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Development of Lightweight FRP-Based Front Mudguard for Three-Wheeler Electric Vehicle Using Low-Cost Manufacturing Technique

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Abstract

Fiber Reinforced Plastic (FRP) materials are increasingly used in the automotive industry due to their lightweight properties, corrosion resistance, high strength-to-weight ratio, and design flexibility. Conventional manufacturing methods used for automotive plastic components such as injection molding and blow molding require expensive molds, high setup costs, and complex machinery, making them unsuitable for prototype development and small-scale electric vehicle manufacturing.

The present research focuses on the design and fabrication of an FRP-based front mudguard for a three-wheeler electric vehicle using a low-cost hand lay-up manufacturing technique. The study compares previously published FRP research papers and identifies major research gaps such as high manufacturing cost, lack of practical prototype development, absence of small-scale EV applications, and dependency on advanced automated manufacturing systems.

The fabricated mudguard was successfully fitted on the vehicle and demonstrated satisfactory structural performance, lightweight characteristics, and manufacturing feasibility. The project proves that FRP materials can be effectively utilized for low-cost electric vehicle body components in small-scale manufacturing industries.

1. Materials and Fundamental Characteristics of FRP Used in the Present Project

Fiber Reinforced Plastic (FRP) is a composite material made by combining reinforcing fibers with a polymer resin matrix. The reinforcing fibers provide mechanical strength and stiffness, while the polymer matrix binds the fibers together and transfers the applied load uniformly throughout the structure.

FRP materials are widely used in automotive, aerospace, marine, and construction industries due to their excellent mechanical properties and lightweight characteristics. Compared to conventional metallic materials and thermoplastics, FRP provides better corrosion resistance, improved strength-to-weight ratio, and higher design flexibility.

In this project, Glass Fiber Reinforced Plastic (GFRP) material was used for the fabrication of the front mudguard of a three-wheeler electric vehicle.

Materials Used

1. Glass Fiber Mat

Glass fiber acts as the reinforcement material in the composite structure. It provides tensile strength, stiffness, and structural rigidity to the mudguard.

2. Epoxy Resin

Epoxy resin was used as the binding matrix material. The resin binds the glass fibers together and provides shape, surface finish, and load transfer capability.

3. Hardener

The hardener was mixed with epoxy resin to initiate the curing process and improve bonding strength.

4. Mold

A mold was prepared according to the required mudguard geometry to manufacture the final component using the hand lay-up process.

Advantages of FRP Material

- Lightweight structure
- High strength-to-weight ratio
- Corrosion resistance
- Low manufacturing cost
- Easy fabrication
- Better surface finish
- Design flexibility
- Suitable for electric vehicles

2. Critical Literature Review and Research Gap Analysis of Published FRP Studies

Several researchers have studied Fiber Reinforced Plastic (FRP) materials for automotive applications. Previous studies mainly focused on lightweight structural components, manufacturing techniques, composite material behavior, and industrial-scale applications.

Prof. V. L. Kadlag and Akshay Hire reviewed the applications of FRP composites in the automotive industry and concluded that FRP materials can significantly reduce vehicle weight and improve fuel efficiency. However, their study identified major challenges related to machining damage, high manufacturing energy consumption, and moisture absorption in natural fiber composites.

Shahram Mahboubizadeh and co-authors discussed modern advancements in FRP composites, including nano-additives, surface modification techniques, and additive manufacturing technologies. Their research mainly focused on advanced composite technologies but lacked practical implementation for low-cost automotive component manufacturing.

Dipen Kumar Rajak and co-authors reviewed manufacturing methods and applications of FRP composites in different engineering sectors. Their study highlighted challenges such as void formation, high automation cost, and long-term environmental degradation of composites.

Alpa Tapan Bhatt and co-authors analyzed primary manufacturing processes for FRP composites and discussed industrial challenges related to standardization, surface quality, and manufacturing consistency. Their study emphasized the limitations of advanced molding systems for economical production.

Recent research papers published in 2025 focused on advanced automated manufacturing systems, thermal behavior, environmental sustainability, and lightweight automotive applications. However, most studies concentrated on large-scale industries, high-cost automated processes, and theoretical analysis instead of practical prototype fabrication.

Major Research Gaps Identified

- High tooling and manufacturing cost
- Lack of low-cost prototype development
- Limited three-wheeler EV applications
- Dependency on advanced automated systems
- Lack of practical fabricated automotive components
- Absence of real vehicle fitment validation

3. Comparative Analysis of Manufacturing Methodologies: Existing Research vs Present Project

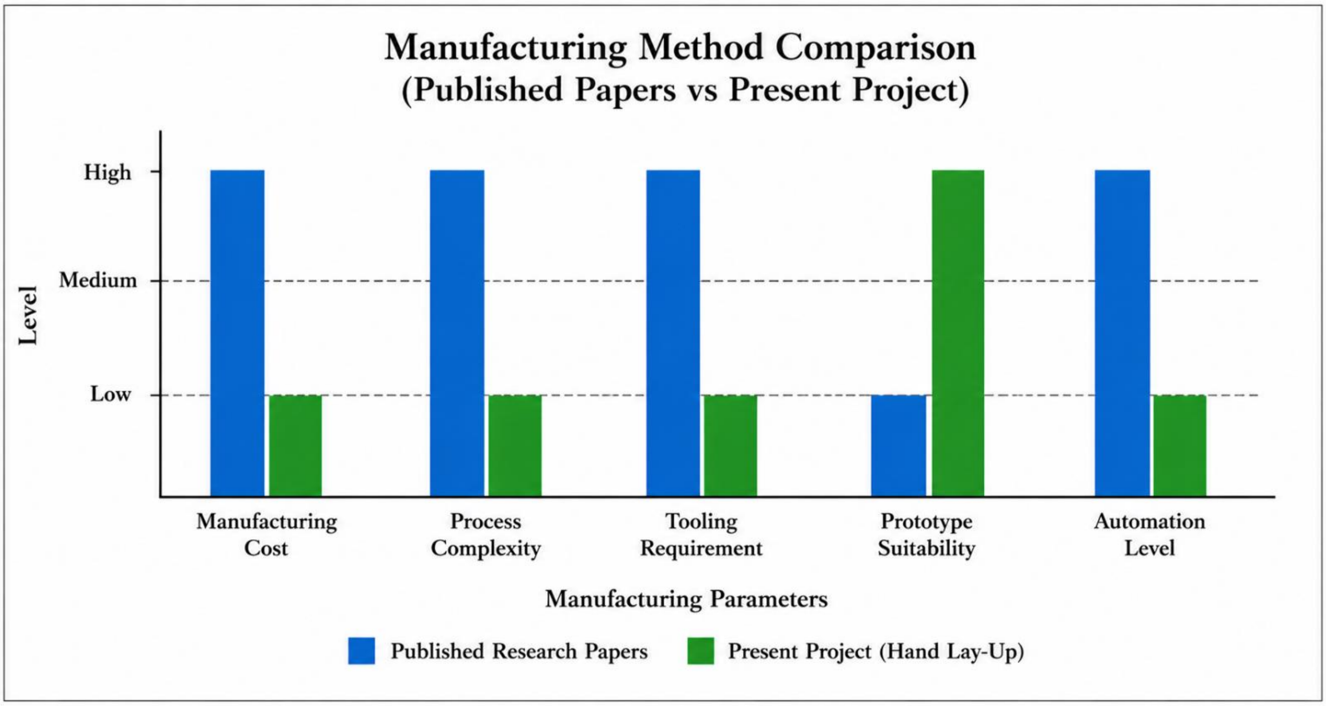
Previous FRP research papers mainly focused on advanced industrial manufacturing methods such as compression molding, Resin Transfer Molding (RTM), vacuum-assisted molding, automated fiber placement, and additive manufacturing techniques. These manufacturing methods are highly suitable for large-scale automotive industries because they provide high dimensional accuracy, uniform thickness distribution, and better production speed. However, these methods require expensive machinery, skilled operators, complex tooling systems, and high initial investment, making them unsuitable for small-scale industries and prototype development.

Many published research papers also concentrated more on simulation studies and automated industrial manufacturing processes instead of practical low-cost fabrication techniques. As a result, limited work has been done on economical FRP component development for small electric vehicles, especially three-wheeler EVs.

In contrast, the present project focuses on the practical fabrication of an FRP-based front mudguard using a simple hand lay-up process. The selected manufacturing technique is economical, easy to implement, and suitable for prototype manufacturing. The hand lay-up process also reduces dependency on costly industrial equipment and allows flexible design modification during fabrication.

The methodology followed in the present project includes literature review, design modeling using CREO software, mold preparation, glass fiber layering, resin application, curing process, trimming, finishing, and final vehicle fitment. Unlike automated industrial processes, the present methodology emphasizes simplicity, low production cost, and real-world implementation.

4. Comparative Methodology Table



Methodology Comparison Explanation

The comparison clearly indicates that previous studies mainly concentrated on high-end industrial manufacturing systems, whereas the present project focused on developing a practical and economical FRP automotive component using a simple hand lay-up process. The present methodology significantly reduces manufacturing complexity, tooling cost, and machine dependency while making FRP fabrication suitable for prototype development and small-scale EV manufacturing. This approach is highly beneficial for startup industries, research laboratories, and low-volume electric vehicle manufacturers.

5. Comparative Experimental Investigation: Published Research Studies vs Present FRP Mudguard Development

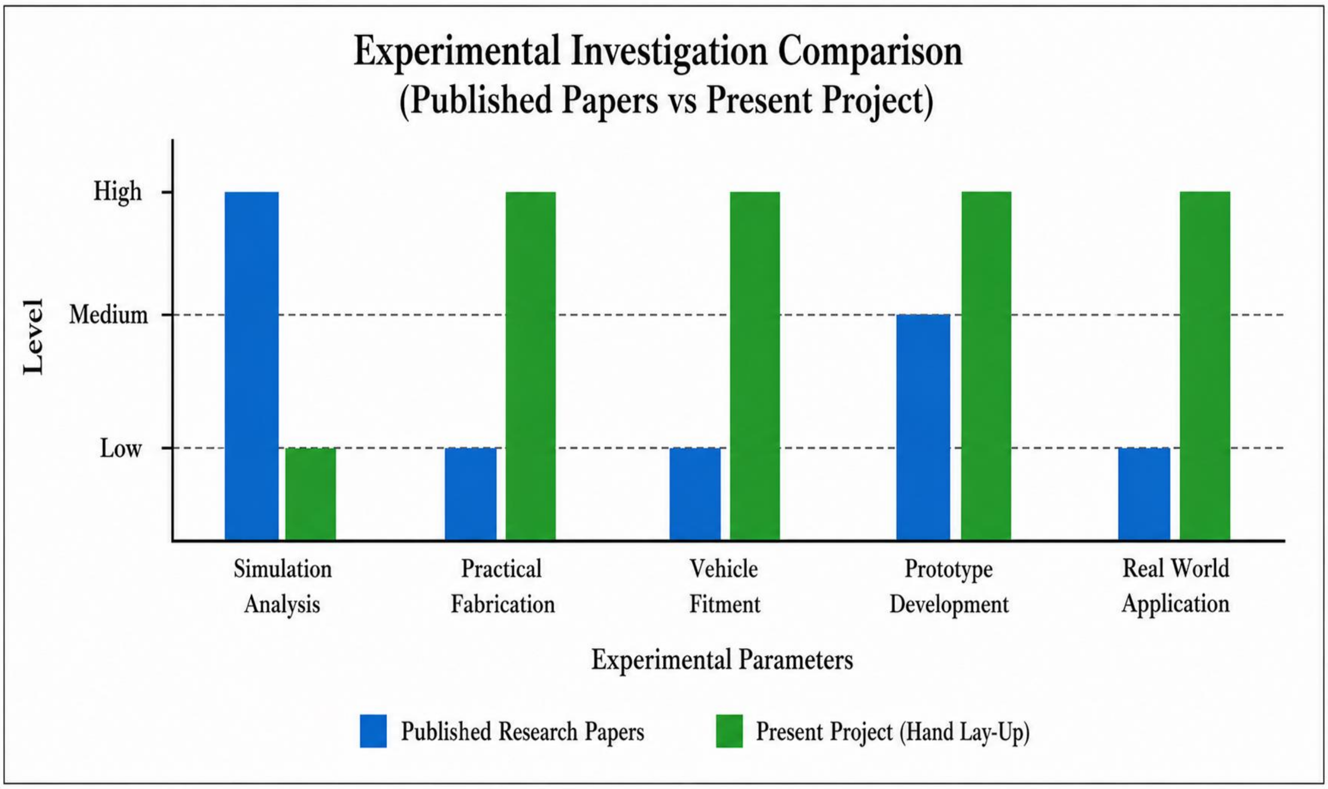
Most previously published FRP research papers focused on laboratory-based material testing and simulation analysis. The experiments mainly involved tensile testing, flexural analysis, thermal characterization, fatigue behavior, moisture absorption studies, and nano-material investigations. These studies were primarily intended for advanced composite material evaluation rather than practical automotive prototype development.

Several researchers also conducted finite element analysis and computer simulations to predict the structural behavior of composite materials under different loading conditions. While these studies provided important theoretical understanding of FRP behavior, many of them lacked actual fabrication and real-world implementation of automotive components.

The present project differs from previous research by focusing on practical experimentation associated with the fabrication and implementation of an FRP front mudguard for a three-wheeler electric vehicle. The experimental work was aimed at validating manufacturing feasibility, component integrity, lightweight characteristics, and practical usability.

The hand lay-up fabrication experiment involved proper layering of glass fiber and epoxy resin over the prepared mold surface. The curing process was carefully monitored to achieve sufficient structural rigidity and surface quality. The fabricated mudguard was then trimmed, finished, and fitted on the electric vehicle for practical validation.

Comparative Experimental Table



Experimental Comparison Explanation

Previous research papers mainly emphasized laboratory testing, advanced material characterization, and simulation-based analysis. However, the present project concentrated on practical fabrication and real-world implementation. The successful fabrication and fitment of the FRP mudguard demonstrate the practical feasibility of using low-cost composite manufacturing techniques for electric vehicle applications. The project proves that economical FRP fabrication methods can be effectively used to manufacture lightweight automotive body components without depending on expensive industrial infrastructure.

6. Comparative Results Analysis and Performance Evaluation of the Developed FRP Mudguard

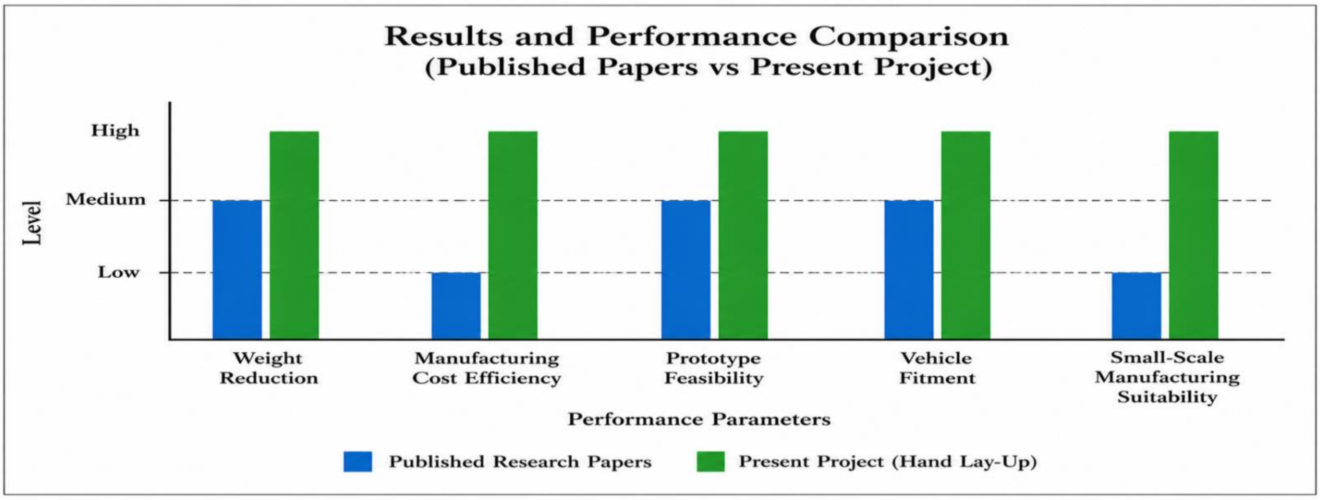
Previous FRP studies concluded that composite materials provide excellent lightweight characteristics, corrosion resistance, improved fuel efficiency, and high mechanical strength. Many researchers demonstrated that FRP structures can significantly reduce overall vehicle weight, which directly contributes to better energy efficiency and improved vehicle performance.

However, several published studies also highlighted major limitations such as expensive tooling systems, complex manufacturing processes, high setup costs, delamination issues, and the requirement for advanced automated machinery. In many cases, the practical application of FRP materials for low-cost automotive prototype development was not sufficiently addressed.

The present project successfully demonstrated the development of a lightweight and cost-effective FRP mudguard using a simple hand lay-up process. The fabricated component achieved satisfactory structural integrity and successful fitment on the three-wheeler electric vehicle. The project also proved that lightweight automotive body parts can be economically manufactured without using expensive industrial molding systems.

The hand lay-up manufacturing process reduced tooling cost and manufacturing complexity while providing sufficient flexibility for prototype fabrication. The fabricated mudguard also showed acceptable surface finish and structural stability for practical automotive applications.

Comparative Results Table



Results Comparison Explanation

The comparative analysis shows that while previous research papers focused on achieving high-performance composite structures using advanced industrial methods, the present project successfully demonstrated that practical and economical FRP automotive components can also be developed using simple manufacturing techniques. The project achieved major objectives such as weight reduction, cost reduction, practical fabrication, prototype feasibility, and real vehicle fitment, making it highly suitable for small-scale electric vehicle manufacturing applications. The results also indicate that hand lay-up fabricated FRP components can serve as an effective alternative to conventional plastic automotive parts.

7. Conclusion

The present research successfully developed an FRP-based front mudguard for a three-wheeler electric vehicle using a low-cost hand lay-up manufacturing process. The study included detailed analysis of previously published FRP research papers and identified important research gaps related to high manufacturing cost, expensive tooling systems, limited prototype development, lack of small-scale EV applications, and dependency on advanced automated manufacturing technologies.

The project successfully addressed these limitations by developing a lightweight, economical, and practically fabricated automotive component suitable for prototype and low-volume production. Unlike many previous studies that focused mainly on theoretical analysis and industrial-scale manufacturing systems, the present work emphasized practical implementation and real-world application.

The fabricated FRP mudguard demonstrated satisfactory structural performance, acceptable surface quality, lightweight characteristics, and successful vehicle fitment. The hand lay-up process proved to be an effective low-cost manufacturing technique capable of reducing tooling expenses and manufacturing complexity.

The comparative study between previously published research papers and the present project clearly indicates that economical FRP fabrication methods can play a significant role in future lightweight electric vehicle manufacturing. The project also highlights the suitability of FRP materials for small-scale industries, startup EV manufacturers, and prototype development applications.

Overall, the study concludes that FRP materials can effectively replace conventional plastic components in automotive applications while improving lightweight performance, reducing manufacturing cost, and simplifying fabrication processes.

8. Future Scope

- Development of additional FRP automotive body parts
- Application of hybrid composite materials
- Mechanical strength testing and finite element analysis
- Improvement of surface finish using advanced molding techniques
- Integration of recyclable composite materials
- Development of automated low-cost FRP manufacturing systems

- Large-scale application in lightweight electric vehicles
- Structural optimization using simulation software
- Use of natural fiber composites for eco-friendly automotive applications

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