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International Conference on Sustainable Solutions in Engineering and Technology (SSET-2024)

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09	Dr. Rashmi R. Hunnur Basaveshwar Engineering College, Bagalkote	**10**	Dr. A. N. Sonnad Basaveshwar Engineering College, Bagalkote

Chairman's Message

It is my distinct honor and privilege to welcome you to the International Conference on Sustainable Solutions in Engineering and Technology, hosted by Basaveshwar Engineering College. This prestigious event brings together thought leaders, researchers, and practitioners from around the globe to explore innovative solutions that address the critical challenges of sustainability in engineering and technology.

Our Sangha is deeply committed to fostering an environment of academic excellence and innovation. We believe that the interdisciplinary exchange of knowledge and ideas at this conference will lead to meaningful collaborations and impactful solutions. The topics covered here, ranging from renewable energy to sustainable infrastructure, are crucial for building a resilient and sustainable world.

The themes and discussions of this conference are more pertinent than ever as we face the dual imperatives of advancing technology and preserving our environment. I am confident that the insights and solutions that emerge from this conference will make significant contributions to our shared mission of sustainability.

I extend my heartfelt thanks to all the keynote speakers and participants for making this event successful. I congratulate the organizers for their hard work and dedication.

Dr. Veeranna C. Charantimath
Chairman,
B. V. V. Sangha, Bagalkote

Secretary's Message

As we navigate the complexities of modern development, it is imperative that we integrate sustainable practices into every facet of our technological advancements. This conference provides a vital platform for researchers, practitioners, and innovators to share their insights, discoveries, and strategies for creating sustainable solutions that will shape our future.

At Basaveshwar Engineering College, we are deeply committed to fostering an environment of academic excellence and innovation. Our goal is to drive forward the boundaries of knowledge and practice in ways that are sustainable and beneficial for society as a whole. This conference is a testament to our dedication to these principles and our belief in the power of collaborative effort.

Shri. Mahesh Athani
Hon. Secretary
B. V. V. Sangha, Bagalkote

Technical Director's Message

I am particularly excited about the innovative solutions and cutting-edge research that will be presented during this conference. The intersection of engineering and sustainability presents unique challenges and opportunities, and it is through gatherings like this that we can share knowledge, inspire innovation, and collaborate on projects that will have a profound impact on our world.

Our commitment to sustainability is not just a goal but a guiding principle that influences all aspects of our work. This conference is an ideal platform to explore new ideas, methodologies, and technologies that can lead to sustainable growth and development. The diverse array of topics and the expertise of our participants promise a rich and enlightening experience for all.

I extend my heartfelt thanks to all the participants, keynote speakers, and organizing committee members for their dedication and hard work in making this conference a reality. Your contributions are invaluable to the success of this event and to the advancement of sustainable engineering and technology.

Dr. R. N. Herkal
Director of Technical Institutes
B. V. V. Sangha, Bagalkote

Principal's Message

Dear Collegues & Researchers

I feel happy to organize International Conference titled "Sustainable Solutions in Engineering and Technology" in Basaveshwar Engineering College, Bagalkote. This prestigious event, promises to be a landmark occasion, bringing together leading experts, researchers, and innovators from around the globe.

Focus of this conference will be on exploring cutting-edge approaches and technologies that address the pressing challenges of sustainability in engineering and technology. With a diverse array of topics ranging from renewable energy solutions and sustainable materials to smart infrastructure and green manufacturing, we aim to foster collaboration and inspire breakthrough ideas. Researchers from all disciplines gather here to explore the multidisciplinary approaches in designing and implementing systems that meet present needs without compromising the needs of future generations.

Our institution is honored to be the venue for this significant event and is committed to providing an enriching experience for all participants. We are confident that the key notes from experts, presentations from researchers will lead to valuable insights and partnerships that will drive forward the agenda of sustainable development.

I extend my deepest gratitude to Management for their continued support. I thank all the Keynote speakers, participants and orgnaising committee members for their continued support and engagement in this crucial event.

Dr. Veena Soraganvi
Principal
BEC, Bagalkote

Dean (R & D)'s Message

Dear Esteemed Colleagues and Participants,

It is with great pleasure and pride that I welcome you to the International Conference on Sustainable Solutions in Engineering and Technology. This conference is a testament to our collective commitment to advancing research and innovation in ways that are both technologically forward-thinking and environmentally sustainable.

Our institution has long been at the forefront of fostering research that addresses global challenges. This conference serves as a crucial platform for sharing knowledge, exchanging ideas, and forging collaborations that can lead to sustainable advancements. The contributions from our distinguished speakers and participants are essential for driving forward the agenda of sustainable development in engineering and technology.

I extend my deepest appreciation to all the researchers, practitioners, and organizers who have worked tirelessly to make this conference a success. Your dedication and expertise is the cornerstone of this event, and your contributions are instrumental in shaping a sustainable future.

Let us seize this opportunity to collaborate, innovate, and inspire one another as we work towards sustainable solutions that will benefit not only our generation but those to come.

Dr. Mahabaleshwar S. K.
Dean (R & D) and ICT
BEC, Bagalkote

CONTENT

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Track 3:

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INTERNATIONAL JOURNAL OF RESEARCH AND ANALYSIS IN SCIENCE AND ENGINEERING

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57. An Empirical Investigation into User Preferences: A Comparative Analysis of Netflix and Amazon Prime OTT Platforms with Emphasis on User Familiarity and Preference

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ABSTRACT:

Platforms like Netflix and Amazon Prime Video thrive in the highly competitive streaming market by meeting consumer preferences and satisfaction and study presents a comparative analysis of user preferences for Netflix and Amazon Prime, focusing on e-service quality factors such as streaming quality, user interface, and pricing, rather than content.

Data was collected from 150 respondents via an online survey and analysed using SPSS and Excel, employing descriptive statistics, t-tests, and correlation tests.

Findings reveal that both platforms enjoy high user satisfaction with minimal significant differences in preference levels. Amazon Prime shows a slight edge in user preference, likely due to its extensive content library and competitive pricing.

The positive correlation between preferences for Netflix and Amazon Prime suggests that users value both services, highlighting the need for further investigation into the factors driving user choice.

This study provides insights into the competitive dynamics of the OTT market and suggests potential strategies for leveraging the positive relationship between the two platforms.

KEYWORDS:

Netflix, Amazon Prime Video, User Preferences, Streaming Services.

Introduction:

Technical advancement and digitalization trends have greatly changed the entertainment industry, resulting in the enormous development of Over the Top (OTT). These platforms depict streaming media that provides watched material directly to the viewers through the internet and have become more common nowadays as they present a wider variety of content and the users have more freedom regarding the choice of material. With the availability of so many streaming applications globally, still, Netflix and Amazon Prime Video are in the top of the list of most used services.

II. Literature Review:

The perception of e-service quality on streaming platforms like Amazon Prime and Netflix has been the subject of extensive research. The analysis focuses on e-service quality factors such as streaming quality, user interface, and pricing, rather than content diversity or genre preferences. Recent studies highlight several dimensions of service quality including content, video and audio quality, ease of use, and price. A comprehensive analysis of 600 reviews using text mining and sentiment analysis revealed that while both platforms are viewed positively,Netflix consistently receives a higher percentage of positive feedback, suggesting a more favourable perception among users [1]. In a study focusing on the German market, quantitative data from a survey of 1,267 respondents indicated that Netflix is perceived more positively in terms of brand identification and prestige compared to Amazon Prime Video. This enhanced perception contributes to Netflix's competitive advantage in the market [2]. A study conducted in Kerala examined users' perceptions of over-the-top (OTT) platforms, emphasizing use, ease, perceived usefulness, and satisfaction. Utilizing an online survey with validated reliability through an alpha test, the research underscored the importance of customer care strategies in enhancing overall user satisfaction [3]. Further investigation into user intentions revealed key factors impacting choices regarding OTT platforms. Factors such as entertainment value, convenience, and content diversity were shown to significantly influence perceived usefulness, ease of use, and overall intention to use the service. This study, guided by the Technology Acceptance Model, offers valuable insights for industry players aiming to optimize their service offerings [4]. Additionally, a survey-based study analysed the factors affecting consumer choice in video streaming services, including price, content quality, user interface, auto-recommendation systems, and device compatibility. Data analysis through SPSS and AMOS demonstrated the relevance of these factors in shaping consumer preferences, providing a nuanced understanding of what drives user decisions in the streaming service market [5].

Problem Statement:

In today's fiercely competitive streaming market, the success of platforms such as Netflix and Amazon Prime Video hinges on understanding and catering to user preferences. Conducting a comparative study of user preferences between Netflix and Amazon Prime Video is crucial to gaining a comprehensive insight into consumers' perspectives and choices. This research aims to assess the preference levels of users between Netflix and Amazon Prime Video streaming services and to ascertain the relationship between these preferences.

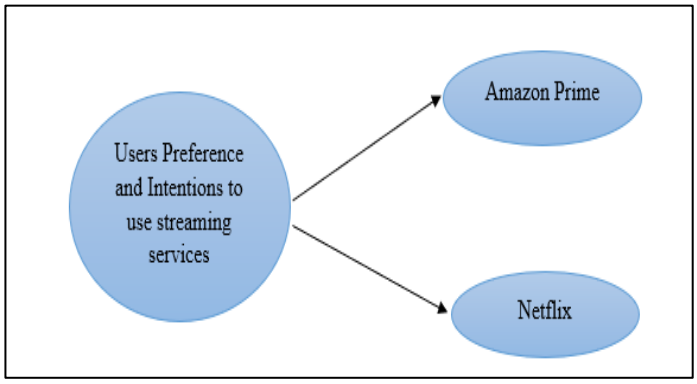
Objectives:

1. To assess the user preference level between Netflix and Amazon Prime video streaming services.
2. To ascertain the relation between the user preference of Netflix and Amazon Prime video streaming services.

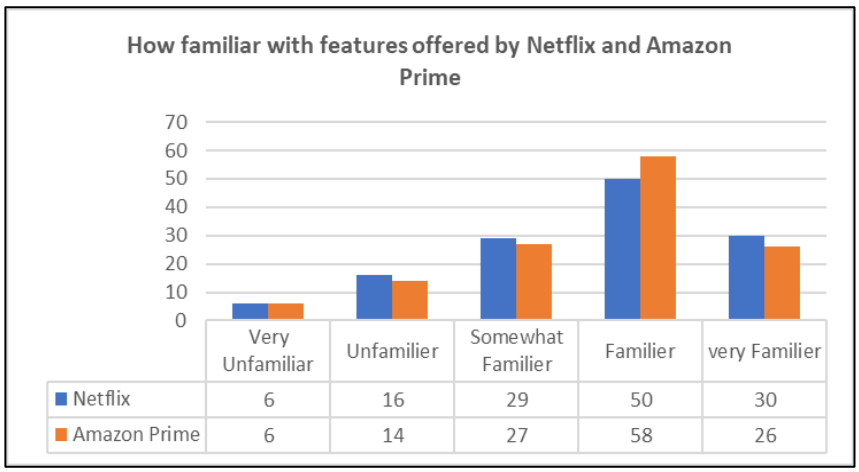
III. Research Methodology:

The method used for this study is descriptive research having the goal of identifying the difference in the user's preference between these two platforms. Primary data will therefore be gathered through completed online surveys. And collected data represents the people of Karnataka and Secondary data will be collected from journals, periodicals, articles, and previous research works. The sampling technique used is simple random sampling to recruit one hundred and fifty participants. SPSS and Microsoft Excel will be used to analyze the data and test the formulated hypothesis to conclude.

Framework:



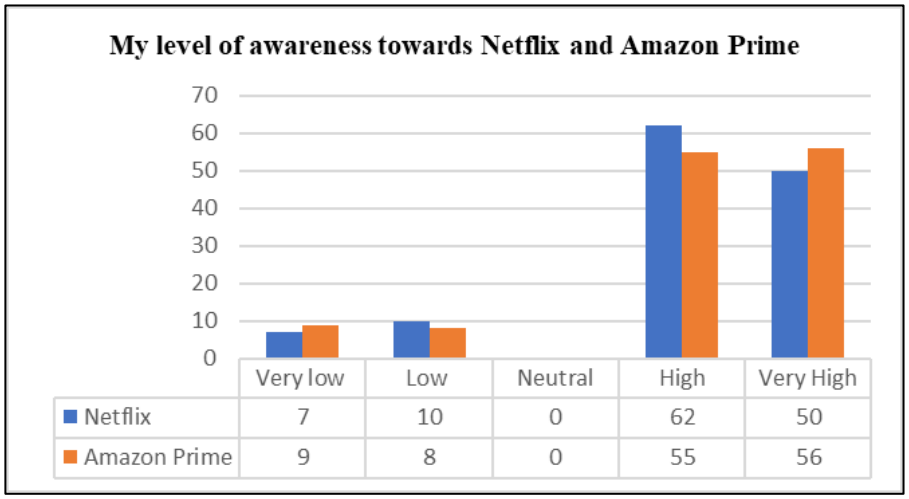
Data Analysis:



Netflix: Out of 131 respondents 33% of the respondents recognized Netflix and out of that 20% of respondents claim to be very familiar with Netflix 19% find themselves to be somewhat familiar while 11% of the respondents are still unfamiliar with Netflix and 4% are very unfamiliar with Netflix.

Amazon Prime: Out of 131 respondents, 39% of respondents said they are Familiar with Amazon Prime while 18% said that they are somewhat familiar with Amazon Prime 17% of respondents said that they are very familiar with it, 9% said that they are unfamiliar and 4% said that they are very unfamiliar.

Interpretation: based on the above-analyzed data, it can be postulated that more respondents are aware of Amazon Prime compared to Netflix. The reason could be the variety of services offered by Amazon Prime, pricing, or due to its closer integration with other Amazon services. The analysis here is focused on e-service quality such as quality of streams, user interface, and pricing rather than content diversification or genre choices.



Netflix: Out of all the respondents 7 chose very low, 10 selected low, none chose neutral, 62 selected high, and 50 selected very high for their preference rating. This means that most of the users have a high (47. 3%) or very high (38. 2%) perception of Netflix, while an insignificant number claimed to have a low or very low perception of Netflix.

Amazon Prime: Concerning the rating of preference, 9 out of the respondents selected very low, 8 selected low, 0 selected neutral, 55 selected high, and 56 selected very high. This proves that 43. 4% of the users have a high and 44. 2% very high preference for Amazon Prime, and infrequent users have a low or very low preference.

Interpretation: "Hence, from the results obtained above, a postulation can be made that Netflix and Amazon Prime both have high user preference, although Amazon Prime is relatively more preferred probably because of competitive pricing and being linked with all other services of Amazon. The analysis emphasizes e-service quality, including streaming quality and user interface, and does not include anything related to content diversity or any particular genre."

1. To assess the user preference level between Netflix and Amazon Prime video streaming services.

Ho: There is no significant difference between the User Preference of Netflix and Amazon Prime.

H1: There is a significant difference between the User preference of Netflix and Amazon Prime.

T-Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	UPIN	3.8359	131	.77570	.06777
	UPIAP	3.8473	131	.79637	.06958

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	UPIN & UPIAP	131	.230	.008

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	UPIN - UPIAP	-.01145	.97560	.08524	-.18008	.15718	-.134	130	.893

Analysis: A paired samples t-test was conducted to compare the User Preference levels between Netflix and Amazon Prime. The correlation coefficient between the two preference measures was 0.230, which is a low positive correlation. This correlation was statistically significant, with a p-value of 0.008, suggesting a relationship between the User Preference levels for Netflix and Amazon Prime.

The mean difference in User Preference levels was -0.01145, with a standard deviation of 0.97560 and a standard error mean of 0.08524. The 95% confidence interval for the difference ranged from -0.18008 to 0.15718, indicating that the mean difference could plausibly be zero. The t-value was -0.134 with 130 degrees of freedom, and the associated p-value was 0.893.

Interpretation: The paired samples t-test results show there is not a significant difference in user preference between Netflix and Amazon Prime. In particular, it has a mean difference of −0.01145, which would indicate almost the same level of preference among users for the two services. Given the p-value of 0.893 and an alpha level of 0.05, this difference is statistically insignificant. Hence, we fail to have enough evidence to reject the null hypothesis, which states that users are indifferent to Netflix and Amazon Prime, and thus have no particular affinity for one compared with the other.

2. To ascertain the relation between the user preference of Netflix and Amazon Prime video streaming services.

Ho: There is no significant correlation between the User Preference of Netflix and Amazon Prime.

H1: There is a significant correlation between the User preference for Netflix and Amazon Prime.

Correlations

		UPIN	UPIAP
UPIN	Pearson Correlation	1	.230**
	Sig. (2-tailed)		.008
	N	131	131
UPIAP	Pearson Correlation	.230**	1
	Sig. (2-tailed)	.008	
	N	131	131

**. Correlation is significant at the 0.01 level (2-tailed).

Analysis: The correlation test examined the relationship between the User Preference levels for Netflix and Amazon Prime. The Pearson correlation coefficient was calculated as 0.230, with a significance level (p-value) of 0.008. This indicates a low positive correlation between the two preference measures. The correlation is statistically significant at the 0.01 level, meaning that there is a high likelihood that the observed relationship is not due to random chance.

Interpretation: The significant positive correlation of 0.230 between the User Preference levels of Netflix and Amazon Prime suggests a low relationship where a higher preference for one service is associated with a higher preference for the other. Given the p-value of 0.008, which is below 0.01, we reject the null hypothesis that there is no significant correlation between the User Preference levels of the two services. This implies that users who prefer Netflix tend to also prefer Amazon Prime to some extent, indicating a notable relationship between the preferences for the two platforms.

Findings:

Users from Karnataka are delighted with Netflix and Amazon Prime; hence, both platforms meet the user's expectations about e-service quality.

- There is no significant difference in user preference between Netflix and Amazon Prime, indicating equal value perception on the part of the users.
- Familiarity with Netflix and Amazon Prime was positively correlated, thus proving that any person familiar with one would prefer the other too.
- It showed a slight preference for Amazon Prime, probably due to the competitive pricing and additional benefits associated with other Amazon services, such as Prime shipping.

IV. Suggestions:

- Also, Netflix and Amazon Prime should investigate joint promotions or bundled offers to leverage their common user base, capitalizing on the positive correlation in user preferences.
- Improve variety in content and enhance the experience for users to further satisfy and retain them on both platforms.
- Further research has to be done on how user preferences may evolve with the change in content offerings, pricing, and market dynamics to make strategic adjustments to strategy.

Such research would involve the study of how and why users hop from one streaming platform to another, and what makes them use more than one service simultaneously.

V. Conclusion:

This paper compares and contrasts the user preferences of Netflix and Amazon Prime concerning only e-service quality factors, such as streaming quality, user interface, and pricing. It turned out in the analysis that both platforms enjoy a high level of satisfaction

among their users within Karnataka, India, with no significant differences in overall preference. A positive correlation between familiarities with both platforms suggests that users who prefer one are likely to appreciate the other. The slight bias toward Amazon Prime can be explained by the competitive pricing and, more often than not, the bundling of other Amazon services. Further research should hence consider other factors, such as differentiation of content, to know more about user preferences and mutual benefit strategies like product bundling or cross-promotion.

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INTERNATIONAL JOURNAL OF RESEARCH AND ANALYSIS IN SCIENCE AND ENGINEERING

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58. A Study on Impact of Micro Finance on Self Help Groups (SHG's)

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ABSTRACT:

Microfinance has emerged as a powerful tool for promoting financial inclusion and empowering marginalized communities, particularly women, through initiatives like Self Help Groups (SHG's). This paper explores the interconnections among microfinance, financial inclusion, SHG's, and women empowerment. It begins by defining microfinance as the provision of financial services to low-income individuals who lack access to traditional banking services. Financial inclusion a broader concept encompasses ensuring access to a range of financial services and products at affordable costs. Self Help Groups (SHG's) play a crucial role in microfinance by mobilizing individuals, predominantly women, into small community-based organizations that pool savings and provide access to credit. SHG's not only enhance financial literacy and entrepreneurship skills but also foster social empowerment through collective decision-making and mutual support networks.

Women in particular benefit significantly from Micro Finance and SHG's as these initiatives enable them to generate income, gain economic independence, and contribute to household and community welfare. Moreover, access to financial services enhances women decision making power within their households and communities, leading to improved social status and gender equality. Despite the successes, challenges remain in scaling up microfinance programs sustainably and ensuring equitable access for all marginalized groups. Issues such as over indebtedness, high transaction costs, and regulatory constraints need addressing to maximize the potential of microfinance in promoting inclusive economic growth and poverty reduction. In short microfinance, driven by initiatives like SHG's, holds promise as a catalyst for financial inclusion and women's empowerment. By addressing barriers to access and ensuring sustainability, policymakers and stakeholders can leverage these tools to foster inclusive development and empower marginalized communities, ultimately contributing to broader social and economic advancement.

KEYWORDS:

Micro Finance, Financial Inclusion, Self Help Groups, Women Empowerment.

1. Introduction:

Microfinance is a specialized financial service that targets low-income individuals and communities who have limited access to traditional banking services. It encompasses a range of financial products such as small loans, savings accounts, insurance, and money transfer services, tailored to meet the unique needs of underserved populations.

The concept of microfinance emerged from the recognition that conventional financial institutions often overlook small scale borrowers due to perceived risks and high transaction costs associated with serving them. Microfinance institutions (MFI's) and organizations aim to bridge this gap by providing accessible and affordable financial services to those who are excluded from the formal banking sector.

Financial inclusion refers to the availability and accessibility of essential financial services to all individuals and businesses, regardless of their socioeconomic status. It aims to ensure that everyone has access to affordable and appropriate financial products and services that meet their needs and are delivered in a responsible and sustainable manner.

Financial inclusion is not only a matter of social justice and equality but also a key driver of economic growth and development. By expanding access to financial services, financial inclusion helps to unlock entrepreneurial potential, increase productivity, and improve overall standards of living. Governments, financial institutions, civil society organizations, and technology providers all plays important role in advancing financial inclusion initiatives and ensuring that no one is left behind in the global economy.

Self Help Groups (SHG's) are informal associations of people who come together to address common socio-economic needs. These groups typically consist of 10-20 members, primarily women from economically poor backgrounds, although men also form SHG's in some contexts. The primary objective of SHG's is to promote collective savings, provide access to credit, and foster socio-economic empowerment within their communities.

SHG's have proven to be a powerful tool for poverty alleviation, social empowerment, and community development, particularly in rural and underdeveloped area. They promote sustainable development by fostering local initiatives and leveraging collective action for positive socio-economic change. Governments, NGOs, and development organizations often support the formation and strengthening of SHG's as a part of broader efforts to promote inclusive growth and reduce poverty worldwide.

Women empowerment refers to the process of enhancing women's ability to access and control resources, make decisions, and achieve their full potential within societies. It encompasses economic, social, political, and educational empowerment, aiming to create an environment where women can participate equally in all spheres of life.

Women empowerment is not only a matter of human rights and social justice but also a key driver of sustainable development. Empowered women contribute to stronger economies, healthier communities, and more inclusive societies. Governments, civil society organizations, international agencies, and the private sector play crucial roles in advancing women empowerment through policies, programs, and partnerships that promote gender equality and women's rights worldwide.

Objectives of Research:

1. To provide brief introduction about Micro Finance in India, Financial Inclusion, Self Help Group's and Women Empowerment.
2. To outline the impact of Microfinance Institutions on Self Help Groups and Women's Empowerment in India through the lens of financial inclusion.

II. Theoretical Framework:

These theoretical frameworks collectively guide the design, implementation, and evaluation of microfinance initiatives through SHG's in India. They provide a comprehensive understanding of how SHG's contribute to financial inclusion, social empowerment, poverty alleviation, and sustainable development at both individual and community levels. The theoretical framework of Microfinance in India, particularly through Self Help Groups (SHG's) draws on several key concepts and theories that support its operation and impact. Here are the main theoretical frameworks relevant to Micro Finance and SHG's in India:

- **Financial Inclusion Theory:**

Financial inclusion theory emphasizes the importance of providing access to a full suite of financial services to low income and marginalized populations, Its application to SHG's in India facilitate financial inclusion by offering savings facilities, credit access, and insurance options to members who would otherwise be excluded from formal financial systems.

- **Empowerment Theory:**

Empowerment theory focuses on enhancing individual capabilities, opportunities, and control over their lives and resources, its applications on SHG's empower women in India by providing them with financial resources, decision making power within their households, and opportunities for leadership roles within the group. This theory underscores how SHG's contribute to women's economic, social, and political empowerment.

- **Poverty Alleviation Theory:**

This theory focuses on strategies and interventions aimed at reducing poverty through economic growth and income redistribution, its application on SHG's in India are seen as effective tools for poverty alleviation by providing poor households with access to credit and opportunities for income generation. By enhancing livelihoods and building assets, SHG's contribute to long term poverty reduction efforts.

Scope of the Study:

The scope of studying Micro Finance in India through Self Help Groups encompasses a comprehensive examination of its economic, social, and policy dimensions, aiming to understand its impact on poverty alleviation, women empowerment, community development, and sustainable economic growth. Such studies contribute valuable insights into designing effective policies, interventions, and strategies for promoting inclusive and sustainable development through microfinance initiatives.

III. Research Methodology:

This is descriptive research paper which is based on secondary data. The data has been collected through various books, websites, research publications etc.

IV. Literature Reviews:

1. Literature underscores the importance of supportive policy frameworks and regulations that facilitate the growth and sustainability of microfinance interventions through SHG's. Future research directions include exploring the long-term impacts of microfinance on SHG members, scalability of successful models, and innovative approaches to enhance the effectiveness of microfinance in promoting inclusive development.
2. Microfinance and the empowerment of women: A review of the key issues. Gender and Development, 8(1), 20-29 in this paper SHG's often composed predominantly of women, play a crucial role in empowering female members. Microfinance initiatives within SHG's have been shown to enhance women's decision-making power within households, increase their economic independence, and improve their socio-economic status.
3. In this research paper despite the positive impacts observed, studies also highlighted challenges such as high transaction costs, dependency on external funding, and sustainability issues post intervention. Effective management, capacity building, and linkages with formal financial institutions are identified as critical factors for the sustainability of microfinance initiatives through SHG's.
4. In this research paper SHG's foster social capital by promoting solidarity, mutual support, and collective action among members. These social networks are crucial for disseminating information, sharing experiences, and collectively addressing common challenges faced by group members.
5. SHG's promote a culture of savings among members, which not only provides a safety net but also serves as a source of internal lending. Members contribute regularly to savings, which collectively strengthen the financial resilience of the group.
6. In this paper many studies highlighted that microfinance through SHG's significantly improves access to credit for members who are typically excluded from formal financial systems. This access enables members to invest in income generating activities, smooth consumption patterns, and cope with emergencies.
7. In this research paper indicates that microfinance interventions through SHG's contribute to poverty reduction by enabling members to increase their income levels, accumulate assets, and improve their living standards over time.

Self Help Groups in India:

Self Help Groups (SHG's) in India have emerged as a significant grassroots mechanism for socio economic empowerment, particularly among women in rural and semi urban areas. Here is an overview of SHG's in India, their structure, objectives, impact, and government support:

V. Structure and Formation:

SHG's typically consist of 10 to 20 members who come together voluntarily, often based on geographic proximity, economic similarity, or shared social ties. While initially focused on women, men also participate in SHG's in some regions. SHG's are formed with the support of NGO's, government agencies, or other development organizations. They undergo training on group dynamics, financial management, and income generating activities to build cohesion and sustainability.

An objective is to collective savings where SHG's promote regular savings among members, pooling funds to create a collective corpus. This savings mechanism enhances financial discipline and serves as a source of internal lending for members and access to credit where one of the primary objectives of SHG's is to provide microcredit to members.

Members can borrow from the group's savings for various purposes such as starting or expanding small businesses, meeting household expenses, or emergencies and about empowerment SHG's aim to empower women by providing them with a platform to enhance their decision-making abilities, participate in economic activities, and improve their socio-economic status within their families and communities.

SHG's have been instrumental in empowering women across India. They have facilitated increased financial independence, improved decision making power within households, and enhanced social status and self-esteem among female members and also poverty alleviation where in this SHG's contribute to poverty reduction by promoting income generating activities, creating employment opportunities, and enhancing livelihoods among members and their families and also regarding social capital where SHG's foster social cohesion and mutual support among members, leading to stronger community ties, information sharing, and collective action to address common challenges.

Government also supports through National Rural Livelihoods Mission (NRLM) Launched by the Government of India, NRLM promotes SHG's as a key strategy for poverty alleviation and rural development.

It aims to reach out to rural poor households across the country and strengthen their livelihoods through SHG based interventions and also SHG bank linkage program where government facilitates linkages between SHG's and formal financial institutions such as banks to ensure members have access to credit, savings facilities, and other financial services and also Government initiatives focus on training SHG members in various skills, financial literacy, and entrepreneurship to enhance their income-generating capabilities and sustainability. Where SHG faces various challenges such as sustainability, ensuring the long-term sustainability of SHG's remains a challenge, particularly in terms of maintaining

active participation, managing internal dynamics, and securing continuous access to financial resources along with this scaling up, while SHG's have demonstrated success at the local level, scaling up these initiatives to reach a larger number of beneficiaries across diverse geographical and socio economic contexts poses logistical and operational challenges.

Historical Evolution of SHG's Self Help Groups (SHG's) have evolved over time to address various social and economic issues, particularly in developing countries. Here is an overview of their historical evolution:

Early Beginnings:

- 1900's-1950: Early forms of SHG's emerged as informal savings and credit groups in rural communities, particularly in Asia and Africa. These groups were often small, community-based, and operated without formal structures.
- 1960's-1970: Micro Finance and cooperative movements gained momentum. Governments and NGOs began to recognize the potential of SHG's in poverty alleviation and women empowerment.

Formalization and Growth:

- 1980's: The concept of SHG's became more structured. In India, the National Bank for Agriculture and Rural Development (NABARD) launched the SHG Bank Linkage Program in 1992, which aimed to connect SHG's with formal banking institutions.
- 1990's: SHG's gained significant traction. Various international organizations, including the World Bank, began supporting SHG initiatives. The Grameen Bank in Bangladesh, founded by Muhammad Yunus, became a model for SHG based microfinance.

Expansion and Impact:

- 2000's: The success of SHG's in India and Bangladesh inspired similar models in other countries, including Nepal, Sri Lanka, and parts of Africa and Latin America. SHG's expanded their focus to include not only savings and credit but also health, education, and community development.
- 2010's: SHG's continued to grow, with millions of members worldwide. Digital technology started to play a role in enhancing the efficiency and reach of SHG's. Governments and international bodies integrated SHG's into broader development programs.

Recent Trends:

- 2020's: SHG's are increasingly recognized as vital for achieving Sustainable Development Goals (SDG's). They are involved in climate resilience, digital inclusion, and entrepreneurship. The COVID-19 pandemic highlighted the importance of SHG's in providing social safety nets and supporting vulnerable populations.

Key Features and Functions of SHG's:

- Economic Empowerment: SHG's provide members, particularly women, with access to credit and savings, enabling them to start small businesses and improve their livelihoods.
- Social Support: SHG's offer a platform for members to share experiences, support each other, and address common issues.
- Capacity Building: Through training and education, SHG's enhance members' skills and knowledge, promoting self-reliance and community development.
- Advocacy and Governance: SHG's empower members to participate in local governance and advocate for their rights and needs.

Challenges and Future Directions:

- Sustainability: Ensuring the long-term sustainability of SHG's remains a challenge, particularly in terms of financial management and leadership.
- Scaling Up: While SHG's have been successful in many regions, scaling up to reach more communities and individuals requires continuous innovation and support.
- Integration with Technology: Leveraging digital tools and platforms can enhance the efficiency and impact of SHG's, but this requires addressing issues of digital literacy and infrastructure.

The evolution of SHG's demonstrates their potential to transform lives and communities by promoting economic and social development from the grassroots level.

Progress of SHG's:

The progress of Self-Help Groups (SHG's) has been notable, particularly in countries like India, Bangladesh, and several African and Latin American nations. Here is an overview of their progress across various dimensions:

Economic Impact

1. Income Generation and Livelihoods:

- SHG's have facilitated access to microcredit, enabling members to start small businesses and improve their livelihoods.
- Many SHG's have diversified into various economic activities such as agriculture, livestock rearing, handicrafts, and small-scale manufacturing.

2. Savings and Credit:

- SHG's promote a culture of savings among members, providing a financial safety net.
- The SHG Bank Linkage Program in India, initiated by NABARD, has significantly improved access to formal financial services for rural populations.

Social Empowerment:

1. Women Empowerment:

- SHG's have been instrumental in empowering women by providing them with financial independence and a platform to voice their opinions.
- Women members have reported increased self-confidence, decision making power, and social status.

2. Education and Health:

- Many SHG's are involved in spreading awareness about health and hygiene, leading to improved community health outcomes.
- SHG's often support educational initiatives, promoting literacy and skill development among members and their families.

Community Development:

1. Collective Action:

- SHG's encourage collective action to address common issues, such as improving local infrastructure, water supply, and sanitation.
- They play a significant role in disaster management and recovery, providing immediate support and resources to affected members.

2. Local Governance:

- SHG members are increasingly participating in local governance, advocating for their rights, and influencing decision making processes.
- In India, SHG members have been elected to local government bodies, further enhancing their role in community development.

Technological Integration:

1. Digital Financial Services:

- The integration of digital technology has improved the efficiency and reach of SHG's. Mobile banking and digital payment platforms have made financial transactions more accessible.
- Digital literacy programs are helping SHG members to leverage technology for better financial management and business operations.

2. Training and Capacity Building:

- Online training modules and digital tools are being used to enhance the skills and knowledge of SHG members.

- E-commerce platforms are enabling SHG products to reach wider markets, increasing their income potential.

Challenges and Areas for Improvement:

1. Sustainability:

- Ensuring the long-term sustainability of SHG's is crucial. This includes maintaining financial discipline, effective leadership, and continuous capacity building.
- Addressing the dropout rates and ensuring consistent participation remain challenges.

2. Scaling Up:

- While SHG's have made significant progress, there is a need to scale up their reach to include more marginalized communities.
- Enhancing the quality of SHG operations and governance can help in scaling up successfully.

3. Addressing Gender Bias:

- Despite the progress, gender bias and socio-cultural barriers still pose challenges to the full empowerment of women through SHG's.
- Continuous efforts are needed to challenge and change these norms to achieve true gender equality.

Key Statistics and Achievements:

1. India:

- As per recent reports, there are over 7 million SHG's in India, with around 80 million members, the majority being women.
- The SHG Bank Linkage Program has mobilized over $10 billion in loans to SHG's.

2. Bangladesh:

- The Grameen Bank model has reached millions of women, significantly reducing poverty levels in participating communities.

3. Africa:

- SHG initiatives in countries like Kenya, Uganda, and Ethiopia have shown positive impacts on women's empowerment and community development.

Future Directions:

1. **Policy Support:**

- Continued policy support from governments and international organizations is essential to sustain and expand SHG initiatives.
- Integrating SHG's into broader economic and social development programs can enhance their impact.

2. **Innovation and Adaptation:**

- Encouraging innovation within SHG's, such as adopting new technologies and business models, can help them adapt to changing economic environments.
- Tailoring SHG models to local contexts and needs is crucial for their success.

3. **Monitoring and Evaluation:**

- Implementing robust monitoring and evaluation systems can help track the progress and impact of SHG's, ensuring accountability and continuous improvement.
- The progress of SHG's highlights their potential to drive inclusive and sustainable development, empowering individuals and transforming communities from the ground up.

Sustaining of Self-Help Groups (SHG's): Sustaining of Self-Help Groups (SHG's) requires addressing various economic, social, and organizational challenges to ensure their long-term viability and impact. Here are key strategies and considerations for sustaining SHG's:

Economic Sustainability:

1. **Diversified Income Sources:**

- Encourage SHG's to diversify their income-generating activities to reduce dependency on a single source. This could include agriculture, handicrafts, retail, and services.
- Provide training and support to help members develop new skills and explore different business opportunities.

2. **Access to Finance:**

- Strengthen linkages with formal financial institutions to ensure SHG's have continued access to credit and savings facilities.
- Promote the use of digital financial services to enhance efficiency and reach.

3. **Market Linkages:**

- Facilitate access to markets for SHG products through partnerships with retailers, e-commerce platforms, and local market.

- Organize trade fairs, exhibitions, and buyer seller meets to help SHG members market their products.

4. Financial Literacy:

- Conduct regular financial literacy programs to educate SHG members on financial management, savings, investments, and credit utilization.
- Use digital tools and mobile applications to make financial education more accessible and engaging.

Social Sustainability:

1. Capacity Building:

- Invest in continuous training and capacity building programs to enhance the skills and knowledge of SHG members.
- Focus on leadership development, financial management, business planning, and digital literacy.

2. Community Engagement:

- Encourage SHG's to engage with the broader community to build social capital and support networks.
- Promote collective action on community issues such as health, education, and infrastructure development.

3. Gender Equality:

- Address socio cultural barriers that hinder womens participation and leadership in SHG's.
- Implement programs that promote gender equality and women's rights, ensuring that SHG's provide a safe and empowering environment for all members.

Organizational Sustainability

1. Strong Governance:

- Establish clear governance structures and processes within SHG's to ensure transparency, accountability, and effective decision-making.
- Provide training on governance and leadership to SHG leaders and members.

2. Record Keeping:

- Maintain accurate and up to date records of meetings, financial transactions, and member activities.
- Use digital tools to streamline record keeping and data management.

3. Regular Monitoring and Evaluation:

- Implement regular monitoring and evaluation systems to track the progress and performance of SHG's.
- Use the insights gained to make informed decisions and improve the functioning of SHG's.

Institutional Support

1. Government Policies and Programs:

- Advocate for supportive government policies and programs that promote the growth and sustainability of SHG's.
- Leverage government schemes and subsidies designed to support SHG's and their activities.

2. NGO and Private Sector Partnership:

- Foster partnerships with NGO's, private sector companies, and development agencies to provide technical assistance, funding, and market linkages.
- Collaborate on capacity building initiatives and innovative projects.

Technology Integration

1. Digital Tools and Platforms:

- Integrate digital tools and platforms to enhance the efficiency and reach of SHG's. This includes mobile banking, e-commerce, and digital training programs.
- Provide training on using digital tools to ensure all members can benefit from technology integration.

2. Data Analytics:

- Utilize data analytics to gain insights into SHG performance, member needs, and market trends.
- Use data driven decision making to optimize operations and improve outcomes.

Networking and Advocacy

1. SHG Federations:

- Promote the formation of SHG federations and networks to provide a collective voice and greater bargaining power.
- Use federations to facilitate knowledge sharing, peer learning, and collective problem solving.

2. Advocacy and Awareness:

- Raise awareness about the importance and impact of SHG's through advocacy and communication campaigns.
- Engage with policymakers, media, and the public to build support for SHG initiatives.

By implementing these strategies, SHG's can achieve long term sustainability, empower the members of SHG's and can contribute to broader social and economic development.

VI. Conclusion:

Overall, the study confirms that microfinance has had a profound impact on the development and sustainability of SHG's. By providing access to financial resources, fostering social empowerment, and promoting community development, microfinance has empowered SHG members to improve their livelihoods and contribute to the wellbeing of their communities.

To build on these successes, it is essential to address the identified challenges and continue supporting SHG's through targeted interventions, policy support, and innovative approaches. This will ensure that SHG's remain a powerful tool for inclusive and sustainable development.

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59. Analyzing Critical Inventory Management Factors in Indian MSMEs using DEMATEL Technique

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ABSTRACT:

Organizations must comprehend the connection between their supply chain management (SCM) system and their success criteria in order to survive in this competitive market. This study aims to analyze the supply chain management (SCM) of Indian MSME's situated in the border region of Karnataka and Maharashtra by identifying the critical inventory management factors that contribute to their performance enhancement and establishing their causal relationship.

Factor analysis is applied to reduce down the variables from 20 to significant 10, which in turn summarized into five factors. The considered five factors are: Economy & Efficiency, Customer service optimization, Inventory Stabilization, Cost Reduction, Competitive ability. The DEMATEL (Decision Making Trial and Evaluation Laboratory) technique is used to quantify and visualize the interdependencies among these different inventory management factors, hence supporting decision-making by identifying cause-and-effect correlations among these factors.

Analysis reveals that the factor, "Cost Reduction" is most important factor among all other criteria considered. By employing this technique, we seek to provide a comprehensive understanding of the interdependencies among factors considered and their impact on SCM performance. Ultimately, the study aims to contribute insights that can guide MSMEs in formulating effective Inventory Management strategies tailored to their unique operational constraints.

KEYWORDS:

SCM, DEMATEL, MSME, Inventory management.

1. Introduction:

1.1 Significance of Inventory Management in MSMEs:

Inventory Management is the cornerstone of SCM, influencing the balance between operational efficiency and cost-effectiveness. MSMEs, often faced with limited resources, must navigate a complex terrain of demand variability, supplier relationships, and customer expectations. Inefficient inventory practices can result in increased costs, stock outs, and customer dissatisfaction, underscoring the need for a nuanced understanding of the success factors in Inventory Management for MSMEs.

Inventory management plays a key function in optimizing operational competence and minimizing costs within supply chain systems [1][2]. As organizations strive to enhance their competitiveness in dynamic business environments, the need for effective inventory control mechanisms becomes imperative [3].

The growth of inventory management has prompted researchers to explore new methodologies capable of handling complexities in supply chain dynamics. Collaborative approaches, such as Vendor Managed Inventory (VMI) and Collaborative Planning, Forecasting, and Replenishment (CPFR), have emerged to enhance coordination among supply chain partners [4]. Additionally, technological advancements, including the integration of Internet of Things (IoT) and data analytics, offer opportunities for real-time monitoring and decision-making [5].

1.2 Research Gap and the Need for DEMATEL Approach:

While existing literature acknowledges the significance of Inventory Management in MSMEs, A significant research gap exists in the systematic investigation of the correlations between success factors. The DEMATEL (Decision Making Trial and Evaluation Laboratory) methodology presents an opportunity to fill this void by providing a structured approach to analyze and quantify the cause-and-effect relationships within the context of Inventory Management. In recent years, In order to analyze intricate relationships inside inventory management systems, the DEMATEL methodology has become increasingly popular [6].

DEMATEL, originating from operations research, provides a systematic approach for analyzing cause-and-effect relationships among various factors [7]. Its application in inventory management allows for a nuanced understanding of the interdependencies among factors influencing stock levels, ordering policies, and overall supply chain performance [8].

Researchers have highlighted the role of DEMATEL in decision support for inventory management, emphasizing its ability to identify critical factors and prioritize strategies for improvement [9] [10]. By quantifying the strength and direction of relationships, DEMATEL aids decision-makers in making informed choices for resource allocation, risk assessment, and policy formulation [11].

II. RESEARCH METHODOLOGY:

The flow chart in Figure 1, illustrates the eight processes in which the DEMATEL approach has been used to the current research. To create the CER diagram, first create the Direct Answer Matrix, Original Average Matrix, Normalize the Direct Influence Matrix, Derive the Total Relation Matrix, and choose a threshold value. [12].

Step 1: Construct the Direct Answer Matrix;

The Direct Answer Matrix for each dimension are to be constructed by the scores awarded by 'm' Decision Makers (DM) with 'n' factors. Each DM is asked to view the degree of direct influence between two factors based on pair-wise comparison. The degree to which the DM perceived factor 'i' effects on factor "j" is denoted by a^k_{ij}. The integer score of '0' to '4' is assigned for each pairs as per the values given in Table I.

TABLE 1 Degree of Influence and Numerical Score for Pair Wise Comparisons

Sl.no.	Degree of influence	Score
1	No influence	0
2	Low influence	1
3	Medium influence	2
4	High influence	3
5	Very high influence	4

For each DM, 'n x n' the structure of a nonnegative Direct Answer Matrix is as:

$A^k = [a^k_{ij}]$, (1)

When every diagonal element is set to "0," where k is the total number of DMs taking part in the assessment procedure, with $1 \leq k \leq m$, and so A1, A2, A3... Am the he Direct Answer Matrix fro 'm' DMs.

Step 2: Determine the Initial Average Matrix;

The 'n x n' initial Average Matrix, $B=[b_{ij}]$, the opinions of all DMs can be calculated by taking the average of the'm' DMs' scores, as indicated below:

$b_{ij} = \frac{1}{m}\sum_{i=1}^{m} a_{ij}^k$ ..... (2)

Step 3: Determine the Initial Direct Relation Matrix in normalized form;

By normalizing the initial Average Matrix B using the following technique, the normalized Initial Direct Relation Matrix D is produced:

$$S = max\left[\max 1 \le i \le n \sum_{j=1}^{n} b_{ij,} \max 1 \le i \le n \sum_{i=1}^{n} b_{ij}\right]$$

Thus D = B/s …… (4)

The greater of two extreme sums is the value of the positive scalar. Each element of matrix "B" is divided by the scalar to get the matrix "D."

And hence that each element 'd_{ij}' of matrix is 'D' is between 0 and 1.

Step 4: Calculate the Total Relation Matrix;

Powers of "D" are used to quantify indirect effects between components. The indirect impacts of elements continuously decline to the power of matrix 'D', namely, D^1, D^2, D^3…D^∞, Provides convergent matrix inversion solutions that resemble absorbing Markov Chain Theories.

Note $\lim_{m\to\infty} D^m = [0]_{n\times n}$ and,

Where "I" represents the "n x n" identity matrix and "0" represents the "n x n" null matrix. The definition of the "n x n" total relation matrix "T" is as follows.

$$T = \left[t_{ij}\right]\sum_{i=1}^{\infty} D = D(1-D)^{-1}$$

i,j= 1,2,3,…,n ……..(5)

As $\lim_{k\to\infty} D^k = [0]_{n\times n}$

Where D=[d_{ij}]n x n, $0\le d_{ij}\le 1$ and $0\le(\Sigma i\ d_{ij}$, $\le 1\le(\Sigma i\ d_{ij})<1$ and at least one column sum $\le(\Sigma\ i\ d_{ij}$ or

One row sum m$\le(\Sigma j\ d_{ij}$ equals to 1.

Step 5: Determine the Factors and Cause-effect links;

The total relation matrix "T"'s sum of rows and sum of columns are represented by the vectors "r" and "c," respectively. Below is the computation of "r" and "c."

$r = [r_i]_{n\times 1} = \langle\sum_{j=1}^{\infty} t_{ij}\rangle_{n\times 1}$…… (6)

$$c = [r_j]_{1\times n} = \langle \sum_{i=1}^{\infty} t_{ij} \rangle_{1\times n}^{t} \qquad \ldots\ldots\ldots (7)$$

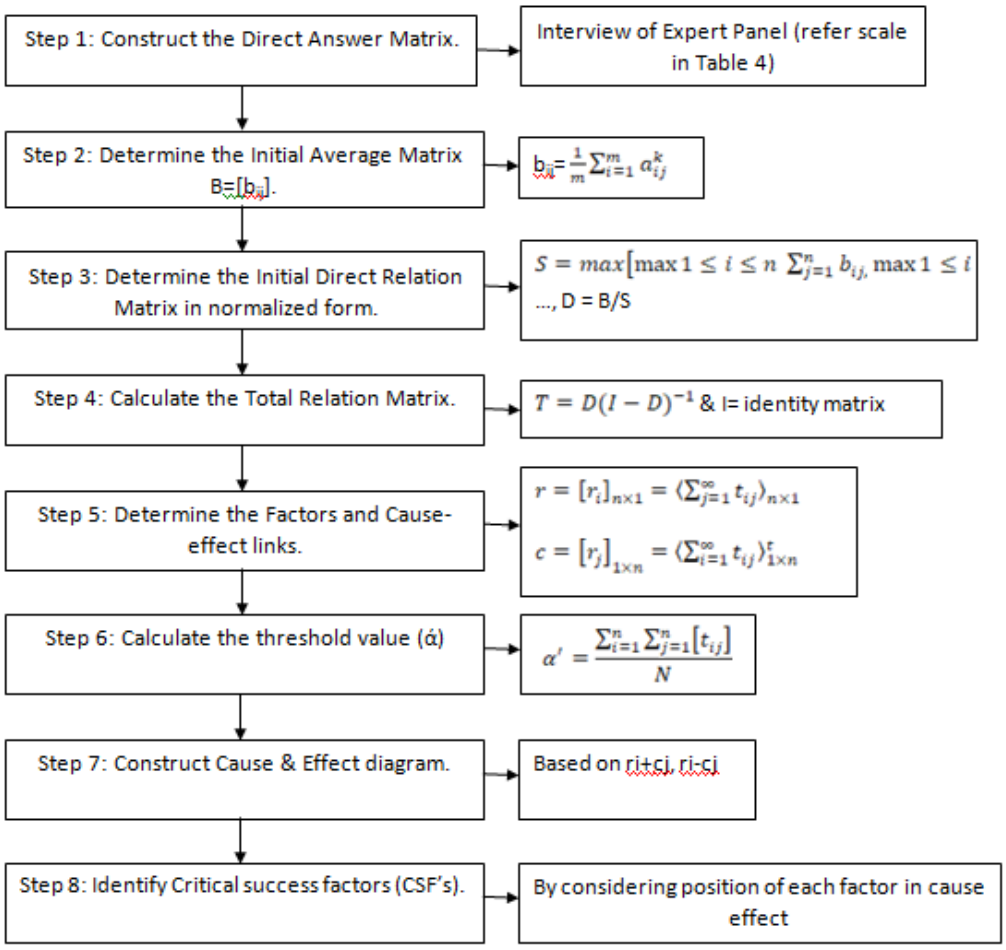

Figure 1. DEMATEL Application Methodology

Where transpositions are indicated by superscript "t".

- Assume that 'r_i' represents the sum of rows i^{th} in matrix 'T'. The overall impacts of the i^{th} factor on other factors, both direct and indirect, are represented by the value "r_i."
- Assume that 'c_j' is the total of the j^{th} column matrix 'T'. The total effects—direct and indirect—that the j^{th} factor received from other factors are indicated by the value "c_j."
- An index known as the "factors," which represents the overall effects delivered and received by the i^{th} factor, is obtained by adding the values of r_i and c_j, i.e. (r_i+c_j) indicates how significant the i^{th} element is to the system.
- The "interactions," which is an index derived from the difference (r_i-c_j), illustrates the system's overall impact and the contribution of the i^{th} element.
- If (r_i-c_j) is positive, then i^{th} factor is a 'Dispatcher' and,

- If (r_i-c_j) is negative, then i^{th} factor is a 'Impact Relationships'.

Step 6: Calculate the threshold value (ά);

The total relation matrix 'T' can be used to calculate the threshold value (ά) by averaging its elements. By setting a threshold value, some of the small effects elements of the total relation matrix "T" can be eliminated. [12].

$$\alpha' = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}[t_{ij}]}{N} \qquad \text{…….. (8)}$$

Step 7: Construct Cause and Effect Relationship diagram;

To visualize the complicated interdependence, the Cause-and-Effect Relationship diagram is produced by mapping all coordinate sets of (r_i+c_j, r_i-c_j). And offer data to determine which factors are important and how their effect affects other factors. [13]. In the cause-and-effect relationship diagram, only the factors whose value (t_{ij}) above the threshold (ά) are chosen and represented.

III. CASE STUDY:

MSME Organization X, a notable Indian firm specializing in automotive parts manufacturing with an annual turnover exceeding 7 crores and a workforce of over 21 employees, is strategically prioritizing the optimization of its inventory management processes. With established relationships maintained across 8 suppliers and vendors, the organization is committed to enhancing its competitive edge through improved inventory management systems.

In pursuit of operational excellence, Organization X has embarked on a path to implement alternative solutions, driven by a comprehensive inventory management analysis report. This report aims to identify critical factors influencing inventory management and establish their interdependencies using validated analytical techniques. By leveraging data-driven insights and methodological validation, the organization seeks to streamline procurement processes, optimize inventory levels, and strengthen supplier relationships. This strategic initiative underscores Organization X's proactive approach to adapt and thrive in the competitive landscape of automotive parts manufacturing, positioning it for sustained growth and market leadership.

A) Factors determined by carrying out factor analysis

A survey-based questionnaire using a five-point Likert scale has been designed and distributed to many MSME industries in the vicinity of Kolhapur and Belagavi, situated in the Indian states of Karnataka and Maharashtra, respectively. We have collected 85 responses & there were also a few one-on-one discussions with the subject matter specialists.

Reliability analysis was then performed using SPSS 20 software to verify the internal consistency of the data collected. The Cronbach's alpha coefficient was calculated, and the

result was 0.811, which is less than the recommended range of $0.7 < \alpha < 0.95$. The factor's identified by factor analysis is as below. [16]

Economy and Efficiency (FI): This factor focuses on efficiently adjusting inventory levels to meet fluctuating demand, streamlining order cycle times to improve overall efficiency, and minimizing lead times for optimal inventory management and order fulfillment.

Service Optimization (FII): Emphasizing customer service excellence, this factor includes ensuring prompt order processing and delivery, collaborating with reliable suppliers to enhance supply chain performance, and maintaining adequate safety stock levels to prevent stockouts and uphold customer satisfaction.

Inventory Stabilization (FIII): To stabilize inventory against demand variability, this factor involves effectively managing inventory levels, reducing lead times to enhance stability, and implementing safety stock buffers to ensure continuous supply.

Cost Reduction (FIV): This factor aims at minimizing holding costs through efficient inventory management practices, reducing ordering costs associated with procurement processes, and optimizing economic order quantities (EOQ) for cost-effective replenishment.

Competitive Ability (FV): Focused on maintaining competitiveness, this factor includes building strong supplier relationships to ensure reliable supply chain performance, enhancing responsiveness through adequate safety stock levels, and leveraging technology for real-time tracking and data accuracy to gain a competitive edge.

B) Applying DEMATEL

STEP 1 & 2:

Here, we have gathered responses according to eqns. 1 and 2, and according to eqns. 3, we have discussed and deliberated with professionals and decision-makers in the Belagavi and Kolhapur regions of Karnataka and Maharashtra, respectively. The pair wise comparison matrix is calculated below.

Table 2. Pair wise comparison of responses

Factors	FI	FII	FIII	FIV	FV	SUM
FI	0	1	3	4	3	11
FII	2	0	2	3	3	10
FIII	4	2	0	4	3	13
FIV	4	3	4	0	3	14
FV	2	3	3	4	0	12

STEP 3:

After dividing each element by the scalar, as per eqns. 3 and 4, the normalization decision matrix, as displayed in table 3 below, is produced, with each element falling between 0 and 1.

Table 3. Normalized Decision matrix (Y)

Factors	**FI**	**FII**	**FIII**	**FIV**	**FV**
FI	0	0.071	0.214	0.285	0.214
FII	0.142	0	0.142	0.214	0.214
FIII	0.285	0.142	0	0.285	0.214
FIV	0.285	0.214	0.285	0	0.214
FV	0.142	0.214	0.214	0.285	0

STEP 4:

Now as per the eqns. 5 the total relational matrix that is $T=Y*(I-Y)^{-1}$ is determined as indicated in table 4 below, where "I" represents the identity matrix in the formula.

Table 4. Total Relation Matrix (T)

FI	1.130	0.941	1.304	1.545	1.269
FII	1.134	0.784	1.136	1.362	1.161
FIII	1.498	1.102	1.271	1.716	1.411
FIV	1.561	1.201	1.557	1.570	1.476
FV	1.314	1.096	1.361	1.615	1.154

STEP 5:

According to the eqns. 6 & 7 the computation of vector Ri & Ci is done respectively for all factors as shown in below table 5.

Table 5. Values of Vector Ri & Vector Ci

Ri	**Ci**
6.1912	6.6403
5.5794	5.1253
7.0012	6.6311
7.3668	7.8110

Ri	Ci
6.5422	6.4731

Also, the computational values of factors and Cause-and-Effect Links that is & Ri-Ci respectively are shown in below table 6. As per the DEMATEL method if Ri+Ci is positive, then the corresponding factor is a 'net causer' and, If Ri-Ci is negative, then the corresponding factor is a 'net receiver' which is also known as effect. So here Factors II, III & V are net causer & remaining I & IV are net receiver.

Table 6. Factors and Cause-and-Effect Links

Factors	Ri+Ci	Ri-Ci	Identity
FI	12.8316	-0.4491	Effect
FII	10.7048	0.4540	Cause
FIII	13.6323	0.3701	Cause
FIV	15.1778	-0.4442	Effect
FV	13.0153	0.0691	Cause

STEP 6:

According to the eqns. 8 threshold value (α) is computed & its values is given below. We can remove some of the minor effects elements of the total relation matrix "T" by setting a threshold value as shown in table 7 below. Key influencers in our analysis are the values that are highlighted.

Average of T matrix & its threshold value(α)	1.3072

Table 7. Major and Minor effects of factors

Factors	**FI**	**FII**	**FIII**	**FIV**	**FV**
FI	1.130	0.941	1.304	1.545	1.269
FII	1.134	0.784	1.136	1.362	1.161
FIII	1.498	1.102	1.271	1.716	1.411
FIV	1.561	1.201	1.557	1.570	1.476
FV	1.314	1.096	1.361	1.615	1.154

STEP 7:

Lastly, to visualize the intricate interdependence, the Cause-and-Effect Relationship diagram is created by mapping all coordinate sets of (Ri+Ci, Ri-Ci). As you can see, factor FI and factor FIV are important elements that are influenced by other factors.

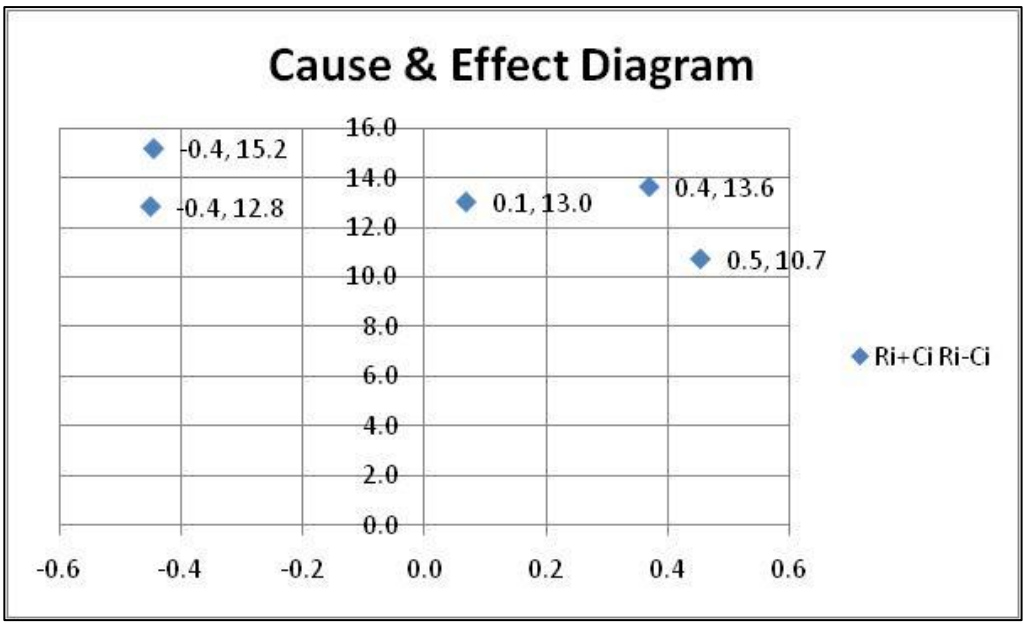

Figure. 2 Cause and effect relationship diagram

IV. RESULT & DISCUSSIONS:

This paper presents a systematic approach to identify the causal relationship between the significant factors of inventory management. The present study is carried out in MSME's located at Belagavi & Kolhapur regions of Karnataka & Maharashtra States of India respectively. In this study, firstly the prominent factors were identified by factor analysis. These factors were considered for applying DEMATEL technique. The factors identified are Economy & Efficiency (FI), Customer service optimization (FII), Inventory Stabilization (FIII), Cost Reduction (FIV), Competitive ability (FV). After application of DEMATEL approach it concludes that in inventory management in MSME "Cost reduction" is the important factor as its Ri+Ci values come out to be highest out of all other factors i.e. 15.1778. Also, it concludes that the factors 'Economy & Efficiency' & Cost reduction" are found out to be dispatcher as their Ri-Ci values are negative i.e. -0.4491 & -0.4442 respectively. The factors "Customer service optimization, Inventory Stabilization & Competitive ability" are found out to be receiver as their Ri-Ci values are positive i.e. 0.4540, 0.3701 & 0.0691 respectively. The causal relationship is shown in Figure2 above.

V. CONCLUSION:

This study provides a comprehensive analysis of inventory management practices among MSMEs emphasizing the pivotal role of key variables such as lead time, holding costs, ordering costs, and economic order quantity (EOQ) in optimizing supply chain management (SCM) performance. These variables are significantly influenced by factors including

supplier performance, safety stock levels, order cycle time, and demand variability. By employing factor analysis and the DEMATEL technique, the study identified five critical factors: Economy & Efficiency (FI), Customer Service Optimization (FII), Inventory Stabilization (FIII), Cost Reduction (FIV), and Competitive Ability (FV).

The analysis revealed that "Cost Reduction" is the most crucial factor, Furthermore, "Economy & Efficiency" and "Cost Reduction" are classified as dispatcher factors whereas "Customer Service Optimization," "Inventory Stabilization," and "Competitive Ability" are identified as receiver factors. Understanding these interdependencies allows MSMEs to implement targeted, alternative solutions that enhance inventory management effectiveness, leading to improved operational efficiency, cost reduction, and competitive advantage. This research establishes a foundational framework for MSMEs to refine their SCM practices, ensuring sustained growth and competitiveness in the dynamic market landscape.

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60. Comparative Analysis of Wear Performance of Ti6Al4V Alloy Produced through Additive Manufacturing and Conventional Casting with Post-Processing Approaches: A Review

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ABSTRACT:

Ti6Al4V alloy has excellent strength-to-weight ratio, high temperature stability, and biocompatibility, which make it a viable option for the chemical, biomedical, automotive, and aerospace industries. Despite having several desirable qualities, the alloy's use is limited to sliding interfaces.

Additive manufacturing (AM) technologies enable the fabrication of innovative structures with complex geometries not easily manufactured by traditional processes. Additive manufacturing Ti6Al4V alloys such as Selective Laser Melting (SLM) are considered for making some Ti6Al4V part for potential applications. In the present study, the wear resistance, hardness and microstructure of Ti6Al4V alloys fabricated using various routes were reviewed. The specifics of the unmodified, 3D and modified by post processing/ surface coating of Ti6Al4V alloy's tribological behavior under varied operating and environmental situations can serve as a starting point for upcoming studies intended to enhance its tribological characteristics. As a result, the current review is an attempt to compile the research done to assess the sliding wear behavior of Ti6Al4V at room and elevated temperatures in both lubricated and dry conditions.

KEYWORDS

Ti6Al4V alloy, Additive manufacturing, microstructure, Tribology.

1. Introduction:

Titanium alloys have wide range of applications for which they have received considerable interest recently because they show an astonishing range of mechanical properties. the Ti6Al4V alloy, which alone covers about 50% of the total world production of titanium alloys and Ti6Al4V alloy is widely used in aerospace, medical, and industrial applications due to its high strength-to-weight ratio, corrosion resistance, and biocompatibility [1].Ti-6Al-4V alloy is the most frequently and successfully used as $\alpha + \beta$. Titanium alloy in various industries due to its many favorable properties, including its high strength to weight ratio, low density and biocompatibility [2]. However, wear resistance of titanium alloys was proved to be poor due to their low shear strength and low work hardening, as well as weak surface oxides protection due to friction heat [3]. Nevertheless, Ti6Al-4V alloy has poor surface wear properties when used in some harsh environments. It limits the product service life in mechanical friction engineering and transmission components for human body, such as hip implants [4].

Additive Manufacturing (AM) is a significant advancement in the manufacturing industry due to its distinct benefits. It enables the production of intricate shapes with almost unlimited design flexibility in a quick design-to-manufacture process [5]. Among AM technologies, Laser Powder Bed Fusion (LPBF) is one of the most widely used for manufacturing metallic parts with good resolution and surface finish [6]. In this technology the laser source selectively melts the powders paved on the substrate layer-by-layer starting from a 3D digital model. Due to its intrinsic deposition principle, the LPBF process induces directionality on the material microstructure as well as on the defects of the manufactured part, causing a marked anisotropy on the artefact mechanical properties. The selective laser melting (SLM) is a novel preparation method, which uses a high energy laser beam to selectively melt metal powder, directly prepares metal parts with metallurgical bonding and has excellent performance [7]. Compared to conventional fabrication techniques, it has advantages of a reduction of production steps, high level of flexibility, high material use efficiency and near net shape production. Ti-6Al-4V is suitable for both selective laser melting (SLM) and electron beam melting (EBM) processes, which are powder bed additive manufacturing techniques. These techniques [8] are increasingly used for rapid prototyping and low volume manufacturing of metallic parts.

The dry sliding wear behaviour of Ti-6Al-4V alloy has been extensively studied by Sharma & Sehgal (2012) [9] under various conditions. Research shows that wear rate generally decreases with increasing sliding velocity and decreasing normal load, with some exceptions Mishra et al (2014) [10] reported that the Ti-6Al-4V alloy exhibits different wear mechanisms depending on sliding velocity, including oxidation wear at low velocities and metallic delamination at high velocities Ndaliman et al [11]. Reported that the severe wear rates are observed under conditions of low disk speed with high input weight and longer sliding distances. Li et al., (2019) [12] concluded that the wear rate is not significantly affected by different processing methods (laser PBF, electron beam PBF, or conventional processing) despite variations in microstructure and hardness. According to Sharma &Sehgal, the coefficient of friction generally decreases with increasing normal load and increases with sliding distance. These findings contribute to understanding the tribological performance of Ti-6Al-4V alloy in various applications, particularly in aerospace and engineering industries.

The wear behaviour of Ti-6Al-4V alloy processed by laser powder bed fusion (L-PBF) and conventional methods has been extensively studied. While Hua Li et al. (2019) [13] found no significant difference in wear rate between L-PBF and conventionally processed samples, other studies reported contrasting results. Jeyaprakash et al. [14] observed that L-PBF specimens exhibited 62.1% lower wear rate and 62.7% less coefficient of friction compared to conventional specimens, attributing this to finer microstructures and higher hardness. Kang et al [15]. Reported lower wear rates for conventionally processed samples compared to L-PBF and laser directed energy deposition (L-DED) samples. Herrera et al. [16] found that electron beam melting (EBM) specimens showed twice the abrasive wear of conventionally processed samples. These studies highlight the complex relationship between processing methods, microstructure, and wear behaviour in Ti-6Al-4V alloy, emphasizing the need for further research to fully understand these interactions.

According to Juan Manuel Vazquez Martinez et al. (2019) [17], by regulating the surface's wettability qualities, laser micro texturing of Ti6Al4V alloy can dramatically improve its sliding wear behaviour in wet environments, lowering friction and wear by as much as 70% in comparison to untreated surfaces. The wear behaviour of Ti-6Al-4V alloy with nitrogen in planting was examined by R Hutchings and W C Oliver [18]. It has been noted that nitrogen implantation can more than 100-fold lower the Ti-6Al-4V wear rate. The development of a thin, low-friction layer of TiO in the wear track is the cause of the increased wear resistance. The wear behaviour of the Ti-6Al-4V alloy under vacuum and high temperature in comparison to SS316L steel was studied by Deepak Kumar (2019) [19]. Because adiabatic shear bands (ASBs) do not form at higher temperatures and a self-lubricating oxide layer form, it has been discovered that the wear rate of Ti-6Al-4V rapidly decreases as the temperature rises from 25℃ to 400°C. The formation of a mechanically mixed layer (MML) on the surface of Ti-6Al-4V reduces wear. Under vacuum conditions, at higher temperatures of 300°C and 400°C, a uniformly distributed and thicker MML (up to 46 μm) formed on the surface of the Ti-6Al-4V pin, greatly reducing wear. In both ambient and vacuum settings, Ashok Raj et al. [20] investigated the dry sliding wear behaviour of Ti-6Al-4V (Ti64) pins against SS316L disks. discovers that, in comparison to no-oxide tribo-layers created at lower temperatures, the oxide coating and dense tribo-oxide layers formed at high temperatures (600°C) both greatly increased the wear resistance of Ti-6Al-4V alloy. The effect of an oxide coating and a tribo-oxide layer on dry sliding wear of Ti-6Al-4V alloy was comparatively studied by Yin Zhou et al. [21] The oxide coating and dense tribo-oxide layers formed at high temperatures (600°C) both significantly improved the wear resistance of Ti-6Al-4V alloy compared to no-oxide tribo-layers formed at lower temperatures.

The wear resistance of Ti-6Al-4V alloy is closely related to the type of tribo-layer formed, with dense tribo-oxide layers providing the best protection X H Cui et al. [22] investigated the impact of temperature on the sliding wear behaviour of Ti-6Al-4V alloy fabricated via different manufacturing techniques. Their research revealed that, despite the alloy's reduced strength and hardness at elevated temperatures, the formation of an oxygen-rich oxide debris layer provided a protective barrier that enhanced wear resistance. This layer, which formed at temperatures up to 600°C, offset the negative effects of reduced strength and hardness, resulting in no significant temperature-related changes in the wear rate. Notably, the oxygen content in the debris increased more rapidly between 400°C to 600°C compared to lower temperatures.

This study highlights the complex interplay between temperature, oxide layer formation, and wear resistance in Ti-6Al-4V alloy. In their study, Mathieu Marquer et al. [23] investigate the effects of machining and SLM orientation on the friction coefficient and wear of Ti6Al4V in high-speed, high-pressure sliding conditions. They discover that, in contrast to machined parts, SLM parts had higher friction coefficients but less wear, and that wear was characterized by a single energy-based pattern independent of the manufacturing method. According to Ashok Raj et al. [24], wear debris morphology evolved during the dry sliding of Ti-6Al-4V against SS316L in both ambient and vacuum conditions. The wear debris characteristics are influenced by the dominant wear mechanisms, which include Adiabatic Shear Band (ASB), Tribo-Chemical Reaction (TCR), and Mechanically Mixed Layer (MML). It was concluded that because of the embedding of hard contaminant particles, the wear debris at low sliding speeds was composed of large chip-like particles and short splintery particles. Higher sliding speeds caused the wear mechanism to change to severe wear, and the wear debris comprised of lump-like particles created by the separation of fin-like ridges. The primary factors influencing the wear behaviour of Ti-6Al-4V are adhesion wear and adiabatic shear band (ASB) formation, which result in coarse wear debris. Tribo-oxidation and mechanically mixed layer (MML) generation, on the other hand, tend to produce finer wear debris. W. Kan et al. [25] compared the sliding behaviour and wear mechanisms of titanium alloys processed by laser powder bed fusion (LPBF) with and without heat treatment, to their conventionally-processed counterparts. The study found that all samples exhibited oxidative, abrasive, and adhesive wear, but wear rates were similar across samples when material removal was primarily due to abrasion and/or adhesion. Notably, martensitic phases decomposed during sliding, while nanocrystalline grains enhanced oxidative wear and reduced friction. The results suggest that a stable nanocrystalline microstructure with ultrahigh hardness can significantly reduce wear rate and friction by promoting oxidative wear over abrasive or adhesive wear. A comparative analysis by Jay Airao et al. [26] examined the impact of microstructure on tool wear during micro-turning of conventionally manufactured and selective laser melting (SLM) or laser powder bed fusion (LPBF) fabricated Ti6Al4V. The study found that SLM Ti6Al4V alloys exhibited greater tool wear compared to work Ti6Al4V due to the instability of the β phase. Ajay Kushwaha et al. [27] studied the effects of build direction on microstructure, microhardness, and wear properties of thin-walled Ti6Al4V parts produced by laser powder bed fusion (LPBF). The results showed that LPBF-processed Ti6Al4V had a harder microstructure with variable wear properties compared to conventional processing. The microstructure contained harder α' and Ti_3Al phases, with a linear relationship between microhardness and wear loss. However, the presence of Ti3Al phase led to poorer sliding wear along the build direction. The mechanical properties of Ti6Al4V fabricated through laser powder bed fusion were examined by F. Bartolomeu et al. [28] with a focus on processing and microstructural parameters. LPBF Ti6Al4V demonstrates high density and superior strength compared to conventional processing techniques. This material meets the necessary tensile property standards for use in implants and aerospace applications, with fatigue properties influenced by part densification, microstructure, and surface condition. In comparison to traditional processing, Xiaojie Shi et al. [29] investigated the impact of laser line energy density (LLED) on the mechanical and tribological properties of Ti-6Al-4V alloy formed by powder bed fusion laser beam. As LLED increases, the phase composition of the Ti-6Al-4V alloy does not change appreciably. The Ti-6Al-4V alloy has a maximum micro-hardness of 388.17 HV0.2 and an ultimate tensile strength of 1197.5 MPa. These properties first increase and then decrease. With an average friction coefficient of 0.15005, a volume wear rate of $6.95x10^{-8}$ mm^2xN^{-1},

a wear mechanism of moderate furrow wear and adhesion wear beneath the aviation lubricant medium, and an optimal LLED of 0.24 J mm-1 for the best wear resistance of the Ti-6Al-4V alloy. W. Toh et al. [30] investigated the microstructure and wear properties of Ti-6Al-4V parts made by electron beam melting (EBM) were and compared to conventionally cast Ti-6Al-4Valloy. It was concluded that the EBM-built Ti-6Al-4V parts exhibit higher micro hardness, larger coefficient of friction, and better wear resistance compared to conventionally cast Ti-6Al-4V. The microstructure and characteristics of the Ti-6Al-4V alloy manufactured by laser powder bed fusion are reviewed by S. Cao et al. [31]. This includes the difficulties in obtaining the right blends of strength, ductility, and fracture toughness. It was determined that regulating the microstructure and characteristics, decreasing porosity, and obtaining high surface quality remain difficult tasks for the LPBF manufacturing of Ti-6Al-4V. The inconsistencies in LPBF Ti-6Al-4V alloy ability to simultaneously achieve high strength/ductility and strength/fracture toughness/creep resistance. A study gap in the understanding of the effects of the growing bi-modal microstructure on the fracture toughness and fatigue characteristics of LPBF Ti-6Al-4V has been discovered by the review. A comparative analysis of Ti-6Al-4V alloy produced by electron beam melting (EBM), selective laser melting (SLM), and conventional forging was conducted by Zhen Wang et al. [32] In comparison to samples that were traditionally forged, they found that the Ti-6Al-4V alloy created using additive manufacturing techniques (SLM and EBM) has better wear resistance. Because the SLM sample had more horizontal cracks that resulted in more tribo-layer delamination, the EBM sample showed a lower wear rate than the SLM sample. Because of its fine microstructure and α martensitic phase, the SLM sample had the maximum hardness. Z. Wanga et al. (2020) [33] investigated the wear behaviour of selective laser melted (SLM) Ti6Al4V alloy after undergoing a direct current assisted ultrasonic surface rolling process (DC-USRP). The study revealed that DC-USRP treatment significantly enhanced the wear resistance of SLM Ti6Al4V alloy, achieving the lowest wear rate and friction coefficient compared to other post-treatments, including heat treatment and ultrasonic surface rolling process (USRP) alone. The DC-USRP treatment demonstrated superior wear performance, making it a promising post-processing technique for SLM Ti6Al4V alloy. The effects of boron addition on the microstructure, hardness, and wear performance of Ti-6Al-4 V alloy produced by laser powder bed fusion additive manufacturing were studied by P. Verma et al. [34] It was that the TiB particles formed from the addition of elemental boron to the Ti-6Al-4V alloy powder during laser powder bed fusion (L-PBF) additive manufacturing enhanced the microstructure, hardness, and wear performance of the final Ti-6Al-4V nanocomposite material. The microstructure, corrosion, and wear characteristics of laser surface melting of Ti-6Al-4V were investigated by Raghuvir Singh et al. (2006) [35] and contrasted with the alloy without treatment. The results demonstrate that, in comparison to the untreated alloy, the Ti-6Al-4V alloy undergoes laser surface melting, which enhances the alloy's microstructure, corrosion resistance, and wear resistance in simulated biofluid (Ringer's solution). The research by Yi Zhu and team [36] delves into the wear performance of metal parts produced via selective laser melting (SLM) and suggests potential research directions to enhance the wear resistance of SLM parts for friction pair applications. SLM-fabricated metal parts exhibit superior wear resistance compared to conventionally processed materials, attributed to their fine grain structure and high hardness levels. In another study, V. Balla et al. [37] investigated the microstructure, mechanical and wear properties of laser surface melted Ti6Al4V alloy and observed thatthe Laser surface melting of Ti6Al4V alloy improves its microstructure, hardness, and wear properties compared to the untreated substrate. The wear performance of laser-clad Ti-6Al-4V alloy with BN powder investigated by P. Molian and

L. Hualun [38] The results showed that laser cladding produced layers with excellent adhesion, high hardness (up to 1600 HV), and 10-200 times improved wear resistance compared to age-hardened and surface-melted Ti-6Al-4V. The enhanced wear performance was attributed to the high hardness and low friction properties of the laser-clad layers. H. Qin et al. [39] conducted a comprehensive literature review on the wear performance of metal materials fabricated by powder bed fusion (PBF) additive manufacturing. The review revealed that PBF materials exhibit higher hardness and wear resistance compared to traditional materials, attributed to their fine-grained microstructure and solid solution strengthening. Additionally, controlling processing parameters can improve the density of PBF parts, further enhancing their wear resistance. Notably, surface porosity in PBF parts can have a positive effect on lubrication conditions by storing lubricating oil and facilitating the formation of lubricating films. The study by M. N. Mokgalakaet al. [40] centred on the application of NiTi intermetallic coatings on Ti6Al4V substrates via laser melting of Ti and Ni elemental powder mixtures. The researchers examined the impact of varying Ti content on the microstructure and wear properties of the coatings. Notably, the wear resistance of the NiTi intermetallic coatings exhibited a significant improvement of up to 80% when compared to the Ti6Al4V substrate. The mechanical property and wear performance of in-situ fabricated gradient titanium oxide ceramic coating on laser surface textured Ti6Al4V alloy was investigated by Shuo Yuan et al. [41] They found that conducting a duplex treatment of laser surface texturing (LST) and thermal oxidation (TO) on Ti6Al4V alloy led to an enhancement in its mechanical properties and wear performance. Additionally, the thermal oxidation (TO) treatment increased the surface hardness and elasticity modulus of the Ti6Al4V alloy. The best wear performance was observed with the duplex treatment of laser surface texturing (LST) and thermal oxidation (DT-Ti6Al4V) in comparison to other treatments (TO-Ti6Al4V, LST-Ti6Al4V, and original Ti6Al4V). In a study by M. Das et al.[42], the microstructure, tribological properties, and in-vitro biocompatibility of composite coatings made of Ti6Al4V alloy reinforced with In situ synthesized TiB-TiN were investigated. The findings indicated that the composite coatings, produced using laser deposition, demonstrate exceptional wear resistance, high rigidity, and biocompatibility, making them potentially suitable for use in orthopedic implants. These composite coatings, with their outstanding in vitro wear resistance, high rigidity, and appropriate biocompatibility, have the potential to be used as materials for load-bearing articulating surfaces in orthopedic implants. The wear properties of selective laser melted Ti-6Al-4V alloy were examined by L. Yao et al. [43] following various heat treatments. The findings indicated that the wear properties were enhanced in samples subjected to solution-aging treatment due to the formation of Ti_3Al nanoparticles, as opposed to the as-built and solution-only treated samples. Zhinan Zhang et al [44] conducted research on the Mechanical Characteristics and high-temperature wear Behavior of Ti6Al4V Alloy Produced by Laser Solid Forming. The study revealed that the Laser solid forming of Ti6Al4V alloy improves its mechanical properties and high-temperature wear resistance in comparison to traditional processing. In a study by S A Kumar et al. [45], they investigated the fretting wear characteristics of Laser Peened Ti-6Al-4V alloy. The findings indicated that subjecting the Ti-6Al-4V alloy to laser peening post processing leads to enhanced fretting wear resilience through the augmentation of surface hardness, generation of compressive residual stress, and heightened resistance to plastic deformation. The wear behavior of nitrogen-implanted and nitrided Ti6Al4V alloy was compared by R. Martinella [46] et al and it was discovered that both treatments can enhance wear resistance. It was found that nitriding at higher temperatures is more effective than implantation. In a study by Yun Tian et al. [47] the wear and oxidation resistance of composite coatings fabricated

on Ti-6Al-4V using B+Ti and B+Ni+Ti mixed powders through laser surface alloying technique was investigated. The findings indicate that compared to the uncoated Ti-6Al-4V alloy, the coatings exhibited high hardness, exceptional wear resistance, and impressive oxidation resistance. Additionally, it was observed that the coatings produced with the B+Ni+Ti powder mixture displayed superior wear and oxidation resistance properties in comparison to the coatings produced using the B+Ti powder mixture. H. McKellop et al. [48] examined the wear behavior of ion-implanted Ti-6A1-4V in relation to UHMW polyethylene. The study concluded that nitrogen-ion-implanted Ti-6Al-4V exhibited decreased metallic wear when interacting with UHMW polyethylene, although the long-term durability of the implanted layer requires additional investigation. In a study by D. Sharma et al. [49], the dry sliding wear characteristics of Ti-6Al-4V alloy parts manufactured via electron beam melting (EBM) were examined, along with the impact of various post-processing heat treatments on the wear performance of EBM components. The findings indicate that specimens that underwent water-quenching subsequent to heat treatment exhibited the least amount of wear. Conversely, samples that were furnace-cooled following heat treatment demonstrated the highest wear, attributed to their coarser microstructure and reduced microhardness.

The predominant wear type observed in most samples was abrasive wear, while the furnace-cooled sample above the β transus temperature displayed adhesive wear and delamination. H. Li et al. [50] conducted a study on the wear performance of Ti-6Al-4V alloy manufactured through powder bed fusion (SLM, EBM) and conventional methods at temperatures up to 600 °C. The findings revealed that the formation of an oxygen-rich oxide debris layer at elevated temperatures served as a protective coating, enhancing the wear resistance of Ti-6Al-4V alloy specimens, despite the decreased strength and hardness at high temperatures. The presence of this protective oxide layer, along with the lower strength and hardness, resulted in no significant impact of temperature on the wear rate of the Ti-6Al-4V alloy. The investigation by B. Meier et al [51] delved into the effects of process parameters, print orientation, and post-process treatments on the microstructure, physical, and mechanical properties of Ti6Al4V processed through laser powder bed fusion. The researchers managed to optimize the process parameters to achieve a high relative density and significantly enhance surface roughness, particularly through the use of electrochemical polishing. While yield and tensile strength exhibited minimal anisotropy, build orientation strongly influenced ductility and fracture behaviour, with the as-built and stress-relieved conditions displaying brittle fracture behaviour. Heat treatments, such as furnace annealing and hot isostatic pressing, were effective in increasing ductility and reducing strength anisotropy, with angled samples showing behaviour closer to the vertical orientation than the horizontal orientation.

II. Conclusion:

The aim of this research review was to compare the behaviour of conventional, 3D-printed and post processed Ti6Al4V alloys under severe tribological loading conditions. Additive manufactured Ti6Al4V alloy often exhibits superior wear resistance compared to its conventional counterpart. This improvement is attributed to the unique microstructure and finer grain size produced during the additive manufacturing process, which can enhance the material's hardness and reduce wear.

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61. Economic Volatility in the Wake of the Russia-Ukraine War: Analyzing Macro Economic Trends and Market Dynamics

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ABSTRACT:

This study examines the multifaceted impacts of the Russia-Ukraine war on global economic indicators from February 2022 to June 2024. The primary objectives include analyzing the effect of the conflict on inflation rates across major economies, investigating the correlation between inflation and stock market indices, and assessing the war's influence on market volatility. Utilizing secondary data from journal articles and reputable sources, the research explores key variables such as food inflation, general inflation, GDP, interest rates, and market volatility. Findings reveal a substantial increase in food inflation and commodity prices during the early phase of the war, with a subsequent decline in food prices and a varying trend in global commodities. Inflation peaked in several major economies but showed signs of stabilization by mid-2024. The study also identifies an inverse relationship between inflation and stock market indices, indicating that rising inflation adversely impacts stock markets. Moreover, the analysis highlights a notable increase in market volatility coinciding with the onset of the conflict. The results underscore the interconnectedness of economic indicators and the significant influence of geopolitical events on global economic stability. These insights are essential for policymakers and investors to navigate the complexities of economic uncertainty and develop strategic responses.

1. Introductions:

History has witnessed that War has terrible effects on a nation, including human casualties, physical harm, and mass migration, destruction of physical capital and public infrastructure, and hindered economic growth.

The repercussions of Russia's invasion of Ukraine, which triggered the largest conflict in Europe since World War II, are still being felt around the world. In addition to causing a geopolitical realignment, the war in Ukraine has also adversely impacted economies away from the immediate lines of conflict.

1.1 History of War:

After Russian and Mexican revolution in early nineties, World War 1 had disrupted the socio-economic development of various countries apart from mass destruction and thousands of casualties. Even while most of the main European superpowers' governments were still monarchies in 1914, they had all undergone a significant industrialization. In terms of productivity and inventiveness, the production of products, machinery, and weapons had reached an all-time high. A major conflict looked unavoidable given the abundance of modern technologies and military hardware.

The assassination of Archduke Franz Ferdinand of Austria-Hungary was only the spark that ignited an already impending war; numerous covert agreements and alliances had already been made before the war started. By the time trench lines were established, no side had achieved much ground because these alliances were already set up and every nation was prepared for war. Both sides' armies suffered devastating losses.

Around 1920s Russian, Chinese and Spanish civil war, Irish and Turkish wars of independence were fought. In Germany, poverty, unemployment, and crime were major issues during the 1920s. The country was able to unite behind Adolf Hitler owing to the opportunity and promise provided by strong Nazi nationalism coupled with accumulated blame and hatred for the Jewish people. While Germany's economy was recovering, the Great Depression of the 1930s devastated the economies of other Western powers. Nazi Germany began to arm itself for a prolonged military struggle, essentially starting in 1933, due to coordinated military development under Hitler's leadership.

World War II was, in many ways, a continuation of the First World War, engaging almost all nations, with only a handful remaining neutral. It was fought in four main areas, or stages, including the Middle East and Mediterranean, which also featured some engagements in Africa, Western European Theatre, Eastern European Theatre, Pacific Theatre in Eastern Asia, and Eastern Asia.The two largest errors made by the Axis forces during the war were the rupture of the alliance with Europe and the attack on Pearl Harbor.

The conclusion of the war was inescapable once the Americans sided with the British in the West against the Germans and began battling the Japanese in the Pacific, particularly after the Soviet Union forced the Germans to flee in the East. The Germans and their Axis allies have been portrayed as villains by history when it comes to the Holocaust's crimes and their roles as the war's first aggressors; yet, this is despite the persistent airstrikes and firebombing attacks carried out by the American and British forces.The Soviet Union and its Warsaw Pact allies and the United States and its NATO allies were at war during the Cold War on social, political, and military frontiers. Although neither nation launched full-scale military assaults, there were a number of significant regional military battles, and both nations prepared for a full-fledged nuclear world war. After its Warsaw Pact Allies began to strive for independence and its economic foundation fell apart, the Cold War finally came to an end in 1991.Various other wars after the cold war like Korean, Algerian, Vietnam, Soviet-Afghan, Iran-Iraq, Gulf and Croatian war of independence between 1991-1995 had disrupted societies and brought injuries and deaths, violence, hunger and malnutrition and various illnesses.

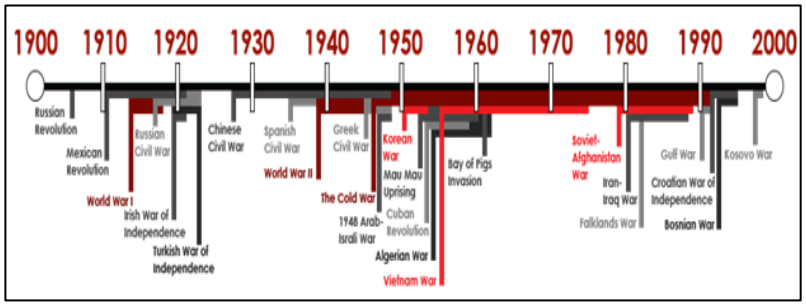

Figure 1 Timeline of War

Despite of these wars as shown in the above Figure 1, major economies of the world have grown substantially over the century.Due to their weak fiscal positions, the most of post-conflict nations are unable to provide internally financed subsidies. But then many financially sound economies have provided financial support to these nations which helped their economy to grow. The below Figure 2 shows how the global GDP per capita increased in the century despite several war conflicts.

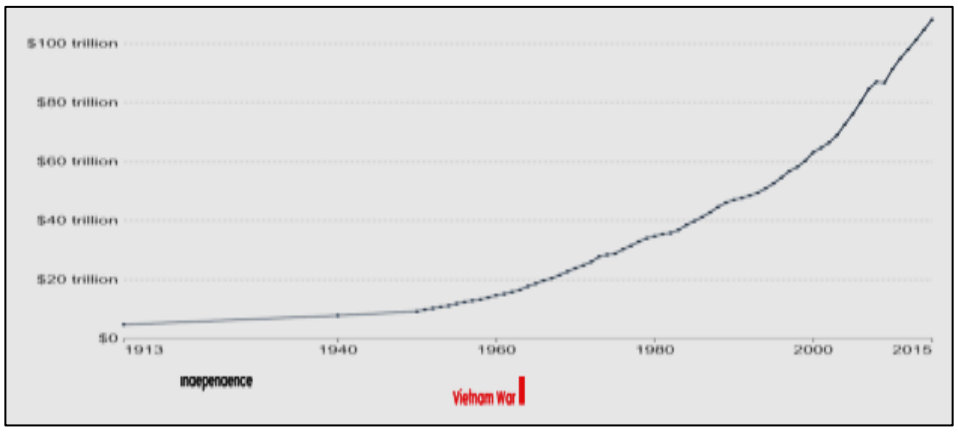

Figure 2 Global GDP per capita

The study aims to examine whether global economies have started to recover or whether they are indicating any sign of revival as still the Russia-Ukraine war continues.

2. Literature Review:

Colin O'reilly state that nevertheless, the association between investment/ GDP and per capita GDP growth becomes considerably greater once economic institutions have been strengthened, indicating that the significance of investment in post-conflict recovery is reliant on the strength of economic institutions.

The research indicates that in a post-conflict country with a high score for property rights, a small increase in investment or GDP will result in an increase in yearly per capita growth [1].

Nearly as extraordinary as the tale of the war appears to be the tale of the Soviet Union's post-war years of recovery. The USSR won in 1945 with more than 25 million deaths, but quickly came back to its previous form. Political and economic movement picked up again. Rapid post-war economic recovery in the Soviet Union was evidence of economic resilience [2].

Economic historians have credited the British rearmament program of 1935–1938 with playing a crucial role in fostering economic recovery. This research develops a model (a Social Accounting Matrix) to handle this issue in an effort to fill in this gap. The model is briefly described, and its applicability to the post-war era is addressed.

The creation of a Social Accounting Matrix (SAM) for I935 is described in an appendix. The basic exercise's findings indicate that over I935-8, rearmament generated nearly a million man-years of employment. The disaggregated analysis reveals that iron and steel, coal, and engineering were the program's main beneficiaries [3].

Angola's transition to a market economy and democracy has finally started after 20 years of civil conflict and the destruction that followed. Individuals now anticipate higher real incomes as a result of the war's end. But as a first step, the consolidation of peace comes with expenses that must be paid, including those related to demobilizing the military, repairing the infrastructure, and modernizing the nation. Therefore, one could attempt to measure the expectation of peace by speaking to economic agents [4].

Beirut was rebuilt after a devastating 16-year civil war. The author of this piece examines the basic demographic shifts that underlie Lebanon's internal power struggle as well as the factors that led to the destruction of the city. Plans for rehabilitation that are currently being carried out intended for a brand-new, tranquil Beirut.

Despite their intentions, the plans do not address the fundamental conflicts in the religiously and economically divided Lebanese nation. The author then evaluates the chances of Beirut's economic revival in light of the regional political climate at the time [5].

The ultimate weapon in the fight against the depression is not war. Since war, to the detriment of any meaningful discussion about the source of the recovery, the astonishing extent and vigor of the German corporate rebirth has been almost completely attributed to rearmament.

The "motor-car revolution" and how it influenced the German economy in the 1930s is a long-forgotten topic that at the time took on a very real significance. The purpose of the study was to explore the nature of these impacts and show how, along with rearmament, the motor road and the motor car were crucial in starting and maintaining the upswing in Germany during I932 and I938[6].

It is commonly known how far Britain's economy recovered in the 1930s. Late in 1932, the economy started to recover from the Great Depression, and this boom lasted until 1937, when another slump hit just before the Second World War. A minor contribution from exports, which saw some improvement from the pitiful levels to which they had sunk during the Great Depression, helped to support the recovery in this decade, which was mostly based

on the rise of the consumer goods sector and the construction industry. In comparison to the majority of the top capitalist economies, the decade's rate of economic growth appears to have been relatively significant overall [7]

Objectives of the study:

1. To analyze the impact of the Russia-Ukraine war on the inflation rates of major economies.
2. To examine the correlation between inflation and stock market indices.
3. To assess the effect of the Russia-Ukraine war on volatility.

3. Methodology:

The study is conceptual in nature and uses secondary data from various journal articles and websites. The time frame of the data of economic indicators has been taken from the beginning of the Russia-Ukraine war, i.e., from February, 2022 to June 2024. The variables considered for the study are Food Inflation, Inflation, GDP, and Interest rates and volatility.

4. Discussion:

4.1 Food Inflation:

The below figure 3 shows the prices of a basket of food commodities internationally sourced from Food and Agriculture Organization (FAO) of the United Nations. The FAO Food Price Index (FFPI) was 92.6 in April 2020 and rose to 159.8 points in March 2022.

Further declined to 118 points in January 2024. This drop in prices index is due to the fall in the price indices of dairy, cereals and vegetable oils, whereas the prices of sugar and meat were relatively stable.

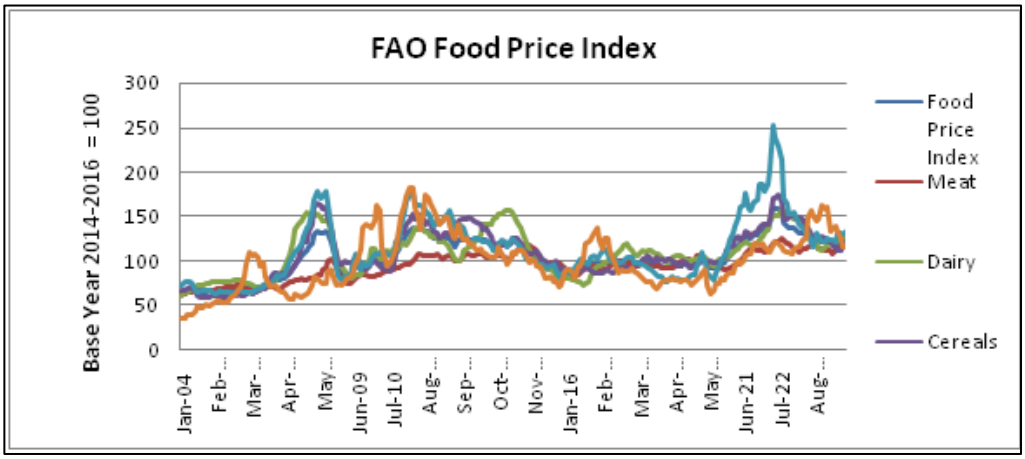

Figure 3 International Food Prices

Global Commodities: The below figure 4 shows the global commodities prices considering the base year 2016 price as 100. Fuel and Non-fuel commodities prices in the month of July 2020 were 103 which rose to the peak of 242 in August 2022. The index eased to 163 in the month of November 2023. Similar is the case with Industrial inputs, base and precious metals.

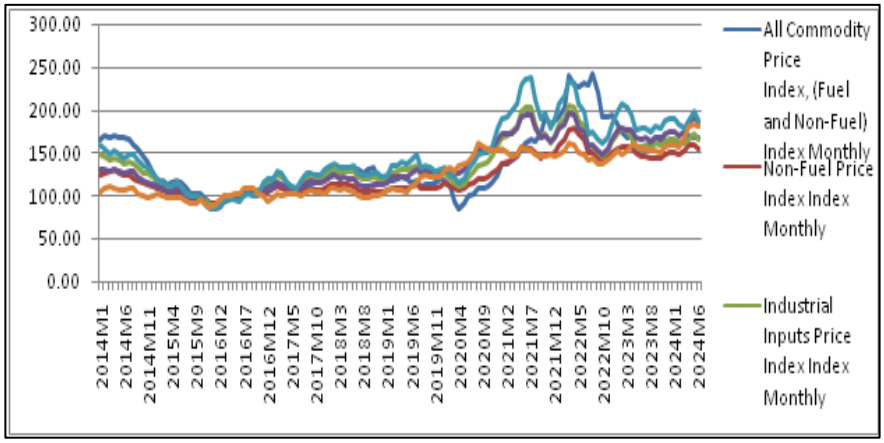

Figure 4 Global Commodities Prices

Inflation: The below figure 5 shows the inflation of leading countries. Inflation of European Union which touched peak of 11.5% in October 2022 declined to 10% in the month of January 2023. U. K's inflation eased to less than 6% in April 2024. Inflation of US was at its peak, 9.06%, in the month of June 2022 which eased down less than 4% in the month of April 2024.

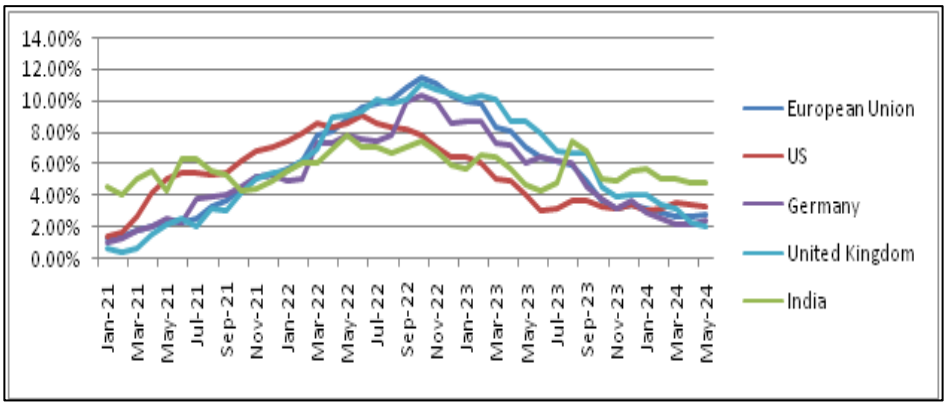

Figure 5 Leading Countries Inflation

4.2 Real GDP Growth Rate (Annual):

World Economic Outlook (2024) data released by IMF World as shown in the below figure 6 state that United States GDP stood at 0.1% in 2023fell from 8.7% in 2021, stabilized again to 2.7% in 2024.United Kingdom's GDP stood at 1.9% in 2022 fell from 5.8% in 2021, stabilized again to 0.5% in 2024.India's GDP stood at 7% in 2022 fell from 9.7% in 2021, stabilized again to 6.8% in 2024.

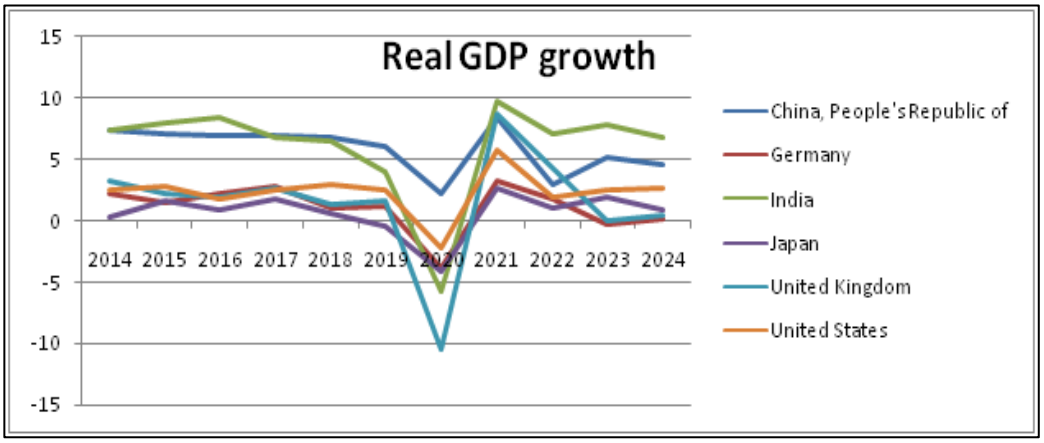

Figure 6 Global Real GDP Growth Rate (Annual)

4.3 Interest Rates:

The below figure 7 shows the hike in Interest rates of leading countries.CentralBanks of leading countries have hiked interest rates continuously since March 2022. The key rates started to rise from 0 to 1% in the US, Australia, Great Britain and Euro-Zone to the range of 4% to 5%.

Figure 7 Leading Countries Interest Rates

4.4 Exchange Rates:

The below figure 8 shows Exchange rates of leading countries. US Dollars began appreciating greatly against major currencies like Indian Rupees, Great Britain pounds, Euro and Yuan from 2022 and reached to their peak in mid-2023 and have been easing 2024.

Figure 8 Exchange Rates

4.5 Correlation between inflation and stock market indices

Table 1 correlation between U.S. Inflation and S&P 500 Index

Correlations			
		U.S. Inflation	S&P 500 Index
U.S. Inflation	Pearson Correlation	1	-.664**
	Sig. (2-tailed)		.000
	N	41	41
S&P 500 Index	Pearson Correlation	-.664**	1
	Sig. (2-tailed)	.000	
	N	41	41
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 2 Correlation between U.K. Inflation and FTSE 100 Index

Correlations			
		UK Inflation	FTSE 100 Index
UK Inflation	Pearson Correlation	1	-.187
	Sig. (2-tailed)		.242
	N	41	41
FTSE 100 Index	Pearson Correlation	-.187	1
	Sig. (2-tailed)	.242	
	N	41	41

Table 3 Correlation between Indian Inflation and Nifty

Correlations			
		India Inflation	Nifty
India Inflation	Pearson Correlation	1	-.104
	Sig. (2-tailed)		.517
	N	41	41
Nifty	Pearson Correlation	-.104	1
	Sig. (2-tailed)	.517	
	N	41	41

Above tables 1, 2 and 3 show the correlation between U.S. Inflation and S&P 500 Index, Correlation between U.K. Inflation and FTSE 100 Index and Correlation between Indian Inflation and Nifty respectively.

The r values of all the correlations are negative indicating an inverse relationship between the variables. Hence it can be inferred that inflation affects negatively on stock markets.

4.6 The effect of the Russia-Ukraine war on volatility

Figure 9: India VIX Index - One year before and After the Event (February 24, 2022)

The above figure 9 illustrates the effect of war on volatility of the stock market. The figure clearly indicates that India VIX was at its peak when the news broke out regarding Russia's invasion on 24th February 2022.

5. Conclusion:

The study provides a comprehensive analysis of various economic indicators and their fluctuations over recent years. Several key findings emerge from this analysis.The study highlights significant recent fluctuations in global economic indicators, emphasizing the interconnected nature of food inflation, commodity prices, inflation rates, GDP growth, interest rates, and exchange rates. The negative impact of inflation on stock markets and the effect of geopolitical events on volatility underscore the complexity of the global economic environment. These insights are crucial for policymakers and investors to navigate economic uncertainties and make informed decisions.

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62. Effect of Carbon Fiber Composition on Mechanical and Wear Properties of Hybrid Polymer Composite

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ABSTRACT:

Today, polymer composites play a crucial role in manufacturing due to their lightweight and strong properties. Various matrices for reinforcement, such as epoxy, are available; however, their high cost limits their use in some applications. Instead, materials like polyester resin can be utilized to enhance properties, and filler materials can be incorporated based on the specific application. In this work, we aimed to develop polyester composites with carbon fiber in different compositions to improve strength. The mechanical properties are analyzed, and the wear behavior of the material is examined.

1. Introductions:

Polymers are widely utilized across all economic sectors, and this trend is rapidly increasing. However, polymers often lack certain properties necessary to meet specific product application requirements. The incorporation of additives has been regarded as a cost-effective, quicker, and simpler method to enhance the properties of polymers. Since the introduction of polymers as commodity materials on an industrial scale, blends of polymers and fillers have been employed [1]. Nevertheless, intensive research into advanced composites began in the late 1970s, driven by the need for stronger, lighter, and corrosion-resistant materials for defense applications, with substantial funding from the

Ministry of Defense. Thermosetting matrices have been extensively utilized in fiber-reinforced composites and hold the largest market share in this category of materials. With the advent of nano-sized particles, the focus of composite research is beginning to shift towards nano composites, and efforts are underway to unlock their full potential [1]. In polymer composites, fillers are materials that can lead to significant weight savings. Compared to resins and reinforcements, fillers are the most cost-effective of the primary components, and these materials play a crucial role in determining the composite's performance for several reasons.

- Filler minimizes the shrinkage of composites.
- Filler affects fire resistance.
- Filler decreases the cost of composites by reducing the amount of costly resin and reinforcing fibers.
- Filler transfers stresses between the matrix and reinforcement in a composite, thereby enhancing mechanical and physical performance.
- Crack resistance and prevention properties are improved with the filled resin system [2].

III. OBJECTIVES:

Fabrication of a hybrid polymer composite using S-glass, carbon fiber, and polyester has a base matrix (hand lay-up technique). The fabrication of the hybrid polymer composite varies the weight percentage of carbon fiber from 0, 2.5, 5.0, 7.5, to 10%. This study aims to understand and characterize the various mechanical and tribological properties of the hybrid polymer composite in accordance with ASTM standards.

IV. MATERIALS AND METHODOLOGY

Materials used Carbon Fiber:

- Carbon fibers of 200 GSM are utilized.
- Bi-directional Mats made of carbon fibers are employed.
- Sourced from Vijay Trading Corporation, J.C. Road, and Bengaluru.

Glass Fiber:

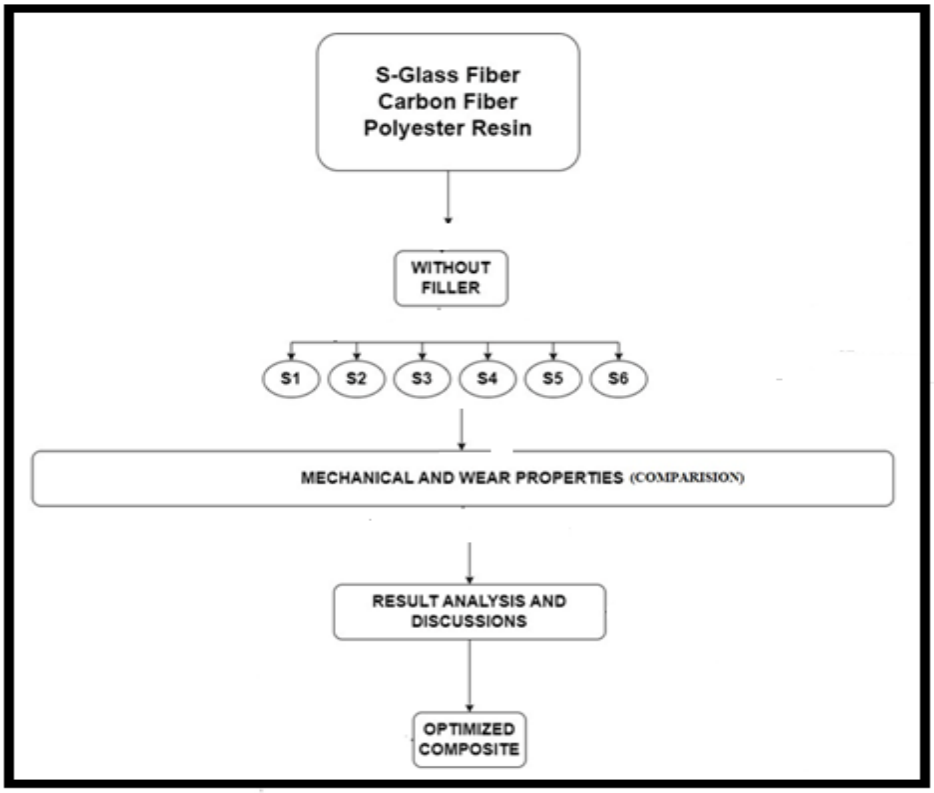
- S-Glass fibers of 200 GSM are utilized.
- Bi-directional Mats made of carbon fibers are employed
- Sourced from Vijay Trading Corporation, J.C. Road, and Bengaluru.

Resin:

- Unsaturated Polyester.
- Methyl Ethyl Ketone Peroxide (MEKP).
- Cobalt Napthanate as an oxidizer.
- Procured from Leo Enterprise, Nagercoil, And Tamil Nadu.

V. SPECIMENS STANDARDS:

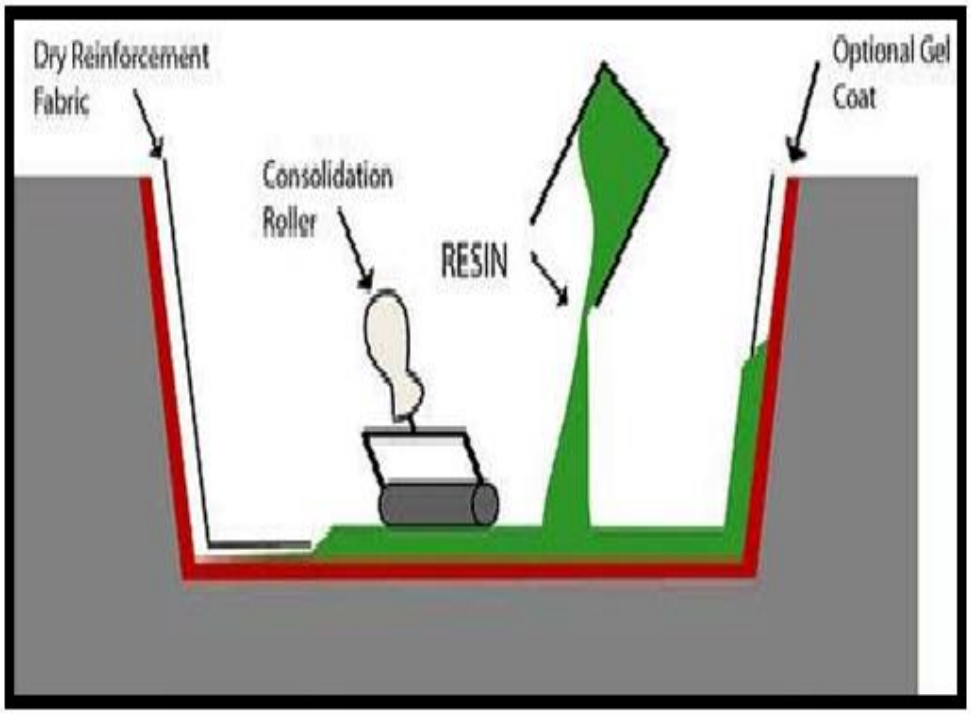
Test Specimen	GF Wt.%	CF Wt.%	Resin Wt.%
1	**90**	**0**	**10**
2	**0**	**90**	**10**
3	**50**	**2.5**	**47.5**
4	**50**	**5**	**45**
5	**50**	**7.5**	**42.5**
6	**50**	**10**	**40**



Methodology

VI. FABRICATION OF COMPOSITE BY HAND LAY-UP TECHNIQUE

Hand lay-up is an open molding technique ideal for creating a diverse range of composite products, from very small to very large. Although the production volume per mold is low, it is possible to achieve significant production quantities by utilizing multiple molds. Hand lay-up is the most straightforward composite molding method, providing low-cost tooling, uncomplicated processing, and accommodating a wide variety of part sizes [3].



Hand Layup Technique (www.researchgate.net)

VII. MECHANICAL TESTS

1. Tensile Test

Specimens for Tensile test:

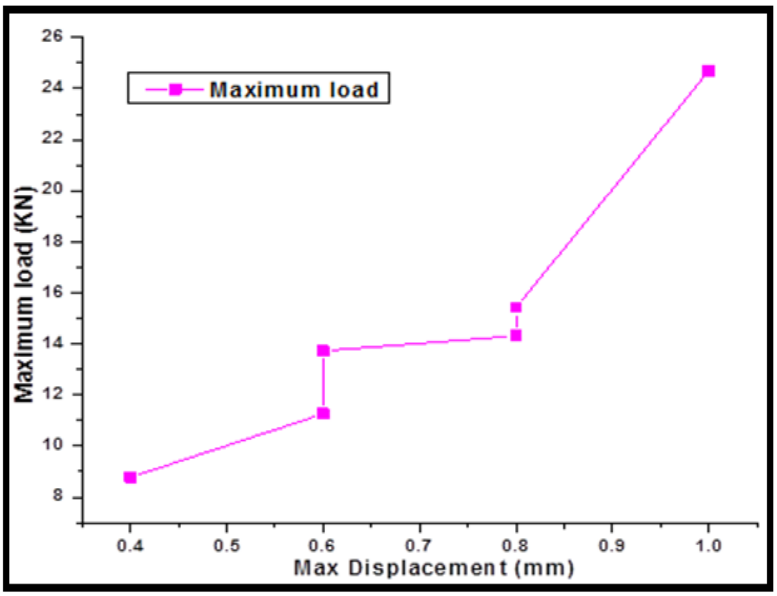
ASTM D638

Specimen dimensions: 165mmX13mmX3.5mm (Gauge Length=50mm)

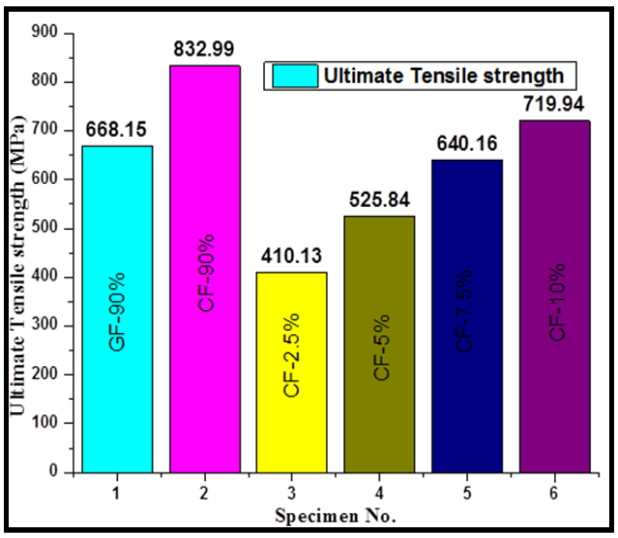
No.	Content (%)	Maximum load (KN)	Max Displacement (mm)	Ultimate Tensile strength (MPa)
1	GF=90%	14.32	0.8	668.15
2	CF=90%	24.68	1.0	832.99
3	2.5%	8.79	0.4	410.13
4	5%	11.27	0.6	525.84
5	7.5%	13.72	0.6	640.16
6	10%	15.43	0.8	719.94

Effect of carbon fiber contents on tensile strength of fabricated composites.

Tensile Test Graph:



Max. Load Vs. Displacement For Tensile Test



Ultimate Tensile Strength Vs. No. of Specimens

Tensile Test Result Analysis

- The tensile properties of the composites are influenced by the materials, method, specimen condition, preparation, and the percentage of reinforcement.
- The tensile strength increased from 668.15 MPa to 719.94 MPa, with the maximum tensile strength observed in the composite containing 90% carbon fiber.

- The tensile strength of the fabricated composite largely depends on the interfacial bonding strength between the matrix and reinforcement, as well as the inherent properties of the composite ingredients.
- The tensile strength of the specimen with 10% carbon content is 719.94 MPa, compared to those with 2.5%, 5%, and 7.5% carbon content.

2. Flexural Test:

The test measures the force needed to bend a beam under three-point loading conditions.

- It provides values for the modulus of elasticity in bending, flexural stress, and the flexural strain of the material [4].

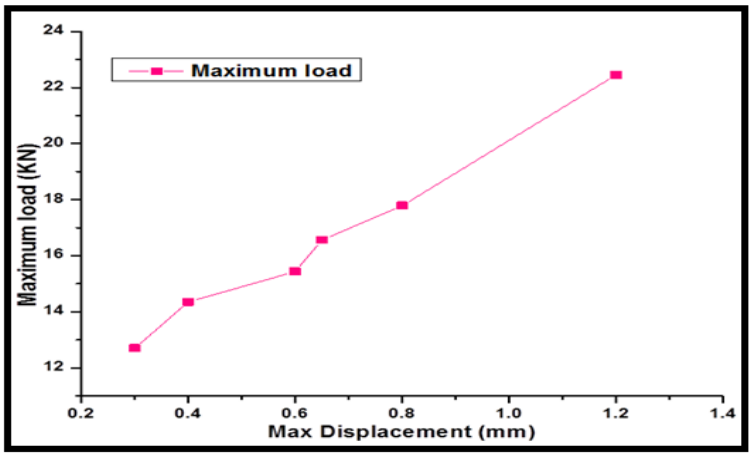
Specimens for bending test: ASTM D7264

Specimen dimensions: 130mmX13mmX3.5mm

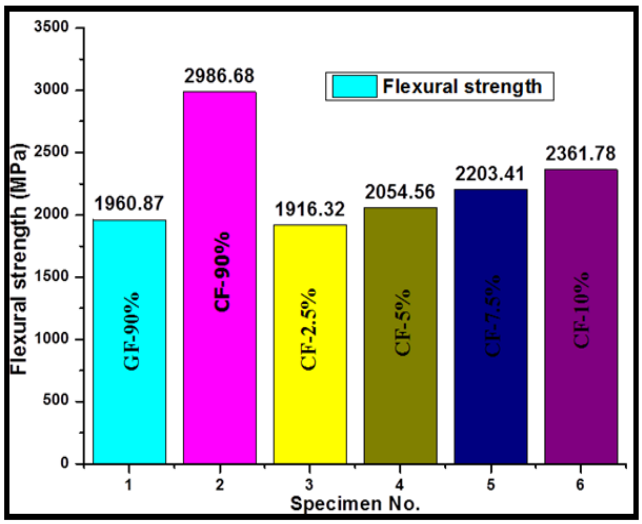
No.	Content (%)	Maximum load (KN)	Max Displacement (mm)	Flexural strength (MPa)
1	GF=90%	12.70	0.3	1960.87
2	CF=90%	22.45	1.2	2986.68
3	2.5%	14.35	0.4	1916.32
4	5%	15.43	0.6	2054.56
5	7.5%	16.56	0.6	2203.41
6	10%	17.78	0.8	2361.78

Effect of carbon fiber contents on flexural strength of fabricated composites

Bending Test Graph:



Maximum Load Vs Displacement for Flexural Test



Flexural Strength Vs. No of Specimens

- Bending properties of the composites are influenced by the materials, method, specimen condition and preparation, as well as the percentage of reinforcement.
- It was observed that the bending strength increased from 1960.87 MPa to 2986.68 MPa, with the maximum bending strength achieved by the composite containing 90% carbon fiber, which exhibited a bending strength of 2986.68 MPa.
- The composite with 10% carbon content has a bending strength of 2361.78 MPa when compared to specimens with 2.5%, 5%, and 7.5% carbon fiber content.
- The bending strength of the fabricated composite largely depends on the interfacial bonding strength between the matrix and reinforcement, as well as the inherent properties of the composite materials.

3. Impact Charpy Test

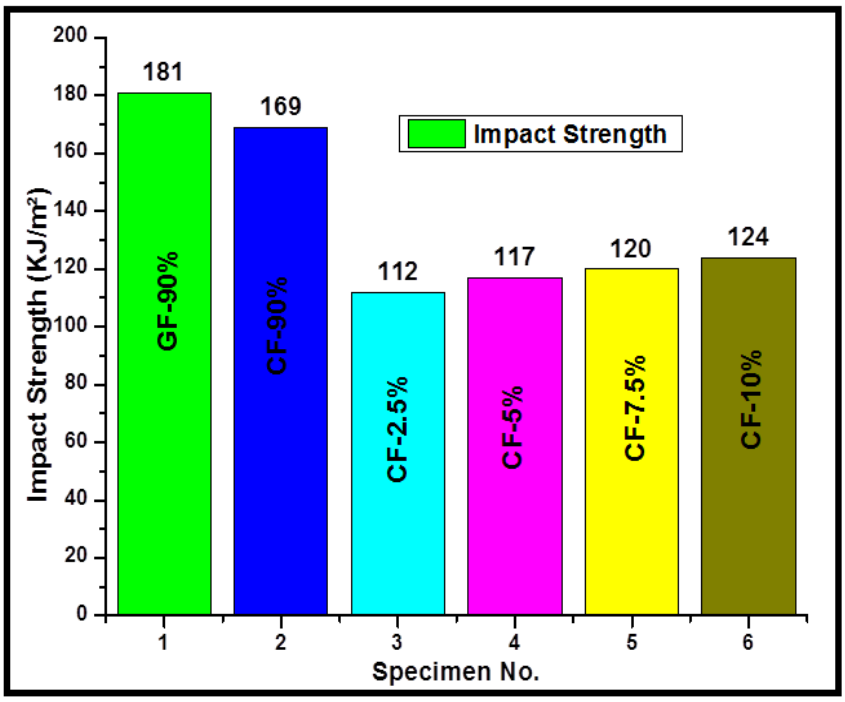
In materials science, the Charpy impact test, also referred to as the Charpy V-notch test, is a standardized high strain rate test that measures the energy absorbed by a material during fracture. This absorbed energy indicates the material's notch toughness. It is widely utilized in industry due to its straightforward preparation and execution, allowing for quick and cost-effective results [5].

Impact Strength Results

ASTM D6110-18		
Specimen dimensions: 130mmX13mmX3.5mm		
Sample No.	**Content (%)**	**Impact Strength KJ/m²**
01	**GF=90%**	**181**
02	**CF=90%**	**169**

ASTM D6110-18		
Specimen dimensions: 130mmX13mmX3.5mm		
Sample No.	**Content (%)**	**Impact Strength KJ/m²**
03	**2.5%**	**112**
04	**5%**	**117**
05	**7.5%**	**120**
06	**10%**	**124**

Impact Test Results



Impact Strength Vs No. of Specimens

Impact Test Result Analysis

- One of the significant drawbacks of composite material is the damages caused due to impact load.
- It is essential to understand the effect of an unsymmetrical stacking sequence of carbon/glass fiber on the composite energy absorption or damage-tolerant behavior.
- The notch was not created on the plain and hybrid composites samples. This is because; creation of 1.5 mm depth of notch will eliminate the hybrid effect of carbon fibre on the impact resistance of the composites.

- It is observed that with the increase in glass fibre layers, the amount of deformation in the composites increases and vice versa.
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- It is observed that with the increase in glass fiber layers, the amount of deformation in the composites increases and vice versa.

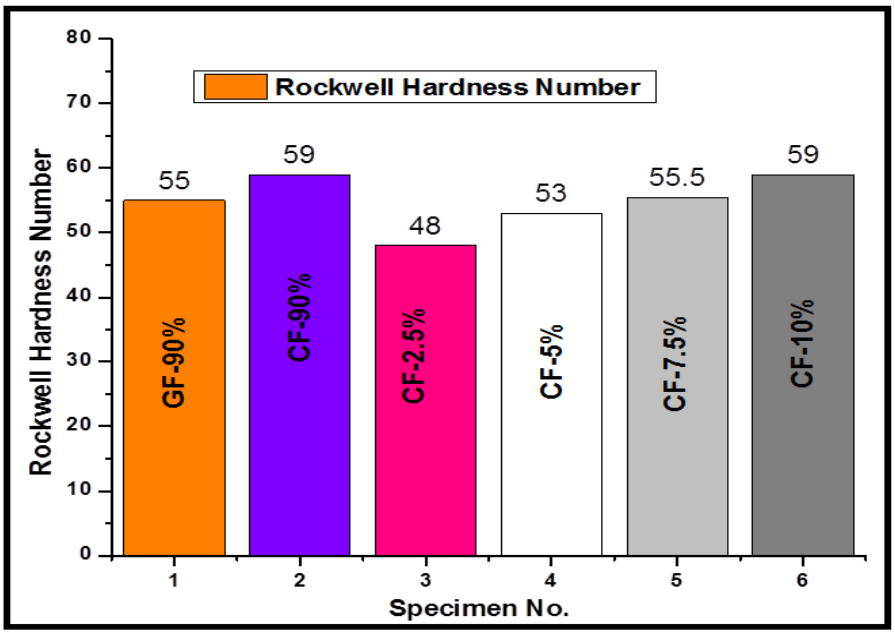
4. Rockwell Hardness Test:

The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test measures the depth of penetration of an indenter under a large load (major load) compared to the penetration made by a preload (minor load).

There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, HRB, HRC, etc., where the last letter is the respective Rockwell scale. Larger numbers correspond to harder materials [6]

Specimen dimensions: 25mmX25mmX3.5mm			
Load:187.5N			
Sample No	**Contents (%)**		**RHN**
01	**GF=90%**		**55**
02	**CF=90%**		**59**
03	**2.5%**		**48**
04	**5%**		**53**
05	**7.5%**		**55.5**
06	**10%**		**59**

Hardness Test Results



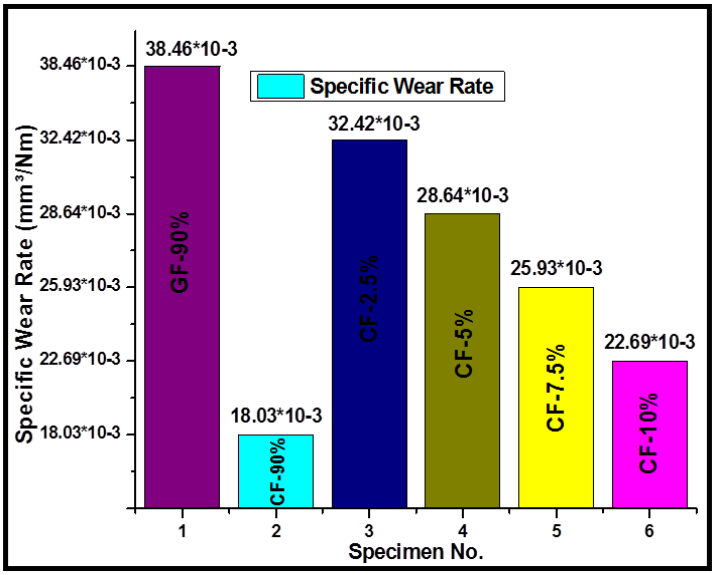
Rockwell Hardness Number Vs No. of Specimens

Hardness Test Result Analysis: From the findings, it is evident that carbon fiber composites exhibit greater toughness compared to other composites. In contrast, glass fiber composites demonstrate lower toughness than carbon fiber composites. Specifically, a carbon fiber composite containing 10% carbon exhibits a toughness of RHN 59 higher than other composites. Therefore, composites containing carbon are suitable for applications involving ballistic.

5. **Dry Abrasive Wear Test:** Abrasive wear is the type of wear mechanism that results in the disintegration of the material on the surface due to the influence of the hard particle in contact with the surface. It also occurs when a hard surface or particles interacts or slides on the soft surface and causes material loss. This is a type of the wear that occurs due to the loading of solid particle on the surface of the material which is having hardness that is equal or lesser compared to the loaded particle [7].

ASTM: G65		
Specimen dimensions: 70mmX25mmX3.5mm		
Sample No	**Contents (%)**	**Specific Wear Rate mm^3/Nm**
01	**GF=90%**	**$38.46*10^{-3}$**
02	**CF=90%**	**$18.03*10^{-3}$**
03	**2.5%**	**$32.42*10^{-3}$**
04	**5%**	**$28.64*10^{-3}$**
05	**7.5%**	**$25.93*10^{-3}$**
06	**10%**	**$22.69*10^{-3}$**

Abrasive Wear Test Results



Specific Wear Rate Vs No. of Specimens.

Dry Abrasive Wear Test Result Analysis

The specific wear rate of glass fiber composites is higher compared to other composites. Carbon fiber composites exhibit a lower specific wear rate. This indicates that carbon fiber composites offer greater resistance to wear compared to other composites. A composite containing 10% carbon has a specific wear rate of 22.69x10.-3. Therefore, these composites are suitable for applications such as brake liners, gears, and brake shoes.

VIII. CONCLUSION:

- The study on the mechanical behavior of glass, carbon fiber reinforced polyester resin composites yields these findings:
- This research demonstrates that it is feasible and cost-efficient to produce glass and carbon fiber reinforced polyester composites with random orientation and varying fiber contents using a simple hand lay-up technique.
- The study observed fluctuations in tensile strength from 668.15MPa to 832.99 MPa and in flexural strength from 1960.87MPa to 2986.68MPa.
- The composite with 10% carbon content exhibits an ultimate tensile strength of 719.94Mpa and a flexural strength of 2361.78Mpa, surpassing other composites.
- Increasing the carbon fiber content gradually enhances the load-carrying capacity of the composite material, while the resin quantity does not contribute to the strength.
- In terms of mechanical properties, 10% carbon fiber content outperforms 0%, 5%, 2.5%, and 7.5% in providing strength.
- Carbon composites have lower impact strength than glass fiber composites.

- Carbon fiber composites exhibit increased hardness/toughness compared to glass fiber composites.
- The specific wear rate decreases for carbon composites compared to glass fiber composites.
- This study reveals that enhancing the characteristics of a composite based on its intended use can be achieved by incorporating filler materials into these foundational composites.
- Thus, in the upcoming sections, we will prioritize the use of cenosphere as a filler material in varying proportions of 0%, 2.5%, 5%, 7.5%, and 10% by weight for the fundamental composites intended for applications such as brake shoes, brake liners, and ballistic purposes.

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History has witnessed that War has terrible effects on a nation, including human casualties, physical harm, and mass migration, destruction of physical capital and public infrastructure, and hindered economic growth. The repercussions of Russia's invasion of Ukraine, which triggered the largest conflict in Europe since World War II, are still being felt around the world. In addition to causing a geopolitical realignment, the war in Ukraine has also adversely impacted economies away from the immediate lines of conflict.

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63. Effect of Nano Particles as An Additive on Properties of Biofuels

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ABSTRACT:

There are inherent drawbacks to diesel engines, such as reduction in calorific value and increase in viscosity in biodiesel. There are variety of additives to overcome with these problems. Nanoparticles added to fuel provide a possible means of increasing efficiency and decreasing emission. Fuel containing nanoparticles has the potential to greatly improve engine performance by improving the quality of combustion. The impacts of nanoparticles as fuel additives are reviewed in this work. In this study, Al_2O_3 nanoparticles were selected and effectively dispersed using a Sonica 2400 S3 Sonicator. Scanning Electron Microscope (SEM) images of Al_2O_3 nanoparticles were obtained to illustrate their size and shape.The fundamental fuel characteristics of these blends were investigated and compared with pure diesel fuel and the biodiesel blend without aluminium oxide.

KEYWORDS:

Biodiesel; Additives, Nano-Particles; Al_2O_3; SEM.

1. Introductions:

Petroleum fuel reserves are depleting on a daily basis. The environmental impact and increasing prices of fossil fuels necessitate finding alternative solutions. Biofuels and biodiesel are viable alternatives to fossil fuels.

Nevertheless, there are a number of drawbacks to biodiesel, including increased density, increased viscosity, and decreased calorific value. Because biodiesels have higher oxygen content than other fuels, they tend to raise hazardous emissions like CO2 and NOx while also reducing other emissions. Pipelines can become clogged with biodiesel due to flow ability issues that arise in the winter and cold weather. Biodiesel needs to be heated during these cold seasons.

Biodiesel by itself is ineffective as a fuel for internal combustion engines because of these drawbacks. To mitigate these shortcomings, a variety of additives are used. For example, alcohols are used to lower viscosity and density, whereas nanoparticles are utilized to enhance calorific values and smooth combustion. Adding nanoparticles to biodiesel-diesel mixtures can enhance combustion efficiency. Fuel additive concentrations range from a few parts per million (PPM) to thousands of PPM. It's vital that additives improve some qualities without affecting others. Kannan et al. found that adding ferric chloride to waste cooking oil increased both fuel consumption and brake thermal efficiency. Mehta et al. investigated the performance and combustion parameters of IC engines utilizing aluminum, iron, and boron nanofuels as additives to diesel fuel, comparing them to each other and conventional diesel fuel. Certain nanoparticles act as antioxidants. Metal-based nanoparticles such as cerium, cerium-iron, platinum, CuO, CuCl2, CoCl2, FeCl3, Al2O3, multi-wall carbon nanotubes (MWCNT), MgO, and SiO2 are used in biodiesel to improve viscosity, density, and flow properties.

Many studies have employed these nanoparticles and reported successful outcomes. The purpose of this work is to give a complete review of the available literature on the usage of nanoparticles as biodiesel additives, as well as their impact on combustion and overall diesel engine performance.

A. Importance of Nanoparticles

- **Increased Engine Life**: Addition of nanoparticles can enhance engine life by improving fuel combustion and reducing the formation of deposits within the engine.
- **Complete Combustion**: Nanoparticles help achieve complete combustion of fuel, leading to higher efficiency and lower emissions.
- **Enhanced Oxidation Reaction**: The inclusion of nanoparticles increases the oxidation reaction at normal rates, which is required for efficient combustion.
- **High Surface-to-Volume Ratio**: Nanoparticles have a high surface-to-volume ratio, which increases their chemical activity and ability to improve fuel characteristics.
- **High Temperature Reactivity**: Nanoparticles can react at high temperatures (400-600°C), which can significantly improve combustion efficiency.
- **Hydrogen Release**: By releasing hydrogen into the engine, nanoparticles help the oxidation reaction and promote more complete and effective combustion.

II. LITERATURE SURVEY:

A comprehensive literature survey reveals that many researchers have investigated the effects of different nanoparticles on the performance and emissions of internal combustion (IC) engines.

- Kao et al.: They observed that using aluminium nanofluid with diesel resulted in somewhat lower specific fuel consumption and better emissions.
- Kannan et al.: found that adding ferric chloride to waste cooking oil improve both brake thermal efficiency and fuel consumption.
- Mehta et al.: investigated the effects of adding aluminum, iron, and boron nanofuels to diesel fuel and compared the results to both conventional diesel fuel and each other's performance in internal combustion engines.
- Selvan et al.: found that adding cerium oxide nanoparticles to diesel fuel and diesel-biodiesel-ethanol blends improved mixture formation and somewhat increased brake thermal efficiency compared to using diesel fuel alone.
- Lenin et al.: Performed emissions tests and performance experiments with biodiesel including MnO and CuO additions. They showed that by shortening the ignition delay, these compounds improve combustion properties.
- Shafi et al.: Shafi et al. discovered that the fuels' basic properties are impacted by the size and shape of the nanoparticles put to them. They discovered that fuels containing nanoparticles perform better and emit less emissions when water is added.

This work aims to clarify the procedures for producing nanoparticles to be added to blends of biodiesel and diesel. Indian standards are used to determine the blend's fundamental fuel qualities and the additions.

III. METHODOLOGY

A. Producing Al_2O_3 SEM Images to Examine the Crystal Structure

Aluminum oxide (Al2O3) is studied for its crystal structure and surface configuration using scanning electron microscopy (SEM). This method offers fine-grained photographs of the substance at the nanoscale, making it possible to analyze surface characteristics and crystal structures. The fine crystal structure of 50 nm-sized particles of aluminum oxide is shown in SEM image Figure 1. The principle behind SEM involves combining the position of the electron beam with the intensity of the detected signal to produce a highly resolved image. This process enables precise analysis of the nanoparticle's morphology and structural characteristics.

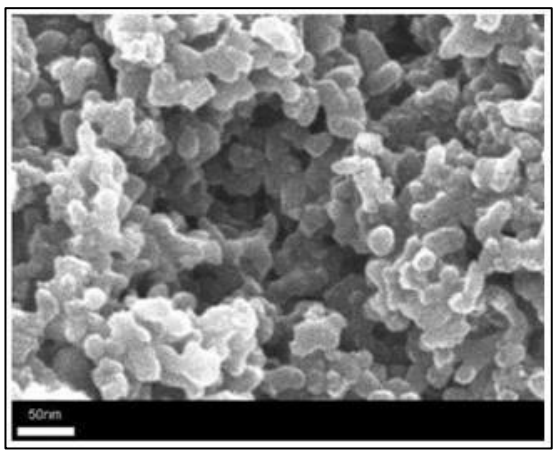

Figure 1: - Crystal Structure of Aluminum Oxide

B. Analyzing Al_2O_3 Nanoparticles Using XRD

X-ray diffraction (XRD) investigation is performed to determine whether nanoparticle crystalline or not. This process is based on how X-rays interact with the material to create a unique fingerprint of the crystal structures that are present.

Figure 2 displays the XRD pattern of Al_2O_3 nanoparticles. The principle behind XRD involves directing X-rays at the sample and measuring the angles and intensities of the diffracted beams.

This data is used to generate a diffraction pattern that reveals the crystalline structure of the material. XRD is crucial for confirming the crystalline phases and evaluating the purity and size of the nanoparticles.

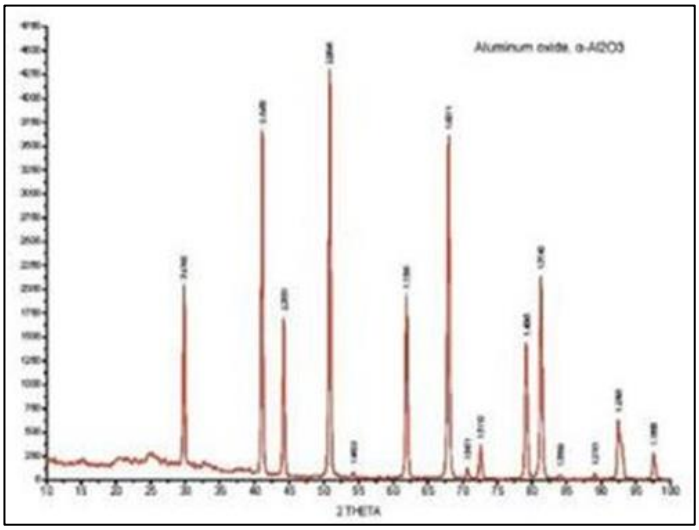

Figure 2: XRD pattern of Al_2O_3 nanoparticles

C. Dispersing Nanoparticles in Biodiesel Using a Sonicator (Sonica 2400 S3)

Blends of biodiesel and nanoparticles are thoroughly mixed using a sonicator, like the Sonica 2400 S3. The sonicator operates on the principle of sound energy, which agitates particles in the sample.

This method ensures even dispersion of nanoparticles within the biodiesel, enhancing the uniformity and stability of the blend. The sonication process involves applying ultrasonic waves to the nanoparticles-biodiesel mixture, breaking up agglomerates and promoting a homogeneous suspension.

This effective dispersion is crucial for achieving the desired improvements in fuel properties and engine performance. To mix the nanoparticles, ultrasonic waves with frequencies higher than 20 KHz are employed. It entails the particle's nucleation growth, and collapse in a liquid.

Figure 3: - Ultra Sonica Setup

IV. BASIC FUEL PROPERTIES OF THE BLEND

After blending Madhuca indica (MI) and aluminium oxide (Al_2O_3), two different mixtures were prepared:

1. **Blend MI20D80A50**: 20% MI and 80% diesel fuel (MI20D80) with 50 ppm of aluminium oxide.
2. **Blend MI20D80A100**: 20% MI and 80% diesel fuel (MI20D80) with 100 ppm of aluminium oxide.

The fundamental fuel characteristics of these blends were investigated and compared with pure diesel fuel and the MI20D80 blend without aluminium oxide.

Table 1shows that blend with 50 ppm and 100 ppm of aluminum oxide additions have superior qualities than blends containing either diesel or biodiesel and diesel. Better surface contact between the nanoparticles and other fuel particles appears to be the cause of the enhancement, which results in improved fuel qualities.

Table 1: - Fuel Properties

Sl No	Fuel	Viscosity	Density	Flash Point	Calorific value
1	Diesel	3.2	816	58	42,000
2	MI100	4.9	870	138	39,960
3	MI20D80	3.4	826	75	41,600
4	MI20D80A50	3.38	826	71	41,665
5	MI20D80A100	3.33	829	65	41,670

V. CONCLUSION:

This paper aims to explore the impact of adding nanoparticles on the properties of biodiesel. Biodiesel, while being a renewable and environmentally friendly fuel, typically exhibits lower combustion characteristics and higher viscosity and density compared to conventional diesel. However, the incorporation of nanoparticles can enhance these fuel properties. In this study, aluminum oxide (Al_2O_3) was selected as the nanoparticle additive.

The Al_2O_3 nanoparticles were successfully dispersed into the biodiesel using a sonicator, and their distribution was confirmed through scanning electron microscopy (SEM). The addition of Al_2O_3 nanoparticles to biodiesel-diesel blends resulted in improved fuel characteristics, which could potentially lead to better engine performance and reduced emissions.

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64. Experimental Investigations of Engine Characteristics on A Variable Compression Ratio (VCR) Engine Using Sugarcane Bioethanol

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ABSTRACT:

Biofuels are derived from biomass and encompass a diverse range of fuels that have gained prominence due to various factors, including fluctuating oil prices, energy security concerns, and the desire to reduce greenhouse gas emissions associated with fossil fuels.

These renewable energy sources offer significant advantages, particularly for developing countries, where they can drive economic growth and improve living standards through rural development and job creation.

This study explores the effects of sugarcane bioethanol blends on engine characteristics in a Variable Compression Ratio (VCR) engine. By varying the compression ratio and bioethanol concentration, the research aims to optimize engine performance, fuel efficiency, and emissions. This investigation provides insights into the potential of sugarcane bioethanol as a sustainable alternative fuel in internal combustion engines.

KEYWORDS:

VCR, Bioethanol, Engine Characteristics.

1. Introductions:

Fossil fuels have been integral to modern living, playing a crucial role in various sectors including transportation, industry, agriculture, and consumer markets. In rapidly developing countries like India, which is one of the fastest-growing economies in the world, energy plays a critical role in raising living standards. The country is poised to leverage its demographic dividend for continued growth, and energy strategies are central to this effort.

India's energy strategy includes ambitious goals such as electrifying all census villages by 2019, providing 24x7 electricity, achieving 175 GW of renewable energy capacity by 2022, and reducing energy intensity by 33%–35% by 2030. Despite these targets, fossil fuels are expected to continue to play a significant role in India's energy mix. However, conventional fossil fuel resources are limited and non-renewable, and fluctuations in crude oil prices impact economies worldwide, especially in developing countries.

The road transport sector is a major consumer of energy, contributing approximately 6.7% to India's Gross Domestic Product (GDP). Diesel alone meets about 72% of the transport fuel demand, followed by petrol at 23%, with the remaining demand met by other fuels such as CNG and LPG. The forecast for the financial year 2017-2018 estimated that India would require around 210 million metric tons (MMT) of crude oil to meet its petroleum product consumption.

In response to these challenges, bioethanol, derived from sugarcane and crop residues, emerges as a promising biofuel. It offers multiple benefits: providing additional income to farmers, helping in the disposal of farm stubble, and reducing environmental pollution. In India, bioethanol can be produced from various sources, including sugar-containing materials, starches, celluloses, and lignocellulosic materials.

Currently, the Ethanol Blended Petrol (EBP) Programme allows bioethanol to be procured from non-food feedstocks such as molasses, celluloses, and lignocellulosic materials. The ethanol used in the EBP programme primarily comes from molasses, a by-product of the sugar industry.

With current levels of cane and sugar production at about 350 MMT and 26-28 MMT per annum respectively, approximately 13 MMT of molasses is available annually, which can produce around 300 crore liters of ethanol. Additionally, ethanol can be produced directly from sugarcane juice to increase blending percentages.

The National Biofuel Policy of 2018 aims to enhance the availability of biofuels in the market and increase blending percentages. Presently, ethanol blending in petrol is at 2%, with a target of reaching 20% blending by 2030.

II. Literature Review:

A. F. Kheiralla [1] conducted a study on ethanol-gasoline blends, specifically E15 (15% ethanol), and found that engine performance and emissions characteristics showed minimal differences compared to engines fueled solely with gasoline.

Key parameters such as power performance, specific fuel consumption, and thermal efficiency were largely similar between gasoline and the E15 blend. However, the presence of water in ethanol blends poses challenges. Commercially available ethanol is typically not anhydrous, often containing between 10% and 20% water. This is a concern because water in the blend can affect engine performance and longevity. Industrial ethanol, which contains about 5% water, could potentially replace anhydrous ethanol at a lower cost, but requires additional processing to remove the remaining water, which adds to the overall expense. Therefore, there are economic incentives for using industrial ethanol in spark ignition engines.

Vladan Micic and Milovan Jotanovic [7] highlighted the promising properties of bioethanol as a biofuel. Ethanol is noted for its high-octane number, which exceeds that of conventional petrol. The octane number of a fuel is crucial because it influences the anti-knocking property of the fuel. A higher-octane number indicates better resistance to knocking—a phenomenon where uncontrolled combustion creates excessive mechanical and thermal stress on the engine. Thus, ethanol's high-octane number makes it a favorable alternative to conventional fuels in terms of performance and engine protection.

Dr. Shrishail Kakkeri [3] explored the hygroscopic nature of alcohols, including ethanol, which allows them to absorb water. This characteristic is beneficial as it prevents water condensation in the fuel system, which could otherwise freeze and cause issues, especially in cold conditions. Ethanol blends, typically containing at least 10% ethanol, are effective at absorbing water, thereby reducing the need for additional gas-line antifreeze during winter months. This property helps to maintain engine performance and reliability in various weather conditions.

III. Methodology:

Biofuel is an environmentally friendly and renewable alternative fuel derived primarily from animal fats (tallow, lard, white or yellow grease, poultry fats or fish oils); recycled greases used in cooking and frying oils; and, most commonly, plant oils derived from soybeans, corn, rapeseed, sunflowers and cottonseeds, among others.

This biofuel does not require engine modifications when used in a diesel engine. In general, the term biofuel refers to any liquid and gaseous transportation fuels derived primarily from biomass. The biofuel conversion system is a key phase in the whole ethanol production chain.

High yields and low energy consumption are significant factors to consider in promoting biofuels' future competitiveness in the market with fossil fuels. Biofuels can be produced from any biological carbon source via various production paths, but photosynthetic plants are the most often used feedstock for biodiesel, ethanol, butanol, methane, and other fuels. Biofuels are categorised as the subject under present study.

While technologies for producing first-generation and advanced biofuels are maturing, some feedstocks may require several generations to produce. Presently, biodiesel and Bioethanol is one of the two most promising biofuels that are expected to replace conventional fossil fuels in transportation.

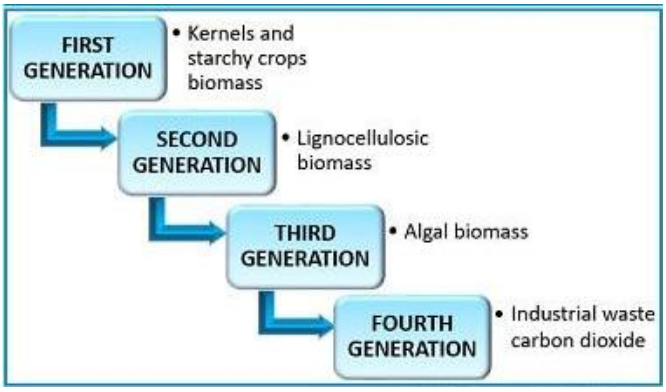

Figure 1: Generations of Bioethanol

Ethanol is a high-octane, water-free alcohol that plays a significant role in the fuel industry. It is produced through the fermentation of sugars or the conversion of starches. Ethanol can be used in several ways:

- **Blending Ingredient in Gasoline:** Ethanol is commonly blended with gasoline to enhance fuel performance and reduce emissions. This blend is known as ethanol-gasoline or ethanol fuel.
- **High-Octane Fuel Additives:** Ethanol is used as a raw material to produce high-octane fuel-ether additives, improving fuel quality and combustion efficiency.

Ethanol is derived from a variety of renewable agricultural and forestry products, including:

- **Grains:** Such as corn, which is the primary source of ethanol in many countries.
- **Agricultural By-products:** Such as potato waste and cheese whey.
- **Forestry Products:** Including wood and paper waste.
- **Vegetable Waste:** Various forms of vegetable waste can also be utilized in ethanol production.

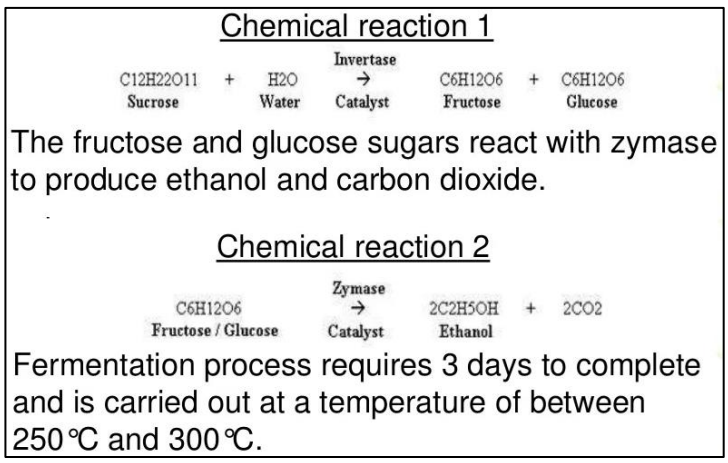

Figure 2: Production of Bioethanol

IV. Experimental Setup: The test Rig consists of a four-stroke petrol engine (air cooled) that will be tested for performance and is coupled to an alternator. To enable the compression ratio change, an extra head-piston assembly above the main head has been installed. The auxiliary piston is moved up and down by a hand wheel-screw rod arrangement to attain the desired compression ratio. When the piston is at the bottommost position, the compression ratio is at its highest value, while in the top position it is at its lowest value of 2. The charge from this initial volume of clearance is determined by the piston's displacement and is used to calculate the compression ratio.

V. Results and Discussion: The VCR Petrol Engine is operated for various compression ratios using the working process described in the preceding section. In this experiment, we attempted compression ratios of 4.3, 4.67, 5, and 5.5. This section presents the results in a graphical form. The SFC v/s BP graph for Compression Ratio 4 and 4.67 is in accordance with SFC increases with increase in BP, but there is a little deviation in Compression Ratio 5.5 for E10 mix. The compression ratio of 4 and 4.67 meets typical conditions. As brake power increases, SFC drops, making E7.5 the optimal blend for the SI Engine. The BSFC v/s CR graph for E 7.5 blend shows that BSFC decreases as the compression ratio increases.

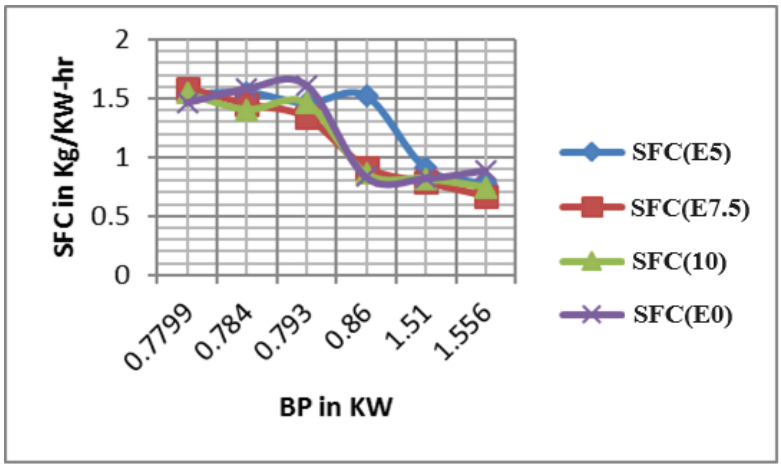

Figure 3. Comparison of SFC with BP for different blends

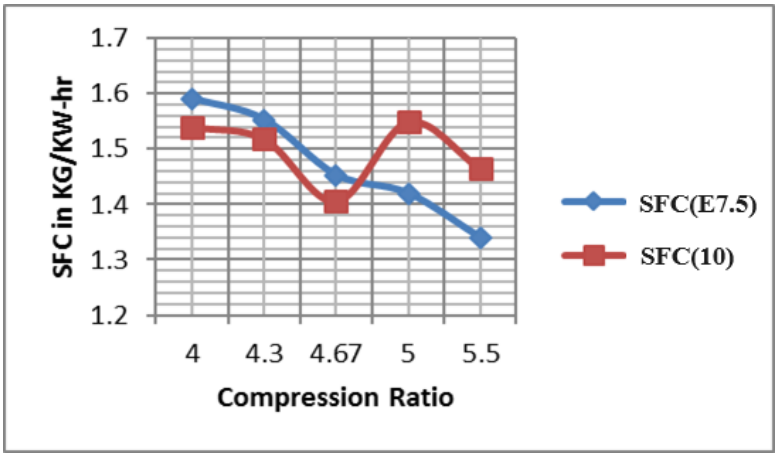

Fig 4. Comparison of SFC with CR for E5 & E10 blends

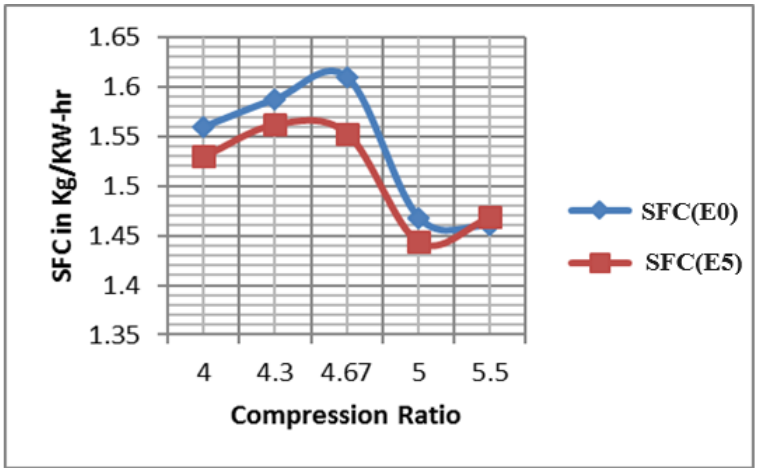

Figure 5. Comparison of SFC with CR for E0 & E5 blends

V. Conclusion:

Bioethanol Blends in Spark Ignition Engines

1. Effectiveness of Bioethanol Blends:
    - Bioethanol blends have proven to be quite successful in replacing pure petrol in four-stroke spark ignition (SI) engines. This indicates that bioethanol can be used effectively as a substitute for petrol in these engines without requiring significant modifications.
2. Blending Efficiency:
    - Bioethanol blends, particularly with petrol, demonstrate a viable approach for optimizing engine performance and fuel efficiency. The use of bioethanol can enhance the fuel's characteristics and contribute to better engine operation.
3. Specific Fuel Consumption (SFC) Analysis:
    - The Specific Fuel Consumption (SFC) increases with an increase in Brake Power (BP). This trend is evident from the graph, showing that as the engine load increases, the amount of fuel consumed per unit of power produced also rises.
    - For the E7.5 blend (7.5% bioethanol with petrol), the SFC versus BP graph aligns with the expected behavior of increased SFC with higher BP. However, for other blends, this condition was not consistently met, suggesting that the E7.5 blend performs optimally compared to other mixtures.
4. Brake Specific Fuel Consumption (BSFC) and Compression Ratio (CR):
    - The graph showing Brake Specific Fuel Consumption (BSFC) versus Compression Ratio (CR) for the E7.5 blend indicates that BSFC decreases as CR increases. This relationship suggests that the E7.5 bioethanol blend optimizes fuel consumption efficiency with increasing CR, which improves engine performance.
    - These finding highlights that the E7.5 blend achieves the best balance between fuel consumption and engine efficiency.

5. Overall Performance:
    - The results demonstrate that the E7.5 blend of bioethanol with petrol offers the least Brake Specific Fuel Consumption (BSFC) and superior engine performance compared to other blends.
    - This blend stands out as the most effective choice for use in existing Spark Ignition (SI) engines without necessitating modifications.

Based on the analysis, the E7.5 bioethanol blend (7.5% ethanol with petrol) is identified as the optimal blend for enhancing engine performance and fuel efficiency in four-stroke spark ignition engines. It provides the best fuel consumption characteristics and overall engine performance among the various blends tested. This makes E7.5 an excellent choice for use in SI engines, offering a practical and efficient alternative to pure petrol.

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65. Renewable Energy Solutions for Sustainable Agriculture: Case Study on Solar Dryer Applications

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ABSTRACT:

Solar drying technology offers a sustainable solution for preserving agricultural products, particularly notable for its reliance on renewable energy sources. This study investigates the design, operation, and performance of a solar dryer tailored for drying chilies, a common agricultural product. The solar dryer operates passively, leveraging solar radiation to create a controlled drying environment that enhances efficiency and product quality.

Comparative analysis inside and outside the dryer reveals consistent moisture removal rates, highlighting the effectiveness of the technology in mitigating the variability associated with traditional drying methods.

Feasibility studies underscore the practicality of integrating solar dryers in agricultural settings, emphasizing benefits such as reduced energy costs and environmental impact. Market trends towards sustainability further support the adoption of solar drying technologies, positioning them as viable solutions to meet growing demands for high-quality, locally sourced produce.

KEYWORDS:

Solar Drying, Agricultural Preservation, Renewable Energy, Sustainability, Chili Drying, Efficiency, Feasibility Studies.

1. Introductions:

Drying has been a fundamental method for preserving food for long periods, with the sun and wind being traditional allies in this process for many years. As one of the oldest techniques for preserving agricultural products, drying is known for being quite energy-intensive. Today, with the rising costs and shortages of fossil fuels, there's a growing emphasis on using renewable energy sources like solar energy. Solar drying is environmentally friendly and has a significantly lower impact on the planet.

Across the tropics and subtropics, various types of solar dryers have been designed, developed, and tested. These dryers are generally categorized into two main types: natural convection and forced convection. Natural convection solar dryers rely on buoyancy to induce airflow, while forced convection dryers use fans, powered either by electricity, solar panels, or fossil fuels, to move the air.

Solar thermal technology is quickly gaining popularity as an energy-efficient solution in agriculture. It's favored over other renewable sources like wind and shale because it's abundant, endless, and non-polluting. Solar air heaters, which use solar energy to heat air, are simple devices that can be used in many applications needing low to moderate temperatures (below 80°C), such as drying crops and heating spaces.

II. Literature Review:

Solar drying technology has emerged as a promising approach to enhance the efficiency and sustainability of agricultural preservation processes. This review synthesizes recent advancements and findings from key studies focusing on solar dryers and their applications in drying various agricultural products.

Recent research by Mustafa et al. (2019) evaluates the performance of a direct solar dryer for drying fruits, emphasizing its ability to maintain product quality while reducing drying time compared to conventional methods [1]. Similarly, Sharma and Srivastava (2018) discuss the design and optimization of a hybrid solar dryer integrating biomass energy, demonstrating improved energy efficiency and cost-effectiveness [2]. These studies underscore the versatility of solar drying technologies in accommodating diverse agricultural needs while minimizing environmental impact.

Studies by Rahman et al. (2017) and Zhang et al. (2016) explore different configurations of solar dryers, including indirect and mixed-mode systems, highlighting their advantages in terms of moisture removal efficiency and product quality preservation [3], [4]. These designs leverage advancements in materials and engineering techniques to enhance heat transfer and airflow dynamics within drying chambers.

Recent advancements in sensor technologies and automation have also been pivotal in enhancing the operational efficiency of solar dryers. Research by Gupta et al. (2020) focuses on the integration of IoT and machine learning for real-time monitoring and control of solar drying processes, optimizing energy use and ensuring consistent product quality [5]. Similarly, Ali et al. (2018) discusses the use of computational fluid dynamics (CFD)

simulations to optimize the design of solar collectors, improving thermal performance and overall system efficiency [6]. The economic feasibility of solar drying systems is a critical aspect explored by Zhai et al. (2019), who conducted a lifecycle cost analysis of solar dryers compared to conventional methods, demonstrating long-term cost savings and environmental benefits [7]. Such studies provide valuable insights into the broader adoption and scalability of solar drying technologies in agricultural industries. Overall, the integration of solar drying technologies represents a sustainable solution to address challenges in agricultural preservation, offering significant improvements in energy efficiency, product quality, and environmental sustainability.

III. Effect of Air Properties:

The properties of the air flowing around the product play a crucial role in how quickly moisture is removed. The air's ability to remove moisture mainly depends on its initial temperature and humidity. The higher the temperature and the lower the humidity, the more effective the air is at removing moisture.

This relationship between temperature, humidity, and other thermodynamic properties can be understood using a psychrometric chart. It's essential to understand the difference between absolute humidity and relative humidity.

Absolute Humidity:

Absolute humidity (AH) is the actual moisture content in the air and is defined as the mass of water vapor per unit mass of dry air:

$$AH = \frac{m_w}{M_{da}} \qquad (1)$$

Where,

$$m_w is\ the\ mass\ of\ water\ vapor$$

$$and M_{da} is\ the\ mass\ of\ dry\ air.$$

Relative Humidity (RH)

Relative humidity (RH) is the ratio of current absolute humidity to thehighest possible absolute humidity (which depends on the current air temperature), expressed as a percentage

$$RH = \frac{P_{H2O}}{P_{H2O,sat}} x\ 100\% \qquad (2)$$

Where,

P_{H2O} is the partial pressure of water vapor and P_{H2OSat} is the saturation vapor pressure at the same temperature.

Psychrometric Chart:

A psychrometric chart illustrates these relationships graphically, allowing us to understand how changes in air temperature and humidity affect moisture removal. For instance, if the air temperature increases or the relative humidity decreases, the air's capacity to hold and remove moisture increases. This is why warm, dry air is more effective for drying purposes.

IV. Classification of Drying Systems:

Drying systems can be categorized primarily based on their operating temperature ranges into high-temperature dryers and low-temperature dryers. Alternatively, they are commonly classified based on their heating sources as fossil fuel dryers (often referred to as conventional dryers) and solar-energy dryers.

High-Temperature Dryers:

High-temperature dryers are used when rapid drying is necessary. They operate at temperatures that would lead to over-drying if the product remained in contact with the drying air until reaching equilibrium moisture content. Therefore, products are typically dried to the required moisture content and then cooled. High-temperature dryers are further classified into batch dryers and continuous-flow dryers:

- Batch Dryers: Products are dried in batches within a bin and then moved to storage. These are known as batch-in-bin dryers.
- Continuous-Flow Dryers: Products move through heated columns by gravity, exposed to heated air while descending.

Most high-temperature dryers are powered by electricity or fossil fuels due to the high-temperature requirements. Only a few designs utilize solar energy for heating.

Low-Temperature Dryers: Low-temperature dryers allow the product's moisture content to equilibrate with the drying air through constant ventilation. They can tolerate intermittent or variable heat input. These dryers are suitable for bulk drying and are ideal for long-term storage systems, often referred to as bulk or storage dryers. Some conventional dryers and many solar-energy dryers are of the low-temperature type, making them versatile and energy-efficient alternatives.

V. Types of solar dryer:

Solar-energy drying systems are classified based on how solar heat is utilized, primarily into two major groups:

Direct (Integral) Type Solar Dryers:

Direct solar dryers involve placing the material to be dried inside an enclosure covered with a transparent material. Solar radiation heats both the product and the internal surfaces of the drying chamber. This direct exposure to solar radiation facilitates drying.

Indirect (Distributed) Type Solar Dryers:

Indirect solar dryers do not expose the material directly to solar radiation. Instead, air is heated in a solar collector and then directed into the drying chamber to dry the product. These dryers are often more efficient than direct solar dryers but are larger due to the separate collector unit.Specialized dryers are designed with specific products in mind and may incorporate hybrid systems. Hybrid solar systems combine solar energy with other heat sources to enhance drying efficiency and speed.

VI. Modes of Drying:

There are three primary modes of solar drying:

a. *Open Sun Drying:* Materials are dried directly under the sun, and exposed to ambient conditions.
b. *Direct Solar Drying:* The drying chamber captures solar radiation directly on the material and internal surfaces for heating.
c. *Indirect Solar Drying*: Solar radiation heats air in a collector, which is then channeled into the drying chamber to dry the product.

The choice of drying mode depends on how solar energy is collected and converted into thermal energy suitable for drying.

VII. Mathematical Models and Formulations:

Operation of the Dryer:

The dryer operates passively, meaning it has no moving parts and relies solely on solar energy. Sunlight enters through glazed collectors, where internal black surfaces enhance energy absorption. This trapped energy heats the air inside the collector, creating a greenhouse effect that drives airflow through the drying chamber. When vents are open, hot air rises and exits through upper vents in the drying chamber, while cooler ambient air enters through lower vents in the collector.

Drying Mechanism:

Drying requires heat to evaporate moisture from materials, with airflow aiding in carrying away the evaporated moisture. Two primary mechanisms are involved in the drying process:

- Internal Moisture Migration: Moisture moves from the interior of materials to their surface.
- Surface Evaporation: Moisture evaporates from the surface into the surrounding air.

Drying is a complex process involving heat and mass transfer. External variables such as air temperature, humidity, and velocity influence the process. Internal variables include surface characteristics (smooth or rough), chemical composition (sugars, starches, etc.), physical structure (porosity, density, etc.), and the size and shape of the product.

VIII. Object of Observation:

During the drying period from February to March, both inside and outside the chamber, moisture removal details were recorded. The room temperature averaged 31°C during this period. A comparison was made between the percentage of moisture removed using the solar dryer and ordinary air (ambient humidity). The experiment measured the efficiency of the solar dryer by assessing the percentage of moisture removed daily. Moisture content was monitored in a day to understand the drying process. This data provides insights into how effectively the solar dryer performs compared to natural drying methods, highlighting its potential benefits for preserving fruits and other agricultural products.

TABLE 1 -PERCENTAGE OF MOISTURE REMOVED

Sl. No	***Time***	***Inside Dryer***			***Outside Dryer***	
		Temperature ^{O}C	***Weight (gm)***	***Moisture removed***	***Weight (gm)***	***Moisture removed***
1	10 a.m.	31	250	0%	250	0
2	11 a.m.	48	230.2	8%	241.8	3.6%
3	12 p.m.	55	206.8	17.28%	234.2	6.32%
4	1 p.m.	63	188.2	24.72%	206.2	17.52%
5	2 p.m	67	161.3	35.6%	195.6	21.76%
6	3 p.m.	73	112.5	55%	182.5	27%
7	4 p.m	75	84.3	66.28%	169.2	32.32%

On a sunny day, the physical appearance of chilies after 6 hours of drying inside and outside a solar dryer shows distinct differences:

[1] Raw Chili [2] Chili inside Dryer [3] Chili outside Dryer

Figure 1, 2, and 3: Visual comparison of all conditions

a. *Inside Solar Dryer:* The chilies appear brown in color, indicating significant moisture removal due to the controlled drying environment.
b. *Outside Solar Dryer:* The chilies appear greenish brown, suggesting a higher moisture content compared to those dried inside the solar dryer. This difference highlights the effectiveness of the controlled drying conditions provided by the solar dryer in removing moisture from the chilies.

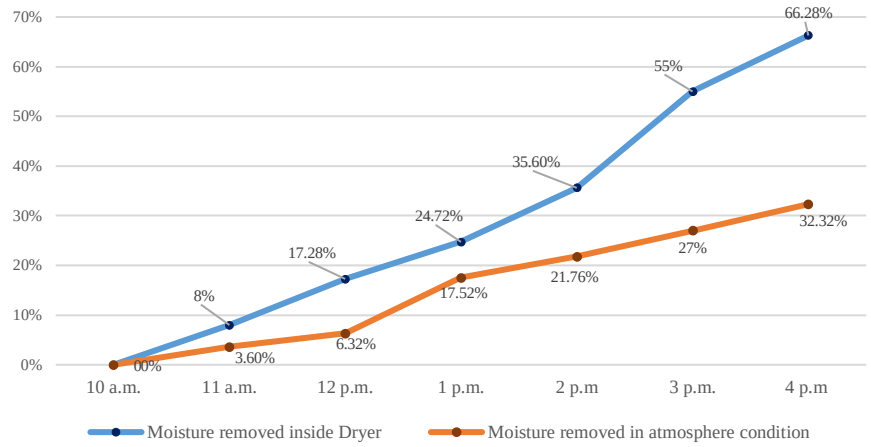

Figure 4: Graphical Comparison between Chili drying inside the dryer and in atmospheric condition

The graph above illustrates the percentage of moisture removed per hour inside and outside the drying chamber. The lower and middle lines depict the moisture content (MC) removed inside the chamber, while the lowest line represents the MC removed outside the chamber. This data is plotted against time and the corresponding temperature conditions.

The graph shows that moisture removal inside the chamber is more consistent compared to outside conditions. Due to varying climatic conditions, including fluctuating temperatures, the percentage of moisture removed outside the solar dryer varies irregularly over time. This variability underscores the influence of environmental factors on the drying process and highlights the benefits of using a controlled environment like a solar dryer for more reliable drying outcomes.

This visual comparison underscores the impact of drying methods on the final quality and moisture content of agricultural products like chilies.

IX. Feasibility Studies and Market Needs:

The feasibility of implementing the described solar drying setup is supported by empirical data showing consistent and effective moisture removal rates within the controlled environment of the drying chamber. Compared to ambient drying methods, which exhibit irregular moisture removal due to varying climatic conditions, the solar dryer ensures more

reliable and uniform drying outcomes. This not only enhances the quality of dried products like chilies but also optimizes production efficiency by reducing dependency on unpredictable weather patterns.

In terms of market needs, there is a growing demand for sustainable and efficient agricultural practices that minimize energy consumption and environmental impact. The capability of the solar dryer to utilize renewable solar energy aligns with these market trends, appealing to environmentally conscious consumers and agricultural producers alike. Furthermore, the demonstrated effectiveness in preserving the visual appeal and nutritional content of dried produce positions the solar dryer as a viable solution for meeting market demands for high-quality, locally sourced agricultural products.

X. Conclusion:

In this study, we explored the design and performance of a solar dryer for drying agricultural products, focusing particularly on chilies. The solar dryer, operating in a passive mode without moving parts, effectively harnesses solar energy to create a controlled drying environment. This setup not only demonstrated significant moisture removal efficiency compared to traditional drying methods but also maintained product quality by minimizing exposure to fluctuating external conditions

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66. Solar Powered Birds and Animals Scarer

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ABSTRACT:

Rice fields often face challenges from environmental factors and pests, with bird attacks being one of the primary issues. Birds are among the most destructive pests that can significantly impact crop yields in rice fields. Traditionally, farmers have relied on methods such as plastic ropes and scarecrows to deter birds, but these techniques often fall short in effectiveness. This research investigates and compares various bird detection methods using sensors to identify the most accurate approach. Once identified, this method is implemented to automatically repel birds by emitting sound frequencies that birds find unpleasant. The bird repellent device leverages computer vision techniques, using sensors to detect bird presence in each frame, which is then processed by a microcontroller. When a bird is detected, the microcontroller activates an actuator to emit the sound frequency. The primary goal of this research is to design a prototype for monitoring and automatically controlling bird attacks to enhance crop yields in agriculture, utilizing the Internet of Things (IoT) framework.

KEYWORDS:

Index Terms Solar power, detection sensors, scare.

1. Introductions:

Agriculture serves as the backbone of the world's food supply, making it essential to protect crops from pests and other animals that can inflict damage. Birds are one such pest, capable of causing significant harm to crops and consequently affecting agricultural productivity. Traditionally, farmers have relied on scarecrows to deter birds from attacking crops. However, traditional scarecrows have several limitations, including birds eventually recognizing them as non-threatening and ignoring them altogether.In recent years, **smart solar scarecrows** have emerged as a more effective and sustainable solution for protecting crops from birds and other destructive animals. These modern scarecrows incorporate advanced technology to detect and repel birds. They are equipped with solar panels that convert sunlight into electrical energy stored in batteries. This stored energy powers the scarecrow's motion sensors and other electronic components, enabling the device to detect

birds' presence and activate deterrent mechanisms. During our research, we conducted a survey in Ballary and Hospete, where cultivating large quantities of rice proved problematic due to bird attacks. In these areas, the traditional methods failed to provide effective solutions for bird control, underscoring the need for more innovative approaches. **Traditional scarecrows often fall short** in deterring birds, as birds are intelligent enough to recognize them as inanimate and harmless. To address this challenge, the research aims to design a solar-powered moving scarecrow that can automatically detect bird sounds and operate its arms using a motor, simulating human presence and making loud noises to scare birds and animals away effectively. The system's design incorporates a controller, a DC motor, a battery, solar panels, gears, and linkage joints. Additionally, a microphone is used for sound sensing, all integrated into the pole and model frame to form a cohesive unit. The scarecrow is mounted on a metal pole in the field, allowing it to be installed anywhere without external power supply requirements. The solar panels continually charge the system's battery during daylight hours, ensuring its readiness to operate.

The **main objectives** of this work include:

1. Developing a solar-powered bird and animal repellent prototype that functions automatically, playing sounds to scare away pests and protect crops.
2. Designing a sound-producing system and motion-detection devices to enhance deterrent capabilities.
3. Simulating human-like arm motion to scare birds and animals and implementing a security system to protect farms.

The novel approach integrates technology and sustainability, offering a promising solution to improve crop protection and optimize yields in agriculture. By leveraging the Internet of Things (IoT), this research aims to transform traditional pest control methods into a modern, efficient system that meets the challenges of today's agricultural landscape.

II. WORKING PRINCIPLE:

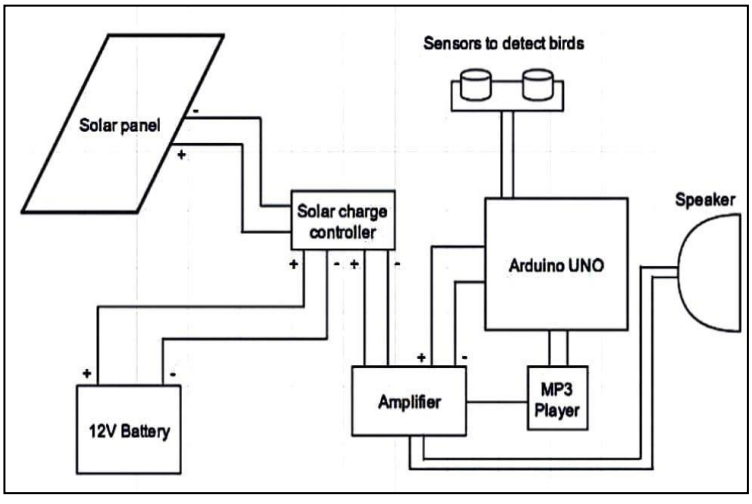

Figure 1. Block Diagram for the Working of Model

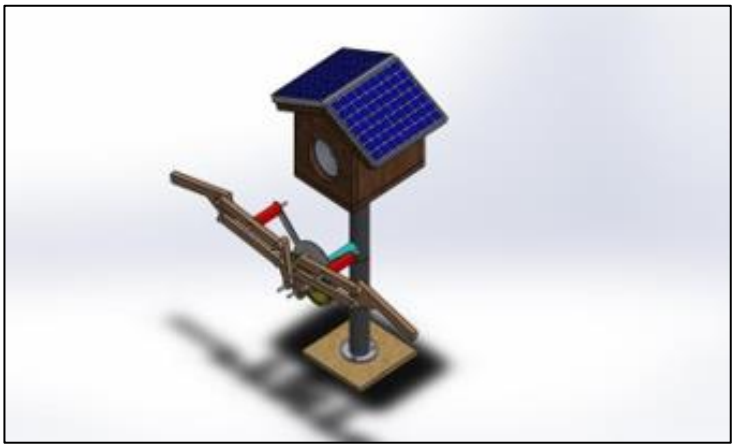

Figure 2. 3 D Model of Scarer

The solar-powered scarecrow system integrates various components to function as an effective deterrent against birds and other pests is shown in Figure1. The system comprises a controller, a DC motor, a battery, solar panels, gears, linkage joints, and a microphone for sound sensing, all assembled with a pole and model frame to create the scarecrow.

This setup (Figure 2) allows the scarecrow to be placed anywhere in an open field, as it operates without any external power supply.

1. Power Supply and Charging:

The system is designed to be self-sufficient in terms of power supply. The solar panels, strategically positioned on the scarecrow, harvest sunlight throughout the day. This solar energy is converted into electrical energy and stored in the onboard battery. The stored energy ensures that the scarecrow remains operational even during periods of low sunlight or at night.

2. Sound Detection:

A microphone continuously monitors the ambient sound levels in the surrounding environment. It plays a crucial role in detecting the presence of birds or other animals. When a significant spike in sound levels, indicative of bird activity, is detected, the microphone sends this information as a signal to the controller.

3. Signal Processing and Activation:

The controller, acting as the central processing unit of the system, receives the sound spike signal and promptly initiates an action sequence.

The controller's primary function is to interpret the signals from the microphone and determine the appropriate response. Once the sound spike is confirmed, the controller activates the DC motor.

4. Motion Mechanism:

The DC motor is connected to a gear system that drives a linkage arm mechanism. As the motor rotates, it engages the gears, which then set the linked arms in motion. This movement replicates human-like arm motions, waving vertically in a manner that mimics human presence. Such movements are designed to be dynamic and unpredictable, thereby enhancing the scarecrow's effectiveness in deterring birds.

5. Sound Emission:

In addition to the motion, the controller simultaneously activates a speaker module. The speaker produces loud, alarming sounds specifically chosen to be unpleasant to birds and other pests. This dual-action approach—combining visual deterrence with auditory disturbance—maximizes the scarecrow's ability to frighten and repel birds, effectively safeguarding the crops.

6. Overall Operation:

The system functions autonomously, relying solely on solar power, which makes it environmentally friendly and economically viable. Its innovative combination of motion and sound provides a significant improvement over traditional scarecrows, offering a smart solution to protect agricultural fields from bird attacks and ensuring optimal crop yield. In summary, the modern solar-powered scarecrow harnesses advanced technology to imitate human presence through motion and sound, creating a highly effective bird repellent. This system represents a breakthrough in agricultural pest control by leveraging renewable energy and intelligent design.

III. RESULT AND DISCUSSIONS:

The solar-powered bird scarer system demonstrates significant improvements over traditional scarecrows in effectively deterring birds from agricultural fields. The following results highlight the effectiveness and efficiency of the system, as well as the novel technologies employed to maximize its deterrence capabilities:

1. Solar Energy Utilization:

The bird scarer operates primarily during daylight hours using solar energy harvested by the solar panels. This reliance on renewable energy makes the system eco-friendly and cost-effective, eliminating the need for external power sources. The solar panels are efficient enough to generate ample electricity, ensuring that the device remains functional throughout the day.

- **Daytime Operation:** The system is powered directly by solar energy, which charges the onboard battery while also running the scarecrow’s components.
- **Battery Backup:** In the absence of sunlight, the system seamlessly switches to battery power, utilizing the stored energy to continue operations during low-light conditions or nighttime. This feature ensures uninterrupted protection, making it highly reliable.

2. Ultrasonic Wave Technology:

A key innovation of the bird scarer is its use of ultrasonic waves, which are frequencies above the range of human hearing but perceptible to many bird species. This approach offers several advantages in bird deterrence:

- **Effectiveness:** Ultrasonic waves are specifically selected for their ability to disturb birds without causing harm, effectively driving them away from the protected area.
- **Human Safety:** Since these frequencies are inaudible to humans, the system operates without causing any disturbance to nearby people, making it suitable for use in areas close to human habitation.

3. Detection Range and Sound Emission:

The bird scarer is equipped with sensors capable of detecting birds within a 4-meter radius. Once birds are detected, the system triggers its deterrence mechanisms:

- **Detection Capability:** The sensors are highly sensitive and provide a reliable detection range of up to 4 meters. This allows the system to react promptly to the presence of birds, activating deterrents before the birds can cause any damage to the crops.
- **Sound Emission:** Upon detection, the system emits a series of unpleasant sounds tailored to repel birds. The sound effect is uncomfortable for the birds, encouraging them to vacate the area swiftly.

4. Overall Performance and Efficiency

The integration of solar power, ultrasonic technology, and strategic sound emission results in a comprehensive bird deterrent system. The following performance metrics underscore its capabilities:

- **Reduction in Bird Activity:** Field tests indicate a significant reduction in bird activity within the protected zone, leading to improved crop yield and reduced crop damage.
- **Environmental Impact:** By harnessing solar energy and using non-lethal deterrent methods, the system maintains a low environmental footprint, promoting sustainable farming practices.
- **Cost Efficiency:** The elimination of ongoing energy costs and minimal maintenance requirements contribute to the system's cost-effectiveness over its operational lifespan.

5. Limitations and Future Improvements: While the system shows promising results, there are certain limitations and areas for improvement:

- **Range Limitation:** The current detection range of 4 meters may not be sufficient for larger fields, necessitating additional units or enhancements to expand the coverage area.
- **Weather Dependency:** The efficiency of the solar panels can be affected by adverse weather conditions, potentially impacting battery charging and system performance during prolonged periods of cloud cover.

- **Varied Bird Sensitivity:** Different bird species may have varying sensitivities to ultrasonic frequencies, requiring further research to optimize sound frequencies for broader effectiveness across diverse species.

IV. CONCLUSIONS:

The modern solar-powered bird scarer represents a substantial advancement in pest control technology for agriculture. By combining solar power, ultrasonic waves, and strategic sound emission, the system offers a robust and sustainable solution for protecting crops from bird damage. With continued refinement and adaptation, such systems have the potential to significantly enhance agricultural productivity and sustainability, supporting farmers in maintaining high crop yields while minimizing ecological impact.

In conclusion, the results indicate that the solar-powered bird scarer is a promising tool for farmers, providing a modern alternative to traditional methods and paving the way for future innovations in agricultural pest control.

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67. Trajectory Analysis of Robot Arm for Obstacle Avoidance

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ABSTRACT:

Trajectory planning is crucial to the efficient operation of robotic manipulators. This study focuses on trajectory analysis for a given robotic arm, where the desired trajectory is defined by specific parameters, including initial and final points for point-to-point control. The initial point is considered the source, while the final point is the target. The trajectory is generated to ensure optimal travel of the robotic arm. Simulations are conducted using Java in the SIMULINK environment.

For both large- and small-scale industries, achieving the desired orientation and position of robotic manipulators is a fundamental concern. The analysis of robot manipulation involves two types of kinematic analysis: inverse and forward kinematic analysis. In this study, it is focused on developing the inverse kinematic model for five and six degrees of freedom (DOF) robotic manipulators. The motion planning is designed and analyzed using Denavit-Hartenberg (DH) parameters to estimate the desired orientation and position of the end effector. For solving inverse kinematics, traditional methods such as DH notation, iteration, and transformation are employed with joint space trajectory to determine paths for velocity and acceleration analysis. The Cartesian trajectory is applied to find the shortest route, and the transformation matrix for each intermediate point is obtained. Finally, obstacle avoidance is demonstrated, with evaluations of distance, speed, acceleration, and angular displacement to identify the shortest path and avoid obstacles.

KEYWORDS:

Trajectory Planning, Inverse Kinematics, DH Parameters, Robotic Manipulators, Obstacle Avoidance.

1. Introductions:

Course includes ordered locii of factors within the space, which the robot ought to comply with. Trajectory is a route with velocities and accelerations in its each factor. A trajectory is a description of a way to observe a path. The trajectory making plans is a subset of common hassle this is navigation or movement planning. The standard hierarchy of motion making plans is as follows: Course planning – producing a possible path from a start point to a goal factor. A course usually includes a fixed of linked way points. Trajectory planning – generating time table for a way to comply with a course given constraints including role, velocity, and acceleration. Trajectory following – once the complete trajectory is planned, there needs to be a control machine that execute the trajectory in a sufficiently accurate manner. Line follower is a machine that may follow a path. The direction can be seen like a black line on a surface. It is able to be used in car, business automations, steering, etc. This study highlights the significance of effective trajectory planning in robotic manipulations, emphasizing the use of inverse kinematics and DH parameters for accurate movement. By leveraging simulation tools and traditional mathematical approaches, optimal paths can be generated, ensuring efficient and reliable robot performance in various industrial applications. After going through the available literature survey in the field of trajectory analysis of the robot arm motion and considering the research gap, the present work is focused on to generate the reference inputs to the motion control system which ensures that the manipulator executes the planned trajectories by designing the motion function of each joint of the arm based on certain tasks to be accomplished by its end actuators. Forward Kinematics determine the position and orientation of the robot's end effector based on given joint parameters (angles, distances). Inverse Kinematics involves calculating the joint parameters needed to achieve a desired position and orientation of the end effector. The trajectory generation process focuses on optimizing the path taken by the robotic arm to minimize travel time and energy consumption while maintaining accuracy. The joint space trajectory is crucial for defining velocity and acceleration profiles along the path.

Using Java in the SIMULINK environment provides a flexible platform for testing various trajectory planning algorithms. The DH parameter analysis is vital for setting up the robot's kinematic equations, allowing for precise control over its movements.

II. Obstacle Avoidance Techniques:

A. Introduction:

Various algorithms, such as potential fields, visibility graphs, or sampling-based methods, can be integrated to enhance the robot's ability to navigate complex environments. Evaluating parameters such as distance, speed, and angular displacement helps in refining the path for smooth and collision-free operation.

The parental segment [6] should be given size, length and the angle. Once the parental segment is created it helps to move the robot arm. The other segments are known as child segment. The child segments will move with respective to the parental segment. The child segment created with a length smaller to the parental segment. The child segment is made to follow the Parental segment. Once the parental segment is joined with a child segment, it is called robot arm, it is consisting of number of segments (joints) is called tentacles. The arm is stretched from initial point to reach the target point the movement of arm takes place. The parental segment helps in movement and rotating of a robot arm. The creation of a Parental and child segment is shown in Figure 1. These segments help the robot arm in the movement to reach its final position.

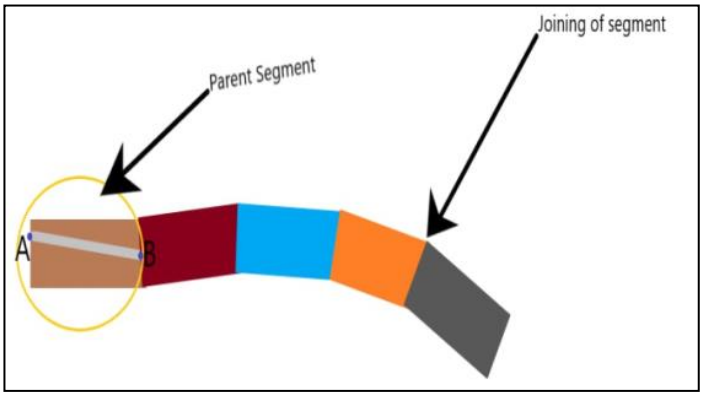

Figure 1. Segments of Robot Arm

B. Scalar Projection [8]

The Scalar Projection of a vector {a} on (or onto) a vector b, also known as the scalar resolute of {a} in the direction of {b}

Scalar Projection = Vector A . Vector B

The scalar projection of vector A on vector B is shown in Figure 2. ‘a2’ is the normal distance of scalar projection.

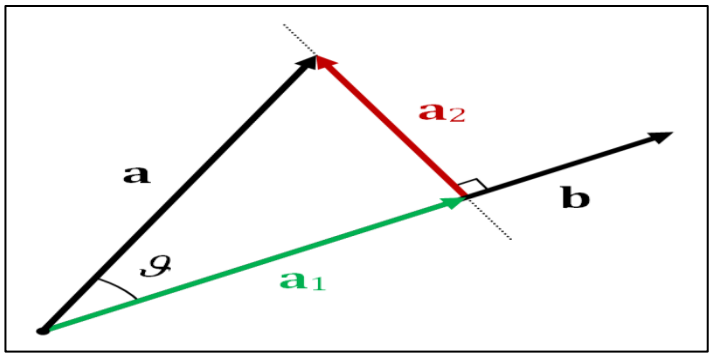

Figure 2. Scalar Projection

C. Path Following Principle of Robot Arm

The path following by a robot arm is based on the Scalar Projection. Velocity vector V1 is the beginning of the path to the future location of arm. Velocity vector V2 is the total path from start to end.

The main objective is to find the distance between the future point, 'a' and end point of projection, 'b' (vector V1 on vector V2).

The initial, future and projected positions of a robot following the path is shown in Figure 3. Vector V1 shows the distance from the initial to future position of a robot. Vector V2 shows the total path length.

The distance,'d' of this normal vector is calculated by Scalar Projection.

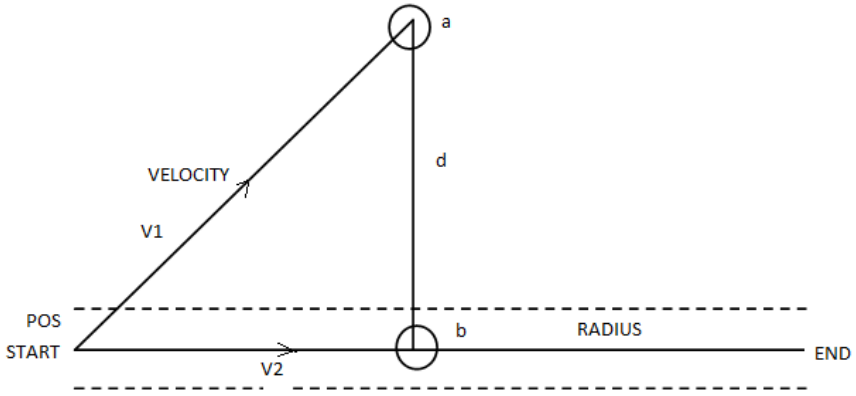

Figure 3. Path Following

Step 1: Calculate the future position of arm: The arm is to continue at the same velocity that of the future point.

Step 2: Checking the future position is on the path: So that it will be helpful to calculate the distance between the future position and the projected point of the future position.

Step 3: Finding the projection point and calculating: Calculating the normal distance between the projection point and the future point is based on the scalar projection.

Step 4: Tracking the projected point as target: Once it is on the path it does not require steering of arm of the robot.

The radius of the path and the normal distance between the future point and projected point is shown in Figure 4. The condition for the future point is should be greater than the radius of the path.

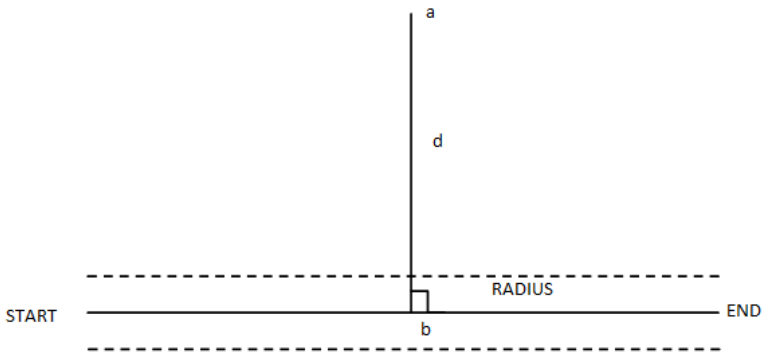

Figure 4 Projected Points

D. Path Following Steering Behavior [4]

Path following is implemented here by performing corrective steering only when the arm begins to head off. A prediction of the arm future position is made based on its current velocity of the arm (red dot). This predicted future position is mapped onto the nearest point (point 'a') on the path spine (black line). When the distance between these points exceeds the path radius (indicated by a red line) corrective steering is required. (In the Figure 4, an equivalent condition is that the point 'a' moves outside the region included in the radius.) Corrective steering is obtained using seek behavior on a target point 'b', further down the path. The robot arm's position is mapped into a distance moved along the path. Increment in speed is proportional to increment in distance and converted back to a target point 'b' on the path (green circle.) The path following goal is considered to be met as long as the robot arm is within a certain neighborhood of the path spine. The path following requirement can be made stricter by reducing the radius towards zero.

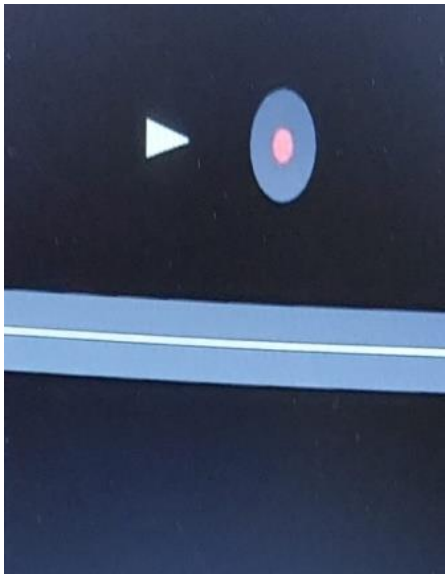

Figure 5. Steering Behavior

The future position of robot arm (red dot) confined to the path radius is shown in Figure 5. The future position of a robot arm (red dot) can be brought to the path by applying steering force of maximum of 0.1N and it can be brought to the path easily by making the path radius zero. The projected point of future position of a robot arm (green dot) is shown in Figure 6. The projected point (green dot) will be always parallel to the future point (red dot).

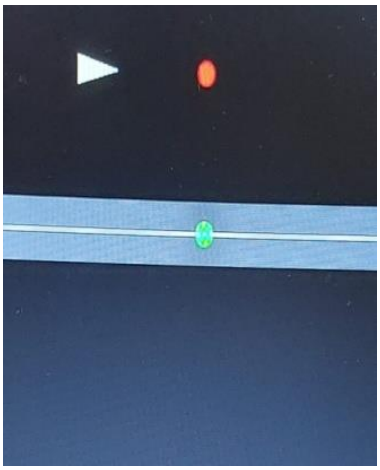

Figure 6. Path Following Arm

III. Results and Discussions:

Steering force applied must be greater than 0.1N in order to maintain a path. The Following observations are made.

- Future point of arm – Point coordinates
- Future position radius – Path radius (Increase or decrease)
- Projection point distance – Normal vector (Increase or decrease)
- Arm shape – (Triangular shape in this study)
- The speed of the robot arm is controlled by changing speed value between minimum and maximum.
- Due to which speed is also decreased. On the command over the speed and the direction is also controlled.

The creation of a cross arm is shown in Figure 7. Cross arm is the initial step for the configuration of the robot arm.

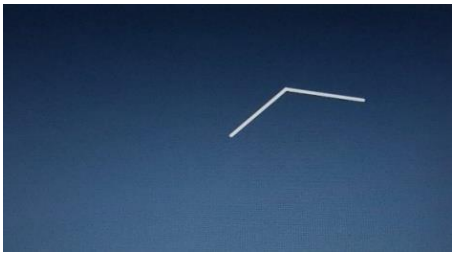

Figure 7. Cross Arm

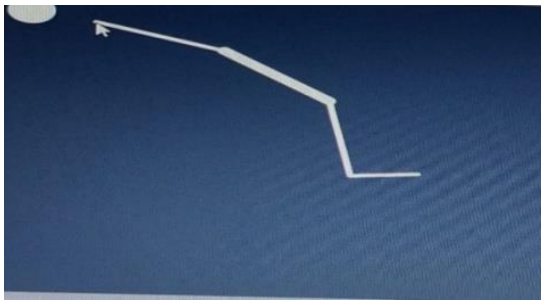

Figure 8. Robot Arm Segments

The robot arm segments which is created on the principles of forward and inverse kinematics is shown in Figure 8. The movement of the robot arm segments is done by child segments following the parental segments to reach the target position.

The future positions (red dot) of a robot can be altered as shown in Figure 9. The coordinates of the future position and radius of future position can be altered. The alteration of the projected point (green dot) of the future position is shown in Figure 10. The coordinates of projected point and radius of the projected point can be altered.

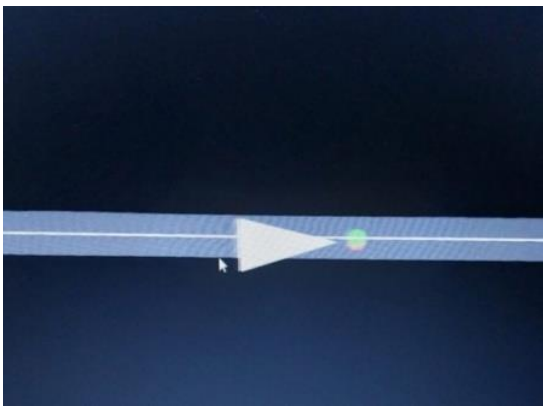

Figure 9: Path Following Arm

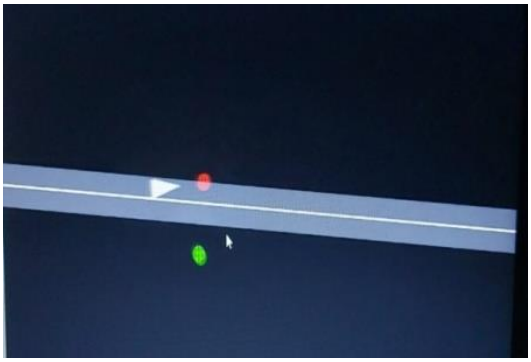

Figure 10: Projected Arm Point

IV. Conclusions:

This study concludes that the line-following robot represents an autonomous system capable of recognizing its path and efficiently adjusting its position to remain on track within a three-dimensional space (x, y, z). The robot's ability to autonomously detect and follow its designated trajectory demonstrates its potential for various applications in robotics and automation.

The trajectory tracking of the robot arm is effectively projected using inverse kinematic transformations, implemented through Java programming in a SIMULINK environment. This approach provides precise control over the robot's movements and ensures that it can adapt to changes in the path while maintaining accurate positioning.

The effectiveness of inverse kinematic solutions is further highlighted in the design and implementation of robotic systems within manufacturing environments. This method proves particularly advantageous in scenarios where precision, speed, and flexibility are paramount. By leveraging inverse kinematics, robots can be programmed to follow complex trajectories with high accuracy, reducing the need for manual intervention and enhancing overall productivity.

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68. Understanding Measurement System, Determining and Analyzing the Measurement Variations

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ABSTRACT:

To compete in a global marketplace, manufacturers are increasingly turning to advanced manufacturing techniques to increase productivity and gain a competitive advantage. The paper is concentrated on understanding the measurement system and the instruments used for measurements in the industries. Measurement System Analysis is the six- sigma method of determining the variations in measurement system. For the continuous gauges Gage R&R method is adopted for determining the variations caused due to the appraiser and instrument and analysis is done by ANOVA method using the Minitab Software. For the attribute gauges Kappa study is adopted to determine the variations and analysis is done using the Minitab Software.

KEYWORDS:

Measurement System Analysis (MSA), Gage R&R, Kappa Study, Measurement Variation.

1. Introductions:

Measurement System is the total procedure used to acquire measurements. i.e. Measurement system is the accumulation of instruments, person, standard, environment, method, fixtures used to quantify the amount or fix evaluation to the characteristic being measured. The Standards in Measurement System are divided into three groups: (1) Primary standards: They have the highest quality and are compared with the next level of standards. (2) Secondary standard: The secondary standard is calibrated with reference to primary standards. (3) Working standards: The working standards are calibrated using secondary standards. The Measurement Process consists of obtaining a quantitative comparison between a measure and predefined standard.

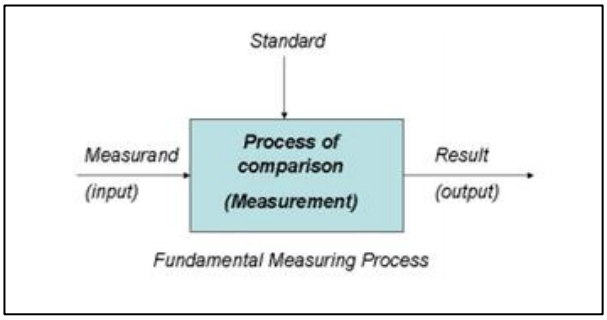


Figure 1: Measurement System

Measurement System Analysis (MSA) is used to determine the Variations in the Measurement System. There are two types of errors Random errors and the systematic errors. (1) Random Errors.

There are two types of variations in the measuring system. The variation caused by continuous characteristics and the variation caused by discrete characteristics. The continuous characteristics are those which can be measured and the discrete characteristics are those which cannot be measured. There are different procedures for continuous characteristics and for the discrete characteristics. The variations in the Measurement system is occurs by standard, work piece, instrument, person and environment.

II. LITERATURE SURVEY:

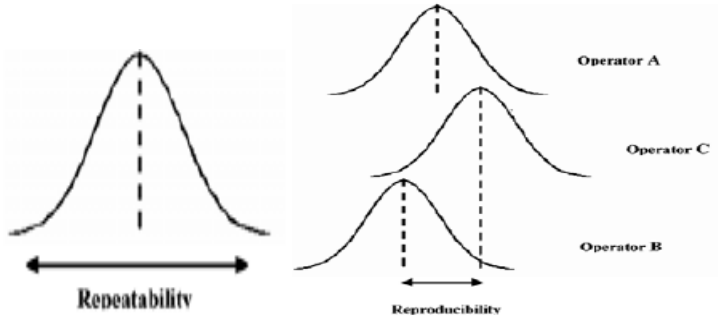
A. Gauges

A gauge or gage is a device used to make measurements. A device for measuring a physical quantity is called as gage, example to determine, diameter, thickness, pressure etc. The different Types of Gauges used in this project are Bore Gauge, Depth Gauge and Go- No-Go Gauges. In the OP 10 Workstation of Fuel Pump total of 4 Bore Gauges, 6 depth Gauges and 1 Thread gauge, 1 Thread Plug Gauge and 2 Go-NOGO Gauges are used.

B. Measurement Variation

The measurement system is caused because of both systematic and random sources of variation. Common and special causes are the sources of Variation. Variance of a process caused by chance factors that cannot be anticipated, detected, identified, or eliminated or many irregular and erratic fluctuations. To analyze the type of measurement errors the accuracy and precision is important. (1) Accuracy: The Accuracy is the difference between the actual values obtained to the expected value of measurement. A ‘good’ measurement is one in which the difference is as smaller as possible. Accuracy is divided into three aspects: Stability, Bias and Linearity. (2) Precision: While measuring the same part with same instrument the variation occurs. The precision in the measurement system will be more when the variation is less. Precision is divided into two aspects: (i) Repeatability: The variation in readings of measurement when the same part is measured by same equipment and by the same person.

There is a index which shows the capability of measurement for the system to obtain same result from repeated measurement. (ii) Reproducibility (appraiser variation): The Variation in the average of measurements when the same part is measured by different operators with unique equipment. Reproducibility shows the variation of human factors in using one unique tool and method.



C. Measurement System Analysis:

Measurement System Analyses is the method of determining the variations in the measurement system. It is one of the 6-SiGMA technique used in the industries for determining the measurement variations. Different techniques are employed to determine the variations for the continuous and the discrete characteristics. Gage R&R is the method used for determining the variations in the variable gauges. Under the Gage R&R there are different methods to determining the variations. In this Project ANOVA method is adopted for determining the variations in the measuring instruments with the variable gauges. For the discrete characteristics KAPPA study is adopted in determining the variations for the discrete characteristics. For the Attribute gauges the KAPPA Study is the Gauge R&R like method which can determine variations.

III. OBJECTIVES:

- To understand the measurement system and the instruments used for measurements.
- To determine the type of variation in the workstation 1 of CP1 fuel pumps.
- To determine the variations of continuous gauges by ANOVA Method
- To determine the variations of attribute gauges by Kappa Study.
- Analyze the variations using Minitab Software.
- To suggest for improvement in the measurement system.

IV. METHODOLOGY:

Similar to all processes, the measurement system is impacted by both random and systematic sources of variation. There are six element which represent the variations in the measurement system which is represented by S.W.I.P.E. S.W.I.P.E. stands for Standard, Work piece, Instrument, Person and Procedure, and Environment.[1] The measurement variation can be controlled by understanding these areas and can be eliminated. The figure 3 shows the Fishbone or the cause and effect diagram for measurement variation.The Variations due to the Work piece and Environment is negligible since the operation is not

manual the parts produced are through CNC machine. The environment should be maintained at 25°C and by the continuous coolant supply during machining the work piece cools fast. The variations due to the Standard, Instrument and Person can be using six-sigma method. There are different Procedures to determine the variations according to the BOSCH Quality Booklet 10. Procedure 1 is carried out to determine the variation in the Standard, Procedure 2 is used to determine the variation in the measuring Instrument and also the Appraiser Variation.

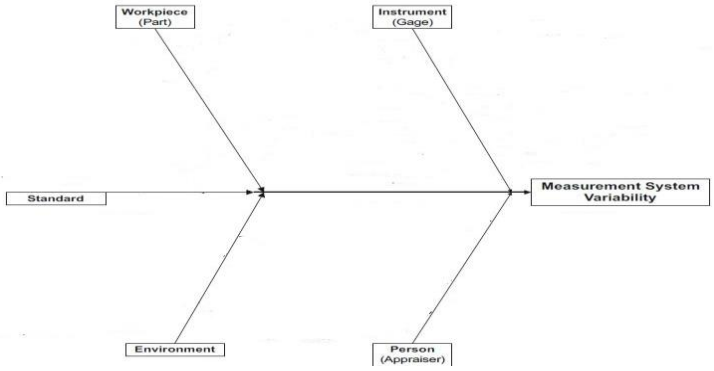


Table 1: The Documentation for the Procedure 1

Observations:

Tolerance T=USL-LSL (2) Reference Value = X_m (3) No of Measured Values = n (4) Measured Values Xi (i=1, 2,3)

Calculations:

Mean of Standard Values: $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$

Standard Deviation of Mean Values: $s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$

Potential Capability Index: $C_g = \frac{0.2 \times T}{6 \times S}$

Critical Capability Index: $C_{gk} = \frac{0.1 \times T - |\bar{x} - x_m|}{3 \times s}$

The Capability results can be obtained by the following calculations of Cg and Cgk. Manual Calculations are recommended so the evaluation of Procedure 1 is done by usng the statistical software such as the Qs_Statot he Minitab.

From the results from the procedure 1 the analysis is done on the Setting Master/ Standard. Setting Master should be checked for its form parameters such as the Roundness, Cylindricity, Parallelity, Run-out and do the corrections according to that while using the gauge/ Instrument.

Procedure 2: Repeatability and Reproducibility with operator influence.

A type-2 study is done using at least 10 (n ≥10) repeatably measurable and randomly selected serial parts as measuring objects. The characteristic values of these parts should preferably lie within the tolerance range. All factors should take effect that also will take effect during operation of the measuring system in series production. The selected serial parts are measured in random order by at least three (k ≥3) operators in at least two (r ≥2) measurement series under repeatability conditions.

After completion of the first measurement series, each operator measures again the same serial parts in random order. If further measurement series are intended, the procedure is repeated in the same manner until all measurement series are completed. The next series must not be started before the preceding series has been completed. The measurement results have to be documented.

Table 2: Data Collection Sheet for Procedure 2

MSA-Type 2 study -Repeatability and reproducibility (gage R&R) with operator influence						
n	**Xa1**	**Xa2**	**Xb1**	**Xb2**	**Xc1**	**Xc2**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

The capability of the procedure 2 can be described as below.

- %GRR ≤10% : measurement process is capable
- 10% < %GRR ≤ 30% : measurement process is conditionally capable
- %GRR > 30%: measurement process is not capable

GRR is given by Formula:

%GRR = $\%GRR = \frac{6 \times GRR}{T} X 100\%$

Procedure 3: Test decisions for discreate and discreatized continuous characteristics.

To do the study, the reference parts are used as test objects. They are tested under serial conditions in a random order that is unknown to the test personnel using the specified test equipment and test methods (e.g. according to the test plan) or an automatic test system. Each part is allocated to a rating category. The test personnel must be adequately trained and instructed. If the test results (i.e. the ratings) can be affected by the handling and/or subjective decision of the test personnel (e.g. when manual calipers are used for testing or in case of visual inspections), the test objects must be tested by (at least) 3 appraisers in 2 test runs, respectively. If handling and/or subjective decisions are irrelevant (e.g. in case of automatic test systems), the test objects must be tested in multiple test runs (6 test runs are recommended). In either case, the order of the test objects must be randomly rearranged for each test run. The test results (i.e. the ratings) are documented.

Table 3: Data Collection Sheet for Procedure 3

MSA-Type 3 Kappa Study							
i	**Reference Value**	**Xa1**	**Xa2**	**Xb1**	**Xb2**	**Xc1**	**Xc2**
1							
2							
3							
4							
5							
6							
7							
::							
::							
::							
47							
49							
50							

The capability is classified by means of the parameter κ(“kappa”):

- $\kappa \geq 0.9$ test process is capable,
- $0.9 > \kappa \geq 0.7$ test process is conditionally capable,
- $\kappa < 0.7$ test process is not capable.

The minimum of all determined κ-values are relevant for the final classification of the test process. If the test process is conditionally capable or not capable, it must be improved by taking suitable measures. The unambiguousness of test decisions is analyzed by means of pair-wise agreements of individual ratings. The parameter κ(“kappa”) is used as a quantitative measure

$$k = \frac{observed\ non\ random\ agreements}{possible\ non\ random\ agrements}$$

The analysis comprises the following comparisons and calculations of the corresponding parameter 'κ':

- Within appraisers: Compare all test runs of each individual appraiser without comparing to the reference (repeatability).
- Between appraisers: Compare all test runs of all appraisers without comparing to the reference (reproducibility).
- Compare all test runs of each individual appraiser to the reference.
- Compare all test runs of all appraisers to the reference.

V. Results and Discussion:

There are 14 gauges used for measurement in the workstation 1 of CP1 fuel pumps. Out of which there are 5 Bore gauges, 5 Depth gauges and 2 Thread gauges and 2 Plug Gauges. Bore Gauges and Depth Gauges are called as the Continuous Gauges while the Thread and Plug Gauges are called the attribute gauges. The Continuous gauges give values where as in attribute gauges it gives result as OK and Not OK. The Capability of these gauges is obtained from the Statistical Software such as the Minitab17 and Minitab 18. In the Minitab Software Gage study 1 gives the results of the Measuring standard. Gage study 2 gives results of the variations due to Instrument, Appraiser. Attribute Gage study gives the results of the attribute gauges such as the thread gauge and the plug gauges.

Results of Continuous Gauges:

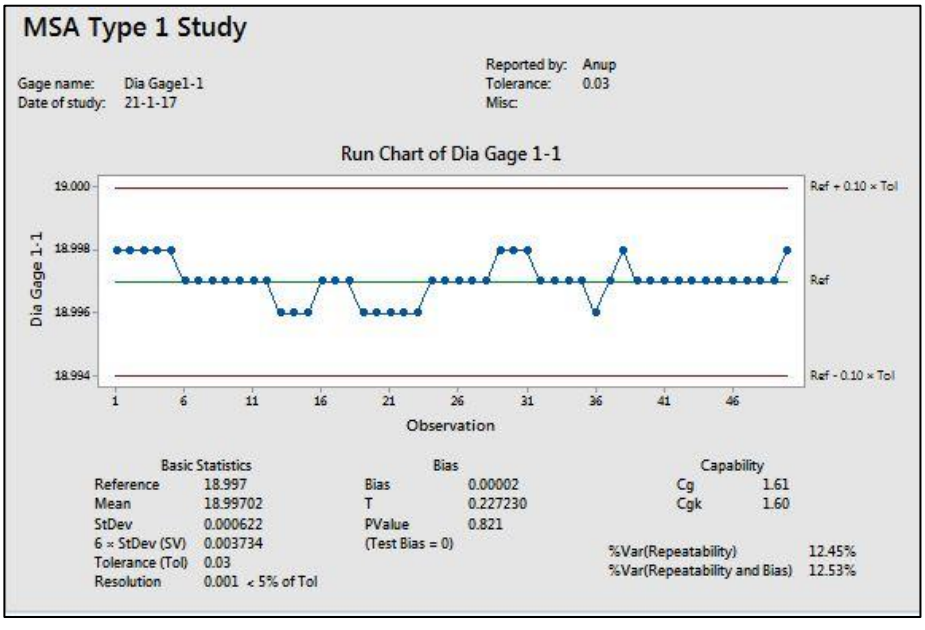


Figure 4: Minitab Result sheet of Procedure 1

Results of Procedure 1				
Sl no	**Gage**	**Cg**	**Cgk**	**Result**
1	Gage 1	1.61	1.6	Measurement System is Capable
2	Gage 2	1.35	1.33	Measurement System is Capable
3	Gage 3	1.55	1.36	Measurement System is Capable
4	Gage 4	0.76	0.61	Measurement System is Not Capable
5	Gage 5	0.53	0.44	Measurement System is Not Capable
6	Gage 6	1.57	1.52	Measurement System is Capable
7	Gage 7	2.01	1.72	Measurement System is Capable
8	Gage 8	1.64	1.58	Measurement System is Capable
9	Gage 9	5.71	5.23	Measurement System is Capable
10	Gage 10	1.62	1.35	Measurement System is Capable

The Results obtained of all the guages are as follows:

Table 4: Result sheet of Procedure 1

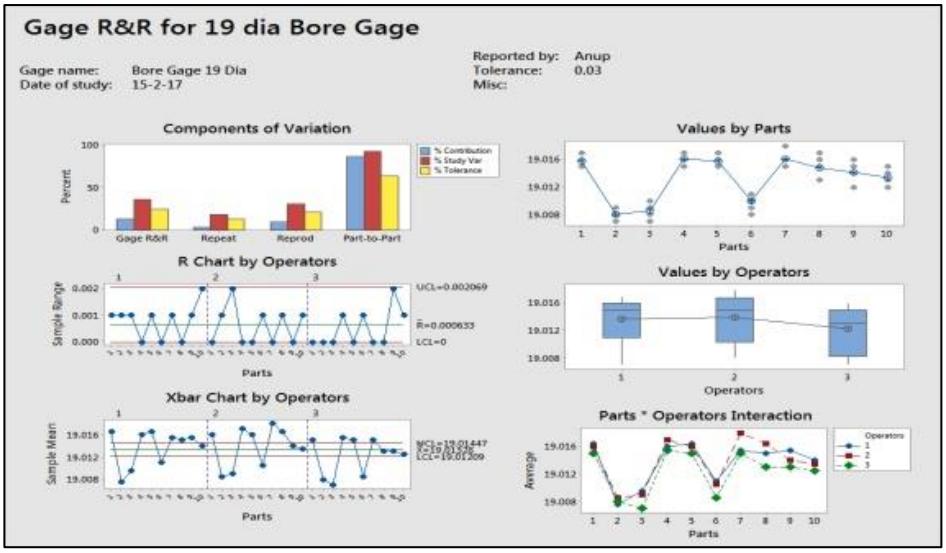


Figure 5: Minitab Result sheet of Procedure 2

Table 5: Result sheet of Procedure 2

Results of Procedure 2			
Sl no	**Gage**	**%GRR**	**Result**
1	Gage 1	24.83	Measurement System is Marginally Capable
2	Gage 2	7.75	Measurement System is Capable
3	Gage 3	18.3	Measurement System is Marginally Capable
4	Gage 4	21.81	Measurement System is Marginally Capable

Results of Procedure 2			
Sl no	**Gage**	**%GRR**	**Result**
5	Gage 5	58.21	Measurement System is Not Capable
6	Gage 6	22.02	Measurement System is Marginally Capable
7	Gage 7	18.45	Measurement System is Marginally Capable
8	Gage 8	19.86	Measurement System is Marginally Capable
9	Gage 9	5.74	Measurement System is Capable
10	Gage 10	45.41	Measurement System is Not Capable

From the results of Procedure 1 8 gauges are capable and 2 gauges are not capable. Applying the Conditionally capable principle i.e Cg, Cgk 0.7-1.33 are conditionally capable. By these 9 gauges are capable and 1 gauge is not capable. Now by checking the roundness of ring gauge of dia 64.4 it is found that the roundness is 12µm so the master gauge is correct.

From the result obtained from the Procedure 2 of Gage study from the Minitab Software we can analyze that out of 10 gauges only 2 gauges are capable i.e %GRR≤10% and 6 gauges are marginally capable i.e. 10%≤%GRR≤30% and 2 gauges are not capable i.e %GRR≥30%. %GRR is the combination of Repeatability and Reproducibility values. So to further determine the variations we need to analyze individually repeatability and reproducibility values of all the gauges.

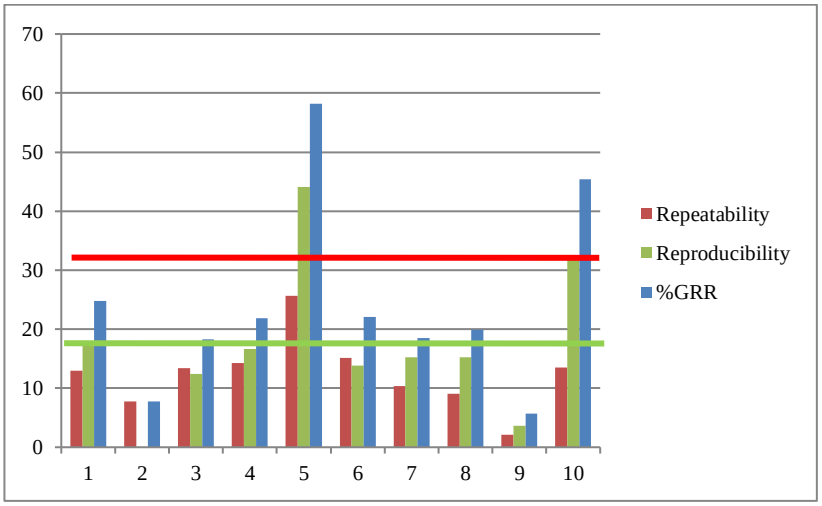


Figure 6: Result of Continuous Gauges

If we consider 15 % as acceptable then,

Repeatability: 0-15% --- 8 gauges 15-30% 2 gauges.

Reproducibility: 0-15% -4 gauges 15-30% - 4 gauges, 30+ 2 gauges

By Repeatability 2 gauges are marginally capable. By Reproducibility error 2 gauges are not capable and 4 gauges are marginally capable. Repeatability is caused due to the

instrument error. And Reproducibility is caused due to the Appraiser error. GRR=Repeatability+ Reproducibility.

The Problem caused by Reproducibility is more than Repeatability. The appraiser variation is more in the measurement system. Measure has to be taken by operators to reduce the error.

B. Results of Attribute Gauges:

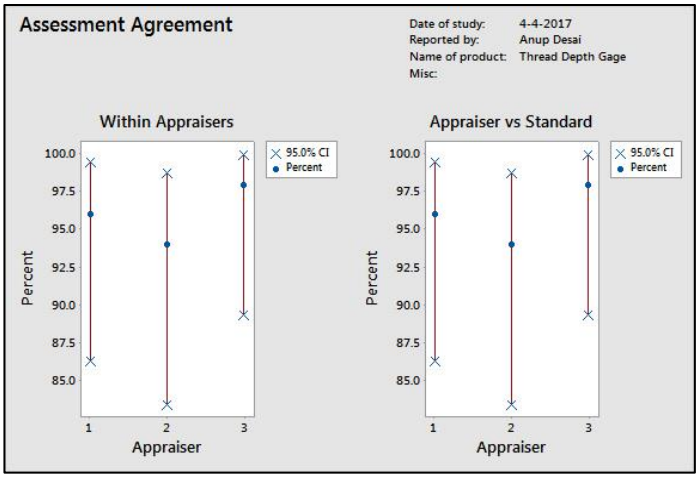


Figure 7: Minitab Result of Attribute Gauges

Table 6: Result sheet of Procedure 3

Results of Procedure 3			
Sl no	**Gage**	**k**	**Result**
1	Gage 1	0.96	Measurement System is Capable
2	Gage 2	0.98	Measurement System is Capable
3	Gage 3	0.9	Measurement System is Capable
4	Gage 4	0.96	Measurement System is Capable

From the above result 4 gauges are capable i.e k>0.9.

Fixture for CP1 Fuel pump housing

To reduce the reproducibility error and to improve the measurement process a fixture is suggested as show in the figure. The fixture consists of 3 legs. The two sides of the pump housing are supported at the mounting holes by the longer legs and the whole body is supported by the shorter leg of the fixture. Then it's locked by locking key provided at the top.

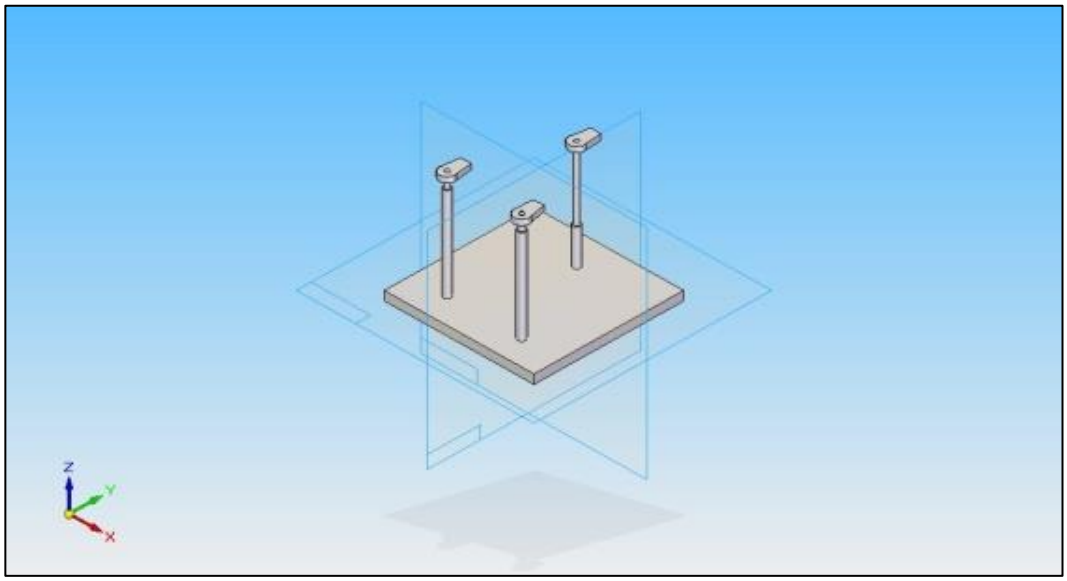


Figure 8: Model of Fixture for CP1 Fuel Pump Housing.

VI. Conclusion:

The variations in the measuring system are caused due to the S.W.I.P.E that is Standard, Work piece, Instrument, Person and Environment. The Variations due to the Work piece and Environment is negligible since the operation is not manual the parts produced are through CNC machine. The environment should be maintained at 25°C and by the continuous coolant supply during machining the work piece cools fast. The variations due to the Standard, Instrument and Person can be using six-sigma method. The variation in standard is determined by Procedure 1 of BOSCH quality booklet. The variation due to the instrument and person is determined by Gage R&R method – Procedure 2 of BOSCH quality booklet for continuous gauges and kappa study Procedure 3 of BOSCH quality booklet for attribute gauges.

From results of Procedure 1- 1 gauge is not capable and 1 gauge is marginally capable.

From the results of Procedure 2 -2 gauges are capable, 6 gauges were marginally capable and 2 gauges are not capable. From the analysis of the results the problem is caused more due Reproducibility error. The reproducibility error is caused due to the appraiser/operator.

To reduce the reproducibility error the measures to be taken are:

- Proper training has to be given to the operators.
- A fixture has to be provided during the measurements so that movement or rotation of work piece can be avoided.

From the results from procedure 3 all the attribute gauges were capable.

VII. References:

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69. Factors Influencing Grievance Management and Employee Engagement in the Workplace: A Case Study of Cement Industry

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ABSTRACT:

This study examines the factors influencing the effectiveness of grievance procedures and their impact on employee engagement within the cement industry. The analysis highlights that while the grievance procedure itself has a limited impact on its effectiveness, significant contributions come from management style, the work environment, and promotion systems. Supportive management and a positive work environment greatly enhance the effectiveness of grievance handling. Fair and transparent promotion practices also significantly reinforce the credibility of grievance processes. Although effective grievance procedures positively influence employee engagement, the effect is relatively modest compared to other factors. The findings suggest that improving grievance management requires a multifaceted approach, incorporating supportive management practices, a conducive work environment, and equitable promotion systems to foster effective grievance resolution and boost overall employee engagement.

KEYWORDS:

Grievance, Procedure, Management Style, Promotion System, Work Environment, Employee Engagement.

1. Introductions:

Effective grievance management is crucial for maintaining a positive work environment and ensuring employee satisfaction. In the context of the cement industry, understanding the factors that influence the effectiveness of grievance procedures and their impact on employee engagement is essential for fostering a productive and motivated workforce. This study explores several key variables affecting grievance management, including the

grievance procedure itself, management style, work environment, and promotion system. Additionally, it examines how the effectiveness of grievance procedures influences overall employee engagement. The analysis reveals that while the grievance procedure has a modest impact on its own effectiveness, significant contributions come from management style, work environment, and promotion practices. Specifically, supportive management and a positive work environment are shown to substantially enhance grievance handling effectiveness. Fair and transparent promotion systems also play a crucial role in reinforcing the credibility of grievance processes. Moreover, the study highlights that although effective grievance procedures positively impact employee engagement, the effect is relatively modest compared to other engagement factors. By investigating these relationships, this analysis aims to provide insights into how organizations can improve their grievance management practices and, consequently, their employee engagement levels. The findings underscore the importance of addressing various organizational factors to create a supportive and fair work environment that effectively manages grievances and enhances overall employee satisfaction.

II. Literature Review:

The Study offers a thorough examination of organizational behavior concepts, encompassing grievance management and employee engagement. It integrates various factors influencing these processes, providing a broad understanding of how organizational dynamics impact employee interactions, grievance resolution, and overall engagement. The book serves as a foundational resource for understanding the complexities of workplace behavior and the interplay between different organizational elements. Robinson [1].

This paper provides a comparative analysis of grievance procedures across different industries, revealing that industry-specific factors significantly affect grievance handling effectiveness [2].

The study identifies best practices for managing grievances, including clear procedures, timely resolutions, and supportive environments, applicable across various organizational contexts [3].

Management Style and Grievance Procedures:

This study explores how different leadership styles impact the handling of employee grievances. It finds that transformational and supportive leadership significantly enhance the effectiveness of grievance resolution by fostering open communication and trust [4]. The research highlights that participative and empathetic management styles lead to more effective grievance procedures by improving employee satisfaction and resolution outcomes [5].

Work Environment and Grievance Procedures:

This paper examines how physical and psychological aspects of the work environment affect grievance management. It concludes that a supportive and safe work environment significantly improves grievance handling [6].

The study finds that improvements in workplace conditions, including better ergonomics and safety measures, contribute to more effective grievance resolution by reducing stress and dissatisfaction [7].

Promotion Systems and Grievance Procedures:

This research investigates the relationship between promotion fairness and grievance handling. It demonstrates that transparent and merit-based promotion systems enhance the effectiveness of grievance procedures [8].

The paper reviews various promotion practices and their impact on grievance management, highlighting that fair promotion processes contribute to improved grievance resolution outcomes [9].

Grievance Procedures and Employee Engagement:

This study examines how the effectiveness of grievance procedures affects employee engagement. It finds that while effective grievance procedures positively impact engagement, the effect is relatively modest compared to other engagement drivers. Taylor, M., & Lee, D. (2023).

The research explores the influence of grievance resolution on employee motivation and engagement, finding that although effective grievance handling improves engagement, it is only one of several factors [10].

Objectives:

1. To identify various factors influencing Effective Grievance Procedure.
2. To ascertain the influence of factors on Effective Grievance Procedure.
3. To evaluate the influence of Effective Grievance Procedure on the Employee Engagement.

III. Research Methodology:

Research Design:

This study uses a quantitative approach to explore how management style, work environment, and promotion systems impact grievance management and employee engagement in the cement industry.

Data Collection:

Sampling Method: Stratified random sampling ensures representation from various departments and levels within the industry. Data Sources: Primary data is gathered via structured surveys with Likert scale questions, assessing grievance procedures, management style, work environment, promotion practices, and employee engagement.

Data Analysis:

Regression Analysis: Evaluate the impact of management style, work environment, and promotion systems on grievance effectiveness, and how effective grievance procedures influence employee engagement.

Limitations:

Generalizability: Results may be specific to the cement industry.

Response Bias: Potential biases in self-reported data.

Cross-Sectional Nature: Provides a snapshot, requiring longitudinal studies for long-term insights.

Hypothesis:

H1: Grievance Procedure Influences significantly on Effective Grievance Procedure.

H2: Management Style Influences significantly on Effective Grievance Procedure.

H3: Work Environment Influences significantly on Effective Grievance Procedure.

H4: Promotion System Influences significantly on Effective Grievance Procedure.

H5: Effectiveness of Grievance Procedure Influences significantly on Employee Engagement.

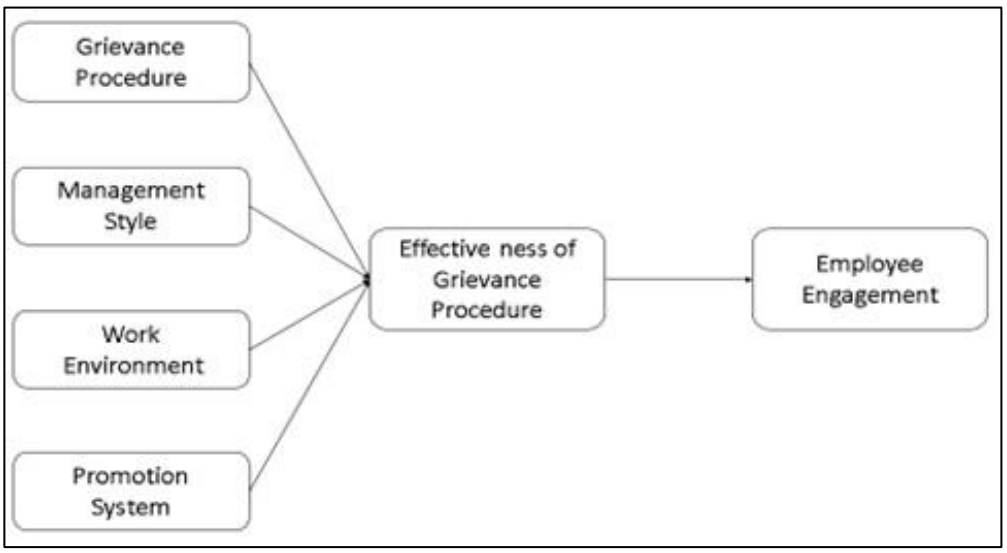

Figure 10*: *Theoretical frame work

IV. Data Analysis:

H1: Grievance Procedure Influences significantly on Effectiveness of Grievance Procedure.

Table 4 H1 Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.181[a]	.033	.028	.53764
a. Predictors: (Constant), Grievance_Procedure				

Table 5 H1 Anova

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2.180	1	2.180	7.541	.007[b]
	Residual	64.460	223	.289		
	Total	66.640	224			
a. Dependent Variable: Effectiveness_of_Greviance_Procedure						
b. Predictors: (Constant), Greviance_Procedure						

The grievance procedure has a significant but weak positive influence on the effectiveness of the grievance procedure, explaining 3.3% of the variance in the dependent variable. The p-value is less than 0.05, indicating that the grievance procedure has a significant influence on the effectiveness of the grievance procedure. Hypothesis H1 is accepted.

H2: Management Style Influences significantly on Effectiveness of Grievance Procedure.

Table 6 H2 Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.678[a]	.460	.458	.40160
a. Predictors: (Constant), Management_Style				

Table 7 H2 Anova

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	30.673	1	30.673	190.180	.000[b]
	Residual	35.967	223	.161		
	Total	66.640	224			
a. Dependent Variable: Effectiveness_of_Grievance_Procedure						
b. Predictors: (Constant), Management_Style						

Management style has a strong and significant positive influence on the effectiveness of the grievance procedure, explaining 46% of the variance in the dependent variable. The p-value is less than 0.05, indicating that management style has a significant influence on the effectiveness of the grievance procedure. Hypothesis H2 is accepted.

H3: Work Environment Influences significantly on Effectiveness of Grievance Procedure.

Table 8 H3 Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.701[a]	.491	.489	.38982
a. Predictors: (Constant), Work_Environment				

Table 9 H3 Anova

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	32.752	1	32.752	215.528	.000[b]
	Residual	33.888	223	.152		
	Total	66.640	224			
a. Dependent Variable: Effectiveness_of_Grievance_Procedure						
b. Predictors: (Constant), Work_Environment						

The work environment has a strong and significant positive influence on the effectiveness of the grievance procedure, explaining 49.1% of the variance in the dependent variable. The p-value is less than 0.05, indicating that the work environment has a significant influence on the effectiveness of the grievance procedure. Hypothesis H3 is accepted.

H4: Promotion System Influences significantly on Effectiveness of Grievance Procedure.

Table 10 H4 Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.660[a]	.436	.433	.41064
a. Predictors: (Constant), Promotion_System				

Table 11 H4 Anova

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	29.036	1	29.036	172.188	.000[b]
	Residual	37.604	223	.169		
	Total	66.640	224			
a. Dependent Variable: Effectiveness_of_Grievance_Procedure						
b. Predictors: (Constant), Promotion_System						

The promotion system has a strong and significant positive influence on the effectiveness of the grievance procedure, explaining 43.6% of the variance in the dependent variable. The p-value is less than 0.05, indicating that the promotion system has a significant influence on the effectiveness of the grievance procedure. Hypothesis H4 is accepted.

H5: Effectiveness of Grievance ProcedureInfluences significantly on Employee Engagement.

Table 12 H5 Model Summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.192[a]	.037	.033	.73335
a. Predictors: (Constant), Effectiveness_of_Grievance_Procedure				

Table 13H5 Anova

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4.613	1	4.613	8.578	.004[b]
	Residual	119.929	223	.538		
	Total	124.542	224			
a. Dependent Variable: Employee_Engagement						
b. Predictors: (Constant), Effectiveness_of_Grievance_Procedure						

An effective grievance procedure has a significant but weak positive influence on employee engagement, explaining 3.7% of the variance in the dependent variable. The p-value is less than 0.05, indicating that an effective grievance procedure has a significant influence on employee engagement. Hypothesis H5 is accepted.

V. Findings

1. Grievance Procedure has a small but significant influence on its effectiveness.
2. Management Style significantly impacts the effectiveness of the grievance procedure, suggesting that better management practices lead to more effective grievance handling.
3. Work Environment also significantly influences the effectiveness of the grievance procedure, indicating that a better work environment contributes to a more effective grievance process.
4. Promotion System significantly affects the effectiveness of the grievance procedure, implying that fair and transparent promotions lead to better grievance handling.
5. Effective Grievance Procedure has a small but significant influence on Employee Engagement, highlighting that improving grievance handling can slightly enhance employee engagement.

VI. Suggestions:

To enhance grievance procedures and boost employee engagement, companies should focus on several key strategies. Grievance procedures need to be clearly documented and communicated to ensure they are easily understood and accessible, with strong support and confidentiality measures to build trust. Prompt resolution of grievances is crucial to prevent escalation and demonstrate the company's commitment.

Improving management style is essential; fostering open communication, ensuring managers are approachable and supportive, and providing training in leadership and conflict resolution will improve grievance handling.

Optimizing the work environment involves investing in safety, health, and positive working conditions, while also promoting a culture of teamwork and work-life balance. Ensuring employees have the necessary resources and support is also critical.

The promotion system should be transparent, with clear criteria and merit-based promotions to ensure fairness. Providing constructive feedback can help employees achieve their career goals. To increase employee engagement, regularly recognizing and appreciating employees' efforts, offering professional development opportunities, and encouraging participation in company activities can enhance motivation and a sense of belonging. By focusing on these areas, companies can improve grievance procedures and create a more engaged and motivated workforce.

VII. Conclusion:

The analysis highlights key insights into grievance procedures. While the grievance procedure itself has a modest impact on its effectiveness, explaining only 3.3% of the variance, it is clear that other factors also play significant roles. Management style has a major influence, accounting for 46% of the variance, demonstrating that supportive and transparent management is crucial for effective grievance resolution. The work environment is equally important, explaining 49.1% of the variance, indicating that a safe and positive workplace is essential for managing grievances effectively. The promotion system also significantly affects grievance handling, with 43.6% of the variance, underscoring the importance of fair and transparent promotion practices. Lastly, although an effective grievance procedure positively impacts employee engagement, the effect is modest at 3.7%, suggesting that other factors are also vital in enhancing engagement.

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70. Digital Transformation in Foundries: Harnessing IoT for Smart Industry 4.0

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ABSTRACT:

The 21st century is marked by the dominance of the internet and electronics, penetrating virtually every facet of existence, spanning from household realms to space-age technologies.

This evolving landscape of cutting-edge technology holds potential for application within manufacturing industries, particularly the foundry sector. Presently, the foundry industry faces challenges in terms of energy efficiency and operational hurdles. By integrating IoT resources into this field, fresh avenues for innovation open up.

For instance, the utilization of technologies like the Internet of Things (IoT), extensive data analysis, cloud computing, and cybersecurity can help address system complexities. These technologies serve to enhance process efficiency and confer competitive advantages in terms of production speed.

In effect, this presents an advanced toolkit that expeditiously bolsters the efficacy of foundry enterprises through the digitization of their processes. This digitization holds promises of diminishing rejection rates, conserving energy, streamlining manpower utilization, and curbing industrial pollution. The implementation of IoT in conjunction with virtual initiatives on the Internet enables real-time monitoring and control of conditions. This synergy aligns with the paradigm shift towards greater digitalization, redefining the foundry landscape and its operational efficiency.

KEYWORDS:

Internet of Things (IoT), Foundry 4.0, castings, Automation, Quality, Rejection.

1. Introductions:

The Indian foundry industry produces metal cast segments for applications in Automotive, locomotives, marine, agriculture equipment, Machine devices, Defense, Aerospace, Earth Movers, Cement, Electrical, Pumps/Valves, turbine generators, and so forth. The FoundryIndustryhasaturnoverofapproximately1500billionrupees. There are approximately 6000 units in India out of which 90% can be named MSMEs. Approximately 600units are having International Quality Accreditation. Only a few large foundries are present-day and internationally serious about the upcoming challenges as they are facing several difficulties like skilled labor, government pollution norms, waste disposal, and changing technology of machinery and as a consequence, huge capital is required. India produced castings at an estimation of 11 million tons in 2018 and is normally extended at a compound yearly development rate (CAGR) of ~12.7% from 2018 until 2023 [1]. Figure 1 shows the production rate of castings in the country which is the second largest casting manufacturer in the world followed by China intheyear2018-19.

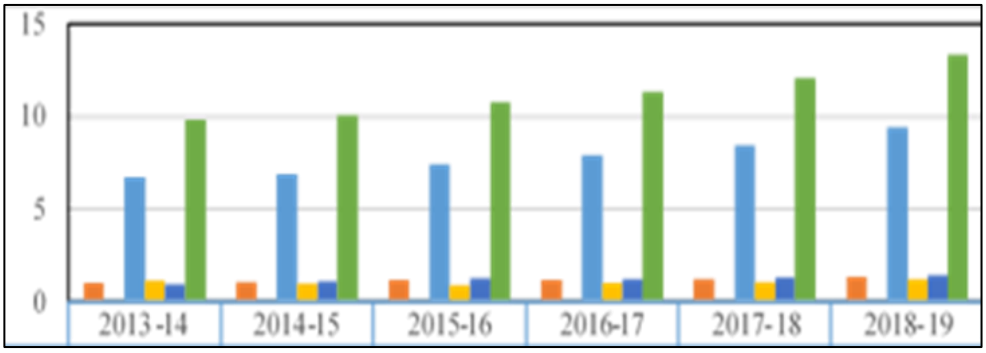

Figure 1: shows the Foundry castings production rate in India (Million Tonnes)

Sector-wise consumption of Casting: The market survey shows the distribution of foundry castings catering to some specific end-use markets like automotive, locomotive, energy, diesel engines, machinery, pipe fittings, etc. in which the automobile sector is the largest consumer of castings. Figure 2 shows the general view and subdivisions in the foundry industry.

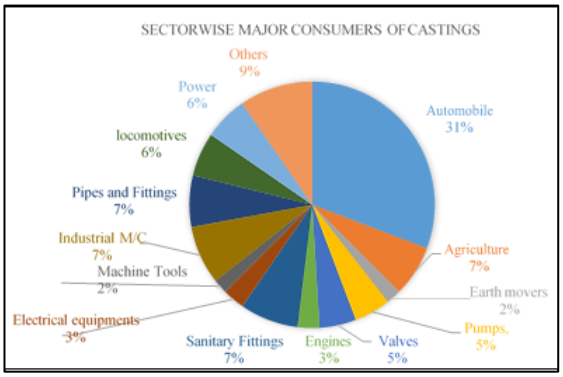

Figure 2: shows the sector wise major consumers of castings

A general foundry industry comprises many sections as shown in Figure 3, where each section has many variable significant contributions in producing the quality of castings. Despite everything staying.

aworkmanship,with immense factors and changes, there are a few zones that have advanced into a science, giving alikelihood to build up and regulate the framework, A great deal of quantifiable data has been collected and broken down prompting take the foundry from "workmanship" to "science" by automation. Previously, until the last decade, all foundry operations were performed manually. During this period, the creation process was also manual, resembling more of an Industry 1.0 level, requiring skilled labor to minimize rejection rates. Even in 2018, some foundries in India remain at Industry 1.0 to 2.0 levels, gradually starting to mechanize their processes on a smaller scale. This slow transition is due to the lack of available data and the large capital investments needed to streamline processes through automation [2]. The foundry needs the executives of various interdisciplinary engineers to evaluate the process variables to streamline the processes. The overall efficiency of the foundry process is comparatively low compared to their industries. Hence, presently foundry industry is facing a lot of challenges for its survival due to many factors like skilled labor, industrial pollution, power tariffs, technology transfers, and non-stable government policies.

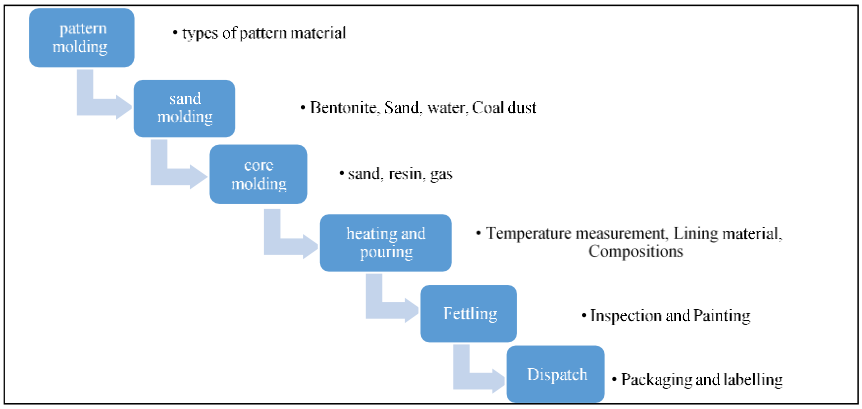

Figure3: General foundry layout

MSME foundry Sector in a threatening situation

A large number of foundry units that are under miniaturized scale (MSME) (little and medium ventures) have confronted the risk of closure. The Indian government is concentrating on foundry a segment that faces a large number of talented laborers leaving this industry to decide on elective methods for survival [3]. Additionally, attributable to dubious government strategy, the up-and-coming age of existing foundry unitholders has begun relocating into high profit-making industries. Numerous foundry players need to redesign their units to overcome the labor problem by mechanizing the process, however as it is costly it requires huge capital, small units can't bear the cost, and there are no supportive measures from the government. The foundry segment in India is set to experience some significant development throughout the following four years, posting a Compound Annual Growth Rate of 19.67 percent in terms of income from 2013-2018.

Shortfall of Skilled Manpower:

Presently Indian foundries are facing a major setback due to a shortage of skilled manpower, government is focusing on skill development of manpower named “Skill India” and also Foundry Development Councils, foundry clusters, and Indian steel-making councils started the training programs under the Branch of Industrial Policy and Promotion (DIPP) secretary and different partners has started many training programs but still the problem is not resolved, and there is always a shortage of talented work force in the foundry industry.

II. IIOTASANALTERNATESOLUTIONFORSMARTFOUNDRY4.0:

IIOT – Industrial Internet of Things is currently turning into a revolutionary empowering influence for foundries from any of the levels 1.0 to 3.0 to change to a Smart Foundry or Intelligent Foundry 4.0. Foundry 4.0 isn't one innovation however a combination of present-day innovations joined to make a 'clever industrial facility'. The 4.0 represents the fourth mechanical insurgency which from the start sounds extraordinary yet when you begin to take a glance at the potential outcomes it is anything but difficult to see how these advancements can turn out to be genuine game-changers [4-6]. The principal point is to make more intelligent, progressively effective assembling through the utilization of SMART production lines in the not-very-far-off future. As to the foundry business, this implies the improvement in effectiveness also, increasing the speed of the procedures and processes.

Industry 4.0:

Industry 4.0 refers to the current trend of automation and data exchange within manufacturing technologies. This encompasses elements such as cyber-physical systems, the Industrial Internet of Things (IIoT), cloud computing, and cognitive computing [6-8]. Industry 4.0 is often described as creating a "smart factory" and is given the name "4.0" as it represents the fourth phase of industrial evolution. The preceding three revolutions in the modern industry were:

1. Mechanization, powered by water and steam.
2. Mass production is characterized by assembly lines, conveyor belts, and electricity.
3. Electronics, involving computers, information technology, and multi-axis industrial robots.

Modern information and communication technologies, including cyber-physical systems, big data analysis, and cloud computing, play a pivotal role in Industry 4.0. They enable early detection of defects, machine conditions, work progress, and other crucial factors [9-12]. This, in turn, helps improve productivity, quality, and manufacturing speed by reducing the waste of materials, such as scrap castings. Big data analysis is comprised of six key elements within the integrated Industry 4.0 and cyber-physical systems environment, known as the 6C framework:

1. Connection/Interface (sensors and systems).
2. Cloud (on-demand processing and data storage).
3. Cyber (modeling and memory).

4. Content/Context (meaning and relationships).
5. Community (collaboration and sharing).
6. Customization (personalization and added value).

Right now, to give helpful understanding to foundry the board, information must be handled with cutting-edge strategies to create important data. In the present world many applications and manufacturing industries are progressing very fast by improving their company's performance by implementing Industry 2 and 3.0 through robotics and automation, but they are not self-sufficient in advancing industry or smart Industry 4.0, Figure 4, shows that growth of IoT in India, at the beginning of the internet in 2003 was very limited and was used for only limited applications like banking and educational purposes, but nowadays it has entered into almost every sector and reducing the human efforts.

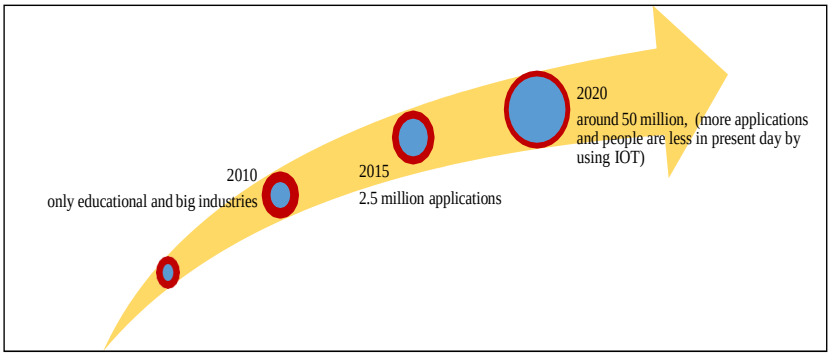

Figure 4: Road Map of Internet in India

Benefits of Foundry 4.0:

Technology is always a boon if used positively. Following are a few benefits.

1. Foundry 4.0 is not labor-demanding. Conventional foundries are labor-concentrated, subjected to the skill and experience of laborers.
2. Manufacturing targets can be achieved easily by automatization of the process.
3. Decreasing the cycle time.
4. Lower inventory.
5. Lower rejection rate, hence the Quality product is obtained
6. Higher Productivity gain and higher profits.

III. UNDERSTANDING THE ELEMENTS OF BUILDING SMART FOUNDRY 4.0:

When we have comprehended the procedure, we move on to the five basic components for Foundry 4.0: *Process Automation*–This is the most powerful testing component. No set procedure will give a conclusive result where the item will be with no abnormalities. It is hard to advance something whose procedure isn't characterized. By assortment of information on procedures required over some undefined time frame, there can be greater clarity concerning what are the criteria for ideal execution.

Machine Automation – Many big organizations are moving towards the robotization of their hardware. The foundry process should be reframed for reconciliation. The Process data needs to originate from the Casting Manufacturer (Foundry) and they have to mutually work with machine producers to share their foundry information to conquer any hindrance.

System Automation– System Automation presents two significant challenges. Firstly, the current landscape consists of Discrete Manufacturers, Discrete Platforms, and Discrete Systems, all operating independently. The need arises for a unified layer to amalgamate these elements seamlessly. Secondly, our reliance on Electronic Records (ERP) primarily involves retrospective analysis of the system, rather than proactive system control. To address these issues, a return to fundamental Manufacturing Process principles is imperative. Specifically, in Production Planning and Control (PPC), there's a pressing need for the seamless integration of systems, driven by real-time demand. The system should possess the capability to accurately predict when a casting will be produced upon receiving an order, identify the machines to be employed, and quantify the precise amount of material required for the task [13].

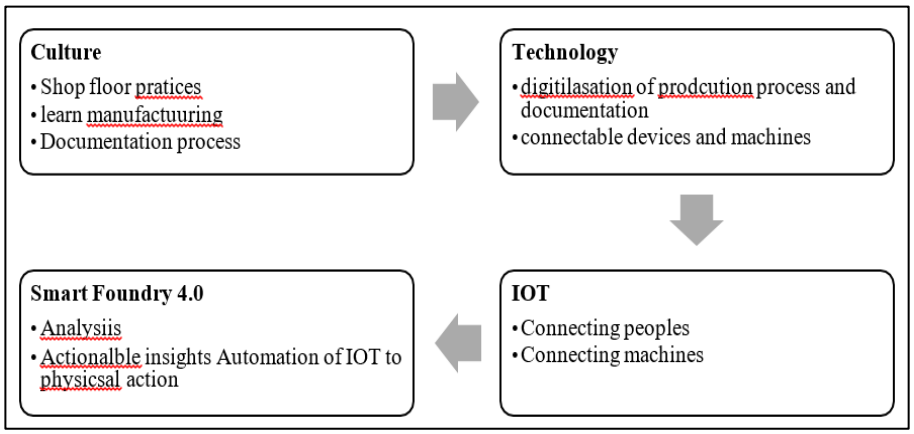

Figure5: Steps to build Smart Foundry 4.0

Upskilling Human Resources – Enhancing the Skills of our Workforce - Currently, our nation lacks a solid foundation for human resources development. To truly transform SMART Foundry into an Industry 4.0 entity, it must be run by knowledgeable and empowered individuals [14]. Unfortunately, there is a significant disconnect between the industry and educational institutions in India. Neither side is willing to collaborate or extend a helping hand. The only way to bridge this gap is through robust communication and collaboration between the industry and academia.

IV. ROLEOFIOTINFOUNDRY

Everything revolves around DATA, and every Decision Making or Business Intelligence Tool must commence with data. Every decision necessitates Action or a tangible Activity to achieve objectives [15]. The Internet of Things (IoT) gathers data and employs decision-making tools to offer practical insights regarding physical activities. In the contemporary world, technology stands as the most potent instrument [5, 6].

- Cultivating a conducive Culture.
- Enhancing Shop Floor Practices.
- Gaining proficiency in Manufacturing.
- Documenting Processes meticulously.
- Implementing Smart Foundry 4.0 principles.
- Employing Analytics.
- Utilizing Actionable Insights.
- Automating the translation of insights into physical actions.
- Leveraging Technology. Digitizing production processes and documentation.
- Integrating Connectable Devices and Machinery. Embracing IoT.
- Establishing connections between Machinery.
- Fostering connections among individuals.

Different sections of the foundry which are shown in Figure 3 can be grouped into There are three verticals.

Pattern making, Core molding, and Sand molding • Automation of Machinery and Processes within the Green Sand Production Method • Management of Sand Handling and Molding Systems
Sand preparation / Sand Reclamation • Automation of Machinery and Processes in Sand Recycling Procedures • Reclaiming Green Sand and Core Sand through Reclamation Processes
Heating, pouring, and sliding • Management of Assets and Processes Utilizing Industrial IoT and Analytical Tools • Optimizing the Melt Shop and Analyzing Motors and Transformers

In today's rapidly evolving industrial landscape, the Internet of Things (IoT) is reshaping the foundry industry, ushering in a new era of smart manufacturing, known as Industry 4.0. At its core, IoT enables the seamless integration of digital technology with physical operations, creating a data-driven ecosystem that enhances efficiency, quality, and productivity.

Data is the lifeblood of modern foundry operations, serving as the foundation for decision-making, process optimization, and innovation. In the foundry context, IoT is pivotal in collecting, processing, and utilizing vast amounts of data generated by interconnected devices and machinery.

By leveraging this data, foundries can gain valuable insights into their operations, enabling more informed decision-making and enhanced business intelligence.

Key Concepts:

Data-Driven Decisions: Every decision in a foundry is based on data, driving actionable insights that lead to tangible outcomes.

Business Intelligence: IoT systems empower foundries with real-time data analytics, offering comprehensive views of operations to identify trends, anomalies, and opportunities for improvement.

In a foundry setting, IoT sensors and devices are strategically placed throughout the production process to gather critical data points such as temperature, pressure, machine health, energy consumption, and more. This data forms the backbone of the foundry's decision-making framework, enabling stakeholders to make informed choices that optimize production, reduce waste, and enhance overall efficiency.

The Power of Technology

Technology serves as the most powerful tool in the contemporary world, driving advancements across various sectors, including the foundry industry. IoT stands at the forefront of this technological revolution, acting as a catalyst for change and innovation in foundries by enabling the collection, processing, and analysis of data at unprecedented levels.

IoT's Contribution to Foundries:

Data Collection: IoT systems gather real-time data from various points in the foundry, including machinery, sensors, and operators. This data is crucial for monitoring performance and identifying areas for improvement.

Decision-Making Tools: By employing advanced analytics and machine learning algorithms, IoT systems transform raw data into actionable insights, empowering foundries to make informed decisions quickly and accurately.

Actionable Insights: IoT provides a deeper understanding of operational processes, allowing foundries to identify inefficiencies and implement corrective actions to optimize performance.

Through IoT, foundries can leverage cutting-edge technologies to streamline their operations, improve product quality, and enhance worker safety. By embracing digital transformation, foundries can stay competitive in an increasingly complex and demanding market environment.

Cultivating a Conducive Culture:

The successful integration of IoT in foundries requires more than just technological advancements; it necessitates a cultural shift towards embracing digital innovation and data-

driven decision-making. Foundries must cultivate a conducive culture that fosters openness to change, encourages experimentation, and prioritizes continuous improvement.

Key Cultural Shifts:

Openness to Innovation: Encouraging employees to adopt new technologies and processes, fostering a culture of innovation.

Data-Driven Mindset: Shifting the organizational mindset to prioritize data-driven decision-making and insights.

Collaborative Environment: Promoting collaboration between departments to ensure seamless integration of IoT solutions across the foundry.

Enhancing Shop Floor Practices

IoT technology plays a pivotal role in revolutionizing shop floor practices in foundries, enabling more efficient and streamlined operations. Through the integration of IoT devices and systems, foundries can enhance shop floor practices by automating processes, improving communication, and optimizing resource utilization.

By nurturing a culture that values innovation and data-driven practices, foundries can unlock the full potential of IoT, driving transformative change that enhances efficiency, productivity, and competitiveness.

Improvements on the Shop Floor:

Process Automation: IoT enables automation of repetitive tasks, reducing manual labor and minimizing the risk of errors. Automated systems can handle complex processes with precision and consistency.

Real-Time Monitoring: IoT sensors provide real-time data on machinery performance, allowing operators to monitor operations continuously and detect issues before they escalate.

Resource Optimization: By analyzing data on resource usage, foundries can optimize material consumption and reduce waste, leading to cost savings and environmental benefits.

With IoT, foundries can enhance shop floor practices by streamlining operations, reducing downtime, and improving overall productivity. This transformation results in a more agile and responsive production environment that meets the demands of modern manufacturing.

Gaining Proficiency in Manufacturing

IoT technologies empower foundries to gain proficiency in manufacturing by providing a comprehensive understanding of production processes and enabling data-driven optimization.

By leveraging IoT insights, foundries can refine their manufacturing capabilities, enhance product quality, and achieve greater operational efficiency.

Key Proficiency Enhancements:

Process Optimization: IoT data analytics identify bottlenecks and inefficiencies in manufacturing processes, allowing foundries to implement targeted improvements and optimize workflows.

Quality Assurance: IoT systems enable real-time quality monitoring, ensuring that products meet stringent quality standards and reducing the risk of defects.

Predictive Maintenance: IoT sensors track equipment health, predicting maintenance needs before failures occur, minimizing downtime and prolonging machinery lifespan.

By gaining proficiency in manufacturing through IoT, foundries can achieve higher levels of efficiency, consistency, and quality, positioning themselves as leaders in the competitive manufacturing landscape.

Documenting Processes Meticulously Documentation is a critical aspect of foundry operations, ensuring transparency, traceability, and compliance with industry standards. IoT enhances documentation processes by automating data collection, storage, and retrieval, providing a comprehensive record of all activities and processes within the foundry.

Benefits of IoT-Enabled Documentation:

Automated Data Collection: IoT devices capture data automatically, reducing the need for manual data entry and minimizing the risk of errors.

Real-Time Access: IoT systems provide real-time access to process data, enabling operators and managers to track performance and make informed decisions.

Traceability: IoT documentation ensures traceability of materials, processes, and products, facilitating compliance with industry regulations and standards. With IoT-enabled documentation, foundries can maintain accurate records of their operations, enhancing transparency, accountability, and compliance.

Implementing Smart Foundry 4.0 Principles: Smart Foundry 4.0 represents the next generation of foundry operations, characterized by the integration of IoT technologies, automation, and data analytics. By implementing Smart Foundry 4.0 principles, foundries can achieve unprecedented levels of efficiency, quality, and innovation.

Key Principles:

Interconnectivity: Seamless communication between machines, systems, and humans, enabling real-time data exchange and collaboration.

Automation: Automated processes and systems reduce manual intervention, enhancing efficiency and precision.

Data Analytics: Advanced analytics provide insights into operations, driving informed decision-making and continuous improvement.

Flexibility: Agile production systems that adapt to changing demands and optimize resource utilization.

By adopting Smart Foundry 4.0 principles, foundries can transform their operations into intelligent, data-driven ecosystems that deliver superior performance and value.

Employing Analytics

Data analytics is a cornerstone of IoT implementation in foundries, providing valuable insights into operations, performance, and efficiency. By employing advanced analytics, foundries can unlock the potential of their data, driving process optimization and strategic decision-making.

Key Analytics Applications:

Process Optimization: Analytics tools identify inefficiencies and opportunities for improvement in production processes, enabling targeted interventions and optimization.

Predictive Maintenance: Data analytics predict equipment failures and maintenance needs, reducing downtime and enhancing equipment reliability.

Quality Control: Analytics systems monitor product quality in real-time, ensuring compliance with standards and minimizing defects.

By leveraging analytics, foundries can enhance their operational capabilities, reduce costs, and improve overall productivity.

Utilizing Actionable Insights

IoT systems generate vast amounts of data, but the true value lies in transforming this data into actionable insights. Actionable insights empower foundries to make informed decisions that drive tangible improvements in efficiency, quality, and competitiveness.

Turning Data into Action:

Real-Time Monitoring: IoT devices provide real-time data on machinery and processes, enabling operators to identify issues and implement corrective actions immediately.

Informed Decision-Making: Data-driven insights inform strategic decisions, optimizing resource allocation, production schedules, and quality control measures.

Continuous Improvement: By analyzing data trends, foundries can identify areas for continuous improvement, fostering a culture of innovation and excellence.

Utilizing actionable insights, foundries can enhance their decision-making processes, driving operational excellence and achieving strategic objectives. The IoT integration in foundries can be grouped into three main verticals, each focusing on specific aspects of the foundry process. These verticals highlight the areas where IoT can have the most significant impact, driving efficiency, quality, and innovation.

Pattern Making, Core Molding, and Sand Molding

This vertical encompasses the initial stages of the foundry process, where patterns are created, cores are molded, and sand is prepared for casting. IoT technologies play a crucial role in automating these processes, enhancing precision, and ensuring quality.

Key Focus Areas:

Automation of Machinery and Processes: IoT systems automate tasks within the green sand production method, streamlining operations and improving consistency.

Real-Time Monitoring: IoT sensors provide real-time data on machinery performance, enabling operators to monitor operations and detect issues proactively.

Process Optimization: IoT analytics identify inefficiencies and opportunities for improvement, enabling targeted interventions and optimization. By integrating IoT into pattern making, core molding, and sand molding, foundries can achieve higher levels of efficiency, precision, and quality, positioning themselves as leaders in the competitive manufacturing landscape.

Sand Preparation / Sand Reclamation

This vertical focuses on the preparation and reclamation of sand used in the casting process. IoT technologies enhance these processes by providing real-time data, automation, and analytics capabilities, ensuring quality and efficiency.

Key Focus Areas: Automation of Machinery and Processes: IoT systems automate tasks in sand recycling procedures, reducing manual labor and minimizing the risk of errors.

Real-Time Monitoring: IoT sensors provide real-time data on sand preparation and reclamation, enabling operators to monitor operations and detect issues proactively.

Process Optimization: IoT analytics identify inefficiencies and opportunities for improvement, enabling targeted interventions and optimization. Through IoT integration, foundries can optimize sand preparation and reclamation processes, enhancing efficiency, quality, and sustainability.

Heating, Pouring, and Sliding

This vertical focuses on the critical stages of heating, pouring, and sliding in the casting process. IoT technologies enhance these processes by providing real-time data, automation, and analytics capabilities, ensuring precision and efficiency.

Key Focus Areas:

Asset Management: IoT systems enable real-time monitoring and management of assets, ensuring optimal performance and minimizing downtime.

Process Optimization: IoT analytics identify inefficiencies and opportunities for improvement, enabling targeted interventions and optimization.

Predictive Maintenance: IoT sensors track equipment health, predicting maintenance needs before failures occur, minimizing downtime and prolonging machinery lifespan.

By leveraging IoT in heating, pouring, and sliding, foundries can achieve higher levels of efficiency, precision, and quality, positioning themselves as leaders in the competitive manufacturing landscape.

V. CONCLUSIONS:

Foundry 4.0 is a crucial shift in the manufacturing sector, necessitating swift adaptation and rapid technological adoption. The Indian foundry sector is ready for this transformation, requiring changes such as upgrading engineers to "thinking" assets, collaborating with academia to integrate IoT, IT, and technology, and realigning business models with values like transparency, flexibility, and adaptability. The sector is expected to experience substantial growth over the next four years, with a Compound Annual Growth Rate (CAGR) of 19.67% in revenue from 2018 to 2023.

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71. IoT based System for Prevention of Accidents on Pedestrian Bridges

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ABSTRACT:

The increasing frequency and number of bridge collapses, especially the pedestrian bridges worldwide emphasize the immediate attention to strong monitoring and maintenance systems to ensure structural integrity and public safety. The Morbi Bridge (Gujarat) collapse in 2022 is the latest example of such tragic incidents. The major causes for the collapse of the age-old pedestrian bridges are poor maintenance and overloading. An IoT based system is designed and built to avoid an excess number of persons on the long-haul pedestrian bridges to prevent overloading for ensuring the safety of the pedestrians. The system comprising a user-friendly interface, integrates state-of-the-art sensor technologies, real-time data analysis, and preventive maintenance algorithms for continuous monitoring of the structural well-being of pedestrian bridges. Thus, by facilitating proactive maintenance and timely interventions, the system can significantly reduce the possibility of bridge collapses. This paper deliberates on the conception, application, and effectiveness of the system, highlighting its capacity to ensure the safety of the bridges.

KEYWORDS:

Pedestrian Bridges, Public Safety, Sensor Technologies, IoT

I. Introduction:

Bridges built over rivers and other water bodies and highway crossings are important components of transportation facilities that provide essential connectivity for economic activities and daily commuting. Varieties of pedestrian bridges or footbridges are still playing a crucial role in linking the rural public, especially in areas with challenging terrain and numerous rivers.

Serving as vital lifelines for villagers, these bridges are typically built using traditional approaches and locally available materials like bamboo, wood, and sometimes, cables. This shows the inventiveness and resilience of the local communities. These bridges help people in having access to schools, hospitals, markets, and other essential services. Such pedestrian bridges are indispensable for daily life in some parts of the Dakshina Kannada district of Karnataka. In the states like Nagaland, Arunachal Pradesh, and Meghalaya which are characterized by dense forests, hilly landscapes, and several water bodies, traditional footbridges play a vital role in connectivity.

The pedestrian bridges either combined with roads for vehicles or independently for pedestrians, are constructed in dense traffic areas and on the highways to help the commuters in crossing the roads safely. Other examples of the presence of pedestrian bridges can be found in public and amusement parks, sightseeing locations, and tourist spots. Most of such bridges in India are very old, some of them built centuries ago.

These bridges are prone to deterioration and collapse because of the absence of essential engineering solutions, and frequent and preventive maintenance. One such pedestrian suspension bridge, locally known as “Jhulto Pul”, across the Machchhu River connected Darbargarh Palace and Lakhdhirji Engineering College in the city of Morbi, Gujarat state. Inaugurated in 1879, during the rule of Sir Waghji Ravaji, it was a famous tourist attraction and had been considered as a wonderful engineering marvel.

But the unfortunate incident happened when the bridge collapsed on 30 October 2022, leading to the death of more than 141 people including 50 children. As per the reports, there were more than 181 people on the bridge at the time of the incident, while its capacity was 150 only. Number of such incidents have taken place across the world leading to casualties. Hence, it is the need of the moment to investigate the reasons behind the tragedies on pedestrian bridges and find feasible solutions. The following paragraph reviews the literature regarding disastrous events that happened on footbridges, the reasons, and the solutions suggested.

II Literature Review:

Bridges are the structures spanning between the pillars, for the road to carry railway or other moving loads above a gap or obstacle like road, river, valley, canyon, channel, or railway. Some bridges are built for the exclusive use of pedestrians, cyclists, and animals, and they are called pedestrian bridges or footbridges. Since the bridges are built for the use of the public with their money, they have to be efficient, economical, and well-designed for the safety of the public [1, 2].

We hear about the disasters happening on bridges more frequently nowadays. Pedestrian bridges are no exception to this. As per Wikipedia webpage [3], Florida International University foot-over bridge under construction collapsed in 2018, causing 6 deaths, and 10 injuries, and 8 vehicles were crushed beneath.

Morbi bridge collapse discussed in the Introduction section above is a fresh example of such disasters on pedestrian bridges in India. The following Table I summarizes few of the incidents that happened in India in the past.

Table I: Examples of Pedestrian Bridge Collapses in India and The Impact [A]

S. No.	Name of Pedestrian Bridge Collapsed, Place, Year	Causes for Collapse (Casualties: Deaths, Injuries)
1	Morbi Suspension Bridge, Gujarat, 2022	Poor maintenance, Overcrowding, Overloading **(Deaths** 141, Injuries Over 181)
2	CST Station Foot Over Bridge, Mumbai, Maharashtra, 2019	Poor maintenance and structural failure (6, 33)
3	Andheri Foot-Over Bridge, Mumbai, Maharashtra, 2018	Heavy rains causing structural failure (0, 5)
4	Majerhat Bridge, Kolkata, West Bengal, 2018	Structural failure (3, 24)
5	Vivekananda Flyover, Kolkata, West Bengal, 2016	Construction failure (27, 80)
6	Burdwan Bridge Collapse, Burdwan, West Bengal, 2016	Poor construction quality (24, 80)

Data for table from [4-8].

It can be noted from the Table I that, majority of the collapses occur because of the structural failures, environmental effects or age of the bridges. The pedestrian bridges are subjected to corrosion and become weaker and their load bearing capacity reduces. As per [9], the major cause for the collapse of pedestrian foot-over bridge in Hatras of Uttar Pradesh was due to stampede and the incident underscores the dangers of overcrowding and insufficient safety precautions.

Stampedes caused by panic and non-availability of sufficient physical space may end up in fatalities and injuries. Key factors contributing for such incidents are psychological triggers, environmental design errors, and poor management of the crowd flow. Incidents in India like Morbi Suspension Bridge collapse, Mata Vaishnodevi Shrine and Munbai Pedestrian Bridge stampedes call for effective safety protocols with the aid of latest technologies.

Dhanalakshmi et al. [10] have proposed a safety and monitoring system using wireless nodes to collect data like vibration, water level in the river and bridge weight. Similar device developed by [11] employs wireless technology to automate real-time bridge health monitoring to minimize accidents and restoration efforts needed.

Similar use of Internet of Things can be found in the works of [12-16] that are developed to collect data, analyze and respond in real time to avoid mishaps in the future on bridges even including the flyovers. Combining various capabilities of the IoT in a single system can help the authorities in monitoring the real time situation on the bridge. The following sections deal about the development and building prototype of a system for preventing accidents on the pedestrian bridges.

III. Development of The System:

The system is designed to address the challenges discussed above by integrating modern sensor technologies, real-time data analytics, and machine learning algorithms to continuously monitor and evaluate the structural health of bridges.

A. Objectives of The System: The objectives of the IoT Based System for Prevention of Accidents on Pedestrian Bridges are:

- To ensure safety of the pedestrians on the foot-over bridges by limiting the number of people entering the bridge that exceed the threshold.
- To make improvement in the bridge durability/life span by minimizing load.
- To minimize the use of work force for monitoring the bridges.
- To reduce the cost of maintenance and monitoring.

The system can be adopted to prevent the collapses of bridges with very less human interference except during the renovation. Additionally, it can be very useful during the emergency situations.

B. Architecture of the System: The components used in the proposed system for data collection, analysis and monitoring of the traffic to ensure that the total load on the bridge is within the specified/permitted limits are:

- GSM Module –sends the status data of the overall bridge to the database.
- IR Sensors –count the number of people at a particular time on the bridge
- Load Cells – measure the weight of the people before they enter the bridge and calculate the overall weight to check if it exceeds the threshold.
- Micro Processor –process all the inputs and provide an appropriate output.
- Water Level Sensor –checks the water level below the bridge in order to block people entering the bridge during the flood or when access water is flowing.
- Ultrasonic sensor –checks the cracks or any other damages in the bridge.
- Vibration sensor –senses the vibration of the bridge to check the structural health of the bridge.
- Gates using Servo Motors – open and allow the people to enter the bridge and block the entry when the threshold of weight and number of persons is reached on the bridge.

Figure. 1 shows the algorithmic steps, and the exchange of data between the microprocessor/microcontroller with sensors are demonstrated in the Figure 2. The Figure 3 depicts the schematic diagram of the system.

C. System Design and Prototyping:

1. System Design: As in Figure 1 the integration of different components in the system design.

Consists of the following essential elements:

- **Sensors:** IR sensors are used to count pedestrians, vibration sensors monitor the structural integrity, and load cells measure the weight. Sensors are chosen for their accuracy and dependability.
- **Microprocessor:** chosen for its processing capacity and interoperability with actuators and sensors.
- **Software:** Real-time sensor data processing and actuator control based on preset criteria are accomplished by Arduino coding.

Figure 1: Architecture of the Proposed System

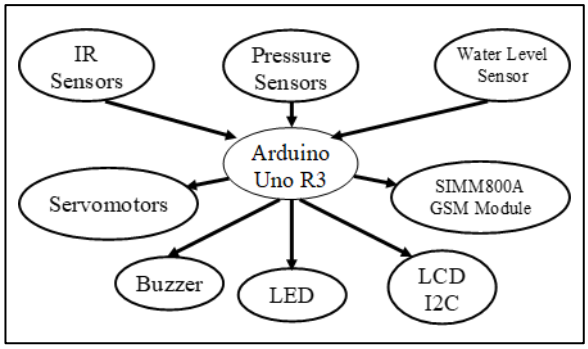

Figure 2: Exchange of Data between the Microprocessor and Sensors

2. Prototyping: Using readily available parts, the prototype was put together in accordance with the design guidelines. Figure 4 shows the prototype model of the system. Important actions comprised in developing the prototype are as discussed below:

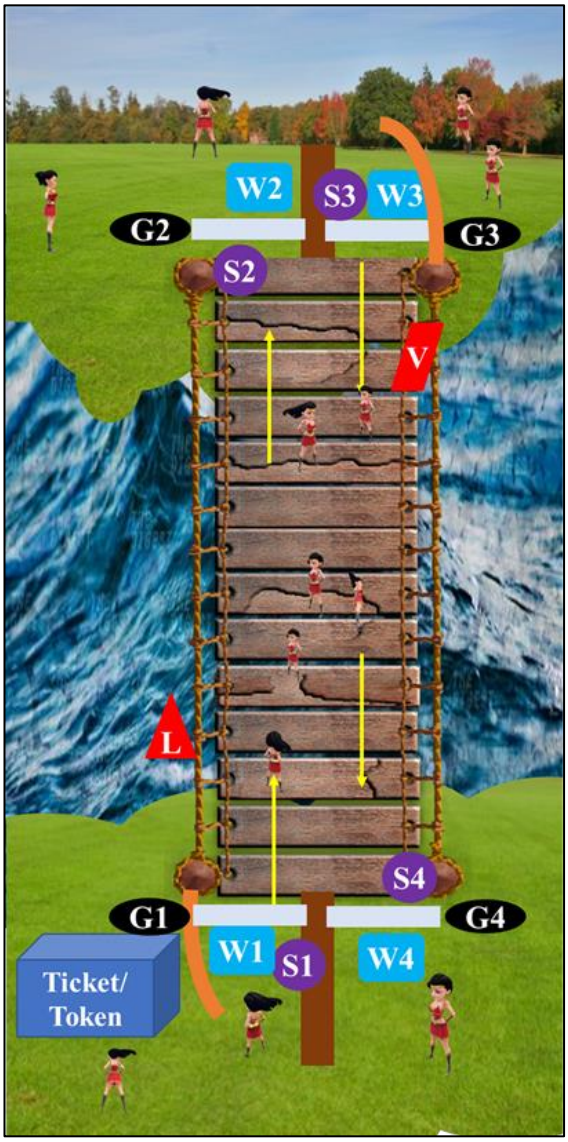

Figure 3: Schematic diagram of the proposed system

- **Assembly:** Connecting sensors to the CPU and incorporating actuators, like servo motors, into the system.
- **Testing:** To evaluate sensor accuracy and system reactions under different conditions, preliminary testing was conducted. For instance, to guarantee precise weight measurement, load cells were calibrated. Test results showed that the system could assess weight with 95% accuracy and detect threshold reaches in less than 2 seconds. To enhance system integration and sensor calibration, modifications were made.

Figure 4: Prototype Model of the System

3. Problems and Solutions: It was first difficult to determine weight accurately under different load circumstances. To improve accuracy, calibration procedures were put in place and sensor positioning was modified. Overall, the system performance and opportunities for development were better understood during the prototyping phase, which resulted in a more solid and trustworthy final design.

IV. Working of The System:

Operational procedure of the system as per the prototype model shown in Figure 4 is:

- The maximum threshold values of number of persons allowed and maximum weight permitted on the bridge, vibration and safe water level are assigned by the authorities.
- Once the system is activated, the welcome message is displayed on LCD (D) and number of persons and weight are initialized to Zero.
- When a person getting ticket/token from the counter approaches the first gate G1, the weight sensor (L1) takes the weight of the person and will be incremented. Sensor S1 senses the presence of the person and actuates gate G1. The gate G1 will open and the person can enter bridge area. The total number of persons on the bridge will be incremented by 1.
- This will be continued till the thresholds on the number of persons on the bridge and/or weight thresholds are reached. All the gates G1-G4 will be closed and buzzer will be activated sending message to authorities in the counter via the GSM.
- On the other side of the bridge, when a person comes near gate 2 (G2), L2 measures the weight, sensor S2 actuates and the gate opens allowing the person to enter the open area. Meanwhile, the total number of persons and the total weight on the bridge will be decremented allowing G1 to open for other person in the queue.
- When a person from the open area comes near Gate G3, S3 will sense and sends signal to open the gate G3, and L3 records the weight. The total number of persons and total weight will be incremented. G1 and G3 are closed.
- The sensor S4 senses the person and opens G4 when a person tries to come out of the bridge area. Weight is noted by L4 and the total weight is decremented. In the meantime, the number of persons is decremented allowing entry through G1 and G3.

- The buzzers will operate and LEDs start glowing at the counter when the water and/or the vibration level reach their threshold values.

V. Advantages of the System:

The proposed system helps in:

- Fixing the maximum load and number of persons permissible based on the load bearing capacity of the bridge
- Preventing excess number of persons entering the bridge thereby minimizing the stampedes
- Preventing accidents and injury/deaths
- Reducing infrastructure/financial losses due to accidents.
- Overcoming the feelings of fright between the initial period after the crisis and several days after the event.

With suitable modifications, the same project can be extended to the bridges meant for vehicles also.

VI Conclusion:

The proposed system utilizes the power of a network of sensors tactically located on bridges for collection of data on critical parameters like load, vibrations, and water level. The project can be implemented on the pedestrian bridges like Gokak Falls and other bridges in places like Dakshin Kannada District and North Eastern Sates as a measure of safety. Real time processing and analysis of data provide actionable insights and alerts to bridge authorities. By implementing the proposed system, bridge monitoring and control can transition from reactive to proactive maintenance strategies, eventually ensuring public safety, increasing the lifespan of bridges, and reducing maintenance costs.

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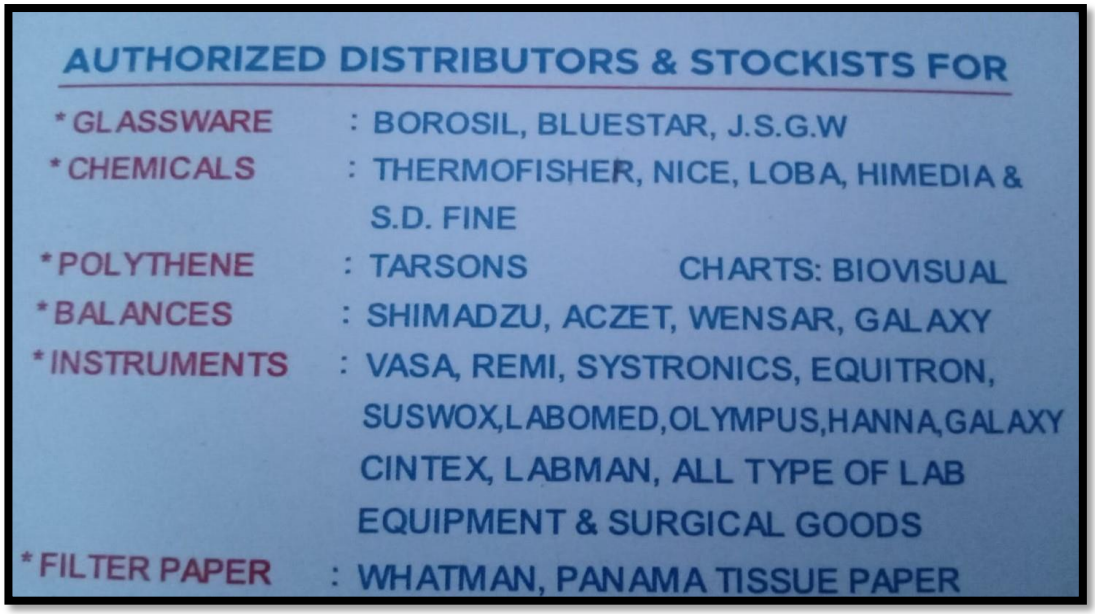

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