Study on weight reduction of automotive body structures for energy saving and emission reduction

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Abstract

As a result of energy saving and emission reduction, there is a way to reduce the weight of vehicle in order to reduce the consumption of gasoline. This paper is mainly devoted to several lightweight materials and technical methods in automobile applications ,and introduces a new approach to lightweight materials instead of mild steel .The use of sandwich materials in the automobile body panels is investigated in this study. It is concluded that lightweight materials will be widely used in the automobile industry if the costs of lightweight materials are as much as traditional materials.

Keywords: lightweight materials, energy saving, emission reduction, sandwich materials .

1. Introduction

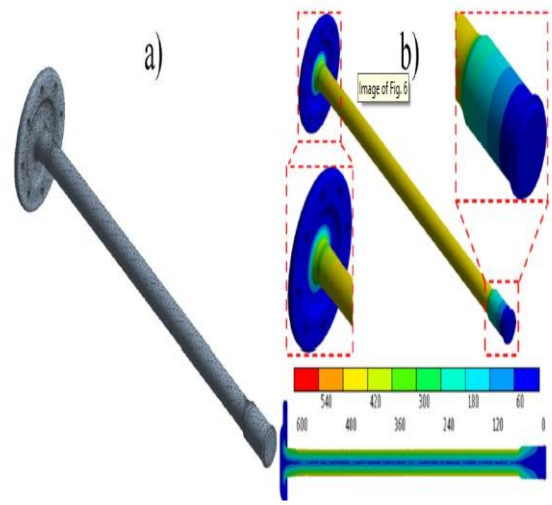
The world has become increasingly aware of impact of vehicles on the quality of the atmosphere, especially in relation to the formation of greenhouse gases, smog, acid rain, and other harmful contaminates. There are many ways to reduce to reduce this emissions, including producing more efficient engines, improving fuel quality and reducing vehicle weight. (James Lowrie, 2017). Car bodies contribute 25% to the total weight of a car and influence the mass of fuel consumption. Light metals are seen as a promising opportunity to decrease the weight decisively. (Sun Wenlong, 2015) Aluminum has some properties that make it interesting for bodies in automobile applications. The strength of aluminum sheet panels and extruded sections is approximately same as that of steel body panels. In addition, the density of aluminum is 1/3 the density of steel.(Sun Wenlong, 2015) Magnesium is 33% even lighter than aluminum and 75% lighter than steel or cast-iron components .The corrosion resistance of high purity magnesium alloys is better than that of conventional aluminum die cast alloys. (Sun Wenlong, 2015) The weight reduction potential of 50-70% for CRP (carbon fiber reinforced plastic) materials results in comparison to metallic materials and other compound materials even if the different demand criteria as buckling, bending, E-module, compression strength and tensile strength taken into account. (H. Adam, 1997)Considering the sandwich materials for the body panels the structure gains high flexural rigidity thus a high stiffness to weight ratio and also a high bending strength to weight ratio. This will enable reduction in weight of the car body with a static performance kept same as the sheet metal based design of the body panels. (Deniz Hara, 2016) Sandwich structures are composed of a weak(low elasticity modulus) and light weight core material sandwiched between two strong (high elasticity modulus) and heavy face materials. Due to their high bending stiffness to weight ratio, sandwich structures results in lower lateral deformations, higher buckling resistance and higher natural frequencies than do sheet metals. Therefore, at the same loading and boundary conditions, sandwich structure of similar static, strength and buckling performance can be obtained with overall weight.(Deniz Hara, 2016) Another method to achieve weight reduction is by geometric modifications and improved heat treating of power train components. (JamesLowrie, 2016)

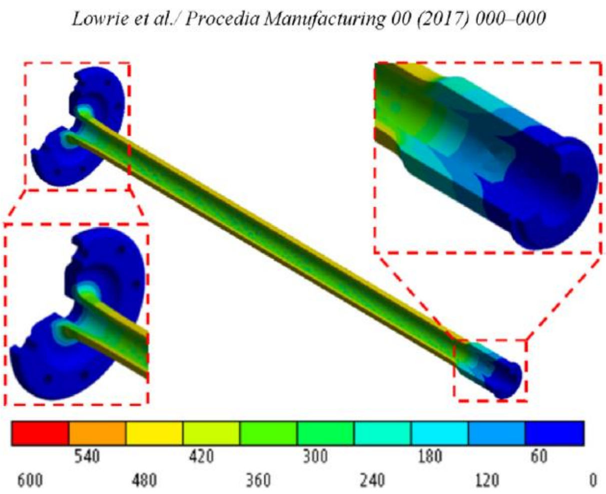
2. Literature Survey

Case Study – 1

In this article analysis is carried out by techniques such as modification in geometry and by introducing new manufacturing processes. In this article it is about the geometric modification of rear axle is considered .

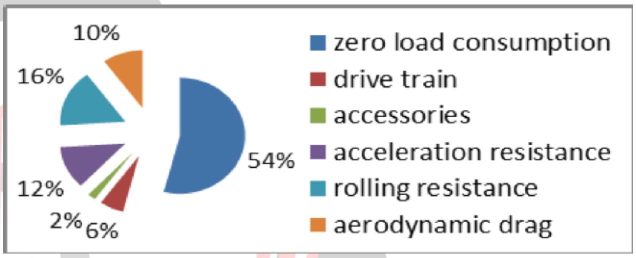
The rear axle shafts in a typical tractor trailer which is using a 6 × 4drivetrain. This is a good place to start the analysis because the four rear axle shafts can collectively weigh 86 kg (190lbs). The torque is transmitted through the various gears in the differential to the splines at the ends of the axle shafts which then transmits the torque to the wheel. Axle shafts commonly encountered in heavy duty trucks generally come in one of two configurations, the full floating con-figuration or the semi-floating configuration. This section of the study will only focus on the fully floating axle shaft. The commercial software package ANSYSW or kbench 17 was used to carry out the finite element the shaft. The shaft was modeled with a linear elastic material with a young's Modulus of 200 GP a and a Poison's ratio of 0.3. The geometry was meshed with tetrahedral elements with a body size of 12.7 mm and level 2 mesh refinement in areas of geometric stress concentration, as shown in Fig. a . The torque was applied as a moment about the shaft axis on the spline end of the shaft and the bolt holes on the other end of the shaft were held fixed. Additionally, there was a rotation speed of 50.4 rad/s applied to approximate any momentum effects produced by the rotation of the axle shaft. The von Mises stresses in the component are shown in Fig. b. The maximum stress on the part is about 275 MP a and occurs on the outside surface of the shaft. Notice that the stress on the interior of the shaft is much lower than the stress on the outside surface of the shaft, which is the expected result for a shaft under pure torsion. This material on the inside of the part is essentially dead weight carrying very little load, but still significantly affecting the weight of the part. If the shaft was made into a hollow part, this dead weight could be removed from the part entirely. This combined with a moderate increase in the diameter of the component could lead to large increase in the average stress carried by the material without leading to an increase in the maximum stress in the shaft. Thus the material in a hollow shaft is used much more efficiently than the material in a solid shaft allowing for significant weight savings. A finite element analysis carried out using the same boundary conditions as the previous simulation, but with a hollow geometry (outer diameter of 50.8 mm and inner diameter of 33.8 mm) was run to illustrate this point





The von Mises stress in the part is shown in fig. The maximum stress in the part is 273 MP a and still occurs on the outside of the part, but, as expected, the material in the shaft carries a much higher average stress.

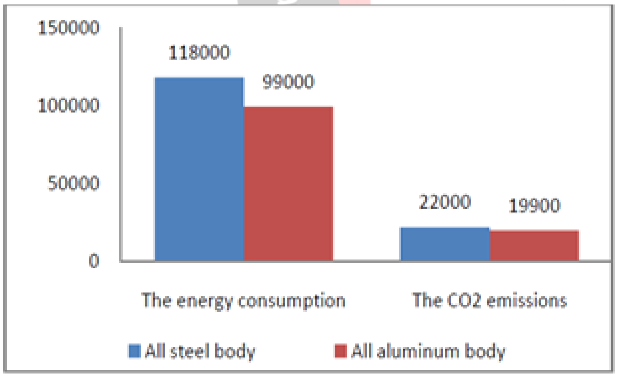
Case Study – 2



Car bodies contribute 25% to the total weight of a car and offer an appropriate way of breaking this circle. Light metals are seen as a promising opportunity to decrease the body in weight decisively. Aluminum has some properties that make it interesting for bodies in automobile applications. The strength of aluminum sheet panels and extruded sections is approximately same as that of steel body panels. That means to achieve a certain permanent distortion or a break of the panel, the same force must be applied in processing cycle. In addition, the density of aluminum is 1/3 the density of steel. However, the rigidity of aluminum is lower than that of steel. The effect is that aluminum has a higher elastic distortion when exposed to the same force as steel. Crash tests are more and more important since occupant safety is a feature that is receiving considerable public attention. Tubular aluminum sections crumple in the ideal way when subjected to impacts. They develop a crumple pattern that can absorb more energy than equivalent steel elements.

Consequently, with half the weight of steel an aluminum structural member provides the same safety. Another advantage the aluminum body implies is that a lower mass of a moving vehicle develops less kinetic energy and therefore protects other road users in case of a crash.

The environmental aspect of different materials can be assessed by a comparison of the energy household of an aluminum-made and steel-made car during production and over their whole lives. Only having regard to all processes that cause energy consumption during production and operating life, can an accurate result be given of the eco-friendliness of a car. It includes material cycles and the amounts of energy needed to produce and maintain a vehicle during operating life time, including fuel. Undoubtedly aluminum is more expensive to manufacture than steel. The costs of a sophisticated aluminum car body like that of the Audi A8 are many times larger than of a traditional steel body. A further comparison can be made in terms of carbon dioxide emissions. If primary aluminum is used it takes 90000 km until the lighter aluminum auto has compensated the higher CO2 emission during production. However, when the proportion of recycled increasing, secondary aluminum exceeds 75% the CO2 emission household is positive for aluminum.1kg aluminum of application in automobile, the car weight of 2kg can be reduced. Generally, every 10% reduction in weight of car, the fuel consumption can be reduced by 6% to 8%. And reducing 100kg weight of vehicles, CO2emissions can be decreased about 5g/km. Currently, CO2Emission Standards draw up by the EU is about 230g/km. A typical aluminum parts can be reduced by 30% to 40% of the vehicle weight. This paper uses Audi A8 as an example, because it uses the aluminum body. Audi A8 mass is 2075 kg, the average fuel consumption is 9.9L/100km and Emissions are 199g/km. Since the body system is about 20%-30% of total vehicle weight, if using the steel body, the car mass is about 2500 kg.



As shown in the above graph the reduction in the energy consumption and CO2 emissions can be seen.

The energy consumption and CO2 emissions in 100,000 km journey, because the operating life of the vehicle is more than 10 years at least so that 100,000 km is just a short distance. In addition, manufacturing process of aluminum requires 50,000 km energy compensation and about 90,000 km emissions compensation. It is found that the result is very worthy.

Case Study -3

Sandwich structures are composed of a weak (low elasticity modulus) and light-weight core material sandwiched between two strong (high elasticity modulus) and heavy face materials. Due to their high bending stiffness-to-weight ratio, sandwich structures results in lower lateral deformations, higher buckling resistance and higher natural frequencies than do sheet metals. Therefore, at the same loading and boundary conditions, sandwich structure of similar static, strength and buckling performance can be obtained with lower overall weight.

With the use of sandwich panels with thin viscoelastic core, the vibrational characteristics can be improved without adding much weight. This allows the reduction or elimination of vibration damping materials used on the automobile body panels.

The finite element model of FIAT Car body model that Özgen (2001), has used in his study is again used

In this design study, the curvatures and shapes of panels are not changed but its sandwich configurations such as thicknesses and materials of both face and core layers are determined. It is aimed to obtain a minimum weighted sandwich panel for these panels having the same static performance as steel panel. This performance is maximum displacement in the panels observed in the bending stiffness analysis of car body-in-white under test loads. For this purpose, while determining the sandwich material configurations for these panels, the sandwich material parameters that give maximum displacement close to the maximum displacement given by sheet metal panels are determined. Bending stiffness of an automobile body may be determined by applying 6432 N vertical load on mid floor area of the body and clamping the regions where suspension springs are located as seen in fig below

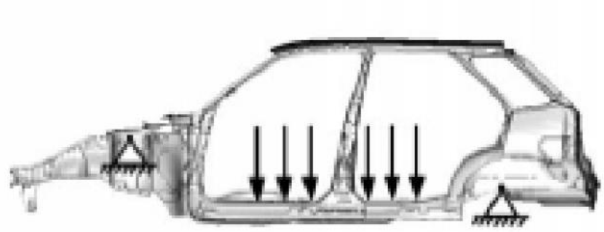
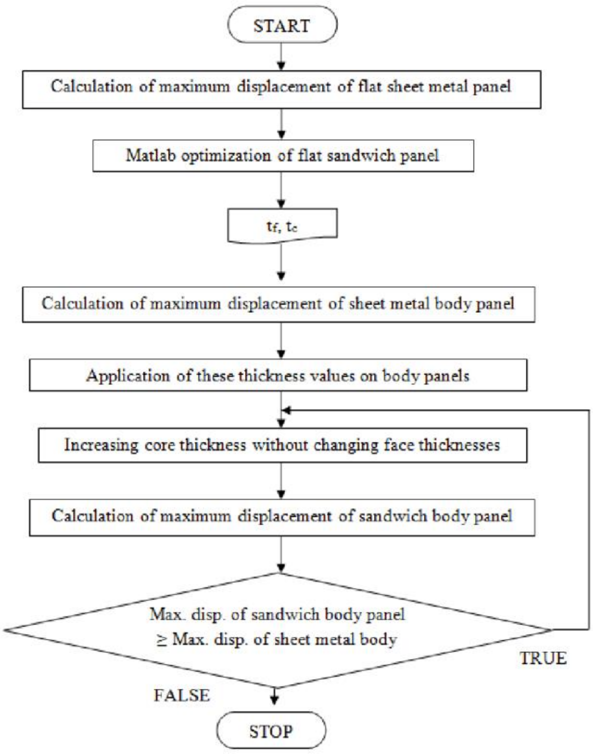


Fig. Load/Boundary conditions of FIAT car model in the study of Özgen (2001).

The optimization is divided into two constraint type. As first type is one in which the face thickness must be equal and have at least 0.2 mm thickness each and total thickness of sandwich panel must not exceed 10 mm. As second of constraint is the type in which only the thickness limitations are changed in order to see how optimization results depend upon thickness limitations. For better results, thicknesses must also be equal and have at least 0.1 mm thickness each and total thickness of sandwich panel must not exceed 20 mm.

Design procedure for different panel size for optimization: -



According to their study and design procedure the results obtained are as follows:-

Part	Weight Reduction
Luggage	54.9%
Firewall	52.4%
Rear Wheel	49%

As per the results obtained it can be clearly seen that weight reduction of considerable amount is possible by using sandwich materials.

The materials like cellular foamed, honeycomb cored and balsa wood cored sandwich panels may be used for reducing weights of the panels under physical loads such as bending, torsion and buckling etc. Using sandwich structures instead of sheet metals the amount of emissions can be decreased because the power needs are reduced by weight reduction.

Conclusions

1. Reducing vehicle weight is an important way to reduce the fuel use and greenhouse gas emissions from passenger vehicles. We find that a 10% reduction in vehicle weight will reduce fuel consumption by about 7%. In absolute terms, every 100 kg weight reduction will yield a 0.39 L/100 km reduction in fuel consumption for a current average midsize gasoline car.

2.To construct designs with equal stiffness, magnesium offers around 60% weight reduction over steel, and 20% weight reduction over aluminum. Besides reduced weight, magnesium also offers strength, durability and thermal stability.

3.It is seen that, foam cored sandwich structures can show the same bending stiffness performance as the steel sheet metal panel with at least 50% less weight. It is also shown that, instead of damping treatments added on the panels, using sandwich panel with a thin viscoelastic material core can reduce the weight by approximately 60–70% keeping the same damping performance.

Considering these benefits of sandwich structures, they can be very widely used in car body design.

4. By switching from conventional solid shaft geometry to hollow shaft geometry allows for the radical reduction in part weight, but requires at least a small increase of the outer diameter of the shaft. In this study, the weight of the axle shaft could be reduced by 26%, if the solid shaft was replaced with a hollow axle shaft with diameter just 5.8% larger than the solid axle.

5.Intensive quenching offers the opportunity to increase the volume fraction of marten site in the part to improve surface and core hardness, as well as overall part strength, allowing for the reduction in part weight. The weight of the axle shaft examined in this study could be reduced by 3% if the intensive quenching method was used in place of the oil quench.

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