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Natural Fiber Reinforced Polymer in Automotive Application: A Systematic Literature Review

Natural Fiber Reinforced Polymer in Automotive Application: A Systematic Literature Review

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Abstract. Efforts to develop effective and innovative materials are increasingly being developed by researchers, especially in the development and utilization of NFRP (Natural Fiber Reinforced Polymer) in the automotive sector due to increased demand and increased ecological awareness. The purpose of this literature review article is to provide up-to-date information on the application of NFRP and plastic recycling in the automotive sector as well as consideration of selecting natural fibers for use as reinforcing composites in the automotive sector. This literature review focuses on the progress of the development of polymeric materials applied in the automotive field. Referring to defined inclusion and exclusion criteria, 30 articles in polymer composite studies published between 2015 and 2020 were selected for further investigation. The analysis of selected studies revealed that several leading car manufacturers have produced and developed products from NFRP or recycled plastics with natural fiber reinforcement because they are relatively cheap, lightweight, and able to reduce exhaust emissions. The great potential of using NFRP materials and recycled plastics in the automotive sector presents a future challenge, namely the increasing need for natural fiber in the long term which will certainly have an impact on ecosystems and biodiversity.

1. Introduction

Vehicles have become an important aspect of economic terms. Vehicles can facilitate access for someone to move to another place. This vehicle is very dependent on the availability of oil and other oil-based fuels. OPEC which is the Organization of Petroleum Exporting Countries has estimated that world oil demand in the transportation sector is 43.6 mb / day (million barrels per day). It is important to increase awareness in limiting the use of oil because this material is a non-renewable resource. It has been predicted that there will be an increase in the estimated number of passenger vehicles from 1102 million in 2017 to 1980 million in 2040 which is also offset by an increase in commercial vehicles from 230 million to 462 million in the same time period. Therefore, many vehicle manufacturers try to reduce the weight of the vehicle by changing the material to be used. Another thing that is a strong reason is the existence of demands from strict laws in the European Union as well as guidelines from Asian countries regarding the final life in the automotive field. Ecological factors must be considered in determining the raw materials and prospects of the vehicle in the future [1].

Many of the researchers have a goal in making use of used cars and recycling plastic that can be utilized [2] because in addition to the physical and metaphysical benefits obtained, the material chosen will make an important contribution to customer satisfaction [3]. Characteristics of NFRP materials such as biodegradation, fiber modification, thermal stability, crystallinity are the main focus for researchers [1]. Furthermore, Al-Oqla and Sapuan [3] mentioned that the presence of pollution is another reason for the optimal use of resources. The use of recycled plastic is claimed to be able to reduce 80% of greenhouse gas emissions. This demand for social-ecological awareness makes plastic an appropriate alternative [3]. This is the reason for the development of polymer or plastic recycling that can be applied in the automotive field.

With the potential use of NFRP or plastic recycling in the automotive sector, this literature review will discuss the latest developments in the application of NFRP and plastic recycling in the automotive sector. The reviews that will be discussed are NFRP in the automotive industry, plastic materials and natural fibers that are most often used in the automotive sector, products produced from NFRP and challenges in the use of NFRP and plastic recycling.

2. NFRP and Recycled Plastics

NFRP composites use a polymer matrix and are classified into two types, namely thermoset and thermoplastic [4]. Thermosets are polymers that have stronger stiffness and bonds than thermoplastics. Thermosets cannot be recycled because of their resistance to dimensional stability at high temperatures. Meanwhile, thermoplastics have properties that are easy to recycle, high impact resistance, and are chemically inert. Thermoplastics are easy to reshape because they are easily melted or softened by heating to a certain temperature and hardening by cooling [5]. Polyester, phenolic, and epoxy are polymers that are classified as thermosetting polymers. Meanwhile, PP (polypropylene), PVC (polyvinyl chloride), PE (polystyrene), and PS (polystyrene) are some examples of thermoplastic polymers [6]. Thermoplastic polymers were further classified into traditional (commodity) plastics such as PE and PP, and engineering plastics such as PA (polyamides), PC (polycarbonate), and ABS (acrylonitrile butadiene styrene). The materials most often used in the automotive sector are PA, PP, PC, and PE[1].

The greater need for plastic has an impact on the larger amount of plastic waste. Utilization is widely used in the transportation, electronics, and electricity sectors. With concerns about environmental impacts and greater regulations by government organizations, the industry is required to be able to manage and utilize plastic waste. One of the plastics that have good specifications is engineering plastic because it has good characteristics and high performance. The Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96 / EC) is a directive issued by the European Commission which aims to improve the collection, recovery, and recycling of electronic waste and electrical equipment. From various types of electrical and electronic equipment, there are 10-15 types of polymers and their mixtures and types of plastic resins, some of which are PE, PP, PA, PC, PS, ABS, and thermoset. In the process of separating engineering plastics from WEEE, it can be done by mechanical or physical processing and the problem faced in the WEEE plastic separation process is the presence of impurities in the polymer matrix and foreign materials, which affect the quality of the recycled plastic [1].

In the manufacture of NFRP composites or using recycled plastics, natural fibers are often used as reinforcing composites. Three main groups in the classification of natural fibers have a morphological structure, namely (1) Bast fibers, (2) leaf fibers (3) seed-hair fibers. Cellulose, hemicellulose, and lignin contained in natural fibers are the main constituents, and pectin grease or inorganic parts are usually found in fewer levels [7][8]. Based on the source, natural fibers are grouped into plant fibers, animal fibers, and mineral fibers [9]. Plant fibers are further classified into six types, namely: seed/fruit fibers, straw/stem fibers, tree bark fibers, leaf fibers, wood fibers, and grass fibers [10]. Fruit fibers are fibers derived from the outer skin of the fruit, such as coir fiber extracted from coconut coir and seed fibers derived from pods or bolls such as cotton and kapok. Stem fibers that come from plant stem such as corn, sugar cane, or rice. Leaf fibers produced from plant leaves such as sisal fiber and abaca fiber. Bark fibers such as hemp, hemp, kenaf, hemp, hemp fiber. Other types of fiber are wood fibers that are produced from trees and are classified into hardwoods and softwoods. And the last is grass fibers produced from grass such as elephant grass or bamboo. Some of these natural fibers are often used as reinforcement for pure plastics and recycled plastics. The natural fibers most commonly used as reinforcement in the transportation sector are kenaf, hemp, hemp, sisal, hemp, coir, wood, and abaca [6][11].

Given the potential use of thermoplastic polymers, recycled plastics, and natural fibers, the use of NFRP or recycled natural fiber reinforced plastics in the transportation sector has been investigated by several researchers, who have studied the characteristics and properties of various NFRP composites, for example, fiber modification, thermal stability, crystallinity, and biodegradation [1].

3. Methodology

The literature review was carried out with a systematic approach in which research questions were based on a process of identification, assessment, and interpretation of all research. This review is a Systematic Literature Review (SLR) [12]. According to Khan, Kunz, Kleijnen, and Antes, the process in this SLR follows five stages [13]. These stages are compiling questions, identifying appropriate/relevant articles, assessing the quality of the literature study, summarizing some evidence, and interpreting the final findings [14].

The research objectives are based on the research questions that have been prepared. The procedure for searching for relevant articles is adjusted based on predetermined include and exclude criteria. After that, a quality assessment is carried out and an in-depth evaluation is carried out on each article. The evaluation that has been carried out is then used as a basis for summarizing the evidence and avoiding the risk of evidence bias. These selected articles are then collected and able to be used as data to answer the research questions that have been compiled. Existing data are synthesized and presented consistently to answer research questions.

The last stage is interpreting some of the findings, where the findings are based on answers to research questions that have been developed previously. The conclusions presented must also be in accordance with the available evidence.

4. Results and Discussion

Systematic literature review is carried out in five stages, including:

4.1. First Step (Framing the Question)

The literature review that will be discussed is about the application of polymer materials or recycled plastics and natural fibers in the automotive field. This research question will be focused to guide this literature review.

- Q1 : How is the progress on recent automotive applications of natural fibre reinforced recycled plastics?
- Q2 : What are the challenges and future trends of fibre reinforcement in recycled composites?

The research questions that have been built are based on motivation as presented in Table 1.

Table 1: Research questions and motivation.

Q1	How is the progress on recent automotive applications of natural fibre reinforced recycled plastics?	Identification of types of natural fibers and recycled polymers that are often used and able to be developed for automotive applications
Q2	What are the challenges and future trends of fibre reinforcement in recycled composites?	Identification of issues affecting the application of natural fiber reinforced plastic recycling in the automotive sector and also a prediction of future conditions.

4.2. Second Step (Identification of Relevant Articles)

Searching for articles was carried out on five scientific databases, namely: Sage, Elsevier, IEEE, Springer, and IOPScience journals. The search procedure technique is varied by modifying the 'search string' in order to collect research articles with the same and relevant topics. Five scientific databases used were consulted in July 2020. The search terms used include: Natural Fiber Reinforced Recycled Polymer Application in Automotive. A total of 2181 hits were obtained from five databases. Also besides, the results are enhanced by advanced search terms: ("Natural Fiber Reinforced Recycled Polymer" OR "Natural Fiber" OR "Recycle Plastics") AND ("application" OR "appliance" OR "function") AND ("Automotive" OR " Automobile ”), produced 587 hits. The total articles found previously were then refocused based on the year published. Articles to be reviewed were selected based on the last five years published between (January) 2015 and (July) 2020 and received 212 hit titles.

After screening in terms of the year of publication, the selected articles were identified and adjusted to the inclusion and exclusion criteria that had been set. The inclusion criteria set out in the article selection process were as follows: (a) natural fibers in recycled engineered polymers or plastics, (b) NFRP in automotive applications, (c) processing of natural fiber reinforcement in recycled engineering plastics, and (d) challenges and trends future in the application of automotive materials. Articles will be excluded if they do not meet one of these criteria: (a) Research studies that do not use recycled plastic materials and natural fibers (b) The full content of the article is not available, (c) The article is a review of the book chapter.

After identifying the title and abstract, 37 articles that met the inclusion criteria were determined. The final stage is to identify the entirety of the article, and obtain 30 articles because there are 7 articles that fall into the exclusion criteria.all inclusion criteria. Therefore, the last 30 articles were included in the discussion of this literature. General description of the search for support procedures in Figure 1.

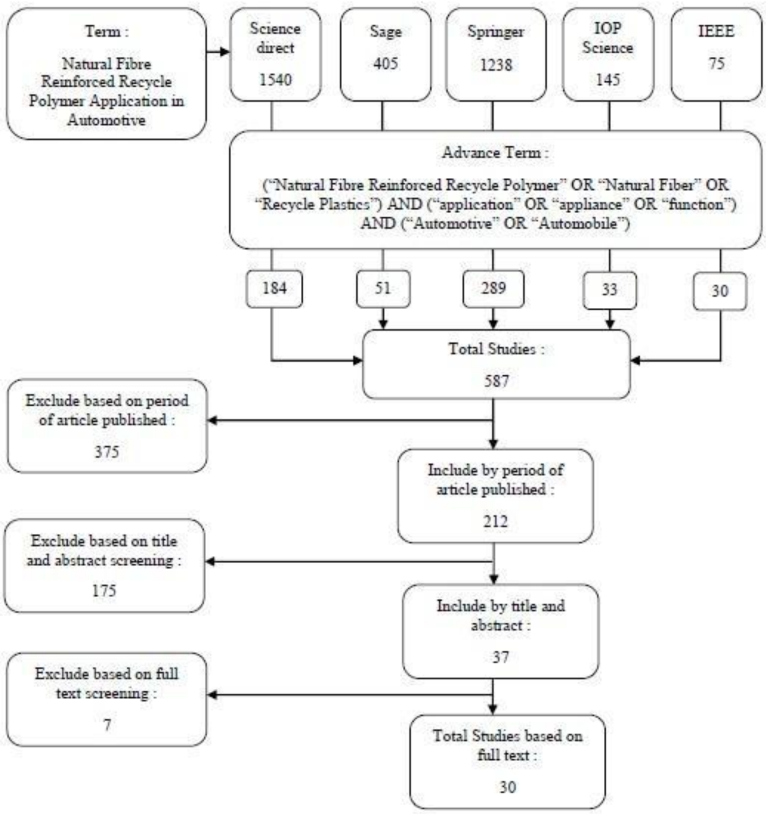

Figure 1: Search procedure of literature

4.3. Third Step (Assessment of Study Quality)

The purpose of this study is to review what researchers have done about thermoplastic / recycled polymer/plastic composite materials and natural fibers that require these materials in the automotive sector. The full text of all selected articles was consulted. The study estimates the potential for usable materials, suitable material specifications, and the latest increase in the use of NFRP in the automotive sector. In addition, it also discussed related to the manufacturing process and future challenges in the use of these materials.

4.4. Fourth Step (Summary of Evidence)

At this stage, an overview is presented regarding the context of the articles that have been selected. The research background of the thirty articles reviewed here is the majority in the Department of Mechanical Engineering (50%). Then followed by several research institutions, was in the next place with (20%) the number of studies, followed by Chemical Engineering (10%), Textile Science (10%). Another study that also conducted research was Environmental Engineering and Physics, as described in Figure 2.

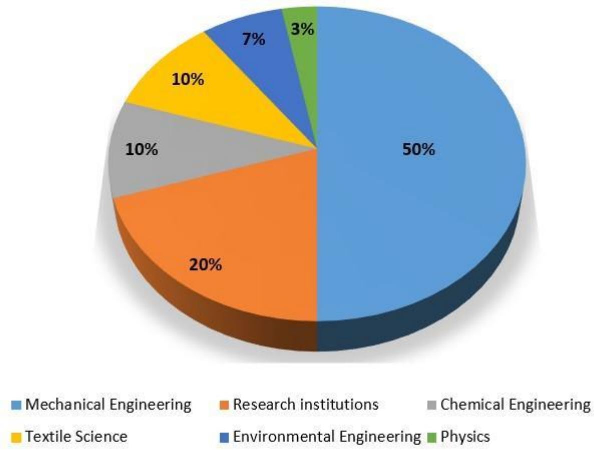

Figure 2: Background of the studies

The topic of the paper chosen was divided into three categories. Namely, the application of materials in the automotive sector, types of fibers or polymers that explain the material specifications accompanied by the process of maintenance to fabrication, and the last to discuss the challenges and future trends in material selection. As described in Figure 3.

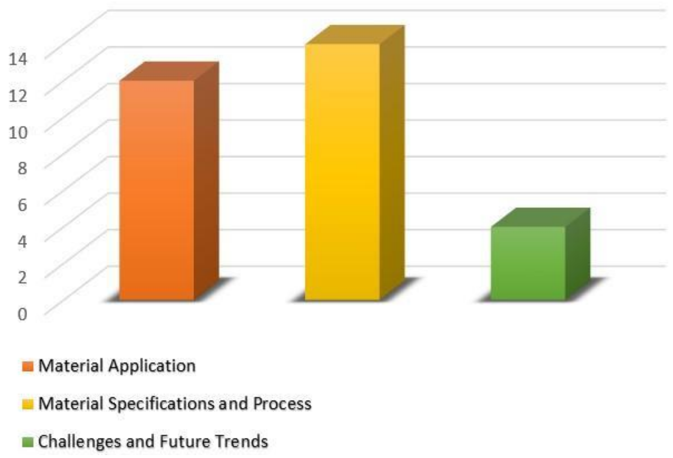

Figure 3: Number of papers that discuss the topic categories

4.5. Fifth Step (Interpretation of Findings)

4.5.1 How is the progress on recent automotive applications of natural fibre reinforced recycled plastics?

Various strategies and designs of car components are increasingly being developed in order to reduce the total weight of the car and reduce carbon emissions. Therefore, thermoplastics with natural fiber reinforcement are used [15][16]. According to Koniuszewska [17], polymer composites from high-strength thermoplastics have become the main focus in metal replacement efforts. And it should be noted also that the automotive sector today is not only a trend but also the necessities of life. The existence of a legal order introduced by CAFÉ (Corporate Average Fuel Economy) which was passed at the US Congress in 1975 made automotive manufacturers more adapted to the regulation because they had no other choice. [18] The transportation sector contributes approximately 25% of GHG (Greenhouse Gas) emissions, which is certainly one of the main contributors that have an impact on global energy. As a result, in the last few decades, there has been a growing desire to reduce the weight of automotive components, thereby reducing exhaust emissions.

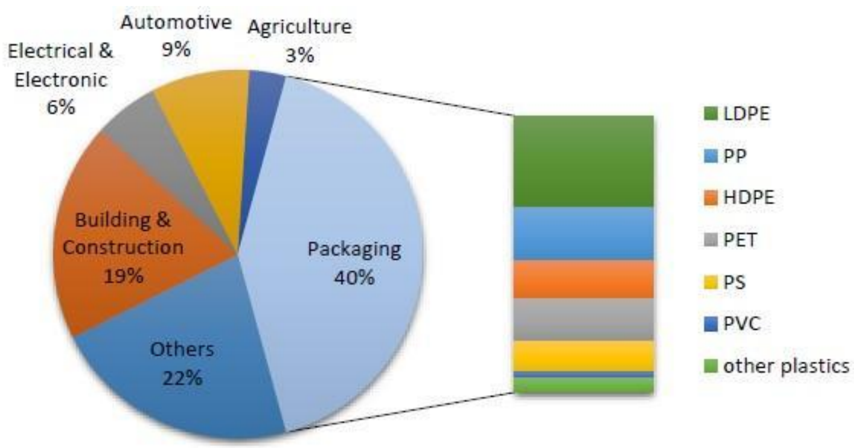

Figure 4: Applications of plastic materials and types of polymers are mostly used in packaging. The automotive sector uses only 9% of the use of plastics. [19]. Abbreviations description: PVC (polyvinyl chloride), PS (polystyrene), PET (polyethylene terephthalate), LDPE (low-density polyethene), PA (polyamide), PP (polypropene), HDPE (high density polyethene).

According to Boland, [20] Recently, many natural fiber reinforced plastics have been researched and developed for automotive applications. The natural fibers used as reinforcement for these composites are hemp, kenaf, and the last is sisal fiber. With the presence of natural fibers, it can be used as an alternative material that is cost-effective and becomes a material that is renewable. With this renewable nature, the potential for natural fibers to reduce the burden on environmental ecosystems is of course high. Compared to other composites, the density in natural fiber composites is lower even with the same mechanical properties. The application of natural fibers to vehicle components can certainly reduce weight without reducing the functional performance of the vehicle. [21] The increasing awareness of ecology and environmental sustainability, the more natural fibers are used because of their sustainable benefits, such as being environmentally friendly, more economical, and biodegradable.

Recycling trends are growing rapidly due to environmental problems from polymer disposal. This is a good approach to reduce the problem of environmental pollution. In addition, polymer recycling can also be an alternative that provides benefits in terms of energy conservation, minimizing production costs, and even profitable in terms of conservation of material resources [22]. Not only the automotive industry, the military, and aerospace marine sectors have also often applied Polymer Matrix Composites that have been modified to become polymers that have better strength. Coupled with corrosion resistance, attenuation of mechanical vibrations, formability, and high specific strength of PMC make PMC the choice in terms of reducing the final weight of car structures in the automotive industry [17]. Demands for environmentally friendly materials and ecological awareness make an important focus for automotive manufacturers. [22] recycled plastics are an important issue for automotive manufacturers, the use of recycled plastics offers huge energy savings as well as costs for the company.

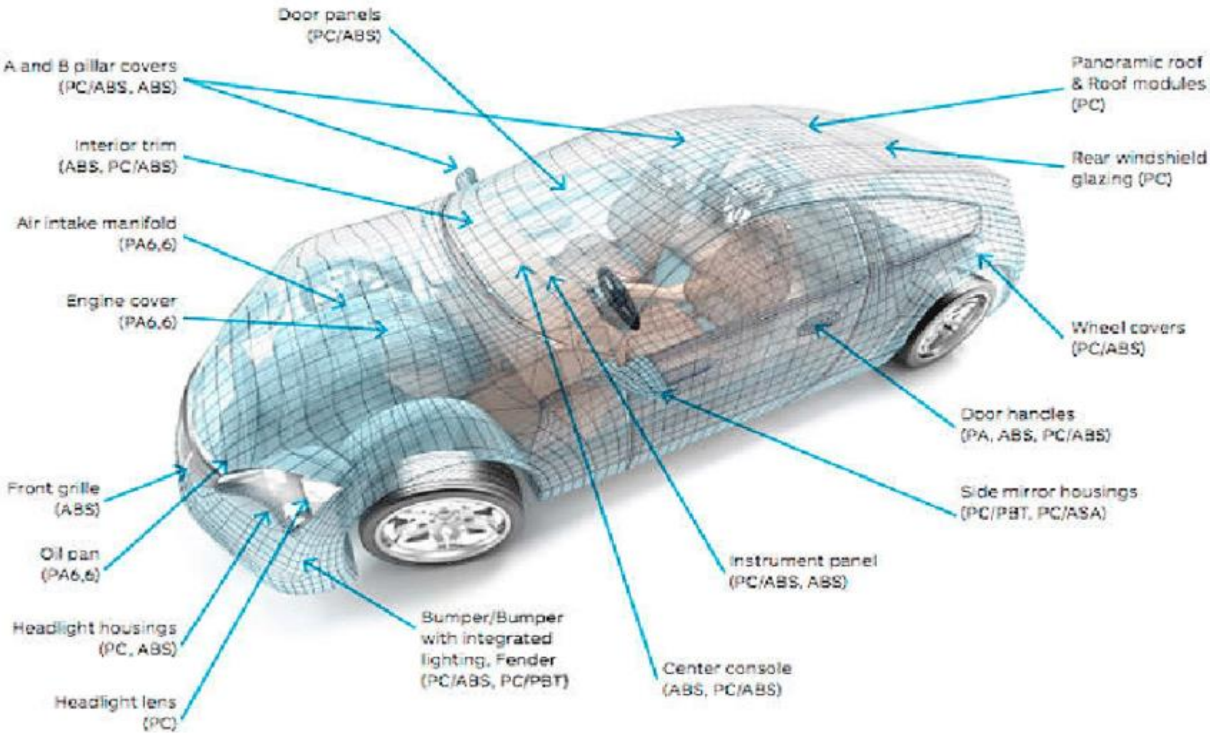

Figure 5: Technical plastics used in an automotive vehicle [14]

The increasing popularity of engineering plastics used in the automotive industry in the world makes automotive manufacturers choose certain plastic specifications that are suitable for use. Several engineering plastics that are often used in the automotive industry are presented in Figure 5, some of which are PC, PA, ABS, PET, and Polybutylene Terephthalate (PBT) [1].

Referring to the volume-based, ABS plastic is a common material that is often used in car components such as dashboards, bumpers, even car bodies. ABS plastic is often used because it has good characteristics such as good impact strength, easy paint, tough, and resistant to chemicals. After ABS plastic, another plastic that is often found in automotive applications is PA plastic. Many industries use PA even up to 35% of total PA consumption. In its application, PA is applied in the manufacture of components such as seat belts, tires, fan blades, and is also capable of under-the-bonnet applications such as parts of the engine compartment, fuel system, air intake manifold, housing switch, to the cooling system. Then the other materials are PC and PBT, which have a relatively low volume. PC material is very suitable for the application of car headlights because the optical transparency that a PC material has is very good. On the other hand, PBT is more often used in the vehicle interior and exterior components such as windshield wipers and also housing of mirrors [23]. Furthermore, [23] PC and ABS materials have been investigated by FTTR (Fourier transformed infrared spectroscopy) for material degradation and found that recycled ABS has little degradation, and PC material has not found any signs of degradation.

For natural fibers used as reinforcing composites, Hemp fiber and cotton have also been applied in the manufacture of floor panels, car headscarves, and back seat covers. Then flax and sisal fibers are used as upholstery for chair backs and door cladding. Flax fiber has superior characteristics because it can be applied to car disc brake materials that replace asbestos. According to Vardaan, [1] in the last few decades the application of NFRP in the automotive sector began to be applied by major car manufacturers. One of them is a European car manufacturer that uses sisal fiber as a reinforcing material in the manufacture of door panels, dashboards, and headliners. Other fibers that are also applied in several components are hemp, flax, and jute. The results given of course reduce the weight of the car, more environmentally friendly because it reduces CO2 emissions and finally lowers costs. In addition, there is also coconut fiber which is used for the bottom of the seat, headrests, and back area pillows. For the inner panels using kenaf fiber, and floor body panels, abaca fiber is used as a material. Other large manufacturers that also utilize NFRP composites, some of which are Volkswagen, BMW, Mercedes, Audi, and Daimler Chrysler [1]. The application of natural fibers in the European automotive industry in 2012 is presented in Figure 6.

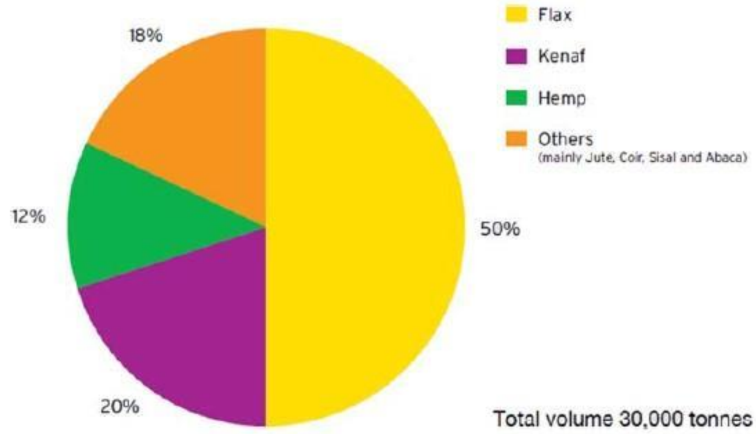

Figure 6 : The application of natural fibers in the European automotive industry in 2012 [24]

Hemp is a natural fiber, available in several countries, such as Nigeria, Guana, India, Yugoslavia, Sierra Leone, and China. Then, jute producers are produced by Bangladesh and China. Sisal fiber is produced in Brazil and Tanzania. Carpet and rope manufacturing is a product that is often produced from sisal fibers. And one of the fibers that can be applied in various applications is kenaf fiber which has the advantage of growing quickly [25].

One of the automotive manufacturers that have used recycled plastics and natural fibers is Mazda. Mazda, which is one of the major car manufacturers, has applied around 30% recycled material and 70% raw material in the manufacture of bumpers which of course have good specifications such as surface quality and adequate mechanical properties for the bumper. In the process, a mixing machine was created using a shear force that was able to peel off crushed bumper paint pellets. The invention of this effective engine was created by Mazda researchers [2]. With the increasing popularity of recycled materials in today's conditions, many researchers are involved in trying to improve plastic recycling technology in the automotive field. The utilization of recycling is taken from used cars throughout the world.

American automotive seating and all-interior specialist, Johnson Controls Interiors, is innovating and investing to make their products cleaner consumption. In fact, they have conducted research on natural fiber reinforced polyols for use in automotive components that are specialized in car interiors such as seats and door panels. Lately, they are also doing large-scale production using biocomposite materials which is carried out by wet processing-based methods with vehicle interior products that use wood fiber. They started commercial production in 2004 with a spare wheel cover product on the Mercedes A-Class (W169), part of the use of glass fibers as composite reinforcement has been replaced with abaca fiber. In addition, Visteon Corporation has also made car interior products with environmentally friendly materials. The material used is a mixture of kenaf and hemp fibers as reinforcement and PP as a matrix, and the processing method is carried out by a one-step printing process [26] .

According to Obed, [26] hybrid composites containing 25% hemp weight and 15% weight of glass fibers which reinforce PP polymers have good flexural modulus and good thermal properties. which of course can be an option for structural applications that have high stiffness and also have thermal resistance properties. In addition, Mitsubishi motors with Fiat SpA has also developed an interior component of the car with plant-based polybutylene resin based on bamboo fiber-reinforced material. The use of PLA, flax, and nylon materials is often applied in the manufacture of floor mats, and also the use of hemp or cotton materials that are applied in the manufacture of back seat covers, indoor covers, and floor panels.

Until recently, many natural fiber reinforced polymer composites for ballistic-resistant biocomposites [27]. The majority of products focus on structural protection, personal body armor, and vehicle protection. The roles and functions of natural fibers in the application of automotive components are presented in Table 2.

In addition to the advantages that many natural fibers have, several things in their processing also need to be considered. The selection of processing techniques that can be carried out, such as extrusion, resin transfer molding, compression, and injection molding, needs to be considered in order to produce optimal products capable of providing differences in the results of the structural and thermal properties of natural fibers [20].

Several composite making processes are in application today, however, not all of them can be applied in the forming of biocomposites for automotive applications. Due to the special properties of the materials involved, for a forming process to be used, it should ensure minimum thermal degradation. Thermoset and thermoplastic press molding take a very big chunk of forming methods used. Compression molding is in particular an established and proven technique for the production of extensive, light weight, and high-class interior parts in medium and luxury cars for it is cost effectiveness, being suited for light construction, good crash resistance, and deformation properties. In this process, flat semi-finished products or hybrid fleeces that are either larger or same size as the form are cut exactly to the size of the desired part which together with the matrix are put into the preheating station (mold) heated to the melting temperature of the matrix material that is subsequently guided into the pressure tool unit, condensed, and reshaped [26].

Methods in the manufacture of conventional composites from thermoset matrices and thermoplastic composites can also be used in the manufacture of NFRP composites. These traditional composite fabrication techniques include resin transfer molding, compression molding, vacuum infusion, extrusion, and injection molding. With all the different methods used and also the different constituents of each material, of course, it greatly affects the final properties of the material. Therefore, it is necessary to adjust the properties of natural fiber composites with the right manufacturing method so that they can be applied into quality products [28].

Table 2: Natural fibers in automotive components [1]

Manufacturers	Model	Applications	Natural fiber
Daimler Chrysler	A, C, E, and S Class	Door panels, floor panels, trunk panels, dashboards, pillar cover panels, seat back rests, insulation	Flax, sisal, coir, wood, banana, cotton
BMW	3, 5, and 7 series	Door panels, boot linings, seat backs, headliner panels, noise insulation panels	Flax, sisal, cotton, wood, hemp
Audi	A2, A3, A4, A6, A8, A4 Avant, Coupe, Roadster	Seat backs, back door panels, side door panels, boot liners, spare tire liners	Flax, sisal
Volkswagen	Golf, Passat, Bora, A4	Seat backs, door panels, boot liners, boot lid finish panels	Flax, sisal
Ford	Mondeo, Focus	Door panels, boot liners, floor trays, door inserts	Kenaf, wheat, castor
Toyota	Raum, Brevis, Harrier, Celsior	Floor mats, spare tire covers, door panels and seat backs, luggage compartments	Kenaf, sugarcane, bamboo
General Motors	Cadillac DeVille, Chevy Trailblazer, Chevy Impala, GMC Envoy	Seat backs, cargo area floor mats, noise insulation, door panels, trim	Cotton, flax, wood, kenaf, hemp
Opel	Vectra, Astra, Zafira	Door panels, head liner panels, instrumental panels	Flax, kenaf
Lotus	Eco Elsie	Body panels, interior mats, seats	Hemp, sisal
Peugeot	406	Front and rear door panels, seat backs, packaging trays	
Fiat	Punto, Brava, Alfa Romeo 146, 156, 159	Door panels	
Volvo	V70, C70	Seat cushions, cargo floor mats	
Mitsubishi		Cargo area floors, door panels, instrument panels	

The incorporation of the initial forms in the matrix resin in the fabrication process is divided into 2 groups. The first group is reactive processes, in which short, continuous fibers and direct matrix are processed into a single structure. Examples in this first group include filament winding, RTM, injection molding, and spray. Then, the second group used a method where there was a process between forming a print-ready sheet and inserting the reinforcement into the matrix resin system. After that, the ready-to-print sheets are available in prepreg and sheet molding compounds which can then be processed to manufacture laminar composites by compression or autoclave printing. The most popular processing technique for forming thermoplastic NFRP is the hot press molding method. The reinforcement from natural fibers is a mat and non-woven. Interior components in the automotive industry are applications that are often used by thermoplastic reinforced nonwoven fiber mats [28].

4.5.2 What are the challenges and future trends of fibre reinforcement in recycled composites?

The challenge facing the automotive industry is the diversity of mechanical properties that natural fibers have. The various properties of natural fibers make engineers in every industry have to be able to adapt and predict which ones can be used because some engineers in the automotive industry are familiar with the properties of synthetic fibers that are often used. Another problem that needs attention is that the hydrophilic nature of the lignocellulose content results in poor resistance to the polymer as a hydrophobic matrix. This mismatch causes the mechanical properties of the composite to weaken. Therefore, the attachment between the matrix and the fiber must be considered in order to have good mechanical strength [29]. Physically-chemical natural fibers are heterogeneous and have a rough surface, this of course greatly affects the adhesive strength of the matrix fiber interface. The mechanical properties of the bio composite will be damaged if the interface bonds are weak [30].

According to Kim, [28] there are obstacles in the application of natural fibers in the automotive field. The harvesting process, production area, cultivar, and processing route greatly influence the mechanical properties of the composite. Another problem that arises is the presence of moss and fungi attack which causes natural fibers to degrade because they are stored for a long time and are also very vulnerable to thermal/mechanical degradation during processing. The poor compatibility comes from the hydrophilic nature of the matrix resin which is hydrophobic, which makes the mechanical strength of the composite lower. Natural fiber-reinforced composites are very sensitive to moisture and the resulting mechanical properties also depend on the orientation distribution and fiber length.

Another disadvantage of NFRP is its inhomogeneous structure, discontinuous fibers resulting in low composite durability and performance. The high moisture absorption property also affects the swelling of the composite and limited thermal stability. Therefore, factors that greatly influence the final quality of the composites include fiber selection (fiber type, fiber content, extraction, and harvest time), matrix selection, adhesion properties/interface strength, dispersion of fibers, porosity properties, and the last is the process in making composites [30].

To overcome this problem, NFRP can be treated with a surface treatment method. One of its applications is by chemical processing of natural fibers to be used. It aims to increase interface adhesion and reduce water intake in order to produce good mechanical properties. The connecting material or it can be called an adjustment material needs to be added to the fiber in the surface treatment process with all chemical processes. Some of these treatments are such as acetylation, alkali, silane, male coupling, benzoylation, and also anhydrides. All types of treatment are carried out with the aim of increasing the interface bond between the matrix and the fiber, this can be done because with this method the moisture intake will be reduced and the surface roughness will increase. [1]

Another important factor to consider is the changing properties of the recycled thermoplastic elastomer which also needs to be considered. In each application, special properties are needed, because changes in properties during the recycling process make the materials unsafe and even unusable. The existence of thermal degradation has a different effect on thermoplastic elastomers and thermoplastic polymers. HDPE as a thermoplastic polymer will experience tensile properties, young modulus, and decreasing density when the recycling cycle is increased. Another effect similar to thermal degradation is ultraviolet degradation. The yield strength of thermoplastic polymers will increase up to 43.80% after exposure to ultraviolet light. The mechanical properties of thermoplastic elastomers show different behavior compared to thermoplastic polymers. The recycling cycle has no effect on young modulus, tensile strength, and yield strength of thermoplastic elastomers. However, thermoplastic elastomers which have antioxidant fillers when the polymer is exposed to ultraviolet light will increase the young modulus by 29.16% and tensile strength up to 28.23%. [22]

Currently, sisal fiber in the car industry is required around 170,000 tonnes/year to manufacture spare parts. In addition, the refilling approach will not necessarily produce 50% fiber in the next 50 years. Another fiber that is in demand is coir fiber because of its high hardness and hard-wearing qualities for materials used as automotive components. The demand for natural fibers around the world is increasing every year, as shown in Figure 7.

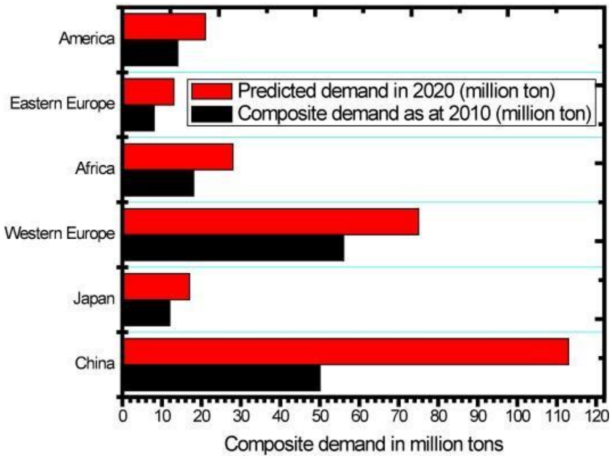

Figure 7: Composite demand in million tons

In China, always trying to reduce weight to light, and the demand for composite materials is predicted to tend to increase to 110 million tons by 2020. In addition, Europe is also predicted to increase to 80 million tons, especially in the application of automotive spare parts. Due to the advantages of natural properties that can reduce weight, the demand for natural fibers in every industry is also increasing. In this case, of course, it will affect the ecosystem, given the large demand for needs in the industry [31].

The huge demand for natural fibers in the automotive industry has not been matched by public awareness of the deficits experienced in global forests. Research focuses too much on energy conservation and weight loss using natural fibers. Due to the continued loss of biological diversity in all areas of the earth, climate change is certainly a major threat to species and ecosystems [31].

Every year the demand for natural fibers always increases according to the increasing usage as well. It is felt that automotive manufacturers need to have a comprehensive understanding of usage, total cost/kg, annual production, chemical composition, advantages, and disadvantages of using natural fibers on a large scale.

Table 3: Total natural fiber production in the world

Fibre source	World production in (10^3 tons)
Abaca	70.0
Bamboo	10,000.0
Banana	200.0
Coir	100.0
Cotton lint	18,500.0
Flax	830.0
Hemp	215.0
Jute	2500.0
Kapok	315.37
Kenaf	770.0
Pineapple	13,700.0
Ramie	100.0
Sisal	380.0
Sugarcane bagasse	75,000.0

Table 3 shows the level of natural fiber production each year [1]. The potential use of natural fibers in the automotive sector is influenced by the proximity of sources, such as in India and Asia, the most commonly used natural fibers are jute and kenaf. Then in the European region, flax and hemp fibers are more often used. And major South American car manufacturers use the majority of sisal or hemp fiber. The overall properties of the fiber and its application are significantly affected by the cellulose, hemicellulose, and lignin content contained in the fiber [32][21]. Influences such as thermal degradation, moisture absorption properties, and biodegradation are influenced by hemicellulose levels. While lignin content affects UV degradation. [32]

In addition to the raw materials used, the chemical composition, environment, and final structure of the composites greatly affect biodegradability. It is possible for some biobased plastics to be biodegradable, due to the specification of the polymer structure. Some other polymers exist that can degrade in a few months, some even in just a few weeks have degraded in a position in the same environment [33]. In the automotive sector, for End of Life Vehicles (ELVs) the constraint of recycling vehicle components is expensive and difficult. It is inversely proportional to the use of materials from a relatively simple recycling process [34]. Most of the ancient cars contained about 4% of rubber products and 8% plastic [35].

Another obstacle faced by the automotive industry today is the alignment between material processes that are trying to be innovatively designed with their production processes which are of course large volumes. Although aluminum or steel has good specifications for use in car components, weight reduction is considered more important and the use of Fiber Reinforced Plastics composites can be modified to high performance as substitutes for steel and aluminum. With recycling techniques carried out optimally, the overall life cycle can be improved. Although energy recovery is not considered recycled, it is mandatory for cars to recycle 85% of vehicle components under the end of life instructions for cars[36].

Apart from some of the challenges that exist in natural fibers, plastic recycling also has a weakness, namely the difficult plastic separation process due to impurities on the polymer and foreign materials that have been mixed. This of course affects product quality [1]. The selection of the most appropriate recycling method depends on the quality of plastic waste and the degree of degradation. Currently, upcycling is feasible only with clean, non-contaminated waste. Contamination and inappropriate use of plastic goods significantly diminish material’s quality. Furthermore, degradation also occurs during recycling operations. There are different types of plastic contaminants. For example, coating, inks, adhesives, and additives, intentionally added (IAS) . Plastic recycling has become a business opportunity and existing recycling companies compete with their European and American counterparts. In Asia and Africa, waste management strategies only exist in big cities and metropolitan areas. The costs of sorting and recycling processes are usually too high, therefore, the collected waste is merely landfilled. [38]

Despite many challenges, the automotive industry is always innovating and developing natural fiber reinforced polymer composites in the manufacture of automotive components. In the future, hybrid composites have been seen as a major role in the automotive field due to their specifications that allow their mechanical and physical properties to balance the strength-to-weight ratio of the car. In terms of structure, car components if using hybrid composite materials will work more effectively and better. Pollution control can still be done because it is effective in reducing the weight of several metal components in a car without sacrificing its strength [36].

As there have been many revolutionary changes at this time that demonstrate that the critical need to match automotive material requirements, a metal-plastic hybrid material that is lightweight, durable, increases efficiency, and vehicle functionality certainly has great potential to be able to optimize future advanced vehicle technologies. At present, data from The American Chemistry Council (ACC) shows that: (a) Plastic composites are widely used with the use of about 150 kg of plastic, compared to when using iron and steel which reaches 1,163 kg. , (b) There is material engineering in various automatic industrial applications such as using polymer and plastic composites, (c) There are about 50% of all components of the interior material of commercial vehicles using plastics, (d) Industry trends are starting to project that the use of plastic composites or hybrid plastics in the next two decades undertaken for the sake of substantial improvements in vehicle weight reduction and fuel efficiency in order to reduce environmental impact and still meet consumer needs [37]. Thermoplastic hybrid composites make it possible to provide solutions with a reduction in vehicle weight which is generally 900 kg with steel and other metal materials can be reduced by weight up to 300 kg [38].

Several methods that can be done in terms of combining plastics with metals for hybrid composites is to use the insert injection molding method. A preset metal insert is placed in the mold cavity, then thermoplastic begins to be injected into the cavity after closing the mold. Then, the metal is buried and fixed in the thermoplastic [39]. However, from the various advantages of hybrid composites, there are weaknesses, namely the multi-material component of the hybrid composite which causes difficulties in terms of recycling. For now, there are two options, namely damaging components or dismantling components with this hybrid material [40]. The production of hybrid composite materials is expected to increase in the future [36]. From the perspective of an environmentally sound consumer, car manufacturers certainly benefit from using more environmentally friendly materials. With the presence of biocomposite technology, of course, car manufacturers can separate themselves from several competitors by promoting environmentally friendly products from them [41].

5. Conclusion

The results of a systematic literature review revealed that many researchers are increasingly developing metal substitutes in automotives to achieve an overall reduction in car weight which affects vehicle exhaust emissions. Polymer and recycled plastics are the choices because they are environmentally friendly, cheap, lightweight, and have good mechanical properties. Several automotive manufacturers such as in America, Japan, Korea, and several European countries have implemented renewable materials. The challenge that needs to be faced today is aware of the growing need for natural fiber in the long term which will certainly have an impact on ecosystems and biodiversity. With understanding and awareness regarding the impact on the automotive life cycle, manufacturers can make wiser decisions regarding material selection and decisions about which vehicles to target for replacement of natural composite materials in order to achieve greater benefits. In addition, further research related to hybrid composite materials can be carried out as sustainable development of materials that can be applied in the automotive field in the future.

6. References

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