Carbon Fiber Reinforced Composites in Automobile – A Review

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Abstract — The Carbon fiber-reinforced composites (CFRP) in the automotive industry offer a significant advantage due to their superior strength-to-weight ratio, high stiffness, and excellent fatigue and impact resistance. These composites consist of carbon fibers embedded in a polymer matrix, providing a material that is both lightweight and extremely strong. The use of CFRP in automobiles leads to reduced vehicle weight, which enhances fuel efficiency, accelerates performance, and improves handling. Additionally, the material's high impact resistance contributes to increased safety. CFRP also allows for greater design flexibility, enabling the creation of complex and aerodynamic shapes. Despite its high cost and the challenges associated with manufacturing, CFRP is increasingly being adopted in high-performance and luxury vehicles. Ongoing research aims to make CFRP more cost-effective and easier to produce, paving the way for broader application in the automotive industry.

Keywords: Carbon Fiber, Aumotive Industry, (CFRP), Strength

I. INTRODUCTION

- Tyre The introduction of carbon fiber-reinforced composites (CFRP) in the automotive industry marks a significant advancement in material science, driven by the need for lighter, stronger, and more fuel-efficient vehicles.
- CFRP consists of carbon fibers embedded within a polymer matrix, combining the high strength and stiffness of carbon fibers with the versatility and durability of the polymer.
- This composite material offers an exceptional strength-to-weight ratio, surpassing traditional metals such as steel and aluminum, which translates to substantial weight reductions in vehicle design. The automotive sector has increasingly adopted CFRP in the production of high-performance and luxury vehicles, primarily to enhance performance, fuel efficiency, and safety.
- Reduced vehicle weight directly contributes to lower fuel consumption and emissions, aligning with stringent environmental regulations and the global push for sustainability.

A. Types of Carbon Fiber

- Tyre Pyrolysis Plant
- Plastic Pyrolysis Plant
- Biomass Pyrolysis Plant
- Municipal Solid Waste (MSW) Pyrolysis Plant
- Medical Waste Pyrolysis Plant

Each type of pyrolysis plant has its own set of advantages and limitations, making them suitable for different waste types and applications. The choice of plant depends on the specific feedstock available and the desired end products. As shown in the below figure.

II. LITERATURE REVIEW

By Pyrolysis method waste tyres are used to produce TPO oil. We studied some of the papers, those are explained below:

Huile Zhang,Zeyu sun,Pengpeng et.al.,[1] In this journal the author said that The article presents a novel multiscale method for designing carbon-fiber-reinforced composite car doors, integrating material and structural optimization through parametric modeling, finite element analysis, and a unique algorithm. The study achieves up to 15.85% weight reduction, emphasizing the importance of microstructure design. It highlights the balance between stiffness and mass, offering a systematic and efficient approach to lightweight, crashworthy car door design. The findings have broader implications for material efficiency in various industries, making it a significant contribution to composite materials and automotive engineering.

Andoko Andoko et.al.,[2] The author proposed that This study The article explores the development of hybrid polymer composites reinforced with carbon fiber (CF) and Ceiba petandra fiber (CPF), achieving a balance of mechanical properties and thermal stability. By incorporating CPF, the study addresses the brittleness and cost issues of CF composites, leading to a decrease in density, beneficial for lightweight applications. The research provides valuable insights into the trade-offs between mechanical properties and density, with potential applications in automotive, aerospace, and construction industries. It offers a promising approach to sustainable, high-performance materials.

Jing Chen et.al.,[3] In this article the author said The article examines the effectiveness of microwave curing for carbon fiber/epoxy resin composites in automobile rear-view mirrors, showing it significantly speeds up curing and enhances material properties compared to traditional thermal methods. Microwave curing improves the glass transition temperature, specific heat change, and mechanical properties, with a curing degree nearly double that of conventional techniques. SEM analysis reveals a more uniform matrix, indicating better material integrity. This method offers a faster, more efficient alternative for processing complex 3D components, with promising implications for the automotive industry.

H Ahmad1 et.al.,[4] In this journal the author said that The article reviews carbon fiber reinforced plastic (CFRP) and its potential impact on the automotive industry, emphasizing its role in reducing vehicle weight and improving efficiency. CFRP is noted for its superior stiffness, strength, and fatigue resistance, making it ideal for enhancing fuel economy and safety. Despite its higher cost compared to materials like steel, CFRP offers significant weight reduction benefits, particularly in high-performance and luxury cars. The review covers current applications in components like bumpers and body panels, highlighting durability and performance advantages. However, widespread adoption is hindered by cost and manufacturing challenges, with ongoing research focused on reducing costs and improving recyclability. The article concludes that while CFRP technology is progressing, further innovation is necessary to expand its use beyond luxury vehicles to mainstream automotive markets.

Rajeev Kumar et.al.,[5] The research This study reviews The paper reviews the effectiveness of self-healing systems in glass fiber-reinforced composite (GFRC) mono-leaf springs, focusing on microcapsule-based healing agents. The study shows that these agents significantly improve load-carrying capacity and fracture resistance in GFRC samples. While self-healing technology extends the lifespan of composites, challenges like fatigue, environmental effects, and long-term durability remain. The research highlights the potential of these systems in automotive suspension components but calls for further investigation into environmental factors affecting their performance. Overall, the study emphasizes the promise of self-healing technologies in enhancing the reliability of composite materials in automotive applications.

Fanran Meng et.al.,[6] The author proposed This study The study evaluates the environmental benefits of using recycled carbon fiber reinforced plastic (rCFRP) in automotive applications, showing that it offers a lower environmental impact compared to steel, aluminum, and virgin carbon fiber (vCF). rCFRP significantly reduces greenhouse gas emissions and energy consumption, with only 17% to 26% of the global warming potential of virgin CFRP. The research highlights the importance of design factors in optimizing rCFRP's environmental performance and supports its increased adoption to promote sustainability in automotive manufacturing..

Murlidhar Patel, et.al.,[7] The review article analyzes the benefits of lightweight composites in the automotive industry, highlighting their potential to reduce vehicle weight by 10% to 60%, improving fuel economy and performance. It discusses the advantages of metal, ceramic, and polymer matrix composites, while noting their higher costs compared to traditional materials. The review also explores the environmental impact and manufacturing challenges of these composites, emphasizing the need for further research to make them more affordable and recyclable. The study concludes that advanced composites are crucial for enhancing fuel efficiency and reducing emissions in the automotive sector.

Rozaini Othman et.al.,[8] The author proposed that The study examines the potential of carbon fiber reinforced plastics (CFRP) in the automotive industry, emphasizing its ability to reduce vehicle weight by up to 60%, improve fuel efficiency by 30%, and cut CO2 emissions by 20%. Despite these benefits, widespread adoption is hindered by high costs, production challenges, and recycling issues. CFRP is increasingly used in high-performance vehicles, but overcoming these barriers is crucial for broader application in mainstream cars. The research highlights the need for innovation to unlock CFRP's full potential in the automotive sector.

R.Masilamaniet.al.,[9] In this journal the author said that The article examines the potential of Carbon Fiber Reinforced Plastics (CFRP) in the automotive industry, noting its strength-to-weight ratio and benefits such as up to 30% weight reduction, improved fuel efficiency, and enhanced safety. CFRP's application is expanding from high-performance sports cars to conventional vehicles, though high costs and complex manufacturing limit its broader use. Advances in technology and cost reduction are expected to enhance CFRP's accessibility, making it a promising material for future automotive designs.

K. Gowtham et.al.,[10] In this journal the author The article explores the use of short fiber reinforced composites in automotive applications, focusing on non-structural components and their benefits in lightweight design. It highlights the cost, ecological, and emission advantages of fiber reinforced plastics (FRP), especially glass fiber reinforced plastics. Various CFRP production techniques are reviewed for their efficiency and economic viability, with CFRPs showing promise for enhancing vehicle performance, safety, and crash management. The study underscores how advanced composites can transform automotive design by combining lightweight construction with improved safety.

Ananda babu et.al.,[11] In this journal the author said The article highlights carbon fiber's transformative impact on the automotive industry, emphasizing its superior strength-to-weight ratio, fatigue strength, and resistance to thermal expansion and corrosion. Initially limited by brittleness and high costs, carbon fiber's advantages in performance and energy efficiency have led to its adoption in high-performance and mainstream vehicles. The use of carbon fiber reinforced plastics (CFRP) in components like bumpers and chassis enhances vehicle performance, fuel efficiency, and stability. The study underscores CFRP's potential to revolutionize automotive design by combining lightweight and performance benefits.

Sivasaravanan.S et.al.,[12] In this journal the author said that The article explores epoxy resin composites reinforced with E-type glass fiber, carbon fiber, and natural fibers, fabricated using the hand layup technique. Mechanical tests reveal high ultimate strength (208.66 N/mm²), good impact resistance (7.73 J), and solid hardness (91.2 RHL). The study highlights the composites' robust properties and their potential applications in aerospace, automotive, and engineering fields. The inclusion of natural fibers offers an environmentally friendly enhancement to traditional composite materials.

K. S.R. Naqvi et.al.,[13] In this journal the author said that The article explores managing end-of-life waste from carbon and glass fiber reinforced composites (CFRC/GFRC) through pyrolysis, a recycling process that recovers valuable resources and produces fuel. While pyrolysis shows promise, it requires optimization for improved efficiency and fiber quality. The study highlights the advantages and challenges of pyrolysis in the circular economy and compares it with mechanical recycling for glass fibers. It underscores the need for further research to enhance pyrolysis conditions and overall recycling effectiveness.

K. Harmeet singh et.al.,[14] In this journal the author said The article compares the mechanical properties of Aluminum-Boron Carbide Metal Matrix Composite (MMC) and Carbon Epoxy Composite for leaf springs with traditional EN45A spring steel in a Tata Ace mini truck. Both composites reduce weight and maintain comparable strength, with enhanced strength and hardness as weight fraction and dimensions increase. While offering performance benefits, the higher fabrication costs of these composites are a drawback compared to steel. The study highlights the potential for composites to improve fuel efficiency and vehicle weight, but cost-effectiveness remains a challenge for broader adoption.

K Abdulrahman et.al.,[15] In this journal the author said The article reviews natural fiber-reinforced polymer composites (NFRPCs) in the automotive industry, highlighting their lightweight, renewable, cost-effective, and eco-friendly benefits. It focuses on lignocellulosic-based NFRPCs, noting their promise in reducing emissions and fuel consumption but also addressing challenges like fiber-matrix compatibility and durability. The study outlines extraction and processing methods and emphasizes the need for further research to improve mechanical and thermal properties. Overall, it advocates for advancing NFRPC technology to enhance automotive applications and environmental sustainability.

Hossein Rahmani a et.al.,[16] In this journal the author said The article investigates predicting elastic constants in carbon fiber-reinforced epoxy laminated composites using MATLAB Calculation Code (MCC). It evaluates different fiber orientations and volume fractions, validating predictions with experimental data. Results show MCC effectively forecasts tensile properties, with optimal performance at ±35º orientations, despite some discrepancies due to fabrication defects. The study confirms MCC’s reliability for designing and optimizing CFRP composites for high-performance applications in aerospace, automotive, and sports industries.

Anizah Kalam a et.al.,[17] In this journal the author said This study compares the mechanical and fatigue properties of oil palm fruit bunch fiber (OPFBF)/epoxy and carbon fiber (CF)/epoxy composites. The results show that increasing the fiber volume ratio in OPFBF/epoxy composites reduces tensile strength but increases Young's modulus. CF/epoxy composites exhibit a more linear stress-strain behavior and superior fatigue life compared to OPFBF/epoxy composites, attributed to the higher strength and stiffness of carbon fibers.

Kamyar Shirvanimoghaddam et.al.,[18] In this journal the author said that The paper reviews carbon fiber reinforced metal matrix composites (CFR-MMCs), focusing on how carbon fiber structure and bonding affect their properties. It covers optimization of fabrication processes and compares various methods, including infiltration, casting, powder metallurgy, and vapor deposition. CFR-MMCs offer advantages such as low thermal expansion, high wear resistance, and improved strength, but challenges remain in fiber dispersion and surface modifications. Future research aims to explore advanced fiber types and mathematical modeling to enhance CFR-MMC performance.

Fanran Menget.al.,[19] In this journal the author said that The article assesses the financial feasibility of recycled carbon fiber (rCF) for automotive use, highlighting that recycling carbon fiber costs about $5/kg, significantly lower than virgin carbon fiber. Life cycle cost analysis shows rCF composites offer substantial savings compared to virgin carbon fiber, steel, and aluminum. The study underscores rCF's market potential due to weight savings and fuel cost reductions, affirming its competitiveness and commercial viability in automotive and other industries.

Sharun Hegdeet.al.,[20] In this journal the author said that The article reviews the evolution and applications of Carbon Fiber Reinforced Polymer (CFRP), noting its exceptional strength-to-weight ratio and corrosion resistance. It highlights CFRP's increasing use in aerospace and automotive sectors due to falling costs, while emphasizing factors affecting its performance such as fiber-resin combinations and curing conditions. Despite challenges in durability and recycling, CFRP's benefits in weight reduction and fuel efficiency make it valuable across various industries. The article concludes that CFRP has significant potential for widespread use with continued advancements in production and workforce development.

K. Muhammad ateeq et.al.,[21] In this journal The literature on 3D printing recycled carbon fiber reinforced polymer composites (rCFRPCs) emphasizes the benefits of incorporating rCF into thermoplastic matrices, improving tensile strength and modulus. Additive manufacturing techniques like FDM and SLS offer advantages in cost and quality but face challenges in fiber dispersion and energy consumption. Environmental benefits include reduced landfill waste and CO2 emissions. Future research aims to enhance mechanical properties, fiber-matrix interactions, and recycling technologies for higher quality rCF and lower environmental impact.

KYadvinder Singh et.al.,[22] In this journal the author said that Hybrid composites using coir and carbon fibers offer a balance between sustainability and performance. Coir's natural properties enhance the eco-friendliness of composites, while carbon fiber boosts mechanical strength. Research has shown that combining these fibers improves tensile and impact resistance, though challenges in fiber-matrix adhesion and consistent quality remain. Future studies should explore alternative treatments and optimal fiber combinations to enhance hybrid composite performance.

KMarcelle Det.al.,[23] In this journal the author said Recycling carbon fiber reinforced polymers (CFRPs) is increasingly vital due to environmental and economic concerns with traditional disposal methods. Superheated steam (SH-steam) has shown promise in efficiently recovering high-quality carbon fibers by degrading the polymer matrix while preserving fiber integrity. Studies indicate that SH-steam can retain up to 100% of the original fibers' tensile strength and modulus. The process also offers environmental benefits over conventional methods but faces challenges in scaling and optimizing for various CFRP formats. Future research should focus on improving process efficiency and analyzing matrix degradation.

Rupam Gogoiet.al.,[24] In this journal the author said that Carbon fiber reinforced polyolefin composites, particularly with polypropylene (PP) and polyethylene (PE), are gaining attention for their balance of high strength, lightweight, and recyclability. Research shows that carbon fibers significantly improve tensile strength and modulus in these matrices. Challenges include enhancing interfacial adhesion between the hydrophobic polyolefin and carbon fibers, which can be addressed with surface treatments and coupling agents. Advances in manufacturing techniques like injection molding and extrusion have improved production quality. However, reducing costs and optimizing fiber dispersion remain ongoing challenges, requiring further research into novel treatments and processing methods.

Hanie Zarafsh ani a,et.al.,[25] In this journal the author said that Woven hemp fiber reinforced epoxy composites are gaining traction as sustainable alternatives to synthetic fibers, particularly in aerospace and electric scooters. Studies show that hemp fiber composites provide significant tensile and flexural strength while being lighter and more environmentally friendly. Life Cycle Assessments reveal that hemp fibers have a much lower global warming potential compared to carbon fibers. Challenges include optimizing fiber-matrix adhesion and scaling up production, but surface treatments and resin modifications show promise. Overall, hemp composites offer a strong, eco-friendly option for lightweight applications.

Prantik Goswami et.al.,[26] In this journal the author said that The automotive industry's shift towards lightweight materials has heightened interest in carbon fiber reinforced polymers (CFRP) due to their high tensile strength, low weight, and excellent stiffness. CFRP's superior strength-to-weight ratio, allowing for significant weight reduction and improved fuel efficiency, has been particularly beneficial in high-performance and luxury vehicles. Research highlights that CFRP can reduce vehicle weight by up to 60%, though high costs and manufacturing complexity remain challenges. Advances in production techniques are helping make CFRP more accessible for mass production. Overall, CFRP offers a promising future for lighter, more efficient vehicles.

Fardin Khan aet.al.,[27] In this journal the author said that Composite materials, including carbon fiber, glass fiber, and natural fibers, are increasingly crucial in the automotive industry for their high strength, low weight, and durability. CFRP, for example, reduces vehicle weight, improves fuel efficiency, and enhances safety features while offering excellent corrosion resistance. Despite these benefits, high manufacturing costs and recycling challenges limit widespread adoption. Ongoing innovations in fabrication, such as 3D printing and natural fiber composites, are addressing these issues. Overall, composites offer a promising path for lighter, safer, and more sustainable vehicles.

Murlidhar Patelet.al.,[28] In this journal the author said that The automotive industry increasingly relies on lightweight composite materials to meet energy efficiency and environmental regulations. Carbon fiber reinforced polymers (CFRP) and glass fiber reinforced polymers (GFRP) significantly reduce vehicle weight, improving fuel efficiency and lowering emissions, with potential weight reductions of up to 40%. Metal matrix composites (MMCs) with magnesium and aluminum also offer substantial weight savings, up to 60%, compared to traditional metals. Challenges include high material costs and limited recycling options, but advancements in 3D printing, automated processes, and new recycling techniques are improving accessibility and cost-effectiveness. Overall, lightweight composites are crucial for developing more energy-efficient and eco-friendly vehicles.

Manoj Kumar et.al.,[29] In this journal the author said that Carbon-fiber reinforced polymers (CFRPs) are crucial in automotive, aerospace, and other industries due to their high strength, low weight, and durability. They significantly enhance vehicle performance by reducing weight, improving fuel efficiency, and increasing safety. Despite their benefits, high costs and complex recycling processes limit widespread adoption. Research is focusing on developing alternative materials and advancing manufacturing technologies to address these challenges. Ongoing innovations aim to integrate sustainable materials and reduce production costs, ensuring CFRPs continue to lead in high-performance applications.

Prantik Met.al.,[30] In this journal the author said Carbon-based composites, including those with carbon nanotubes, graphene, and activated carbon, are highly valued in defense for their lightweight, high strength, and thermal stability. They enhance performance in aeronautics, naval applications, and electronics by reducing weight and improving durability. Carbon nanotubes and graphene further improve functionality in radar, communication, and thermal management. Challenges remain with the high cost and scalability of production. Ongoing research aims to address these issues and improve material integration, supporting the future advancement of defense technologies.

Stefan Junk et.al.,[31] In this journal the author said Integrating generative design (GD) with fiber-reinforced additive manufacturing (FRAM) represents a significant advancement in lightweight automotive component design. GD optimizes complex geometries for reduced weight while maintaining structural integrity, and FRAM enables precise fabrication with reinforced fibers. Studies show this approach results in substantial weight and cost reductions, enhancing fuel efficiency and reducing emissions. Challenges include the need for better generative design software to model long fibers accurately, affecting component performance predictions. Addressing these software limitations could further enhance the efficiency and effectiveness of this technology.

Brijesh Gangil et.al.,[32] In this journal the author said that Using waste materials like dolomite dust as fillers in polymer composites offers benefits such as enhanced mechanical properties, reduced costs, and environmental impact mitigation. Research has shown that fillers like cenosphere and cement by-pass dust improve properties like hardness and tensile strength in composites. Although dolomite dust has been explored in construction, its use in carbon fiber-reinforced polymer composites is less studied. This research focuses on evaluating dolomite dust as a filler in carbon fiber-reinforced vinyl ester composites, aiming to improve performance and sustainability.

Rui Guo et.al.,[33] In this journal the author said that The fatigue performance of Carbon Fiber Reinforced Polymer (CFRP) composites is vital for their use in aerospace, automotive, and civil engineering. Factors affecting fatigue include material composition, service environment, and loading conditions, with high-modulus fibers and tough matrices generally improving fatigue resistance. Environmental conditions like temperature and humidity can accelerate damage, while cyclic loading conditions significantly impact fatigue life. Current models are often phenomenological and need improvement, with future research focusing on developing more accurate prediction models and testing under real-world conditions.

Olusanmi Adeniran et.al.,[34] In this journal the author said Additive manufacturing (AM) of Carbon Fiber Reinforced Plastic (CFRP) composites is transforming component production in aerospace and automotive industries by enabling customized designs and reducing material waste. Key factors include selecting compatible thermoplastic matrices and optimizing printing parameters such as temperature and speed for better mechanical properties. Challenges like managing interlayer voids and environmental susceptibility remain, requiring improved simulation models and processing techniques. Ongoing research is crucial to refine material design and processing for maximizing AM's benefits in high-performance applications.

Eneyw Gardie et.al.,[35] In this journal the author said that Carbon fiber reinforced composites are gaining traction in automotive wheels due to their high strength-to-weight ratio, which enhances vehicle dynamics by reducing unsprung weight. Research shows that these composites can cut wheel weight by up to 80.4% compared to steel, improving performance. Simulations with tools like SOLIDWORKS and ANSYS indicate carbon fiber wheels have lower stress and deformation than steel wheels, showcasing their durability. However, challenges in cost and manufacturability remain, and further research is needed to optimize these composites for real-world applications.

Marcelle D et.al.,[36] In this journal the author said that Recycling carbon fiber reinforced polymers (CFRPs) is critical due to their growing use in aerospace, automotive, and energy sectors. Superheated steam (SH-steam) treatment, which exposes CFRP waste to steam at 400-600°C, effectively breaks down the polymer matrix while preserving the carbon fibers, retaining 90%-100% of their tensile modulus and 65%-100% of their tensile strength. This method is more energy-efficient and environmentally friendly compared to traditional pyrolysis. Despite promising results, further research is needed to optimize the process, scale up for industrial use, and assess economic feasibility.

Jyotishkumar Parameswaranpillai et.al.,[37] In this journal the author said that Plant fiber reinforced polymer composites (PFRPCs) are gaining popularity due to their environmental benefits, including biodegradability and lower CO2 emissions. Although plant fibers like flax and hemp were once overshadowed by synthetic alternatives, recent interest is driven by sustainability and local economic support. Challenges such as lower strength and moisture absorption are being addressed through surface modifications and coupling agents. The PFRPC market is growing rapidly, but further research is needed to improve their performance, especially in outdoor conditions and high-load applications.

Alaa M. Almushaikeh et.al.,[38] In this journal the author said that Carbon fiber reinforced thermoplastics (CFRTP) are valued for their high strength, light weight, and recyclability, offering a superior alternative to traditional composites. Production methods range from conventional techniques like injection molding to emerging automated methods such as 3D printing, which reduce costs and enhance precision. Current research focuses on improving the recyclability of CFRTP through chemical recycling methods. Despite their advantages, challenges such as high costs and complex manufacturing persist. Ongoing advancements in automation and recycling are crucial for making CFRTP more accessible and sustainable.

Jogendra Kumar et.al.,[39] In this journal the author said that Machinability of carbon fiber reinforced polymers (CFRP) modified with graphene oxide (GO) is challenging due to their abrasiveness and tendency for damage like delamination. Recent studies using Response Surface Methodology (RSM) and Principal Component Analysis (PCA) have optimized drilling parameters, finding feed rate to be critical in minimizing damage. GO enhances strength and stiffness but complicates machining, requiring careful parameter adjustment and the use of advanced drill bits. Future research should explore additional factors such as tool geometry and cooling methods to improve drilling performance.

Sunday A et.al.,[40] In this journal the author said that Nanofluids, containing nanoparticles, are enhancing CFRP machining by reducing tool wear, cutting forces, and temperatures. Their superior thermal conductivity and lubrication improve efficiency and sustainability compared to traditional coolants. Studies show that nanofluids, especially in minimum quantity lubrication (MQL) and cryogenic machining, reduce delamination and extend tool life. However, challenges include ensuring nanoparticle dispersion and optimizing formulations. Continued research is needed to address these issues and fully leverage nanofluids in precision and sustainable machining processes.

III. CONCLUSION

This Paper Concludes That Carbon fiber reinforced composites (CFRCs) are transforming the automotive industry by providing a unique combination of lightweight properties and high strength, which are critical for improving vehicle performance, fuel efficiency, and reducing emissions. While CFRCs offer significant advantages, including the potential to extend the range of electric vehicles, they also present challenges related to cost, recyclability, and specialized repair needs. Moving forward, the successful integration of CFRCs into the automotive sector will depend on overcoming these challenges through ongoing innovation and collaboration between material scientists and automotive engineers. Ultimately, CFRCs have the potential to play a crucial role in the future of sustainable and high-performance automotive design.

REFERENCES:

[1] Huile Zhang,Zeyu sun,Pengpeng,Wei Wang, and Zhonglai Wang " Material-Structure Integrated Design and Optimization of a Carbon-Fiber- Reinforced Composite Car Door " “MDPI” https://doi.org/10.3390/app14020930” “page no 1-19” “2024"

[2] " Andoko Andoko a, Femiana Gapsari b,, Indradi Wijatmiko c, Kuncoro Diharjo d " Performance of carbon fiber (CF)/Ceiba petandra fiber (CPF) reinforced hybrid polymer composites for lightweight high Performance applications " “journal of material research and technology

"https://doi.org/10.1016/j.jmrt.2023.11.103 " "page no 7636–7644" "2023"

[3] " Jing Chen ,Shenghui Guo ,Kaihua Chen Guozhen Zhao ,Xiaobao Zhu ,Ming Hou, " Microwave curing carbon fiber composites automobile rearview mirror " International Arabian journal of chemistry" https://doi.org/10.1016/j.arabjc.2023.104901" page no 1-10" "2023"

[4] " H Ahmad, A A Markina2, M V Porotnikov2 and F Ahmad3 " " A review of carbon fiber materials in automotive industry " Materials Science and Engineering " "doi:10.1088/1757-899X/971/3/032011" "page no 1-11" "2020"

[5] " Rajeev Kumar ,Shubham Sharma ,Piyush Gulati ,Jaiinder Preet Singh " " Fabrication and characterizations of glass fiber-reinforced functional leaf spring composites with or without microcapsule-based dicyclopentadiene as self-healing agent for automobile industry" " Journal of materials reasearch and technology" https://doi.org/10.1016/j.jmrt.2023.06.039 " page no 1-18" "2023"

[6] "Fanran Meng, Jon McKechnie, Thomas Turner, Kok H Wong , Stephen J Pickering" " Environmental aspects of use of recycled carbon fibre composites in automotive applications " "Department of Mechanical, Materials and Manufacturing Engineering, University" "page no 1-31" " 2023"

[7] Murlidhar Patel, Bhupendra Pardhi, Sulabh Chopara, Manoj Pal " Lightweight Composite Materials for Automotive " international research journal of engineering technology "e-ISSN: 2395-0056 " page no " 2020"

[8] " Rozaini Othman, Noor Iswadi Ismail " : Application of carbon fiber reinforced plastics in automotive industry: a review " International Journal Of Recent Technology And Engineering ""Vol 1, ""page no 144-154" ""2020"

[9] " R.Masilamani, N.V. Dhandapani, K. Vignesh Kumar and K. Tamil Mani "A Review on Usage of Carbon Fiber Reinforced Plastics in Automobiles "International Journal of Pure and applied mathematics "ISSN: 1314-3395" " Volume 117 No. 20 , page no 537-544,"2017"

[10] " K. Gowtham, G. Gokulnath, K. Jeevanand, C. Senthilraja, L. Vinoth " Carbon fibre in automotive applications " International Journal of Innovative Research in Science, Engineering and Technology "Vol. 18, Nos. 4r6, pp. page no 349-355 "2022"

[11] "Ananda Babu, Abhishak Bhattacharya Review on Use of Carbon Fibre " "(Reinforced Plastics) in Automotive Sector" Journal of critical reviews" ISSN- 2394-5125" "OL 7, ISSUE , page no 679-684," 02 January 2020"

[12] "Sivasaravanan.S a Bupesh Raja.V.K b,Avinash Babu.K c,Chandra Mouli.B" "mechanical characterization of gfrp/cfrp/natural fiber laminated in epoxy resin composite" material Today proceedings" page no 934–938 "2019"

[13] "S.R. Naqvia,c H. Mysore Prabhakaraa E.A. Bramera W. Dierkesa, "A critical review on recycling of end-of-life carbon fibre/glass fibre reinforced composites waste using pyrolysis towards a circular economy" Resources, Conservation & Recycling https://doi.org/10.1016/ j.resconrec.2018.04.013 ", page no 118–129, "2018"

[14] "Harmeet Singha Gurinder Singh Brarb" "Characterization and Investigation of Mechanical Properties of Composite Materials used for Leaf Spring" Materials Today Proceedings, page no 5857–586 , "2017"

[15] "Abdulrahman Adeiza Musa a,b Azikiwe Peter Onwualu b" "Potential of lignocellulosic fiber reinforced polymer composites for automobile parts production: Current knowledge,searchneeds, and future direction" "Heliyon" https://doi.org/10.1016/ j.heliyon .2024 .e24683 "page no 1-19" " 2024"

[16] "Hossein Rahmani a S. Heydar Mahmoudi Najafi a Alireza Ashori a and Mahdi Golriz b "Elastic properties of carbon fibre-reinforced epoxy composites"" Iranian Research Organization for Science " Vol. 23, No. 7, "page no 475-481" "2015"

[17] Anizah Kalam a, B.B. Sahari b,*, Y.A. Khalid b, S.V. Wong b "Fatigue behaviour of oil palm fruit bunch fibre/epoxy and carbon fibre/epoxy composites" Composite Structures" http://dx.doi.org/10.1016/j " .compositesa.2017.05.016"page no 34–44", "2020 January"

[18] "Kamyar Shirvanimoghaddam a,⇑, Salah U. Hamim b, Mohammad Karbalaei Akbari" "Carbon fiber reinforced metal matrix composites: Fabrication processes and properties " "composites " page no:70-96 " http://dx.doi.org/10.1016/j.compositesa.2016.10.032" "2017"

[19] "Fanran Meng,Jon McKechnie Steve J Pickering" "An Assessment of Financial Viability of Recycled Carbon Fibre in Automotive Applications" Applied Science and manufacturing "" https://doi.org/10.1016/j.composites " "page no 1-36" "2018"

[20] "Sharun Hegde,B.SatishShenoy,K.N.Chethan" "Review on carbon fiber reinforced polymer (CFRP) and their mechanical performance" " material today Proceedings " https://doi.org/10.10 16/j.matpr2019.07.749 " page no 1-5 "

[21] "Muhammad Ateeq a, Muhammad Shafique b,Anam Azam C Muhammad Rafiq" d "A review of 3D printing of the recycled carbon fiber reinforced polymer composites: Processing,potential, and perspectives " Journal of material Research and technology " https://doi.org/10.1016/j.jmrt2023.07.171" page no 2291 -2309, "2023"

[22] "Yadvinder Singh a Jujhar Singh a Shubham Sharma a Thanh-Danh Lam bDuc-Nam Nguyen " "Fabrication and characterization of coir/carbon-fiber reinforced epoxy based hybrid composite for helmet shells and sports-good applications influence of fiber surface modifications on the mechanical, thermal and morphological properties"Journal of material Research and Technology https://doi.org/10.1016/j.jmrt.2020.11.023, "15593 15603" "page no 15593-15603 " 7 November 2020"

[23] "Marcelle D. Hecker, Marco L. Longana Ole Thomsen, Ian Hamerton" "Recycling of carbon fibre reinforced polymer composites with superheated steam – A review" Journal of cleaner production" "page no 1-12 "2023"

[24] Rupam Gogoi, Atul K. Maurya, Gaurav Manik "A review on recent development tin carbon fiber

reinforced polyolefin composites" Composites parts" "page no 1-13" "2022"

[25] Hanie Zarafsh ani a,b Ponnapat Watjanatepin a Mark Lepelaar c Jens Verbruggen "Environmental assessment of woven hemp fibre reinforced epoxy composites and potential applications in aerospace and electric scooter industries" Results in Materials", https:// doi.org/10.1016 /j.rinma.2023 .100474 "page no 1-14" "2023"

[26] Prantik Goswami, Swapnil V. Ghogardare " Carbon Fibre in Automobiles" International Journal For Research & Development In Technology "ISSN (O) :- 2349-3585" Volume-8,Issue-1, page no 10-13, "2023"

[27] "Fardin Khan a, Nayem Hossain a,Juhi Jannat Mim aSM Maksudur Rahman a " "Advances of composite materials in automobile applications" Journal of Engineering Research" https://doi.org/10.5109/4843 099" page no 1-23, "2023"

[28] " Murlidhar Patel, Bhupendra Pardhi, Sulabh Chopara, Manoj Pal "Lightweight Composite Materials for Automotive" "International Research Journal of Engineering and Technology" "International Research Journal of Engineering and Technology "ISSN: 2395-0056 " Volume: 05 Issue: 11 | page no :41-47, Nov "2018"

[29] "Manoj Kumar Gupta,Singhal, Vishesh,Nitesh Singh Rajput" "A review Applications and Challenges of Carbon-fibres reinforced Composites" Kyushu University Institutional Repository" https://doi.org/10.5109/4843099" "Vol. 09, Issue 03, page no: 682-693, September 2022

[30] Prantik M.M. Harussani aS.M. Sapuan a, b, Go"harNadeem c, dTahrim Rafin "A review Recent applications of carbon-based composites in defence industry" Defence Technology" https://doi.org/10.1016/j.dt.2022.03.006 " "page no: 1281-1300, "2022"

[31] Stefan Junk, Nils Rothe" A review Lightweight design of automotive components using generative design with fiber-reinforced additive manufacturing" lRP(laboratory for rapid prototyping)"page no 119-124" "2022"

[32] Brijesh Gangil a, Lalit Ranakoti b, Shashi Kant Ver "ma c, Tej Singh d, "A Utilization of waste dolomite dust in carbon fiber reinforced viny lester composites" JMR&T "https://doi.org/10.1016/j. jmrt.2022.04.018 "page no 3291-3301" "2022"

[33] Rui Guo , Chenggao Li , Yanzhao Niu , Guijun Xian "The fatigue performances of carbon fiber reinforced polymer composites": JMR&T" https://doi.org/10.1016/j.jmrt.2022.11.053 " page no: 4773-4789" "2022"

[34] Olusanmi Adeniran , Weilong Cong , Adedeji Aremu "A Material design factors in the additive manufacturing of Carbon Fiber Reinforced Plastic Composites:" I&ME "https://doi.org/10.1016/j.aime.2022.100100" 1-18" "2022"

[35] Eneyw Gardie , Velmurugan Paramasivam , Habtamu Dubale , Ewnetu Tefera Chekol Senthil Kumaran Selvaraj "A Numerical analysis of reinforced carbon fiber composite material for lightweight automotive wheel application "https://doi.org/10.1016/j.matpr.2020.12.1047 " page no 1-6 "2022"

[36] Marcelle D. Hecker, Marco L. Longana 1, Ole Thomsen, Ian Hamerton « A Recycling of carbon fibre reinforced polymer composites with superheated steam https://doi.org/10.101 6/j.jclepro.2023.139320 "page no 1-12"2022"

[37] Jyotishkumar Parameswaranpillai, Jineesh Ayippadath Gopi,Sabarish Radoor "Jyotishkumar Parameswaranpillai, Jineesh Ayippadath Gopi , Sabarish Radoor" https://doi.org/10.1016/j.jcomc .2022.100333 " page no:1-15" "2023"

[38] Alaa M. Almushaikeh , Saleh O. Alaswad , Mohammed S. Alsuhybani , Bandar M. AlOtaibi "A review Manufacturing of carbon fiber reinforced thermoplastics and its recovery of carbon fiber" https://doi.org/10.1016/j.polymertesting.2023.108029 " 1-19" "2023"

[39] Jogendra Kumar, Rajesh Kumar Verma" Experimental investigation for machinability aspects of carbon fiber reinforced polymer" https://doi.org/10.1016/j.dt.2020.09.009 " 1671-1686" "2021"

[40] Sunday A. Lawal , Rasaq O. Medupin , Kelvin O. Yoro , Uzoma G. Okoro "ma c, Tej Singh "Nanofluids and their application in carbon fibre reinforced plastics" https://doi.org/10.10 16/j.arabjc 2023.104908" " page no:1-14 " "2023"

