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AN OVERVIEW ON FIBER-REINFORCED COMPOSITES USED IN THE AUTOMOTIVE INDUSTRY

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Abstract: The automotive composite materials, fiber-reinforced polymers are among one of the widely preferred alternatives for light weighting of the automobile as they offer enhanced properties such as impact strength, easy mold–ability, improved aesthetics, and reduced weight as compared to conventional automotive components. The main advantages, which offer opportunities in the automotive industry, are their potential for maximum mass reduction of automobile and carbon emission reduction potential by light weighting of the vehicle.
Keywords: automotive industry, composite materials, reinforced plastics and polymers, requirements

1. INTRODUCTORY NOTES

The automotive composite materials, reinforced plastics and polymers are among one of the widely preferred alternatives for light weighting of the automobile as they offer enhanced properties such as impact strength, easy mold–ability, improved aesthetics, and reduced weight as compared to conventional automotive components. The main advantages, which offer opportunities in the automotive industry, are their potential for maximum mass reduction of automobile and carbon emission reduction potential by light weighting of the vehicle. [7] Globally, the automobile sector is currently facing a period of unprecedented change. New fuel economy and emissions standards are driving significant changes across the industry. While producing lighter weight vehicles is one of the top strategies to meet these regulations, it is also one of the most challenging tasks. New material strategies, including the use of automotive composites, play a critical role for taking the weight out of vehicles. [13,14]

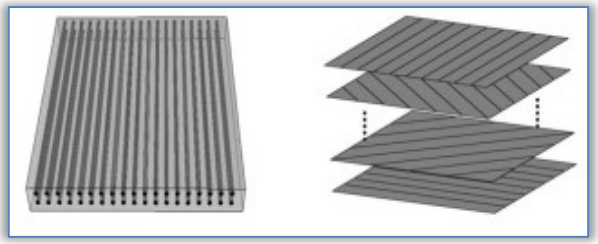

Figure 1. Fiber-reinforced composites

Composite materials offer an opportunity to significantly reduce the weight of a vehicle while still meeting strength requirements. [10] Today, engineered plastics are fast becoming the future for two industries – chemical and automotive – as environmental concerns are increasingly affecting both. To preserve optimum fuel efficiency, automakers are using materials that are more lightweight – plastics and polymer–based components. [9]

Composites are being considered to make lighter, safer and more fuel–efficient vehicles. A composite is composed of a high–performance fiber (such as carbon or glass) in a matrix material (epoxy polymer) that when combined provides enhanced properties compared with the individual materials by themselves. [13] Fiber reinforced composites offer a wide range of advantages to the automotive industry. It is because the composite structures are the high strength/low weight ratio. Carbon fiber–reinforced composites offer numerous new design possibilities for structural components in cars. These advanced materials are not only light in weight, but also stiff, strong and durable. The future lightweight materials will be used in the automobile industry. [2] The careful selection of automotive materials enables designers to improve durability, meet load–bearing requirements, and achieve reduction in vehicle weight. [7] Now carbon fiber is very expensive, but the automobile industry has in development affordable carbon fiber, so the future's car will be lighter. Fiber–reinforced composites are now being

used to make structural and non–structural components such as seat structures, bumpers, hoods, and fuel tanks. [2,13] The creation of industrial processing capacity will further stimulate the use of these advanced materials in the automotive industry. [3] The thermoplastic composites enable automotive manufacturers to produce affordable structural components to substitute conventional metal solutions. With decades of development work behind it, the natural fibers industry is maturing. Indeed, it appears to be on the verge of leveraging the products' numerous cost, performance and environmental benefits for big-time technical and potentially high-volume commercial applications. In the auto industry, for example, natural fibers — hemp, flax and others — are used in combination with polypropylene and other resins. They are especially well suited for door and trunk liners because of their lower cost and lower density.

Figure 2. Natural fibers for environmentally friendly composites

2. INVESTIGATIONS & RESEARCH

To develop new automotive materials, components, and systems in the most effective way, the completely automotive supply chain needs to work together. [4] Industries investigate new production and assembly processes, such as a way to join metals, lightweight plastics and composite materials. [7] To become more lightweight composite material–oriented, the automotive industry and the chemical industry are likely to join forces in a value chain that includes peripheral companies such as plastic–injection companies and automotive suppliers. Collaborative research and development is more focused on material properties and technology issues (on innovative forming processes).

The use of lightweight plastics and composite materials in the automotive industry has been increasing in recent years due to legislative and consumer demands for lighter weight, fuel–efficient vehicles. In some cases, plastics are replacing heavier ferrous materials whereas, in other cases, plastics and composites are being added for consumer comfort purposes. In addition to being lightweight, these materials are also durable and easily molded. Substituting heavier materials with plastics leads to an overall weight reduction. [8]The percent plastics by mass in an average vehicle has gone from 6% in 1970 up to 16% in 2010 and is expected to reach 18% in 2020 (see Figure 3).[8] Lightweight plastics and composite materials are increasingly a preferred material choice in designing and developing complex, consumer products, such as auto vehicles. [8]

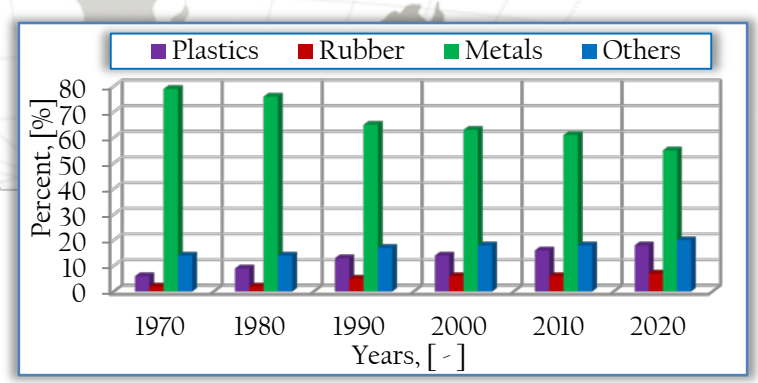

Figure 3. Change in vehicle composition from 1970 to 2010 [8]

The ability to leverage this kind of lightweight material gives a competitive advantage that will benefit the cars, as well as the production process, in the future.

The weight reduction can be obtained by three ways:

- replacing materials of high specific weight with lower density materials without reducing rigidity and durability.
- optimizing the design of load–carrying elements and exterior attachments to reduce their weight without any loss in rigidity or functionality.
- optimizing the production process

By continuing to develop the composite materials technologies, the automobile industry are able to create cars increasing their performance and their appearance.

3. REQUIREMENTS OF THE MATERIALS IN AUTOMOTIVE DESIGN

The automotive industry increasingly is relying on a systematic approach to materials selection. The choice of materials for a vehicle is the first and most important factor for automotive design. There is a variety of materials that can be used in the automotive body and chassis, but the purpose of design is the main challenge here. [13] For the automobile manufacturers, the most important criteria that a material should meet are:

- lightweight, which is the most important one for an automotive industry, in the context of the reduction of emissions and improving fuel efficiency;
- economic effectiveness, (i.e. the cost), that determines whether any new material has an opportunity to be selected for a vehicle component;
- safety, which have in view the ability to absorb impact energy through controlled failure modes and mechanisms and be survivable for the passengers;
- recyclability of their products and life cycle considerations, having in view that the most important concerns in automotive industries are the protection of resources and the recycling possibilities, including strategies on research and development targeted on recycling techniques and the development of more easily recyclable materials and their incorporation into the vehicle and its constituent components.

For vehicle manufacturers and their suppliers, materials have never been more strategic. Materials choice influences cost, safety, risk, weight, market image, and vehicle emissions. In this sense, the polymer fiber composites provide the weight savings, strength, and versatility the automotive industry needs to meet new standards without sacrificing quality. [4,13]

The complexity of an automobile and its manufacturing process presents many difficult challenges and decisions to an automotive manufacturer. Traditionally, environmental factors have not weighed as heavily as other criteria in material selection decisions. [11-13] However, the balance of environmental and other factors has begun to change, as the industry now faces increasing pressure from government regulations, environmental action groups, and its own internal cost constraints. These changes require a fundamental rethinking of industry's traditional methods of analyzing, allocating, and considering costs. [11-13]

Plastics and polymer composites, which already dominate vehicle interiors, exteriors, trim, and lighting, are gaining use in other vehicle systems as lightweight, value–producing materials that can meet increasingly challenging automotive requirements. [4,13] These materials' many advantages have enabled them to grow to become a significant part of the materials mix in the automotive industry over the past 40 years. As the push to lightweight vehicles intensifies, projections indicate that polymer composites must play an even more substantial role in the automotive industry through 2025 and beyond. [4,13] This evolution will largely reflect changes in the vehicle and component development processes to make them more responsive-in terms of accuracy, time, and cost-to market and regulatory demands. [11-13]

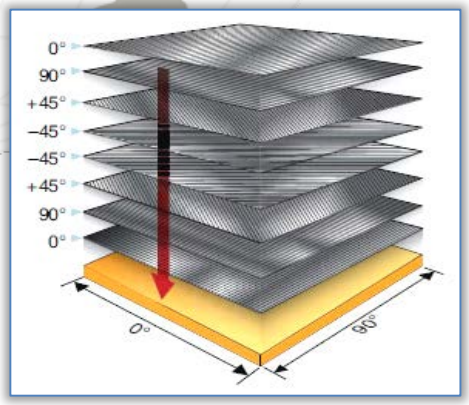

Figure 4. Textile preforms (prepregs) in structural fiber–inforced composites

Since about 20 years there has been an increasing interest in environmentally friendly composites, based on natural resources. Work started with research on natural fibers, but recently attention is also shifting to bio-based matrices. Also, fiber-matrix interaction is of high importance. Over the last years several textile technologies have been developed in order to manufacture textile preforms for three-dimensionally reinforced polymer-, ceramic- and metal-matrix composites.

In the recent years, the use of textile structures made from high performance fibers is finding increasing importance in composites applications. In textile process, there is direct control over fiber placements and ease of handling of fibers. Developments in the field of preforming have led to the production of preforms with fibers orientated in different directions with weaving, knitting and braiding individually or in combinations. The aim was, on the one hand, to improve the mechanical performance, above all the damage tolerance and, on the other hand, to decrease manual work during the manufacturing process. The essential properties of textile preforms for composites include high flexibility, formability, stability and high axial rigidity. Consideration of geometrical properties in designing textile preforms will help to predict the resistance of preforms to mechanical deformation such as initial extension, bending and shear in terms of resistance to deformation of individual fibers. It will also provide the information regarding maximum achievable packing of a fabric.

4. CONCLUSIONS

The potential of fiber–reinforced composites is great. There are excellent possibilities for combining advanced materials with technologies that are already familiar from the processing of plastics. The

fiber–reinforced composites present major light weighting opportunities for structural vehicle components. At a weight 50% lighter than conventional steel and 30% lighter than aluminum, more automakers use these materials as the body structure or other car components. With advantages that align directly with the automotive industry's needs, plastics and polymer composites can be a major part of the solution for automakers.

In order to use continuous fiber materials for more automotive applications, automakers are working with industry partners to improve the processing technologies needed to accurately create multilayer continuous fiber inserts at automotive cycle time speeds. The answer really is going to be a mix solution. That can even include a combination of composites to metals, for example. It is not going to be exclusively all composite materials, but it is going to be the best combination depending on what the design for the part is and how it should function. Therefore, to produce weight–saving automotive components and structures, the automotive industry together with her partners, will gradually develop an increasing number of customized applications using thermoplastic composites.

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