Advantages of using composite materials in automotive manufacture process

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Abstract: *The advantages of using composite materials are currently manifested in various industries. This creates space for their even greater application in the automotive industry. Car manufacturers strive to constantly reduce the weight of the car, increasing its durability and safety at the same time. Car consumption and associated emissions are closely monitored. Composite materials therefore offer a range of properties that meet today's automotive requirements to a large extent.*
Keywords*: COMPOSITE MATERIAL, AUTOMOBILE PRODUCTION, CARBON FIBERS, APPLICATION*

1. Introduction

Composites are materials created by combining existing materials and using the knowledge of physical metallurgy. They consist of at least two components. The first continuous component - the matrix - serves as a binder, the secondary discontinuous component (disperse particles, fibers or layers) has a reinforcing function. They have excellent mechanical properties and have therefore started to be applied in all industries. The main disadvantage of composites is their high price and demanding production. Composites in the automotive industry were first used in motorsport. At present, composite materials are applied not only in sports and luxury cars but also in mass-produced vehicles. Automotive manufacturers are working to reduce weight and emissions, and increase the safety and durability of cars. For this reason, they cooperate with manufacturers of composite materials who have many years of experience with the extensive use of composites. Together, they are trying to find a suitable technology that will make the production of composite parts easier, cheaper and faster. The production of composite structures for the automotive industry is the most advanced new market and their use in the production of automotive components has a very great future.

2. Materials for Production of Prototype Parts

The use of composites in automotive production is mainly based on the effort to replace steel and other metallic materials, reduce weight, increase strength, durability, etc. Composite components have excellent properties that cannot be achieved with other materials.

In the early 1990s, the use of modern composite materials caused a revolution in the world's automotive engineering. In 1984, McLaren produced the monocoque of his F1 vehicle from carbon fiber. At present, the use of composites is more or less the norm, especially for sports cars.

Composites advantages:

- fatigue resistance,
- high strength and modulus of elasticity,
- resistance against crack propagation,
- high collision and notch toughness,
- resistance to fire,
- vibrations absorbing ability,
- surface quality,
- corrosion resistance,
- ballistic proprieties,
- electrical conductivity,
- renewable usability. [2]

Main disadvantage of the composites is their high price and difficult production. Main reasons for using the composites materials in car production are:

- decreasing of the car weight,
- decreasing of the car fuel consumption,
- increasing of the safety and the impact strength,
- renewable usability. [2]

Table 1: *Mechanical properties of metallic and composite materials comparison [4].*

Material	Specific mass ($g.cm^{-3}$)	Tensile strength (MPa)	Modulus of elasticity of tensile E(GPa)	Specific strength (N.m/kg)
Steel	7.8	1300	200	167
Aluminum	2.81	350	73	124
Titan	4	900	108	204
Magnesium	1.8	270	45	150
Fiberglass	2.10	1100	75	524
Aramid	1.32	1400	45	1060
IM Carbon	1.51	2500	151	1656
HM Carbon	1.54	1550	212	138

Weight reduction and reduction of vehicle consumption

Through weight reduction the fuel consumption may also be decreasing. By the 10% weight decreasing, the fuel consumption is circa 7% decreasing, what also means that reducing the weight by about 1kg will measurable reduce the CO_2 emissions. [3]

Automotive manufacturers are working to reduce greenhouse gas emissions by using new ultralight materials. The only obstacle to the use of such materials is their high price, which is why great emphasis is placed on the development of new technologies and production processes.

Table 2: *Decreasing of the consumption by the car weight reduction [3]*

Design/ Engine type	Car weight	Fuel consumption (l/100 km)	Increasing of the fuel efficiency
Basic state	500 kg	10	0 %
A) High strength steel	350 kg (30%)	9.58	4.20 %
B) Carbon composites structure	270 kg (42%)	9.31	7 %

C1) Diesel engine		7	30 %
C2) Full hybrid(Otto)		6.5	35 %
C3) Full hybrid (Diesel)		5.5	45 %

As the figure shows, against of the new materials application, the weight of modern cars isn´t much different from the cars from the 70 s. Of course, this isn't caused only by false of materials, but "weight problem" of the cars can be in the future solved with intensive using of composite materials. [4]

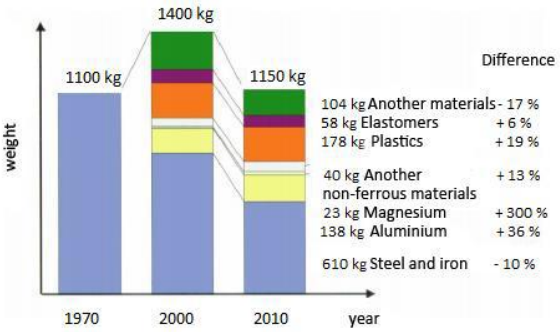

Fig. 1 *Working principle of 3D the printer EOSINT M 2701.*

Increasing safety and impact resistance

The impact strength is an ability of the material structure to absorb the energy through a controlled way. The demands for car impact strength are:

- Deformable end section of the car, which preserve the integrity of the back passenger space and protect the fuel tank.
- Right designed the side structure and the doors.
- Strength roof construction, that protect by the turnover.
- Properly designed interior space.

Composite materials have great ability to absorb the energy. They are made up from layers that are absorbing the impact energy by the separating process. The ability of the energy absorbing is shown on the next figure. (Fig. 2).

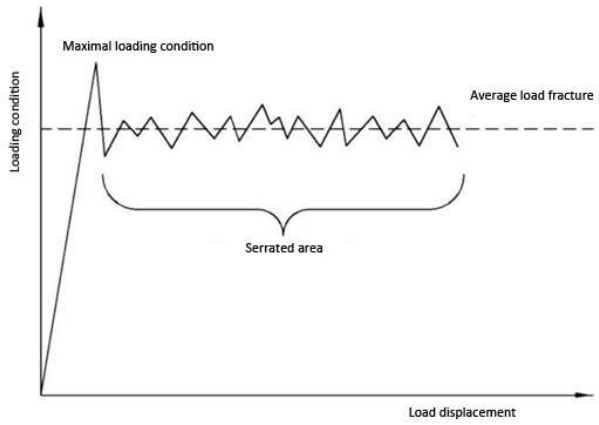

Fig. 2 Graph of the impact energy absorbing [5].

Through the energy absorbing testing, there are developing variously kinds of the surface damages.

We know 3 types of composite materials damage::

a) The fibres disruption.

b) Fragmentation.

c) Brittle fracture.

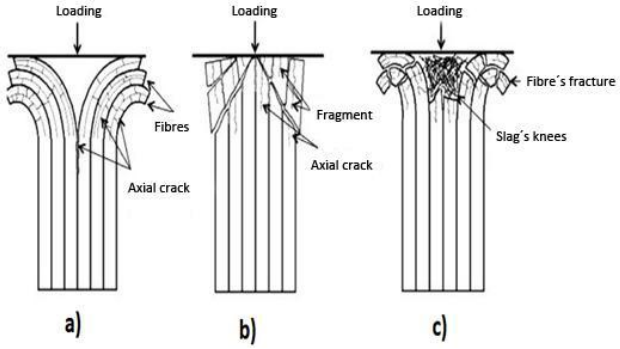

Fig. 3 The types of material damages: - a) The fibres disruption b) Fragmentation c) Brittle fracture [5].

We can present the ability of absorbing the impact energy by the SEA parameter (Specific Energy of Absorption). SEA is J/g and for composite materials is at intervals of 15-80 J/g. [6]

We can get SEA as:

$$SEA = \frac{EA}{\rho . A . l}$$

EA - Energy Absorbed.

A – Cross-section of the sample.

ρ – Density.

l - Length of the energy absorbing.

We can get EA from the graph of the impact energy absorbing:

$$EA = \int F . dl$$

F – Immediate strength of the crush.

As we can see on figure 4, the composite materials have a great ability to absorb the impact energy in comparison to metal materials.

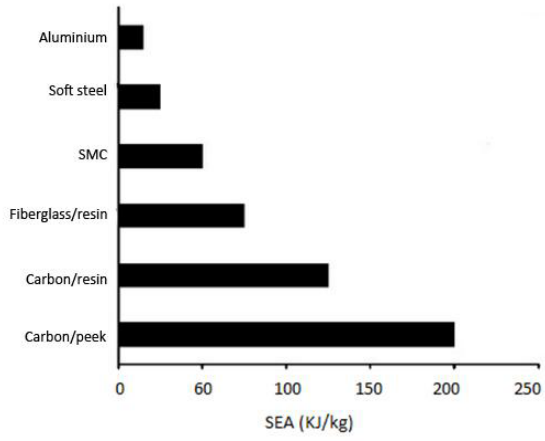

Fig. 4 The energy absorbtion of specific materials [3].

The use of composite materials in car construction was also included in the project of a student prototype car with the working name ICAR, which was implemented at the Faculty of Mechanical Engineering of the Technical University in Košice. Students

designed the car's body and interior. The production of the body was carried out using carbon fibers. The car was built on the chassis of the Škoda Fabia 1.9 TDI and is fully functional. It achieves excellent driving characteristics, because the use of composite materials has significantly reduced the weight of the car. In addition, it has a modified chassis, reduced center of gravity and computer-modified engine parameters. All body parts, including some interior elements, were made of composite materials. It was a very large project involving 25 engineering students. When solving individual tasks, they got acquainted with the whole process from the design of the car to the actual implementation of the production of a functional prototype of the car. They verified on a real project the advantages of using composite materials in the construction of a car and their overall contribution, which was reflected in the driving characteristics of the ICAR car.

Fig. 5 Prototype ICAR.

Fig. 6 Interior prototype ICAR.

3. Conclusion

The use of new materials such as composites allow designers to design different shapes of components that can be applied in automobiles. The design of modern cars affects safety, performance, aerodynamics, car consumption, production costs and many other important factors. Likewise, composite materials are used to improve the appearance of exteriors or interiors, such as. seats, dashboards, wings, bumpers, etc. Research is currently underway and various studies are underway on conventional all-carbon cars. The advantages of using composite materials in automotive production will therefore become more and more important and the scope for their application will be constantly expanding.

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