcraft, and increasing the propellers' relative speed is an effective way to do it. The idea of quadrotors is not new, however current multirotor is often unmanned developments in the field of compact inertia measuring units (IMUs). In addition, brushless high-speed motors are readily available, and their power-to-weight ratio is quite high. The quadrotor's design and construction have been greatly simplified and made more maintainable because of advances in Li-polymer battery technology. In the proposed work, quadcopter dynamics are modeled using a mathematical model. Hovering control is made easier by applying momentum theory in which the air friction and gyroscopes are ignored, which results in a simpler model that can be used to create the quadcopter's control system. The suggested model is non-linear because the rotary dynamics are a function of the square of the motor inputs. Different equations are used to keep the system's role, pitch, and yaw capabilities in balance with the inputs it receives from the environment. The yaw angle produced by the mechanism and the motor speed is also linked[7].

As a result of this study, a quadrotor aircraft (VTOL) has been developed that is capable of vertical takeoff and landing. This study takes a look at control architecture, which includes a vision-based control mechanism. Quadrotors have caught the interest of both the military and control community owing to the complexity of their dynamics and the advantages they offer over conventional air vehicles. The gyroscope and the strategies used to control it are explored in the proposed model. A stabilization control algorithm for a quadrotor has been presented in this paper, which summarizes previous research on the subject. The controller's primary objective is to move the multi-rotor in the x, and y coordinate axes by controlling pitch and roll angles, while also controlling elevation using thrust actuation. Quadcopter yaw angle can be controlled independently by the controller. Finally, it is demonstrated and practiced that a quadrotor having an onboard camera can follow the marking on the ground and hover over that pattern that the desired altitude using vision-based control. [8]

In this article, a decomposition strategy is utilized to construct a real-time filter that estimates the height of a tiny four-rotor helicopter. Measurements from an onboard computer vision system and three-axis gyroscopes are used to create an instantaneous real-time filter. Simulink was employed to design the code and space to apply the three-component decomposition approach to the control computer processor. Low-frequency vision measurements and gyro measurements are combined to get the estimated angle. Gyro drifting and low data rates and delay in vision measurements are eliminated from the ideal estimate, which is more accurate [9].

A concept of the dynamics of the X4-flyer, a four-rotor (VTOL) vehicle, is presented. For quasi-stationary flying circumstances, the model combines airframe and motor characteristics, gyroscopic effects, and aerodynamic effects as well related to the rotors. For configuration stability of quasi-stationary flying situations, a novel control approach is provided. Splitting the complete body (airframe) dynamic from the actuator dynamics and generating independent control is the strategy utilized. Using Lyapunov functions for synchronous machines and then constraining the disturbance error due to interaction, considerable practical stabilization of the entire system may be achieved [4].

The main focus of this study is an unmanned aerial vehicle (UAV) having non-planar rotor pairs, which uses a test rig and a wind tunnel to investigate its aerodynamics. Face-to-face (F-F) and back-to-back (B-B) non-planar rotary pairs are studied at variable disc plane inclination angles varying from 0° to 50° and transverse rotor spacing ranging from 1.0 to 1.8 times rotor diameter. Non-rotor pairs are also tested inside a wind duct at varying wind speeds, varying from 0 to 4m/s, to examine the effects of air on them. The results of the experiments show that the overall aerodynamic performance of two adjacent non-planar rotors is significantly impacted by significant aerodynamic interference. Using the proper adjustable angle and rotor spacing, on the other hand, can improve aerodynamic performance. Aerodynamic performance suffers when rotors are spaced closer together, but wider rotor spacing and larger tilt angles often raise the total thrust of rotor pairs. The design specifications of non-planar rotating pairs are severely impacted by wind, resulting in a significant reduction in thrust and efficiency. In comparison to the F-F rotor pair, the B-B rotor pair's aerodynamic performance decreased significantly with wind speed because it is more susceptible to wind disturbance [5].

Unmanned aircraft (UAVs) of the quad-robot type (QRT) has been created for speedy detection and monitoring of situations in a disaster setting, such as interior fire spots. An integrated controller, an Inertial Guidance System (INS) with three rate accelerometers and gyroscopes, CCD (Charge Coupled Devices) cameras with cordless transmission broadcaster for observing, and an ultrasonic distance sensor for controlling height are all included in the UAV. This paper focuses on accurate modeling and stable flight management of QRT UAVs. In both the referencing and body frame coordinates, a comprehensive dynamic model of a QRT UAV is generated. For robust hovering control, a disturbing observation (DOB) based controller based on the resulting dynamic models is also provided. DOB's control input allows for the employment of simple equations that fulfill precisely computed dynamics. Under the use of DOB and a vision-based localization approach, the created hovering robot demonstrates reliable flying performance. Even if a model is inaccurate, the DOB approach may build a controller by considering the portion of the faulty model. Eight IR (infrared) infrared ionic distance sensors help the UAV avoid obstacles. This type of micro-UAV may be employed in a variety of disaster surveillance domains without endangering humans in a hazardous environment. The suggested control algorithm's performance is demonstrated by the experimental findings [6].

Platforms, control stations, payloads, and sensors constitute Unmanned Aerial Vehicle (UAV) systems. Advanced flight controls are needed to offer the amount of autonomy required to achieve mission objectives while also maintaining round-the-clock reliability. There will be a study of existing systems, with a concentration on airframes. Specific mission goals and aircraft functional properties may provide useful information for control system designers to customize their systems to the specific applications required. Unmanned Air Vehicles come in a variety of configurations, from traditional fixed wings to novel shrouded coaxial rotary and tiltrotor designs. For waypoint maneuvering, navigation and guiding, and autonomous takeoff and landing, each configuration have its own set of control needs. Innovative high-risk designs necessitate ever-more complicated flight control mechanisms that are both cost-effective and reliable. The most difficult problems for automatic control designers working in the UAV domain will be autonomous landing and transitional maneuvers from vertically to horizontal flight [7].

The formation control law is used to govern a bunch of four quadrotors in three dimensions in this research. Three-dimensional formation control methods have caught the interest of both the remote

sensing community and its applications. The quad-rotor has also gained a lot of interest since it can hover, take off and land vertically. We apply a three-dimensional formation control law based on inter-agent distances. The Euclidean coordinate system is directly under the jurisdiction of the Euclidean coordinate system. We apply the control rule from a time-based derivative of Euclidean distance matrices with the group's distance matrix as a result of the group's revelation. Assuming that initial and targeted formations are not collinear and that the informational graph is completed, the group's desired formation is asymptotically stable, while all square inter-agent errors exponentially lowering to zero. The formation controlling of 4 quad-rotors in three dimensions is stable, according to simulation results, and it supports the control rule [8].

We analyze three control strategies in this paper: Nested Saturations, Back stepping, and Sliding Modes. When utilizing visual feedback, the main objective is to determine the optimal control technique for maintaining the location of a quadrotor. We present a technique for determining both translational speed and the UAV's 3D location in a local frame. In real-time experiments, the recommended controllers were installed and tested. The generated findings show that such techniques may be used to enhance the performance of a quadrotor. To maintain the UAV's attitude steady, control algorithms were put aboard. All control methods get the vehicle's Euler angles very close to the target values. When compared to other current controllers, the nested saturation control technique is the ideal solution for our system, since it improves the vehicle's behavior while lowering energy usage [9].

This paper identified a navigation system for unmanned aerial vehicles (UAVs) in certain situations. A maneuverable quad-rotor UAV's route planning seems to be using a limit-cycle navigation idea based on the limit-cycle properties of a second-order nonlinear function. In addition, the three-dimensional limit-cycle approach for trajectory tracking is extended from the two-dimensional limit-cycle approach. Quad-rotor aircraft dynamics are also investigated in implementing an autonomous flight system that avoids fixed objects. Furthermore, shown in the simulation results are the efficiency and advantages of the proposed autonomous path planning method. Simulation results revealed a way to overcome local minima and undesirable effects caused by potential field methods by adjusting their avoidance circles' radius and direction. With the addition of the three-dimensional space limit cycle approach, the UAV was also able to prevent all obstacles without colliding. We tested the advantages of the suggested technology in simulations, but there are a variety of real-world scenarios that might cause the autonomous flight system to fail. These include severe winds that can render the quad-rotor UAV uncontrolled and obstructions that move unexpectedly, potentially causing crashes [10].

This paper presents the notion of control and its first application on an unmanned automated quadrotor aircraft. This is a back stepping-based centralized embedded model-based control method developed on quadrotor hardware that contains an integrated onboard computer, inertial sensor unit, as well as other elements that make it appropriate for the use of an indoor positioning system and a current wireless communication network. This realization is a significant step in the development of a more complex UAV that is compatible with practical applications; it aims to clarify control principles, gain an understanding of overcoming control issues, and build skills for future realization development [11].

Four-rotor micro helicopter's dynamic properties were experimentally defined in this research. Several phenomena, including gyroscopic effects and aerodynamic friction, are incorporated into the modulization approach to generate an acceptable model for identification and control synthesis. In a closed loop system with the same controller, a comparison of simulated and actual systems is done. The findings suggest that the dynamic model was well estimated. The practical detection of a quadrotor UAV is discussed in this research. The system's entire model is created by using Newton's formalism and represented in a format that allows the identification of the relevant dynamic parameters in the first phase. We used a series of trials in the second stage to create a database that the identification algorithm needed to figure out the mode parameters. A similar PID controller was deployed to the predicted model and the actual system to verify the model generated through

parameter estimation. The regulatory test results reveal that the hypothesis is closer to the actual one [12].

For decades, unmanned aerial vehicles (UAVs) have captivated the curiosity of the control and commerce communities due to their benefits over manned systems. The non-linear mathematical modeling of the quad-rotor unmanned aerial vehicles is the main focus of this research. For flight testing, there is also a flying mill. Linearized models developed in the quasi-LPV or Jacobian manner can be utilized as a preliminary step for H ∞ loop shaping-based robust control design. An H∞ loop-shaped flight controller is devised for position control based on such a nonlinear model. The quadrotor UAV Dragan flyer III presented nonlinear modeling. A flying mill was proposed, which is utilized for test flights and parameter identification. For position control, an H∞ loop shaping flight controller is created using this nonlinear model. The simulation results show that it is stable, has good reference tracking, and can reject disturbances [13].

Configuration	Material	Motor
Quadrotor (+)	Aluminum	BLDC
Quadrotor (X)	Carbon Fiber	BLDC
Hexacopter	Aluminum	BLDC
Quadrotor	Carbon fiber	BLDC
Octocopter	Carbon fiber	BLDC

Table 4. Comparative Analysis

3. STRUCTURAL ANALYSIS OF ARM OF MULTIROTOR

The employment of small unmanned air systems, sometimes known as drones, Unmanned Aerial Vehicles (UAVs), or Unmanned Aerial Systems, has resulted in significant progress. Because this system has so many components, considerable research has been done on new UAV applications, control optimization, Endurance Limit Enhancement, GPS, Autopilot, and so on. A minor amount of research has been done on the structural components of hex rotors. The structural analysis must be completed to achieve High Endurance. Multirotor has a lightweight frame, high-thrust motor landing gear, and a standard structural design. Structural analysis of the arm of a multirotor with a motor mounted is urgently required. Hex rotor Carbon Fiber Arm Structural Vibration Analysis, as the arm is affected by multiple structural loads due to the high RPM of the motors. The experimental and numerical vibration study of a Hex rotor Arm and subordinate structure is discussed in this work. This study examines the vibration factors that affect the Hex rotor, as well as experimental modal analysis of the carbon fiber arm of the Hex rotor. The collected data will reveal a low-vibration zone, allowing other instruments to be mounted for better functioning.

SOLIDWORKS 2015 x64 Premium Edition analyses all of the model's components. The multi-copter's arm is simulated in this edition with some boundary conditions. We can estimate stress, strain, and the safety factor with the help of these analyses, and we can optimize our model's performance. The model is weak in the highlighted area of the model in this static analysis, and extra material should be applied in that area to prevent failure. The element has a volume of 22.94 percent. Extra resin and fiber coatings should be put in this area to make it exceptionally strong and able to withstand a considerable amount of weight. A particular amount of load is given to the motor mount in this static study. The motor mount has the largest displacement, which is 0.001034mm. According to the results, the model has a very minimal amount of displacement. The arm has a minor displacement, indicating that it is safe, and there is no substantial displacement, indicating that our design is safe based on these data. When a given amount of load is applied to the motor mount, the body will hold up to almost 2.4 times the applied load, according to the static structural analysis of the arm and mount. That signifies that the body's safety factor is 2.4. The ratio of the ultimate load to the applied load is known as the factor of safety.

This helicopter's dynamic model is essentially a 3D rigid body developing under the influence of a primary

force and three moments. As indicated in Fig. 1, let I = Ix, Iy, Iz signify earth fixed reference frame. This is a right-handed orthogonal axis system, with the origin at the center of gravity of the helicopter at the start of the motion. I am considered the inertial reference frame under simplified conditions. Let B = Bx, By, Bz be a body-fixed reference frame that is a right-handed orthogonal system with the origin at the center of mass of the helicopter. The axes of the B-frame are thought to correlate with the body's major axis of inertia

Figure 22: Earth fixed reference frame and body fixed reference.

Euler-Lagrange equations can be applied to get the complete mathematical model of the full rotorcraft. Furthermore, because it has no coupling factors, the vehicle dynamics may be divided into translational and rotational dynamics The final attribute also aids in the classification of the generalized forces operating on the vehicle into two categories, the first of which is made up of translational forces and the second of which is made up of rotating torques of motion, as discussed below.

Thrust is the term used to describe the force produced by a rotor. The vector push should always be perpendicular to the rotor disc and directed upwards.

4. RESULTS

The results of this analysis are 11.073 MPa, 15.7 mm, and 0.004 in terms of maximum stress, displacement, and strain. Maximum stress, displacement, and strain are depicted in Figures 6, 7, and 8, respectively. Following the modeling of the drone body, it was discovered that the majority of the tension was generated in the y portion of the arm. Von Mises's stress is indicated in this image, which is created all over the drone body. This stress value is less than the material's maximum strength of 32.2 MPa. This stress value yields a FOS (factor of safety) of 2.91, which is within my targeted factor of safety range of 2.5 to 3.

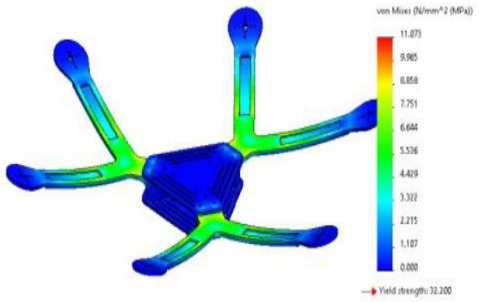

Figure 23: Maximum stress

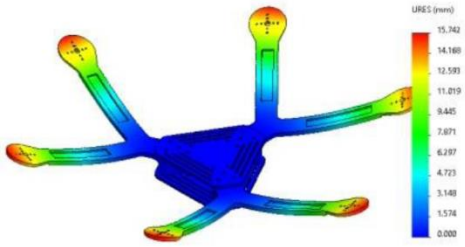

Figure 24: Maximum strain

The impact analysis was carried out to determine the drone body frame's durability. Impact analysis is carried out in two iterations, following the first iteration is 3 m in height and the second iteration is 5 m in height.

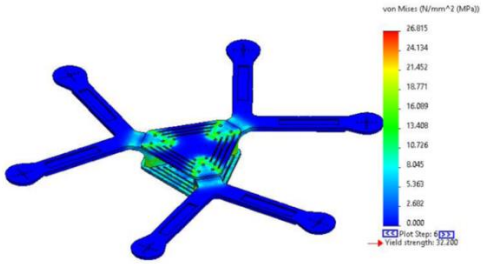

Figure 25: Impact analysis

Solid works simulation tool was used to do the impact study. The drop test was conducted at two distinct heights of 3 and 5 meters. The findings of the impact Figure 6: Maximum stress concentrated areas

Result of impact analysis for the height of 3m 22 study suggest that the majority of the stress is created at the bolted component of the assembly. The maximum stress was 29.487 MPa at a drop height of 5 meters, which is less than the ultimate tensile strength. As a result, the design was secure. The drone body was constructed using the following three materials: ABS, CF-ABS, and GF-ABS. UTM was used to test the ultimate tensile strength of the three materials mentioned above. The tensile strength of GF-ABS was found to be the highest (46.7 MPa), that of CF-ABS was intermediate (32.2 MPa), and that of ABS was the lowest (29.7 MPa). However, the GF-ABS was found to have issues with warping and nozzle jamming. CF-ABS was the next best option. Different types of patterns were subjected to static structural analysis. The best factor of safety was achieved by using a rectangular 3mm deep slot layout (2.91). Impact stress analysis in Solid Works was used to conduct the drop test. At a drop height of 5 meters, the maximum stress was 24.81 MPa, which is less than the ultimate tensile strength. As a result, the design was secure to carry a payload of 50 kgs.

5. CONCLUSIONS

The design and analysis of a multirotor UAV have been completed successfully. Our design for this project is incredibly aerodynamic and small. We conducted structurally and flow simulation analyses, among other things. We obtained a very satisfying and enjoyable result based on the analysis results. Our project is based on rotor vehicles, which we used to design this new UAV; there are far too many drones in use these days in every industry. The primary goal of this UAV is to replace outdated technology. Our design has the potential to produce superior results and performance. In comparison to other drones, our proposal has an extremely modest budget. It compresses all of the features found in other drones that are quite expensive. It is primarily designed for military operations to offer the most up-to-date information on the battleground and to carry out various operations on the battlefield. It has a night vision camera and a duplex communication system that allows it to work at night and communicate information to other people in real-time. The project's future goals include developing a thermal sensor camera, increasing the UAV's flight time, and improving performance. This UAV could be utilized for both defense and civil purposes in the future

NOMENCLATURE

UAV	Unmanned Aerial Vehicle
CF	Carbon Fiber
VTOL	Vertical Take-Off and Landing
IMU	Inertia Measuring Unit
Li-Po	Lithium-Polymer
IGS	Inertial Guidance System
ESC	Electronic Speed Controller

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