european
aluminium association

THE SUPERIOR LIGHTWEIGHTING POTENTIAL OF ALUMINIUM

INTRODUCTION

It is often claimed that high-strength materials make an effective contribution to lightweight car body components. The idea behind this is that stronger materials enable the thickness of parts to be reduced without influencing the performance of the car. This is not possible for all components, however.

The “Stiffness and Crash Relevance of Car Body Components” study shows that the use of aluminium could result in significant weight savings for the typical components of a compact class car body. Based on a state-of-the art steel reference car, the maximum weight reduction potential of aluminium in car bodies is approximately 40%.

Weight reduction potential using high-strength steel was limited to a reduction of only 11%. The reason why the potential weight reduction using high strength steel is lower is that nearly 40% of the parts analysed simply cannot be made thinner without reducing the car’s overall stiffness, whereas aluminium can be used without reducing thickness or causing the car’s stiffness to suffer.

A more detailed explanation of the study can be found in this leaflet.

To download the full study “Stiffness and strength relevance of car body components”, please visit : http://www.alueurope.eu/publications-automotive.

1

STIFFNESS AND STRENGTH, HOW DO THEY DIFFER?

The strength of a part decides how much load it can take before it breaks, while the stiffness of a part decides how little it will elastically deform under a certain load.

Since all materials based on the same parent metal[1] have approximately the same elasticity (E-modulus), switching to a higher strength solution from the same metal family allows for down-gauging but automatically decreases the stiffness of a part, as illustrated in Figure 1.

In the case of car bodies, strength and stiffness are conditioning factors for the stability and the safety of a car. Some parts are vital for the stiffness of the complete car body, which is an important factor determining the driving characteristics of the car. Other parts are more important for its strength, like components whose main function is to maintain a survival space for passengers in case of crash. For each car body component that one wishes to lightweight, an understanding of both its stiffness relevance and its strength relevance is key to making the right material decision.

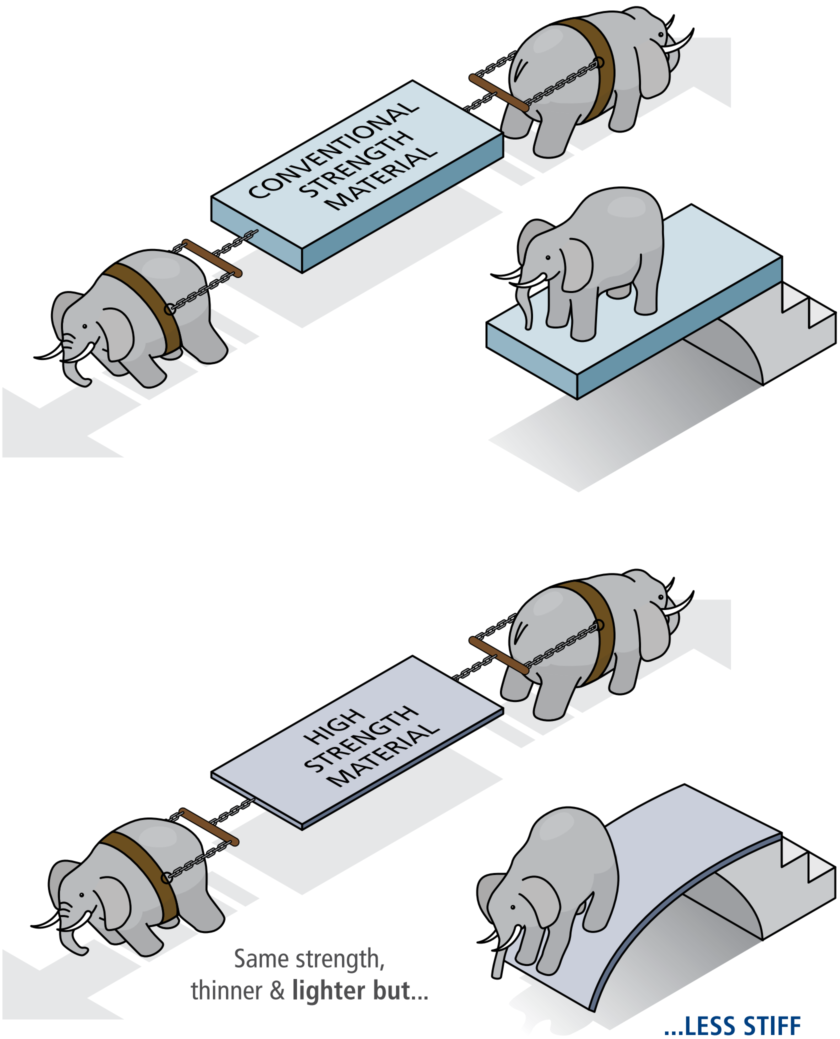

Figure 1: Down-gauging a part with high strength material, while staying in the same metal family

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E.g. iron (Fe) for steel grades or aluminium (Al) for aluminium alloys.

2

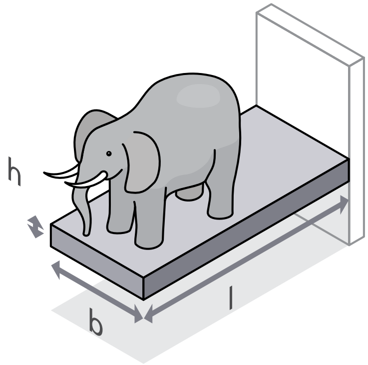
STIFFNESS IS A COMPLEX METRIC

Stiffness depends both on the E-modulus and the cross section of a component. This means that if a steel bar is compared to an aluminium bar with exactly the same cross section, the steel bar would be much stiffer because the E-modulus is higher for steel. The advantage of aluminium is that its density is much lower than that of steel (the density of aluminium is 1/3 of that of steel), meaning that a larger cross section can be used to compensate for the lower E-modulus.

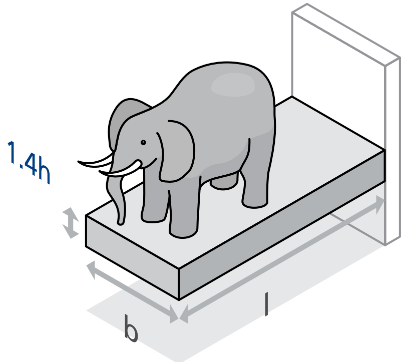
To demonstrate this, a simple bending stiffness case can be taken. The lower E-modulus for aluminium means that the thickness of the aluminium bar must be increased to reach the same stiffness as for a steel bar.

In the example shown below the height (h) would have to be increased to 1.4 x h, but since the density is just 1/3 of the density of steel, the aluminium bar will still be 50% lighter than the steel bar.

The reality in a car design situation is naturally much more complex. There are many design boundaries that limit the lightweighting that is actually achieved. For example, packaging restrictions will limit the possibilities of increasing the dimensions of the aluminium components, and the risk of buckling sets a limit to how thin you can make the steel sheets. An understanding of stiffness and strength relevance is important, however, when thinking about new design possibilities.



Steel



Aluminium, 40% thicker, but 50% lighter

3

STIFFNESS & STRENGTH RELEVANCE OF CAR BODY COMPONENTS

As all car body components have different functions and call for different lightweighting solutions, the European Aluminium Association commissioned a study from ika Aachen that looked at different car body components and closures to assess if they were of primary importance for the stiffness of the car or for the strength of the car in the event of a crash.


Scope of the study

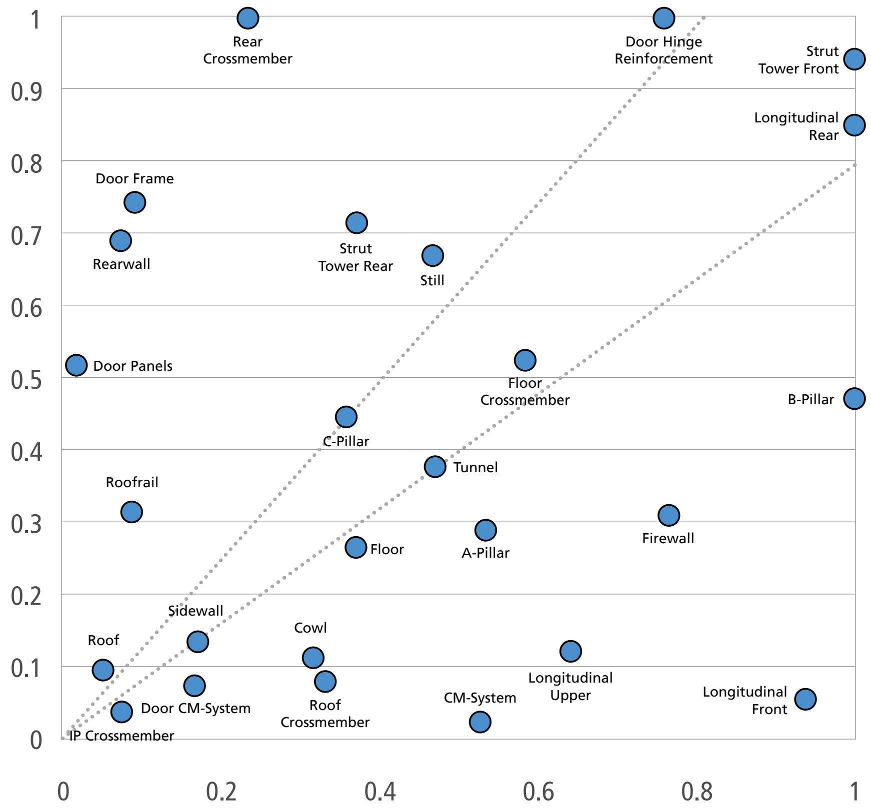


Figure 4: Stiffness and strength relevance of car body components

Based on numerical simulations, the different components were given a score (between 0 and 1) to rate their relevance for the stiffness of the car body and their relevance for the strength of the car body in the event of a crash (Figure 4).

The study showed that about 40% of the components are highly relevant for global stiffness, but have low-strength relevance in crash situations. These components are not suitable for efficient weight reduction using steel grades with higher yield strength, since making the part thinner will automatically reduce the stiffness of the part. Instead, these components are very suitable for weight reduction using conventional car body aluminium alloys. With aluminium, these parts can be made lighter without reducing their stiffness.

On the other hand, components identified as highly relevant for global strength in the event of a crash are suitable for efficient weight reductions using steel grades, but also with aluminium alloys with higher yield strength.

4

ACHIEVABLE WEIGHT REDUCTIONS WITH STEEL AND ALUMINIUM

A systematic approach was developed, based on stiffness and strength relevance as well as the current yield strength of the component, in order to assess the possible weight reduction for steel components by using materials with a higher strength. The application of this approach to the reference vehicle showed that the remaining weight reduction potential of high-strength steel (including TWIP[2] steel) in modern car bodies could be estimated at about 11%.

A similar approach was also developed to assess the weight reduction potential by substituting steel by aluminium. Using this approach, the weight reduction potential, when designing the reference car body and the closures in aluminium, using conventional car body aluminium alloys and new high-strength alloy variants[3] currently under investigation, was estimated at 40%.

2) Twinning-Induced Plasticity steel

3) High Strength Aluminium alloys have yield strength from 300 MPa to 400 Mpa. Ultra High Strength Aluminium alloys have yield strength above 400 MPa.

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