EUROPEAN ALUMINIUM ASSOCIATION

PRESS INFORMATION

Aluminium improves transport safety

Texts and illustrations for the European transport press

December 2004

Summary:
In the context of its Road Safety Action Programme, the European Commission seems willing to introduce energy absorption criteria for trucks. The aluminium industry developed several solutions for the automotive and railway sectors and would be ready to take up this challenge for trucks.

Contents:

For more information, please contact
Bernard Gilmont
European Aluminium Association
Phone: + 32 2 775-63 40 Fax: -63 43
www.alutransport.org (trucks)
www.aluminium.org (general)

Introduction

When jumping from a wall, everyone will agree that it is preferable to fall onto one's feet while bending the knees rather than falling onto one's head and stiffening the body.
The same principle prevails with regard to transport safety.

To increase the chances of survival in an accident, vehicles must be designed to keep deformation out of manned areas and to dampen the shock undergone by the occupants.

In this context, aluminium components are increasingly used in the automotive and railway sectors. They increase safety at an advantageous cost and with a minimal weight penalty.

With regard to trucks, after having imposed the front, side and rear end under-run protection, Europe now seems willing to go further in order to save lives by introducing energy absorption criteria. Indeed, some manufacturers claim that introducing a deformable zone at the front end of the cabins could reduce the number of deaths by 900 units per annum on European roads.

This document explains what the aluminium industry developed for the automotive and railway sectors, and describes what could be done for trucks.

The principle

When a vehicle is moving, it has a certain quantity of kinetic energy proportional to its mass and the square of its speed. To slow down the vehicle in case of emergency, most of this energy must be dissipated in the form of heat at the level of the brakes and the tires. If these are not sufficient, a collision will be inevitable and the vehicle will absorb the major part of the residual energy by plastic deformation[1].
In order to limit the damage to the occupants in the case of accident, it is necessary to avoid the deformation of the passenger compartment by a controlled deformation of the un-manned parts. Whatever the material used, the areas intended to crash will therefore be less resistant than the passenger compartment.

Moreover, the longer the deformation zone, the softer the average deceleration for occupants. Unfortunately, this also means extra volume and weight whereas the current trend is for more compact and lightweight vehicles. It will thus be necessary to find the best compromise between softest deceleration and lowest weight.

A compromise to be found between softest deceleration and lightness

To better understand what this means, let us examine two cylindrical aluminium tubes in the simplified case of an axial shock in laboratory conditions.

If, for a defined quantity of energy to be absorbed, one seeks the most compact solution and the lightest possible weight, one will choose a very resistant, short and thick tube, of which the entire volume will undergo important plastic deformations[2], as illustrated by figure 1.

---

[1] However, if the vehicle and/or the obstacle are still moving after the accident, the system will have preserved a part of its initial kinetic energy, reducing by the same extent the quantity of energy to be absorbed by plastic deformation. This situation can be found in reference accidents considered in the railway sector.
[2] Deformation mode: 100% plastic buckling

This solution makes it possible to absorb nearly 50 kilojoules (kJ) of energy per kg of aluminium[3], is very compact, but will impose a strong deceleration to the passengers in case of accident.

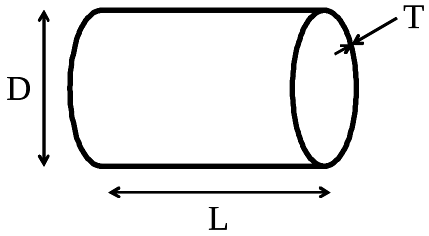
If a soft solution is required, one will choose a less resistant and less thick element, which will crush like a beverage can, as illustrated by figure 2. As many parts will remain plane and almost not deformed, the energy absorption will be limited to approximately 25 kJ per kg of aluminium[4] and a longer element will be required. On the pro side, the deceleration in case of accident will be much softer.

Comparison between two extreme aluminium solutions, for the same capacity of energy absorption (7.5 kJ)

Dimensions before crushing

Short and thick cylinder

D = 70 mm
T = 5 mm
L = 54 mm
Weight: 150 g



Long and thin cylinder

D = 92 mm
T = 1,5 mm
L = 261 mm
Weight: 300 g

Results after crushing

100% plastic buckling
Strong deceleration
7,5 kJ absorbed, i.e. 50 kJ/kg_{alu}

Mix of elastic & plastic buckling
Soft deceleration
7,5 kJ absorbed, i.e. 25 kJ/kg_{alu}


Fig. 1


Fig. 2

In practice, 100% plastic buckling is not achievable and a compromise must generally be found between these two philosophies.

There is a multitude of intermediary solutions, and sections can be much more complex (rectangular, multi-chamber, with variable thickness etc…).

[3] +-20%, depending on the exact aluminium alloy composition and the heat treatment undergone.
[4] Deformation mode: mix of elastic and plastic buckling

The most frequently used in the automotive sector allow 20 to 35 kJ per kg of aluminium[5] to be absorbed and ensure an acceptable deceleration rate. Their deformation mode look like the one illustrated by fig.2

Systems deforming as illustrated in fig.1 can be found in the railway sector.

In practice, the shock scenarios are much more complex and the energy absorbing systems are not limited to one single element. Nevertheless, the principles illustrated above remain applicable.

Advantages of aluminium safety parts

Lightness

Considering the modes of deformation that energy-absorbing elements undergo, aluminium systems make it possible to absorb significantly more energy per unit of weight than traditional steel systems. As a rule of thumb, the light-weighting potential exceeds 40%.

High added value semi-products

Aluminium can easily be extruded and the complexity of the profiles that it is possible to obtain is almost unlimited. This enables not only better control of the deformation in case of a crash, but also the integration of a great number of functions in one part.

If necessary, the profiles can always be further transformed (bending, stamping, drilling etc…).

Depending on production volume, solutions containing sheets, castings or forged products can also be used.

Diversity of alloys and the treatments

Depending on technical and economical constraints, a broad range of alloys and heat treatments allow designers to optimise their product.
The most frequently used alloys are aluminium-magnesium-silicon (series 6000) and aluminium-zinc (series 7000).

Some examples

Automotive

Elected car of the year in 2003, Renault Mégane II is equipped with an aluminium front bumper and two aluminium crash boxes.
Among other criteria, the system is calculated to absorb the energy of a shock up to 16 km/h impact speed.
This avoids the deformation of the car's structure during typical city accidents and facilitates repairs.

[5] In the case of axial unidirectional shocks.

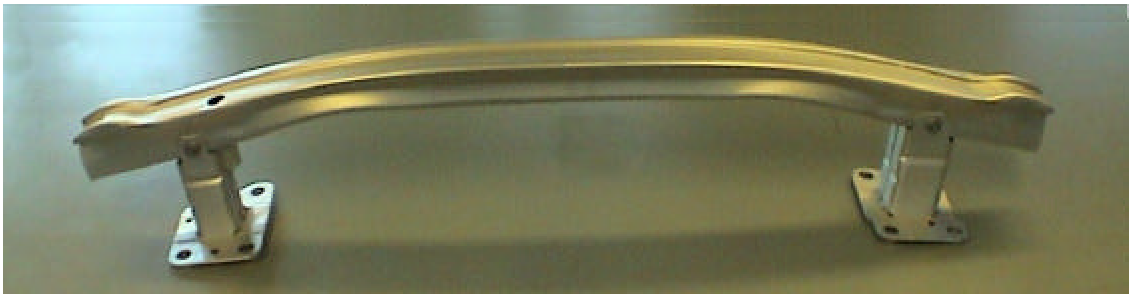


Fig. 3

Result: at equal performance with traditional solutions, the light-weighting provided by aluminium exceeds 40%[6].
The weight saving achieved on the front bumper also improves the cornering performance of the car.

Aluminium front and rear bumpers have already conquered one third of the European car market.

<u>On the rails</u>

An aluminium energy-absorbing module was recently developed and tested within the framework of the European Safetram programme, with the aim to improve the passive safety of tramways.

In order to face the multiple accident scenarios, the developed system makes it possible to absorb shocks from various obstacles coming from different directions.

For example, it is designed to dampen a head-on shock at 20 km/h with an identical tramway weighing 35t (see fig.4, 5 & 6) or a 45°-collision at 25 km/h with a light commercial vehicle (3t).

The weight was not a decisive criterion for this project but, thanks to aluminium, the module weighs no more than 68 kg.

As far as trains are concerned and without going into details, let us mention that double-decker TGV wagons, made of aluminium, are designed to undergo a collision at 110 km with an obstacle of 80t, without wagons overlapping or deformation of passenger compartments[7].

---

[6] Compared with traditional solutions used on vehicles belonging to the same category and having obtained the same score (5 stars) in the EURO NCAP crash test.
[7] Speed after shock: 90 km/h. Other reference scenarios are foreseen in the upcoming European crashworthiness standard for railway structures: 1) running train at 36km/h against identical train at 0km/h; 2) running train at 36km/h against 80t freight wagon ; 3) running train at 110km/h against a 15t truck;

Crash-test carried out within the framework of the Safetram programme

Fig. 4

Fig. 5

Fig. 6

What could be done for trucks?

The adopted solutions will depend on truck energy absorption standards and regulations that do not exist at present. However, basic research projects on which they could be based have been and continue to be carried out[8].

Whatever the final regulation will be, the weight and dimensions of the deformable area will directly depend on the following data:

- The resistance of the obstacles and the impact angles to be considered, which will dictate the resistance of the deformable area. Thus, for a given shock angle, the latter will have to be lower than the resistance of the weakest obstacle that may come from that direction.

[8] The European Enhanced Vehicle-safety Committee (EEVC) worked on test procedure and performance criteria for energy absorbing truck front under-run protection systems (www.eevc.org)
The Vehicle Crash Compatibility consortium (VC-COMPAT) is presently continuing the EEVC work (http://vc-compat.rtdproject.net)
An expert group on transport accident investigation is effective from the 1st of July 2004 and will advise the EU Commission on its transport safety strategy.

- Mass of the truck and the obstacles to be considered, their speeds and their nature (fixed or mobile, deformable or non-deformable): They will define the quantities of energy that the system should be able to absorb for each direction.

The higher the variety of scenarios to consider, the more complex the geometry and weight optimisation will be.

The future?

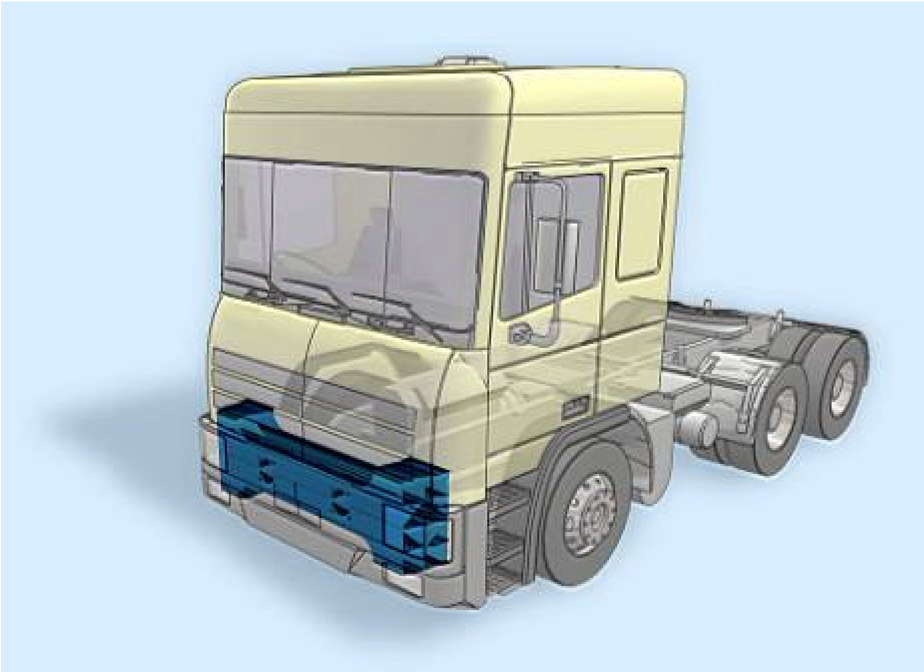


Figure 7

Figure 7 shows what a road tractor could look like if the reference accidents were comparable with those of the Safetram programme.

Finally, it has to be underlined that other parts of the vehicle, such as front and rear end under-run protection devices, could also play a significant role in energy absorption.

Based on what could be developed to meet the expectations of the automotive and railway sectors, there is no doubt that the aluminium industry is able to take up the challenge of improving truck safety.

References:

- Dr. Pius Schwellinger & Dr Ernst Lutz (Alcan): *Aluminiumprofilwerkstoffe für energieabsorbierende Bauteile im Fahrzeugbau*; ATZ/MTZ Special Issue "Werkstoffe im Automobilbau 98/99"
- Dr. Wolfgang Guth & Dipl.-Ing. Christian E.Lodgaard (Hydro): *Leichtes Design für leistungsstarke passive Sicherheit*; ATZ/MTZ Special Issue
- Dipl. Ing Jürg Zehnder (Alcan): *Ueber die Crash-Sicherheit von Aluminium-Wagenkästen*