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An overview of the role of composites in the application of lightweight body parts and their environmental impact: Review

Melese Shiferaw[a*], Asmamaw Tegegne[b], Assefa Asmare[a], Teshome Mulatie[a] and Samuel Tesfaye[c]

[a]*Faculty of Mechanical and Industrial Engineering, Bahir Dar Institute of Technology, Bahir Dar University, Bahir Dar, Ethiopia*
[b]*Federal Technical and Vocational Education and Training Institute, Addis Ababa, Ethiopia*
[c]*School of Mechanical and Industrial Engineering, Institute of Technology, University of Gondar, Gondar, Ethiopia*

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ABSTRACT

The purpose of this overview is to discover materials commonly used in the automotive industry and provide an overview of optimized composites to reduce weight, cost, fuel consumption and CO_2 emissions. The cost of carbon fiber, Al and Mg lightweight composites is much higher than conventional materials. It is therefore important for research and development in the area of reducing costs, increasing recyclability, enabling integration and maximizing the fuel economy benefits of automobiles. In order to meet these characteristics, natural fibers have better properties and, in addition to being environmentally friendly, will become the material of choice for the future automotive industry. Composites can reduce weight by 10-60%. Researchers are already working with bio composites, investigating not only the economic aspects, but also the properties and associated manufacturing processes for environmentally friendly transportation and CO_2 reduction.

1. Introduction

The 2016 report on the trends in global CO_2 emission explained that Greenhouse gas emissions, such as carbon dioxide (CO_2), methane, and ozone in the atmosphere, are widely acknowledged as the primary causes of global warming. Many activities, such as industrialization, power generation, heat production, agriculture, forestry, and transportation, contribute to the production of greenhouse gases (Jos G.J. Olivier (PBL), Greet Janssens-Maenhout (EC-JRC), Marilena Muntean (EC-JRC), 2016). The automotive industry's currently working on reducing the environmental impacts of vehicles during their use phase by using renewable materials and cleaner production. Renewable lightweight materials are used to replace traditional materials in the production of lightweight automotive parts, resulting in lower fuel consumption and helping the industry meet its environmental impact target (Tadele et al., 2020). On-road cars have evolved dramatically in terms of design and other functional characteristics in the current world. In a short period, the market requires faster and greater transportation. Vehicle makers are building big load-carrying vehicles to satisfy this market demand. These large-load transport trucks offer the benefit of speedier, heavy transportation in a short period. On the other hand, the safety of the big load-carrying vehicle must be ensured (Rajasekar & Saravanan, 2014). The search for sustainable fiber-reinforced polymer composites for automobile structures has been accelerated by the need to balance the performance, durability, and safety requirements of automotive systems with the regulatory landscape in a climate-change environment(Balaji et al., 2020). The need to reduce fuel consumption and greenhouse gas emissions, as well as the growing desire for better performance and, finally, the wide availability of materials with improved mechanical properties for automotive applications, has led to the use of high-specific strength and stiffness materials such as composites and lightweight alloys. They are being evaluated as a possible replacement for the present steel-made primary and secondary vehicle structural parts. Composite materials, in particular, are attracting the automotive and aerospace industries due to their high strength-to-weight ratio and directional-dependent stiffness. Intake manifolds, dashboards, roofs, floors, front and rear bumpers, passenger safety cells, and, in a few cases, A-pillars and B-pillars

* Corresponding author.
E-mail addresses: melese.sh07@gmail.com (M. Shiferaw)

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are among the newest applications of composite materials in the automotive industry (Belingardi & Koricho, 2014). **"**Nowadays, fuel consumption and exhaust emissions are topical issues in the automotive field, as environmental safeguard legislation constraints are going to get tougher. Indeed, one of the most efficient methods to contain fuel consumption and emissions is the weight reduction of the vehicle**"** (Monsurrò & Cozzolino, 2020). Many automobile manufacturers attempt to minimize vehicle weight by altering the materials used. Another important reason is the existence of expectations from severe European Union legislation as well as Asian country recommendations addressing the end of life in the automobile business. When choosing the raw materials and future possibilities of the vehicle, environmental considerations must be considered (Rul & Widiastuti, IndahHuda, 2021). Because of their high specific strength and modulus when compared to metals, fiber-reinforced polymeric composites are well-known and widely used. Biomaterials have recently been identified as a high-demand technology for researchers to investigate, particularly for industrial applications. This is due to environmental awareness and the overuse of petroleum resources, which has led to the development of new materials known as Biocomposites, which will ensure a better future (Nurazzi & Shazleen, 2018). Due to their unique qualities and requirements, fiber-reinforced polymers are the most widely used material in the manufacturing of a wide range of engineering goods. High resistance, corrosion resistance, and fatigue resistance are among the most important of these properties or requirements, as are lightweight and low density in contrast to other materials (Abd-Ali & Madeh, 2021). Polymeric materials currently account for nearly half of the volume of materials used in automobiles. Plastics account for 10–12% of a vehicle's total weight in developed countries and globally. According to the Corporate Average Fuel Economy (CAFE), a 10% weight reduction in an automobile will result in a 6–8% reduction in fuel consumption. Automakers are increasingly interested in bio-based materials, particularly natural-fiber-reinforced polymer composites such as kenaf, hemp, sisal, jute, and flax, to make vehicles lighter and lower their carbon footprint. Natural fibers have been used as a reinforcing phase for polymer composites in door panels, seat backs, headliners, package trays, dashboards, and other interior parts by automobile makers (Annandarajah et al., 2019; Ferreira et al., 2019). Due to the obvious unique properties of fiber-reinforced composites, they became an ideal substitute for conventional materials. Because of their lightweight, polymer matrix fiber-reinforced composites are preferred by the majority of automobile manufacturers (Yogeshwaran et al., 2020). Composites have been discovered to be the most promising and discerning material available in this century. Composites reinforced with fibers of synthetic or natural materials are gaining popularity as the market grows in demand for lightweight materials with high strength for specific applications. Fiber-reinforced polymer composites not only have a high strength-to-weight ratio, but they also have exceptional properties such as high durability, stiffness, damping property, flexural strength, corrosion resistance, wear, impact, and fire. These diverse properties have led to composite materials finding applications in mechanical, construction, aerospace, automobile, biomedical, marine, and many other manufacturing industries (Rajak et al., 2019). Natural fiber-based polymer composites have many advantages over synthetic fibers, including increased availability, low density, reusable, high stiffness, high degree of flexibility, lower energy consumption, lower health risk, and low abrasiveness. Natural fibers are biodegradable, have a low cost, and provide good performance (Kumar et al., 2019; Lokesh et al., 2020; Wu et al., 2020). Bio- and green composites are primarily used in non-structural automotive elements such as interior panels and vehicle under panels. Currently, the use of bio-composites as a viable alternative to glass fiber-reinforced plastics (GFRPs) in structural applications needs to be thoroughly examined (Colomer-Romero et al., 2020). Due to their high strength-to-weight ratio and versatility, composite materials have recently piqued the interest of the automotive industry. Sheet molded compound (SMC) composites, which consist of random fibers and are therefore inexpensive candidates for non-structural applications in future vehicles, are among the various composite materials used in mass-produced vehicles (Kelly & Cyr, 2018).

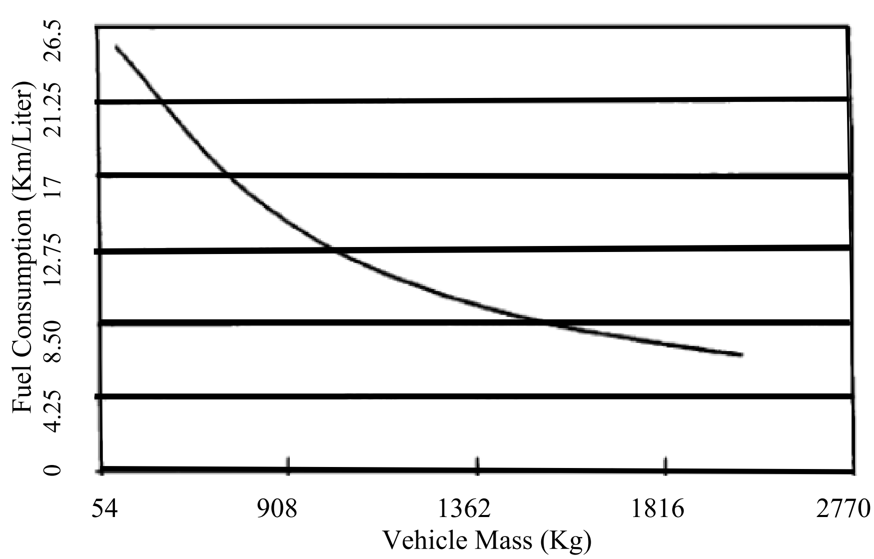

Fig. 1. The relation between vehicle mass and fuel consumption "(Eliezer et al., 1998)" (Musfirah & Jaharah, 2012).

Literature Review: Potential Materials for the weight reduction of automotive bodies

1.1 Magnesium and its alloy

According to the general rule for passenger cars, carrying their weight and the person around accounts for 86% of their energy consumption. If the car weight is reduced by 10%, the mileage may increase by 5-10%. A 1 kg weight reduction in a 1000 kg car could increase mileage by 0.016 km/l. As a result, weight reduction technology for automobiles and structural materials is critical for increased energy savings. As a result, it would be critical to use a material with a high strength-to-weight ratio that has the potential to replace steel and aluminum components in large quantities. Magnesium metal matrix composites are best suited for widespread use in the automotive and aerospace industries(Joost & Krajewski, 2017). Magnesium, the lightest metal known to man, has great potential for use as a structural alloy. The lightweight alloy and composite properties attract automobile and aerospace companies and provide an alternative to denser metals such as steel, cast iron, zinc alloys, and even aluminum alloys. The current scenario of global warming and increased CO2 content has triggered the fascination with magnesium alloys and their composites. Because of its low density, magnesium has seen increased use in the last decade, and several programs involving processing, development, and improvement in design and production are underway to reduce the environmental threat posed by emissions(D. Kumar et al., 2020). The most plentiful metal is magnesium. It has a density of 1.74–2.0 g/cm3, making it 33% lighter than aluminum and 77% lighter than steel. Mg has a density that is two-thirds that of aluminum and one-fifth that of steel. The Mg alloy enhances corrosion resistance and mechanical characteristics. Magnesium is the lightest structural metal, with a hexagonal lattice structure that affects its fundamental properties. Mg alloys are made up of magnesium and other metals such as aluminum, zinc, and copper(Jayasathyakawin et al., 2020). One of the lightest structural metals is magnesium. The potential of magnesium to reduce vehicle weight and improve performance is its primary benefit. Magnesium parts can be modified to reduce noise, vibration, and harshness at specific frequencies(Patel et al., 2020). Magnesium alloys are the lightest structural materials and have excellent heat dissipation and dampening properties, making them popular in automotive applications. Magnesium alloys, for example, are used in low-temperature automobile components such as brackets, covers, and casings(Ramalingam et al., 2020). Increasing fuel economy, meeting regulatory criteria, and meeting consumer needs all require reducing vehicle weight. Magnesium alloys are among the lightest structural metals and have enormous weight-saving potential; but, due to obstacles in production and processing, assembly, service performance, and cost, their usage in today's vehicles and trucks is limited(Joost & Krajewski, 2017). Ruther than the automotive application Due to its strong chemical reactivity, magnesium plays a significant part in non-automotive industries such as organic chemistry, pharmaceuticals, and the electrochemical industry(Citation et al., 2017). Research has shown that one of the automobile manufacturer companies, Toyota, has developed a composite material that combines natural fibers from plants such as potatoes with biodegradable plastic. This was done primarily to produce a more fuel-efficient pillar trim for the ES3 concept. Kenaf is also used in the manufacture of luggage racks and is incorporated into the structure of Toyota's i-Foot concept car. Kenaf, also imported from Bangladesh, is used by the German car company Ford in the door panels of a model called the Mondeo (Chandramohan & Bharanichandar, 2014).

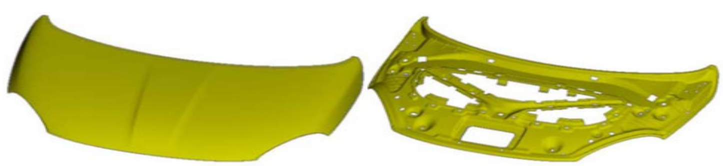

Fig. 2. Outer and inner hood panel (Monsurrò & Cozzolino, 2020).

According to the studies states that Flax, hemp, sisal, wool, and other natural fibers are used to make 50 Mercedes-Benz E-Class components (Holbery et al., 2013). The figure above shows the hood components of an automobile class made from some natural fibers. Fig. 3. below also shows the evolution of natural fiber composites 3000 years up to now.

Fig. 3. Mercedes E-class automotive components are made from different bio-fiber reinforced composites (Holbery et al., 2013).

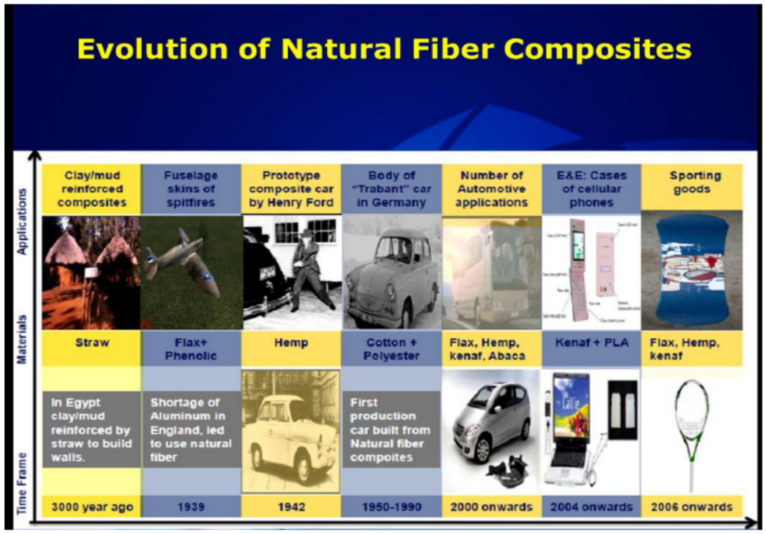

Fig. 4. "Evolution of natural fiber before 3000 years up to now" (Yimer, 2013).

1.2 Aluminum and its alloy

The research and development of new aluminum alloy materials for automobiles are primarily focused on three aspects: the whole body or large aluminum materials; the all-alloimmunization of some structural parts such as doors; and if aluminum is used instead of steel in automobile parts, the weight of automobile parts can be reduced by 30% to 50%; and the alienization of the automobile structure can reduce the mass of the entire automobile. However, there are still numerous immature applications of aluminum as a primary vehicle material (Han, 2020). For automotive applications, aluminum alloys provide the following benefits over steel: Aluminum alloys have a lower density (2.7 g/cm3 vs. 7.87 g/cm3 for steel), higher crash energy absorption per unit weight, and better thermal conductivity for radiator cores and other heat exchanger applications. Aluminum alloys, both cast and wrought, are employed in a variety of automotive applications. 319 for intake manifolds and gearbox housings, 383 for engine blocks, 356 for cylinder heads, and A356 for wheels are the most common cast alloys. Silicon (Si) is the main alloying ingredient in these alloys, which contributes to their great fluidity. They can be made using a variety of methods, including sand casting and die casting (Limited. WoodhLimited 2010).

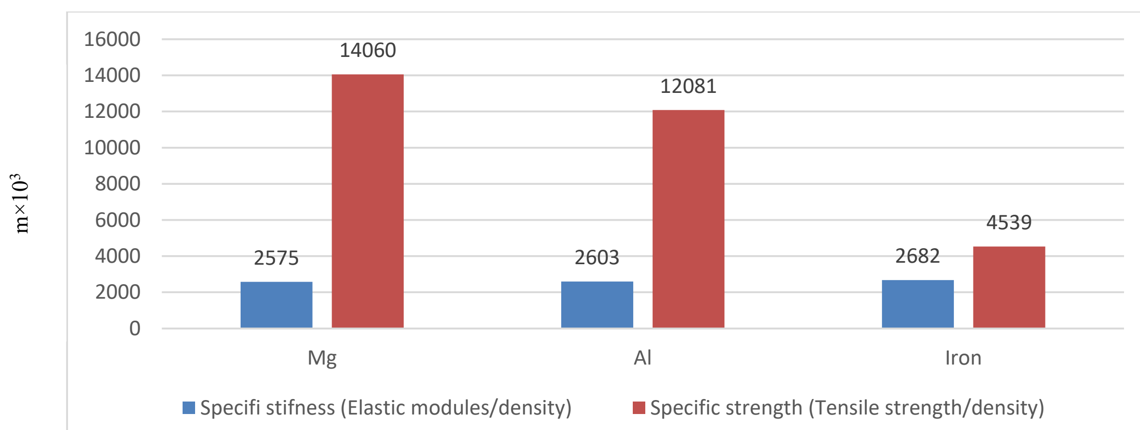

Fig. 5. Comparison of Basic Properties of Mg, Al, and Fe (Mustafa 2008; Kumar et al., 2015)

2 . Thermosetting and thermoplastic composite

Thermoplastics and thermosets are the two major types of polymers. Thermoplastics are a type of polymer that may be melted and softened when heated. This differs from thermosets, which cannot be melted by heating. Thermoplastics have higher recyclability, ductility, and impact resistance than thermosets, as well as a faster production time. Due to its lower viscosity than thermoplastic, thermoset polymers can be used with long and continuous fibers to generate high-strength composite constructions. Bumper beams, fenders, hoods, roof panels, radiator supports, deck lids, and exterior and interior body components are all examples of composite structures. In today's automobile industry, high-performance plastic applications are crucial. This tendency is projected to continue. The design of automobiles, their usefulness, and more economical construction, as well as lower fuel consumption, are the most important factors in choosing high-performance plastic materials over other materials used in automobiles. Every 10% reduction in vehicle weight is projected to result in a 5% to 7% reduction in fuel consumption (Patil et al., 2017).

3. Biocomposite materials

Composite materials based on environment-friendly natural fibers have emerged as the most promising materials for use in automobile bodies, leading to overall weight reduction (Alemayehu et al., 2020; Rajamurugan, 2021). Lightweight materials and vehicle electrification are among the most viable and economical solutions for improving vehicle fuel efficiency and reducing environmental impact during the operational phase of a typical vehicle lifecycle (Mayyas et al., 2017; Gary Kardys, 2021).

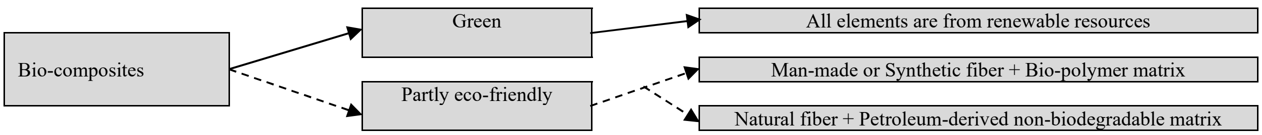

Fig. 6. Classification of biocomposites, Adapted from (Peças et al., 2018)

While traditional composites are usually made from synthetic products that are non-degradable and pollute the environment, green composites have recently become popular in the composites industry as the whole world promotes sustainability. It attracts a lot of attention (Babaremu, 2021).

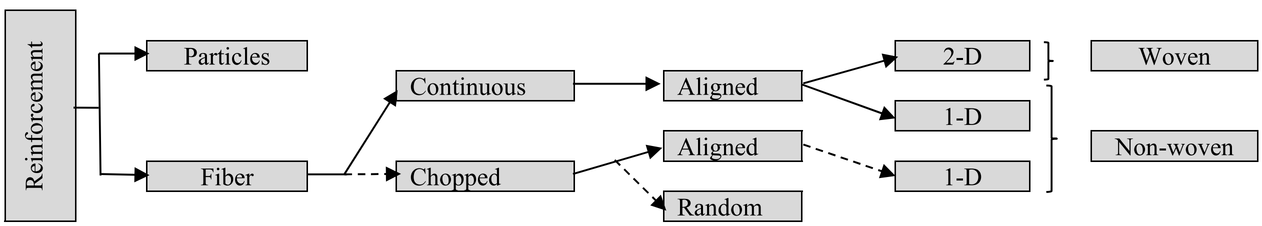

Fig. 7. Types of natural fiber reinforcement, Adapted from (P.K. Mallick, 2007)

ECOSHELL Project (Development of environmentally friendly high-performance Shinko) states that Composites from Biomaterials and Bio resins for Electric Vehicle applications deal with the development of optimal structural solutions for ultralight electric vehicles. In particular, ECOSHELL proposes to realize a complete bio composite of high-performance natural fibers and biodegradable resins, an all-natural environment with enhanced strength and biodegradability properties developed for electric vehicles. It aims to reduce weight by 20%, reduce fuel consumption and CO2 emissions by 22%, and reduce the price by 15% compared to conventional vehicles (Fan et al., 2011). A prime reason for selecting natural fibers for new products is that the net contribution to the greenhouse effect is minimal. Equally important is their low weight compared to glass fibers. Based on an advantageous cost/performance ratio, natural fiber-based composites have been in use for quite a few years in structural and automotive industry applications (Raftoyiannis, 2012; Kumar et al., 2021).

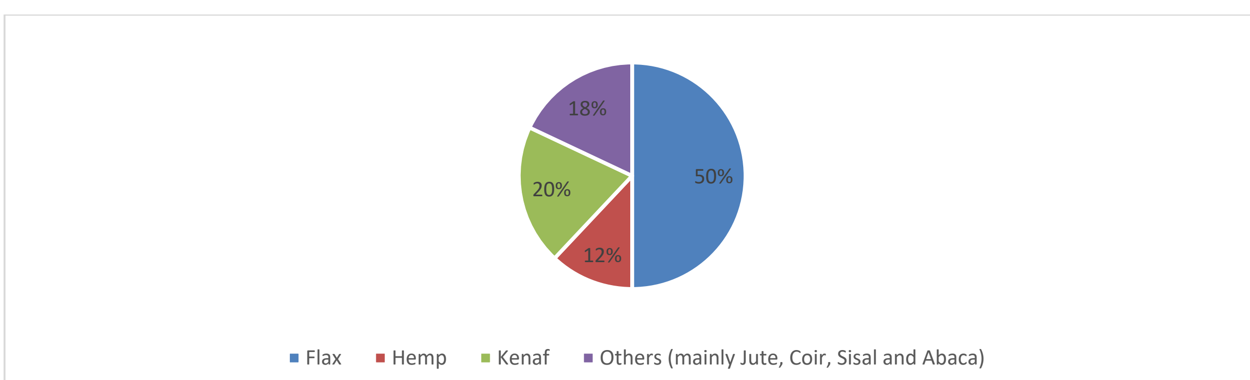

Fig. 8. The application of natural fibers in the European automotive industry in 2012 (de Beus et al., 2019).

Table 1. Mechanical Properties of Natural and synthetic fiber (Jariwala, 2019)

Fiber	Density (g/m^3)	Tensile strength (MPa)	Stiffness (young's modulus (GPa)	Specific tensile strength (MPa/gcm^{-3})	Specific young's modulus (GPa/gcm^{-3})
Ramie	1.5	400 - 938	44 – 128	270 – 620	29 – 85
Flax	1.5	345 - 1830	27 – 80	230 – 1220	18 – 53
Hemp	1.5	530 - 1110	58 – 70	370 – 740	39 – 47
Jute	1.3-1.5	393 - 800	10 – 55	300 – 610	7.1 – 39
Sisal	1.3-1.5	507 - 855	9.4 – 28	362 – 610	6.7 – 20
Cotton	1.5-1.6	287 - 800	5.5 - 13	190 – 530	3.7 – 8.4
Coir	1.2	131 – 220	4 – 6	110 – 180	3.3 – 5
Silk	1.3	100 – 1500	5 – 25	100 – 1500	4 – 20
Feather	0.9	100 – 203	3 – 10	112 – 226	3.3 – 11
Wool	1.3	50 – 315	2.3 – 5	38 – 242	1.8 – 3.8
E-glass	2.5	2000 - 3000	70	800 - 1400	29

Why do We Use Composite Materials in Place of Conventional Metals?

Do composite materials have some advantages over conventional materials as follows (Patel et al., 2020)?

- Lightweight
- High specific stiffness and strength
- Easy moldable to complex forms
- Easy bondable
- Good dumping
- Low electrical conductivity and thermal expansion
- Good fatigue resistance
- Part consolidation due to lower overall system costs and Low radar visibility

The potential benefits of the polymer matrix composites structure for the automotive industries are as follows(Patel et al., 2020):

- Weight reduction, which may be translated into improved fuel economy and performance,
- Improved overall vehicle quality and consistency in manufacturing,
- Corrosion resistance,
- Part consolidation resulted in lower vehicle and manufacturing costs,
- Improved ride performance (reduced noise, vibration, and harshness),
- Vehicle style differentiation with acceptable cost,
- Lower cost of vehicle ownership,
- Lower investment costs for plants, facilities, and tooling depends on cost/volume relationships

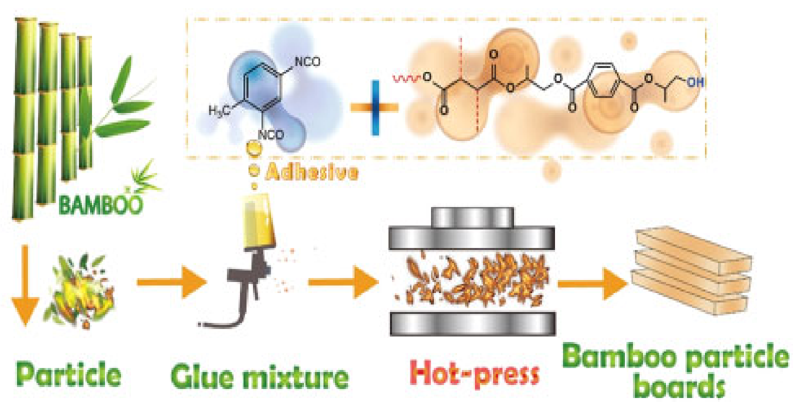

Fig. 9. An Example of the Preparation process of Natural fiber composite (Wu et al., 2022)

Comparison of natural fiber and metal matrix composite

Due to limited natural resources, scientists are looking for new materials to replace the heavy and expensive materials needed to manufacture products. Based on this idea, the concept of composite materials was born, and composite materials are now an important research area. problems due to their diverse property uses, and economic use of resources. Metallic materials have their properties, whereas composite materials' properties can be customized by specific fibers. Fiber Orientation, Fiber Volume, and Fiber Modification. This bespoke property is driving rapidly growing interest in composites for automotive, aerospace, underwater, and household applications, from small to large parts(Shahinur & Hasan, 2020).

4. Conclusion

- Due to the huge amount of research on composites of synthetic and natural fibers, we are in an uncertain world when it comes to choosing composite fibers based on:
  - ✓ manufacturing process,
  - ✓ mechanical properties,
  - ✓ cost, environmental impact, and sustainability.
- This article provides an overview of natural and synthetic fiber composites, where the matrix material is specifically polymeric, thermoplastic, thermoset, and biodegradable. We reviewed the physical properties, performance, cost, environmental impact, etc.
- The Property Comparison section provides a comparison of the properties of natural and synthetic fiber composites. The Performance of Natural and Synthetic Fiber Reinforced Polymer Composites section provides an overview of the performance of natural and synthetic fiber composites.
- Generally, in many aspects of the preseason, natural fiber composite material is the better reinforcing material for future automobile, aircraft, and marine Industries for many reasons; cost, eco-friendly, lightweight, fuel consumption reduction, CO_2 pollution reduction, and other properties which are suitable for consumers. When we generalized this compressive review the natural fiber composite had better properties than the synthetic composite and future researchers may do such types of research areas.

References

Abd-Ali, N. K., & Madeh, A. R. (2021). Investigation of Mechanical Properties for Unsaturated Polyester-Based Fibre Glass Composites Filled by Recycled Milled Composites. *IOP Conference Series: Materials Science and Engineering*, *1094*(1), 012129. https://doi.org/10.1088/1757-899x/1094/1/012129

Alemayehu, Z., Babu, R., Liben, M., & Kishan, S. (2020). Materials Today : Proceedings Experimental investigation on characteristics of sisal fiber as composite material for light vehicle body applications. *Materials Today: Proceedings*, *xxxx*, 0–5. https://doi.org/10.1016/j.matpr.2020.07.386

Annandarajah, C., Langhorst, A., Kiziltas, A., Grewell, D., Mielewski, D., & Montazami, R. (2019). Hybrid cellulose-glass fiber composites for automotive applications. *Spriger*, *12*(19), 1–11. https://doi.org/10.3390/ma12193189

Babaremu, K. O. O. K. (2021). Overview of Composite Materials from Green Product in Mechanical Application Overview of Composite Materials from Green Product in Mechanical Application. *4th International Conference on Science and Sustainable Development (ICSSD 2020)*. https://doi.org/10.1088/1755-1315/655/1/012043

Balaji, K. V, Shirvanimoghaddam, K., Sankar, G., Ellis, A. V, & Naebe, M. (2020). Surface treatment of Basalt fi ber for use in automotive composites. *Materials Today Chemistry*, *17*, 100334. https://doi.org/10.1016/j.mtchem.2020.100334

Belingardi, G., & Koricho, E. G. (2014). Design of a composite engine support sub-frame to achieve lightweight vehicles. *International Journal of Automotive Composites*, *1*(1), 90. https://doi.org/10.1504/ijautoc.2014.064129

Chandramohan, D., & Bharanichandar, J. (2014). Natural fiber reinforced polymer composites for automobile accessories. *American Journal of Environmental Sciences*, *9*(6), 494–504. https://doi.org/10.3844/ajessp.2013.494.504

Citation, O., Access, O., & Article, P. (2017). Politecnico di Torino Light-weight Design of Vehicle Roof Panel for Stiffness and Crash Analyses. *Ph.D Dissertation*. https://doi.org/10.6092/polito/porto/2678846

Colomer-romero, V., Rogiest, D., Antonio, J., & Crespo, J. E. (2020). *Comparison of Mechanical Properties of Hemp-Fibre Biocomposites Fabricated with Biobased and Regular Epoxy Resins*.

de Beus, N., Carus, M., & Barth, M. (2019). Carbon Footprint and Sustainability of Different Natural Fibres for Biocomposites and Insulation Material Study providing data for the automotive and insulation industry MultiHemp. *Http://Nova-Institute.Eu/Press/?Id=104*, *March*, 4–45. www.nova-institut.eu

Fan, J., Nassiopoulos, E., Brighton, J., De Larminat, A., & Njuguna, J. (2011). New structural biocomposites for car applications. *Society of Plastics Engineers - EUROTEC 2011 Conference Proceedings*, *November*.

Ferreira, V., Merchán, M., Egizabal, P., García, M., Cortázar, D., Irazustabarrena, A., López-sabirón, A. M., & Ferreira, G. (2019). Technical and environmental evaluation of a new high performance material based on magnesium alloy reinforced with submicrometre-sized TiC particles to develop automotive lightweight components and make transport sector more sustainable. *Integrative Medicine Research*, *8*(3), 2549–2564. https://doi.org/10.1016/j.jmrt.2019.02.012

Gary Kardys. (2021). *How Composite Materials Challenge the Automotive Manufacturing Industry - Part 1 Cost Barriers*.

Han, C. (2020). *Research on the Development and Application of Lightweight Automotive Materials Research on the Development and Application of Lightweight Automotive Materials*. https://doi.org/10.1088/1742-6596/1676/1/012085

Holbery, J., Simmons, K., Nguyen, N., Johnson, K., Pilli, S., Howe, D., & Karri, N. (2013). Reinforced Composite Material Research Energy & Environment Directorate Washington is one of only 7 states to host a multi-program DOE national lab. *Polymer Composites*.

Jariwala, H. (2019). A review on mechanical behavior of natural fiber reinforced polymer composites and its applications. *Journal of Reinforced Plastics and Composites, Springer*. https://doi.org/10.1177/0731684419828524

Jayasathyakawin, S., Ravichandran, M., Baskar, N., Chairman, C. A., & Balasundaram, R. (2020). Mechanical properties and applications of Magnesium alloy – Review. *Materials Today: Proceedings,Elsevier*, *27*(xxxx), 909–913. https://doi.org/10.1016/j.matpr.2020.01.255

Joost, W. J., & Krajewski, P. E. (2017). Towards magnesium alloys for high-volume automotive applications. *Scripta Materialia, Elsevier*, *128*, 107–112. https://doi.org/10.1016/j.scriptamat.2016.07.035

Jos G.J. Olivier (PBL), Greet Janssens-Maenhout (EC-JRC), Marilena Muntean (EC-JRC), J. A. H. W. P. (PBL). (2016). *Trends in global co 2 emissions 2016*.

Kelly, J., & Cyr, E. (2018). *Finite Element Analysis and Experimental Characterisation of SMC Composite Car Hood Specimens under*

Complex Loadings. https://doi.org/10.3390/jcs2030053

Kumar, D., Kumar, R., & Thakur, L. (2020). Materials Today : Proceedings A review on environment friendly and lightweight Magnesium-Based metal matrix composites and alloys. *Materials Today: Proceedings*, *xxxx*. https://doi.org/10.1016/j.matpr.2020.07.424

Kumar, D., Nayak, S., Saroj, S., & Sadarang, J. (2021). Materials Today : Proceedings Evaluation of flexural and vibration property of glass / bamboo / jute hybrid fiber composite in hydrothermal environment. *Materials Today: Proceedings, Elsevier*, *xxxx*. https://doi.org/10.1016/j.matpr.2021.03.062

Kumar, D. S., Sasanka, C. T., Ravindra, K., & Suman, K. N. S. (2015). Magnesium and Its Alloys in Automotive Applications – A Review. *American Journal of Materials Science and Technology*, *February*. https://doi.org/10.7726/ajmst.2015.1002

Kumar, S., Prasad, L., Kumar, S., & Patel, V. K. (2019). Physico-mechanical and Taguchi-designed sliding wear properties of Himalayan agave fiber reinforced polyester composite. *Journal of Materials Research and Technology*, *8*(4), 3662–3671. https://doi.org/10.1016/j.jmrt.2019.06.004

Lokesh, P., Surya Kumari, T. S. A., Gopi, R., & Loganathan, G. B. (2020). A study on mechanical properties of bamboo fiber reinforced polymer composite. *Materials Today: Proceedings*, *22*(November), 897–903. https://doi.org/10.1016/j.matpr.2019.11.100

Mayyas, A., Omar, M., Hayajneh, M., & Mayyas, A. R. (2017). Vehicle's Lightweight Design vs. Electrification from Life Cycle Assessment Perspective. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2017.08.145

Monsurrò, G., & Cozzolino, A. (2020). Feasibility Study On The Redesign Of A Metallic Car Hood By Using Composite Materials. *International Journal of Automotive Technology*, *21*(2), 471–479. https://doi.org/10.1007/s12239

Musfirah, A. H., & Jaharah, A. G. (2012). Magnesium and aluminum alloys in automotive industry. *Journal of Applied Sciences Research*, *8*(10), 4865–4875.

Nurazzi, N. M., & Shazleen, S. S. (2018). Natural fiber for green technology in automotive industry : A brief review Natural fiber for green technology in automotive industry : A brief review. *IOP Conf. Series: Materials Science and Engineering 368 (2018) 012012*. https://doi.org/10.1088/1757-899X/368/1/012012

Mallick, P.K. (2007). Fiber-Reinforced Composites: Materials, Manufacturing, and Design. In *CRC Press* (Vol. 19).

Patel, M., Pardhi, B., Chopara, S., & Pal, M. (2020). Lightweight Composite Materials for Automotive -A Review Lightweight Composite Materials for Automotive - A Review. *International Research Journal of Engineering and Technology (IRJET)*, *November 2018*.

Patil, A., Patel, A., & Purohit, R. (2017). An overview of Polymeric Materials for Automotive Applications. *Materials Today: Proceedings, Elsevier*, *4*(2), 3807–3815. https://doi.org/10.1016/j.matpr.2017.02.278

Peças, P., Carvalho, H., Salman, H., & Leite, M. (2018). Natural fibre composites and their applications: A review. *Journal of Composites Science*, *2*(4), 1–20. https://doi.org/10.3390/jcs2040066

Raftoyiannis, I. G. (2012). Experimental Testing of Composite Panels Reinforced with Cotton Fibers. *Open Journal of Composite Materials, Scientific Research*, *02*(02), 31–39. https://doi.org/10.4236/ojcm.2012.22005

Rajak, D. K., Pagar, D. D., Kumar, R., & Pruncu, C. I. (2019). Recent progress of reinforcement materials: A comprehensive overview of composite materials. *Journal of Materials Research and Technology, Elsevier*, *8*(6), 6354–6374. https://doi.org/10.1016/j.jmrt.2019.09.068

Rajamurugan, G. (2021). Natural Fiber Reinforced Polymer in Automotive Application : A Systematic Literature Review Natural Fiber Reinforced Polymer in Automotive Application : A Systematic Literature Review. *Journal of Physics: Conference Series*. https://doi.org/10.1088/1742-6596/1808/1/012015

Rajasekar, K., & Saravanan, R. (2014). Literature review on chassis design of on-road heavy vehicles. *IJISET - International Journal of Innovative Science, Engineering & Technology*, *1*(7), 428–433.

Ramalingam, V. V., Ramasamy, P., Kovukkal, M. Das, & Myilsamy, G. (2020). Research and Development in Magnesium Alloys for Industrial and Biomedical Applications: A Review. *Metals and Materials International, Springer*, *26*(4), 409–430. https://doi.org/10.1007/s12540-019-00346-8

Rul, & Widiastuti, IndahHuda, M. K. (2021). Natural Fiber Reinforced Polymer in Automotive Application: A Systematic Literature Review. *IOP Conference Series: Earth and Environmental Science*, *1808*(1). https://doi.org/10.1088/1742-6596/1808/1/012015

Shahinur, S., & Hasan, M. (2020). Natural Fiber and Synthetic Fiber Composites: Comparison of Properties, Performance, Cost and Environmental Benefits. In *Encyclopedia of Renewable and Sustainable Materials*. Elsevier Ltd. https://doi.org/10.1016/b978-0-12-803581-8.10994-4

Tadele, D., Roy, P., Defersha, F., Misra, M., & Mohanty, A. K. (2020). A comparative life - cycle assessment of talc - and biochar - reinforced composites for lightweight automotive parts. *Clean Technologies and Environmental Policy*, *22*(3), 639–649. https://doi.org/10.1007/s10098-019-01807-9

Wu, Y., Cai, L., Mei, C., Shiung, S., Sonne, C., Shi, S. Q., & Xia, C. (2020). Development and evaluation of zinc oxide-blended kenaf fiber biocomposite for automotive applications. *Materials Today Communications*, *24*(June 2018), 101008. https://doi.org/10.1016/j.mtcomm.2020.101008

Wu, Z., Aladejana, J. T., Liu, S., Gong, X., Wang, A., & Xie, Y. (2022). *Unsaturated Polyester Resin as a Nonformaldehyde Adhesive Used in Bamboo Particle Boards*. *7*, 3490. https://doi.org/10.1021/acsomega.1c05969

Yimer, T. (2013). *Development of Natural Fiber composites for Automotive Applications* (Issue July).

Yogeshwaran, S., Natrayan, L., Rajaraman, S., Parthasarathi, S., & Nestro, S. (2020). Experimental investigation on mechanical properties of Epoxy/graphene/fish scale and fermented spinach hybrid bio composite by hand lay-up technique. *Materials Today: Proceedings*, *37*(Part 2), 1578–1583. https://doi.org/10.1016/j.matpr.2020.07.160