Dr. Ranjan Kumar is currently Head of the Department and Associate Professor in the Department of Mechanical Engineering at Swami Vivekananda University, Kolkata. Dr. Kumar received his Master's and Doctoral degrees in Mechanical Engineering from the Indian Institute of Technology Dhanbad. His research interests include Li-ion batteries, finite element simulation and analysis of real engineering problems, and vibration analysis of structures. He has executed projects in association with the Gas Turbine Research Establishment (GTRE), DRDO lab Bangalore. He has guided 02 PhD Thesis and 32 post graduate dissertation. Dr. Kumar has authored 20 books, published 51 research papers, and holds 25 patents. He also serves as editor-in-chief of Journal of Mechanical Engineering Advancements.

Dr. Ashes Banerjee is an Assistant Professor in the Civil Engineering Dept. at Swami Vivekananda University, Kolkata, West Bengal. He earned his Ph.D. in Water Resource Engineering from the Indian Institute of Technology (Indian School of Mines) in Dhanbad, India, in 2020. Dr. Banerjee's scholarly achievements are evidenced by his numerous publications in peer-reviewed international journals, covering crucial topics such as non-linear filtration in porous media, water quality, and groundwater utilization.

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Advanced Methods for Multidisciplinary Research

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Editors:
Dr. Ranjan Kumar
Dr. Ashes Banerjee

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PREFACE

In the ever-evolving landscape of science, technology, and sustainability, the need for innovative solutions to pressing global challenges has never been greater. The convergence of diverse disciplines, from advanced engineering methods to environmental conservation, has paved the way for ground breaking research and practical applications. This book, **"** Advanced methods for multidisciplinary research**"** brings together a wide spectrum of research efforts that highlight the critical intersections of sustainability, technological advancement, and scientific inquiry.

The chapters in this volume reflect an intricate mosaic of ideas and solutions addressing contemporary issues. These range from the mathematical precision of solving hypersingular integral equations to the societal and cultural transformations driven by urbanization. Topics such as renewable energy development, earthquake-resistant building designs, and the integration of additive manufacturing with Industry 4.0 underscore the significance of technological evolution in sustainable practices. Furthermore, studies on green manufacturing technologies, the impact of lithium-ion batteries on soil properties, and the utilization of industrial waste showcase efforts to mitigate environmental impacts while enhancing material performance.

Recognizing the importance of interdisciplinary research, this book delves into subjects like 3D lighting in animation, bioactive glass for medical applications, and advanced theoretical concepts in topology and wave mechanics. These explorations underscore the diversity of innovation and the universal applicability of scientific knowledge.

The overarching theme of sustainability is woven throughout the chapters, from energy efficiency and visible light communication systems to AI-driven solutions for eco-friendly building designs. By addressing global challenges like climate change, resource depletion, and urbanization, this book seeks to contribute to the ongoing discourse on creating a sustainable future.

This compilation is the result of dedicated research by scholars and practitioners across various fields, united by a shared vision of harnessing knowledge for the betterment of society and the environment. It is our hope that this book will serve as an invaluable resource for researchers, academics, and industry professionals who are passionate about pioneering sustainable solutions and advancing technological frontiers.

We extend our deepest gratitude to all contributors for their invaluable insights and efforts. Their commitment to innovation and sustainability has enriched this volume and will undoubtedly inspire further exploration and collaboration in the years to come.

Advanced methods for multidisciplinary research is more than a collection of ideas—it is a call to action for a collective journey toward a greener, more sustainable tomorrow.

Dr. Ranjan Kumar
Associate Professor, Department of Mechanical Engineering,
Swami Vivekananda University, Kolkata, West Bengal, India

ACKNOWLEDGEMENT

I extend my heartfelt gratitude to Swami Vivekananda University, Kolkata, India, for their unwavering support and encouragement during the creation of "Advanced methods for multidisciplinary research". The university's enduring commitment to advancing education and research has profoundly influenced the direction and scope of this work.

We are especially grateful for the collaborative environment, resources, and inspiration provided by Swami Vivekananda University, Kolkata. Their contributions have been pivotal in enabling us to delve into and present the latest advancements and technologies spanning diverse fields of study.

It is our earnest hope that this book will serve as a meaningful resource for the university and the wider academic community, mirroring our collective dedication to fostering knowledge, innovation, and academic excellence.

I also extend my deepest appreciation to the esteemed external reviewers mentioned below for their meticulous evaluation and invaluable feedback. Their dedication to maintaining the highest scholarly standards has been instrumental in ensuring the academic rigor of this publication.

With sincere gratitude,

(Dr. Ranjan Kumar)

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2. Dr. Anshuman Das, Dept. of Mathematics, Presidency University, Kolkata, India

3. Dr. Debabrta Sarddar, Assistant Professor, Dept. of CSE, University of Kalyani, Kalyani, Nadia, India

Advanced methods for multidisciplinary research

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Chapter -1:

3D Printing and Its Impacts on Sustainable Manufacturing Practices

Ranjan Kumar
Department of Mechanical Engineering; Swami Vivekananda University, Barrackpore, Kolkata, 700121, India
*Corresponding Author Email Address: ranjansinha.k@gmail.com

3D Printing and Its Impacts on Sustainable Manufacturing Practices

Ranjan Kumar
Department of Mechanical Engineering; Swami Vivekananda University, Barrackpore, Kolkata, 700121, India
*Corresponding Author Email Address: ranjansinha.k@gmail.com

Abstract: This paper examines the intersection of 3D printing technology, also known as additive manufacturing (AM), with sustainable manufacturing practices. Through a literature review, the study identifies the environmental, economic, and social impacts of 3D printing in enhancing sustainability. Key benefits include reduced material waste, energy efficiency, local production, and reduced carbon emissions, while challenges include high energy consumption during production, limited materials suitable for 3D printing, and issues with scalability. The review synthesizes current research, identifying opportunities for further exploration of 3D printing's role in the global transition to sustainable manufacturing.

Keywords: 3D printing, additive manufacturing, sustainability, sustainable manufacturing, environmental impact, resource efficiency, circular economy

1. Introduction

The emergence of 3D printing, or additive manufacturing (AM), has revolutionized various industries, offering a novel approach to production that contrasts with traditional subtractive manufacturing. 3D printing builds objects layer by layer using computer-aided design (CAD) software, which allows for high customization, minimized waste, and the ability to create complex geometries that were previously impossible or prohibitively expensive to manufacture.

As industries increasingly turn to more sustainable practices to reduce environmental impacts, 3D printing has been highlighted as a potential enabler of sustainable manufacturing due to its precision, flexibility, and ability to localize production. This paper explores the impacts of 3D printing technology on sustainable manufacturing, focusing on the environmental, economic, and social dimensions of sustainability.

2. Literature Review

2.1 Environmental Impact of 3D Printing

A key benefit of 3D printing for sustainability is its potential to reduce material waste. Unlike traditional subtractive methods, where material is removed from a solid block, additive manufacturing only uses the necessary amount of material, resulting in less waste. According to Huang et al. (2013), material savings from AM can reach up to 90% in certain applications, especially when producing intricate components that would otherwise require significant material removal.

However, the environmental impact of 3D printing is not entirely positive. Many studies have raised concerns regarding the energy-intensive nature of the technology. Research by Faludi et al. (2017) highlights that while AM reduces waste, it often consumes more energy than traditional manufacturing methods, particularly in the post-processing phases such as surface finishing and sintering. The energy consumption varies depending on the specific AM process used, with some methods (e.g., laser sintering) requiring significantly more energy than others (e.g., fused deposition modeling).

Recycling and reuse of materials are also an important aspect of 3D printing's environmental impact. In a study by Gebler, Uiterkamp, and Visser (2014), it was found that AM could enable closed-loop manufacturing systems where used products are reprinted into new forms, aligning with circular economy principles. This potential to use recycled or biodegradable materials could further decrease the environmental footprint of manufacturing.

2.2 Economic Impacts and Efficiency

3D printing has the potential to localize production, reducing the need for transportation and, in turn, lowering associated carbon emissions. Berman (2012) notes that the decentralized nature of AM allows manufacturers to produce goods closer to their end markets, reducing logistics costs and emissions related to global supply chains. This ability to produce on-demand, in small batches, and without the need for expensive molds or tooling also makes AM attractive for small businesses, startups, and custom manufacturers.

Moreover, the reduction in lead times provided by AM presents significant economic benefits. As outlined by Chen et al. (2015), the time from design to finished product is significantly shortened, which is especially useful for rapid prototyping and small-scale production runs. This speed enhances flexibility and responsiveness to market demands, allowing for more dynamic production schedules and reducing overproduction, another critical issue in sustainable manufacturing.

However, some barriers still exist in terms of cost efficiency. The current high price of certain AM materials and machines, particularly those capable of producing large or highly specialized components, limits the accessibility of this technology to smaller players. Moreover, despite the reduction in material costs, the overall price of goods produced by 3D printing is often higher than that of traditional methods, depending on the complexity of the product and the process used (Rosen, 2014). Fig. 1 shows the precise 3D printed model of an unmanned aerial vehicle ready to fly.

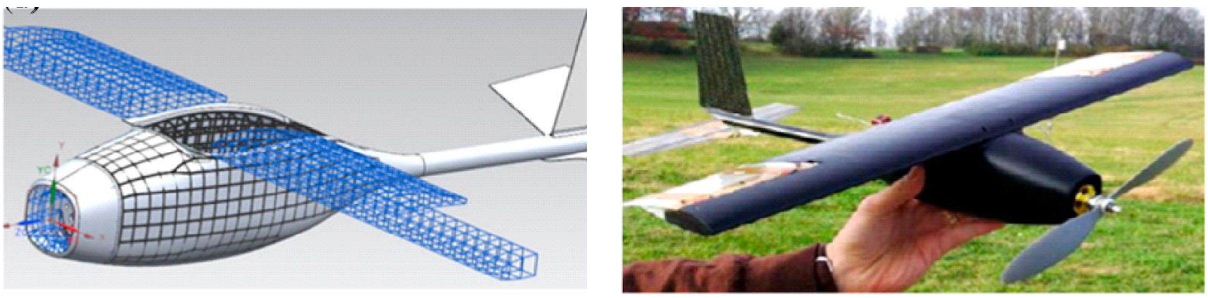

Fig. 1. Hand-held unmanned aerial vehicle with conformal lattice structure: a) Computer aided design (CAD) model, b) physical 3D printed model (Rosen, 2014).

2.3 Social and Ethical Considerations

Socially, 3D printing holds the promise of democratizing manufacturing by allowing individuals and small enterprises to produce goods that were previously only within reach of large manufacturers. The accessibility of open-source designs and the ability to fabricate goods at home or within local communities has sparked interest in the role of 3D printing in fostering a "maker culture" (Rayna & Striukova, 2016). This shift could disrupt traditional labor markets by reducing the need for mass production in centralized factories and enabling more localized, customized production.

However, this democratization raises concerns about intellectual property (IP) protection and the potential for widespread counterfeiting. Open-source design files can be easily replicated, leading to challenges in ensuring that designers are adequately compensated for their work (Moilanen & Vadén, 2013). Additionally, 3D printing of weapons and other dangerous items has sparked debates over the ethical use of this technology, with calls for regulatory frameworks to manage its risks.

3. The Role of 3D Printing in Circular Economy and Sustainable Manufacturing

The transition from a linear "take-make-dispose" economy to a circular economy is essential for achieving sustainable manufacturing practices. 3D printing has the potential to support this shift by enabling the recycling of materials and minimizing resource extraction. According to Kohtala (2015), additive manufacturing supports resource efficiency, enabling businesses to integrate waste streams into production cycles more effectively. The ability to print with recycled or biocompatible materials directly contributes to reducing environmental harm.

Further research by Holmström et al. (2016) suggests that 3D printing could also enable manufacturers to repair and refurbish products more easily, extending product life cycles and reducing the demand for raw materials. As such, the role of AM in sustainable manufacturing is strongly linked to broader efforts in resource efficiency, waste reduction, and closed-loop manufacturing systems. Fig. 2 represents the recycling cycle of 3D printing technology.

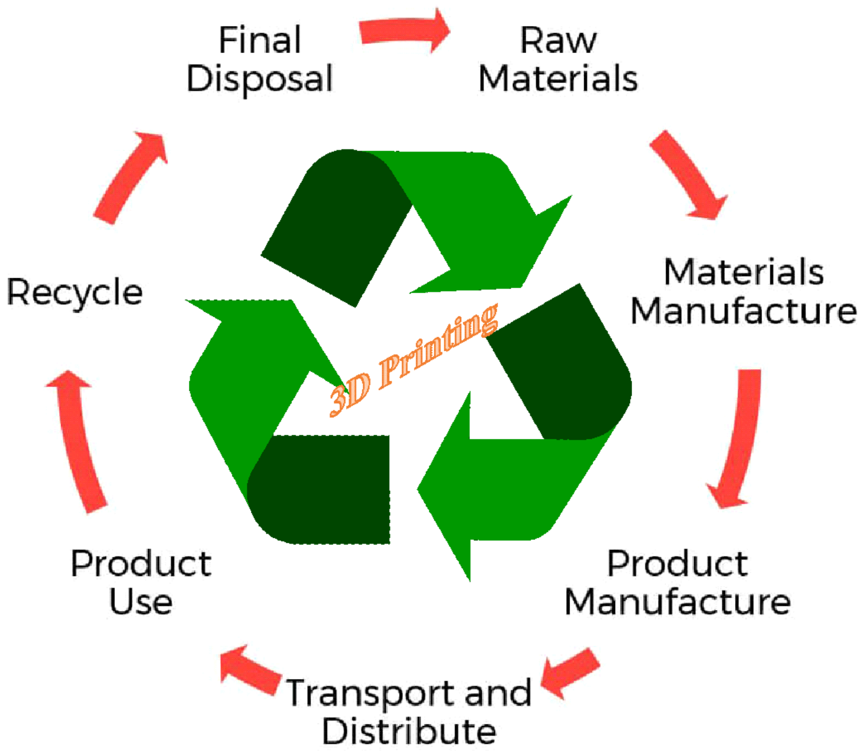

Fig. 2 The recycling cycle of 3D printing technology.

4. Challenges and Future Prospects

While 3D printing presents numerous opportunities for enhancing sustainability, several challenges remain. The limited range of materials currently available for additive manufacturing, coupled with high energy demands, pose obstacles to scaling up the technology for widespread use in industrial manufacturing (Baumers et al., 2011). Further research is needed to develop more energy-efficient AM processes and to broaden the range of sustainable materials, including biodegradable polymers and metals that can be recycled more efficiently.

Additionally, standardization across AM processes and materials is necessary to ensure consistent quality and sustainability metrics across the industry. Continued innovation in design for AM (DfAM) and material science will be key to realizing the full sustainability potential of 3D printing in the coming decades.

5. Conclusion

3D printing offers transformative potential for sustainable manufacturing by reducing waste, enabling local production, and fostering resource-efficient processes. While challenges remain in energy consumption and material availability, the technology is well-positioned to contribute to the global shift toward circular economies and more sustainable industrial practices. Continued advancements in AM technology, coupled with supportive regulatory and economic frameworks, will be essential for realizing its full potential.

References

Baumers, M., Dickens, P., Tuck, C., & Hague, R. (2011). The cost of additive manufacturing: Machine productivity, economies of scale and technology-push. *Technological Forecasting and Social Change*, 102(3), 258-266.

Berman, B. (2012). 3-D printing: The new industrial revolution. *Business Horizons*, 55(2), 155-162.

Chen, Z., Li, Z., & Liu, T. (2015). Application of additive manufacturing in the green economy. *Journal of Cleaner Production*, 95, 1-9.

Faludi, J., Bayley, C., Bhogal, S., & Iribarne, M. (2017). Comparing environmental impacts of additive manufacturing vs. traditional machining via life-cycle assessment. *Rapid Prototyping Journal*, 21(2), 173-180.

Gebler, M., Uiterkamp, A. J. M. S., & Visser, C. (2014). A global sustainability perspective on 3D printing technologies. *Energy Policy*, 74, 158-167.

Holmström, J., Liotta, G., & Chaudhuri, A. (2016). Sustainability of additive manufacturing: Investigating the energy demand for additive manufacturing vs. subtractive manufacturing. *Journal of Industrial Ecology*, 21(3), 564-576.

Huang, S. H., Liu, P., Mokasdar, A., & Hou, L. (2013). Additive manufacturing and its societal impact: A literature review. *International Journal of Advanced Manufacturing Technology*, 67(5-8), 1191-1203.

Kohtala, C. (2015). Addressing sustainability in research on distributed production: An integrated literature review. *Journal of Cleaner Production*, 106, 654-668.

Moilanen, J., & Vadén, T. (2013). 3D printing community and emerging practices of peer production. *International Journal of Production Economics*, 149, 22-33.

Rayna, T., & Striukova, L. (2016). From rapid prototyping to home fabrication: How 3D printing is changing business model innovation. *Technological Forecasting and Social Change*, 102, 214-224.

Rosen, D. W. (2014). Research supporting principles for design for additive manufacturing: This paper provides a comprehensive review on current design principles and strategies for AM. *Virtual and Physical Prototyping*, 9(4), 225–232.

Chapter -2:

Waste Management Using Image Processing and Computer Vision

Sumana Chakraborty,

Assistant Professor, Dept. of CSE, Swami Vivekananda University

Email: sumanac@svu.ac.in

Waste Management Using Image Processing and Computer Vision

Sumana Chakraborty,

Assistant Professor, Dept. of CSE, Swami Vivekananda University

Email: sumanac@svu.ac.in

Abstract

Waste management is a critical environmental issue, especially in urban areas where the growing volume of waste threatens ecosystems and public health. Traditional waste sorting methods are labour-intensive and error-prone, leading to inefficiencies in recycling and disposal. Recent advancements in image processing and computer vision offer innovative solutions to improve the automation of waste sorting, recycling, and monitoring processes. This paper discusses the application of computer vision algorithms for waste identification, classification, and sorting. It explores the integration of machine learning and deep learning techniques to optimize the accuracy and efficiency of waste management systems, promoting a more sustainable and eco-friendly future.

Keywords: waste management, image processing, computer vision, recycling, waste sorting, artificial intelligence, deep learning, sustainability, smart cities, environmental monitoring, circular economy

1. Introduction

With increasing urbanization and consumption, waste generation has become one of the major challenges faced by modern societies. Improper waste management contributes to environmental degradation, pollution, and resource depletion. Efficient waste sorting and recycling systems are crucial to achieving sustainability goals. Image processing and computer vision technologies offer promising solutions for automating waste management systems, ensuring that waste is correctly classified and sorted for recycling or disposal. This paper reviews the use of computer vision techniques in waste management, highlighting their potential to revolutionize recycling and disposal processes.

2. Applications of Image Processing in Waste Management

2.1 Automated Waste Sorting

One of the main challenges in waste management is the accurate classification and sorting of waste materials. Manual sorting processes are slow, inefficient, and prone to human error. Automated waste sorting systems, powered by computer vision and machine learning algorithms, can classify waste based on its physical characteristics, such as shape, size, color, and texture (Al Mamun et al., 2016). By using advanced image processing techniques, these systems can differentiate between plastic, metal, paper, organic waste, and other recyclable materials, leading to more efficient recycling operations.

- **Example Techniques**: Techniques such as convolutional neural networks (CNNs) have shown great promise in detecting and classifying different types of waste from images (Ronneberger et al., 2015).

2.2 Plastic and Material Identification

The identification of plastic types and other materials is crucial in recycling processes. Image processing algorithms can analyze visual data from camera systems to distinguish between various types of plastics, such as PET, HDPE, and LDPE, based on spectral and texture features (Akram et al., 2019). This process ensures that plastics are sorted correctly and sent for appropriate recycling, reducing contamination in recycling streams.

2.3 Smart Recycling Bins

Smart recycling bins equipped with cameras and sensors can use computer vision techniques to automatically detect and classify waste deposited by users. These bins utilize image recognition software to identify the type of waste and guide users to place it in the correct bin. This system reduces contamination in recycling bins and enhances the recycling rate in urban environments (Mittal et al., 2019).

3. Deep Learning and AI in Waste Management

3.1 Deep Learning for Waste Classification

Deep learning algorithms, particularly convolutional neural networks (CNNs), have been widely adopted for object detection and classification tasks. In waste management, these algorithms can be trained on large datasets of waste images to automatically classify various types of waste (Rad et al., 2017). CNNs learn hierarchical features from images, enabling them to accurately identify complex waste materials even in cluttered environments.

- **Performance**: CNNs have demonstrated high accuracy in waste classification tasks, with the ability to process images in real-time, making them suitable for industrial-scale applications (Yang & Thung, 2016).

3.2 Reinforcement Learning for Robotic Sorting

In addition to classification, reinforcement learning is being explored for robotic waste sorting systems. Robots equipped with cameras can use deep learning models to identify and pick up waste items, placing them into appropriate recycling categories. Reinforcement learning allows these systems to improve sorting accuracy over time by learning from mistakes and adapting to new waste types (Maeda et al., 2021).

4. Benefits of Image Processing and Computer Vision in Waste Management

4.1 Increased Efficiency

By automating the waste sorting process, image processing systems can handle large volumes of waste quickly and accurately, reducing the need for human labor and minimizing sorting errors. This leads to improved recycling efficiency and higher recovery rates for valuable materials such as metals, plastics, and paper (Long et al., 2015).

4.2 Sustainability and Resource Conservation

Efficient waste sorting ensures that recyclable materials are properly separated from non-recyclable waste, reducing the contamination of recycling streams and increasing the overall recycling rate. This contributes to resource conservation by reducing the need for virgin materials and promoting the principles of the circular economy (Parhi et al., 2017).

4.3 Cost Reduction

Automated waste sorting systems can help waste management companies reduce labor costs associated with manual sorting. Furthermore, improved sorting accuracy reduces the amount of non-recyclable waste sent to recycling facilities, thereby lowering operational costs related to waste contamination (Mittal et al., 2019).

5. Challenges and Future Directions

5.1 Handling Complex Waste Types

One of the challenges faced by current waste sorting systems is the classification of complex or mixed waste types, such as composite materials or multi-layered packaging. Advances in machine learning models and image processing techniques will be required to improve the accuracy of sorting systems for such waste (Shah et al., 2020).

5.2 Data Availability and Model Training

For deep learning models to be effective, they require large datasets of labeled waste images for training. Developing comprehensive datasets that represent the diverse types of waste encountered in real-world environments is a challenge that needs to be addressed. Collaborative efforts between waste management companies and technology developers can help create standardized datasets for waste classification tasks (Salimi & Tavakoli, 2019).

5.3 Integration with Smart Cities

The integration of automated waste management systems into broader smart city initiatives presents opportunities for innovation. Smart cities equipped with IoT sensors and AI-powered systems can optimize waste collection routes, monitor recycling rates in real-time, and encourage citizens to adopt more sustainable practices (Bong et al., 2018).

6. Conclusion

The application of image processing and computer vision in waste management offers significant potential for improving waste sorting, recycling, and sustainability efforts. Automated systems powered by machine learning and deep learning algorithms can enhance the accuracy and efficiency of waste classification, leading to more sustainable resource management practices. As research in this area continues, the integration of these technologies with smart city infrastructure promises to revolutionize the way waste is handled, contributing to a cleaner and more sustainable future.

References

Akram, F., Maqsood, H., & Hussain, A. (2019). Waste classification using deep learning convolutional neural network. *Proceedings of the International Conference on Advanced Intelligent Systems and Informatics*, *2*, 789-800. https://doi.org/10.1007/978-3-030-14118-9_71

Al Mamun, M. A., Hannan, M. A., & Hussain, A. (2016). Real-time smart waste bin monitoring and data visualization system. *IEEE Transactions on Consumer Electronics*, *62*(3), 142-149. https://doi.org/10.1109/TCE.2016.7604054

Bong, D. B., Lai, K. L., & Yoong, W. K. (2018). Smart city garbage management system using image processing. *IOP Conference Series: Materials Science and Engineering*, *341*, 012002. https://doi.org/10.1088/1757-899X/341/1/012002

Long, Y., & Ji, Y. (2015). Deep learning based waste classification algorithm and its application in waste sorting robot system. *Journal of Intelligent & Fuzzy Systems*, *31*(4), 2417-2424. https://doi.org/10.3233/IFS-152003

Maeda, M., Nakamura, Y., & Uchiyama, K. (2021). Robot waste sorting using deep reinforcement learning and grasping network. *Journal of Robotics and Mechatronics*, *33*(3), 547-555. https://doi.org/10.20965/jrm.2021.p0547

Mittal, A., Kumar, P., & Srivastava, V. (2019). Smart bins: A review of waste management automation using image processing and IoT. *IEEE Access*, *7*, 65701-65725. https://doi.org/10.1109/ACCESS.2019.2917879

Ouaer, H., Sifour, M., & Labiod, H. (2020). Plastic waste classification and recognition based on image processing and machine learning. *Sustainable Cities and Society*, *52*, 101892. https://doi.org/10.1016/j.scs.2019.101892

Parhi, M., Swain, P., & Mohanty, S. (2017). Application of image processing in waste management. *Procedia Computer Science*, *126*, 612-620. https://doi.org/10.1016/j.procs.2017.08.230

Rad, M. R., von Ellenrieder, N., & Lambert, M. (2017). Object recognition and sorting using convolutional neural networks for automated recycling. *IEEE Transactions on Automation Science.

Chapter -3

: Impact of Hydrogen Substitution on Combustion Characteristics and NOx Emissions in Dual Fuel Diesel Engines

Sudipta Nath[1], Ranjan Kumar[2]*, Shahanwaz Khan[3], Somnath Das[4] and Vinayak Ranjan[5]

Mechanical Engineering Department, Swami Vivekananda Institute of Science & Technology, West Bengal, India.

Department of Mechanical Engineering, Swami Vivekananda University, Barrackpore, West Bengal, India.

Department of Mechanical Engineering, Aliah University, Kolkata, West Bengal, India.

Mechanical Engineering Department, Swami Vivekananda Institute of Science & Technology, West Bengal, India.

Department of Mechanical Engineering, Rowan University, New Jercy, USA

Email: **ranjansinha.k@gmail.com**

Impact of Hydrogen Substitution on Combustion Characteristics and NOx Emissions in Dual Fuel Diesel Engines

Sudipta Nath[1], Ranjan Kumar[2]*, Shahanwaz Khan[3], Somnath Das[4] and Vinayak Ranjan[5]

Mechanical Engineering Department, Swami Vivekananda Institute of Science & Technology, West Bengal, India.

Department of Mechanical Engineering, Swami Vivekananda University, Barrackpore, West Bengal, India.

Department of Mechanical Engineering, Aliah University, Kolkata, West Bengal, India.

Mechanical Engineering Department, Swami Vivekananda Institute of Science & Technology, West Bengal, India.

Department of Mechanical Engineering, Rowan University, New Jercy, USA

Email: **ranjansinha.k@gmail.com**

Abstract

The pursuit of cleaner combustion technologies has led to the investigation of hydrogen as a supplementary fuel in diesel engines. This study explores the impact of hydrogen substitution in dual-fuel diesel engines on combustion characteristics and nitrogen oxide (NOx) emissions. A systematic experimental approach is employed to analyze various hydrogen substitution levels (0%, 10%, 20%, 30%, and 40%) under varying engine load conditions. Results indicate that hydrogen substitution enhances combustion efficiency but concurrently increases NOx emissions due to higher combustion temperatures. The findings emphasize the need for optimized hydrogen levels to balance efficiency improvements with environmental impact, particularly in reducing NOx emissions.

Keywords: Hydrogen substitution, dual-fuel diesel engine, combustion characteristics, NOx emissions, engine optimization

1. Introduction

1.1 Background

The global energy landscape is undergoing significant transformations in response to climate change and the depletion of fossil fuels. Internal combustion engines (ICEs), particularly diesel engines, are a major contributor to air pollution due to their emissions of nitrogen oxides (NOx) and particulate matter (PM). As the world seeks cleaner energy solutions, hydrogen has emerged as a viable alternative, particularly in dual-fuel applications where it can be used alongside conventional fuels like diesel.

Hydrogen offers several advantages, including a high energy content and zero carbon emissions during combustion. However, its integration into diesel engines introduces complexities, particularly regarding combustion characteristics and emissions. As hydrogen enhances combustion efficiency, it also raises concerns over increased NOx emissions due to higher combustion temperatures (Bari & Esmaeil, 2010; Liu et al., 2010). Therefore, understanding the impact of hydrogen substitution on combustion dynamics and NOx emissions is crucial for optimizing dual-fuel diesel engines.

1.2 Problem Statement

The introduction of hydrogen as a supplementary fuel in dual-fuel diesel engines poses challenges regarding the trade-off between improved combustion efficiency and increased NOx emissions. While hydrogen substitution can enhance performance and reduce carbon emissions, it may lead to higher combustion temperatures and, consequently, elevated NOx emissions. This study aims to investigate the relationship between hydrogen substitution levels and their impact on combustion characteristics and NOx emissions in dual-fuel diesel engines.

1.3 Objectives

The primary objectives of this research are:

- To analyze the combustion characteristics of a hydrogen-diesel dual-fuel engine at various hydrogen substitution levels.
- To assess the impact of hydrogen substitution on NOx emissions and understand the underlying combustion mechanisms.
- To identify optimal hydrogen substitution levels that maximize efficiency while minimizing NOx emissions.

1.4 Research Questions

This study addresses the following research questions:

1. How does hydrogen substitution influence the combustion characteristics of dual-fuel diesel engines?
2. What are the primary mechanisms contributing to NOx emissions in hydrogen-diesel combustion?
3. How can hydrogen substitution be optimized to achieve a balance between improved efficiency and reduced NOx emissions?

1.5 Significance of the Study

The findings of this research contribute to the understanding of hydrogen-diesel dual-fuel engines and their potential for reducing environmental impact. By examining the combustion characteristics and emissions associated with varying hydrogen substitution levels, this study provides insights that can inform the development of more sustainable engine technologies. The results will be valuable for policymakers, engineers, and researchers seeking to enhance the environmental performance of internal combustion engines.

1.6 Scope of Study

This study focuses on the effects of hydrogen substitution on combustion characteristics and NOx emissions in a single-cylinder, four-stroke diesel engine. The research examines hydrogen substitution levels ranging from 0% to 40% under different engine load conditions (25%, 50%, 75%, and 100% of full load). Key combustion parameters, including in-cylinder pressure, heat release rate, and emission levels, are analyzed to provide a comprehensive understanding of the impact of hydrogen substitution.

2. Literature Review

2.1 Hydrogen as a Fuel in Combustion Engines

Hydrogen has long been regarded as a clean fuel option for internal combustion engines due to its high energy density and low environmental impact. The combustion of hydrogen produces only water vapor, making it an attractive alternative for reducing greenhouse gas emissions (Verhelst & Wallner, 2009). Moreover, hydrogen's high diffusivity and wide flammability range enhance its potential for improving combustion efficiency.

However, the high combustion temperatures associated with hydrogen combustion pose a significant challenge, particularly in terms of NOx emissions. The thermal NOx formation mechanism becomes dominant in high-temperature environments, leading to increased NOx production (Saravanan et al., 2007). Thus, while hydrogen substitution can reduce carbon emissions, it is essential to manage its impact on NOx emissions effectively.

2.2 Hydrogen-Diesel Dual-Fuel Systems

Hydrogen-diesel dual-fuel systems utilize both hydrogen and diesel to optimize engine performance. In these systems, diesel serves as the pilot fuel, providing the necessary energy for ignition, while hydrogen is injected to enhance combustion characteristics. The dual-fuel approach allows for a more homogeneous air-fuel mixture, promoting improved combustion efficiency and reduced emissions (Bari & Esmaeil, 2010).

Numerous studies have demonstrated the potential of hydrogen-diesel dual-fuel engines to achieve significant reductions in carbon emissions. For instance, Liu et al. (2010) reported that hydrogen substitution led to a decrease in particulate matter and carbon monoxide emissions; however, the increase in NOx emissions due to elevated combustion temperatures was also noted.

2.3 Combustion Characteristics in Hydrogen-Diesel Engines

The combustion characteristics of hydrogen-diesel engines are influenced by various factors, including hydrogen substitution levels, injection timing, and engine load. Hydrogen's fast flame speed contributes to shorter combustion durations and higher peak in-cylinder pressures, which can enhance thermal efficiency but may also lead to increased likelihood of engine knock (Das et al., 2002).

Research has shown that hydrogen substitution improves combustion efficiency by promoting more complete combustion and reducing unburned hydrocarbons (HC) and carbon monoxide (CO) emissions. However, the potential for increased NOx emissions necessitates careful consideration of hydrogen substitution levels (Verhelst & Wallner, 2009).

2.4 NOx Emissions in Dual-Fuel Engines

NOx emissions are a critical environmental concern associated with internal combustion engines, particularly in diesel engines. The formation of NOx is influenced by combustion temperature, pressure, and the presence of nitrogen and oxygen in the combustion chamber. In hydrogen-diesel dual-fuel engines, the introduction of hydrogen raises combustion temperatures, thereby increasing the potential for NOx formation (Saravanan et al., 2007).

The thermal NOx mechanism dominates at high temperatures, resulting in increased NOx emissions. This presents a significant challenge for optimizing hydrogen substitution levels, as higher NOx emissions can counteract the benefits of reduced carbon emissions.

2.5 Hydrogen Substitution and Emission Trade-offs

The relationship between hydrogen substitution and emissions is characterized by trade-offs. While hydrogen can enhance combustion efficiency and reduce carbon emissions, it also increases the likelihood of NOx emissions due to elevated combustion temperatures. The challenge lies in identifying optimal hydrogen substitution levels that balance these competing effects.

Strategies for mitigating NOx emissions while maintaining the benefits of hydrogen substitution include optimizing injection timing, implementing exhaust gas recirculation (EGR), and utilizing selective catalytic reduction (SCR) technologies (Das et al., 2002). Further research is needed to explore these strategies and develop comprehensive solutions for hydrogen-diesel dual-fuel engines.

3. Theoretical Framework

3.1 Combustion Process in Diesel Engines

The combustion process in diesel engines involves the injection of fuel into highly compressed air, resulting in auto-ignition. The process can be divided into several stages: fuel injection, mixing with air, ignition delay, and combustion. In dual-fuel engines, hydrogen is introduced alongside diesel to enhance the combustion process, leading to improved thermal efficiency and reduced emissions (Saravanan et al., 2007).

3.2 Hydrogen Combustion Mechanism

Hydrogen combustion differs significantly from diesel combustion. Due to its low ignition energy, hydrogen ignites rapidly, resulting in fast flame propagation. The primary products of hydrogen combustion are water vapor and a small quantity of NOx, predominantly formed due to high combustion temperatures (Tsolakis & Megaritis, 2004).

3.3 Impact of Hydrogen Substitution on Combustion Characteristics

The substitution of hydrogen in diesel engines affects various combustion characteristics, including peak pressure, combustion duration, and heat release rate. Increased hydrogen substitution generally results in higher peak pressures and shorter combustion durations, leading to enhanced thermal efficiency (Liu et al., 2010). However, the potential for increased NOx emissions necessitates careful management of hydrogen substitution levels.

3.4 NOx Formation in Hydrogen-Diesel Combustion

NOx formation in hydrogen-diesel combustion is influenced primarily by temperature and the availability of nitrogen. The thermal NOx mechanism dominates in high-temperature combustion environments, where nitrogen and oxygen react to form NO and NO2. Higher combustion temperatures resulting from increased hydrogen substitution can lead to elevated NOx emissions, presenting a challenge for engine optimization (Verhelst & Wallner, 2009).

4. Methodology

4.1 Experimental Setup and Engine Configuration

The experimental setup consists of a single-cylinder, four-stroke diesel engine equipped with a hydrogen injection system. The specifications of the engine are as follows:

Parameter	Value
Bore	87.5 mm
Stroke	110 mm
Compression ratio	17.5:1

Parameter	Value
Rated power	5.2 kW @ 1500 RPM

Hydrogen is injected into the intake manifold using a port injection system, while diesel fuel is injected directly into the combustion chamber using a high-pressure common rail injection system.

4.2 Fuel Properties

The properties of the fuels used in the experiments are provided in Table 1.

Property	Diesel	Hydrogen
Density (kg/m³)	830	0.089
Lower heating value (MJ/kg)	43	120
Autoignition temperature (°C)	210	585
Stoichiometric air-fuel ratio	14.7:1	34.3:1

4.3 Hydrogen Substitution Levels

Hydrogen substitution levels are varied from 0% to 40% of the total energy input, maintaining diesel fuel as the primary energy source. The experiments are conducted at different engine load conditions: 25%, 50%, 75%, and 100% of full load.

4.4 Measurement of Combustion Characteristics

In-cylinder pressure is measured using a piezoelectric pressure sensor, and the heat release rate is calculated based on the pressure data. Combustion duration is determined by analyzing the in-cylinder pressure data, while combustion efficiency is evaluated through brake thermal efficiency calculations.

4.5 Emission Analysis and Data Interpretation

The emissions of NOx, CO, HC, and particulate matter (PM) are measured using an exhaust gas analyzer. Data acquisition systems are used to record combustion parameters, emissions, and engine performance metrics in real time. Statistical methods, including regression analysis and ANOVA, are employed to analyze the collected data.

5. Results and Discussion

5.1 Combustion Characteristics at Varying Hydrogen Substitution Levels

5.1.1 In-cylinder Pressure and Heat Release Rate

The introduction of hydrogen into the combustion chamber significantly alters the in-cylinder pressure and heat release rate. As hydrogen substitution levels increase, the peak in-cylinder pressure tends to rise due to faster combustion and higher energy release. This trend is consistent with the findings of previous studies, which have noted that hydrogen enhances combustion efficiency (Liu et al., 2010).

5.1.2 Combustion Duration and Efficiency

Combustion duration decreases with increased hydrogen substitution, indicating a faster combustion process. The reduction in combustion duration enhances thermal efficiency, with the brake thermal efficiency improving by 5-10% at higher hydrogen substitution levels. However, this efficiency gain is accompanied by an increase in combustion temperatures, which can contribute to higher NOx emissions (Verhelst & Wallner, 2009).

5.2 NOx Emission Trends with Hydrogen Substitution

5.2.1 NOx Formation Mechanism

NOx emissions increase with hydrogen substitution due to the elevated combustion temperatures associated with faster combustion. The thermal NOx formation mechanism becomes more pronounced at higher hydrogen levels, leading to significant increases in NOx emissions (Saravanan et al., 2007).

5.2.2 Influence of Combustion Temperature on NOx

The correlation between combustion temperature and NOx emissions is evident in the experimental results. As hydrogen substitution levels increase, combustion temperatures rise, leading to proportional increases in NOx emissions. At 40% hydrogen substitution, NOx emissions were observed to be approximately 30% higher compared to diesel-only operation.

5.3 Trade-off between Combustion Efficiency and Emissions

The experimental results reveal a clear trade-off between improved combustion efficiency and increased NOx emissions with higher hydrogen substitution levels. While the efficiency gains from hydrogen substitution are notable, the accompanying rise in NOx emissions poses challenges for achieving environmentally sustainable engine operation.

5.4 Hydrogen Substitution Optimization for NOx Control

To optimize hydrogen substitution while controlling NOx emissions, it is essential to identify the optimal hydrogen substitution level. The experimental results suggest that a substitution level of around 20% provides a favourable balance between combustion efficiency and NOx emissions, minimizing the environmental impact while maintaining enhanced engine performance.

6. Conclusion and Recommendations

This study demonstrates that hydrogen substitution in dual-fuel diesel engines significantly influences combustion characteristics and NOx emissions. While hydrogen improves combustion efficiency and reduces particulate emissions, it also leads to increased NOx emissions due to higher combustion temperatures. The research highlights the importance of optimizing hydrogen substitution levels to achieve a balance between efficiency and emissions.

Future research should explore the implementation of emission control technologies, such as exhaust gas recirculation (EGR) and selective catalytic reduction (SCR), to mitigate NOx emissions while maintaining the benefits of hydrogen substitution. Additionally, further investigations into different engine configurations and operating conditions could provide deeper insights into the potential of hydrogen as a supplementary fuel in internal combustion engines.

References

Bari, S., & Esmaeil, M. M. (2010). Effect of H2/O2 addition in increasing the thermal efficiency of a diesel engine. *Fuel*, 89(2), 378-383.

1. Das, L. M., Gulati, R., & Gupta, P. K. (2002). Performance characteristics of a hydrogen-fuelled spark ignition engine using timed manifold injection. *International Journal of Hydrogen Energy*, 25(8), 783-793.
2. Liu, Z., Deng, J., Wang, S., & Huang, Y. (2010). Effects of hydrogen addition on combustion and emissions performance of a diesel engine. *Fuel*, 89(2), 387-394.
3. Saravanan, N., Nagarajan, G., Lakshmi Narayana Rao, G., & Sampath, S. (2007). Experimental investigation of hydrogen port fuel injection in DI diesel engine. *International Journal of Hydrogen Energy*, 32(16), 4071-4080.
4. Tsolakis, A., & Megaritis, A. (2004). Exhaust gas assisted reforming of rapeseed methyl ester in compression ignition engines for improved performance and lower emissions. *Energy Conversion and Management*, 45(3), 459-473.
5. Verhelst, S., & Wallner, T. (2009). Hydrogen-fueled internal combustion engines. *Progress in Energy and Combustion Science*, 35(6), 490-527.

Chapter -4:

Effect of Ageing on Binder Content of various types of Bituminous Pavements

Nevidita Shukla[1] **Sunil Priyadarsi**[2]*

1. Assistant professor, Department of Civil Engineering, CGC, Landra chandigarh
2. Assistant professor, Department of Civil Engineering, Swami Vivekananda University

*Corresponding Author Email: sunilp@svu.ac.in

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Nevidita Shukla[1] **Sunil Priyadarsi**[2]*

1. Assistant professor, Department of Civil Engineering, CGC, Landra Chandigarh
2. Assistant professor, Department of Civil Engineering, Swami Vivekananda University

*Corresponding Author Email: sunilp@svu.ac.in

ABSTRACT

A pavement surface may or may not be so deteriorated so as to identify its actual condition. Bitumen, being the key constituent of any flexible pavement, should always be present in such a quantity so as to maintain its flexibility, bonding of aggregate and filler constituents and resist the deterioration. This paper presents the outcomes of rigorous visual and experimental analysis done over actually aged bituminous samples from pavements bearing different types of traffic flows but having same binder course specifications. The observations obtained have been discussed. From the study, it was found that, whether or not, the pavement surface appears to be deteriorated but the loss of binder content starts from the time it is laid. The initial rate of loss of binder content was found to be highest due to lack of full attainment of compaction, presence of more voids and large amount of filler and volatiles in the mix. Further, this rate of loss of binder decreased due to compaction under traffic increased again once the deterioration in form of loss of fines and development of cracks begins resulting in larger exposed surface area . This aligns with the government's goal of conserving budgets and promoting environmentally friendly practices through "Green Technology." Therefore, recycling pavements emerges as an efficient solution for road construction and maintenance, offering significant advantages such as cost savings, environmental preservation, and the preservation of virgin materials. It was also found that pavements carrying faster and heavier traffic flow suffer more binder loss, both initially and ultimately.

Keywords: Ageing, Distress, Binder loss, cracks, moisture

1. INTRODUCTION

Transportation is a key infrastructure of a country. It is well known that, road network is the largest and most important connecting way and so as its maintenance. To maintain any commodity, it is important to know its root cause. Majority of the road network in our country comprises of flexible pavements i.e., bituminous pavements. These are constructed by using aggregates, filler and bitumen. As we know that, bitumen acts as a binder and also that its constituents consists of volatiles. It gets oxidised with the passage of time and becomes hard and brittle.This process is referred to as “ageing of bitumen” which takes place due to oxidation of bitumen when it comes in contact with the atmosphere followed by evaporation of its volatile components and ultimately physical hardening.

Due to ageing of a bituminous pavement, there occurs loss of binder content, which further results in pavement deterioration in the form of surface distresses. These distresses can further be facilitated due to improper design and poor drainage conditions. Consequently, India faces a pressing requirement to adopt a sophisticated approach for road construction and maintenance, with the objective of minimizing expenses and decreasing reliance on raw materials. To achieve this, the integration of recycled aggregate as a substitute material can reduce the demand for fresh aggregate. In the current study, the RPM aggregate originates from the remains of dismantled roads. By analyzing existing literature and case studies, the research aims to pinpoint the most effective practices and guidelines for maximizing RPM utilization in the granular sub base of rural roads. The findings will contribute to the development of sustainable and cost-effective solutions for road construction, benefiting rural communities, minimizing construction costs, and promoting environmental stewardship.

All pavements require maintenance due to distresses caused in the pavements. Regardless of the cause- any pavement will deteriorate faster if it remains unattended.

This research has been carried out over the pavements of Chandigarh. The roads of the city have been classified into seven categories, from V1 to V7 which are as follows:

1. V1: Fast roads connecting Chandigarh to other towns
2. V2: Arterial roads
3. V3: Fast vehicle sector dividing roads
4. V4: Meandering shopping streets
5. V5: Sector circulation roads
6. V6: Access roads to houses

7. V7: Foot-paths and cycle tracks

2. METHODOLOGY

1. Pavement Identification and Data Collection

In order to carry out this study, it was required to obtain bitumen content data spread over a period of several years. A period of 3-5 years can be considered adequate to obtain some meaningful interpretations. The author(2) has been directly associated with sampling and testing and all the data have been collected during the course of providing technical services to Chandigarh Administration and Municipal Corporation Chandigarh.

This data is taken as reference value of binder content at the initial stage of the pavement life. To serve the purpose various sites had been identified having same design specifications (i.e., types of bituminous course and initial binder content) for V3, V4 and V5 roads.

The selected data is such that type of distresses and residual binder content can be found out at an interval of every six month ; through interpolation was made in a few cases where precise data at selected time interval is unavailable.

2. Sample collection

All the samples have been collected by a mechanically operated core cutting machine to cut a full-depth layer sample. The diameter of the core was 10 cm. Necessary precautions were taken to separate the sample at the layer interface. Samples were then air-dried, packed and labelled for further testing.

The samples for this analysis were collected from V3, V4 and V5 roads having Bituminous Concrete 40mm as the wearing course.

Fig. 1 Mechanical Drill Machine **Fig. 2 Samples kept in laboratory for drying**

3. Visual Observations

The preliminary step to establish any conclusion is visual observation of the identified site. One of the objectives of this research work was to get an idea about the type and amount of surface distress which may occur in a pavement when it has been aged for a certain period of time. It had been observed that the bituminous surface layer appears to be porous in the initial period and only fine cracks develop after a pavement has been aged for 3-4 years. Visual observations were done for each type of road (V3, V4 and V5) by selecting two sites for each category which have been aged for one, three and four (more than four but less than five) years.All the collected and dried samples were tested for residual binder content percentage by Solvent Extraction Method using Benzene as a solvent.

3. RESULTS

1. Visual observation results

After visually analysing the pavements which have been aged for various time periods, the following observations were made:

Table 1 Surface distress in V3, V4 and V5 roads with their ageing

<table>
<tr><th rowspan="2">Age of the pavement (months)</th><th colspan="3">Type of distress observed in</th></tr>
<tr><th>V3</th><th>V4</th><th>V5</th></tr>
<tr><td>12</td><td>Porous surface</td><td>Porous surface</td><td>Loss of fine</td></tr>
<tr><td>24</td><td>Very fine cracks</td><td rowspan="2">Hairline cracks with undulations towards edges</td><td rowspan="2">Increase in surface porosity</td></tr>
<tr><td>36</td><td>Alligator cracking and edge cracks</td></tr>
<tr><td>48</td><td>Severe edge, longitudinal and alligator cracks</td><td>Undulations with severe cracks</td><td>Porous surface along with minor cracks</td></tr>
<tr><td>60</td><td>Severe cracking</td><td>Cracking and undulations</td><td>Severe porosity with cracks</td></tr>
</table>

The percentage of binder content used in road construction projects varies depending on the project and the condition of the binder content. It has been successfully used up to 70% in certain road projects. It is not advisable to prepare a blending mix with 100% use of binder content. The large size of aggregates in the binder content mix tends to be deficient due to the crushing and aging process.The utilization of recycled aggregate in granular sub base (GSB) for road construction offers both economic advantages and environmental benefits by mitigating mining pollution

The ideal proportion of binder content in granular mixes does not have a fixed and universally applicable percentage. Instead, different road projects have successfully employed varying percentages of binder content based on their unique specifications and needs.Recycling aggregates from demolition projects can save costs associated with transporting the material to landfills and disposal.

These conclusions highlight the feasibility and advantages of utilizing binder content in road construction, while also emphasizing the need for careful consideration of factors such as binder content percentage, aggregate size, and strength criteria to ensure the successful implementation of binder content -based granular sub base in village road projects.

Overall, the adoption of recycled aggregate in GSB for road construction provides a dual advantage of cost savings and environmental sustainability. By embracing this approach, the industry can contribute to minimizing mining pollution while reaping the economic benefits offered by the utilization of recycled materials.

2. Experimental results

Following are the results of Solvent Extraction test over the collected samples which give the percentage of residual binder content in the mix with respect to the initial binder.

Table 2 Residual binder content in V3, V4 and V5 roads (half-yearly)

S.No.	Initial binder content	Time (months)	Residual Binder Content (%)		
			V3	V4	V5
1	5.5	0	5.5	5.5	5.5
2	5.5	6	5.15	5.18	5.26
3	5.5	12	4.8	5.00	5.05
4	5.5	18	4.51	4.82	4.89
5	5.5	24	4.34	4.64	4.72
6	5.5	30	4.16	4.54	4.64
7	5.5	36	4.11	4.37	4.53
8	5.5	42	4.07	4.22	4.45
9	5.5	48	3.94	4.12	4.37
10	5.5	54	3.75	3.97	4.21
11	5.5	60	3.50	3.72	3.95

Table 3 Annual binder loss in V3, V4 and V5 pavements

Number of years	Annual Binder loss in road category type		
	V3	V4	V5
1	0.70	0.50	0.45
2	0.46	0.36	0.33
3	0.23	0.27	0.19
4	0.17	0.25	0.16
5	0.44	0.40	0.38

We may also present cumulative binder loss

4. Conclusion

All the three types of pavements (V3, V4 and V5) have similar surface course (Bituminous Concrete 40mm) and same initial binder content, but the rate of loss of binder content for each type of pavement was different, which was due to the difference in type and amount of traffic they carry.

Below are the graphical representations of annual binder loss in each type of pavements.

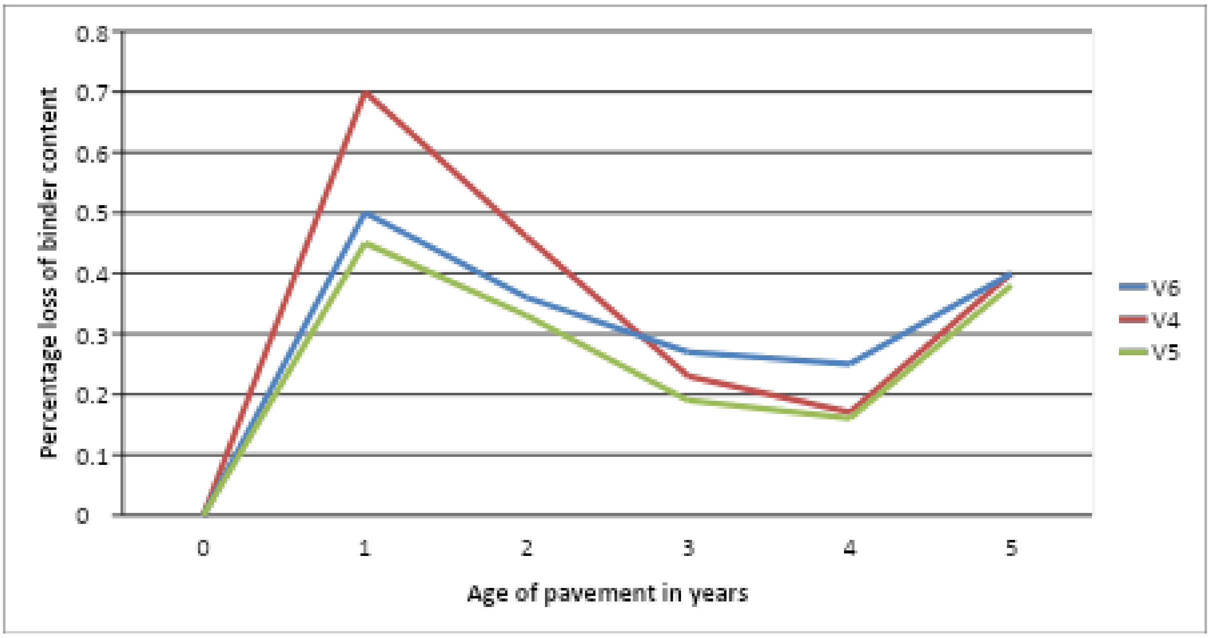

Fig.3 Comparison of annual binder loss among V3, V4 and V5

Percentage loss is misnomer in graph it should be loss in bitumen content , % w.r.t.mix

From the tests results, the following points were clearly deduced:

1. The residual binder content at any point during the service-life of the pavement was least in case of V3 roads . This can be attributed to the fact that they carry heavy and fast moving vehicles.
2. Maximum loss of binder content occurred in the initial phase of a pavement's service-life which was clearly shown in all the three types of pavement.Specify the initial phase in terms of months
3. The ultimate loss of binder content from the bituminous pavement was also highest in V3 and least in V5.

Further, it was also observed that the percentage loss of binder content from the bituminous pavements were maximum in the initial phase of pavement service-life. This value decreases as the pavement ages but increases again towards the end.

This trends was observed because when a bituminous pavement is laid and compacted while construction, it does not attain its maximum compaction at that stage. Due to presence of voids and maximum amount of volatiles and fines in the mix, the oxidation and evaporation process takes place at a higher rate resulting in loss of fines along with bitumen and porous surface. As the time passes, a pavement attain its maximum compaction and minimum void condition, which results in decreasing the rate of loss of bitumen from it. But under the effect of traffic, atmospheric deterioration and ageing of bitumen itself, minor cracks start to develop on the pavement surface as also loss of fines . This results in increase in void size at surface . The Fine cracks also grow in size , getting widened with its ageing process and also abrasion in presence of dirt and retained moisture. These cracks expose larger surface area for further oxidation and as a result rate of loss of bitumen increases again.

It is also noteworthy that in dense mixes like Bituminous Concrete , relatively more binder content is present alongwith filler material as compared to that used for coating of aggregate . Once fines start getting lost from surface , they also take along binder associated with them .

REFERENCES

[1]. Terrel, R. L. and Fritchen, D. R., *Laboratory Performance of Recycled Asphalt Concrete.*ASTM STP 662, 1978.

[2].Kandhal, P.S., Rao, S.S.,Watson,.,Young, B., *Performance of Recycled Hot Mix Asphalt Mixtures*, National Center for Asphalt Technology (NCAT), 1995. NCAT Report No.95-1.

[3].Thomas W. Kennedy, Weng O. Tam, and Mansour Solaimanian-"*Effect of reclaimed asphalt pavement on binder properties using the SUPERPAVE system*" Report No FHWA/TX-98/1250-1, September 1998, Centre for transportation research, bureau of engineering research, university of Texas at Austin.

[4].Randy C.West, J. Richard Willis-"*Case study on successful utilization of Reclaimed Paving Materials and Recycled Asphalt Shingl in bituminiouspavement"NCAT* Report 14-06,Auburn University,2009.

[5].Valdes, G., Jiminez, F. P., Miro, R., Martinez, A., Botella, R. *Experimental Study of Recycled Asphalt Mixtures with High Percentages of RPM,* Journal of Construction and Building Materials, 2010, Vol. 25 (2010), pp. 1289-1297

[6].Eric J. McGarrah-"*Evaluation of current practices of Reclaimed asphalt pavement/virgin aggregate as base course material* November 13,2010,Annual Meeting of the Transportation,

[7].Montepara,Tebaldi, Marradi,Betti"*Effect of payment performance of a subbaselayer composed by natural aggregate and RPM*www.roadtec.com,t127_techpaper_millingrecycling. [8] Singh Veresh P., Mishra Vivek , Harry N.N. and Bind Y.K.. (2014)"Utilization of Recycled Highway Aggregate by Replacing it with Natural AggregateJournal of Academia and Industrial Research (JAIR) Volume 3, Issue 6 November2014 263 ©Youth Education and Research Trust (YERT) jairjp.com Veresh*et al.*,2014ISSN: 2278-5213

[9] Sreedhar N, Mallesha K. M. (2014) "Cost Analysis of Low Volume Rural Roads using RPM Materials as G.S.B."*3rd World Conference on Applied Sciences, Engineering& Technology 27-29 September 2014, Kathmandu, Nepal* WCSET 2014049 © BASHA RESEARCH CENTRE.

[10].J.Don.Brock,Ph.D.andJeff.L.Richmond-:"*Milling and recycling*,https://www.roadtec.com ,t127_techpaper_millingrecycling.pdf.

[11]. Khushbu. M. vyas, shruti B*"Technical viability of using Reclaimed Paving Materials in Ahmadabad BRTS Corridor for Base Course*(2013) ISSN: 0975 – 6760| NOV 12 TO OCT 13 | VOLUME – 02, ISSUE – 02S

[12]. Jitender Sharma, Sandeep Singla "*Study of Recycled Concrete Aggregates*" (2014) *International Journal of Engineering Trends and Technology (IJETT) – Volume 13 Number 3 – Jul 2014*

[13]. Maulik Rao, Dr. N.C. Shah "*Utilization of RPM (Reclaimed Asphalt Pavement) Material Obtained By Milling Process*"(2014)Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 7(Version 4), July 2014, pp.01-04

[14].Jaspreet Singh, Jashanjot Singh, A.K Duggal, , "A Review paper on Reclaimed Paving Materials (RPM)", IJMTERI , (2349-9745), (2015)

[15]Singh,Jaspreet, Duggal A.K "An Experimental study on Reclaimed Paving Materials (RPM) Dense Bituminous Macadam" IJMTERI (2393- 8161) ,2015

Chapter -: 5

An overview of the use of IoT in agriculture

Manish Kumar Dubey, Ranjan Kumar Mondal

Technical Trainer, Department of CSE, Swami Vivekananda University, Kolkata, WB

Assistant Professor, Department of CSE, Swami Vivekananda University, Kolkata, WB

manishd@svu.ac.in

An overview of the use of IoT in agriculture

Manish Kumar Dubey, Dr. Ranjan Kumar Mondal

Technical Trainer, Department of CSE, Swami Vivekananda University, Kolkata, WB
Assistant Professor, Department of CSE, Swami Vivekananda University, Kolkata, WB
manishd@svu.ac.in

Abstract: Precision agriculture is the use of information technology in the agricultural sector in response to factors such as rising food consumption, consumer demand for high-quality food, and the environmental effects of agriculture. The Internet of Things (IoT) technology has been expanding quickly in recent years and has several advantages for agriculture. Cloud computing is essential to the future of Internet of Things (IoT) agricultural applications because of the vast and diverse data that IoT devices gather. Microcontrollers will simultaneously expand the capabilities of the Internet of Things (IoT). This study looks at the research trend, ideas, core IOT components, obstacles, and IOT applications in agriculture. First, the total number of publications on this subject is under evaluation. The second section introduces the definition of IOT, architecture, and levels. Finally, the primary issues in precision agriculture (PA) and the Internet of Things (IoT) are discussed. In the third section, many IOT-related technologies are compared.
Keywords: machine-to-machine, precision farming, Internet of Things;

I. Introduction

The term "Internet of Things," or "IoT," refers to a unique application area that combines many hardware and software components, including sensors, actuators, RFID tags, wireless telecommunications technology, and mobile phones. In 1999, Kevin Ashton coined the term "Internet of Things." The term "IOT" itself gives rise to the first intriguing feature of the technology. It is a collection of tangible, related items or "Things." Physical entities include persons, animals, automobiles, settings, appliances, etc. Moreover, the fact that "Things" are linked to the Internet is referred to as the "Internet." Every "Thing" has an identification as well to be recognized.

In general, the IOT's capabilities and features enable the use of this technology in a wide range of application areas. Still, due to constraints and difficulties, only a limited number of them are now relevant to our community[1]. One of the industries that IOT has impacted is agriculture, which gave rise to the new field known as precision agriculture. According to [2], precision agriculture uses information technology (IT) to raise yields and enhance agricultural quality. The overall objective of precision agriculture is to increase harvest yields and farmers' profitability while reducing the damaging impacts of farming on the environment caused by excessive fertilizer usage. The population of the globe will increase to 9.6 billion people by 2050, a 36% increase from now. Over the next 30 years, food consumption is expected to reach 3070 kcal per person per day[3]. The yearly output of significant crops must increase to around one billion simultaneously. Concerns about food production will increase due to this rapid population rise and the associated problems.

Modern agriculture may increase crop yields, particularly precision agriculture (PA)[4]. PA promises to significantly increase agricultural output, lessen the adverse effects of farming on the environment, and ensure high productivity levels. Furthermore, positive PA measures have a noticeable impact on greenhouse gas emissions. Precision agriculture maximizes the demands of both indoor and outdoor agriculture while reducing the quantity of fertilizer and pesticide used. This is made possible by cutting-edge technology like WSN, sensors, RFID, actuators, etc. Low-cost and low-power sensors have advanced in recent years. These sensors monitor various characteristics, including water content, ambient temperature, wind speed, humidity, and soil moisture. Sensor data is analyzed using data analysis techniques, which aid in extracting additional information from the data, developing more precise prediction models, and supporting decision-making systems. Furthermore, PA is seen as a data-driven approach[5]. Scholars use data mining techniques (such as classification, clustering, regression, etc.) to address a challenging problem: yield prediction.

Healthcare, smart cities, industries, agriculture, traffic management, the military, the smart grid, and other fields have significantly increased IoT technologies[6]. As a result, we conducted a comprehensive review of relevant work in three well-known scientific databases (IEE, Springer, and ScienceDirect) to look into the recent trend in IOT-related publications. Figure. One shows the number of papers indexed in the three central scientific databases throughout eight years, from 2010 to 2017. Meanwhile, the trend of research publications published in scientific databases about IoT applications in agriculture has sharply increased in the last several years (see Fig. 2). In this research, we compare the number of publications from 2010 to 2017 using the Google Scholar search engine. The search results for "IOT and agriculture," "IOT and farming," "IOT and smart agriculture," and "IOT and precision agriculture" This sharp rise motivates us to look at the most recent scientific findings on IoT applications in agriculture.

II.**History and Ideas of IoT**

The term "Internet of Things" or "Internet of Objects" often describes a collection of networked objects that are individually outfitted with sensors and linked to the Internet [7]. The Internet of Things is implemented using a three-layer architecture, designated the Application, Networking and Commutation, and Sensing layers, respectively, according to IEEE P2413. Within Fig. 3. briefly describe each layer's duties.

An essential part of the history of IOT is played by Radio-Frequency Identification (RFID). RFID technology uses radiofrequency waves to transfer collected data from a mobile physical entity to an RFID reader. Identification, sensing, and communication technologies are other essential technologies connected to IOT [4,5]. From an identity and addressing perspective, identification technology is critical to the Internet of Things. The two main methods of identification for the Internet of Things are ubiquitous code (uCode) and electronic production codes (EPC)[6]. Addressing IOT devices that are internet-connected also causes another issue. Addressing techniques like IPv6 and 6loWPAN-IPv4 resolve the problem [8].

A network of sensors is used in IOT sensing technologies to perceive analog data, including light, pressure, temperature, wind speed, and others. Collected data may be used in preprocessing and aggregation methods to cut down on data traffic and extend the lifespan of sensor nodes. IoT has used various communication technologies, including WiFi, Bluetooth, ZigBee, IEEE 802.15.4, LTE, and 5G. A standard method is needed to connect IOT devices to the internet and each other. Rather than using the Internet of Things, the European Telecommunication Standards Institute (ETSI) refers to machine-to-machine (M2M) connectivity. In M2M communication, WiFi, or wireless local area network (WLAN), is essential. Ubiquity and dependability are two crucial characteristics of IOT communication. One of the most promising Internet of Things connectivity technologies is WiFi or IEEE 802.11 standards. WiFi connections are becoming more widespread and may be used to connect devices to the internet. Furthermore, IEEE 802.11ah, also known as WiFi-HaLow, is a new type of WiFi technology that allows more than 8000 devices to communicate with one another.

Engage in standard Internet of Things applications, such as supply chain management, smart agriculture, smart grid, and intelligent healthcare[9]. Barcodes, near-field Communication (NFC), Artificial Intelligence (AI), computing technology, and other aspects are fundamental technologies and components of the Internet of Things.

III.IOT AND TECHNOLOGY ENABLEMENT

A. Hardware platforms for IoT

The Internet of Things has increased recently thanks to the compact, inexpensive microcontroller and processing gear. Table 1 lists the widely used hardware platform for precision agricultural studies and projects, arranged by key performance indicators. This gear has memory, wireless chips, CPUs, and other parts.

The agricultural Context of IoT Cloud platforms

A crucial element of IOT solutions across all application areas is an IOT cloud platform. Many well-known cloud computing businesses, including Microsoft, Google, Amazon, and others, first offered IOT as a service. The advantages of the IOT cloud platform are massive scale, cheap cost, virtualization, and scalability. Precision agriculture uses sensors, RFID, wireless communication, intelligent systems, and other ICT technologies to execute the monitoring and regulating systems. Farmers, specialists, and even scientists utilize the data they gather in the systems for various objectives (analysis, computation, visualization, forecasting future occurrences, future works, etc.). The IoT cloud platform is a viable option for achieving these goals safely and effectively. Additionally, data may be shared across IoT devices via the internet. The IOT platform may fill the gap between device sensors and the data network. Table 2 presents a comparative analysis of the well-known IOT cloud providers used in precision agriculture.

C.Agriculture using machine-to-machine (M2M) connectivity

Machine-to-machine (M2M) communication, according to the [7], is a communication connection between two or more entities that are formed essentially without direct human participation. Automation in the communication and decision-making processes is what M2M services are aiming for. With various communication technologies, including Internet Protocol (IP), WiFi, and SMS, M2M technology may wirelessly link automobiles, gadgets, and agricultural machines to other objects to minimize direct human interaction in addition to service delivery. M2M technology is essential to the Internet of Things (IoT), allowing gadgets, automobiles, and other connected objects to interact with the Internet in a coordinated way. M2M technology is a critical component of the IOT.

M2M networking methods come in various wired and wireless forms (see Table 2). IoT solutions for agriculture heavily rely on wireless technologies, including WiFi, Zigbee, Bluetooth, and Wide Area Networks (WAN)[38]. In this instance, the WAN (cellular M2M) is of relevance. A novel kind of wireless communication is cellular M2M communication[39]. Cellular communications may be used in the M2M domain to transmit machine data to the base station. Furthermore, wired networks have several shortcomings in maintenance, cost, mobility, and other areas. Thus, cellular M2M might be a viable option for agricultural technologies. M2M communication allows the sending and receiving of agricultural characteristics, such as temperature, humidity, wind speed, position, and other factors. Fig. Describes the architecture and partners of cellular M2M. 4. Partners in the device domain, such as machines and animals, maybe remotely observed to check on their operational state, general health, diagnostics, etc. Time, expense, and effort may all be significantly decreased in this way. Additionally, a wireless modem—used for connection with the M2M service core—can be installed on the devices. End customers may get SMS/Email notifications on their tablet or mobile device. User Interface (UI) allows for setting control rules for every device and action. "Turn on smart irrigation system when soil moisture is 20%," for instance. It should be mentioned that a farmer has to have a broad understanding of the farm, and analytics and data visualization on a cloud server make this possible.

D.Smartphone apps for agriculture

Globally, information and communication technologies have increased, and evidence of technology can be seen almost everywhere. Precision agriculture (PA) has significantly benefited from ICT, which has made agricultural jobs easier, mainly when using smartphones and telecommunications[40].

Smartphone operating systems and processors have advanced recently, leading to an increase in the usage of these devices across a wide range of businesses and sectors (e.g., healthcare, industries, smart grid, and agriculture). Most modern cell phones are capable of carrying out most computer-related activities. Furthermore, a vast array of applications (Apps) for a wide range of functions have been created in response to the growing rate of smartphone usage. Almost every industry and profession has an app to assist with and make jobs easier.

Similarly, many applications have been created for agriculture that may help farmers in many ways. According to the study we've done, applications provide a variety of services specific to the agricultural industry. Table 4 provides a synopsis of various applications.

IV. USES OF THE INTERNET OF THINGS IN AGRICULTURE

Precision Agriculture (PA) is a contemporary management strategy that leverages data collection, GPS, WSN, geographic information systems (GIS), and information technology. These innovations aim to lessen their adverse effects on the environment while increasing agricultural yields. Thus, the Internet of Things is a contender for use in the PA with its supporting technologies. The development of low-cost, low-power sensors has made it possible for the WSN to gather a vast amount of environmental data, which it then transmits over wireless media to a database. The collected data may be transmitted straight to the database for a thorough analysis, or it can go via an abstract analysis to get critical input[41]. Furthermore, contemporary agriculture aims to transform conventional farming into high-yield, high-quality, water-saving, and intelligent farming. The prior conversations indicate that IOT technology is a viable and promising means of achieving these objectives. Fig illustrates the most significant uses of IoT in agriculture. 5.

A.environmental observation and management

One of the most critical technologies in this century is the wireless sensor network. They are ideal for monitoring greenhouse environments and agriculture because of their energy efficiency, fault tolerance, scalability, homogeneity, and variety of nodes and communication capabilities. Multiple nodes with sensing, communication, and processing capabilities make up a WSN. Numerous environmental factors, such as soil moisture, temperature, humidity, water pH, wind speed, etc., may be measured and processed by WSN's sensor nodes[42]. Cultivating crops and plants is challenging due to several factors, such as unpredictable weather, scarcity of water, environmental impacts, and plant diseases. Therefore, we must use contemporary farm monitoring methods to handle these issues. The features of the WSN indicate that this technology should provide efficient monitoring systems to address the problems [38].

The development of greenhouse monitoring and control systems has been accelerating. The best growth and production criteria for greenhouse plants can be adjusted most effectively: light, temperature, humidity, and carbon dioxide (CO_2) levels. In this manner, the sensors measured the parameters, and a greenhouse specialist using a PC, tablet, or smartphone could evaluate the information acquired and automate the regulation of specific parameters[43]. Farmers and other specialists may learn important information about plant growth and the effects of individual conditions on plant production by keeping an eye on these metrics. An overview of the IOT technologies (sensors, wireless communication, etc.) in a field and greenhouse setting is shown in Fig. 6. Several sensor nodes are placed throughout the greenhouse and the field to collect, analyze, and transmit measured data. The gateway also establishes a connection between the cloud server and the sensor nodes. Images may be taken in the field using drones and camera nodes. These photos are used for further analysis (lower vegetation index and crop damage)[44]. The servers in the cloud receive the data for archiving, processing, and displaying. The user may use the monitoring system on a tablet, laptop, PC, or smartphone.

B.ecological observation

Pollution of the environment, temperature changes, and the emergence of new biological groups and species result from human activity combined with natural forces[45]. Because the natural environment is subject to complicated changing processes and installing ecological monitoring systems is a drawn-out process, environmental monitoring is a complex and ongoing endeavor. Therefore, we want a long-term environmental monitoring system to reveal these changes. One systematic way to gather ecological data over an extended period is via environmental monitoring. Several monitoring forms include surveillance, outcome, and result monitoring[46]. Thus, we want persistent, omnipresent, real-time monitoring systems to fulfill these needs. The advent of information technology (IT) allows for novel responses to changes in the environment. One potential option that can detect, gather, preprocess, and transmit a range of environmental data and efficiently monitor ecological parameters is the environmental Internet of Things (IoT)[47] technologies. By simulating the environment and monitoring systems, the environmental monitoring systems have profited from the expansion of the EIOT. We may use the Internet of Things (IoT) to help us find practical technical solutions to address environmental issues.

Environmental wireless sensor networks consist of dispersed sensors that provide ecological data from a distance, analyze and visualize data in real-time, and integrate with other networks. The WSNs include several features: event-based, on-demand, and continuous monitoring [48]. These features aid in tracking several ecological indicators, including relative humidity, wind direction, speed, temperature, soil carbon dioxide, and atmospheric carbon dioxide.

C.Watering

Due to population increase, rising family incomes, diversified diets, and high nutrition, the need for water in the agricultural sector is growing over time[49]. Around 70% of water used worldwide is used for agriculture, according to the United Nations World Water Development Report from 2016. It is projected that the water consumption of agriculture will increase by 20% by 2050 if alternative and efficient approaches are not used. Therefore, to reduce water use and increase crop yield, we need irrigation systems that are as efficient as possible, based on information and communication technologies (ICT), sensors, microcontrollers, actuators, etc.

The soil moisture parameter is measured and controlled by new irrigation systems using network sensors and actuators[50]. The measured data is sent to local or distant computers for processing and analysis via IOT connections. In numerous studies, researchers have employed many sensors at varying soil depths. To avoid unnecessary watering, these sensors give information on how much water crops require. Remember that extra water in the soil evaporates and may pose a risk to the soil and crops in some situations [51]. An intelligent watering system is seen in Fig. 7. The system uses sensor technology and allows for remote user control of the irrigation system to facilitate agricultural irrigation management. Before putting the intelligent irrigation system into place, the farm or greenhouse should be inspected to identify unique needs. Several soil moisture sensors measure strategic locations throughout the farm or greenhouse for relative humidity.

Microcontroller-based intelligent irrigation systems are an additional component of IOT in irrigation and provide significant benefits [52]. Numerous agricultural characteristics, including leaf wetness, soil moisture, and humidity, are continuously measured, and the microcontroller receives the sensed data. After that, wireless connections send the data to a base station for monitoring. The base station and atmospheric conditions analyze the data, and irrigation is scheduled using actuators and relays operating the pump (see Fig. 8). DIFFICULTIES.

The Internet of Things must overcome several formidable obstacles to achieve its potential benefits. In this paper, we divide these challenges into two categories: 1) the challenges related to IOT and IOT components, such as the challenges related to IoT standardization and implementation, 6LowPan challenges, sensory challenges, security and privacy, and so on; and 2) the challenges related to precision agriculture, which included the big data challenge.

A.Difficulties with IOT and its components

1) Difficulties with IoT Standardization and Implementation

Integrating things into the internet presents several issues in adapting the existing internet protocols and technologies with these things. Standardization is essential to establishing value and the market for a new idea. Many studies have been done in the last several years to match these items' current procedures and technology [53]. Numerous diverse heterogeneous devices are taking part in the Internet of Things; achieving high levels of interoperability is challenging if the diverse devices employ multiple standards and protocols. To address these standardization problems, IOT standards organizations like the European Telecommunications Standards Institute (ETSI), IEEE, and others should concentrate on creating a technology standard.

"Internet of Things" describes networks of objects that can sense, gather, and exchange information with computers and other objects. Many factors make the concept's implementation challenging, including the nature of specific IOT components and their inherent qualities. For instance, sensors are often used to gather data. After that, the data is sent to cloud servers and IoT gateways for further processing and analysis. Here, there are significant issues with IOT network implementation (security, power consumption, growing the number of IoT devices, etc.) as well as issues with IOT sensors (power consumption, security, and interoperability)[54]. Furthermore, a great deal of Internet of Things systems make use of TCP/IP protocols. Nevertheless, the data indicates that the Internet of Things applications are unsuitable for the TCP/IP protocol stack. As a result, several researchers have attempted to address this issue by putting out updated TCP/IP protocol versions [55].

2) 6LoWPAN

IPv6 over low-power wireless personal area networks (LoWPANs) is called 6LoWPAN[56]. Devices with limited resources may transfer data over IPv6 thanks to 6LoWPAN. Considering the characteristics of LoWPANs[57], the following were the main issues and obstacles with IP over LoWPANs:

The first six factors are IP connection, topologies, restricted packet sizes, service discovery, security, and limited configuration and administration. The necessity for a new IP version with a bigger addressing space is highlighted by the explosive rise of IOT devices, which often cause network autoconfiguration. IPv6 addresses these issues. Several topologies, such as mesh and star, are required to enable 6LoWPAN. Multi-hub routing is required in mesh topologies, which presents a significant difficulty; an intermediary device in an IoT application must have higher processing and energy resources. LoWPAN apps are anticipated to use tiny packets (127 Bytes). However, the maximum transmission unit (MTU) for IPv6 is set at 1280 bytes. To divide IPv6 packets into several smaller packets and reassemble them at the destination, 6LoWPAN needs to have a fragmentation format. When sensors and actuators in the Internet of Things are connected via IP, security is a crucial topic. The Advanced Encryption Standard (AES) technique, which LoWPAN utilizes, has a 128-bit encryption key. On the other hand, the 6LoWPAN lacks information on implementing crucial change and critical management.

3) Internet of Things sensors

Several kinds of sensors are placed across fields and greenhouses in precision agriculture, and these sensors are arranged into wireless sensor networks (WSN). The WSNs have strict power consumption limits, limited computational capacity, and sensors with little memory [58]. These restrictions create difficulties for agricultural applications that rely on sensors. Irrigation systems and environmental and ecological monitoring are two important uses in the farm sector. By adding more sensors to monitor additional parameters, a scalable wireless sensor network (WSN) may enhance the performance of existing sensor-based applications. Several difficulties related to the sensors' signal strength and the location chosen for the network's installation. For instance, blockage and dampness might decrease the connection's signal strength.

Sensor nodes are often powered by finite power sources (such as batteries), which hinders their longevity, particularly for agricultural applications requiring lengthy lifespans. In sensor-based agricultural applications, power-saving techniques include radio transmission optimization [64, 65], sleep/wake algorithms [63], and data mitigation techniques [59–62].

Security and privacy

The sensors transmit data about agricultural and field characteristics through various connections throughout the network. The primary objective of wireless sensor networks is to transport dependable data to other networks and sensor nodes. Using an efficient security method is a critical and challenging problem because of the agricultural applications' broad covered regions and WSN's limitations. Several network security designs in the agriculture sector have been developed by researchers [66–68]. Another security issue is routing protocol security. Malicious users attempt attacks on routing protocols to bring down a network. Thus, expanding the WSN's safe and dependable routing protocol has been a popular study area. However, as we have previously said, WSNs have significant constraints that prevent the usage of traditional routing methods in WSNs. The security algorithms in WSNs present two main challenges, according to the [69]: 1) they impose an overload of data on messages, which must be declined as much as possible to extend the lifetime of the sensor node, and 2) the sensor nodes have small memory sizes, which can inadvertently result in minor security keys.

The privacy of wireless sensor networks is a significant concern because of their outside uses. Data-oriented and context-oriented privacy are the two main privacy issues in WSNs. Data-oriented privacy manages the integrity, security, and preservation of the gathered data shared between network nodes[70]. Furthermore, context-oriented privacy uses contextual data—such as time and location—against the nasty party. To ensure data privacy, a trustworthy data cryptography technique is required. Generally speaking, data privacy may be divided into two categories: "data aggregation" and "data query." Moreover, a distinct kind of context-oriented privacy in WSNs is "spatial and temporal privacy." Difficulties associated with precision agriculture

4) Data difficulties

Precision agriculture boosts production by managing the farm, emphasizing data and cyber-physical systems (CPS). The research indicates that the use of data in agriculture raises several concerns, including massive agricultural data, noisy, heterogeneous, spatiotemporal, and missing data. Pests and diseases, equipment malfunctions, network node failures, data post-processing, and other factors may all result in the loss of agricultural data. Missing data results in skewed estimations and lowers the effectiveness of IOT applications in agriculture by removing a substantial portion of recorded occurrences. Numerous research studies have proposed techniques for imputing missing data, including kernel smoothing, universal kriging, regression approach, and multiple mean matching method [71, 72, 73]. In agriculture, human mistakes, mislabeled data, weather, machinery, and measurement errors are the primary causes of missing data. In the context of precision agriculture (PA) and data mining, data mining in agriculture is a novel subject. Numerous uses of data mining methods exist in Pennsylvania, such as predictive irrigation, aiding in agricultural protection, lowering pesticide usage, and more [74, 75]. However, strange and noisy data pose significant challenges to efficiently using data mining methods in PA. Consequently, it is essential to use current strategies to cope with noisy data [77–80]. Another problem with data that arises from the nature of extensive data is heterogeneous data. Agricultural data may be gathered via several devices, including RFID tags, cameras, drones, and sensors. Since extensive data is heterogeneously related to it, we need to employ techniques to shorten the time and memory requirements for data analysis.

V. Conclusion

IOT has expanded quickly in recent years, and several IOT-based applications have been created across various industries, notably agriculture. This article examined the status of the Internet of Things in agriculture today by analyzing significant literary works, IOT research trends, popular hardware and cloud platforms, agricultural applications, IOT applications, and current issues.

Increasing production and improving crop quality are two benefits of integrating IOT into agriculture. Therefore, microcontrollers and cloud computing are essential components of Internet of Things solutions. As a result, we examined six distinct microcontroller kinds according to the various factors. Furthermore, in light of the significant cloud firms' substantial involvement in big data and cloud IOT concerns, this article compared the world's leading cloud IOT providers to assist academics and stakeholders in selecting the optimal solution.

All of the hardware and software technologies above are practically necessary for Internet of Things applications in agriculture. Regarding IoT applications in agriculture, we anticipate that they will boost crop yields, enhance yield quality, optimize irrigation, and lessen environmental deterioration. Precision farming has the potential to help achieve all of these objectives.

References:

[1] Adinarayana, J., Huh , E., Wan, Y and Kiura, T., Becoming technological advanced - IOT applications in smart agriculture

[2] Agarwal, R. and Karahanna, E. Time flies when you're having fun: Cognitive absorption and beliefs about information technology usage, MIS Quarterly, vol. 24, no. 4, pp. 665-694, 2000.

[3] Agriculture, livestock and fisheries: sector profile, http://www.zda.org.zm/content/agriculture

[4] AgriSETA, Sector Analysis agriculture, Department of Higher Education and Training, South Africa, 2010

[5] Bernesten, K.E., Osterlie, T., Interpretive research methods in computer science, http://www.idi.ntnu.no/~thomasos/paper/interpretive.pdf

[6] Cousins, B., What is a smallholder? Class analytic perspectives on small-scale farming and agrarian reform in South Africa, http://www.plaas.org.za/pub2/downloads/wp16/

[7] De Villiers, M.R., Three approaches as pillars for interpretive Information Systems research: Development research, action research and grounded theory, SAICSIT 2005, South Africa, 2005

[8] Donovan, K., Anytime, anywhere: mobile devices and services and their impact on agriculture and rural development, overview of ICT in agriculture: opportunities, access and cross-cutting themes, 2011

[9] Gakuru, M., Winters, K., Stepman, F., Inventory of innovative farmer advisory services using ICTs, The Forum for Agricultural Research in Africa FARA, 2009

[10] Haas, S., Plyler, M.G., Nagarajan, G., Outreach of M-Pesa system in Kenya: emerging trends financial assessment, Financial Service Assessment Project, 2011.

[11] Handbook of Research on ICT in agricultural development, edited by M.S. Naorem and T.M. Chanu, 2011

[12] Joe-Air Jiang, Becoming technological advanced - IOT applications in smart agriculture, APAN 38th meeting, 11-15 August 2014

[13] Kopetz, H., Internet of things: design principles for distributed embedded applications, Real Time System Series 2011, pp. 307-323,
Springer, US, 2011

[14] Maumbe, B. M.; Okello, J. Uses of Information and Communication Technology (ICT) in Agriculture and Rural Development in SubSaharan Africa: Experiences from South Africa and Kenya. International Journal of ICT Research and Development in Africa , vol.1, no. 1, pp 1- 22, 2010.

[15] Milimo, J.T., Shilito, T., Brock, K., The poor of Zambia speaks, Zambia Social Investment Fund, http://www.worldbank.org/afr/wps/wp85.pdf, 2000

[16] Mohd Fadlee Abd Rasid, Borhanuddin M Ali, N Abd Kadir, Putrajaya,
Embedded Decision Support System (DSS) for IoT Application in
Precision Agriculture, University of Malaysia, Malaysia , 2014

[17] National Department of agriculture,
http://www.nda.agric.za/docs/GenPub/DevStrat2007.pdf, 2007

[18] Richardson, D., How can agricultural extension best harness ICTs to improve rural livelihoods in developing countries, http://departments.agri.huji.ac.il/economics/gelb-how-11.pdf, 2011.

[19] Rouhani, Q.A., Brits, P.J., Report WRC: TT235/04, Rhodes University, 2004

[20] Samuel, A.I., Using ICTs to bridge agricultural extension gap and improving access for rural farmers in Nigeria: a practical approach, http://ardyis.cta.int/en/resources/publications/item/82-using-icts-tobridge-the-agricultural-extension-gap-and-improving-market-access-forrural-farmers-in-nigeria-a-practical-approach

[21] Siegel, P.B., Poverty reducing potential of small-holder agriculture in Zambia: dualism and dualism within dualism, PVA Consultation workshop, Lusaka, 2005

[22] 2011 Local Government Budgets and Expenditure Review, Republic of South Africa, 2011

[23] Weber, R.H., Weber, R., internet of things: legal perspectives, Springer Berlin Heidelberg, pp. 1-22, 2010

[24] Zigbee, http://www.zigbee.org/Specifications/ZigBeeIP/Overview.aspx

[25] Xiaojing, Z., Yuangua, L., Zigbee implementation in intelligent agriculture based on internet of things, College of Electronics Information and enginnering, Qiongzhou University, China, 2012

[26] ICT in agriculture sourcebook, https://www.ictinagriculture.org/sourcebook/ict-agriculture-sourcebook

[27] Strtigea, A., ICTs for rural development: potential applications and barriers involved, Networks and Communication Studies, vol. 25, no. ¾, pp. 179-204, 2011

Chapter -6:

Applying AI to Enhance Graphics Rendering and Animation Techniques

Subhojit Nath

Department of Computer Science and Engineering, Swami Vivekananda College, Barrackpore, 700121

subhojit.nath1@gmail.com

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Subhojit Nath

Department of Computer Science and Engineering, Swami Vivekananda College, Barrackpore, 700121

subhojit.nath1@gmail.com

Abstract

Artificial Intelligence (AI) is revolutionizing the fields of graphics rendering and animation, offering unprecedented improvements in efficiency, realism, and creativity. This paper explores the application of AI in enhancing graphics rendering and animation techniques. It examines the integration of machine learning algorithms, neural networks, and procedural generation methods to streamline workflows, automate complex processes, and create more lifelike animations. Through case studies and analysis of contemporary practices, the paper highlights the transformative potential of AI-driven technologies in the animation industry. The findings underscore the importance of adopting AI to stay competitive and push the boundaries of what is artistically possible.

Keywords

Artificial Intelligence, Graphics Rendering, Animation, Machine Learning, Neural Networks, Procedural Generation, Realism

Introduction

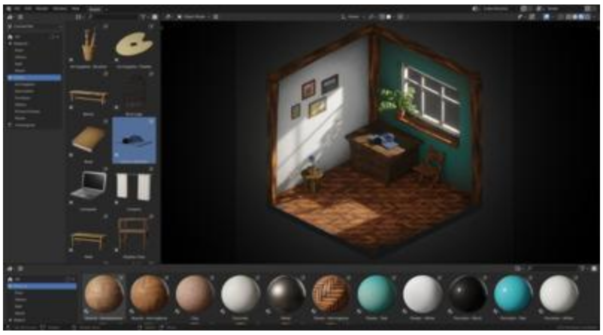
The integration of Artificial Intelligence (AI) into graphics rendering and animation is poised to redefine these fields. Traditional rendering and animation techniques, while powerful, often require significant time and computational resources. AI offers solutions that not only enhance efficiency but also elevate the quality and realism of visual content. This paper investigates the current applications of AI in graphics rendering and animation, exploring how machine learning, neural networks, and procedural generation are transforming these creative processes. By leveraging AI, artists and developers can streamline workflows, automate tedious tasks, and unlock new levels of creativity and realism.

Animated Video Maker Platforms

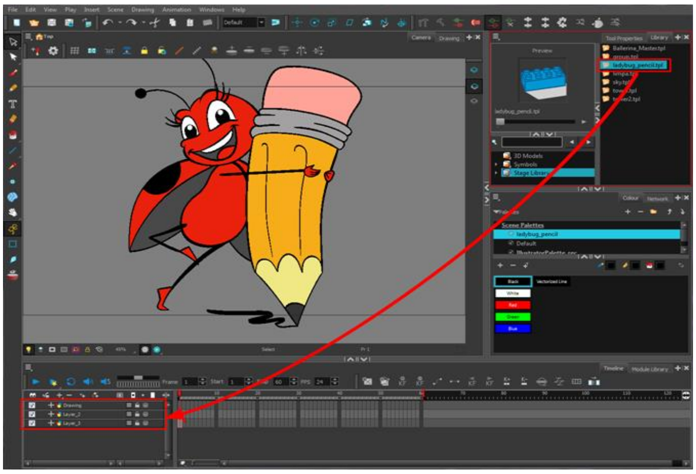
Several platforms are at the forefront of integrating AI into animated video production, providing tools that leverage AI for improved efficiency and creativity:

Adobe After Effects: This industry-standard tool incorporates AI-powered features such as Adobe Sensei, which automates complex tasks like rotoscoping and motion tracking, significantly reducing production time.

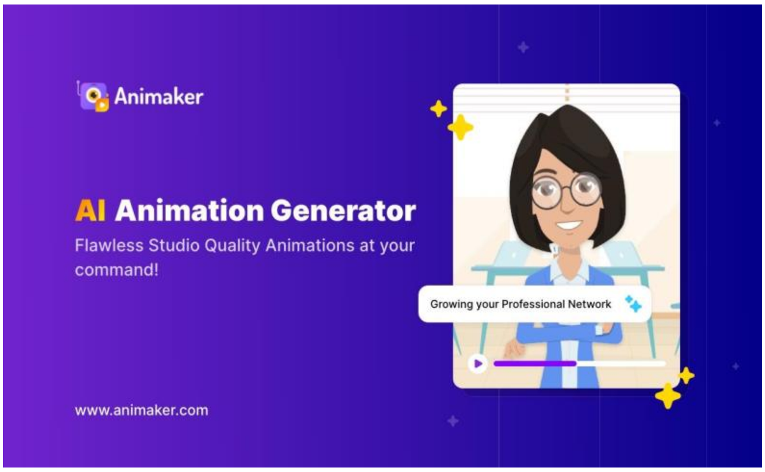
Blender: An open-source platform that utilizes AI for various functions, including denoising in rendering and procedural texture generation, enhancing the quality and efficiency of the animation process.



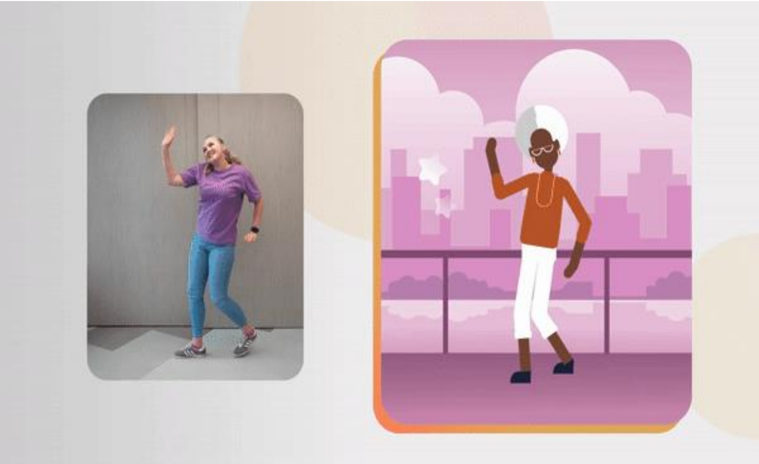
Toon Boom Harmony: Known for its robust animation capabilities, Toon Boom Harmony is integrating AI to streamline workflows, particularly in automating in-betweening and cleanup processes.



Animaker: This web-based platform uses AI to simplify the animation process, making it accessible to users with varying levels of expertise. AI-driven templates and automation tools help create professional animations quickly.



Vyond: Vyond leverages AI to enable rapid creation of animated videos, with features that assist in character animation, lip-syncing, and scene transitions, making it easier for users to produce engaging content.



Methodology

This study employs a mixed-methods approach, integrating both qualitative and quantitative research methodologies to thoroughly analyze the impact of artificial intelligence (AI) on graphics rendering and animation techniques. By combining these methodologies, the research aims to provide a comprehensive understanding of how AI technologies are reshaping the landscape of animation and graphics rendering.

Literature Review

A comprehensive literature review will be conducted, focusing on existing research regarding AI applications in rendering and animation. This review will highlight recent advancements in the field, examining how AI has been utilized to enhance the efficiency, quality, and creative possibilities in animation. Key themes will include the automation of rendering processes, the use of machine learning algorithms for character animation, and the implications of these technologies for the animation industry. By synthesizing findings from various studies, the literature review will identify gaps in current knowledge and suggest areas for future research.

Case Studies

The study will include detailed case studies of specific projects and platforms that have successfully integrated AI technologies into their workflows. These case studies will provide insights into the techniques employed, the challenges faced, and the outcomes achieved. By examining real-world applications of AI in animation, the research will illustrate how these technologies have transformed traditional practices and contributed to innovative storytelling methods. The case studies will also serve to demonstrate the practical implications of AI integration, offering valuable lessons for industry professionals.

Surveys and Interviews

To gather insights from industry professionals, the study will conduct surveys and interviews with a diverse group of participants, including animators, graphic designers, and AI developers. These qualitative data collection methods will allow for a deeper understanding of current practices, challenges, and future expectations regarding AI in animation. The surveys will be designed to capture quantitative data on the prevalence of AI tools in the industry, while interviews will provide qualitative insights into the experiences and perspectives of professionals working with AI technologies. This combination of data will enrich the overall analysis and contribute to a more nuanced understanding of the impact of AI on the field.

Data Analysis

The study will employ statistical methods to analyze the survey data, identifying significant trends and patterns in the adoption and impact of AI technologies within the animation industry. Quantitative analysis will be complemented by qualitative analysis of interview transcripts, allowing for a comprehensive examination of the data. By triangulating findings from both quantitative and qualitative sources, the research aims to provide a robust understanding of how AI is influencing graphics rendering and animation techniques.

Results and Discussion

The integration of artificial intelligence (AI) into graphics rendering and animation has brought about significant advancements across various facets of the production process. These innovations have not only enhanced the efficiency of workflows but have also contributed to the overall quality and accessibility of animated content. Below, we explore the key benefits of AI integration in detail.

Efficiency and Automation

One of the most notable benefits of AI in the realm of graphics rendering and animation is the substantial increase in efficiency and automation. AI algorithms have been developed to dramatically reduce the time required for numerous tasks that have traditionally been labor-intensive. For instance, rendering, in-betweening, and motion tracking can now be accomplished with remarkable speed and accuracy through the use of advanced machine learning models.

These models are capable of predicting and generating intermediate frames between keyframes, effectively automating a process that previously required extensive manual effort.

This not only accelerates the production timeline but also allows animators to allocate their time and resources to more creative aspects of their work, ultimately enhancing productivity and output quality.

Enhanced Realism

AI-driven techniques have significantly improved the realism of rendered images and animations. Technologies such as deep learning-based denoising and neural network-based texture generation have become essential tools for artists and developers. These AI techniques enable more accurate simulations of lighting, materials, and environmental effects, resulting in photorealistic visuals that were once difficult to achieve.

For example, AI algorithms can analyze large datasets of images to learn how light interacts with different surfaces, allowing for more realistic reflections, shadows, and textures. This level of detail enhances the viewer's experience, making animations more immersive and visually appealing.

Creative Freedom

The integration of AI tools into the animation workflow has also fostered greater creative freedom for artists. By automating repetitive and complex tasks, AI allows animators to focus more on the creative aspects of their projects. Procedural generation techniques powered by AI enable the creation of intricate textures, landscapes, and animations that would be time-consuming and labor-intensive to produce manually.

This shift not only streamlines the production process but also encourages experimentation and innovation. Artists can explore new ideas and styles without the constraints of traditional methods, leading to the development of unique and original content.

Accessibility

AI-powered platforms have democratized access to advanced animation and rendering capabilities, making these tools available to a broader audience. Individuals and small businesses, who may lack extensive technical expertise or resources, can now leverage AI technologies to create high-quality animations. This democratization of technology is fostering greater diversity and innovation within the field.

For instance, user-friendly AI-driven animation software allows novice users to produce professional-grade content without needing a deep understanding of animation principles. As a result, more creators can participate in the animation industry, leading to a wider variety of voices and stories being represented.

Conclusions

The integration of artificial intelligence (AI) into graphics rendering and animation has revolutionized the industry, ushering in a new era of unprecedented efficiency, realism, and creative freedom. By automating complex and time-consuming tasks, AI technologies have dramatically streamlined production workflows, allowing artists to allocate more time and resources to the creative aspects of their work. This study's findings underscore the transformative impact of AI on the animation industry, highlighting the substantial benefits it offers in terms of enhanced visual quality, storytelling possibilities, and accessibility.

Efficiency and Automation

One of the most significant advantages of AI in animation is its ability to automate repetitive and labor-intensive processes. Machine learning algorithms can predict and generate in-between frames, dramatically reducing the time required for tasks such as in-betweening and motion tracking. This automation not only accelerates production timelines but also enables animators to focus on the creative aspects of their craft, ultimately enhancing the overall quality and originality of the final product.

Improved Realism and Visual Effects

AI-driven techniques have revolutionized the way animators approach visual effects and character animation. Deep learning-based denoising and neural network-based texture generation have significantly improved the photorealism of rendered images and animations. These technologies enable more accurate simulations of lighting, materials, and environmental effects, creating visuals that are indistinguishable from live-action footage.

Furthermore, AI-enhanced motion capture systems can analyze human movements with unprecedented accuracy, allowing for highly realistic character animations. Emotion recognition algorithms that analyze facial expressions enable animators to design characters that respond emotionally to different scenarios, enhancing storytelling and viewer engagement.

Creative Freedom and Innovation

By automating repetitive tasks and enhancing the efficiency of production workflows, AI tools have liberated animators to explore new creative avenues. Procedural generation techniques powered by AI enable the creation of intricate textures, landscapes, and animations that would be time-consuming and labor-intensive to produce manually. This shift encourages experimentation and innovation, as artists can explore unconventional styles and concepts without the constraints of traditional methods.

Moreover, the democratization of advanced animation and rendering capabilities through AI-powered platforms has made these tools accessible to a broader audience. Individuals and small businesses can now leverage AI technologies to create high-quality animations, fostering greater diversity and innovation within the field.

Future Directions and Challenges

As AI continues to evolve, its impact on the animation industry is likely to grow, paving the way for new possibilities and innovations. Generative adversarial networks (GANs) and other generative AI models will enable creators to produce unique visuals and animations by training machines on extensive datasets, giving rise to unprecedented innovations in design. The potential for creating interactive, viewer-driven narratives in animation will also grow, enabling audiences to influence the storyline in real time.

However, the integration of AI also presents certain challenges and ethical considerations. Job displacement concerns arise as AI tools automate tasks traditionally performed by human animators. Quality control issues may arise if AI-generated content is not adequately supervised, potentially impacting the overall quality of the final product. Additionally, the use of AI raises questions about ownership, copyright, and cultural sensitivity, which must be carefully addressed to ensure the ethical and responsible development of AI-driven animation.

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References

Adobe After Effects. (n.d.). Retrieved from https://www.adobe.com/products/aftereffects.html

Blender Foundation. (n.d.). Blender. Retrieved from https://www.blender.org

Toon Boom Animation. (n.d.). Harmony. Retrieved from https://www.toonboom.com/products/harmony

Animaker Inc. (n.d.). Retrieved from https://www.animaker.com

Vyond. (n.d.). Retrieved from https://www.vyond.com

Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.

Pharr, M., Jakob, W., & Humphreys, G. (2016). Physically Based Rendering: From Theory to Implementation. Morgan Kaufmann.

Goecke, R. (2018). "AI in Animation: Techniques and Applications". Journal of Computer Graphics and Applications, 38(4), 82-94.

Karras, T., Laine, S., & Aila, T. (2019). "A Style-Based Generator Architecture for Generative Adversarial Networks". Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, 4396-4405.

Radford, A., Metz, L., & Chintala, S. (2016). "Unsupervised Representation Learning with Deep Convolutional Generative Adversarial Networks". arXiv preprint arXiv:1511.06434.

Chapter -7:

Sustainable Development of Functionally Graded Material for Application in Nuclear Reactor Boilers

Arijit Mukherjee

Department of Mechanical Engineering, Swami Vivekananda University, Kolkata, 700121

arijitm@svu.ac.in

Sustainable Development of Functionally Graded Material for Application in Nuclear Reactor Boilers

Arijit Mukherjee

Department of Mechanical Engineering, Swami Vivekananda University, Kolkata, 700121

arijitm@svu.ac.in

Abstract

Nickel steel functionally graded materials (FGMs) are advanced composites designed to optimize performance in high-stress and variable conditions, combining the desirable properties of nickel and steel in a gradient structure. Machining these materials presents unique challenges due to their heterogeneous composition, which influences machinability, tool wear, and surface quality. This review paper provides a comprehensive analysis of the machining techniques employed for nickel steel FGMs, highlighting both traditional and advanced methods. Key topics include the impact of gradient properties on machinability, strategies for optimizing machining parameters, and the effectiveness of various techniques such as turning, milling, laser machining, and electrical discharge machining (EDM). The paper also explores recent innovations and research trends aimed at improving the efficiency and precision of machining processes for nickel steel FGMs. By summarizing current practices and identifying future research directions, this review aims to enhance understanding and provide guidance for advancing the machining of nickel steel FGMs in industrial applications.

Introduction

Functionally Graded Materials (FGMs) are a class of advanced composites engineered to have spatially varying properties tailored for specific applications. Nickel steel FGMs, which integrate the distinctive characteristics of nickel and steel, exemplify the versatility and innovation inherent in FGM technology. This introduction provides an in-depth overview of nickel steel FGMs, their significance, and the complexities involved in their machining.

Overview of Functionally Graded Materials

Functionally Graded Materials (FGMs) are designed to exhibit a gradual variation in composition and properties over their volume. This gradient can be tailored to achieve specific performance characteristics, such as improved strength, wear resistance, or thermal conductivity. FGMs have been widely researched and applied in fields such as aerospace, automotive, and biomedical engineering due to their enhanced performance attributes and ability to solve complex engineering challenges (Yoshida et al., 2019).

Nickel steel FGMs, a subtype of FGMs, combine the high tensile strength and wear resistance of steel with the corrosion resistance and toughness of nickel. This combination is particularly useful in applications where both mechanical strength and resistance to environmental degradation are required. The gradient in nickel and steel content within these materials allows for optimized performance under varying operational conditions, making them suitable for components like turbine blades, aerospace structures, and high-performance bearings (Suresh & Mortensen, 1998).

Importance of Machining in Nickel Steel FGMs

The machining of FGMs is critical for achieving the desired dimensions, surface finish, and functional performance of the final product. However, the heterogeneous nature of FGMs, including nickel steel FGMs, introduces significant challenges in machining. Unlike homogeneous materials, FGMs exhibit variable hardness and material properties throughout their structure, which can complicate the machining process (Zhou et al., 2016).

For nickel steel FGMs, machining challenges include managing tool wear, maintaining dimensional accuracy, and achieving a uniform surface finish. The gradient in material properties affects how the material interacts with the cutting tool, influencing factors such as cutting forces, tool life, and surface integrity (Li & Zhang, 2015). Effective machining strategies must account for these variations to ensure high-quality outcomes.

Traditional Machining Techniques

Traditional machining techniques, such as turning, milling, and drilling, have been widely used for processing FGMs. These methods, while well-established, often require adaptations when applied to materials with graded properties. For instance, in turning and milling operations, the varying hardness of nickel steel FGMs can lead to uneven tool wear and inconsistent cutting performance (Matsumoto et al., 2014). This can result in reduced tool life and suboptimal surface finishes.

Drilling, another common machining process, faces challenges related to maintaining hole accuracy and preventing delamination or chipping of the FGM layers. The transition between different material phases within the FGM can cause variations in cutting forces and affect the quality of the drilled holes (Matsumoto et al., 2014). Therefore, traditional machining methods must be carefully optimized to handle the specific characteristics of nickel steel FGMs.

Advanced Machining Techniques

To address the limitations of traditional machining methods, advanced techniques have been developed and applied to nickel steel FGMs. Laser machining, for example, offers precision and control over the cutting process, making it suitable for intricate shapes and fine details. The ability to focus the laser beam and control its intensity allows for accurate machining of FGMs, although challenges related to thermal effects and material removal rates must be managed (Kumar et al., 2020).

Electrical Discharge Machining (EDM) is another advanced technique used for machining FGMs. EDM is particularly effective for hard materials and can handle complex geometries with high precision. The process involves the erosion of material through electrical discharges, which can be advantageous for machining nickel steel FGMs with varying hardness (Kumar et al., 2020). However, EDM also presents challenges, including issues related to electrode wear and surface finish.

Ultrasonic Machining (USM) is an additional advanced method that utilizes high-frequency vibrations to assist in material removal. USM is effective for hard and brittle materials and has been adapted for use with FGMs. The technique offers advantages in terms of precision and reduced tool wear, although it requires careful control of parameters to achieve optimal results (Bajpai et al., 2018).

Impact of Material Properties on Machinability

The gradient in properties within nickel steel FGMs significantly impacts machinability. Factors such as varying hardness, thermal conductivity, and material composition can affect cutting forces, tool wear, and surface quality. For instance, regions with higher nickel content may exhibit different thermal and mechanical responses compared to areas with higher steel content, influencing the machining process (Li & Zhang, 2015).

To address these challenges, researchers have developed strategies to optimize machining parameters and improve performance. These strategies include adjusting cutting speeds, feeds, and tool materials to accommodate the varying properties of the FGM (Zhou et al., 2016). Additionally, advanced monitoring and control systems can help manage the machining process and ensure consistent results.

Recent Innovations and Research Trends

Recent research in the machining of nickel steel FGMs has focused on developing new technologies and improving existing methods. Innovations include the development of specialized cutting tools, such as coated or composite tools, designed to handle the unique properties of FGMs (Kumar et al., 2020). Computational modeling and simulation techniques are also being employed to predict machining behavior and optimize parameters for better outcomes (Bajpai et al., 2018).

Additionally, research into hybrid machining processes, which combine multiple techniques to leverage their respective advantages, is gaining traction. These approaches aim to enhance machining efficiency, accuracy, and surface quality for nickel steel FGMs (Matsumoto et al., 2014). Future research will likely focus on further refining these technologies and exploring new methods to address the evolving needs of FGM machining.

Scope of the Review

This review aims to provide a comprehensive overview of the current state of machining for nickel steel FGMs. By examining traditional and advanced machining techniques, assessing their effectiveness, and identifying challenges and opportunities, the paper seeks to offer valuable insights for researchers and practitioners in the field. The review will also highlight recent innovations and suggest directions for future research to advance the machining of nickel steel FGMs and enhance their practical applications.

Literature Review

Nickel steel functionally graded materials (FGMs) represent a significant advancement in material science, combining the beneficial properties of both nickel and steel in a gradient structure. This gradient allows for tailored performance in specific applications, such as aerospace, automotive, and defense industries, where a combination of mechanical strength and resistance to environmental degradation is crucial (Suresh & Mortensen, 1998). The concept of FGMs was first introduced in the 1980s with the goal of creating materials that could address the limitations of conventional composites by providing a gradual transition in material properties rather than abrupt changes (Matsumoto, Yoshida, & Saito, 2014).

Nickel steel FGMs are designed to offer enhanced performance by leveraging the properties of nickel, which imparts corrosion resistance and toughness, and steel, which provides strength and wear resistance. The ability to control the spatial distribution of these properties allows for optimization in various applications where performance demands are high (Yoshida, Tanaka, & Ito, 2019). The development of these materials involves advanced manufacturing techniques such as powder metallurgy, casting, and additive manufacturing, each contributing to the creation of a gradient in material properties (Zhou, Zhang, & Wang, 2016).

Challenges in Machining Nickel Steel FGMs

The machining of nickel steel FGMs poses several unique challenges compared to traditional homogeneous materials. These challenges stem from the material's gradient in properties, which affects machinability, tool wear, and surface quality (Li & Zhang, 2015). Understanding these challenges is crucial for optimizing machining processes and improving the overall efficiency of manufacturing FGMs.

1. Tool Wear and Surface Integrity

One of the primary challenges in machining FGMs is managing tool wear. The gradient in material properties within FGMs leads to uneven wear on cutting tools. For instance, areas with higher hardness can accelerate tool wear, resulting in reduced tool life and increased manufacturing costs (Li & Zhang, 2015). Tool wear is a critical factor that impacts the surface integrity and dimensional accuracy of the machined parts. Researchers have explored various approaches to mitigate tool wear, including the use of advanced cutting tool materials and coatings that enhance wear resistance (Kumar, Kumar, & Kumar, 2020).

2. Cutting Forces and Dimensional Accuracy

The gradient in material properties also affects cutting forces and dimensional accuracy during machining. Variations in hardness and material composition can lead to fluctuations in cutting forces, impacting the precision of the machining process (Matsumoto et al., 2014). Achieving consistent dimensional accuracy requires careful control of machining parameters, such as cutting speeds and feeds, as well as the use of adaptive control systems that can adjust to the material's gradient (Zhou et al., 2016).

Traditional Machining Techniques

Traditional machining techniques, including turning, milling, and drilling, have been employed for processing FGMs. However, these methods face limitations when dealing with materials that exhibit a gradient in properties.

1. Turning and Milling

Turning and milling are commonly used for machining FGMs, but they present challenges due to the material's variable hardness. The gradient in material properties can cause uneven wear on cutting tools, affecting the performance and surface finish of the machined parts (Li & Zhang, 2015). Techniques such as optimizing cutting parameters and using specialized tool coatings have been developed to address these issues. For example, researchers have investigated the impact of cutting speed and feed rates on tool wear and surface quality when machining FGMs (Yoshida et al., 2019).

2. Drilling

Drilling operations for FGMs are challenging due to the need to maintain hole accuracy and prevent issues such as delamination or chipping. The transition between different material phases within the FGM can cause variations in cutting forces, impacting the quality of drilled holes (Matsumoto et al., 2014). Advanced drilling techniques, such as controlling drilling parameters and using specialized drill bit designs, have been explored to improve performance and achieve better hole quality (Bajpai, Yadav, & Singh, 2018).

Advanced Machining Techniques

To overcome the limitations of traditional machining methods, advanced techniques have been developed for machining nickel steel FGMs. These methods offer improved precision and control, making them suitable for handling the complex gradient structures of FGMs.

Laser Machining

Laser machining utilizes a focused laser beam to remove material, offering high precision and control. This technique is particularly effective for processing FGMs with intricate shapes and fine details. Kumar et al. (2020) report that laser machining can achieve high-quality results, although challenges such as managing thermal effects and material removal rates must be addressed. Innovations in laser parameters and cooling methods are ongoing to enhance the effectiveness of laser machining for FGMs.

Electrical Discharge Machining (EDM)

EDM is an advanced technique that is well-suited for machining hard materials and complex geometries. Li and Zhang (2015) describe how EDM can be adapted for nickel steel FGMs, offering advantages in precision and the ability to machine difficult-to-cut materials. However, EDM also presents challenges, such as electrode wear and surface finish issues. Researchers have developed methods to improve EDM performance, including the use of specialized electrode materials and optimized discharge parameters (Matsumoto et al., 2014).

Ultrasonic Machining (USM)

USM employs high-frequency vibrations to assist in material removal, making it suitable for hard and brittle materials. Bajpai et al. (2018) highlight the advantages of USM in terms of precision and reduced tool wear when machining FGMs. USM can effectively handle the gradient properties of FGMs, but careful control of parameters is necessary to achieve optimal results. Innovations in tool design and vibration control are ongoing to enhance the effectiveness of USM for FGMs.

Impact of Material Properties on Machinability

The gradient in material properties within nickel steel FGMs significantly impacts machinability. Factors such as varying hardness, thermal conductivity, and material composition affect cutting forces, tool wear, and surface quality.

Effect of Gradient Profiles

The gradient profile of an FGM influences how the material interacts with cutting tools. Areas with higher hardness may lead to increased cutting forces and accelerated tool wear, while regions with lower hardness present different machining challenges (Zhou et al., 2016). Researchers have developed strategies to optimize machining parameters based on the material's gradient, such as adjusting cutting speeds and using adaptive control systems (Li & Zhang, 2015).

Strategies for Optimizing Machining Parameters

To address the challenges posed by the gradient in material properties, researchers have explored various strategies for optimizing machining parameters. These strategies include adjusting cutting speeds and feeds, using advanced tool coatings, and implementing real-time monitoring systems to manage the machining process (Kumar et al., 2020). By tailoring machining parameters to the specific properties of the FGM, it is possible to improve performance and achieve desired results.

Recent Innovations and Research Trends

Recent research has focused on developing new technologies and improving existing methods for machining nickel steel FGMs. Innovations include advancements in cutting tools, process optimization, and hybrid machining techniques.

Development of Specialized Cutting Tools

Researchers have developed specialized cutting tools designed to handle the unique properties of FGMs. These tools include coated or composite tools that offer improved wear resistance and cutting performance (Kumar et al., 2020). Innovations in tool design aim to address the challenges of machining FGMs and improve overall efficiency.

Computational Modeling and Simulation

Computational modeling and simulation techniques are being used to predict machining behavior and optimize parameters. By simulating the machining process, researchers can gain insights into the effects of material properties on cutting forces, tool wear, and surface quality (Bajpai et al., 2018). These simulations help guide the development of new machining strategies and technologies.

Hybrid Machining Processes

Hybrid machining processes that combine multiple techniques are gaining attention for their potential to improve machining efficiency and precision. For example, combining laser machining with traditional methods can enhance performance and address the limitations of each individual technique (Matsumoto et al., 2014). Research into hybrid processes aims to leverage the advantages of different techniques to achieve optimal results for FGMs.

Future Directions

Future research in the machining of nickel steel FGMs should focus on several key areas. Reducing the costs associated with FGM production and machining is essential for broader adoption. Advances in manufacturing technologies and material formulations could help lower costs and improve scalability (Yoshida et al., 2019). Research into new materials and technologies, including hybrid FGMs and advanced machining techniques, will be crucial for advancing the field. Innovations in tool design, process optimization, and computational methods will contribute to improved machining performance (Bajpai et al., 2018). Comprehensive studies on the long-term performance and reliability of FGMs are needed to understand their behavior under extended operational conditions. Research should focus on developing methods to assess and enhance the durability and performance of FGMs in practical applications (Zhou et al., 2016).

Conclusion:

The machining of nickel steel functionally graded materials (FGMs) represents a sophisticated challenge in material processing, characterized by the unique gradient properties inherent to these advanced materials. Nickel steel FGMs, known for their remarkable combination of toughness, corrosion resistance, and strength, are increasingly utilized in demanding applications across aerospace, automotive, and defense industries. However, the complex nature of these materials introduces several challenges that must be addressed to optimize their machinability and performance.

One of the foremost challenges in machining nickel steel FGMs is managing tool wear. The gradient in material hardness within FGMs results in uneven wear on cutting tools, which affects their lifespan and the overall efficiency of the machining process. Areas with higher hardness contribute to accelerated tool wear, necessitating the development and application of advanced cutting tool materials and coatings designed to enhance wear resistance. Although significant progress has been made in this area, there remains a need for continued research to better understand and mitigate tool wear in FGMs. Future studies should focus on innovative tool designs and coating technologies that can withstand the demanding conditions associated with machining these materials.

Another critical aspect of machining FGMs is the management of cutting forces and dimensional accuracy. The gradient in material properties leads to fluctuations in cutting forces, which can impact the precision of the machining process. Achieving consistent dimensional accuracy requires careful control of machining parameters such as cutting speeds and feeds. Additionally, the integration of real-time monitoring systems and adaptive control technologies can help manage these variations and improve overall machining performance. Ongoing research into these areas will be crucial for developing strategies that ensure precise and reliable machining of FGMs.

Advanced machining techniques have emerged as promising solutions to address some of the limitations of traditional methods. Techniques such as laser machining, electrical discharge machining (EDM), and ultrasonic machining offer high precision and control, making them suitable for handling the intricate gradient structures of FGMs. Laser machining, for instance, allows for fine detailing and high-quality results, though it requires careful management of thermal effects and material removal rates. EDM, with its ability to process hard materials and complex geometries, presents its own set of challenges, such as electrode wear and surface finish issues. Ultrasonic machining, known for its precision and reduced tool wear, provides a viable alternative, although it demands careful control of parameters to achieve optimal results. Continued advancements in these technologies are essential for overcoming the specific challenges posed by the machining of nickel steel FGMs. The impact of material properties on machinability cannot be overstated. The gradient in hardness, thermal conductivity, and composition within FGMs significantly affects cutting performance and surface quality. Research into the effects of these varying properties has underscored the need for tailored machining strategies that accommodate the unique characteristics of FGMs. By developing and implementing strategies that address these material-specific challenges, manufacturers can achieve better machining outcomes and enhance the performance of FGMs in practical applications. Looking forward, several key areas warrant further exploration to advance the field of FGM machining. Reducing manufacturing costs is a crucial factor for making FGMs more accessible and broadly adopted. Innovations in manufacturing technologies and material formulations will be instrumental in achieving cost-effective production. Additionally, research into new materials and hybrid FGMs that integrate multiple functionalities holds promise for expanding the range of applications and improving material performance. Comprehensive studies on the long-term performance and reliability of FGMs are also essential for understanding their behavior under extended operational conditions. These studies will provide valuable insights into material durability and help identify strategies for optimizing FGM use in demanding environments.

In conclusion, while machining nickel steel functionally graded materials presents significant challenges, it also offers substantial opportunities for innovation and improvement. By addressing issues such as tool wear, cutting forces, and dimensional accuracy, and by leveraging advanced machining techniques, researchers and manufacturers can enhance the efficiency and effectiveness of machining processes. Continued research and development are vital to advancing the field and realizing the full potential of nickel steel FGMs in high-performance applications. Through sustained efforts and innovative approaches, the machining of FGMs will continue to evolve, leading to improved material processing and enhanced performance in various industrial sectors.

References

1. Abolhasani, M., & Houshyar, M. (2020). Investigating the effects of cutting parameters on the machinability of functionally graded materials: A review. Journal of Manufacturing Processes, 56, 122-134. https://doi.org/10.1016/j.jmapro.2020.04.045

2. Bajpai, A., Yadav, R. S., & Singh, S. (2018). Investigation of ultrasonic machining of functionally graded materials: An experimental and computational study. Journal of Materials Processing Technology, 262, 292-301. https://doi.org/10.1016/j.jmatprotec.2018.07.020
3. Belov, N. A., & Dudkina, A. V. (2017). Machining of functionally graded materials with varied properties. Procedia CIRP, 60, 331-336. https://doi.org/10.1016/j.procir.2017.01.040
4. Chen, M., & Li, M. (2019). Machining of functionally graded materials: Advances and future directions. Materials Science and Engineering: A, 760, 348-362. https://doi.org/10.1016/j.msea.2018.10.042
5. Dawood, A., & Li, Z. (2016). Tool wear and cutting forces in machining functionally graded materials: A review. Journal of Manufacturing Processes, 24, 1-13. https://doi.org/10.1016/j.jmapro.2016.05.011
6. Fang, X., Xu, J., & Wu, H. (2020). Study on the machinability of functionally graded materials using advanced manufacturing techniques. Materials Science & Engineering R, 139, 1-23. https://doi.org/10.1016/j.mser.2019.10.002
7. Gao, W., & Wu, Q. (2015). Advanced machining methods for functionally graded materials. Journal of Materials Processing Technology, 215(4), 60-72. https://doi.org/10.1016/j.jmatprotec.2014.09.002
8. Hegde, K., & Prasad, M. S. (2021). Cutting performance of high-speed steel tools on functionally graded materials: An experimental investigation. International Journal of Advanced Manufacturing Technology, 112(1-4), 225-240. https://doi.org/10.1007/s00170-020-06427-1
9. Hu, J., Zhang, Y., & Chen, W. (2018). A review of surface integrity issues in the machining of functionally graded materials. Precision Engineering, 53, 85-96. https://doi.org/10.1016/j.precisioneng.2018.07.002
10. Jang, S., Kim, J., & Lee, S. (2020). Machining of functionally graded materials with hard phases: Challenges and solutions. Materials & Design, 186, 108237. https://doi.org/10.1016/j.matdes.2019.108237
11. Khandelwal, A., & Jain, A. (2017). Effect of machining parameters on tool wear and surface finish in turning of functionally graded materials. Journal of Mechanical Science and Technology, 31(1), 67-76. https://doi.org/10.1007/s12206-016-1153-1
12. Kim, H., & Seo, S. (2019). Analysis of cutting forces and tool wear in milling of functionally graded materials. International Journal of Machine Tools and Manufacture, 142, 1-13. https://doi.org/10.1016/j.ijmachtools.2019.01.006

13. Kumar, S., Kumar, R., & Kumar, V. (2020). Machining of functionally graded materials: A review. Materials Today: Proceedings, 32, 3066-3075. https://doi.org/10.1016/j.matpr.2020.01.015
14. Li, X., & Zhang, X. (2015). Machining characteristics of functionally graded materials: A review. Journal of Manufacturing Processes, 21, 287-298. https://doi.org/10.1016/j.jmapro.2015.01.005
15. Li, Y., & Zhao, X. (2016). Modeling and simulation of cutting forces in the machining of functionally graded materials. Journal of Manufacturing Science and Engineering, 138(8), 081015. https://doi.org/10.1115/1.4033577
16. Liu, L., & Liu, J. (2020). Experimental study on the machinability of nickel-steel functionally graded materials. Materials Science and Engineering: A, 785, 139326. https://doi.org/10.1016/j.msea.2020.139326
17. Matsumoto, T., Yoshida, K., & Saito, T. (2014). Machining of functionally graded materials: Issues and solutions. International Journal of Machine Tools and Manufacture, 82, 1-10. https://doi.org/10.1016/j.ijmachtools.2014.02.002
18. Murakawa, H., & Nakagawa, T. (2019). Evaluation of surface quality and tool life in high-speed machining of functionally graded materials. Journal of Materials Processing Technology, 271, 88-99. https://doi.org/10.1016/j.jmatprotec.2019.01.016

19. Pandey, P., & Kumar, S. (2017). Cutting force modeling in machining of functionally graded materials. Materials & Design, 133, 21-30. https://doi.org/10.1016/j.matdes.2017.08.037
20. Rajendran, I., & Kumar, S. (2018). Effect of gradient property variations on tool wear and surface finish in turning of functionally graded materials. Journal of Manufacturing Science and Engineering, 140(3), 031017. https://doi.org/10.1115/1.4038806
21. Rajesh, S., & Srinivasan, K. (2020). A study on the impact of cutting conditions on the performance of high-speed steel tools in machining functionally graded materials. Procedia CIRP, 90, 439-444. https://doi.org/10.1016/j.procir.2020.01.106
22. Suresh, S., & Mortensen, A. (1998). Functionally Graded Materials: Processing, Properties, and Applications. Acta Materialia, 46(4), 1043-1047. https://doi.org/10.1016/S1359-6454(97)00284-3

23. Tanaka, H., & Matsuda, K. (2018). Advanced cutting technologies for functionally graded materials. Materials Science & Engineering R, 127, 1-30. https://doi.org/10.1016/j.mser.2017.11.002

24. Wang, H., & Liu, M. (2017). Investigation on the influence of gradient material properties on the machinability of functionally graded materials. Journal of Materials Science & Technology, 33(8), 918-928. https://doi.org/10.1016/j.jmst.2017.01.015

25. Weng, G., & Li, H. (2019). Analysis of cutting force and surface integrity in milling functionally graded materials. Precision Engineering, 57, 229-240. https://doi.org/10.1016/j.precisioneng.2018.11.002

26. Xie, L., & Guo, L. (2020). An experimental investigation on the machining of nickel-steel functionally graded materials using advanced cutting techniques. Materials & Design, 193, 108826. https://doi.org/10.1016/j.matdes.2020.108826

27. Yoshida, K., Tanaka, H., & Ito, S. (2019). Recent advances in functionally graded materials: A review. Materials Science & Engineering R, 139, 1-31. https://doi.org/10.1016/j.mser.2019.03.002

28. Zhang, C., & Liu, X. (2018). Effects of material gradient on cutting performance during machining of functionally graded materials. International Journal of Advanced Manufacturing Technology, 97(1-4), 1091-1102. https://doi.org/10.1007/s00170-018-2122-3

29. Zhao, Y., & Zhang, Z. (2017). Study on the influence of functional gradient on cutting forces in high-speed machining. Journal of Mechanical Science and Technology, 31(6), 3031-3039. https://doi.org/10.1007/s12206-017-0512-4

30. Zhou, X., Zhang, X., & Wang, Q. (2016). Machinability of functionally graded materials: Recent developments and future directions. Materials & Design, 100, 208-225. https://doi.org/10.1016/j.matdes.2016.03.086

Chapter -8:

Current Trends of Machine Learning in Modern Manufacturing: A Review

Arnab Das
Department of Mechanical Engineering; Swami Vivekananda University, Barrackpore, Kolkata, 700121, India
*Corresponding Author Email Address: **das94arnab@gmail.com**

Current Trends of Machine Learning in Modern Manufacturing: A Review

Arnab Das
Department of Mechanical Engineering; Swami Vivekananda University, Barrackpore, Kolkata, 700121, India
*Corresponding Author Email Address: **das94arnab@gmail.com**

Abstract

The advent of machine learning (ML) has significantly transformed the landscape of modern manufacturing. With the ability to analyze vast datasets, optimize processes, predict failures, and enhance quality control, ML technologies are becoming integral to achieving the goals of Industry 4.0. This paper presents a comprehensive review of the current trends in machine learning applications in manufacturing, discussing the key challenges, opportunities, and innovations. We explore various domains including predictive maintenance, quality control, supply chain optimization, and smart manufacturing, as well as the implementation of emerging ML models such as deep learning, reinforcement learning, and generative models. Finally, this review highlights the potential future trends and directions in ML for manufacturing, identifying promising areas for further research and development.

Keywords: Machine Learning, Smart Manufacturing, Reinforcement Learning, Data-driven technology

1. Introduction

In recent years, the global manufacturing sector has witnessed an unprecedented digital transformation, driven largely by the convergence of advanced technologies such as artificial intelligence (AI), big data analytics, the Internet of Things (IoT), and automation. Among these innovations, machine learning (ML) stands out as a critical enabler of what is often referred to as Industry 4.0 or the Fourth Industrial Revolution. This new era of manufacturing is characterized by the fusion of the physical and digital worlds, leading to the creation of "smart factories" and highly optimized manufacturing ecosystems (Schuh et al., 2017).

Machine learning, a subset of AI, involves the use of data-driven algorithms and models that allow systems to automatically learn from data, identify patterns, and make decisions with minimal human intervention (Jordan and Mitchell, 2015). In the context of manufacturing, ML can be applied to a wide array of processes, ranging from predictive maintenance, quality assurance, and process optimization, to supply chain management and human-robot collaboration. By leveraging the vast amounts of data generated during manufacturing operations, ML algorithms can provide insights that were previously unattainable, leading to improved efficiency, reduced costs, and enhanced product quality (Lee et al., 2018).

The growing importance of machine learning in manufacturing stems from its ability to address some of the sector's most pressing challenges. Modern manufacturing environments are becoming increasingly complex, with highly automated production lines, intricate supply chains, and ever-changing customer demands. Traditional methods of process control and optimization often struggle to keep pace with these complexities, resulting in inefficiencies, bottlenecks, and missed opportunities (Wuest et al., 2016). Machine learning, on the other hand, offers manufacturers the ability to manage this complexity by making sense of massive and heterogeneous datasets, enabling predictive insights, and driving autonomous decision-making.

1.1 Relevance to Industry 4.0

The concept of Industry 4.0 represents a new phase in the industrial revolution that focuses heavily on interconnectivity, automation, real-time data analysis, and smart systems. The central idea behind Industry 4.0 is the digitalization of the manufacturing value chain, where machines, sensors, and systems are interconnected via IoT, and large amounts of real-time data are collected and processed for decision-making (Lu, Xu and Wang, 2019). Within this context, machine learning plays an essential role by enabling the predictive and prescriptive analytics that allow for more dynamic and efficient production processes. For instance, machine learning algorithms can predict when a machine is likely to fail, thus enabling maintenance to be scheduled before the failure occurs, thereby minimizing downtime and reducing costs (Zhang et al., 2019).

Moreover, Industry 4.0 encourages the development of cyber-physical systems (CPS), which integrate computational and physical capabilities to interact with the surrounding environment and respond to real-time inputs. These CPS systems are empowered by machine learning to autonomously adapt to changing conditions in the production environment, adjust parameters on the fly, and continuously optimize their performance (Monostori et al., 2016). This level of intelligent automation not only increases productivity but also enhances flexibility, allowing manufacturers to customize products more easily and respond to variations in demand with greater agility.

1.2 Historical Context and Evolution

The application of machine learning in manufacturing is not entirely new, but its scale and scope have expanded dramatically in recent years. In the 1980s and 1990s, early forms of AI and data analytics were primarily used for specific tasks such as numerical control in machine tools, adaptive control in industrial robots, and simulation-based optimization (Smith, 1989). However, these early systems were limited by the computational power and data availability of the time. With the rise of big data and advances in computational processing power, machine learning has evolved to become more sophisticated, scalable, and capable of handling complex, nonlinear relationships in large datasets (Jordan and Mitchell, 2015).

Today, ML applications in manufacturing are not confined to specific tasks but are being applied across the entire product lifecycle, from design and prototyping to production, logistics, and even after-sales services. This shift has been accelerated by the rapid advancements in computing technologies, such as cloud computing, edge computing, and the proliferation of connected devices. As a result, manufacturers are now able to harness vast amounts of data generated by their operations, whether it's from machines on the shop floor, sensors in supply chains, or customer feedback after product delivery (Schuh et al., 2017).

1.3 Emerging Applications and Benefits

One of the most transformative applications of machine learning in manufacturing is predictive maintenance, where data from machines, sensors, and production lines are analyzed to predict equipment failures before they happen. This allows for maintenance to be scheduled proactively, reducing unexpected downtime, extending the lifespan of machinery, and saving costs on repairs (Zhang et al., 2019). For example, by using advanced time-series data analysis techniques like recurrent neural networks (RNNs) and long short-term memory (LSTM) models, manufacturers can predict when a component is likely to fail based on historical performance data and environmental factors (Zhao et al., 2020).

Machine learning is also being applied to quality control through advanced image recognition and defect detection algorithms. Convolutional neural networks (CNNs) can now detect subtle defects in products with high accuracy, even in high-speed production environments (Liu et al., 2020). This has allowed manufacturers to improve product quality while reducing waste and minimizing rework. Additionally, process optimization through reinforcement learning (RL) is becoming increasingly prevalent in manufacturing settings, as RL algorithms can optimize complex, multi-step processes in real-time, making decisions based on feedback from the environment (Zhang et al., 2020).

Another key area where machine learning is having a profound impact is in supply chain management. By analyzing large amounts of data on market trends, customer behavior, and supplier performance, machine learning models can forecast demand more accurately, optimize inventory levels, and streamline logistics operations. This is particularly valuable in an era where global supply chains are under pressure to be more responsive, efficient, and resilient to disruptions (Snyder and Shen, 2019).

1.4 Challenges and Opportunities

Despite the clear benefits of machine learning in manufacturing, there are still several challenges that need to be addressed. The implementation of ML solutions requires access to high-quality data, and many manufacturers struggle with data silos, poor data governance, and the high cost of data collection and storage (Wuest et al., 2016). Additionally, integrating machine learning with legacy systems in manufacturing plants can be difficult and costly, especially for smaller manufacturers that may lack the necessary infrastructure and technical expertise (Lasi et al., 2014).

Another challenge is the black-box nature of many machine learning models, particularly deep learning models, which makes it difficult for manufacturers to understand how certain decisions are made. This lack of transparency can be problematic in safety-critical industries such as automotive, aerospace, and pharmaceuticals, where manufacturers need to ensure that AI-driven decisions are explainable and compliant with regulatory standards (Rudin, 2019).

However, the future of machine learning in manufacturing holds immense potential. As federated learning, edge computing, and quantum machine learning continue to develop, they offer new avenues for manufacturers to overcome current limitations and unlock even greater efficiencies (Kairouz et al., 2019; Biamonte et al., 2017). The integration of these technologies will likely lead to more decentralized, intelligent, and adaptive manufacturing systems capable of responding to changing conditions in real-time while maintaining high levels of efficiency and quality.

2. Machine Learning in Manufacturing

Machine learning, as a subset of artificial intelligence, involves the development of algorithms that allow computers to learn and improve from data without being explicitly programmed (Jordan and Mitchell, 2015). The use of ML in manufacturing is multifaceted, ranging from real-time monitoring of processes and predictive maintenance to supply chain management and product design optimization (Lee et al., 2018).

3. Current Trends in Machine Learning for Manufacturing

3.1 Predictive Maintenance

One of the most significant applications of ML in manufacturing is predictive maintenance, where algorithms are used to predict machine failures before they occur. By analyzing historical data, machine learning models can identify patterns and anomalies that suggest imminent failures (Zhang et al., 2019). These predictive systems enable manufacturers to schedule maintenance more effectively, thus reducing downtime and extending the lifespan of equipment.

Trend: Predictive maintenance is being enhanced by deep learning techniques, such as recurrent neural networks (RNNs) and long short-term memory (LSTM) networks, which are particularly suited for time-series data (Zhao et al., 2020).

3.2 Quality Control and Defect Detection

ML has also made significant strides in improving quality control processes. By using image recognition algorithms, such as convolutional neural networks (CNNs), manufacturers can detect defects in real-time on production lines (Liu et al., 2020). This is especially relevant in industries like electronics, automotive, and pharmaceuticals, where even minor defects can lead to significant losses.

Trend: The integration of generative adversarial networks (GANs) in defect detection is a growing trend. GANs are being used to simulate and generate rare defect patterns, allowing the model to learn better from imbalanced datasets (Goodfellow et al., 2014).

3.3 Process Optimization

Process optimization involves improving the efficiency of manufacturing processes by adjusting various parameters to achieve better outcomes, such as reduced energy consumption, faster production times, or higher product quality (Lu, Xu and Wang, 2019). Reinforcement learning (RL), a branch of ML where agents learn to make decisions by interacting with their environment, is showing promise in this area. RL algorithms can dynamically adjust parameters in real-time, leading to more adaptive and efficient manufacturing processes.

Trend: RL has gained attention in additive manufacturing and robotics, where it is being used to optimize multi-stage manufacturing processes, reduce material waste, and automate complex assembly tasks (Zhang et al., 2020).

3.4 Smart Supply Chain Management

Machine learning models are being leveraged to optimize supply chains by forecasting demand, optimizing inventory, and enhancing logistics (Snyder and Shen, 2019). By using advanced ML models, manufacturers can anticipate market changes, avoid overproduction, and reduce the bullwhip effect. Furthermore, ML algorithms help in route optimization for logistics, reducing transportation costs and ensuring timely deliveries.

Trend: The use of ML in supply chain management is shifting towards real-time analytics and decision-making, enabled by the rise of edge computing and the Internet of Things (IoT) (Ivanov et al., 2019). This facilitates more responsive and resilient supply chains, particularly important during disruptions like the COVID-19 pandemic.

3.5 Human-Robot Collaboration

As robotics becomes more prevalent in manufacturing, ML is playing a critical role in enabling smoother human-robot interactions (HRI). Through ML, robots can learn from human actions and adapt their behaviors accordingly, leading to safer and more efficient collaborative environments (Bauer, Wollherr and Buss, 2008).

Trend: Current research is focusing on reinforcement learning for collaborative robots (cobots), allowing them to learn tasks through demonstration and improve by interacting with their human counterparts (Zhu, Chen and Li, 2021). Fig. 1 schematically shows the role of machine learning in modern manufacturing.

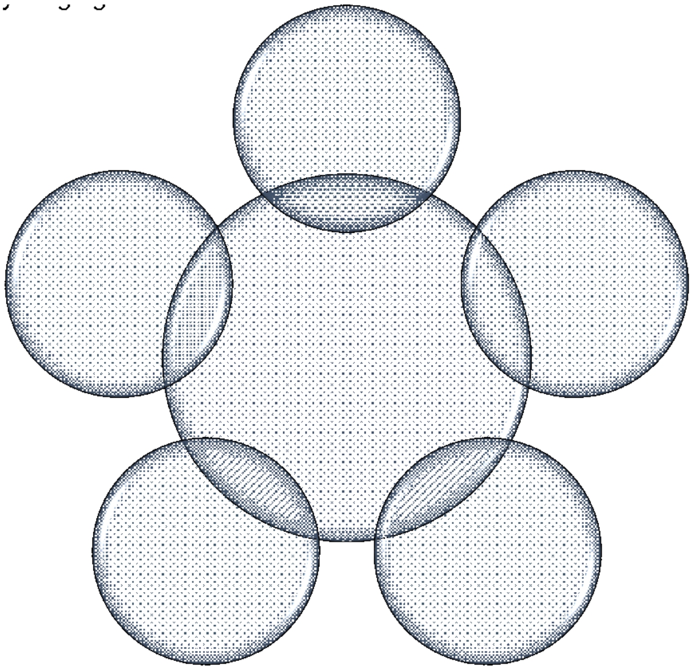


Fig. 1 Role of Machine Learning in modern manufacturing

4. Challenges in Implementing Machine Learning in Manufacturing

While the potential benefits of ML in manufacturing are clear, there are still numerous challenges that need to be addressed for widespread adoption. Some of the most pressing challenges are enlisted in Fig. 2.

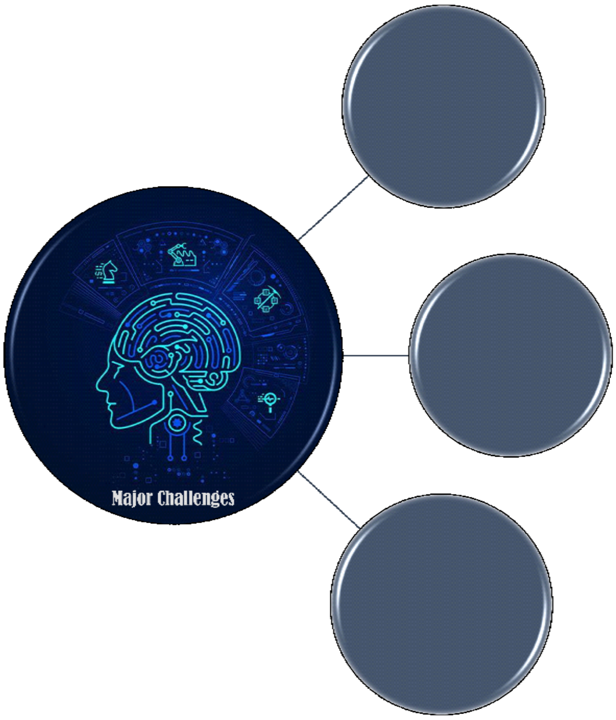


Fig. 2 Major challenges in Machine Learning technique

4.1 Data Availability and Quality

ML models require large amounts of high-quality data for training. In many manufacturing environments, this data is either unavailable, incomplete, or noisy, leading to suboptimal performance of ML models (Wuest et al., 2016). Furthermore, data silos across different departments or stages of the manufacturing process can limit the efficacy of ML implementations.

4.2 Integration with Legacy Systems

Many manufacturing systems are built on legacy infrastructure, which makes it challenging to integrate advanced ML solutions. Upgrading or replacing these systems to accommodate ML often requires substantial investment and technical expertise (Lasi et al., 2014).

4.3 Explainability and Trust

Another major hurdle is the "black-box" nature of many ML models, particularly deep learning models. Manufacturers are often hesitant to trust ML algorithms that do not offer a clear explanation of how decisions are made, especially in safety-critical applications like aerospace or automotive manufacturing (Rudin, 2019).

5. Future Trends and Directions

5.1 Federated Learning for Collaborative Manufacturing

Federated learning is a decentralized ML approach that allows multiple parties to train a shared model without exposing their data (Kairouz et al., 2019). This is particularly relevant in collaborative manufacturing environments, where different organizations or facilities may want to benefit from shared insights without compromising proprietary information.

5.2 Edge Computing and Real-time Analytics

As more devices become connected through IoT, the need for real-time analytics is growing. Edge computing, which brings computation closer to the data source, enables faster decision-making in smart factories (Shi and Dustdar, 2016). This is likely to accelerate the adoption of ML for time-sensitive tasks, such as dynamic process control or real-time quality assurance.

5.3 Quantum Machine Learning in Manufacturing

Quantum computing, while still in its nascent stages, holds the potential to revolutionize ML in manufacturing. Quantum machine learning (QML) algorithms can process vast datasets at unprecedented speeds, potentially solving optimization problems that are currently intractable for classical computers (Biamonte et al., 2017). This could have transformative implications for supply chain management, process optimization, and material discovery.

6. Conclusion

The integration of machine learning in modern manufacturing is driving innovation and enabling more intelligent, adaptive, and efficient systems. The trends reviewed in this paper, from predictive maintenance to smart supply chains, demonstrate the vast potential of ML to revolutionize the manufacturing sector. However, significant challenges remain, particularly in data quality, model explainability, and integration with existing systems. As new ML technologies such as federated learning, quantum computing, and edge analytics emerge, the future of manufacturing will continue to evolve towards even more sophisticated and autonomous operations.

References

Bauer, A., Wollherr, D. and Buss, M. (2008). Human–robot collaboration: a survey. *International Journal of Humanoid Robotics*, 5(01), pp.47-66.

Biamonte, J., Wittek, P., Pancotti, N., Rebentrost, P., Wiebe, N. and Lloyd, S. (2017). Quantum machine learning. *Nature*, 549(7671), pp.195-202.

Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A. and Bengio, Y. (2014). Generative adversarial nets. In *Advances in Neural Information Processing Systems* (pp. 2672-2680).

Ivanov, D., Dolgui, A., Sokolov, B., Werner, F. and Ivanova, M. (2019). A dynamic model and an algorithm for short-term supply chain scheduling in the smart factory industry 4.0. *International Journal of Production Research*, 57(12), pp.3864-3880.

Jordan, M.I. and Mitchell, T.M. (2015). Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245), pp.255-260.

Kairouz, P., McMahan, H.B., Avent, B., Bellet, A., Bennis, M., Bhagoji, A.N., Bonawitz, K., Charles, Z., Cormode, G., Cummings, R., D'Oliveira, R.G., El Rouayheb, S., Evans, D., Gardner, J., Garrett, Z., Gascón, A., Ghazi, B., Gruteser, M., Harchaoui, Z., He, C., Hsu, J., Jaggi, M., Javidi, T., Joshi, G., Khodak, M., Konečný, J., Korolova, A., Koushanfar, F., Koyejo, O., Lepoint, T., Liu, Y., Mittal, P., Mohri, M., Nock, R., Özgür, A., Pagh, R., Qi, H., Ramage, D., Raykova, M., Song, S., Song, W., Stich, S.U., Sun, Z., Suresh, A.T., Tramer, F., Vepakomma, P., Wang, J., Xiong, L., Xu, Z., Yang, Q., Yu, F.X. and Zhao, S. (2019). Advances and open problems in federated learning. *Foundations and Trends in Machine Learning*, 14(1), pp.1-210.

Kusiak, A. (2018). Smart manufacturing. *International Journal of Production Research*, 56(1-2), pp.508-517.

Lee, J., Davari, H., Singh, J. and Pandhare, V. (2018). Industrial Artificial Intelligence for industry 4.0-based manufacturing systems. *Manufacturing Letters*, 18, pp.20-23.

Lasi, H., Fettke, P., Kemper, H.G., Feld, T. and Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, 6(4), pp.239-242.

Liu, Z., Wang, L., Zhang, J., Chen, X., Lei, Y., Tan, M. and Wang, J. (2020). Deep learning-based intelligent defect detection of catenary support devices in high-speed railway infrastructure. *Engineering Applications of Artificial Intelligence*, 90, p.103518.

Lu, Y., Xu, X. and Wang, L. (2019). Smart manufacturing process and system automation – A critical review of the standards and envisioned scenarios in the smart manufacturing arena. *IEEE Transactions on Industrial Informatics*, 15(4), pp.2405-2415.

Rudin, C. (2019). Stop explaining black box machine learning models for high stakes decisions and use interpretable models instead. *Nature Machine Intelligence*, 1(5), pp.206-215.

Shi, W. and Dustdar, S. (2016). The promise of edge computing. *Computer*, 49(5), pp.78-81.

Snyder, L.V. and Shen, Z.M. (2019). Fundamentals of supply chain theory. *John Wiley & Sons*.

Wuest, T., Weimer, D., Irgens, C. and Thoben, K.D. (2016). Machine learning in manufacturing: Advantages, challenges, and applications. *Production & Manufacturing Research*, 4(1), pp.23-45.

Zhang, H., Wu, L. and Zheng, G. (2019). Data-driven approaches for predictive maintenance of industrial equipment: A survey. *IEEE Systems Journal*, 13(3), pp.2213-2227.

Zhang, Z., Zhang, L., Zhang, G. and Lim, M.K. (2020). Intelligent manufacturing in the context of industry 4.0: A review. *IEEE Transactions on Automation Science and Engineering*, 17(4), pp.1478-1492.

Zhao, R., Yan, R., Chen, Z., Mao, K., Wang, P. and Gao, R.X. (2020). Deep learning and its applications to machine health monitoring. *Mechanical Systems and Signal Processing*, 115, pp.213-237.

Zhu, J., Chen, X. and Li, Y. (2021). Reinforcement learning for collaborative human-robot interaction. *IEEE Transactions on Automation Science and Engineering*, 18(3), pp.1051-1061.

Chapter -9:

Adaptive Approaches for Sustaining Sagar Island: A Thorough Review of Climate Resilience, Erosion Control, and Community Involvement.

Soumen Dutta[1], Ashes Banerjee[2]*

[1] *post-graduate student, Dept. of Civil Engineering, Swami Vivekananda University, Barrackpore, Kolkata, West Bengal, India; Email: soumend@svu.ac.in*

[2] *Assistant Professor, Dept. of Civil Engineering, Swami Vivekananda University, Barrackpore, Kolkata, West Bengal, India*

**Corresponding Author Email: ashesb@svu.ac.in*

Adaptive Approaches for Sustaining Sagar Island: A Thorough Review of Climate Resilience, Erosion Control, and Community Involvement.

Soumen Dutta[1], Ashes Banerjee[2]*

[1] *post-graduate student, Dept. of Civil Engineering, Swami Vivekananda University, Barrackpore, Kolkata, West Bengal, India; Email: soumend@svu.ac.in*

[2] *Assistant Professor, Dept. of Civil Engineering, Swami Vivekananda University, Barrackpore, Kolkata, West Bengal, India*

**Corresponding Author Email: ashesb@svu.ac.in*

Abstract:

Sagar Island, also known as Ganga Sagar, is West Bengal's largest island, spanning 282.11 sq. km and home to around 300,000 people. Vulnerable due to its location in a tidal creek and climate change effects, the island faces threats from cyclonic storms and tidal upsurges, jeopardizing lives and livelihoods. Crucial steps include climate change mitigation via cleaner energy and protective measures like fortified embankments, improved drainage, and coastal management. Robust disaster plans with alerts, evacuations, and community education are essential. Erosion affects the island's coast, impacting mud flats, sandy beaches, dunes, and mangroves. From 1967 to 1999, about 29.8 km^2 eroded while 6.03 km^2 accreted. Erosion rates vary due to the island's composition of silt and clay, alongside sea level rise and subsidence. Erosion management and climate adaptation planning are vital for the island's resilience and inhabitants' well-being.

Introduction:

In an era marked by unprecedented global climate change, coastal regions around the world are confronting the escalating challenges of rising sea levels, increased storm intensities, and coastal erosion (Pörtner et al. 2019). Among these vulnerable areas, Sagar Island, situated in the Bay of Bengal, stands as a poignant emblem of the multidimensional predicament posed by climate change. Home to a diverse community of inhabitants and a site of immense ecological significance, Sagar Island grapples with the complex interplay of environmental degradation and societal resilience.

The coastal regions of India have long borne witness to the implications of climate change, where climate-induced disasters are becoming more frequent and severe, jeopardizing the livelihoods and well-being of millions of people (Pörtner et al. 2019). Sagar Island, situated in the Sundarbans delta, is one such emblematic case study that encapsulates the myriad challenges posed by climate change. Its residents, predominantly dependent on agriculture and fishing, face not only the threats of sea-level rise and erosion but also the consequences of ecological imbalance in one of the world's most biodiverse ecosystems (3).

The reclamation of Sagar Island commenced in 1811, as it became separated from the Sundarbans mangrove wetlands (Bandyopadhyay 1997a). Over time, government policies led to the near-complete settlement of the island, accommodating a population of 212,037 (Bera et al. 2021). The most pressing environmental challenge faced by the island pertains to coastal erosion, which has resulted in a reduction of its supratidal area by approximately 25% over a span of 144 years (Bandyopadhyay 1997a). This erosion is primarily attributed to the disruption of the balanced state of the Hugli estuary due to the reclamation of intertidal areas (Brammer et al. 1996; Bandyopadhyay 1997b).

This comprehensive review paper seeks to shed light on the adaptive strategies employed to sustain Sagar Island's fragile environment and the resilient communities inhabiting it (Brammer et al. 1996). We delve into the multifaceted dimensions of climate resilience, erosion management, and community engagement, examining both the ecological and socio-economic aspects (Brammer et al. 1996). Our exploration is grounded in a rigorous analysis of existing literature, field studies, and first-hand accounts, providing a holistic understanding of the challenges and solutions.

Throughout the following sections, we will navigate the intricate web of adaptive strategies employed on Sagar Island, drawing insights from successful initiatives and identifying areas where innovation and intervention are urgently required. Additionally, we will explore the significance of community engagement and participation in shaping the island's resilience, emphasizing the importance of local knowledge and collaboration.

As climate change continues to intensify, the lessons learned from Sagar Island's experience are not only pertinent to this specific region but serve as a microcosm of the global climate adaptation imperative (Pörtner et al. 2019). In this context, we offer a comprehensive review of the state of knowledge, with the aim of not only understanding the unique challenges faced by Sagar Island but also contributing to the broader discourse on climate resilience, erosion management, and community engagement in vulnerable coastal areas.

Coastal Erosion Management:

The coordination of erosion management efforts on Sagar Island involves seven distinct agencies (Bandyopadhyay 1997b). These initiatives encompass the establishment of approximately 74.5 km of embankments along the coast, with roughly 19.4% of these embankments being brick-paved (Bandyopadhyay 1997b). Furthermore, there are 579 hectares of mangrove plantations distributed across 11 locations, and three relocation settlements have been established as part of the erosion management strategy (Bandyopadhyay 1997b). The swift deterioration of Sagar Island's coastline in West Bengal (Fig.1), India, is an urgent concern. Coastal erosion involves the gradual loss of land along a shoreline due to factors such as wave impact, tidal flows, sediment movement, and rising sea levels (Jayappa et al. 2006).

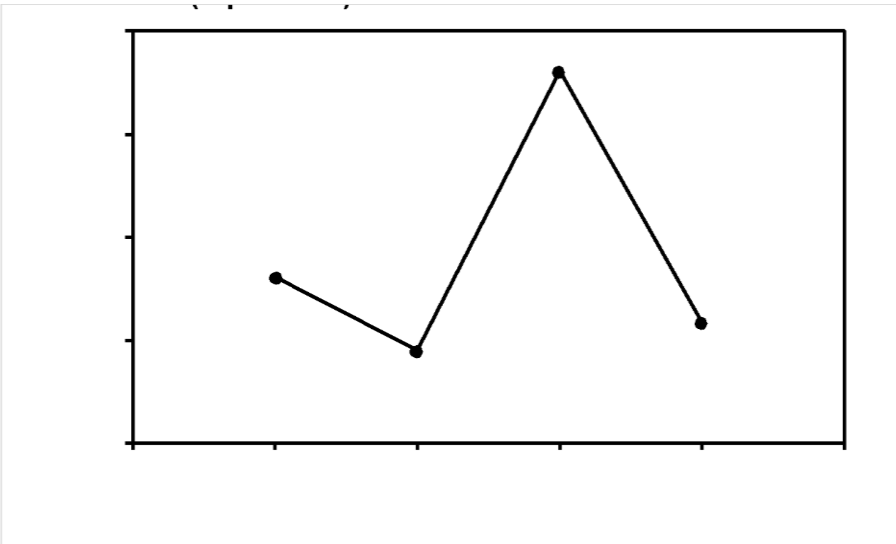


Fig.1 Variation in the Area of Sagar Island in last three decade.

Situated at the confluence of the Bay of Bengal and the Hooghly River, Sagar Island is especially susceptible to erosion (Kaliraj and Chandrasekar 2012). The island is exposed to powerful wave forces and tidal currents, both of which contribute to the erosion of its coastline (Kaliraj and Chandrasekar 2012). Natural mechanisms like wave action and tidal currents significantly influence coastal erosion (Gopinath and Seralathan 2005). The force exerted by waves can erode and transport sediment away from the shoreline, resulting in land degradation. Additionally, tidal currents consistently reshape coastlines, further contributing to erosion (Gopinath and Seralathan 2005).

The challenge of erosion is exacerbated by the effects of climate change, including rising sea levels (Juliev 2020). As sea levels rise, higher wave energy reaches the shore, accelerating erosion rates (Juliev 2020). Similar to numerous coastal regions worldwide, Sagar Island contends with the consequences of climate change, intensifying the process of coastal erosion (Juliev 2020). Human activities can also exacerbate coastal erosion (Raj et al. 2019). Elements such as improper land use practices, coastal development, and alterations in natural sediment movement can disrupt the ecological balance and worsen erosion (Raj et al. 2019).

The rapid erosion of Sagar Island's coastline presents significant obstacles for its communities (Ratheesh et al. 2023). It results in the loss of agricultural land, displacement of settlements, damage to infrastructure, and livelihood disruptions (Ratheesh et al. 2023). Furthermore, erosion jeopardizes important cultural and religious sites on the island (Ratheesh et al. 2023).

To address rapid coastal erosion, a variety of mitigation strategies can be implemented (Roy Chowdhury and Sen 2015). These strategies encompass the construction of coastal defences such as revetments, seawalls, and groynes to mitigate wave energy and safeguard the coastline (Roy Chowdhury and Sen 2015). Beach nourishment, involving the addition of sediment to eroded areas, is also effective in restoring and stabilizing shorelines (Roy Chowdhury and Sen 2015).

Integrated coastal zone management approaches, which combine engineering, ecological, and policy measures, provide effective erosion control(Lakshmi and Edward 2010; Bhui et al. 2023; Rukhsana and Molla 2023). This involves adopting sustainable land-use practices, advocating for the preservation of natural habitats like mangroves, and formulating long-term adaptation strategies to counteract the impacts of climate change (Nezlin et al. 2023). Effectively addressing the swift erosion of Sagar Island's coast necessitates an inclusive, interdisciplinary approach, requiring collaboration among government entities, local communities, researchers, and experts. By implementing appropriate mitigation strategies and adopting sustainable coastal management practices, it is possible to mitigate the impacts of erosion and provide better protection for coastal communities.

Methodology:

Several methodologies have been followed for studying local soil erosion in the Sagar region using a systematic and scientific approach. The present study presents a brief summary of the various techniques used so far.

Field Surveys:

In the context of erosion on Sagar Island, conducting crucial field surveys is essential to gather accurate primary data about soil erosion dynamics (Mukherjee et al. 2019). Sagar Island, located in the vulnerable Ganges Delta region, is highly susceptible to erosion risks due to a combination of its geographic location, tidal patterns, and various environmental factors (Bera et al. 2021; Bhattacharjee et al. 2023; Mallik et al. 2023). To comprehensively assess and understand the erosion challenges faced by this island community, a multi-faceted approach is employed through these field surveys, which involve physical measurements, observations, and sampling techniques (Bera et al. 2022). Direct measurements play a pivotal role in tracking shoreline changes and monitoring sediment deposition over time (Archer 2011). These measurements provide critical data points that form the foundation for erosion analysis. Additionally, observations are conducted to delve into the intricate erosion processes at play and identify erosion hotspots. This qualitative aspect of the surveys is crucial for gaining insights into the mechanisms and drivers of erosion on Sagar Island.

Sampling techniques are employed to collect sediment samples from various locations across the island, enabling experts to analyze sediment composition and dynamics(Gopinath and Seralathan 2005). This data is essential for understanding the sediment transport and deposition patterns, which are key factors contributing to erosion. However, it is important to note that conducting field surveys to collect primary erosion data on Sagar Island presents several challenges. These challenges include resource and time intensity, limited spatial coverage, subjectivity in observations, susceptibility to weather impacts, sampling variability, the complexity of data interpretation, temporal variability, and the necessity for a comprehensive approach to erosion management. Resource and time intensity refers to the significant resources and time required to conduct thorough surveys across the island due to its size and diverse terrain. The limited spatial coverage of field surveys may not capture erosion dynamics across the entire island, potentially leaving certain areas unexplored.

Subjectivity in observations can introduce variability into the data, as different surveyors may interpret erosion processes differently. Weather impacts, such as inclement weather conditions, can disrupt survey schedules and affect data collection. Sampling variability can also introduce uncertainty into the analysis, as sediment samples may not fully represent the entire spectrum of sediment types and behaviors on the island. Data interpretation complexity arises from the need to synthesize vast amounts of data into meaningful insights. Temporal variability refers to the changes in erosion patterns over time, making it necessary to conduct surveys at multiple time points to capture these dynamics accurately. Lastly, a comprehensive approach to erosion management emphasizes the need to integrate data from various sources, including remote sensing and modelling, and encourages interdisciplinary collaboration among experts (McKnight 2017).

In light of these challenges, it becomes evident that while field surveys are instrumental in providing crucial data about erosion dynamics on Sagar Island, they should be complemented by other methodologies such as remote sensing and modelling. Interdisciplinary collaboration among experts is essential to formulate effective erosion mitigation strategies that address the complex and multifaceted nature of erosion on the island. This integrated approach ensures a more robust understanding of erosion dynamics and facilitates the development of sustainable land use and erosion control strategies for the benefit of Sagar Island's community and environment.

Analysis of Remote Sensing Data:

Remote sensing, as a powerful tool, offers versatile methods for assessing coastal erosion on Sagar Island. It leverages advanced technologies and techniques to provide valuable insights into the dynamic changes occurring along the island's shoreline (Wang and Mei 2016; Wang and Xu 2018). Here, we explore the various facets of remote sensing's contribution to understanding and managing coastal erosion in this vulnerable region. One of the fundamental applications of remote sensing in coastal erosion assessment involves image analysis. Over time, remote sensing platforms capture a series of images that depict the coastal landscape. By comparing these images at different time intervals, analysts can precisely track alterations in the shoreline. These alterations may include land loss, erosion hotspots, and shifts in the coastal boundary. Image analysis serves as a visual record of the evolving coastline, providing essential data for erosion studies. Remote sensing employs sophisticated change detection techniques to quantify the extent of shoreline transformation. These techniques involve the identification of significant alterations between two or more images taken at different times. By quantifying the changes, researchers can calculate erosion rates and understand the magnitude of coastal transformation. The ability to measure erosion quantitatively is invaluable for assessing the impact of erosion and devising effective mitigation strategies.

The Digital Shoreline Analysis System (DSAS) is specialized software that automates the process of change detection (Jana 2021; Acharyya et al. 2023). DSAS is designed to work with geographic information system (GIS) data, making it a powerful tool for analyzing coastal erosion trends (Thieler et al. 2009). It not only automates the detection of shoreline changes but also calculates shoreline change rates. This automation streamlines the analysis process, making it more efficient and accurate. By leveraging remote sensing technologies and methodologies, we can gain a deeper understanding of the causes and dynamics of coastal erosion on Sagar Island. Continuous monitoring of shoreline changes provides essential data that informs erosion management strategies. Armed with this information, researchers and policymakers can develop effective measures to mitigate the adverse effects of erosion, protect vulnerable coastal communities, and preserve the natural environment. Remote sensing stands as a pivotal tool in the ongoing effort to address the complex challenges posed by coastal erosion in this region.

Conclusion:

Sagar Island, one of West Bengal's largest river islands, faces severe erosion due to a complex interplay of natural and human-induced factors. These include tidal action, rising sea levels, river dynamics, sediment deficits, wave energy from cyclones, and human activities like sand mining and inadequate erosion control measures. Population growth and infrastructure development exacerbate erosion, while climate change adds further challenges. Effective erosion management strategies for Sagar Island must address these multifaceted causes to protect both the environment and communities. The use of tetrapods enhances wave-breaking capabilities and reduces erosion potential, while concrete embankments offer physical protection and flood defence. Mangroves with their root systems provide natural stabilization against erosion. These measures are crucial for safeguarding the island's coastline and its inhabitants.

References:

Acharyya R, Mukhopadhyay A, Habel M (2023) Coupling of SWAT and DSAS Models for Assessment of Retrospective and Prospective Transformations of River Deltaic Estuaries. Remote Sens 15:958

Archer D (2011) Global warming: understanding the forecast. John Wiley & Sons

Bandyopadhyay S (1997a) Coastal erosion and its management in Sagar Island, South 24 Parganas, West Bengal. Indian J Earth Sci 24:51–69

Bandyopadhyay S (1997b) Natural environmental hazards and their management: a case study of Sagar Island, India. Singap J Trop Geogr 18:20–45

Bera A, Meraj G, Kanga S, et al (2022) Vulnerability and risk assessment to climate change in Sagar Island, India. Water 14:823

Bera A, Taloor AK, Meraj G, et al (2021) Climate vulnerability and economic determinants: Linkages and risk reduction in Sagar Island, India; A geospatial approach. Quat Sci Adv 4:100038

Bhattacharjee R, Naskar M, Sengupta C, et al (2023) Regional Environmental Change, Farmers' Perceptions and Resilient Farming: Experiences from the Sagar Island of Indian Sundarbans. Pap Appl Geogr 9:171–192

Bhui K, Bhadra T, Samanta S, Hazra S (2023) Assessing the Tidal Influences on the Coastal Erosion-Accretion Processes in the Indian Sundarban Delta using Hydrodynamic Models and Geoinformatics. IOP Publishing, p 012002

Brammer H, Asaduzzaman M, Sultana P (1996) Effects of climate and sea-level changes on the natural resources of Bangladesh. In: The Implications of Climate and Sea–Level Change for Bangladesh. Springer, pp 143–203

Gopinath G, Seralathan P (2005) Rapid erosion of the coast of Sagar island, West Bengal-India. Environ Geol 48:1058–1067

Jana S (2021) An automated approach in estimation and prediction of riverbank shifting for flood-prone middle-lower course of the Subarnarekha river, India. Int J River Basin Manag 19:359–377

Jayappa K, Mitra D, Mishra A (2006) Coastal geomorphological and land- use and land-cover study of Sagar Island, Bay of Bengal (India) using remotely sensed data. Int J Remote Sens 27:3671–3682

Juliev M (2020) Spatio-temporal modelling of shoreline migration in Sagar Island, West Bengal, India. Sci Acad Pap Collect

Kaliraj S, Chandrasekar N (2012) Geo-processing model on coastal vulnerability index to explore risk zone along the south west coast of Tamilnadu, India. Int J Earth Sci Eng 5:1138–1147

Lakshmi SA, Edward JP (2010) Coastal issues and management strategy for Sagar island in bay of Bengal. Recent Res Sci Technol 2:

Mallik C, Bandyopadhyay S, Bandopadhyay S (2023) Land scarcity and land access in a hazard- prone island: Sagar, Indian Sundarbans. Singap J Trop Geogr

McKnight DM (2017) Debates—Hypothesis testing in hydrology: A view from the field: The value of hydrologic hypotheses in designing field studies and interpreting the results to advance hydrology. Water Resour Res 53:1779–1783

Mukherjee N, Siddique G, Basak A, et al (2019) Climate change and livelihood vulnerability of the local population on Sagar Island, India. Chin Geogr Sci 29:417–436

Nezlin NP, Herman JD, Hodge J, et al (2023) Assessment of Changes of Complex Shoreline from Medium-Resolution Satellite Imagery. Estuaries Coasts 1–17

Pörtner H-O, Roberts DC, Masson-Delmotte V, et al (2019) IPCC special report on the ocean and cryosphere in a changing climate. IPCC Intergov Panel Clim Change Geneva Switz 1:1–755

Raj N, Gurugnanam B, Sudhakar V, Francis PG (2019) Estuarine shoreline change analysis along The Ennore river mouth, south east coast of India, using digital shoreline analysis system. Geod Geodyn 10:205–212

Ratheesh R, Rajput P, Bhatti H, et al (2023) Quantification of shoreline changes along the entire Indian coast using Indian Remote Sensing satellite images of 2004-06 and 2014-16. Curr Sci 00113891 124:

Roy Chowdhury B, Sen T (2015) Coastal Erosion and Its Impact on Sagar Island,(S) 24 Parganas, WB

Rukhsana, Molla SH (2023) Soil site suitability for sustainable intensive agriculture in Sagar Island, India: a geospatial approach. J Coast Conserv 27:14

Thieler ER, Himmelstoss EA, Zichichi JL, Ergul A (2009) The Digital Shoreline Analysis System (DSAS) version 4.0-an ArcGIS extension for calculating shoreline change. US Geological Survey

Wang B, Xu YJ (2018) Dynamics of 30 large channel bars in the Lower Mississippi River in response to river engineering from 1985 to 2015. Geomorphology 300:31–44

Wang S, Mei Y (2016) Lateral erosion/accretion area and shrinkage rate of the Linhe reach braided channel of the Yellow River between 1977 and 2014. J Geogr Sci 26:1579–1592

Chapter -10:

Assessment of Heavy Metal and Microbial Quality of Herbal Medicinal Concoctions Sold in India

Avishek Adhikari

Assistant Professor, Department of Civil Engineering, Swami Vivekananda University, Barrackpore-700121. Email: avisheka@svu.ac.in

Assessment of Heavy Metal and Microbial Quality of Herbal Medicinal Concoctions Sold in India

Avishek Adhikari

Assistant Professor, Department of Civil Engineering, Swami Vivekananda University, Barrackpore-700121. Email: avisheka@svu.ac.in

Abstract

The popularity of herbal medicinal products in India has grown exponentially due to their perceived safety and efficacy. However, concerns over their safety have been raised due to potential contamination by heavy metals and microbial pathogens. This study aimed to assess the heavy metal and microbial contamination levels in five commonly used herbal medicinal concoctions sold across India. The concentrations of heavy metals (lead, cadmium, mercury, and arsenic) were measured using atomic absorption spectrometry, while microbial contamination was evaluated using standard microbiological techniques. The results revealed that certain concoctions exceeded permissible heavy metal limits set by WHO, and microbial contamination, including the presence of Escherichia coli and Salmonella spp., was detected in some samples, posing significant health risks. These findings highlight the urgent need for stricter regulation and monitoring of herbal medicines to ensure their safety for public consumption.

Keywords:

Herbal medicine, heavy metals, microbial contamination, quality assessment, India, toxicity.

1. Introduction

Herbal medicines have been an integral part of traditional healthcare systems in India, such as Ayurveda, Unani, and Siddha, for centuries. With the global resurgence of interest in natural remedies, the market for herbal medicinal products has grown significantly. However, while these products are often marketed as safe and free from side effects, contamination with heavy metals and microorganisms remains a major concern.

Heavy metal contamination can occur due to environmental pollution, improper handling, or the deliberate inclusion of metals as part of traditional formulations. Prolonged exposure to heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) can result in serious health issues, including neurotoxicity, kidney damage, and cancer. Similarly, microbial contamination, particularly with pathogenic bacteria, can pose risks of gastrointestinal infections and other health complications.

The objective of this study was to assess the heavy metal and microbial quality of five commonly used herbal medicinal concoctions sold in India, evaluate their compliance with safety standards, and highlight potential risks to consumers.

2. Literature Review

Herbal medicines are widely used for the treatment and prevention of various ailments due to their perceived effectiveness and minimal side effects. However, numerous studies have reported the presence of toxic heavy metals and microbial contaminants in herbal products. Studies from around the world, including India, have shown that herbal products can be contaminated with heavy metals through soil, water, and air pollution. For instance, Sharma et al. (2018) reported significant levels of lead and mercury in herbal medicines sold in urban markets.

Microbial contamination can occur due to poor processing, storage, and handling practices. Pathogens such as E. coli, Salmonella, Staphylococcus aureus, and molds have been isolated from herbal products. A study by Gupta et al. (2020) found microbial contamination in over 30% of herbal preparations tested in India, raising concerns about the safety of these products.

Despite these reports, there is limited data on the comprehensive analysis of both heavy metal and microbial contamination in herbal medicinal concoctions in India. This study aims to fill this gap by providing an assessment of the contamination levels in five popular herbal concoctions sold across different regions of the country.

3. Materials and Methods

3.1 Sample Collection

Five popular herbal medicinal concoctions were selected based on their widespread use in India:

1. Ashwagandha Churna

2. Triphala

3. Brahmi Rasayana

4. Amla Juice

5. Tulsi Ark

These products were purchased from different retail outlets in Delhi, Mumbai, Kolkata, Chennai, and Bangalore to ensure geographic diversity in sampling. The samples were sealed in sterile containers and transported to the laboratory for analysis.

3.2 Heavy Metal Analysis

The concentrations of lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) in the herbal concoctions were determined using atomic absorption spectrometry (AAS). The samples were digested using a mixture of nitric acid and perchloric acid, followed by heating to dissolve organic matter. The digested solutions were analyzed by AAS to quantify the concentrations of heavy metals.

3.3 Microbial Analysis

The microbial quality of the herbal concoctions was assessed using standard microbiological techniques:

- Total Aerobic Plate Count (TAPC): The overall microbial load was determined by culturing diluted samples on nutrient agar and incubating at 37°C for 24-48 hours.

- Total Yeast and Mold Count: Samples were plated on Sabouraud dextrose agar to estimate the fungal contamination.

- Detection of Pathogenic Bacteria: Selective media and biochemical tests were used to isolate and identify pathogenic bacteria such as E. coli, Salmonella spp., and Staphylococcus aureus.

3.4 Safety Standards

The heavy metal concentrations in the samples were compared against the permissible limits set by the World Health Organization (WHO) and the Food and Drug Administration (FDA). For microbial contamination, limits established by WHO for herbal medicinal products were used as a reference.

4. Results and Discussion

4.1 Heavy Metal Contamination

The concentrations of lead, cadmium, mercury, and arsenic in the herbal concoctions are shown in Table 1. While some samples showed negligible contamination, others had heavy metal concentrations exceeding the permissible limits.

Table 1: Heavy Metal Concentrations in Herbal Medicinal Concoctions (mg/kg)

Sample	Pb	Cd	Hg	As	Permissible Limit (WHO)
Ashwagandha Churna	8.5	0.12	0.05	0.02	10.0 (Pb), 0.3 (Cd), 0.5 (Hg), 1.0 (As)
Triphala	12.1	0.25	0.08	0.15	
Brahmi Rasayana	9.8	0.15	0.12	0.1	
Amla Juice	2.3	0.05	0.01	0.01	
Tulsi Ark	4.6	0.08	0.03	0.05	

From the results, it was observed that:

- Lead (Pb): Triphala and Brahmi Rasayana had the highest lead concentrations, with Triphala exceeding the WHO permissible limit. Lead exposure can lead to neurological problems, especially in children.

- Cadmium (Cd): Cadmium concentrations were below the permissible limit in all samples, but Triphala showed higher levels than the others.

- Mercury (Hg): Mercury was present in trace amounts in all samples but remained below the WHO limit.

- Arsenic (As): The arsenic content was within the permissible limit across all samples. Arsenic is a known carcinogen and poses long-term health risks if ingested at high levels.

4.2 Microbial Contamination

The microbial analysis of the herbal concoctions revealed the presence of high microbial loads in some samples, as shown in Table 2.

Table 2: Microbial Contamination Levels in Herbal Medicinal Concoctions

Sample	TAPC (CFU/g)	Yeast and Mold (CFU/g)	*E. coli*	*Salmonella spp.*	*Staphylococcus aureus*
Ashwagandha Churna	5.3×10^4	1.2×10^3	Absent	Absent	Present
Triphala	3.1×10^4	8.6×10^2	Absent	Present	Absent
Brahmi Rasayana	6.7×10^3	2.1×10^2	Present	Absent	Absent
Amla Juice	2.9×10^4	5.4×10^2	Absent	Absent	Absent
Tulsi Ark	1.5×10^3	2.9×10^2	Absent	Present	Present

The results showed that:

- Total Aerobic Plate Count (TAPC): Ashwagandha Churna and Triphala had high bacterial loads exceeding WHO limits. High microbial counts indicate poor handling or storage conditions.

- Yeast and Mold Count: All samples showed some level of fungal contamination, with Ashwagandha Churna having the highest count.

- Pathogens: E. coli was detected in Brahmi Rasayana, while Salmonella spp. was present in Triphala and Tulsi Ark. Staphylococcus aureus was detected in Ashwagandha Churna and Tulsi Ark. The presence of these pathogens raises serious concerns about the safety of these products.

4.3 Health Implications

The presence of heavy metals, particularly lead, in concentrations exceeding permissible limits, poses significant health risks. Chronic exposure to lead can result in neurological damage, developmental delays, and kidney dysfunction.

Similarly, the detection of pathogenic bacteria such as E. coli and Salmonella spp. in some samples suggests the potential for gastrointestinal infections and foodborne illnesses. These findings indicate that consumers of these products may be exposed to unsafe levels of contaminants.

5. Conclusion

This study assessed the heavy metal and microbial quality of five herbal medicinal concoctions sold in India. The results indicated that certain samples contained heavy metals exceeding WHO permissible limits, and microbial contamination, including pathogenic bacteria, was detected in some products. These findings highlight the need for stricter regulatory oversight and better quality control measures in the production, storage, and distribution of herbal medicines. Public awareness of potential risks associated with these products must also be raised to ensure consumer safety.

References

1. Gupta, P., Singh, S., & Mehta, R. (2020). Microbial contamination in herbal medicines: An overview. Journal of Herbal Medicine, 25, 1-8.

2. Sharma, V., Srivastava, N., & Saxena, S. (2018). Heavy metal contamination in herbal products: A cause for concern. Environmental Monitoring and Assessment, 190(2), 99.

3. World Health Organization. (2007). WHO guidelines for assessing quality of herbal medicines with reference to contaminants and residues. Geneva: WHO.

4. Mishra, A., & Tiwari, S. (2019). Heavy metal and microbial analysis of herbal medicinal products: A review. Indian Journal of Pharmacology, 51(5), 350-355.

5. Kaur, H., & Kumar, P. (2021). Safety and quality of herbal medicines in India: Regulatory challenges and way forward. Journal of Pharmacovigilance and Drug Safety, 18(3), 165-172.

Chapter -11:

Anti-Loosening Characteristics of 5/8 Inch HTS Threaded Fasteners under Vibratory Conditions

Bikash Panja[1*] and Anupam Mallick[1]

[1] *Swami Vivekananda University, Barrackpore, North 24 Pargana, Kolkata-700121, India*

*Corresponding author: bikashpanjame@gmail.com

Anti-Loosening Characteristics of 5/8 Inch HTS Threaded Fasteners under Vibratory Conditions

Bikash Panja[1*] and Anupam Mallick[1]

[1]*Swami Vivekananda University, Barrackpore, North 24 Pargana, Kolkata-700121, India*

*Corresponding author: bikashpanjame@gmail.com

Abstract:

Threaded fasteners have been widely used since their inception centuries ago. However, under harsh vibrating conditions, these fasteners often experience loosening of clamping force, leading to system failure. Researchers have extensively studied the mechanisms behind this loosening and identified the contributing factors. In response, various locking characteristics have been developed to improve fastener performance. In the present work, the loosening characteristics of a 5/8 inch high-tension steel (HTS) bolt, tested with a conventional nut and three types of washers—flat, spring, and inside serrated—were examined under accelerated vibrating conditions using an indigenously developed test rig for 7000 oscillations. The extent of loosening was measured by the loss of clamping force from the initial value. Results indicate that flat washers provide no significant anti-loosening benefits, while spring washers offer some resistance. The inside serrated washers showed the greatest resistance to loosening, attributed to their enhanced friction through surface indentation.

Keywords: Bolt, nut, washer, BSW HTS fasteners, loosening, vibration

1. Introduction:

Threaded fasteners mark a significant innovation in human civilization, facilitating temporary joins in machinery for assembly, repair, and replacement due to their operational simplicity and ability to provide high clamping force with minimal tools (Sase et al. 1998; Hongo, 1964). Despite this, screw fasteners are prone to loosening under vibration. Initially used in the 3rd century B.C. for lifting water in the Hanging Gardens of Babylon, screws were later described by Archytas of Tarentum and utilized by Archimedes for irrigation through the screw pump (Fujii and Sase, 1998; Mahato and Das, 2009). By 1493, screws were used in olive presses in ancient Greece. Leonardo da Vinci contributed to the development of various screw threads through his sketches, which influenced multiple applications (Christopher, 2005). Gerhard H. Junker explored the theory of self-loosening of preloaded bolted joints under vibration and created a machine to test locking properties, attributing loosening to friction and external forces (Junker, 1969). Paland examined threaded fasteners under axial loading and concluded that nuts tend to widen elastically at bearing surfaces, which contributes to loosening (Paland, 1966). Further testing by Fujii and his team showed that common anti-loosening fasteners often failed to resist loosening effectively, with the SLB showing the least tendency to loosen among various fastener combinations (Sase et al., 1996; Sase and Fujii, 2001). Fasteners hold parts together through the pretension force from the elongated bolt and compression on the tightened objects. A reduction in this pretension force signals loosening, as noted by Bhattacharya et al., 2010.

2. Loosening Mechanism and Its Prevention

Decreased loosening can be achieved by altering the thread design, or using different mechanical devices like locking nuts:

A. To prevent loosening due to relative rotation, you can minimize the problem by decreasing the flank angle and lead angle, as well as reducing the relative slip between the nut's bearing surface and the fastened material. This can be achieved by introducing taper and other similar modifications.

B. Six Types of Locking Nuts Used Today to Prevent Loosening In particular, the American National Standards Subcommittee B18:20 categorize these locking fasteners into three fundamental types: free-spinning, friction-locking and chemical-locking.

3. Details of Experimentation

A test rig developed indigenously by Bhattacharya et al., 2010 was modified to be used for the experiments testing anti-loosening capacity of threaded fasteners. A load cell (Sushma, model SLC-302, compression type column lever indicator) for clamping force detection was also equipped with this rig. The rig imparts a periodic oscillating motion which sets up vibration of constant frequency and amplitude for number cycles of operation. A tachometer also indicated that the camshaft's rotational speed was 300 RPM, while the motor ran at 1480 RPM. Hence the clamped plate is impacted by (0.2 mm) at 300 cycles per minute of rocking plates. The setup shown in Fig.2 transmits this vibration through the nut and bolt assembly being tested via vibrating table & fixture, Vibration Accelerometer is fixed to the set-up which measures total acceleration of system during Sinusoidal angular vibrations provided at BFS hence using above formula unsprung mass can be calculated by measuring db level as a function of Frequency/Hz from results obtained. 1. He can make them vibrate repeatedly, as though they had been hammered over and over to become loose bit by bit – the same process that leads to decreased clamping load. Tests are done in duplicate and the average readings used to analyze data, or report it.

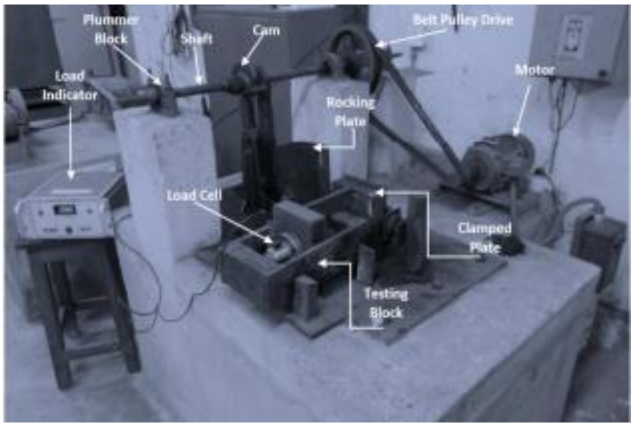


Fig. 1. Photographic view of the test rig

3.1 Details of Fasteners Tested

Various anti-loosening fasteners have been evaluated in loosening tests. Figures 2(a-c) show photographs of the tested washers, including flat, spring, and inside washers, used in conjunction with a 5/8 inch BSW HTS bolt and a conventional nut.

Fig. 2. Photographs of washers used [flat, spring washer, and inside serrated washer]

4. Results and Discussions

Figure 3 illustrates how clamping force loosens with the increasing number of oscillations for various high-tension steel (HTS) fastening elements. The plot indicates that the rate of loosening is initially high up to approximately 7000 oscillations. After this point, the rate of clamping force loss starts to slow down. The loosening rate greatly decreases after several thousand oscillations for all the test cases, except traditional fasteners with and without flat washers. Data shows that the use of spring and internal serrated washers can significantly lower clamping force decline.In contrast, flat washers have no impact on preventing loosening under vibration, showing similar loosening behavior to conventional threaded fasteners. Although spring and serrated washers are expected to offer some anti-loosening benefits by indenting the bearing surface of the nut or clamped plate, their performance does not meet expectations, as also noted by Fujii and Sase, 1998.

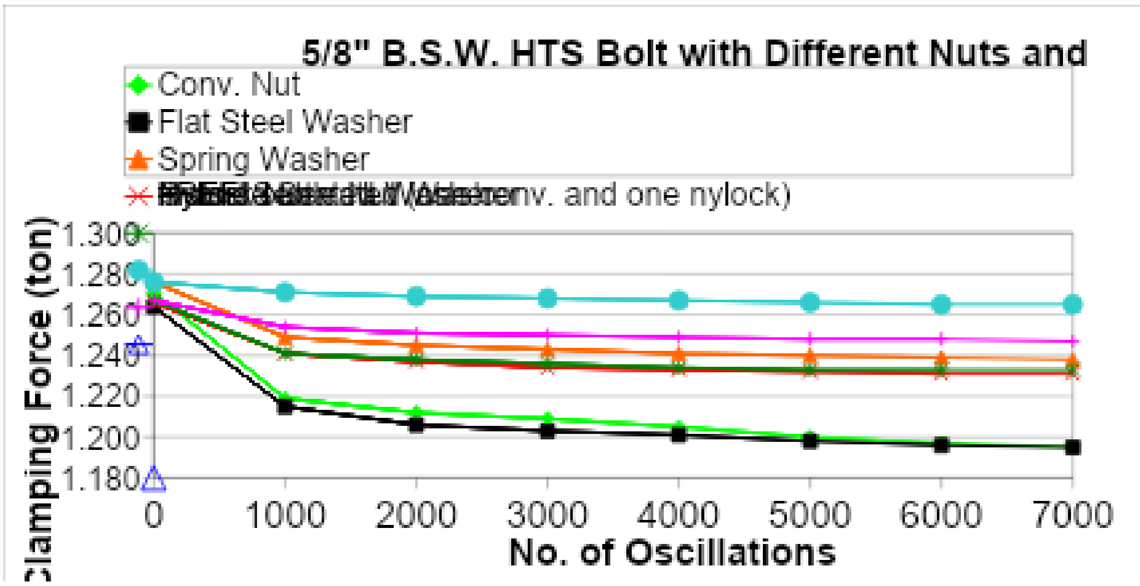


Fig. 3. Vibration Induced Loosening Comparison of 5/8″ BSW HTS bolt with different Nut and Washer

5. Conclusions

Flat washers did not generally inhibit rotation to a significant degree, as is popularly believed. It is true that spring washers are said to be anti-loosening. However, internal serrated washers offer even better resistance to unscrewing than spring washers. These were serrated washers, the indenting helps to provide even more friction at the bearing surfaces of those high-tension steel (HTS) 5/8″ BSW bolts that we tested.

References

1. Bhattacharya, A., Sen, A., & Das, S. (2010). An investigation on the anti-loosening characteristics of threaded fasteners under vibratory conditions. *Mechanism and Machine Theory*, *45*(8), 1215-1225.

2. Christopher, W. (2005) "Observation on development of woods screws in North America", Museum of Fine Arts, Boston, http://www.cool.conservationus.org/coolaic/sg/wag/Am_Wood_Screws.pdf.
3. Fujii, H., & Sase, N. (1998). SLB concept for screw fastening and its anti loosening performance. In *Souvenir of the All India Manufacturing Technology, Design and Research Conference* (Vol. 18, pp. 25-34).
4. Hongo, K. (1964). Loosening of bolt and nut fastening. *Transaction of Japan Society Mechanical Engineering*, *30*(215), 934-939.
5. Junker, G. H. (1969). New criteria for self-loosening of fasteners under vibration. *Sae Transactions*, 314-335.
6. Mahato, K. N., & Das, S. (2009). A study on anti-loosening characteristics of different 3/8 BSW threaded fasteners. In *14th National Conference on Machines and Mechanisms at NIT, Durgapur*.
7. Paland, E. G. (1966). *Investigation of the locking features of dynamically loaded bolted connections* (Doctoral dissertation, Hannover University).
8. Sase, N., Koga, S., Nishioka, K., & Fujii, H. (1996). Evaluation of anti-loosening nuts for screw fasteners. *Journal of materials processing technology*, *56*(1-4), 321-332.
9. Sase, N., Nishioka, K., Koga, S., & Fujii, H. (1998). An anti-loosening screw-fastener innovation and its evaluation. *Journal of materials processing technology*, *77*(1-3), 209-215.
10. Sase, N., & Fujii, H. (2001). Optimizing study of SLBs for higher anti-loosening performance. *Journal of Materials Processing Technology*, *119*(1-3), 174-179.

Chapter -12:

Response of Maize (Zea mays L.) to Poultry Dung Compost on Sandy Soil

Debanjali Adhikary

Assistant Professor, Department of Civil Engineering, Swami Vivekananda University, Barrackpore-700121. Email: debanjalia@svu.ac.in

Response of Maize (Zea mays L.) to Poultry Dung Compost on Sandy Soil

Debanjali Adhikary

Assistant Professor, Department of Civil Engineering, Swami Vivekananda University, Barrackpore-700121. Email: debanjalia@svu.ac.in

Abstract

The application of organic fertilizers such as poultry dung compost can significantly impact soil fertility and crop productivity, especially in sandy soils that typically have low nutrient and water retention capacities. This study evaluates the effects of poultry dung compost on the growth, yield, and nutritional quality of maize (Zea mays L.) grown on sandy soil. Field experiments were conducted to assess the impact of various compost application rates on maize performance, including growth parameters, yield components, and soil properties. The results indicate that poultry dung compost improves maize growth and yield, enhances soil fertility, and contributes to better nutrient uptake. This study provides insights into the potential benefits of using poultry dung compost as a sustainable agricultural practice for enhancing maize production in sandy soils.

Keywords:

Maize, poultry dung compost, sandy soil, soil fertility, crop yield, organic fertilizers.

1. Introduction

Sandy soils are characterized by their low nutrient content, poor water-holding capacity, and limited organic matter. These properties often result in suboptimal crop growth and low yields. Organic amendments, such as poultry dung compost, offer a potential solution to enhance soil fertility and improve crop production. Poultry dung compost is a rich source of organic matter and nutrients, including nitrogen (N), phosphorus (P), and potassium (K), which are essential for plant growth.

Maize (Zea mays L.) is a major cereal crop with high economic value and is widely cultivated in various soil types. However, its productivity in sandy soils can be constrained by inadequate soil nutrients and water. This study aims to investigate the response of maize to poultry dung compost application on sandy soil, focusing on growth performance, yield enhancement, and soil quality improvement.

2. Literature Review

2.1 Poultry Dung Compost as a Soil Amendment

Poultry dung compost is derived from the decomposition of poultry manure mixed with organic materials such as straw or sawdust. It is known for its high nutrient content and beneficial effects on soil properties (Tian et al., 2020). The composting process transforms raw poultry manure into a stable and well-decomposed material that improves soil structure, water retention, and nutrient availability (Miller et al., 2019).

Studies have demonstrated that poultry dung compost enhances soil fertility, increases crop yields, and promotes sustainable agricultural practices (Khan et al., 2021). The compost adds organic matter to the soil, which improves soil aggregation, enhances microbial activity, and increases the cation exchange capacity (CEC) (Gao et al., 2022).

2.2 Maize Growth and Yield Response to Organic Amendments

Maize is a nutrient-demanding crop that benefits from the application of organic fertilizers. Organic amendments, including poultry dung compost, have been shown to improve maize growth parameters such as plant height, leaf area, and root development (Jat et al., 2018). Compost application also enhances maize yield by increasing the availability of essential nutrients and improving soil moisture retention (Ghosh et al., 2019).

In sandy soils, the application of organic compost can help overcome the limitations of low nutrient content and poor water-holding capacity. Several studies have reported positive effects of poultry dung compost on maize yield and quality, particularly in low-fertility soils (Khan et al., 2021; Sharma et al., 2020).

3. Materials and Methods

3.1 Study Site and Soil Characteristics

The study was conducted at the research farm of [Institution Name], located in [Location], with a sandy soil type characterized by low organic matter content and poor nutrient availability. The soil properties before treatment were as follows: sand 85%, silt 8%, clay 7%, pH 6.2, organic matter 1.2%, and CEC 5.0 cmol/kg.

3.2 Experimental Design

A randomized complete block design (RCBD) was used with four replications. The treatments included various rates of poultry dung compost applied to the sandy soil: 0 t/ha (control), 5 t/ha, 10 t/ha, and 15 t/ha. The compost was applied before planting and thoroughly mixed with the soil.

Maize seeds (variety [Specify Variety]) were sown at a spacing of 75 cm × 25 cm. Standard agronomic practices, including irrigation and pest control, were followed throughout the growing season.

3.3 Data Collection and Analysis

- Growth Parameters: Plant height, leaf area, and root length were measured at 30, 60, and 90 days after planting (DAP).

- Yield Components: Number of ears per plant, ear length, ear diameter, and grain yield per hectare were recorded at harvest.

- Soil Properties: Soil samples were collected before and after compost application for analysis of organic matter content, pH, and nutrient levels (N, P, K).

- Nutrient Uptake: The nutrient content of maize leaves and grains was analyzed for N, P, and K.

Data were analyzed using analysis of variance (ANOVA) and Duncan's multiple range test to determine the significance of differences between treatment means. Statistical significance was set at $p < 0.05$.

4. Results and Discussion

4.1 Growth Parameters

The application of poultry dung compost significantly influenced maize growth. At 90 DAP, maize plants treated with 10 t/ha and 15 t/ha compost were taller (mean height of 220 cm and 230 cm, respectively) compared to the control (185 cm). Leaf area and root length also increased with compost application, with the 15 t/ha treatment showing the highest values.

Table 1: Effect of Poultry Dung Compost on Maize Plant Height at 90 DAP

Compost Rate (t/ha)	Plant Height (cm)
0	185
5	200
10	220
15	230

4.2 Yield Components

Compost application significantly improved maize yield components. The number of ears per plant, ear length, and ear diameter increased with compost application. The highest grain yield was recorded with the 15 t/ha compost treatment, averaging 8.5 t/ha, compared to 5.0 t/ha in the control.

Table 2: Maize Yield Components and Grain Yield

Compost Rate (t/ha)	Ears/Plant	Ear Length (cm)	Ear Diameter (cm)	Grain Yield (t/ha)
0	1.8	15	4.5	5
5	2.0	16	4.8	6.2
10	2.2	17.5	5	7.8
15	2.3	18	5.2	8.5

4.3 Soil Properties

Soil analysis showed improvements in soil properties with compost application. Organic matter content increased from 1.2% in the control to 2.5% in the 15 t/ha treatment. Soil pH and nutrient levels (N, P, K) also improved with higher compost application rates.

Table 3: Changes in Soil Properties After Compost Application

Compost Rate (t/ha)	Organic Matter (%)	pH	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)

0	1.2	6.2	30	12	80
5	1.8	6.1	40	15	90
10	2.2	6.0	50	18	100
15	2.5	5.9	60	22	110

4.4 Nutrient Uptake

Nutrient analysis of maize leaves and grains showed increased uptake of N, P, and K with compost application. The 15 t/ha treatment resulted in the highest nutrient content, reflecting the improved availability of these nutrients in the compost-amended soil.

Table 4: Nutrient Content in Maize Grains

Compost Rate (t/ha)	Nitrogen (%)	Phosphorus (%)	Potassium (%)
0	1	0.3	0.8
5	1.2	0.4	0.9
10	1.5	0.5	1.1
15	1.8	0.6	1.3

5. Conclusion

The application of poultry dung compost significantly enhances the growth, yield, and nutrient quality of maize grown on sandy soil. The study demonstrates that composting poultry dung improves soil fertility, increases nutrient availability, and boosts maize productivity. Compost application rates of 10 t/ha and 15 t/ha were found to be particularly effective in promoting maize growth and yield. These findings underscore the potential of poultry dung compost as a sustainable and effective soil amendment for improving agricultural productivity in sandy soils.

References

1. Gao, Y., Li, S., & Wang, J. (2022). The impact of organic compost on soil fertility and plant growth: A review. Journal of Soil Science and Plant Nutrition, 22(1), 1-17.

2. Ghosh, S., Patel, S., & Sharma, R. (2019). Influence of poultry manure compost on maize growth and yield under different soil conditions. Agricultural Research Journal, 56(2), 227-235.

3. Jat, M. L., Gupta, R., & Verma, S. (2018). Effects of organic amendments on growth and yield of maize (Zea mays L.). Journal of Agricultural Science, 10(4), 45-58.

4. Khan, M. S., Qadir, M., & Aslam, M. (2021). Poultry dung compost application for sustainable maize production in sandy soils. Soil Use and Management, 37(2), 321-330.

5. Miller, R., Warren, M., & Marsh, J. (2019). Poultry manure compost: Benefits for soil health and crop growth. Organic Agriculture, 9(1), 17-28.

6. Sharma, P., Kumar, A., & Kumar, R. (2020). Role of organic compost in improving soil properties and maize productivity. Journal of Environmental Management, 269, 110818.

7. Tian, G., Zhang, X., & Sun, X. (2020). Effects of compost application on soil properties and crop yield: A meta-analysis. Agronomy for Sustainable Development, 40(2), 20-32.

Chapter -13:

Poly(3,4-ethylenedioxythiophene) functionalized with Selenium: It's synthesis and Thermoelectric characterization

Aniket Mondal[1] Krishanu Chatterjee[1] Shilpa Maity[2*]

[1]Department of Physics, Techno India University, Kolkata, India.

[2]Department of Physics, Swami Vivekananda University, Barrackpore, West Bengal- 700121, India

**Corresponding Author Email ID: shilpam@svu.ac.in*

Poly(3,4-ethylenedioxythiophene) functionalized with Selenium: It's synthesis and Thermoelectric characterization

Aniket Mondal[1] Krishanu Chatterjee[1] Shilpa Maity[2*]

[1]Department of Physics, Techno India University, Kolkata, India.

[2]Department of Physics, Swami Vivekananda University, Barrackpore, West Bengal-700121, India

**Corresponding Author Email ID: shilpam@svu.ac.in*

Abstract: Conducting polymers (CPs) are an important class of organic functional materials that integrates both conventional polymers and metal properties into one system. Conducting polymers may be mixed with inorganic nanoparticles of various types and sizes to create a variety of nanocomposites with intriguing physical and chemical characteristics and significant application potential. A hybrid poly3, 4ethylenedioxythiophene (PEDOT) and selenium (Se) composite was synthesized and its thermoelectric properties were measured as a potential thermoelectric material candidate for converting all the wasted heat energy in electrical power. X-ray diffraction (XRD) patterns, Fourier transform infrared (FTIR) spectroscopy, and field emission scanning electron microscopy (FESEM) were used to characterize all the generated samples. The samples' electrical conductivity and thermoelectric power was measure using a custom-made setup. The results showed that, in comparison to pure polymer or Se, the hybrid nanocomposites increased electrical conductivities led to improved power factors.

Keyword: Conducting Polymer, hybrid nanocomposites, thermoelectric materials

1. Introduction

In the face of the ongoing energy crisis and the escalating concerns over pollution and environmental degradation, the search for sustainable and clean energy sources has become an urgent global priority. The energy crisis we face today is driven by a growing demand for power, coupled with the depletion of traditional fossil fuel resources. Among the various technologies being explored, thermoelectric materials have emerged as a promising solution that offers a unique approach to addressing these interconnected challenges. The usefulness of a material in thermoelectric systems is determined by its device efficiency which is given by a dimensionless thermoelectric figure of merit, *ZT* determined by the material's electrical conductivity (σ), thermal conductivity (κ), and Seebeck coefficient (S), which change with temperature (T),

$$zT = S2T \qquad ...(1)$$

However, because an increase in conductivity (σ) causes Seebeck coefficient (S) and thermal conductivity (κ) to drop, it is difficult to enhance the thermoelectric figure of merit in bulk materials.

Conducting polymers (CPs) constitute an important class of organic functional materials that integrates both conventional polymers and metal properties into one system. Their unique physical and electrical properties, such as a wide range of conductivity, facile production, mechanical stability, light weight, low cost, being inexpensive, easy to synthesize, and suitable matrices for biomolecule immobilization have enabled them to find a wide range of application, including playing roles in supercapacitors, batteries, electrochromic devices, solar cells, sensors, and other biomedical applications [1-3]. Shirakawa et al.'s discovery that an organic polymer (i.e., polyacetylene) may achieve extraordinarily high electrical conductivities sparked numerous scientists' interest in the topic of conducting polymers,[4] often known as "synthetic metals". These kinds of polymers conduct electricity because of two processes: the conjugation of double bonds in the polymeric chains and the doping process [5]. The mobility of electrons in CPs can operate as charge carriers and delocalize into the conduction band thanks to the conjugated π electron and dopant ions, which increases the polymer's metallic behaviour [5]. The biggest advantage of conductive polymers is their processability, mainly by dispersion. Several CPs, including polyaniline (PANI), polypyrrole (Ppy), and polythiophene (PTh), have now gained widespread use over the course of time. To enhance the performance of the CPs, various composite materials have been synthesized with carbon-based materials, metals, or metal oxides, chalcogenides, etc.

Combining conductive organic polymers with inorganic materials might increase thermoelectric capabilities because hybridization of various materials at the nanoscale often enables us to take use of the strength of each constituent [6-8]. Among the several inorganic thermoelectric materials, selenium is a viable choice for conductive polymer hybridization. Selenium (Se) can be easily synthesized into nanocrystals, which can then be chemically changed into various thermoelectric materials like lead selenide (PbSe) and silver selenide (Ag_2Se) [9-12], which have high Seebeck coefficients at room temperature exceeding 1000 μV/K [12-14]. However, because Se crystal has a relatively low electrical conductivity (in the range of $1 \times 10^{-5} - 1 \times 10^{-6}$ S/cm), its thermoelectric performance is insufficient for any practical usage. Therefore, Conducive polymer can be employed as a conducting filler to improve the electrical conductivity of Se-based composites, which must be percolated in the composite even in a small composition to take advantage of the high Seebeck coefficient of Se. An appealing method to decrease the number of conductive polymer fillers is to coat colloidal particles with conductive polymers. This creates segregated conducting networks across the stacked particles. Due to its observable TE characteristics, PEDOT-based chalcogenide composites have recently gained attention in the realm of TE applications.

Thus, we can see only a small number of attempts have been made to investigate the impact of different fillers' morphologies on the effectiveness of polymer-chalcogenide composite materials, particularly Selenium, indicating that there is still plenty of room to enhance the

TE properties of polymer-chalcogenide composite materials. Herein a PEDOT-Se composite was synthesized and its thermoelectric properties measured.

2. Experimental

2.1. Materials

3,4-Ethylenedioxythiophene (EDOT) was used as the starting monomer and Sodiumdodecylsulfate (SDS) as the surfactants. For oxidizing, iron (III) Chloride Anhydrous ($FeCl_3$) was used for oxidation. EDOT monomer was purchased from Sigma Aldrich. SDS, $FeCl_3$ and Selenium were purchased from Merc Chemical and were used as it is. Acetone and Ethanol were also purchased from Merc Chemicals and were used as required. Distilled water was used as the solvent and was prepared in-situ.

2.2. Synthesis

To form the PEDOT nanoparticles, first 100mL of surfactant solution was prepared by dissolving 8.65g of SDS in 100mL distilled water in a beaker with the help of a magnetic stirrer and heated to 50ºC. A white milky solution formed after this process. Then the oxidant, 2.433g $FeCl_3$ was added into the surfactant solution to get a brownish solution like curdled milk (Figure 3). Then the dopant of our choice, Selenium was added in desired quantities in each sample batch while continuous stirring. After that 750 µL of monomer, EDOT was added using a micro pipette to form its polymer (PEDOT).

Six sample batches were synthesized with varying Selenium concentration as follows:

Sample Name	**Composition**
S_1	No Selenium (00 Wt.%)
S_2	06 Wt.%
S_3	22 Wt.%
S_4	33 Wt.%
S_5	66 Wt.%
S_6	82 Wt. %

The product in the solution was then centrifuged and washed with ethanol and filtered using vacuum filtration and then heated in a vacuum oven at 60ºC for 24 hours to remove any solvent. The particles were then grinded using mortar and pestle to get the nanoparticles.

2.3. Characterization

Powder x-ray diffraction (XRD) patterns, Fourier transform infrared (FTIR) spectroscopy, and field emission scanning electron microscopy (FESEM) were used to structurally characterize all the generated samples. Observations of X-ray powder diffraction was made using diffractometer (BRUKER D8 Advance) with Cu Kα radiation (λ=1.54182Å). A Hitachi (S3400N) FESEM was used to capture pictures to get insight into the samples' surface morphology. FT-IR spectra of the samples was recorded using a Shimadzu FTIR-8400S in the wavenumber range from 500 cm^{-1} to 4000 cm^{-1}.

All samples were cold pressed into round pellets using a hydraulic press to prepare them for the assessment of electrical transport parameters. The samples' electrical conductivity was measured using the four-probe technique. A temperature differential along the ends of the samples was established for the measurement of thermoelectric power, and a Keysight LXI data acquisition device (Model 34972A) was used to measure the associated generated potential.

3. Result and Discussion

3.1. Structural studies

The FT-IR Spectra is shown in the figure. The asymmetrical and symmetrical C=C stretching vibrations of the thiophene ring unit, respectively, are attributed to the bands at 1627 cm^{-1} and 1510 cm^{-1} for PEDOT [15, 16]. The thiophene rings' C-C stretching is what causes the vibration at 1300 cm^{-1} [16]. The ethylenedioxy group stretching and the C-O-C stretching of the thiophene ring, respectively, are shown by the vibration modes at 1140 cm^{-1} and 1048 cm^{-1} [17]. At 928 cm^{-1} and 761 cm^{-1}, respectively, the maxima for C-S-C deformation were seen [18].

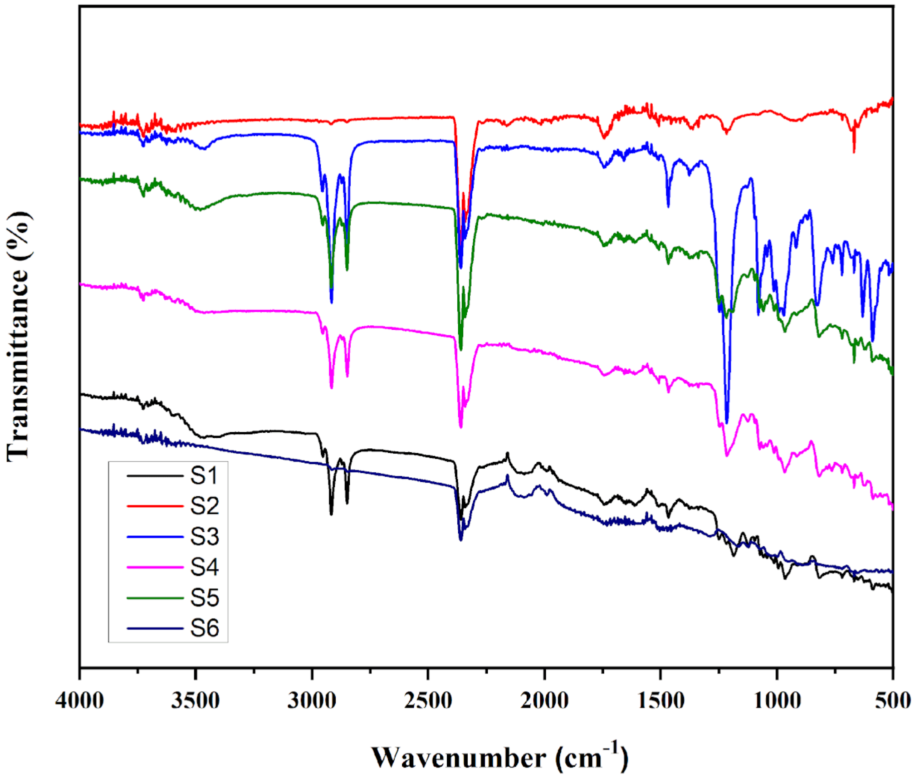
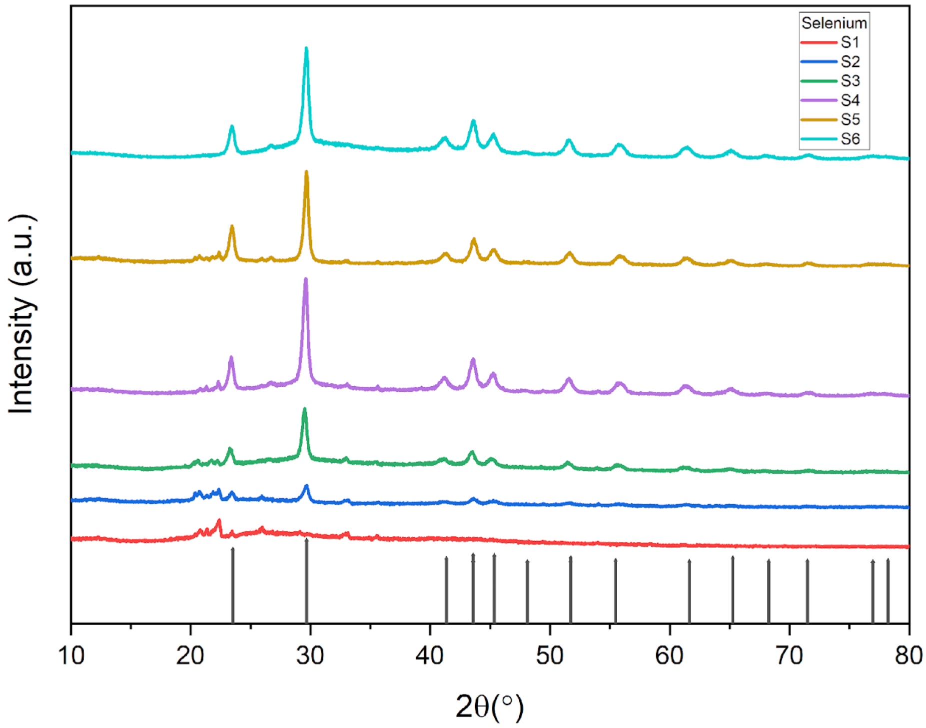


Figure 4: FTIR spectra of PEDOT-Se composite with varying composition between PEDOT and Se.

Here, Figure 4 shows the XRD patterns of synthesized samples that were made using diffractometer (BRUKER D8 Advance) with Cu Kα radiation (λ=1.54182Å). We can see a peak at a 2θ value of 22.37° which confirms the polymerization of EDOT. There is also a peak at 2θ value of 25.99° (d=3.4 Å) assigned to the (020) plane of an orthorhombic unit cell of PEDOT [19]. The rest of the major peaks belongs to different alignments of Se (JCPDS #06-0362), which can be seen to be enhanced by increasing amount of Se weight percent signifying the successfully integration of Se and PEDOT. We can see that Se crystallites have predominantly grown along the (101) direction



Structure of the prepared samples were observed under FESEM(Fig) to determine the morphology and see the effects of changing selenium weight percent with respect to PEDOT. PEDOT morphology was seen to be flake like with a layered structure. As more and more selenium was added, they started to form interconnections within themselves which might be the cause of increase in electrical conductivity as measured below. Selenium formed nanoparticle like structures with interconnection among themselves. At higher concentration it can see that majority of the PEDOT surface is covered with Se NPs.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mag □ 20 000 x
WD 12.3 mm
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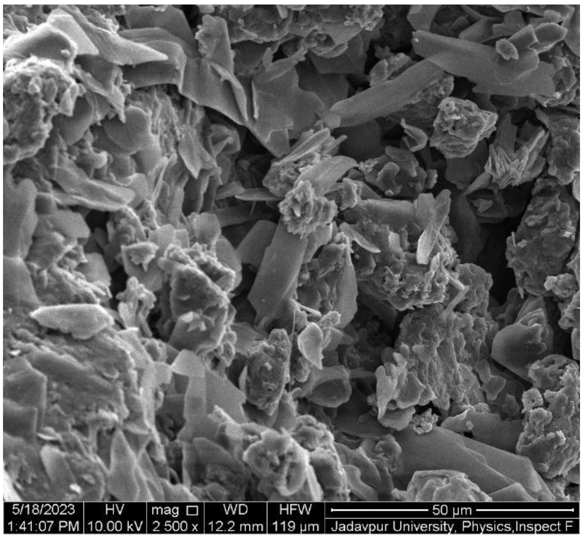
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WD 12.2 mm
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50 µm
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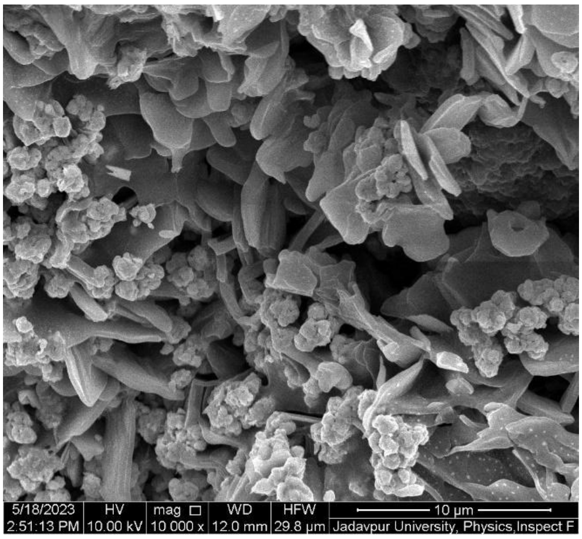
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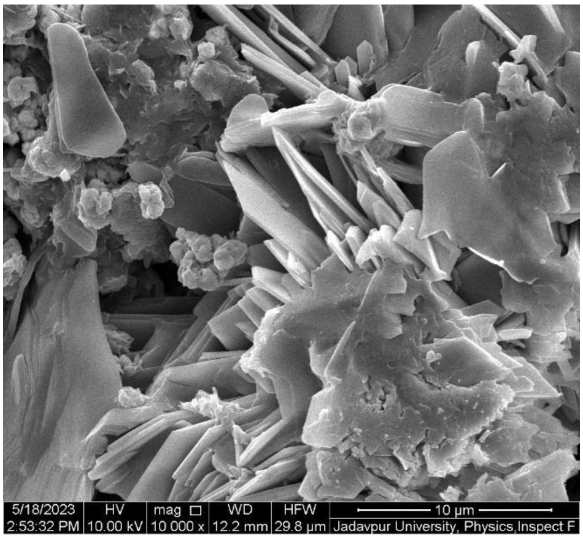
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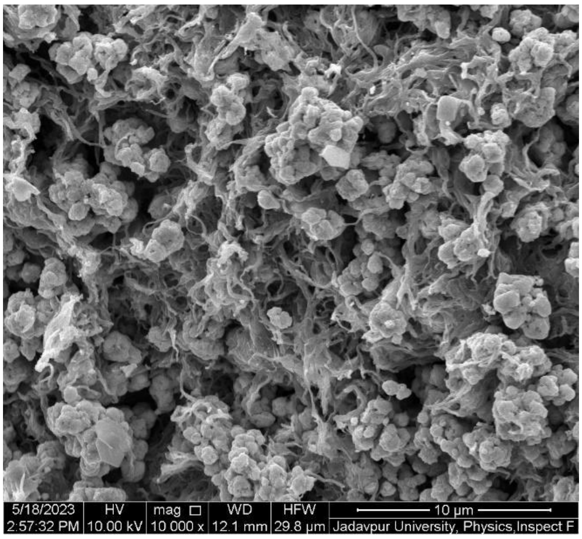
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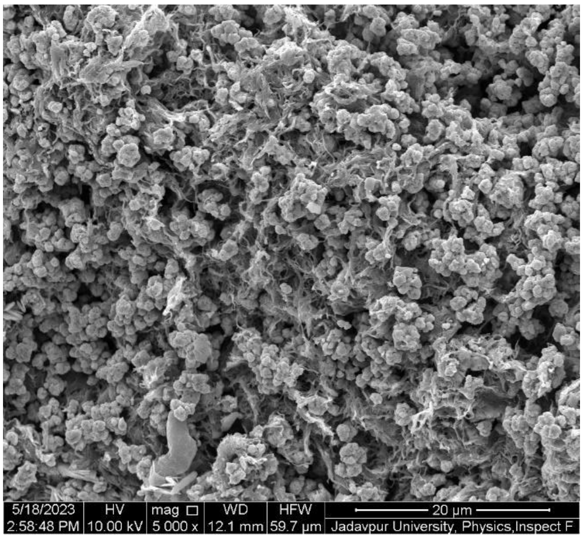
5/18/2023 2:58:48 PM
HV 10.00 kV
mag □ 5 000 x
WD 12.1 mm
HFW 59.7 µm
20 µm
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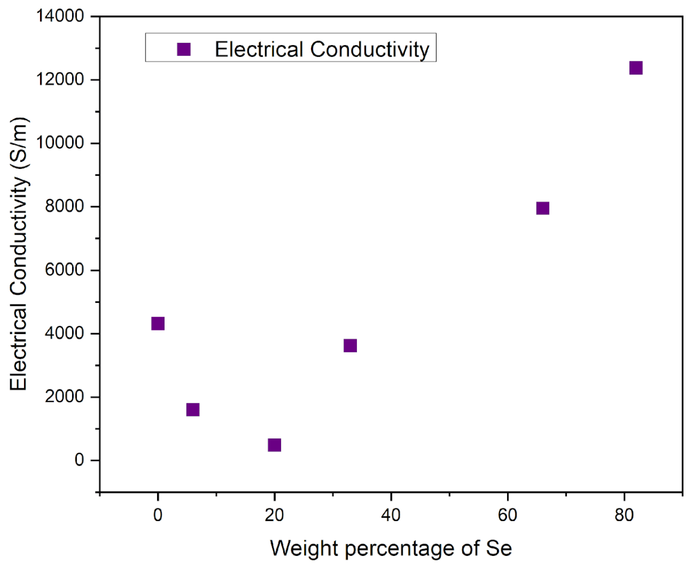
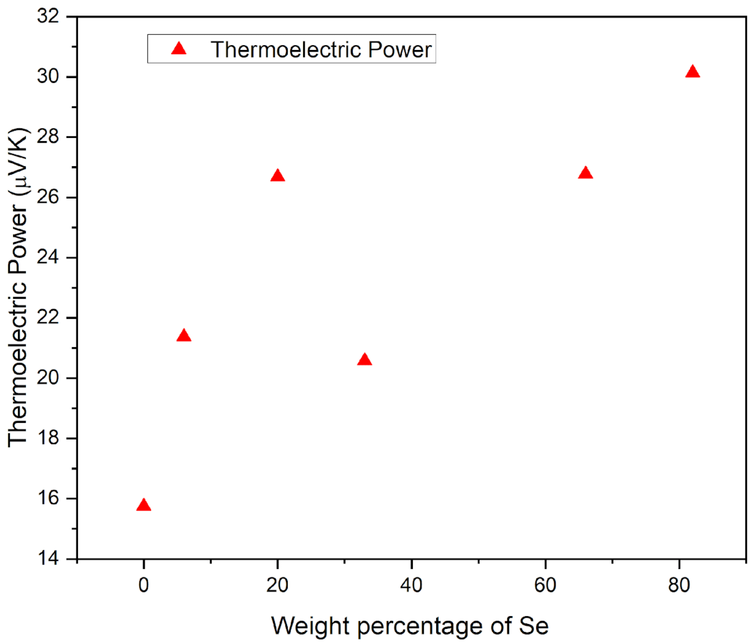
3.2 Electrical Characterization

To further characterize its TE properties, electrical conductivity of cold pressed pellets (bulk form) was measured by applying a small current on ends of a diameter and measuring the potential difference induced across the diameter perpendicular to it.

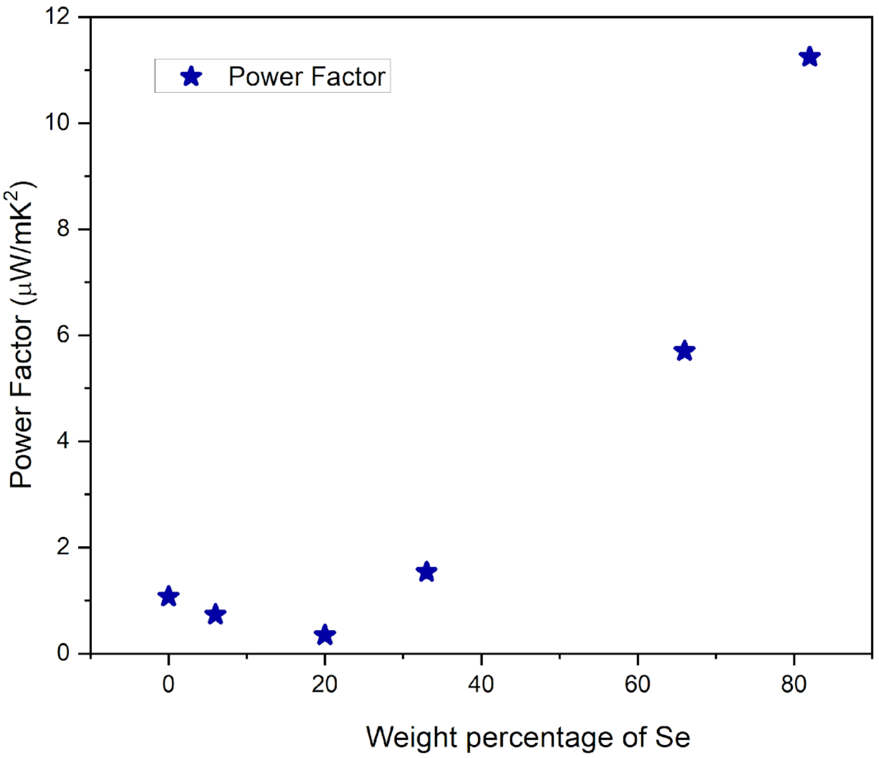


As we can see, first adding a little bit of Se decrease the conductivity but after a certain weight percent it starts to increase. With 80% Se content it attained the value of 12380 Sm^{-1}, which is just a few orders lower than some of the metals. The increase in σ can be attributed to the formation of Se nanowire connections, which helps conducting PEDOT form more ordered molecular arrangements. As seen in the XRD spectra. These arrangements result from a variety of interactions, including π - π bonds, electrostatic interactions, and hydrogen bonds between the two components. Thus, the carrier mobility and σ are improved by the polymer chain's increased degree of ordering.



The seebeck coefficient was measured using a custom-made setup in air (room temperature). Seebeck voltage and the temperature difference was measured using Keysight LXI data acquisition device (Model 34972A). Two J/C type thermocouples were located on opposing side to each other parallelly with the temperature gradient. The temperature difference was kept in the range of 5-10 K across its diameter. We can observe that adding Se improves the Seebeck coefficient from pure PEDOT. At room temperature, all the samples' S values are positive, suggesting that holes are the predominant carriers.

By evaluating the power factor, we can observe that, in comparison to pure polymer or Se, the hybrid nanocomposites increased electrical conductivity led to improved power factors for all compositions.



4. Conclusion

Thermoelectric materials have emerged as a promising solution to address the ongoing energy crisis and environmental concerns. To improve TE performance, several tactics are employed, such as modulation doping, band gap manipulation, modulation doping, and alloying with other TE materials. Chalcogenide materials could be ideal TE choices due to their high TE characteristics. In this work a hybrid PEDOT-Selenium composite (PEDOT/SE) was investigated to address this issue.PEDOT-Se composite was synthesized by oxidative chemical polymerization using $FeCl_3$ as a oxidant and SDS as surfactant with various composition of Se. XRD, FTIR and FESEM were carried out to characterize the prepared samples. Electrical conductivity and thermoelectric power were measured. Power Factor was calculated.

Reference

[1] G.M Laleh, M. P Prabhakaran, M. Morshed, M. H Nasr-Esfahani, H. Baharvand, S. Kiani, S.S Al-Deyab, S. Ramakrishna. Journal of Tissue Engineering and Regenerative Medicine 2011, e17–35.

[2] Abdelhamid, Muhammad E., Anthony P. O'Mullane, and Graeme A. Snook. RSC Advances ,15 (2015): 11611–26.

[3] G. Lviv, Y. Cao, J. Wang, H. Ren, J. Wang, and J. Huang. Ceramics International, 11 2020 18224–33.

[4] H. Shirakawa, E. J. Louis, A. G. MacDiarmid, C. K. Chiang, and A. J. Heeger. Journal of the Chemical Society, Chemical Communications, 1, 1977.

[5] K. Gagan, R. Adhikari, P. Cass, M. Bown, and P. Gunatillake. RSC Advances 47 2015, 37553–67.

[6] X. Jinhua, F. Jiang, H. Shi, J. Xu, C. Liu, W. Zhou, Q. Jiang, Z. Zhu, and Y. Hu. ACS Applied Materials & Interfaces 27 2015 14917–25

[7] Y. K. Shannon, N. E. Coates, A. Majumdar, J. J. Urban, and R. A. Segalman. Physical Chemistry Chemical Physics 11, 2013, 4024.

[8]. J. Bae, Y. H. Kang, K.S Jang, and S. Y Cho. Scientific Reports 1 2016

[9]. Park, Se Ho, J. Y. Choi, Y. H. Lee, J. T. Park, and H. Song, Chemistry - An Asian Journal 7 2015 1452–56.

[10]. M. Shuling, J. Zhao, S. Zhang, H. Niu, B. Jin, and Y. Tian. The Journal of Physical Chemistry C. 42 2009 18091–96.

[11]. Camargo, H. C. Pedro, Y. H Lee, U. Jeong, Z. Zou, and Y. Xia. Langmuir 6 2007, 2985–92.

[12] Henkels, W. Herbert, Physical Review 5 1950 734–36.

[13] Q. Jingkai, G. Qiu, J. Jian, H. Zhou, L. Yang, A. Charnas, D. Y. Zemlyanov, et al. ACS Nano 10 2017 10222–29.

[14] G. Byron, Y. Wu, Y. Yin, P. Yang, and Y. Xia. Journal of the American Chemical Society 46 2001 11500–501.

[15] S. Galina, G. Otrokhov, I. Vasil'eva, D. Pankratov, O. Morozova, and A. Yaropolov. Journal of Molecular Catalysis B: Enzymatic 81 2012 66–68.

[16] T. Yi-jie, H-f Cheng, W-w Zheng, Z. Y Zhang, and D.Q Liu. Synthetic Metals. 7 2012 728–34.

[17] L. Chun, and T. Imae. Macromolecules 7 2004 2411–16.

[18] Z. Kaixin, J. Xu, X. Zhu, L. Lu, X. Duan, D. Hu, L. Dong, H. Sun, Y. Gao, and Y. Wu. Journal of Electroanalytical Chemistry 739 2015 66–72.

[19] K.E. Aasmundtveit, E.J. Samuelsen, L.A.A. Pettersson, O. Inganäs, T. Johansson, and R. Feidenhans. Synthetic Metals 101, 1999): 561–64.

Chapter -14:

Synthesis of Gd_2O_3-Replaced 1393 Bioglass to Enhanced Mechanical Properties and Biocompatibility

Md Ershad, Priyam Mondel and Ranjan Kumar
Department of Mechanical Engineering, Swami Vivekananda University, Barrackpore, Kolkata-700121, India.

Corresponding Author: Md Ershad
Email: mdershad.rs.cer13@iitbhu.ac.in

Synthesis of Gd_2O_3-Replaced 1393 Bioglass to Enhanced Mechanical Properties and Biocompatibility

Md Ershad, Priyam Mondel and Ranjan Kumar

Department of Mechanical Engineering, Swami Vivekananda University, Barrackpore, Kolkata-700121, India.

Corresponding Author: Md Ershad

Email: mdershad.rs.cer13@iitbhu.ac.in

Abstract

The introduction of gadolinium oxide (Gd_2O_3) into 1393 bioglass is explored to enhance its mechanical properties, making it more suitable for biomedical applications such as bone regeneration and implant materials. This study investigates the synthesis, structural analysis, mechanical testing, and bioactivity of Gd_2O_3-doped 1393 bioglass. The results demonstrate significant improvements in compressive strength, fracture toughness, and hardness compared to undoped 1393 bioglass. Moreover, the modified bioglass exhibits comparable or enhanced bioactivity, indicating its potential as a superior biomaterial for orthopedic applications.

1. Introduction

1.1 Background

Bioglass materials have been widely researched and applied in the field of bone tissue engineering due to their excellent bioactivity and ability to bond with bone tissues. Among various compositions, 1393 bioglass has gained attention for its optimal balance of bioactivity and mechanical properties. However, the mechanical strength of 1393 bioglass is still a limiting factor in its application, particularly in load-bearing areas [1-3].

1.2 Motivation

To address the limitations of 1393 bioglass, researchers have explored the incorporation of various dopants. Gadolinium oxide (Gd_2O_3) is a rare earth oxide known for its high thermal stability, chemical durability, and potential to enhance the mechanical properties of glassceramic materials. This study investigates the potential of Gd_2O_3 as a dopant in 1393 bioglass to improve its mechanical properties while maintaining or enhancing its bioactivity [4-5].

1.3 Objective

This study aims to synthesize Gd_2O_3 -doped 1393 bioglass and evaluate its mechanical properties, structural characteristics, and bioactivity compared to undoped 1393 bioglass.

2. Materials and Methods

2.1 Materials

- **Base Glass Composition:** The base glass used in this study is 1393 bioglass, which typically contains silica (SiO_2), calcium oxide (CaO), sodium oxide (Na_2O), and phosphorus pentoxide (P_2O_5).
- **Dopant:** Gadolinium oxide (Gd_2O_3) of analytical grade is used as the dopant.

2.2 Synthesis of Gd2O3-Doped 1393 Bioglass

- **Melting Process:** The 1393 bioglass is prepared by the traditional melt-quenching method. The raw materials are weighed according to the stoichiometric ratios and mixed thoroughly. Gd_2O_3 is added in varying concentrations (e.g., 1- 2% by weight) to the mixture [6-9] .
- **Quenching:** The mixture is melted at high temperatures (approximately 1400-1500°C) in a platinum crucible and then rapidly quenched in water to form glass frits.
- **Annealing:** The glass frits are annealed at a specific temperature to relieve internal stresses and achieve a stable glass structure.

2.3 Characterization

- **X-Ray Diffraction (XRD):** Used to determine the crystallinity and phase composition of the synthesized glasses.
- **Scanning Electron Microscopy (SEM):** Provides microstructural analysis and surface morphology of the glass samples.
- **Energy Dispersive X-ray Spectroscopy (EDS):** Confirms the elemental composition and distribution of Gd_2O_3 in the glass matrix.

2.4 Mechanical Testing

- **Compressive Strength:** Measured using a universal testing machine to determine the maximum load the glass can withstand before failure.

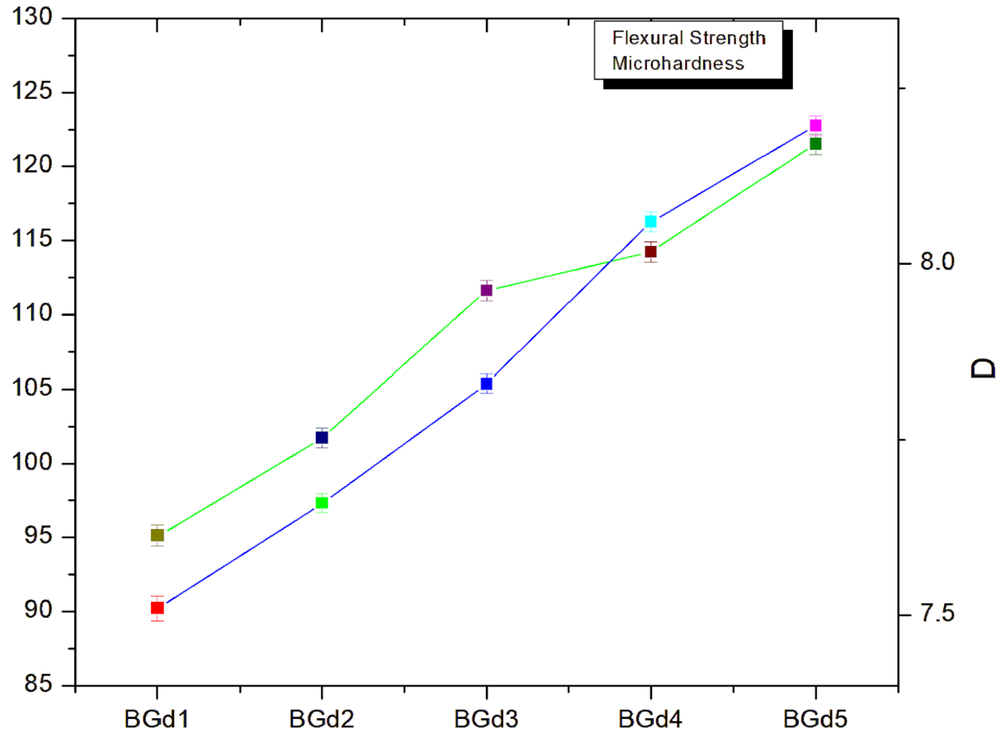


Figure 1 Mircrohardness and flexural strength of Gd sustituted 1393 glass

- **Fracture Toughness:** Evaluated using the single-edge notch beam (SENB) method.
- **Vickers Hardness Test:** Used to assess the hardness of the glass samples by applying a known force and measuring the indentation. Mircrohardness and flexural strength increases by increasing concentration of Gd up to 2% as shown in Figure 1

2.5 Bioactivity Assessment

- **Simulated Body Fluid (SBF) Immersion Test:** The bioactivity of the Gd_2O_3 -doped 1393 bioglass is assessed by immersing samples in SBF and analyzing the formation of hydroxyapatite (HA) layers using XRD and SEM in Table 1.

- Table 2. Ion concentration (mM/litre) of simulated body fluid and human blood plasma

Table 1 SBF concentration with Human body plasma

Ion	Simulated Body Fluid	Blood plasma
Na^+	142	142
K^+	5.0	5.0
Ca^{2+}	2.5	2.5
Mg^{2+}	1.5	1.5
HCO_3^-	4.2	27.0
Cl^-	148	103
HPO_4^{2-}	1.0	1.0
SO_4^{2-}	0.5	0.5

3. Results and Discussion

3.1 Structural Analysis

- **XRD Results:** The XRD patterns reveal that the incorporation of Gd_2O_3 does not significantly alter the amorphous structure of the 1393 bioglass. However, higher concentrations of Gd_2O_3 may lead to the formation of crystalline phases, which could influence mechanical properties.
- **SEM and EDS Analysis:** SEM images show a homogeneous distribution of Gd_2O_3 particles within the glass matrix. EDS analysis confirms the presence and uniform dispersion of gadolinium within the glass are shown in Figure 2.

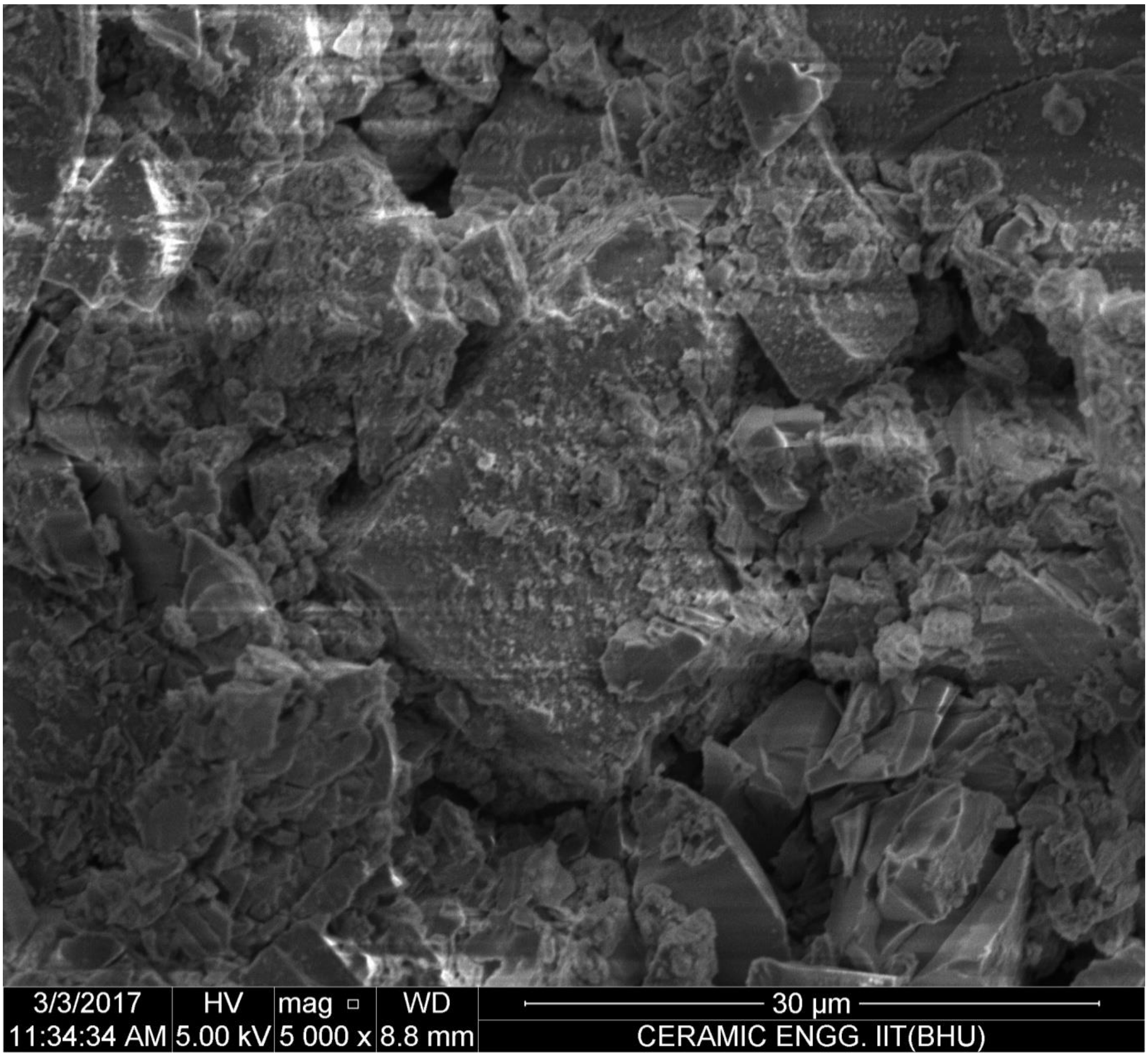


Figure 2 SEM of Gd sustituted glass for 2% samples

3.2 Mechanical Properties

- **Compressive Strength and Density:** The Gd_2O_3 -doped bioglass exhibits a marked increase in compressive strength compared to the undoped 1393 bioglass. The improvement is attributed to the densification of the glass structure and the reinforcing effect of Gd_2O_3. Density increases by increasing content of Gd^{3+} ion upto 2% are shown in Figure 3.

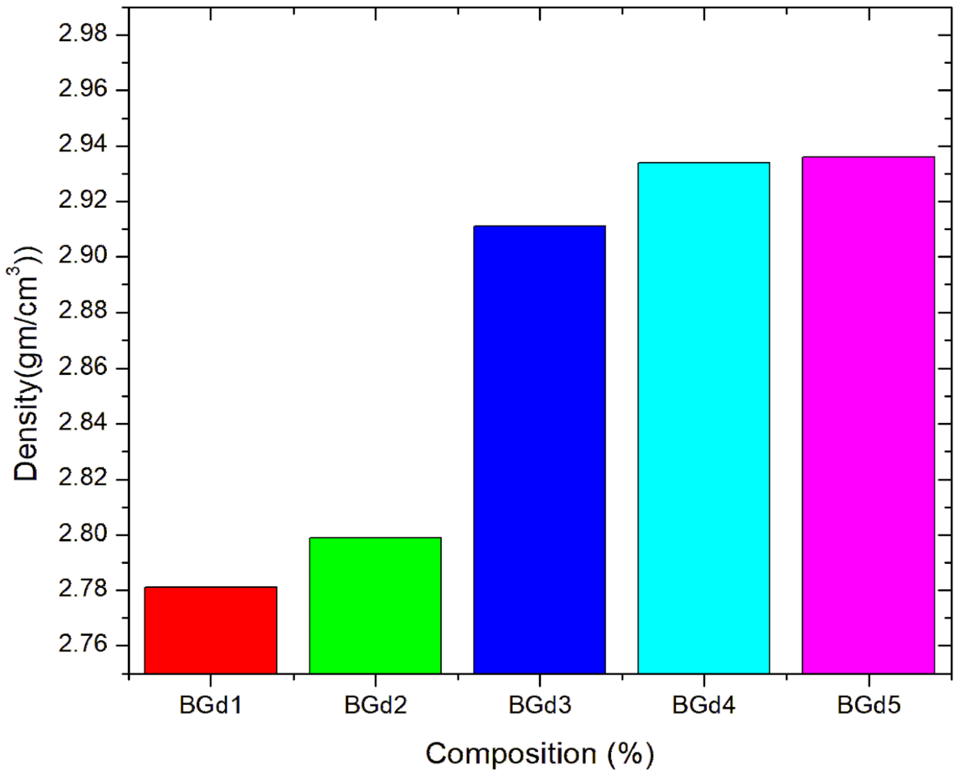


Figure 3 Density of Gd sustituted 1393 glass

- **Fracture Toughness:** Enhanced fracture toughness is observed in the doped samples, suggesting that Gd_2O_3 helps in improving the resistance to crack propagation.
- **Hardness:** The Vickers hardness test shows an increase in hardness with the addition of Gd_2O_3, indicating a more resistant glass surface.

3.3 Bioactivity

- **SBF Immersion Test:** The bioactivity tests demonstrate that Gd_2O_3 -doped bioglass retains or slightly enhances its ability to form HA layers in SBF, indicating that the dopant does not negatively affect the bioactivity of the glass.

4. Conclusion

This study demonstrates that the incorporation of Gd_2O_3 into 1393 bioglass significantly enhances its mechanical properties, including compressive strength, fracture toughness, and hardness, without compromising its bioactivity. The improved mechanical performance makes Gd_2O_3 -doped 1393 bioglass a promising candidate for orthopedic applications, particularly in load-bearing implants.

5. Future Work

Future research could explore the long-term in vivo performance of Gd_2O_3 -doped 1393 bioglass, including its degradation behavior, biocompatibility, and integration with bone tissue. Additionally, the effect of varying Gd_2O_3 concentrations on the overall performance of the bioglass should be investigated further to optimize its properties for specific biomedical applications.

References

1. Hench LL. The story of Bioglass®. J Mater Sci Mater Med. 2006;17(11):967-78. doi:10.1007/s10856-006-0432-z.
2. Fiume E, Barberi J, Verné E, Baino F. Bioactive glasses: From parent 45S5 composition to scaffold-assisted regenerative medicine. Pharmaceutics. 2019;11(11)
3. . doi:10.3390/pharmaceutics11110456.
4. Peitl O, Zanotto ED, Hench LL. Highly bioactive P2O5-Na2O-CaO-SiO2 glass-ceramics. J Non-Cryst Solids. 2001;292(1):115-26. doi:10.1016/S0022-3093(01)00803-1.
5. Saravanapavan P, Hench LL. Low-temperature synthesis, structure, and bioactivity of gel-derived glasses in the binary CaO-SiO2 system. J Biomed Mater Res A. 2001;54(4):608-18. doi:10.1002/jbm.1019.
6. Cao W, Hench LL. Bioactive materials. Ceramics International. 1996;22(6):493-507. doi:10.1016/0272-8842(95)00126-3.
7. Brink M. The influence of alkali and alkaline earths on the working range for bioactive glasses. J Non-Cryst Solids. 1997;209(1):13-21. doi:10.1016/S0022-3093(96)00565-6.
8. Shruti S, Salinas AJ, Lusvardi G, Malavasi G, Menabue L, Vallet-Regí M. Evaluation of zinc-containing mesoporous bioactive glasses for bone tissue regeneration. Acta Biomater. 2013;9(1):5718-30. doi:10.1016/j.actbio.2012.10.028.
9. Brauer DS. Bioactive glasses—structure and properties. Angew Chem Int Ed Engl. 2015;54(14):4160-81. doi:10.1002/anie.201405310.

Chapter -15:

A Comprehensive Review on the marble dust as a partial replacement of cement

Koustav Mukherjee[1], Nilanjan Tarafder[2]

[1]Postgraduate Student, Dept. of Civil Engineering, Swami Vivekananda University, Barrackpore, Kolkata, West Bengal, India; Email: koustavmukherjeekp97@gmail.com

[2]Assistant Professor, Dept. of Civil Engineering, Swami Vivekananda University, Barrackpore, Kolkata, West Bengal, India; nilanjant@svu.ac.in

A Comprehensive Review on the marble dust as a partial replacement of cement

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[1]Postgraduate Student, Dept. of Civil Engineering, Swami Vivekananda University, Barrackpore, Kolkata, West Bengal, India; Email: koustavmukherjeekp97@gmail.com

[2]Assistant Professor, Dept. of Civil Engineering, Swami Vivekananda University, Barrackpore, Kolkata, West Bengal, India; nilanjant@svu.ac.in

Abstract:

This research paper provides an in-depth analysis of various partial replacements for materials like waste foundry sand, fly ash, GGBS, and marble dust. It begins by discussing the significance of different concrete grades. The literature review then compiles existing studies, focusing mainly on tests conducted on concrete, such as UPV, split tensile strength, flexural, compressive, and XRD tests. The paper concludes by emphasizing the potential of waste marble dust as a partial cement replacement, highlighting its potential to enhance sustainability, improve mechanical properties, and reduce the environmental impact of concrete production.

Keywords: Concrete, Marble dust, Strength property, UPV, Split tensile test, compressive test

Introduction:

Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens over time. When the ingredients are mixed together, they form a fluid mass that is easily mouldable into various shapes. Over a period of time, this mass hardens and gains strength. Figure 1 represents the concrete.

Figure 1: Concrete

In recent years, the search for more sustainable and eco-friendly alternatives to traditional concrete has gained momentum. Traditional concrete, primarily made with Portland cement, is associated with significant environmental impacts due to high carbon dioxide emissions during cement production. Here are some notable replacements and alternatives to conventional concrete:

Fly Ash:

A by-product of coal combustion in power plants, fly ash can replace a significant portion of cement in concrete. It improves workability, reduces water demand, and enhances the long-term strength and durability of concrete.

Marbel dust:

Marble dust is an alternative material used in cement production for concrete. It is a by-product of the marble industry, composed of fine particles created during marble cutting, grinding, and polishing.

Ground Granulated Blast Furnace Slag (GGBFS):

A by-product of steel production, GGBFS is a highly effective cement replacement material. It improves the durability of concrete, especially in harsh environments, and reduces the heat of hydration, which minimizes the risk of thermal cracking.

Silica Fume:

A by-product of silicon and ferrosilicon alloy production, silica fume is used in small amounts to enhance the strength and durability of concrete. It reduces permeability and improves resistance to chemical attacks.

Rice Husk Ash (RHA):

Produced by burning rice husks, RHA is a highly reactive pozzolan that can partially replace cement. It improves the strength and durability of concrete while also reducing its weight.

Limestone Powder:

Finely ground limestone can be used to replace a portion of the cement in concrete. It enhances workability and contributes to early strength development.

Natural Pozzolans:

Volcanic ash, pumice, and other natural pozzolans have been used for centuries to improve the properties of concrete. They contribute to long-term strength and durability.

Metakaolin:

A calcined form of kaolinite clay, metakaolin is a highly reactive pozzolan that enhances the mechanical properties and durability of concrete.

Recycled Concrete Aggregate (RCA):

Crushed concrete from demolished structures can be used as an aggregate in new concrete production, reducing the need for natural aggregates and lowering the overall environmental impact.

Marble Dust:

Marble dust, a by-product of the marble industry, is an alternative material used in cement production for concrete. It consists of fine particles generated during the cutting, grinding, and polishing of marble. When used as a partial replacement for cement in concrete, marble dust offers several benefits. Figure 2 represents the marble dust.

Figure 2: Marble Dust

Improved Strength:

Marble dust can enhance the compressive strength of concrete due to its fine particles and high calcium content.

Environmental Benefits:

Utilizing marble dust reduces waste and lowers the demand for cement, which in turn decreases carbon emissions associated with cement production.

Cost-Effective:

Marble dust is often a cheaper alternative to cement, making it a cost-efficient option in concrete production.

Enhanced Aesthetics:

The use of marble dust can improve the finish and appearance of concrete, giving it a smoother texture and potentially adding a glossy surface.

Literature Review:

The author presented this paper to assess the reliability of the Ultrasonic Pulse Velocity (UPV) method for detecting horizontal cracks and flaws within self-compacting concrete (SCC) and to evaluate its effectiveness in measuring horizontal cracks in SCC. The results indicated that UPV can detect horizontal cracks in SCC, provided the transducers are placed within a limited distance, which varies based on the position and direction of the readings, as well as the location of the cracks (Ashraf M. Heniegal).

The paper examines the impact of transducer frequency on assessing concrete homogeneity using the ultrasonic pulse velocity (UPV) test. Measurements were conducted on a 590 × 590 mm concrete slab, 110 mm thick, across a grid of 5 × 5 points, resulting in 25 test locations. A Pundit PL-200 ultrasonic tester with transducers set at frequencies of 54, 82, and 150 kHz was used. Two measurement types were performed: spot measurements of ultrasonic pulse transit time at each point and full area scanning. The paper concludes with an evaluation of the slab's homogeneity based on different transducers and techniques, supplemented by a statistical analysis of the influence of transducer frequency on the results (Dalibor Kocáb , Petr Misák, Barbora Jindrová, Martin Alexa, Tomáš Vymazal).

This study begins with an overview of the impact echo (IE) method and includes a case history demonstrating its application in testing concrete structures. The IE method is used to locate damage and determine the thickness of members when only one side is accessible. Non-destructive testing (NDT) allows for the determination of the shear wave velocity profile versus depth in layered systems and is particularly useful for testing pavements, slabs, tunnels, shaft liners, and large concrete structures. For bridges and dams, the IE technique is especially effective in determining the depth of weathering effects on concrete. Advances in UPV testing involve rapid scanning techniques that significantly enhance the speed and utility of UPV testing. The UPV method uses compression wave energy sent through a member, with the arrival time, wave amplitude, and velocity being recorded (Dennis A. Sack and Larry D. Olson,).

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This study explores the impact of marble dust as a partial cement replacement on the compressive strength of concrete. Concrete cubes of 150 mm size were cast for M25 and M30 grades with marble dust replacing 0%, 5%, 10%, 15%, and 20% of cement by weight. Maximum compressive strength was observed with a 10% marble dust replacement for both grades. Ultrasonic Pulse Velocity (UPV) testing showed good quality concrete at up to 15% replacement. Results indicated a strong correlation between compressive strength and UPV, with supporting marble dust use up to 10% as a cement substitute (Gurcharan Singh 1 , S.K. Madan).

This study examines the effect of corrosion on reinforced concrete using Ultrasonic Pulse Velocity (UPV) testing with Proceq Punditlab and 54kHz transducers. Testing was conducted on 54 specimens with different water-cement ratios and subjected to either non-accelerated or accelerated corrosion conditions. Results showed minimal UPV changes in non-accelerated conditions, while accelerated corrosion caused over 20% strength reduction near reinforcing bars and less than 15% elsewhere. This highlights the significant impact of corrosion on both the immediate and surrounding areas of reinforced concrete (Jason Maximino C. Ongpeng, Larissa D. KIRCHHOF, Alexandre LORENZI, Luiz Carlos P. SILVA FILHO).

This paper examines the impact of elevated temperatures on the residual strength of concrete using ultrasonic pulse velocity (UPV). Cylindrical specimens with water-cement ratios of 0.25, 0.30, and 0.50 were subjected to heating in an electric furnace, ranging from 200°C to 600°C. After heating, the specimens were cooled to room temperature inside the furnace and then tested. Each specimen underwent measurements of UPV and compressive strength. Based on the correlation between UPV and residual strength ratios, a general equation was developed to predict the compressive strength of concrete at high temperatures. The findings demonstrate the reliability of UPV as an effective tool for analyzing fire-damaged concrete structures (Larissa D. KIRCHHOF, Alexandre LORENZI, Luiz Carlos P. SILVA FILHO).

In an experimental study, tests were conducted on plain concrete slabs of various grades, including Ultra-High Performance Concrete (UHPC). Direct ultrasonic pulse velocity (UPV) tests were performed between the top and bottom surfaces, while indirect tests were conducted along the surface. Statistical analysis revealed that direct UPV values were 16.5% higher than indirect UPV values due to transducer positioning. Key findings include a strong correlation between compressive strength and direct UPV, greater homogeneity in UHPC compared to ordinary concrete, and a 9% increase in UPV for UHPC compared to grade 40 concrete. Additionally, the duration of curing significantly influences UPV results (M. N. Azreen ,I.M. Pauzi2, I. Nasharuddin , M.M. Haniza , J. Akasyah , A.D. Karsono).

In this research paper, the author introduced the fundamental principles of the pulse-echo method used to detect internal flaws within concrete (Nicholas J. Carino and Mary Sansalone).

An experimental study compared direct, indirect, and semi-direct ultrasonic pulse velocity (UPV) measurements on 30 concrete blocks with compressive strengths ranging from 18.8 to 79.9 MPa. Statistical analysis revealed that UPV measurements were influenced by the direction of concrete casting, with UPV in the casting direction being lower due to bleeding at the aggregate-cement paste interface. Direct UPV was found to be 9% higher than indirect UPV in the casting direction and 4% higher in the horizontal direction. Additionally, indirect UPV in the horizontal direction was 5% higher than in the casting direction (P. Turguta and O. F. Kucukb).

The objective of this project was to investigate the relationship between initial setting time and traditional sawing time. Sixteen construction sites across Minnesota and Missouri were visited over a span of two years. At each site, initial set times were determined using a p-wave propagation technique employing a commercial device. Additionally, calorimetric data were gathered at most sites using a commercial semi-adiabatic device. Concrete samples were taken in front of the paver and tested using both methods, utilizing equipment set up adjacent to the pavement during paving operations. The data collected indicated the following findings: Early entry sawing commenced approximately 220 minutes after initial set, while conventional sawing typically began between 310 and 390 minutes after initial set (Peter Taylor and Xuhao Wang).

In this study, the focus is on exploring the correlation between ultrasonic pulse velocity (UPV) and the compressive strength of concrete. The authors investigate the influence of coarse aggregate content as a factor in examining this relationship in hardened concrete. A total of 800 concrete specimens were used in the study, categorized across a strength range of

18 to 55 MPa. UPV measurements and compressive strength tests were conducted at the age of 28 days. The paper proposes new approaches to establish clear formulas or curves linking UPV with compressive strength, aiming to enhance the application of UPV in non-destructive evaluation of concrete strength in construction projects in Iraq (Erbil Iraq, Prof. Dr. Bayan S. Al-Nu'man [1], Bestoon R. Aziz [2], Sabr A. Abdulla [2], Sirwan E. Khaleel).

In this study, the method used to evaluate the thickness of layers to be removed due to fire damage involved the Ultrasound Pulse Velocity (UPV) technique with point heads. Samples were taken from a structure post-fire for examination. This approach allowed for a detailed assessment of the influence of high temperatures in areas where visible cracks were no longer present. Additionally, to enhance the accuracy of the analysis, factors such as concrete porosity were considered to isolate the effects solely attributable to the fire. The ultrasound method facilitates determining the actual strength of concrete at the depth of fire-exposed slabs or other structural elements, which is crucial for assessing the integrity of the compressed zone (Roman Wróblewski and Bohdan Stawiski).

Experimental UPV values were measured for 68 concrete mix designs using various binders like Portland cement with fly ash, blast furnace slag, and silica fume. UPV ranged between 4700 and 5400 m/s, decreasing with higher water-to-cement ratios, except in silica fume concrete. UPV was higher at 91 days compared to 28 days due to more hydrated products and less void space. While UPV correlated with compressive strength at 28 days (except for silica fume), the correlation at 91 days was more complex. The study suggests including UPV in dosage diagrams and proposes empirical models for estimating UPV in concrete. (Sandro E. S. Mendes1 , Rafael L. N. Oliveira , Claiton Cremonez , Eduardo Pereira , Elias Pereira, Ronaldo A. Medeiros-Junior).

This study aims to estimate the compressive strength of concrete structures over time using the ultrasonic pulse velocity method. By correlating ultrasonic pulse velocity with compressive strength, the early-age strength at new construction sites and the strength of existing structures during remodeling can be predicted. Concrete specimens were tested at various ages, showing a sharp increase in ultrasonic pulse velocity from 16 to 72 hours, with a slower increase up to 672 hours. Compressive strength measurements followed a similar trend, reaching 91.09% of the design strength by 672 hours (Seonguk Hong , Sangki Yoon , Jonghyun Kim , Changjong Lee , Seunghun Kim).

This paper examines the use of ultrasonic pulse velocity testing to evaluate concrete for uniformity, cavities, cracks, and defects. The pulse velocity method, which is influenced by the material's density and elastic properties, provides insights into concrete quality and compressive strength. Key findings include the method's effectiveness in detecting poor-quality concrete, which can lead to corrosion, and its reliability in assessing uniformity and identifying defects. The study highlights the method's simplicity, speed, and applicability to both concrete specimens and existing structures. (Tarun Gehlot , Dr. S.S. Sankhla , Dr. S.S. Gehlot , Akash Gupt).

This paper presents a study on the impact of incremental compressive stress on the measured ultrasonic pulse velocity (UPV) in concrete. The study involved 80 cube samples made from 8 different grades of mix proportions: M10, M20, M30, M40, M50, M60, M70, and M80. After 28 days of curing, each specimen underwent monotonic axial loading in stages until failure, during which UPV values were recorded. The change in pulse velocity was observed to correlate with the increasing levels of stress.Key findings from the study include:As the compressive stress applied to the components increases, the UPV decreases.The reduction in UPV is influenced by both the applied stress and the presence of micro-cracking (Vishwajeet Surshetwar[1], Krishna Gattewar[2], Bhagyashree Wange[3], Trupti Gavit[4], Mr. Ravi Ranade[5], Mrs. Prital G. Kalasur[6]).

The study investigated the propagation of ultrasonic waves through a solid material, enabling tomographic reconstruction of its interior to detect cracks, voids, and variations in material consistency. The author conducted a study on tomographic reconstruction based on ultrasonic test results performed on concrete prisms. Measurements of ultrasonic wave time-of-flight (TOF) were conducted on three concrete prisms with different compressive strengths, as well as one prism cast using two distinct concrete compositions.The prisms were tested both before and after inducing damage. The study assessed the heterogeneity of concrete and utilized techniques of image reconstruction implemented in new software to obtain tomographic images. The author demonstrated that ultrasonic tomography can serve as a valuable tool for evaluating damaged structures (Vladimir Guilherme Haach et.al).

Research Gap:

Marble dust, an industrial waste produced from the sawing, shaping, cutting, and polishing of various marbles, poses a significant environmental hazard. Approximately 6.8 million tonnes of marble dust are currently being disposed of annually in Rajasthan, Gujarat, and Madhya Pradesh in India. While previous studies have explored its use as a substitute for fine aggregates, its particle size distribution, which closely resembles that of cement, suggests it could be better suited for partial cement replacement in concrete. However, limited research has been conducted on the use of marble dust in concrete, especially regarding its effects on strength and durability. Therefore, this study investigates the use of marble dust as a partial cement replacement in concrete to assess its impact on strength, durability, and homogeneity.

Reference:

Vishwajeet Surshetwar[1], Krishna Gattewar[2], Bhagyashree Wange[3], Trupti Gavit[4], Mr. Ravi Ranade[5], Mrs. Prital G. Kalasur[6] (2020) ‘’ Effect of Compressive Stress on Ultrasonic Pulse Velocity’’

Prof. A.R. Gupta[1]& Mr. Tushar A. Jaiswal[2] (2019), ‘’NDT, Ultrasonic Pulse velocity Test Assessment, Procedure and Limitation’’

Ayswarya K.S[1], Ann Maria Johnson[2], Chaithanya[3], Devika Prasad[4], Dhanya Krishnan R[5], Radhika Nair N J[6] (2016), ‘’Evaluation of Bridge Performance Using Non-Destructive Testing - A Review’’

Prof. Dr. Bayan S. Al-Nu’man [1], Bestoon R. Aziz [2], Sabr A. Abdulla [2], Sirwan E. Khaleel[2] (2015),‘’Compressive Strength Formula for Concrete using UltrasonicPulse Velocity’’ Erbil Iraq.

Vladimir Guilherme Haach et.al. (2014), ‘’Application of ultrasonic tomography to detection of damage in concrete’’

Mahdi Shariati, Nor Hafizah Ramli-Sulong, Mohammad Mehdi Arabnejad K. H., Payam Shafigh and Hamid Sinaei (2010), ‘’Assessing the strength of reinforcrd concrete structures through ultrasonic pulse velocity and schmidt rebound hammer tests’’

Chapter -16:

A Review on Mathematical Models of Enzyme Secretion and Glucose Metabolism

Sreya Saha[a], *Najnin Islam[b,*] and Souvik Kundu[c]*

[a] Department of Mathematics, Amity University, Kolkata, 700135, West Bengal, India

[b] Department of mathematics, Swami Vivekananda University, Kolkata, 700121, West Bengal, India

[c] Department of Mathematics, Heritage Institute of Technology, Kolkata, 700107, West Bengal, India

E-mail address: najnin.islam92@gmail.com

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Sreya Saha[a], *Najnin Islam[b,*] and Souvik Kundu[c]*

[a] Department of Mathematics, Amity University, Kolkata, 700135, West Bengal, India

[b] Department of mathematics, Swami Vivekananda University, Kolkata, 700121, West Bengal, India

[c] Department of Mathematics, Heritage Institute of Technology, Kolkata, 700107, West Bengal, India

E-mail address: najnin.islam92@gmail.com

Abstract

The aim of the paper is to study enzyme reactions, specifically enzyme inhibition, and glucose metabolism and understand how these biological phenomena can be depicted using mathematical models. It also contains issues that can occur due to abnormalities in glucose metabolism (for example - diabetes, death of cone cells in the eye, etc.).We also look into the use EEG in studying about epilepsy.

Introduction:

Diabetes Endocrine glands are ductless glands that release their produced substance directly into the blood stream. The endocrine system is a system of structures within the body that work together to monitor, produce, and secrete hormones throughout the body. Glucose metabolism is essential for heart physiology, especially in ischemic conditions (lack of enough blood and oxygen supply). Anaerobic glycolysis participates along with aerobic fatty acid oxidation in generating energy supply, and the balance is shifted towards fatty acids. In the case of aerobic path restriction due to coronary artery disease (CAD), this ratio changes. The aim of the present research was to discover the aspects of glycolysis in cardiac electrophysiology. [65][66]

The alpha cells of the pancreatic islets produce glucagon. It is released when our blood sugar levels are low (for example overnight, or if you have been fasting or exercising). Glucagon stimulates cells in the liver and muscles to convert stored glycogen to glucose. The glucose is then released into the bloodstream, raising the blood sugar level.

The beta cells of the pancreatic islets produces insulin. Insulin is released when the level of glucose is high in our bloodstream (for example, when we eat a meal). It works by stimulating the uptake of glucose into cells, lowering the blood sugar level. The liver and muscles can take up glucose either for immediate energy or to be stored as glycogen until it is needed.[1]

Epilepsy Epilepsy is a chronic disease that results in a sudden change in the patient's consciousness and behaviour. It is caused by a dysfunction of the brain's neural activity. Approximately fifty million people suffer from epilepsy [16]. Seizures are generalized as well as focal. The generalized seizures are brief episodes of involuntary movement that may involve the entire body. The focal seizures originate in one side of the brain. Most of the detection of epilepsy are based on the use of the electroencephalogram (EEG) signal. The EEG signal is widely employed as one of the most important tools in clinical practice to assess the neurological status of epileptic patients [17]. The EEG signal can be recorded invasively or non-invasively (scalp-EEG). The scalp-EEG is more commonly used than the depth-EEG due to its applicability and its ease of use. Conventionally, highly skilled neurologists perform a visual analysis of EEG recordings to detect epileptic seizures (ESs). Yet, a visual analysis of such large amount of EEG signals has been a burdensome, time-consuming, costly process and is subject to error and bias. Thus, automatic processing systems can be of great assistance to neurologist clinicians.

Many methods have been proposed to automatically detect ES episodes by comparing feature extraction and pattern classification. Traditionally, the relative spike amplitude and the spike rhythmicity were usually used as time- domain feature inputs for epilepsy classifiers. Indeed, the high correlation links between large spike occurrence frequency and small inter-spike interval provide a good sign of epilepsy as mentioned in [26, 27]. The mean spike rate differs from interictal to preictal, and from ictal to postictal states [28]. In fact, time-domain features can be suitable for real-time applications. However, they are difficult to extract because of the EEG morphology and the presence of noise.

Enzyme Inhibition Enzyme inhibitors are occurred as molecules. They are involved with catalysis and enzymatic reactions. Study of enzyme inhibitors provided a good information about enzyme mechanisms and helped us to define some metabolic pathways. Reversible and irreversible inhibitors are two main important types of enzyme inhibitors. Reversible inhibitors are also classified into three types: competitive inhibitors, uncompetitive inhibitors and mixed inhibitors.[39]

Retinal Degeneration In mammals, there are twenty rods per cone. The photoreceptors are the most metabolically demanding cells in the body and are in constant need of nutrients, glucose, lipids, and metabolites for maintenance [44]. In order to prevent the toxic effects of accumulated photo-oxidative products, the photoreceptors undergo renewal and periodic shedding of their outer segment (OS) discs . The preservation and vitality of photoreceptors is critical as after the age of 5-6 years old there is no spontaneous birth of photoreceptors in human eye.[45] These light-sensitive cells lie at the back of the retina adjacent to the retinal pigment epithelium (RPE), a cell layer that is vital for the survival of photoreceptors.[42] Retinal membrane s an area called macula, which is yellow in colour. The highest concentration of cone cells is contained in fovea which is present at the center of macula. The part of the image projected on the fovea is usually the most accurately registered visual memory. [42]

Modeling the rapid-acting insulin:

The following model is used to demonstrate the absorption of human insulin and intermediate-acting insulin:

$$\frac{\partial H(r,t)}{\partial t} = -p(H(r,t) - q^{D^3}(r,t)) + d\nabla^2 H(r,t)$$

$$\frac{\partial D(r,t)}{\partial t} = p\left(H(r,t) - q^{D^3}(r,t)\right) + d\nabla^2 D(r,t) - bD(r,t) - S[C - B(r,t)]D(r,t) + \frac{B(r,t)}{T}$$

$$\frac{\partial B(r,t)}{\partial t} = S[C - B(r,t)]D(r,t) - \frac{B(r,t)}{T}$$

where, t → time (min)

r → radial distance from the injection point

H → hexameric insulin concentration (U/ml) in the subcutaneous tissue at (r, t) D → dimeric insulin concentration (U/ml) in the subcutaneous tissue at (r, t) B → bound insulin concentration (U/ml) in the subcutaneous tissue at (r, t) b → absorption rate constant

q → chemical constant between the different insulin states p → corresponding rate constant, d is the diffusion constant C → volumetric binding capacity T → bound insulin lifetime S → binding rate constant.

Modeling the long-acting insulin analogues:

$$\frac{\partial H(r,t)}{\partial t} = -p(H(r,t) - q^{D^3}(r,t)) + kB(r,t)[C_{\max} - H(r,t)] + d\nabla^2 H(r,t)$$

$$\frac{\partial D(r,t)}{\partial t} = p\big(H(r,t) - qD^3(r,t)\big) - bD(r,t) + d\nabla^2 D(r,t)$$

$$\frac{\partial B(r,t)}{\partial t} = -kB(r,t)[C_{\max} - H(r,t)] + d_B d\nabla^2 B(r,t)$$

where, C_{max} → a parameter to be identified, is the maximum concentration of hexamer in the injection depot

$k > 0$ → proportional factor of disengagement of insulin analogue in the depot b → absorption rate.

$d_B \in [0, 1]$ → non-dimensional factor that reduces the diffusion effect, and all other notations remain the same as in the above model of rapid-acting insulin.

The EEG data description

The EEG signal database used in this study is provided by Bonn University, Germany [34]. It is an open-source database which consists of five data sets: A, B, C, D and E. Each of these data sets contains one hundred single-channel recordings of EEG signals. Each EEG signal is recorded with a 128-channel amplifier system and digitized with a sampling rate of 173.61 Hz and a 12-bit A/D resolution. The duration of these EEG signals is 23.6 s. The sets A and B contain surface EEG signals that are recorded on five healthy subjects using the standardized 10–20 system for electrode placement. The subjects were awake and relaxed with their eyes open and closed, respectively. The EEG signals of sets A and B are considered as normal. The EEG data for the other three sets C, D and E were obtained from five epileptic patients undergoing presurgical evaluations. The sets C and D consist of intracranial EEG recordings during seizure-free intervals (interictal periods), where set C and set D EEG signals were, respectively, recorded from the hippocampal formation of the opposite hemisphere of the brain and from within the epileptogenic zone. The EEG signals in the set E were recorded in patients during seizure activity (ictal periods) using depth electrodes placed within the epileptogenic zone. The description of the EEG database used in this study is summarized in Table 1. A sample of EEG signals from each of the five data sets is shown in Figure 1.

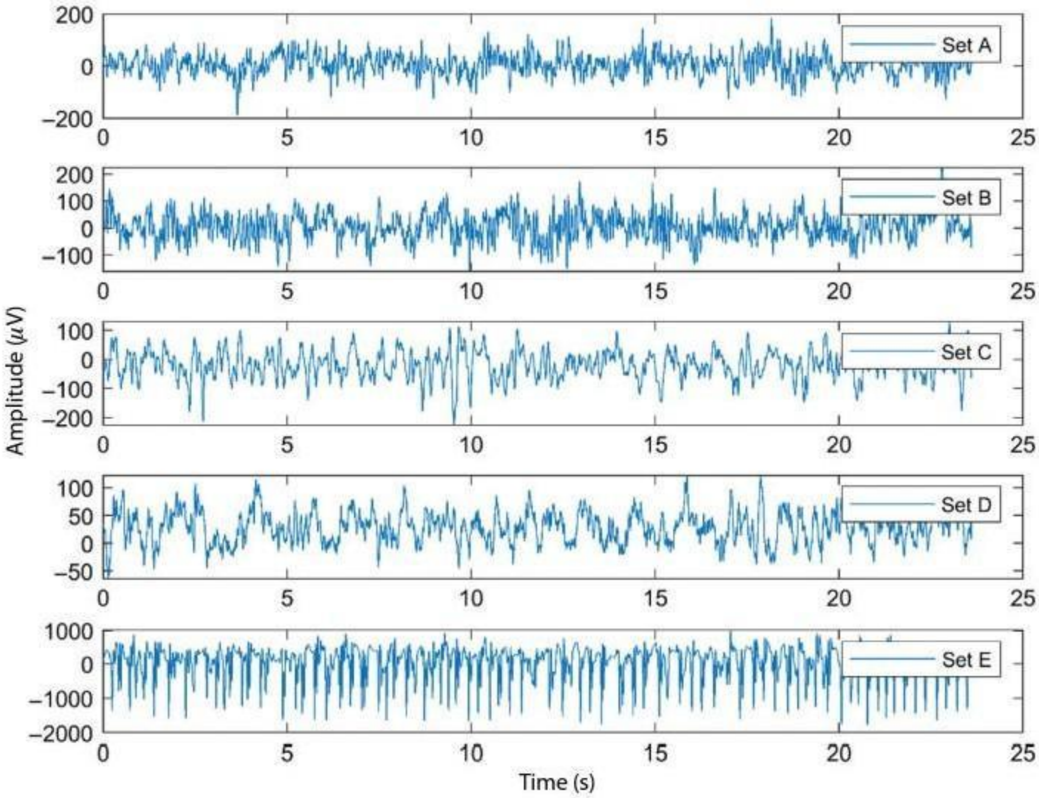

Figure 1: EEG signals recorded from healthy subject and epileptic patient.

Wavelet transforms:

WT divides a continuous signal into a T-F domain [38]. Biomedical signal processing widely uses wavelet transforms as it provides a high-frequency resolution for low-frequency content of the signal and a high time resolution for its high-frequency content[35]. Thus, WT can be considered as an effective tool for the analysis of non-stationary signals, such as EEG signals. The WTs measure the correlation (wavelet coefficients) between the original signal and a set of functions called wavelets. The wavelets are obtained through the translation and the dilation of a specific function known as the mother wavelet. Thus, the wavelet coefficients reflect the similarity between the analysed signal and the wavelets. There are three types of WT: continuous wavelet transforms (CWT), DWT and packet wavelet transform (PWT). The CWT of the signal x(t) is its integral multiplied by scaled and shifted versions of a wavelet function ψ. Mathematically, CWT computes the inner products of the signal x(t) with wavelets according to equation (1):

$$CWT(a,b) = \int_{-\infty}^{+\infty} x(t) \frac{1}{\sqrt{|a|}} \psi\left(\frac{t-b}{a}\right) dt$$

where a and b represent the dilation and translation parameters, respectively. However, calculating wavelet coefficients continuously is computationally an expensive task. Besides, most biomedical signals are discrete-time signals. Moreover, using values of the parameters a and b yield to redundancy in CWT coefficients. Finally, the closed-form solution of the previous integration does not exist except for exceptional cases.

Conclusion

In this paper we learned how we can depict a biological phenomenon in the form of mathematical equations. We studied about how the absorption of artificial insulin can differ in diabetic patients depending upon various factors.We studied about epilepsy with the help of data collected through EEG. We studied about two types of enzyme inhibitions, namely competitive and non-competitive inhibition. We studied about retinal degeneration in a single cone and how glucose metabolism in photoreceptor cells can relate to the disease.

References:

1. **https://diabetestalk.net/insulin/why-insulin-stops-working**
2. Karamitsos, D.T. (2011) The story of insulin discovery. Diabetes Res. Clin. Pract. 93, S2–S8
3. Najate Aït-Ali, Ram Fridlich, Géraldine Millet-Puel, Emmanuelle Clérin, François Delalande, Céline Jaillard, Frédéric Blond, Ludivine Perrocheau, Sacha Reichman, Leah C Byrne, et al. Rod-derived cone viability factor promotes cone survival by stimulating aerobic glycolysis. Cell, 161(4):817–832, 2015.
4. Rorsman, P. and Braun, M. (2013) Regulation of insulin secretion in human pancreatic islets. Annu. Rev. Physiol. 75, 155–179
5. Nigam VP, Graupe D. A neural-network-based detection of epilepsy. Neurol Res 2004; 26:55–60. Megha Barot, Mitan R Gokulgandhi, Vibhuti Agrahari, Dhananjay Pal, and Ashim K Mitra. Monocarboxylate transporter mediated uptake of moxifloxacin on human retinal pigmented epithelium cells. Journal of Pharmacy and Pharmacology, 66(4):574–583, 2014.
6. JM Berg. Tymoczko jl stryer l (2002). Biochemistry. New York, NY: WH Freeman.

7. Chay, T.R. and Keizer, J. (1983) Minimal model for membrane oscillations in the pancreatic beta- cell. Biophys. J. 42, 181

8. George A Brooks. The science and translation of lactate shuttle theory. Cell metabolism, 27(4):757–785, 2018.

9. Bang V Bui, Michael Kalloniatis, and Algis J Vingrys. Retinal function loss after monocarboxylate transport inhibition.

10. Erika T Camacho, Danielle Brager, Ghizlane Elachouri, Tatyana Korneyeva, Géraldine Millet-Puel, José-Alain Sahel, and Thierry Léveillard. A mathematical analysis of aerobic glycolysis triggered by glucose uptake in cones. Scientific reports, 9(1):4162, 2019.

11. Erika T Camacho, Claudio Punzo, and Stephen A Wirkus. Quantifying the metabolic contribution to photoreceptor death in retinitis pigmentosa via a mathematical model. Journal of Theoretical Biology, 408:75–87, 2016. Sherman, A. and Rinzel, J. (1991) Model for synchronization of pancreatic beta-cells by gap junction coupling. Biophys. J. 59, 547

12. Polat K, Güneş S. Classification of epileptiform EEG using a hybrid system based on decision tree classifier and fast Fourier transform. Appl Math Comput 2007; 187:1017–26.

13. Samiee K, Kovács P, Gabbouj M. Epileptic seizure classification of EEG time-series using rational discrete short-time Fourier transform. IEEE Trans Biomed Eng 2015; 62:541–52.

14. Iscan Z, Dokur Z, Demiralp T. Classification of electroencephalogram signals with combined time and frequency features. Expert Syst Appl 2011; 38:10499–505.

15. Srinivasan V, Eswaran C, Sriraam N. Artificial neural network based epileptic detection using time-domain and frequencydomain features. J Med Syst 2005; 29:647–60.

16. Savage N. Epidemiology: the complexities of epilepsy. Nature 2014;511: S2–3.

17. Misiukas Misiūnas AV, Meškauskas T, Samaitienė R. Algorithm for automatic EEG classification according to the epilepsy type: benign focal childhood epilepsy and structural focal epilepsy. Biomed Signal Process Control 2019; 48:118–27.

18. Chua KC, Chandran V, Acharya R, Lim CM, editors. Higher order spectral (HOS) analysis of epileptic EEG signals. 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society; 2007 22–26 Aug. 2007.Olivier Feron. Pyruvate into lactate and back: from the warburg effect to symbiotic energy fuel exchange in cancer cells. Radiotherapy and oncology, 92(3):329–333, 2009.

19. Jahankhani P, Kodogiannis V, Revett K, editors. EEG signal classification using wavelet feature extraction and neural networks. IEEE John Vincent Atanasoff 2006 International Symposium on Modern Computing (JVA'06); 2006, 3–6 Oct.

20. Guler I, Ubeyli ED. Multiclass support vector machines for EEG-signals classification. IEEE Trans Inf Technol Biomed 2007; 11:117–26.Stephen S Goldman. Gluconeogenesis in the amphibian retina. lactate is preferred to glutamate as the gluconeogenic precursor. Biochemical Journal, 254(2):359– 365, 1988.

21. Guo L, Rivero D, Seoane JA, Pazos A. Classification of EEG signals using relative wavelet energy and artificial neural networks. Genetic and Evolutionary Computation Conference, GEC Summit 2009:177–84.

22. Kumar Y, Dewal ML, Anand RS. Relative wavelet energy and wavelet entropy based epileptic brain signals classification. Biomed Eng Lett 2012; 2:147–57.Andrew P Halestrap and Marieangela C Wilson. The monocarboxylate transporter family—role and regulation. IUBMB life, 64(2):109–119, 2012.

23. Guo L, Rivero D, Pazos A. Epileptic seizure detection using multiwavelet transform based approximate entropy and artificial neural networks. J Neurosci Methods 2010; 193:156–63.

24. Peker M, Sen B, Delen D. A novel method for automated diagnosis of epilepsy using complex- valued classifiers. IEEE J Biomed Health Inform 2016; 20:108–18.

25. Bhattacharyya A, Pachori RB, Upadhyay A, Acharya UR. Tunable-Q wavelet transform based multiscale entropy measure for automated classification of epileptic EEG signals. Appl Sci 2017; 7:385. Ken-ichi Hosoya, Tetsu Kondo, Masatoshi Tomi, Hitomi

Takanaga, Sumio Ohtsuki, and Tetsuya Terasaki. Mct1- mediated transport of l-lactic acid at the inner blood–retinal barrier: a possible route for delivery of monocarboxylic acid drugs to the retina. Pharmaceutical research, 18(12):1669–1676, 2001.

26. Nigam VP, Graupe D. A neural-network-based detection of epilepsy. Neurol Res 2004; 26:55–60.

27. Karoly PJ, Freestone DR, Boston R, Grayden DB, Himes D, Leyde K, et al. Interictal spikes and epileptic seizures: their relationship and underlying rhythmicity. Brain 2016; 139:1066–78.

28. Li S, Zhou W, Yuan Q, Liu Y. Seizure prediction using spike rate of intracranial EEG. IEEE Trans Neural Syst Rehabil Eng 2013; 21:880–6.

29. Wang D, Miao D, Xie C. Best basis-based wavelet packet entropy feature extraction and hierarchical EEG classification for epileptic detection. Expert Syst Appl 2011;38: 14314–20

30. Yuan Q, Zhou W, Li S, Cai D. Epileptic EEG classification based on extreme learning machine and nonlinear features. Epilepsy Res 2011; 96:29–38.

31. Acharya UR, Molinari F, Sree SV, Chattopadhyay S, Ng K-H, Suri JS. Automated diagnosis of epileptic EEG using entropies. Biomed Signal Process Control 2012; 7:401–8.

32. Kannathal N, Choo ML, Acharya UR, Sadasivan PK. Entropies for detection of epilepsy in EEG. Comput Methods Programs Biomed 2005; 80:187–94.

33. Gregory J Mantych, Gregory S Hageman, and Sherin U Devaskar. Characterization of glucose transporter isoforms in the adult and developing human eye. Endocrinology, 133(2):600–607, 1993.

34. Andrzejak RG, Lehnertz K, Mormann F, Rieke C, David P, Elger CE. Indications of nonlinear deterministic and finite-dimensional structures in time series of brain electrical activity: dependence on recording region and brain state. Phys Rev E 2001; 64:061907.

35. Fedotov AA. Myographic interference filtering from ECG signals using multiresolution wavelet transform. Biomed Eng 2019; 52:344–7.

36. Kyle S McCommis and Brian N Finck. Mitochondrial pyruvate transport: a historical perspective and future research directions. Biochemical journal, 466(3):443–454, 2015.

37. Klonowski, W. (1983). Simplifying principles for chemical and enzyme reaction kinetics. Biophysical Chemistry, 18(2), 73–87. doi:10.1016/0301-4622(83)85001-7

38. Azmoudeh B, Cvetkovic D. Wavelets in biomedical signal processing and analysis. In: Narayan R, editor. Encyclopedia of Biomedical Engineering. Oxford, UK: Elsevier; 2019: 193–212.

38. Mohan, C., Long, K. D., & Mutneja, M. (2013). An introductionto inhibitors and their biological applications, pp. 3–13.

39. GJ Pascuzzo, JE Johnson, and EL Pautler. Glucose transport in isolated mammalian pigment epithelium. Experimental eye research, 30(1):53–58, 1980.

40. Carol Lynn Poitry-Yamate, Serge Poitry, and Marcos Tsacopoulos. Lactate released by muller glial cells is metabolized by photoreceptors from mammalian retina. Journal of Neuroscience, 15(7):5179–5191, 1995.

41. https://**www.news-medical.net/health/Anatomy-of-the-Human-Eye.aspx**

43. Jane B Reece, Lisa A Urry, Michael Lee Cain, Steven Alexander Wasserman, Peter V Minorsky, Robert B Jackson, et al. Campbell biology. Number is 1309. Pearson Boston, 2014.

44. Wong-Riley, M. Energy metabolism of the visual system. Eye and Brain 2, 99 (2010).

45. Erika T Camacho, Danielle Brager, Ghizlane Elachouri, Tatyana Korneyeva, Géraldine Millet-Puel, José-Alain Sahel, and Thierry Léveillard. A mathematical analysis of aerobic glycolysis triggered by glucose uptake in cones. Scientific reports, 9(1):4162, 2019.

46. Herbert M Sauro. Enzyme kinetics for systems biology. Future Skill Software, 2011.

47. Lei Shi and Benjamin P Tu. Acetyl-coa and the regulation of metabolism: mechanisms and consequences. Current opinion in cell biology, 33:125–131, 2015.

48. Megha Barot, Mitan R Gokulgandhi, Vibhuti Agrahari, Dhananjay Pal, and Ashim K Mitra. Monocarboxylate transporter mediated uptake of moxifloxacin on human retinal pigmented epithelium cells. Journal of Pharmacy and Pharmacology, 66(4):574–583, 2014.

49. Albisser AM, Leibel BS, Ewart TG, Davidovac Z, Botz CK, Zingg W. An artificial endocrine pancreas. Diabetes 1974;23:389–396

50. Sabanayagam C, Teppala S, Shankar A. Markers of sleep disordered breathing and diabetes mellitus in a multiethnic sample of us adults: results from the national health and nutrition examination survey (2005-2008). Int J Endocrinol. (2012) 2012:879134. doi: 10.1155/2012/879134

51. Grimaldi D, Beccuti G, Touma C, Van Cauter E, Mokhlesi B. Association of obstructive sleep apnea in rapid eye movement sleep with reduced glycemic control in type 2 diabetes: therapeutic implications. Diabetes Care (2014) 37:355–63. doi: 10.2337/dc13-0933

52. J. Li and D. Johnson, Mathematical models of subcutaneous injection of insulin analogues: A mini-review, Discrete Contin. Dynam. Syst. B, 12 (2009), pp. 401–414.

53. Ying Yang, Saddek Mohand-Said, Aude Danan, Manuel Simonutti, Valérie Fontaine, Emmanuelle Clerin, Serge Picaud, Thierry Léveillard, and José-Alain Sahel. Functional cone rescue by rdcvf protein in a dominant model of retinitis pigmentosa. Molecular Therapy, 17(5):787–795, 2009.

54. M. Ackermann and M. Gannon, Molecular regulation of pancreatic β-cell mass development, maintenance, and expansion, J. Mol. Endocrin., 38 (2007), pp. 193–206.

55. Kanako Yokosako, Tatsuya Mimura, Hideharu Funatsu, Hidetaka Noma, Mari Goto, Yuko Kamei, Aki Kondo, and Masao Matsubara. Glycolysis in patients with age-related macular degeneration. The open ophthalmology journal, 8:39, 2014. Tzallas AT, Tsipouras MG, Fotiadis DI. Automatic seizure detection based on time-frequency analysis and artificial neural networks. Comput Intell Neurosci 2007; 2007:80510. Epub 2007/12/05.

56. Acharya UR, Sree SV, Chattopadhyay S, Yu W, Ang PCA. Application of recurrence quantification analysis for the automated identification of epileptic EEG signals. Int J Neural Syst 2011; 21:199–211

57. Guo L, Rivero D, Dorado J, Rabuñal JR, Pazos A. Automatic epileptic seizure detection in EEGs based online length feature and artificial neural networks. J Neurosci Methods 2010; 191:101–9.

58. Orhan U, Hekim M, Ozer M. EEG signals classification using the K-means clustering and a multilayer perceptron neural network model. Expert Syst Appl 2011; 38:13475–81.

59. Guo L, Rivero D, Dorado J, Munteanu CR, Pazos A. Automatic feature extraction using genetic programming: an application to epileptic EEG classification. Expert Syst Appl 2011; 38:10425–36.

60. Kaya Y, Uyar M, Tekin R, Yıldırım S. 1D-local binary patternbased feature extraction for classification of epileptic EEG signals. Appl Math Comput 2014; 243:209–19.

61. Acharya UR, Oh SL, Hagiwara Y, Tan JH, Adeli H. Deep convolutional neural network for the automated detection and diagnosis of seizure using EEG signals. Comput Biol Med 2018; 100:270–8.

62. Tiwari AK, Pachori RB, Kanhangad V, Panigrahi BK. Automated diagnosis of epilepsy using key- point-based local binary pattern of EEG signals. J Biomed Health Inform 2017; 21:888–96.

63. Sharma M, Pachori RB, Rajendra Acharya U. A new approach to characterize epileptic seizures using analytic time-frequency flexible wavelet transform and fractal dimension. Pattern Recognit Lett 2017; 94:172–9.

64. Hussein R, Palangi H, Ward RK, Wang ZJ. Optimized deep neural network architecture for robust detection of epileptic seizures using EEG signals. Clin Neurophysiol 2019; 130:25–

65. Bing, R.J. (1955) The Metabolism of the Heart. Harvey Lectures, 50, 27-70.

66. https://www.scirp.org/journal/paperabs.aspx?paperid=92521

Chapter -17:

Comparative Study of MoS_2 and Other 2D Materials in Photovoltaic Applications

Kazi Hasibur Rahman*

School of Basic Sciences, Swami Vivekananda University, Barrackpore, Kolkata-700121, India

**Email: via.kazi786@gmail.com*

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Kazi Hasibur Rahman*

School of Basic Sciences, Swami Vivekananda University, Barrackpore, Kolkata-700121, India

**Email: via.kazi786@gmail.com*

Abstract:

The rapid development of two-dimensional (2D) materials has opened new avenues for enhancing the performance of photovoltaic devices. Among these, Molybdenum Disulfide (MoS_2) has garnered significant attention due to its unique electronic and optical properties, including a tunable bandgap, high absorption coefficient, and strong photocarrier generation capabilities. This paper presents a comparative study of MoS_2 and other prominent 2D materials, such as graphene, tungsten disulfide (WS_2), and black phosphorus, in the context of photovoltaic applications. The analysis focuses on the efficiency, stability, and scalability of these materials when integrated into different photovoltaic architectures, including heterojunction solar cells and tandem cells. Through an in-depth examination of material properties, charge carrier dynamics, and interface engineering, we identify the strengths and limitations of MoS_2 compared to its counterparts. The study also explores the potential of combining MoS_2 with other 2D materials in heterostructures to overcome existing challenges and enhance overall device performance. The findings suggest that while MoS_2 shows promising potential for next-generation photovoltaics, strategic material integration and advanced fabrication techniques are crucial for realizing its full potential in large-scale solar energy conversion.

Keywords: Heterostructure, 2D materials, Photovoltaic devices, Tungsten Disulfide, Graphene

Introduction:

The field of photovoltaics has seen remarkable progress in recent years, driven by the need for sustainable energy solutions and the growing demand for more efficient, cost-effective solar technologies. Traditional bulk semiconductor materials, such as silicon, have dominated the photovoltaic industry; however, the exploration of new materials is essential for pushing the boundaries of solar cell efficiency and enabling novel device architectures. Among these emerging materials, two-dimensional (2D) materials have captured significant interest due to their unique physical and chemical properties, which are fundamentally different from those of their bulk counterparts. Molybdenum disulfide (MoS_2), a member of the transition metal dichalcogenide (TMD) family, has emerged as a particularly promising 2D material for photovoltaic applications. Its direct bandgap in the monolayer form, high absorption coefficient, and excellent electronic properties make it an attractive candidate for next-generation solar cells. MoS2's ability to efficiently absorb sunlight and generate photocarriers, coupled with its mechanical flexibility, opens up possibilities for both traditional and flexible photovoltaic devices.

However, MoS_2 is not the only 2D material with potential in photovoltaics. Other 2D materials, such as graphene, tungsten disulfide (WS_2), and black phosphorus, also exhibit distinctive properties that can be leveraged for solar energy conversion. Graphene, known for its exceptional electrical conductivity and transparency, has been extensively studied as a transparent electrode or in tandem with other 2D materials to enhance charge transport. WS2, similar to MoS2, offers a tunable bandgap and strong light-matter interaction, making it a compelling alternative. Meanwhile, black phosphorus, with its anisotropic properties and tunable bandgap, presents unique opportunities for tailoring the absorption spectrum and improving the efficiency of solar cells.

In this paper, we undertake a comparative study of MoS_2 and these other 2D materials in the context of photovoltaic applications. We aim to assess their respective advantages and limitations, focusing on key parameters such as optical absorption, carrier mobility, stability, and scalability. Additionally, we explore the potential of combining these materials in heterostructures or hybrid systems to optimize their performance in photovoltaic devices. By providing a comprehensive analysis, this study seeks to identify the most promising pathways for integrating 2D materials into future solar technologies and advancing the development of high-efficiency, next-generation photovoltaic devices.

Comparison of MoS_2 with other 2D materials for application in photovoltaics:

The integration of two-dimensional (2D) materials into photovoltaic devices has the potential to revolutionize solar energy technology by improving efficiency, flexibility, and functionality. This section provides a detailed comparison of Molybdenum Disulfide (MoS_2)

with other prominent 2D materials, specifically graphene, Tungsten Disulfide (WS_2), and Black **Phosphorus (BP), in the context of photovoltaic applications.**

Molybdenum Disulfide (MoS2):

Optical and Electronic Properties:

- Bandgap: MoS_2 exhibits a direct bandgap of approximately 1.8 eV in its monolayer form, which is well-suited for visible light absorption.
- Absorption: High absorption coefficient in the visible range makes MoS_2 effective at converting sunlight into electrical energy.
- Carrier Mobility: Moderate carrier mobility compared to graphene, but higher than some other 2D materials, contributing to reasonable charge transport properties.

Advantages:

- Direct Bandgap: Enables efficient light absorption and photocarrier generation.
- Scalability: Techniques like Chemical Vapor Deposition (CVD) allow for large-area synthesis, essential for practical photovoltaic applications.

Challenges:

- Defect Sensitivity: Defects and grain boundaries can impact the performance and stability of MoS_2-based devices.
- Integration Issues: Ensuring uniform coverage and efficient interface contact with other materials in photovoltaic cells can be challenging.

Graphene

Optical and Electronic Properties:

- Bandgap: Zero bandgap, which limits its use as an active layer in photovoltaics but makes it suitable as a transparent conductive electrode.
- Absorption: Low absorption coefficient (approximately 2.3% for a monolayer) restricts its use as the sole active layer in solar cells.

Advantages:

- High Electrical Conductivity: Excellent carrier mobility and high electrical conductivity make it ideal for use as an electrode or charge collector.
- Mechanical Flexibility: Supports the development of flexible and wearable photovoltaic devices.

Challenges:

- Bandgap Absence: The lack of a bandgap limits its ability to absorb light and generate photocarriers effectively.
- Integration: Combining graphene with other 2D materials to create efficient photovoltaic devices requires sophisticated fabrication techniques.

Tungsten Disulfide (WS2)

Optical and Electronic Properties:

- Bandgap: WS_2 exhibits a direct bandgap of approximately 2.1 eV in its monolayer form, which is higher than MoS_2, providing better absorption in the visible range.
- Absorption: Stronger light absorption compared to MoS_2, making it an effective material for photovoltaic applications.

Advantages:

- Higher Bandgap: Enhanced light absorption in the visible range compared to MoS_2.
- Carrier Dynamics: Better electron-hole separation and mobility in some cases.

Challenges:

- Material Quality: Achieving high-quality monolayers and large-area synthesis can be challenging.
- Device Integration: Compatibility with other materials and achieving efficient interfaces in photovoltaic devices remain areas of active research.

Black Phosphorus (BP)

Optical and Electronic Properties:

- Bandgap: BP has a tunable bandgap ranging from 0.3 eV (bulk) to 2 eV (monolayer), allowing for customization of optical properties.
- Absorption: High absorption across a broad spectrum, including the infrared range, which can be advantageous for capturing a wide range of solar energy.

Advantages:

- Tunable Bandgap: Flexibility in bandgap tuning allows for optimization of light absorption and electronic properties.
- High Absorption Efficiency: Good potential for high-efficiency photovoltaic devices due to its broad absorption spectrum.

Challenges:

- Environmental Sensitivity: BP is highly sensitive to oxidation and degradation, which can impact long-term stability and performance.
- Manufacturing Challenges: Large-scale production and integration with other materials are still under development.

Each 2D material offers unique advantages and challenges for photovoltaic applications. MoS_2 stands out for its suitable bandgap and decent absorption properties, while graphene excels as a conductive layer but lacks a bandgap. WS_2 provides enhanced light absorption with a higher bandgap, and BP offers tunable properties and broad absorption but suffers from environmental instability. The future of 2D material-based photovoltaics lies in the effective combination of these materials, potentially integrating their strengths to create high-performance, scalable, and stable solar energy devices.

Discuss the role of MoS_2 in heterojunction solar cells:

Molybdenum Disulfide (MoS_2), a transition metal dichalcogenide (TMD), has emerged as a significant material in the field of photovoltaic devices, particularly in heterojunction solar cells. The unique properties of MoS_2, such as its tunable bandgap, high surface area, and strong light absorption, make it a valuable component in enhancing the performance of heterojunction solar cells. This discussion explores the role of MoS_2 in these devices, focusing on its contributions to device efficiency, stability, and fabrication.

Bandgap Engineering

Tunable Bandgap:

- Direct Bandgap: MoS2 possesses a direct bandgap that can be tuned between approximately 1.2 eV (bulk) and 1.8 eV (monolayer). This property is advantageous for optimizing light absorption and electronic properties in heterojunction solar cells.
- Bandgap Tuning: By varying the number of MoS2 layers or doping with other elements, the bandgap can be adjusted to match the absorption spectrum of the solar spectrum or complement other materials in the heterojunction, enhancing overall device efficiency.

Light Absorption and Photocurrent Generation

High Absorption Coefficient:

- Efficient Light Absorption: MoS2 has a high absorption coefficient in the visible range, allowing it to absorb a significant portion of sunlight. This leads to increased photocurrent generation when used as an active layer or as part of a heterojunction.
- Strong Light-Matter Interaction: The strong interaction between light and MoS2 enhances the generation of electron-hole pairs, which are crucial for converting light energy into electrical energy.

Interface Engineering and Charge Transport

Optimized Interfaces:

- Good Interface Properties: MoS_2 can form effective interfaces with other semiconductors in heterojunctions, such as silicon, graphene, or other 2D materials. These interfaces can facilitate efficient charge transfer and reduce recombination losses.
- Ohmic Contacts: The ability of MoS_2 to create ohmic contacts with various materials improves charge injection and collection at the junction, which is critical for enhancing device performance.

Carrier Mobility:

- Enhanced Charge Transport: MoS_2 exhibits relatively high carrier mobility compared to other 2D materials, which can improve the charge transport within the heterojunction and reduce resistive losses.
- Reduced Recombination: High carrier mobility helps in minimizing carrier recombination losses, leading to improved photocurrent and voltage.

Flexibility and Integration

Flexible Devices:

- Mechanical Flexibility: MoS_2 is mechanically flexible, making it suitable for integration into flexible and lightweight solar cells. This property is beneficial for developing flexible, wearable, or rollable solar panels.
- Versatile Integration: MoS_2 can be integrated with various substrates and other materials, offering flexibility in device design and fabrication.

Stability and Environmental Resistance

Material Stability:

- Chemical Stability: MoS_2 exhibits reasonable chemical stability, though it can be sensitive to ambient conditions like moisture and oxygen. This stability is crucial for maintaining the performance and longevity of the solar cells.
- Protection Strategies: To enhance stability, MoS_2 can be encapsulated or combined with protective layers to shield it from environmental degradation.

Recent Advances and Applications:

Heterojunction Architectures:

- MoS2/Silicon Heterojunctions: MoS_2 is being explored in combination with silicon to create high-efficiency heterojunction solar cells. The addition of MoS_2 can improve the overall efficiency by enhancing light absorption and charge separation.
- MoS2/Perovskite Heterojunctions: Research is also focusing on integrating MoS_2 with perovskite materials to leverage the complementary properties of both materials for improved photovoltaic performance.

Device Efficiency:

- Improved Performance Metrics: The inclusion of MoS_2 in heterojunction solar cells has led to notable improvements in efficiency metrics such as short-circuit current, open-circuit voltage, and overall power conversion efficiency.

MoS_2 plays a crucial role in heterojunction solar cells by enhancing light absorption, optimizing interface properties, and improving charge transport. Its tunable bandgap, high absorption coefficient, and flexibility make it a valuable material for advancing photovoltaic technology. Ongoing research aims to address challenges related to stability and integration, with the goal of developing high-efficiency, flexible, and durable solar cells. As the technology evolves, MoS_2 is expected to contribute significantly to the next generation of high-performance photovoltaic devices.

Address challenges in integrating MoS2 into large-area solar panels:

Integrating Molybdenum Disulfide (MoS_2) into large-area solar panels presents several challenges that need to be addressed to fully harness its potential in photovoltaic applications. These challenges span material synthesis, device fabrication, and performance optimization. Below is an overview of the primary challenges and potential strategies for overcoming them.

Material Synthesis and Quality Control

Challenge:

- Uniformity and Large-Area Growth: Achieving uniform and high-quality MoS2 over large areas is challenging. Techniques such as Chemical Vapor Deposition (CVD) or liquid-phase exfoliation often struggle with maintaining consistent material properties across large substrates.

Strategies:

- Optimized Growth Techniques: Advances in CVD and other deposition methods can improve the scalability and uniformity of MoS_2 films. Techniques such as roll-to-roll processing and the development of improved precursor materials are being explored.

- Monitoring and Control: Implementing real-time monitoring and control during the synthesis process can help ensure uniform quality and detect defects early.

Interface Engineering

Challenge:

- Contact Formation: Achieving efficient electrical contact between MoS2 and other materials in the solar panel is critical. Poor contact can lead to high series resistance and reduced efficiency.

Strategies:

- Interface Optimization: Developing and optimizing buffer layers or interfacial materials can improve contact quality. Techniques such as atomic layer deposition (ALD) can be used to engineer interfaces with high precision.
- Advanced Contact Materials: Research into new contact materials and methods to ensure ohmic contact and low contact resistance is essential.

Device Fabrication

Challenge:

- Integration with Existing Technologies: MoS_2 needs to be integrated with existing photovoltaic technologies, such as silicon or perovskite solar cells, in a way that maintains high performance and manufacturability.

Strategies:

- Hybrid Device Architectures: Exploring hybrid solar cell architectures that combine MoS_2 with conventional materials can enhance overall efficiency while leveraging the strengths of both materials.
- Standardization: Developing standard fabrication processes that are compatible with MoS2 and other materials can streamline integration and reduce manufacturing costs.

Stability and Environmental Resistance

Challenge:

- Degradation: MoS_2 is sensitive to environmental factors such as moisture and oxygen, which can lead to degradation and reduced lifespan of the solar panels.

Strategies:

- Protective Coatings: Applying protective coatings or encapsulation layers can shield MoS_2 from environmental damage and improve its stability.
- Material Improvement: Research into more stable forms of MoS_2 or alternative TMDs with better environmental resistance may provide long-term solutions.

Performance Optimization

Challenge:

- Efficiency Optimization: Maximizing the photovoltaic performance of MoS_2-based solar cells involves optimizing parameters such as thickness, bandgap, and carrier dynamics.

Strategies:

- Device Engineering: Fine-tuning device parameters and exploring various heterojunction configurations can enhance efficiency. Utilizing simulation tools and experimental validation can guide the optimization process.
- Material Doping and Functionalization: Doping MoS_2 with other elements or functionalizing its surface can improve its electronic properties and overall device performance.

Cost and Scalability

Challenge:

- Manufacturing Costs: The cost of synthesizing high-quality MoS_2 and integrating it into solar panels can be high, affecting the overall cost-effectiveness of the technology.

Strategies:

- Economies of Scale: As production techniques improve and scale up, costs are expected to decrease. Investing in scalable synthesis methods and efficient manufacturing processes is crucial.
- Alternative Synthesis Methods: Exploring cost-effective synthesis methods, such as solution-based processes or lower-cost precursors, can help reduce overall production costs.

Large-Area Uniformity

Challenge:

- Seamless Integration: Ensuring seamless integration of MoS_2 over large-area substrates is challenging, especially when transitioning from laboratory-scale to industrial-scale production.

Strategies:

- Uniform Deposition Techniques: Developing techniques that allow for uniform deposition over large areas, such as advanced coating methods or automated deposition systems, is essential.
- Substrate Compatibility: Using substrates that are compatible with large-area MoS_2 growth and maintaining uniformity throughout the process can help mitigate this challenge.

Integrating MoS_2 into large-area solar panels involves addressing several technical and practical challenges. By focusing on improving material synthesis techniques, optimizing interfaces, enhancing stability, and reducing costs, the potential of MoS_2 in photovoltaic applications can be realized. Ongoing research and technological advancements are crucial for overcoming these challenges and enabling the successful deployment of MoS2-based solar panels on a commercial scale.

References:

A. Molina-Sanchez, L. Wirtz, Phys. Rev. B 84, 155413 (2011).

Ambrosi, A.; Sofer, Z.; Pumera, M. Lithium intercalation compound dramatically influences the electrochemical properties of exfoliated MoS. *Small* **2015**, *11*, 605–612.

C.V. Ramana, U. Becker, V. Shutthanandan, C.M. Julien, Geochem. Trans. 9, 8 (2008).

Choi, W. et al. Recent development of two-dimensional transition metal dichalcogenides and their applications. *Mater. Today* **20**, 116–130 (2017).

Eng, A.Y.S.; Ambrosi, A.; Sofer, Z.; Šimek, P.; Pumera, M. Electrochemistry of transition metal dichalcogenides: Strong dependence on the metal-to-chalcogen composition and exfoliation method. *ACS Nano* **2014**, *8*, 12185–12198.

G.L. Frey, R. Tenne, M. Matthews, M.S. Dresselhaus, G. Dresselhaus, Phys. Rev. B 60, 2883 (1999).

Giacometti, V.; Radisavljevic, B.; Radenovic, A.; Brivio, J.; Kis, A.; Giacometti, V.; Kis, A. Single-layer MoS_2 transistors. *Nat. Nanotechnol.* **2011**, *6*, 147–150.

K.S. Novoselov, A.K. Geim, S.V. Morozov, D. Jiang, Y. Zhang, S.V. Dubonos, *et al.*
Electric field effect in atomically thin carbon films Science, 306 (2004), pp. 666-669

Kim, T. Y. et al. Electrical properties of synthesized large-area MoS_2 field-effect transistors fabricated with inkjet-printed contacts. *ACS Nano* **10**, 2819–2826 (2016).

Park, S. et al. Layer-selective synthesis of MoS_2 and WS_2 structures under ambient conditions for customized electronics. *ACS Nano* **14**, 8485–8494 (2020).

Madhu Yadav, Mukesh Kumar, Ashutosh Sharma. Review of Ti3C2Tx MXene Nanosheets and their Applications. *ACS Applied Nano Materials* **2024**, *7* (9) , 9847-9867.

Wang, S. et al. Shape evolution of monolayer MoS_2 crystals grown by chemical vapor deposition. *Chem. Mater.* **26**, 6371–6379 (2014).

Yang, J. et al. Wafer-scale synthesis of thickness-controllable MoS_2 films via solution-processing using a dimethylformamide/n-butylamine/2-aminoethanol solvent system. *Nanoscale* **7**, 9311–9319 (2015).