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Composites in manufacturing of vehicles*

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The trends of development and usage of composite materials in automotive industry were investigated.
The major efforts of the automotive industry are focused on developing and manufacturing of lighter vehicles with reduced fuel consumption and reduced gas emission. More and more car companies are considering the usage of composites in semi-structural applications because composites offer the ability for lighter weight vehicles with fewer corrosion problems.

In this paper, emphasis is placed on analyses of roles and properties of polymer matrix composites witch are the most common used composites in automotive industry and metal matrix composites.
The relative growing rate of composite applications is in stagnation mainly because of their high price and high cost of manufacturing processes.

1. INTRODUCTION

Because of problems connected with resources and increased environmental pollution, the major efforts of the automotive industry are focused on developing of lighter weight vehicles with reduced fuel consumption and reduced gas emission. Demands should be achieved without sacrificing of mechanical properties, safety and affordability. [1]

Engineers in automotive industry are increasingly searching for materials that have low density, are strong, stiff, abrasion and impact resistant and are not easily corroded. Composites are multiphase materials that exhibit a significant proportion of the properties of both constituent phases such that better combination of properties is realized. From that reason, more and more car companies are considering the usage of composites in semi-structural automotive applications. Composites essentially combine the strength and stiffness of metals and the lightweight, flexibility and corrosion resistance of plastic. They offer the ability for lighter weight vehicles with fewer corrosion problems.

2. METAL MATRIX COMPOSITES

The first metal matrix composites (MMC) were developed during the 1960's. The space industry was the first sector interested in the usage of these materials. Nowadays, the

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automotive industry's interest in the development of MMC's applications has even greater economic importance.

Metal matrix composite materials have been intensely researched over the past years that many new high-strength-to-weight materials have been produced. MMC consist matrix (basis) from pure metal or alloy reinforced special elements. In general, according to reinforcement, the three main types of MMCs are continuous-fiber, discontinuous-fiber (polycrystalline) and whiskers (monocrystalline) and particulate reinforced (different sizes and shapes). [2] The particulate reinforcements can be oxides, such as aluminium oxide (Al_2O_3), carbides (SiC, TiC), nitrides, borides, graphite, etc.

Continuous fiber reinforced MMCs have the advantage of linear anisotropic properties, but certain problems restrict their widespread use at present. The cost of the continuous fibers is high and the reactivity of these fibers, both during manufacturing and in operational use, can create problems.

Most popular MMC is aluminium matrix composite reinforced with SiC elements. At the last years a large attention is paid to investigation of mixture of aluminum alloys with SiC particles because this composite materials have improved properties, isotropic properties and it’s cost is not high. [3]

In automotive manufacturing, MMCs are mostly used in powertrain and braking system. In 1990 Honda launched a new generation of aluminium engine blocks with fiber reinforced cylinder walls replacing traditional cast iron liners. Elimination of the cast iron liner using MMC technology allows a reduction in material thickness between the adjacent bores. Tightening the cylinder spacing in this way results in reduction in the overall length of the engine and a weight saving on the block of around 4,5 kg.

Many European automotive manufacturers are evaluating MMC brake discs and drums. They are concentrating mainly on powder metal matrix composites (PMMCs) at present, due to cost considerations. The high thermal conductivity of aluminium PMMCs gives much better cooling than cast iron that runs at 500°C. There are some barriers to widespread use including temperature limitations on PMMC discs and drums and the higher cost compared to the current cast iron components. Development of compatible brake pad materials is necessary, because the performance is dependent upon brake disc / pad interaction.

Unlike brake discs, the main requirement for brake callipers is stiffness. Distortion of the calliper leads to increase pedal travel and braking efficiency loss. The improved modulus of elasticity in MMCs, compared to conventional materials, reduces the flexing of the callipers. MMC callipers are used in racing cars and high performance sports cars, but their high cost has so far precluded their use in family cars.

Many companies are actively involved in the development of MMC applications to meet stringent technical requirements of reinforced aluminium components such as pistons and engine blocks. Automotive pistons take advantage from the reinforcement of MMCs in two main areas. The top ring groove for wears resistance-preventing loosening of the ring and emission control. Currently a short fiber preform of either aluminium or aluminium silicate is used in this area. In a diesel engine, the combustion chamber is in the piston crown, and the inner crown suffers from cracking mainly due to thermal fatigue. The addition of a ceramic fiber preform minimizes this problem and increases piston life.

The biggest barriers for widespread use of aluminium MMC materials in automotive applications are still the costs of the row materials, processing methods and machining and finishing operations.

3. POLYMER MATRIX COMPOSITES

Polymer matrix composites consist of a polymer resin as the matrix with fibers as the reinforcement medium. Both thermoset and thermoplastic matrix composites are used in automotive applications. Polyester, vinyl ester and epoxy resins are the most commonly used. [4]

Glass is popular as a fiber reinforcement material because it is easily drawn into high strength fibers, it is readily available and may be fabricated into glass reinforced plastic economically, using a wide variety of composite manufacturing techniques. Glass fiber plastic composites have high strength to weight ratio, good dimensional stability and good resistance to heat, cold, moisture and corrosion, good electrical insulation properties.

Carbon fiber is primarily in use in the motorsports and aerospace industries because of its significant strength and frictional performance. Unfortunately, the relatively high cost of the carbon fibers and their complex manufacturing techniques restrict their use in automotive industry. Carbon fibers have the highest specific modulus and specific strength of all reinforcing fiber materials. They retain their high tensile modulus and high strength at elevated temperatures. At room temperature, carbon fibers are not affected by moisture or a wide variety of solvents, acids and basis. The main automotive application for carbon fiber continues to be for moving parts in the engine and for transmission.

Aramid fibers, polyamides such as Kevlar, are used in moving parts where lubricity and dimensional consistency are more important than strength or stiffness, such as clutch belts and grease-free ignition switches. They can be also used for bumpers, fenders, wheel wells and lower trim panels, making the parts resistant to atone damage. Aramid fibers are high strength and high modulus materials, with high toughness, impact resistance and resistance to creep and fatigue failure. They are relatively weak in compression.

The tensile properties and density of E-glass, carbon and aramid fibers are compared in table 1.

Table 1
Properties of fiber reinforcement for plastics [2]

Property	E-glass	Carbon	Aramid (Kevlar 49)
Tensile strength, MPa	2410	3100	3617
Tensile modulus, GPa	69	220	124
Elongation to break, %	3,5	1,4	2,5
Density, g / cm^3	2,54	1,75	1,48

It is noted that glass fibers have a lower tensile strength and modulus than carbon and aramid fibers, but a higher elongation. The density of glass fibers is also higher. However, because of their low cost and versatility, glass fibers are by far the most commonly used reinforcing for plastic.

According to the Composites Fabricators Association, about 65 % of all composites produced currently use glass fiber and polyester or vinyl ester resins and are manufacturing using an opening molding method. The remaining 35 % are produced with high volume manufacturing methods or use advanced materials, such as carbon or aramid fibers.

Natural fibers, which were traditionally used to fill and reinforce thermosets, are now rapidly becoming one of the fastest growing additives for thermoplastics. It is expected that the usage of natural fiber composites in automotive applications will increase from 2000 to

2005 for 50 % per year. The most used is wood fiber, which is inexpensive filler that increases stiffness, and the remainder is comprised of such agricultural fibers as flax, kenaf and hemp.

Natural fiber composites include such interior components as door trim panels, package trays, load floors, spare tire covers and seat backs. These composites are primarily compression-molded polypropylene for which the loading of the natural fiber in mat is 50 % by weight. They can be used and for instrument panels, arm rests, glove boxes, rear shelves, headliners, sun visor, seat foundations, trunk trim and head rest inserts.

The driving forces for these new automotive materials are economics, since natural fibers are currently priced at one-third or less of the cost of glass fiber, they are half the weight of glass fiber and they are easier to process and recycle. Consumer desire for green products is also stimulating processors to consider natural fibers. [1]

In the USA, the applications for natural fiber composites in automobiles are limited to interior parts. However, in Europe, which is significantly ahead of the USA in the usage of these materials, applications started to emerge in under-the-hood parts.

4. CONCLUSION

The introduction of composites in mass produced car industries has taken place mainly on the level of replacing steel, cast iron, aluminium and magnesium elements. It would be very useful to introduce composite materials in secondary structures, but they have to be cheap, fast processable and they have to improve the car by a lower weight and high corrosive resistance.

Many projects seek to make aluminium MMC more attractive for widespread use in automotive applications by reducing the costs of the row materials, processing methods and machining and finishing operations.

Polyester, vinyl ester and epoxy resins are the most used resins in polymer matrix composites. Glass fiber remains the dominant composite reinforcement, but carbon fiber is becoming more popular as prices continue to decrease. New interest in natural fibers is being driven by environmental regulations and advances in processing.

The relative growing rate of composite applications is in stagnation mainly because of their high price and high cost of manufacturing processes. The greatest potential for the future development of composites is the possibility of diverse varying of the type of matrix and type, size, share and distribution of reinforcement.

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