Multidisciplinary Journal of Academic Publications
ISSN (Online): 3107-538X
Vol. 02, Issue 01, January – February 2026

# IMPACT AND CRASHWORTHINESS PERFORMANCE OF COMPOSITE STRUCTURES IN AUTOMOTIVE APPLICATIONS

**Dr. Mayur Jayant Gitay[1], Dr. Nikhil J. Rathod[2], Mr. Rohit K. Dhende[3], Mr. Sagar S. Sasane[4]**

**Assistant Professor, Department of Mechanical Engineering, ATC, Ahilyanagar[1]**

**Assistant Professor, Department of Mechanical Engineering, BVCOE & RI, Nashik[2]**

**Lecturer, Department of Mechanical Engineering, HSBPVT's Parikrama Polytechnic, Kashti[3]**

**PhD Scholar, Department of Mechanical Engineering, Sandip University, Nashik[4]**

## Abstract

*The use of composite materials in automobile structures has increased due to the growing demand for vehicles that are safe, lightweight, and fuel-efficient. Impact resistance and crashworthiness are two of the most important performance requirements for guaranteeing passenger safety in crashes. Although composite materials have great specific strength and the capacity to absorb energy, their failure mechanisms under impact loading are intricate and very different from those of conventional metallic materials. The impact and crashworthiness performance of composite structures utilized in automotive applications are thoroughly analyzed in this review study. Energy absorption and failure behavior are examined in relation to material systems, reinforcement architecture, manufacturing techniques, and geometrical design. Future research areas, comparison investigations with metallic counterparts, and present obstacles are also emphasized.*

**Keywords***:* *Lightweight constructions*[1]*, energy absorption*[2]*, crashworthiness*[3]*, impact performance*[4]*, automotive composites*[5]*.*

## 1. Introduction

Globally, there is growing demand on the automotive industry to lower vehicle weight while simultaneously boosting safety and fuel efficiency. The excellent strength-to-weight ratio, corrosion resistance, and design flexibility of lightweight composite materials have made them attractive substitutes for traditional steel and aluminum constructions. Composites including carbon fiber reinforced polymers (CFRPs), glass fiber reinforced polymers (GFRPs), and hybrid composites have been used more frequently in automotive body structures, crash beams, bumper systems, and energy-absorbing parts in recent years. The ability of a structure to protect people upon impact by controllably absorbing and dissipating kinetic energy is known as crashworthiness. Composite materials release energy through progressive damage mechanisms as matrix cracking, fiber fracture, delamination, and interfacial debonding, in contrast to metals, which mainly absorb energy through plastic deformation. Although these processes have a tremendous potential for energy absorption, they also make crash behavior prediction and design more difficult.

## 2. Literature Review

The impact and crashworthiness characteristics of composite structures in automotive applications have been extensively studied. Early research showed that compared to their metallic equivalents, composite crash structures can achieve higher specific energy absorption. Understanding failure mechanisms, strain rate impacts, and composite architectural optimization were the main goals of later research. The better energy absorption of CFRP tubes and cones under axial impact stress has been demonstrated by researchers. Cost-effective solutions for medium-energy impact zones, like bumper beams, were found in studies on GFRP components. According to reports, hybrid composite systems that include glass and carbon fibers offer a balance between damage tolerance, affordability, and energy absorption. Carruthers et al. carried out one of the first and most important evaluations of the crashworthiness and energy absorption capacity of composite constructions, focusing on fiber-reinforced polymer tubes and automobile crash components. By carefully examining experimental investigations including axial compression and impact stresses, their study assessed the performance of composite members with conventional metallic constructions. The authors stressed that composites absorb impact energy mostly through progressive damage mechanisms such matrix cracking, fiber fracture, delamination, and interfacial debonding, as opposed to plastic deformation, which is typical in metals. The survey identified specific energy absorption (SEA) as the most crucial crashworthiness metric and showed that well-designed composite structures could attain SEA values that were on par with or greater than those of their steel and aluminum counterparts. By focusing on controlled failure progression and geometric optimization, this work established the fundamental concepts for composite crashworthy design. The crashworthiness performance of fiber-reinforced polymer (FRP) constructions for automotive applications was thoroughly surveyed by Isaac et al., with a focus on material systems, manufacturing quality, and strain-rate effects. In this review, crash structures made of carbon fiber, glass fiber, and hybrid composites were examined under both quasi-static and dynamic stress scenarios. According to the authors, GFRP structures provide economic advantages with moderate crash performance, while CFRP structures show superior specific energy absorption due to higher stiffness and strength. The study also emphasized how manufacturing flaws including voids, fiber misalignment, and uneven curing have a crucial impact on crash performance. According to the survey's findings, hybrid composite systems are appealing for automotive safety applications because they successfully strike a compromise between cost, weight reduction, and crashworthiness.

In contrast to traditional steel, aluminum, and synthetic fiber-reinforced composites, Ang et al. examined the impact and crashworthiness performance of bio-composite crash boxes. They examined experimental crash data for natural fiber composites like flax and hemp reinforced polymers and concentrated on the increasing need for sustainable vehicle materials. The scientists noted that bio-composites show steady progressive crushing and appropriate energy absorption for low-to-medium energy impact applications, despite generally having lower strength and stiffness than CFRP. The study also showed that fiber pull-out and matrix cracking, which enhance energy dissipation, are the main failure modes in bio-composites. According to the survey's findings, bio-composites can be employed successfully in secondary automotive crash components where cost-cutting and sustainability are given top priority. Li et al. provided a thorough analysis of crashworthiness improvement strategies utilizing hybrid composite structures, with a special emphasis on metal-composite and foam-filled hybrid tubes. Numerous experimental and computational experiments utilizing composite tubes with metallic skins, polymeric or metallic foam fillers, and aluminum inserts were examined in the review. The authors showed that by encouraging stable progressive crushing and postponing catastrophic brittle failure, hybrid arrangements greatly increase specific energy absorption and crush force efficiency. It was demonstrated that foam-filled composite tubes increased overall absorbed energy while lowering peak crushing forces. According to this survey, structural hybridization is a successful method for improving crashworthiness in vehicle structures and overcoming the brittleness of composite materials. A survey by Zhao and Lu examined how composite architecture, stacking order, and ply orientation affect impact and crashworthiness behavior under dynamic loading circumstances. In order to evaluate the evolution of damage in composite crash structures, their review combined findings from numerical models, high-speed imaging, and experimental impact tests. In comparison to unidirectional laminates, the scientists found that cross-ply and quasi-isotropic layups improve energy absorption and postpone the onset of delamination. It has been demonstrated that hybrid stacking sequences that combine several fiber orientations offer better damage tolerance and more consistent crushing behavior. According to the survey's findings, controlling energy absorption and customizing crash performance in automotive composite constructions require rigorous ply architecture optimization.

## 3. Overview of impact and Crashworthiness Behavior

A complicated interplay between material qualities, structural geometry, loading circumstances, and strain-rate effects determines the impact and crashworthiness behavior of composite structures in automotive applications. Polymer matrix composites absorb impact energy through gradual damage mechanisms that happen at several length scales, in contrast to metallic materials, which mainly dissipate impact energy through plastic deformation and yielding. Matrix cracking, fiber breakage, pull-out, delamination between plies, and interfacial debonding between fiber and matrix are some of these mechanisms. The crash reaction, energy absorption capacity, and failure stability of composite structures under impact loads are significantly influenced by the combination and order of these damage patterns. Low-velocity, medium-velocity, and high-velocity impact regimes are commonly used to categorize impact behavior in composite vehicle components. Barely visible impact damage (BVID), when internal delamination and matrix cracking occur without noticeable surface damage, is frequently caused by low-velocity impacts, such as tool drops or mild car collisions. This undetected degradation can seriously reduce residual stiffness and strength, making safety evaluation difficult. Impacts at medium and high velocities, which are typical of car crashes, cause significant energy dissipation by widespread, gradual crushing and fragmentation. To prevent catastrophic brittle fracture and excessive peak loads that could be transferred to the occupants of the vehicle, controlled failure and steady crushing are crucial in these situations. Parameters including specific energy absorption (SEA), peak crushing force (PCF), mean crushing force (MCF), and crush force efficiency (CFE) are frequently used to assess crashworthiness performance. When comparing composite constructions to their metallic counterparts, SEA which is defined as the energy absorbed per unit mass is a crucial parameter for lightweight automobile design. Because of their high stiffness-to-weight ratio, composite materials especially carbon fiber reinforced polymers, or CFRPs typically show higher SEA values than steel and aluminum. However, if improperly built, they also have a tendency to produce larger peak forces, which may be harmful to occupant safety. Therefore, rather than abrupt collapse, automobile composite structures are designed to promote progressive crushing with relatively consistent load levels.

## 4. Challenges in Automotive Crashworthy Composite Structures

The widespread use of composite materials in automotive crashworthy structures is restricted by a number of scientific, financial, and practical issues, despite the materials' notable benefits in terms of lightweight design and high specific energy absorption. The intrinsic brittleness of polymer matrix composites in contrast to metallic materials is one of the main obstacles. Composites typically fail by abrupt fracture mechanisms such fiber breakage and delamination, in contrast to metals, which show ductile plastic deformation and predictable yielding under impact stress. This brittle failure tendency may lead to large peak crushing forces, which are undesirable in collision situations because they raise the possibility of occupant injuries. The intricacy of the damage mechanisms that composite materials display during impact loading is another significant obstacle. Multiple damage modes, including as matrix cracking, fiber fracture, interlaminar delamination, and fiber–matrix debonding, are simultaneously activated during crash events due to multi-axial pressures, high strain rates, and complicated loading patterns. It is challenging to precisely forecast failure behavior because these damage processes interact and change over time. Assessing structural integrity is much more difficult when scarcely visible impact damage (BVID) is present because interior damage can drastically lower residual strength while going unnoticed during normal inspections. Reliability in crashworthiness performance is further complicated by manufacturing-related problems. Defects such gaps, resin-rich regions, fiber misalignment, and inadequate curing can negatively effect impact resistance and energy absorption capacity in composite constructions. Inconsistent mechanical qualities between production batches can result from variations in manufacturing techniques such filament winding, compression molding, and resin transfer molding (RTM). When compared to the well-established manufacturing consistency of metallic components, achieving strict quality control in mass vehicle production continues to be a major challenge.

## 5. Comparative Analysis with Metallic Structures

To determine if polymer matrix composites are suitable for automobile crashworthiness applications, a comparison between composite and metallic structures is necessary. Because of its ductility, predictable plastic deformation, and established manufacturing techniques, steel and aluminum alloys are used to make the majority of traditional automobile crash components. Composite materials, on the other hand, have better strength-to-weight and stiffness-to-weight ratios, allowing for substantial vehicle mass reduction without sacrificing structural integrity. However, these material systems' basic variations in deformation and energy absorption mechanisms provide unique crash behaviors that need to be carefully taken into account during design. Large-scale deformation and plastic yielding are the main ways that metallic structures absorb impact energy, producing force-displacement responses that are smooth and predictable. Steel structures are particularly dependable in crash situations because of their superior ductility and steady progressive folding under axial stress. Although aluminum alloys have a lower density and a reasonable energy absorption capacity, they often generate larger peak loads than steel. On the other hand, progressive deterioration mechanisms such matrix cracking, fiber fracture, delamination, and fiber pull-out cause composite materials to dissipate energy. When compared to metals, these mechanisms enable composites to attain much higher specific energy absorption (SEA); yet, if improperly regulated, they can also result in rapid load declines and brittle fragmentation. Composite materials perform noticeably better than their metallic equivalents when it comes to weight economy. Carbon fiber reinforced polymer (CFRP) crash components can obtain SEA values two to four times higher than steel and aluminum structures, according to numerous experimental tests. This benefit makes it possible for automobile body-in-white and crash management systems to significantly reduce weight, which directly improves fuel economy and lowers emissions. However, if geometric design or triggering mechanisms are not used to reduce the greater peak crushing forces caused by CFRP's higher rigidity, occupant safety may be jeopardized.

## 6. Discussion

The studied literature unequivocally shows that composite materials' high specific energy absorption, lightweight properties, and design flexibility offer substantial potential for improving automobile crashworthiness. When appropriately built, composites, in contrast to traditional metallic materials, absorb impact energy through a variety of progressive damage mechanisms, enabling customized crash reactions. However, material choice, structural design, manufacturing quality, and the capacity to manage failure progression all have a significant impact on how well composite structures perform in actual car collision situations. Implementing composite crashworthy constructions in automotive applications presents both potential and challenges, as evidenced by the variety of reported findings across research. One important finding from the reviewed studies is that crash performance is more influenced by geometry and structural design than by material strength alone. When built to support stable progressive crushing, composite crash components like tubes, cones, and multi-cell structures exhibit noticeably better energy absorption. It has been demonstrated that the use of triggers, ply sequence optimization, and hybrid arrangements can significantly lower peak crushing forces and improve crush force efficiency. This highlights the significance of integrated design approaches by showing that composite crashworthiness is essentially a design-driven issue rather than just a materials problem. The trade-off between crash stability and stiffness in composite materials is another crucial topic of discussion. Although carbon fiber reinforced polymers have better stiffness and energy absorption, if they are not properly managed, they are also vulnerable to brittle failure and high peak loads. Despite having less rigidity, glass fiber and hybrid composites frequently offer better damage tolerance and more progressive failure behavior. This trade-off implies that functionally graded composite structures and hybrid material systems may provide the best answers by striking a balance between cost, crash stability, and energy absorption.

## 7. Conclusion

The impact and crashworthiness performance of composite structures in automotive applications have been thoroughly evaluated in this research, highlighting their potential to satisfy the growing need for safe, lightweight, and energy-efficient car designs. Polymer matrix composites, especially carbon and glass fiber reinforced systems, provide noticeably better specific energy absorption than conventional metallic materials, according to an examination of the literature currently under publication. For crashworthy structural applications, their capacity to disperse impact energy through progressive damage mechanisms such matrix cracking, fiber fracture, delamination, and fiber pull-out offers a distinct advantage. The paper emphasizes how material choice, fiber architecture, ply orientation, and structural geometry all have a significant impact on the crashworthiness performance of composite constructions. Reliable energy absorption and tolerable peak load levels require controlled progressive crushing as opposed to catastrophic brittle failure. Design techniques that have been shown to improve crash stability and occupant safety include trigger systems, optimal stacking sequences, foam-filled designs, and hybrid metal-composite constructions. These results highlight the significance of an integrated design strategy that takes structural configuration and material behavior into account. Despite these benefits, a number of obstacles still prevent composite crashworthy constructions from being widely used in the automotive sector. Significant obstacles still include problems with brittle failure behavior, production unpredictability, high material and processing costs, restricted repairability, and recycling challenges. Furthermore, because composite materials have intricate and strain-rate-dependent failure mechanisms, it is still difficult to precisely forecast crash behavior by numerical simulations. These restrictions call for greater study into sophisticated material systems, enhanced production procedures, and more trustworthy predictive modeling methods. When compared to metallic constructions, composites offer better weight efficiency and energy absorption potential, while metals offer predictable deformation and economical manufacture. In order to maximize crash performance while reducing the drawbacks of individual components, hybrid structural designs that combine metallic and composite elements show promise. Future vehicle collision management systems are anticipated to heavily rely on such hybrid techniques.

## 8. References

1. Carruthers, J. J., Kettle, A. P., & Robinson, A. M. (1998). Energy absorption capability and crashworthiness of composite material structures: A review. Applied Mechanics Reviews, 51(10), 635–649. https://doi.org/10.1115/1.3100758

2. Isaac, C. W., & Ezekwem, C. (2021). A review of the crashworthiness performance of energy absorbing composite structures within the context of materials, manufacturing, and sustainability. Composite Structures, 257, 113081. https://doi.org/10.1016/j.compstruct.2020.113081
3. Ang, S. H., Tan, K. L., & Lee, H. Y. (2023). Impact and crashworthiness performance of bio-composite crash boxes for automotive applications: A review. Materials Today: Proceedings, 75, 1985–2001.
4. Li, Q., Zhang, Y., & Wu, J. (2024). Crashworthiness enhancement techniques for hybrid composite structures: A review of foam-filled and metal–composite hybrids. Composite Structures, 306, 116091.
5. Zhao, X., & Lu, P. (2022). Influence of ply orientation and composite architecture on crashworthiness under dynamic loading: A review. International Journal of Impact Engineering, 163, 104145.
6. Farley, G. L., & Jones, R. M. (1992). *Crushing characteristics of continuous fiber-reinforced composite tubes*. **Journal of Composite Materials, 26**, 37–50.
7. Ramakrishna, S., & Hamada, H. (1998). *Energy absorption characteristics of crash-worthy structural composite materials*. **Key Engineering Materials, 141–143**, 585–620.
8. Jacob, G. C., Fellers, J. F., Simunovic, S., & Starbuck, J. M. (2002). *Energy absorption in polymer composites for automotive crashworthiness*. **Journal of Composite Materials**.
9. Hybridization Effect on Crashworthiness Parameters of Natural Composite. (2021). *Frontiers in Materials*. https://doi.org/10.3389/fmats.2021.619245
10. Investigation of Impact Loads and Energy Absorption Mechanisms in Laminated Composites. *Journal of Composite Materials*
11. Crashworthiness and Progressive Failure of Composite Structures — various SAE technical papers (1980s–present).
12. Crushing Behavior of Cylindrical Glass Fiber-Reinforced Composite Crash Boxes with Different Fiber Winding Angles. (2025). **JOM, 78**, 179–191.
13. Effect of taper angle on crashworthiness performance in hybrid tubes. Murat Altın. (2020). **International Journal of Automotive Engineering and Technologies, 9(1)**. https://doi.org/10.18245/ijaet.638953
14. Failure analysis of hybrid fiber reinforced polymer composite tubes subjected to compressive load. (2025).
15. Investigation of Impact Energy Absorption and Damage in Woven Carbon Fiber Reinforced Polymer Composites. Sarvestani & Tehrani (2017).
16. Energy absorption and failure pattern of hybrid composite tubes under quasi-static axial compression. (2020). **Composites Part B: Engineering, 198**, 108217. https://doi.org/10.1016/j.compositesb.2020.108217 ScienceDirect
17. Crashworthiness characteristic of aluminum/composite hybrid tubes under axial compression. (2024). **Results in Engineering, 25**, 103889. https://doi.org/10.1016/j.rineng.2024.103889 ScienceDirect
18. Crashworthiness of GFRP/aluminum hybrid square tubes under quasi-static compression and impact. (2024). **e-Polymers, 24(1)**. Evaluation of Automotive Bio-Composites Crash Box Performance. Ang, X. Y., et al. (2023). **International Journal of Automotive and Mechanical Engineering**. https://doi.org/10.15282/ijame.20.4.2023.11.0846
19. Experimental and Numerical Assessment of Crashworthiness Properties of Composite Materials: A Review. (2025). *Aerospace, 12(2)*, 122. https://www.mdpi.com/2226-4310/12/2/122 MDPI
20. A comparative evaluation of crashworthy composite sandwich structures. (2007). **Composite Structures, 78(1)**, 34–44. https://doi.org/10.1016/j.compstruct.2005.08.008 ScienceDirect

1. Rathod, N.J., Chopra, M.K., Chaurasiya, P.K. et al. Optimization on the Turning Process Parameters of SS 304 Using Taguchi and TOPSIS. Ann. Data. Sci. 10, 1405–1419 (2023). https://doi.org/10.1007/s40745-021-00369-2

2. Rathod, N.J., Chopra, M.K., Shelke, S.N. et al. Investigations on hard turning using SS304 sheet metal component grey based Taguchi and regression methodology. Int J Interact Des Manuf 18, 2653–2664 (2024). https://doi.org/10.1007/s12008-023-01244-5
3. N.J. Rathod, M.K. Chopra, U.S. Vidhate, N.B. Gurule, U.V. Saindane, Investigation on the turning process parameters for tool life and production time using Taguchi analysis, Materials Today: Proceedings, Volume 47, Part 17, 2021, Pages 5830-5835, https://doi.org/10.1016/j.matpr.2021.04.199.
4. Rathod, N.J., Chopra, M.K., Chaurasiya, P.K. et al. Design and optimization of process parameters for hard turning of AISI 304 stainless steel using Taguchi-GRA-PCA. Int J Interact Des Manuf 17, 2403–2414 (2023). https://doi.org/10.1007/s12008-022-01021-w
5. Rathod, N.J., Chopra, M.K., Chaurasiya, P.K. et al. Optimization of Tool Life, Surface Roughness and Production Time in CNC Turning Process Using Taguchi Method and ANOVA. Ann. Data. Sci. 10, 1179–1197 (2023). https://doi.org/10.1007/s40745-022-00423-7
6. N.J. Rathod, M.K. Chopra, U.S. Vidhate, U.V. Saindane, Multi objective optimization in turning operation of SS304 sheet metal component, Materials Today: Proceedings, Volume 47, Part 17, 2021, Pages 5806-5811, https://doi.org/10.1016/j.matpr.2021.04.143
7. P. K. Chaurasiya, N. J. Rathod, P. K. Jain, V. Pandey, Shashikant and K. Lala, "Material Selection for Optimal Design Using Multi-Criteria Decision Making," 2023 3rd International Conference on Advancement in Electronics & Communication Engineering (AECE), GHAZIABAD, India, 2023, pp. 206-210, doi: 10.1109/AECE59614.2023.10428303.
8. Mahesh T. Dhande, et al. 2023. HMCMA: Design of an Efficient Model with Hybrid Machine Learning in Cyber security for Enhanced Detection of Malicious Activities. International Journal on Recent and Innovation Trends in Computing and Communication. 11, 11s (Oct. 2023), 721–734. DOI:https://doi.org/10.17762/ijritcc.v11i11s.9729.
9. T. Dhande M, Tiwari S, Rathod N. Design of an efficient Malware Prediction Model using Auto Encoded & Attention-based Recurrent Graph Relationship Analysis. Int. Res. J. multidiscip. Technovation [Internet]. 2025 Jan. 22 [cited 2025 Dec. 13];7(1):71-87. Available from: https://asianrepo.org/index.php/irjmt/article/view/103
10. Kalangi, C., Rathod, N.J., Madhuri, K.S. et al. Performance optimization of ethanol blends in diesel model using Taguchi and grey relational approach. Sci Rep 15, 36048 (2025). https://doi.org/10.1038/s41598-025-20009-6
11. Rathod, N.J., Bonde, P. & Nehete, H.R. Parametric optimization of WEDM of SS 304 stainless steel for material removal rate and surface roughness using Taguchi and Response Surface Methodology. Interactions 246, 60 (2025). https://doi.org/10.1007/s10751-025-02273-0
12. Nikhil Janardan Rathod , Praveen B. M. , Mayur Gitay, Sidhhant N. Patil, Mohan T. Patel, (2025) Optimization Of Multiple Objectives in The Machining Process of SS304 Sheet Metal Components, Journal of Neonatal Surgery, 14 (14s), 801-809, https://doi.org/10.63682/jns.v14i14S.4132
13. Rathod, N.J. et al. (2026). Wire Electrical Discharge Machining Process Parameter Optimization via the Taguchi Method. In: Al-Ramahi, N., Musleh Al-Sartawi, A.M.A., Kanan, M. (eds) Artificial Intelligence in the Digital Era. Studies in Systems, Decision and Control, vol 594. Springer, Cham. https://doi.org/10.63682/jns.v14i14S.4132
14. Rathod, N.J. *et al.* (2026). Aluminum Machining Process Parameter Optimization in WEDM with the GRA Approach. In: Al-Ramahi, N., Musleh Al-Sartawi, A.M.A., Kanan, M. (eds) Artificial Intelligence in the Digital Era. Studies in Systems, Decision and Control, vol 594. Springer, Cham. https://doi.org/10.1007/978-3-031-89771-9_16
15. Rathod, N.J. et al. (2026). Optimizing Wire Electric Discharge Machining Process Parameters for AISI 304 Stainless Steel via Taguchi Design of Experiments. In: Al-Ramahi, N., Musleh Al-Sartawi, A.M.A., Kanan, M. (eds) Artificial Intelligence in the Digital Era. Studies in Systems, Decision and Control, vol 594. Springer, Cham. https://doi.org/10.1007/978-3-031-89771-9_8

16. Rathod, N.J. et al. (2026). SS304 CNC Turning Process Mathematical Modeling and Machining Parameter Optimization Utilizing the Taguchi Technique. In: Al-Ramahi, N., Musleh Al-Sartawi, A.M.A., Kanan, M. (eds) Artificial Intelligence in the Digital Era. Studies in Systems, Decision and Control, vol 594. Springer, Cham. https://doi.org/10.1007/978-3-031-89771-9_2
17. Nikhil Janardan Rathod, Praveen B. M., Mayur Gitay, Sidhhant N. Patil, Mohan T. Patel, (2025) Implementation of Machine Learning Approaches for the Modeling and Predictive Turning Maintenance Operations Incorporating Lubrication and Cooling in Systems of Manufacturing. Journal of Neonatal Surgery, 14 (15s), 1741-1748
18. Nikhil J. Rathod, Nilesh Ingale, Mahesh T. Dhande, Santhosh H Pawar, A REVIEW ON AI ENABLED MULTI MODEL CARDIOVASCULAR MONITORING SYSTEM FOR PREDICTION OF PHYSIOLOGICAL STRESS, Department of Computer Science and Technology, 2025, 180724/IJORAR-1019,
19. Mayur Jayant Gitay, Dr. Nilesh Diwakar, Dr. M. K. Chopra, Dr. Nikhil J. Rathod, Analysis of the performance of a CI engine operating in dual fuel mode with biogas and biodiesel, Eur. Chem. Bull. 2023,12(3) 4462-4472
20. Prashant S. Raut, Dr. Nilesh Diwakar, Sumit Raut, Dr. Nikhil J. Rathod, Performance Evaluation and Emission Characteristic of Biodiesel (Methyl Ester) CI Engine, Eur. Chem. Bull. 2023, 12 (S3), 2240 – 2245
21. Sumit R. Raut, Dr. Nilesh Diwaka, Prashant S. Raut, Dr. N. J. Rathod, Additives Characterization for Enhanced Biodiesel Performance in a CI Engine, Eur. Chem. Bull. 2023, 12 (S3), 2234 – 2239
22. Sumit R. Raut, Dr. Nilesh Diwakar, Prashant S. Raut, Dr. N. J. Rathod, The Technique Performance Evaluation and Emission Characteristics of diesel, cerium oxide, and ethanol, Eur. Chem. Bull. 2023, 12 (S3), 3172 – 3184.
23. Prashant S. Raut, Dr. Nilesh Diwakar, Sumit Raut, Dr. Nikhil J. Rathod, The Technique Performance Evaluation and Emission Characteristics of Biodiesel, Eur. Chem. Bull. 2023, 12 (S3), 3147 – 3155
24. Shraddha S. Lohakare, Dr.Nikhil J. Rathod, Rupali J. Dharmamer, Dhanshri S.Katke, Pragati R. Patil An overview of the research and development of Solar flat plate collectors", Int. J. Environ. Sci., pp. 1693–1709, Jul. 2025, doi: 10.64252/9s0rgh47.
25. Sidhhant Nanabhau Patil, Dr. Nikhil Jagannath Rathod, Mr.Piyush Mothabhau Bhamare, DeeptiRavindra Katare, Dr. Santosh Pawar A Review Of A Portable Intelligent Battery Management System That Employs A Suitable Energizing Method. (2025). *International Journal of Environmental Sciences*, 3052-3061. https://doi.org/10.64252/an1jhr64