APPLICATION OF LIGHT-WEIGHT MATERIALS IN MODERN HIGH VOLUME CAR PRODUCTION

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Abstract

The paper contains an overview of light-weight materials being introduced into medium and high volume passenger cars. Achieved weight reduction as well as comparison of basic properties of new components are discussed. A short outlook where we need to go in order to meet demands of fuel economy, environmental targets and legal requirements will be touched.

1. Introduction

The reduction of vehicles curb weight becomes more and more important for both, the vehicle producer as well as for the car user. This is due to extreme competition between the OEM’s, rapid changes in legal requirements and continuous growth of fuel costs. Modern automotive materials we are usually tending to associate with light weight, but with it we are going toward multipurpose advances with regard to safety, comfort, dynamic behaviour, noise reduction and economy. This paper presents an overview of light materials actually introduced into medium and high volume passenger cars.

2. Materials share in automobiles today

The discussion regarding particular materials has been done in relation to main automobile component groups like the body, chassis, transmission and powertrain, Figure 1. The body together with the chassis takes almost 43% of the total car weight, followed by the powertrain with 13%. Interior components, insulation, seats and other parts are taking another 13% of total weight.

A cross-view of materials group, based on a Vectra as a representative of the compact and medium class cars, is shown in Figure 2. The dominance of iron-based alloys with over 60% weight is historically not surprising. Aluminium is represented actually in high volume production with no more than about 5%. The share of plastics and elastomere’s is dominating far over the Al-level and is reaching actually over 20%, from which 13 % contains the interior and about 7% represents the elastomeres mostly as sealings, hoses and various smaller parts. It is generally well known, that polymers are a “pleasant” designing and manufacturing
material for the outer car skin. However, higher costs over steel and recyclability issues limit this material to special vehicles and very low production volumes.

Figure 1. Weight distribution in actual produced cars by components

Figure 2. Share of materials in a Vectra car as a representative for the compact and medium class cars being actually in production
3. New materials for the bodywork and chassis

In the 80-ties the most used material for body application was the soft deep drawing steel with yield strength far below 250 Mpa, Figure 3. Today various new developed steels of high or highest qualities are available. The bake hardening steels having low tensile YS during forming becomes strengthened during drying (baking, 170° C) of the paint in the production line. The outer car skin with 20% higher YS has a better dent resistance or can be made by using thinner sheet metal. Ferritic-martensitic dualphase steels are used for safety structures, still bearing a satisfactory deformation performance in crash situations. TRIP steels with few percent of remained austenite has reduced formability but is still suitable for structures simple bending. It found successful application for example in the rocker reinforcement area. Hot formed martensitic steels having extremely high deformation resistance has been introduced in side door crash beams and B-pillar reinforcements. Introduction of HSS into high production volume cars resulted in significant improvement of the car crash performance as well as in curb weight reduction of 12 kg at a cost-neutral base. It is planed to increase the use of HSS in new body developments to around 60%.

![Application of Steels for the Body](image)

Figure 3. Today there are various steels at designers and engineers disposal

If the customer desires and will be ready to pay for extreme light cars the trend will move toward whole aluminium bodies. One of our sport-cars contain an Al-Chassis with welded and glued extrusion profiles and sheet-elements. For the outer skin this vehicle use about 70 kg sheet moulded compounds, Figure 4. However, no acceptance exists for polymere body of high-volume automobile production.
Fig. 4. The outer skin of the sport car Speedster contains about 70 kg sheet moulded compounds.

Controversial discussions are still alive between various automotive suppliers and car producers about the full aluminium or full steel body. From the economical point of view a mix of various materials is a favourable solution for high volume production, what is also the philosophy used for Opel cars.

Requirements for weight saving regards extensively the car front-side what results in a scenario that can be seen in Figure 5. Changing a steel engine hood into a warm hardening aluminium outer and an inner hood saves about 6.3 kg in weight. An early cooperation between the styling and the engineering department enabled the introduction of this component into production in a short period. It was necessary for aluminium to avoid sharp edges and small radii due to reduced deformability compared to steel. Other examples for introducing light weight materials in the front car area are the extruded and bended Al bumper combined with a modern steel crash box and the magnesium instrument panel beam, optimised by computer calculations. The former steel IP beam was manufactured by welding of 12 various stamped sheet parts onto a central hydroformed tube. This sophisticated part was replaced by one-piece 1.4 meter long magnesium high pressure die casting component. To introduce successfully such a multifunctional part into production it was necessary to provide computational simulation of melt metal feeding into the die and of solidification process to meet required mechanical and technological part performance. The Mg instrument panel beam saves almost 5 kg weight in the front part of the vehicle, enhance the crash performance and reduce the vibration at the steering wheel in the whole area of engine rpm's.
Fig. 5. Light weight components being introduced into the new Vectra MY 2002

New materials and technology used for chassis components are usually associated with high fatigue and safety requirements. If such parts fail due to a misuse case, the driver should become aware of the function lost in a specific system. Figure 6 displays examples of chassis components developed and introduced in the new model Vectra.

4. Advance materials in engines

Let's finally move to the core of every vehicle which is the engine, the transmission and powertrain. A low-weight alternative to a cast iron engine block is actually a whole aluminium engine. Also there is no doubt that the weight saving potential with light metal application is growing with the combustion volume and number of cylinders of the engine. Finally the overall engine concept can influence the weight stronger than the materials selection only.

Figure 7 shows the new 2,2 L, 4 Cylinder Opel-ECOTEC engine with a block and head made in AA 356 aluminium alloy. The block is manufactured using the “lost foam” technology, with a polystyrol model which evaporate when pouring melted Al-metal into the die. This sensible process enables to pour a block with features like oil channels without a sophisticated mechanical treatment. The 2,2 L ECOTEC engine with total weight of 138 kg stands within the most advanced engines of this class.

Another examples of new magnesium parts for the V6 engine is the magnesium intake manifold which enables to save 4.5 kg and a magnesium transmission housing with another 2,4 kg weight saving, Figure 8.
Fig. 6. The new light weight chassis components have usually high safety requirements.

Fig. 7. The whole aluminium 2.2 L. 4-cylinder ECOTEC Engine
Fig. 8. The magnesium gear housing used in the 70-ties are again of interest due to newly developed creep resistant alloys.

The next generation of engines will have introduced more aluminium for subcomponents as well as an magnesium engine block possible with hybridge combination of Al and Mg metals. The liners and the bed-plate could remain as cast-iron. This combination becomes possible due to newly developed magnesium alloys with creep resistance comparable to aluminium alloys. With new creep-resistant calcium and strontium contained Mg-alloys the potential for introduction of the magnesium block within the next 10 years becomes extremely high. Most European automakers are involved in activities to come up with a magnesium block in nearer future. Of course there are still black spots on the road associated with performance at higher temperature to be solved.

5. Final remarks

Introduction of modern light-weight materials is a very important tool for lowering the fuel consumption. Further steps toward fuel economy we found in an internal study are the improvement of the engine performance (combustion, friction, valve and injection management), reduction of the $C_w$-drag coefficient and of the wheel rolling resistance.