

Trends in weight reduction of automobiles “Alu – maximized”

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Abstract - Automobiles tend to become heavier as the safety (e.g., collision safety and comfort features) are improved. On the hand, the demand for higher fuel efficiency and lower environmental impact is also rising. The average mass of passenger cars has dramatically increased since the 70's and because vehicle weight directly impacts fuel consumption, light-weighting is necessary more than ever to reduce CO_2 emissions [1]. 100kg mass reduction achieved on a car saves 9 grams of CO_2 per km at the exhaust pipe. Aluminum is the ideal light-weighting material as it allows a weight saving of up to 50% over competing materials in most applications without compromising safety. This paper reports on developments and trends in aluminum alloy sheets for automotive body panels. As a long term vision, an (“Alu-maximised”) small family car could be 30-35% lighter after primary and maximum secondary weight savings. [2]

Keywords - Efficiency, Aluminium, Safety.

INTRODUCTION

Automobiles are becoming heavier in order to satisfy requirements [3] such as safety (e.g., collision safety and pedestrian protection), drivability, comfort and larger interior space. Meanwhile, automobiles have to meet more stringent regulations against exhaust emissions, including CO_2 and NO_x emissions [4], to protect the environment. Transportation is a significant source of CO_2 emissions with individual transportation (cars) producing a major share of it. Among the many measures to reduce CO_2 emissions from cars, technological ones (i.e. the ones that are intrinsic to the car and do not depend on driver behavior) are the most reliable. Light weighting is one of the most effective and directly impacts CO_2 emissions, as 100kg saved on the mass of a car is equivalent to a reduction of 9 grams of CO_2 per kilometer. Various measures are taken to reduce fuel consumption including new power trains involving hybrid systems or advanced diesel engines. Above all, automotive weight reduction is regarded as one of the most effective means for decreasing fuel consumption. So there are numerous light-weighting solutions based on aluminum and aluminum alloys. By the intensive use of safe and cost efficient light-weight aluminum concepts which can be applied with little adaptations across all car models. For car buyers, fuel consumption is seldom the dominant purchasing decision criteria despite its huge impact on operating costs and the well-known environmental consequences.

1. Reducing mass is necessary to reduce CO_2 emissions

Vehicle mass directly impacts fuel consumption.

Weight reduction directly reduces the energy consumption because the energy required to move a vehicle is, except for aerodynamic resistance, directly proportional to its mass.

On average, 100kg mass reduction achieved on a passenger car save:

- 0.35 liter of fuel per 100km.
- 9 grams of CO_2 per km at the car exhaust pipe [5].

When including emissions for fuel production & supply (well-to-wheel), 100kg mass reduction achieved on a passenger car save:

- 10 grams of CO_2 per km.

2. Reducing mass has benefits [6]

2.1 Acceleration: Keeping the car acceleration performance constant, which is generally reflected by the power to weight ratio, saving weight allows downsizing of the power train (engine, transmission, axle, differential etc...) and thus provides additional weight savings. Keeping the power train un-modified, reduced weight increases the power-to- ration and therefore improves acceleration.

2.2 Braking:

Keeping braking power constant, light-weighting shortens braking distance. Keeping the braking performance constant, light-weighting allows downsizing of the brakes, which offers further weight saving potential.

2.3. Handling

Road handling is improved by light weighting in many different ways:

- Handling of a lighter car is easier in demanding driving situations.

Reducing body weight lowers the Centre of gravity improving the Car's stability and reducing the risk of roll-over.

2.4 Driving Comfort

Saving weight on unsuspended parts like wheels increases driving comfort.

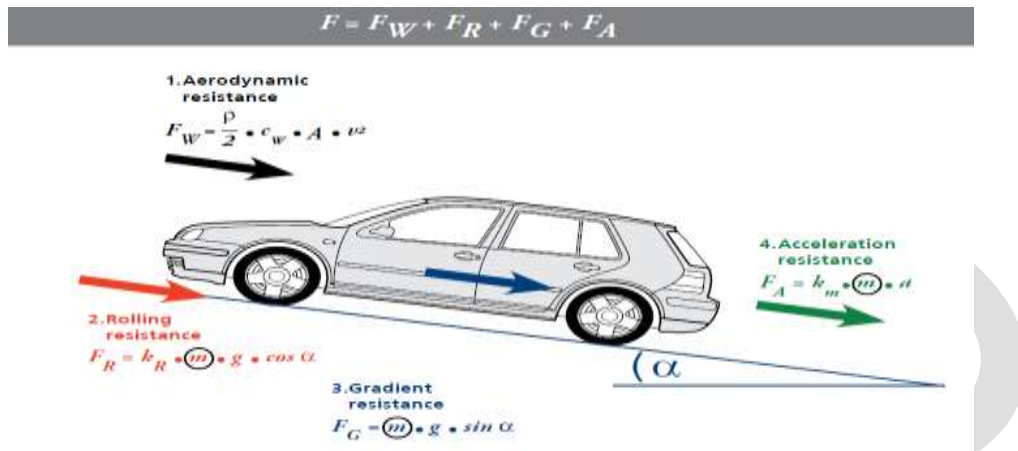


Fig1: Resisting forces [7]

3. Aluminum is the ideal light weighting material. [8] [9]

3.1. Aluminium Properties

With 2,700 kg/m³, the density of aluminum is one third of that of steel. But such a weight reduction is seldom achieved since for a large number of parts, it is necessary to increase the average thickness of aluminum compared to steel to achieve the same part characteristics. The most frequently encountered ratio of thickness in structural applications is approx. 1.5, which means for instance that 0.8 mm steel component can be replaced by a 1.2 mm aluminum component, in this case, the weight reduction is still 50%.

However, the relationship between the material properties and the strength, stiffness and weight of a component is very complex and can be strongly influenced by the part geometry so that there is no absolute rule. In practice, it will be necessary to consider each component individually to determine the actual weight reduction potential. The following section further illustrates this fact. [10]

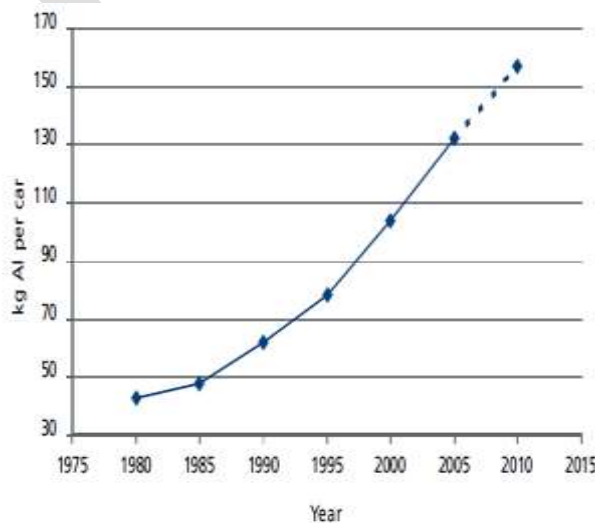


Fig 2: Evolution of aluminum content in European countries

3.2. Primary Weight Savings

Aluminum allows a saving of up to 50% over competing materials in many applications. Typical relative and average absolute weight savings of today's main aluminum applications in mass produced cars are given below

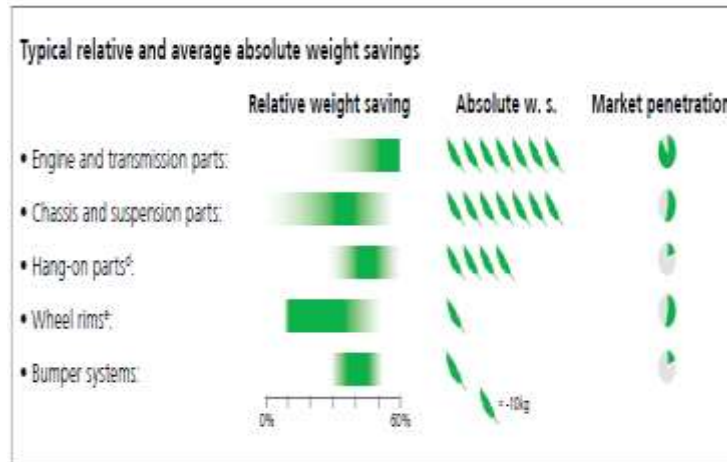


Fig 3: Relative and average weight savings

Keeping a car's performance constant, primary weight savings allow downsizing of other car parts (powertrain, brakes, fuel tank, crash management systems etc...), leading to so called "secondary weight savings". In case the primary weight savings achieved on a defined vehicle are small (i.e. when only little aluminum is used) secondary weight savings are not likely to be achieved by car manufacturers. On the other side, when aluminum is intensively used, secondary weight savings can exceed 50%. For example, in the case of the Audi A2, the intensive use of aluminum allowed direct weight savings of 134kg that allowed 75kg secondary weight savings thanks to drivetrain, motor and chassis downsizing.

3.3. Today's Cars Contain 132kg Of Aluminium

Besides well-known aluminum intensive cars like the Audi A8, which contains about 520kg of aluminum or the Jaguar XJ, many cars contain significant amounts of light metals. A recent study by Knibb, Gormezano & Partners (KGP) in cooperation with the European aluminum Association [11] shows that the amount of aluminum used in new European cars has risen from 50kg in 1990 to 132kg in 2005 and is predicted to grow by another 25kg by 2010. The study is based on the analysis of car models representing a European production volume of 15 million units in 2005.

Key results are summarized below.

Chassis & suspension

- 17 components analyzed
- Highest aluminium application
 - Wheels
 - Suspension arms
 - Steering system
- Aluminum content = 37kg

Drivetrain

- 25 components analyzed
- Highest aluminium application
 - Engine block & cylinder head
 - Transmission housings
 - Radiators

- Aluminum content = 69kg

Car body

- 20 components analyze
- Highest aluminium application
 - Bonnets & doors
 - Front structure
 - Bumper beams
- Aluminum content = 26kg

3.4. Tomorrows Cars Could Easily Be 40kg Lighter ^[12]

Innovative, safe and cost efficient light-weight aluminum bonnets, wings, doors and bumpers can be found across all car models today. For these parts, switching to aluminum is relatively easy and does not need full re-engineering of the car. Together, their light-weighting potential exceeds 40kg per car. However, penetration in the market is less than 20%. In practice, material substitution is generally connected to a model change where extensive re-design takes place anyway. Mixed material design does not present bigger problems provided appropriate design and manufacturing measures are taken. Thus, the weight saving potential could be even significantly greater.

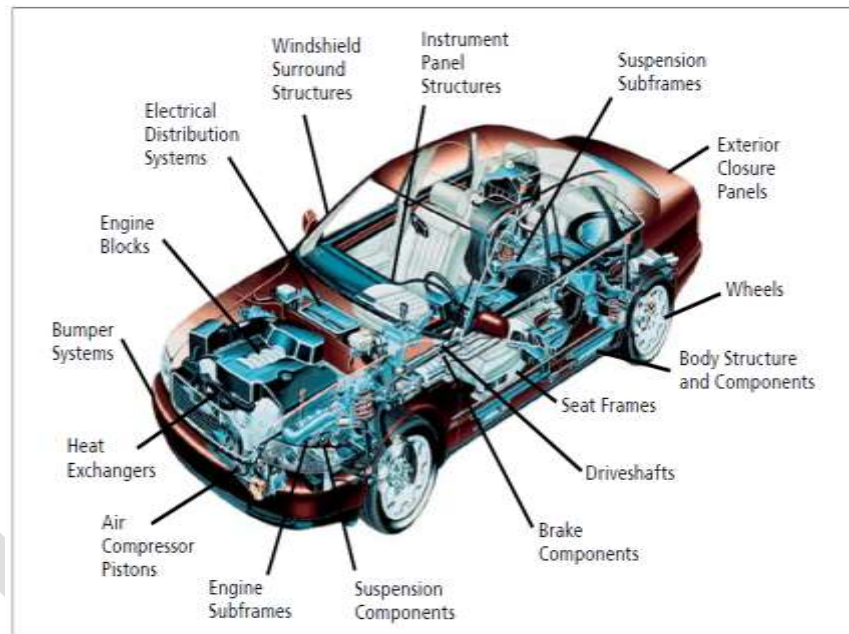


Fig 4: Potential of Aluminium is endless

4. Aluminium is easy to recycle

Aluminum is easy to recycle ^[13]and saves 95% of the energy necessary to produce primary aluminium. RWTH-Aachen recently analyzed the aluminium recycling process and concluded that 95% of the aluminium contained in end-of life vehicles can be recovered by mechanical processing in modern shredder and non-ferrous metal recovery plants.

The End-of-Life vehicle dismantling and aluminium recycling process ^[14] is summarized in figure. Aluminium recycling from end-of life vehicles is an established and profitable business and the proceeds from the recycled aluminium are a most important factor in the economy of the car recycling.

4.2 Aluminium supply

Aluminium supplies will continue to meet the demand because:

- Current reserves of bauxite, used to produce primary aluminium, will last for many generations
- The amount of aluminium available for recycling is constantly increasing.

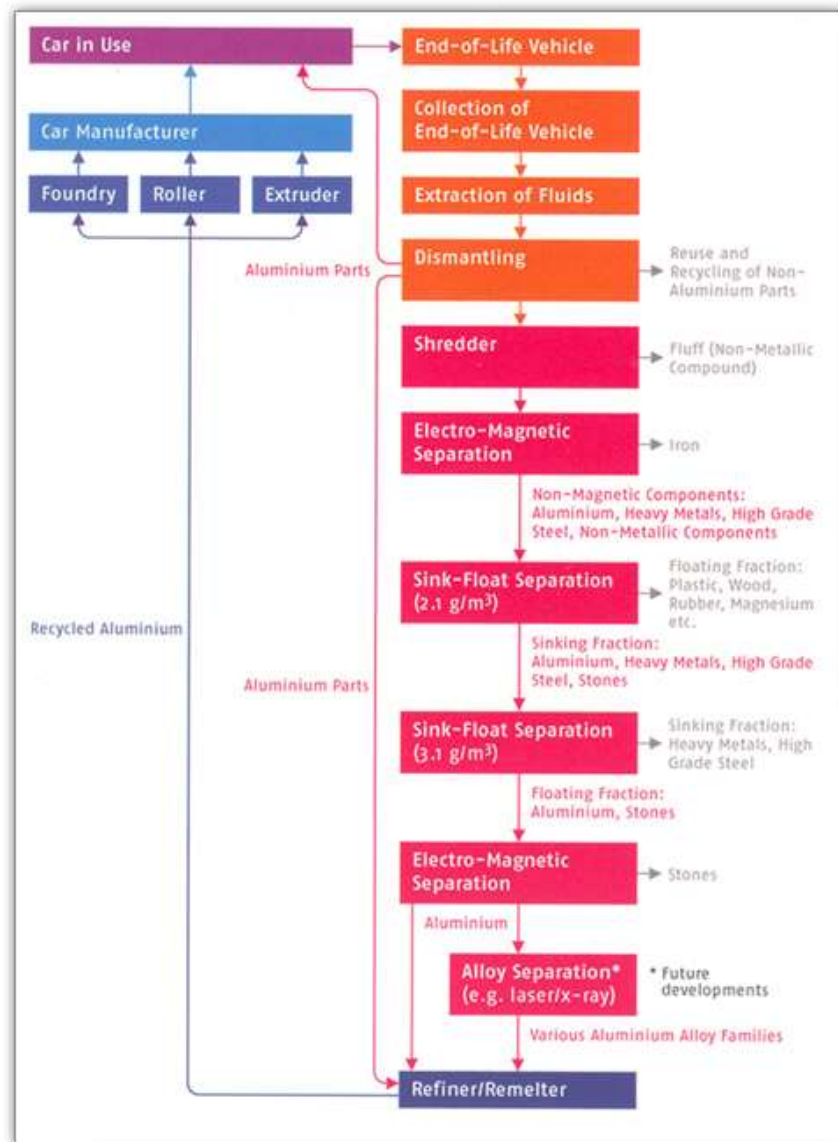


Fig 5: End-of-life vehicle dismantling & recycling process [15]

CONCLUSION

Because the average mass of passenger cars has dramatically increased since the 70's and because vehicle weight directly impacts fuel consumption, light-weighting is necessary more than ever to reduce CO_2 emissions. 100kg mass reduction achieved on a car saves 9 grams of CO_2 per km at the exhaust pipe. Aluminium is the ideal light-weighting material as it allows a weight saving of up to 50% over competing materials in most applications without compromising safety. As a long term vision, an "Alu-maximized" small family car could be 30-35% lighter after primary and maximum secondary weight savings.

The latest trend and new technologies of aluminum sheets have been reviewed with major focus on automotive panels. In the needs for automotive weight reduction, aluminum will continue to be a major candidate for a lighter substitute material.

Functional properties, as well as the weight reduction effect, will be required for aluminum alloys to be used for various automotive parts.

To expand the use of aluminum for automotive panels, forming technologies should be further improved to provide more degree of freedom to automotive design. Tribology is considered to be an area which needs to be pursued to further develop the applications of

aluminum sheets. The formability can be improved by facilitating the material flow in dies by introducing lubricants with low friction coefficients to reduce the cost of aluminum parts for them to be used for various parts of mass produced vehicles. The cost reduction may involve the development of process technologies which simplifies process steps and simultaneously achieve the required quality. Unification and recycling of parts will also be needed.

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