TATA STEEL

TATA

Benefits of steel for responsible lightweighting

Evaluation of a door assembly's lifecycle CO_2 footprint and total cost of ownership

Background

Automotive manufacturers are constantly facing challenges. Globalisation, individualisation, digitalisation and shifting values are changing the face of the automotive industry as we know it. In addition, tighter regulations, as well as higher customer expectations regarding safety and emissions, influence the future car design. 'Greener' in this case is usually associated with maximising fuel efficiency to deliver the lowest possible CO_2 emissions per kilometre. When it comes to materials, lightweighting is often considered the key solution in this area and car designers are always looking for solutions that reduce the vehicle mass with materials such as aluminium and fibre-reinforced plastics.

In current discussions lightweighting usually concentrates on just one phase of the car's lifecycle: the use-phase. But when it comes to measuring a vehicle's real environmental impact, there are several other phases that need to be considered from manufacturing all the way through to end-of-life recycling.

This more holistic approach to the environmental impact of car components can be evaluated using the Life-Cycle Assessment (LCA). Research by Tata Steel demonstrates that alternative materials may reduce CO_2 emission in the use phase, but due to their performance in other areas like production and/or recycling requirements they are not necessarily the best material choice for sustainable car components. This conclusion is reinforced by the fact that there are several other factors automotive manufacturers need to consider in their sustainability strategy, such as the increasing pressure on costs and affordability. Low total cost of ownership (TCO) is key in this area, and aspects like the ease of manufacture, global availability of materials, and a car's appearance play a major role in this context as well.

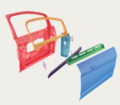
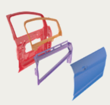
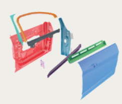
Study set-up

The study conducted by Tata Steel compares four different material solutions, evaluating not only the CO_2 impact throughout the whole lifecycle but also their lightweighting potential and affordability (image 1). As the test object, a door assembly from a C-class car was chosen as it is a well-defined component, which could realistically be designed in a variety of materials while maintaining the same functionality.

The traditional concept that functions as the baseline is based on steel. The outer panel consists of a bake hardening steel (BH220), whereas the inner panel is made of DX56, deep-drawing steel. The beam is made from a hot-formed 22MnB5 steel; the waist rail is made from a cold-rolled UHSS steel, DP1000, and the reinforcements are made of high-strength low-alloy (HSLA) steels.

The three alternative material solutions feature three different approaches: Option 1 is an advanced steel concept also using a bake hardened steel grade for the outer panel, but with an increased strength (BH260). The frame is made of hot-formed steel and the redesigned inner panel parts consist of tailor-welded blanks. All in all, this concept features fewer, but stronger parts.
Option 2 is a multi-material concept with the same structure as the standard steel door assembly, but one part of the component is designed in plastic instead of steel. The door inner and reinforcements are combined with a sheet molding compound (SMC) outer panel.
Option 3, in contrast, utilises aluminium 5xxx and 6xxx sheets and extrusion profiles. Also, the steel sheets have not only been replaced by aluminium, but the whole design has been optimised to fulfil the requirements of a door structure. These requirements are the load cases for door drop and door deflection as well as the dynamic and static dent resistance.

Image 1: Overview of the four material solutions

	Baseline steel	Advanced steel	Steel & SMC	Aluminium
				
	Baseline traditional steel door concept	TWB inner panel parts Hot-formed frame BH260 outer panel	Steel door inner and reinforcements combined with SMC outer panel	Concept optimised to utilise aluminium 5xxx, 6xxx sheet and extrusion
Weight [kg]	15,8	13,1	13,9	10,9
Weight saving [%]	ref	17	12	31
Cost penalty [€/kg saved]*	ref	1.5	3	6
Cost penalty [€/g/km CO_2 saved]*	ref	19	38	75

Baseline and 3 alternative concepts have been developed to meet performance requirements for relevant load cases as door displacement, door deflection and dent resistance.
*Tailpipe emission benefit from light weighting average number: 8g/km CO_2 saving/100kg weight reduction

Weight savings

For all four concepts, Tata Steel's engineering experts determined the weight of the door in kilograms and the percentage weight saving. The costs related to that weight saving were considered later, once the environmental impact could be established. As expected, all three new designs offer weight savings compared to the traditional steel door concept. The multi-material focused concept delivers the lowest weight savings (12%), while the advanced steel concept is 17% lighter than the baseline and the aluminium concept achieves the strongest weight reduction, saving 31%. The results made the advanced steel and aluminium concepts the primary two worth investigating further, although all four concepts were considered throughout.

In addition to the primary weight savings of the door structure that focussed on strength and stiffness, there are additional requirements such as NVH, which have to be taken into account in the overall picture. This can result in additional mass in the aluminium door as compared to steel designs. In the end, these requirements for the complete door can partially reduce the initial weight saving of the aluminium door structure but they have not been included in this assessment.

Lifecycle CO_2 assessment

LCA is a standardised evaluation that takes CO_2 emissions from material production, car manufacturing, use phase as well as recycling benefits into account. Whereas legislation mainly focuses on reducing tailpipe emissions in the use-phase, LCA as a holistic approach to CO_2 reduction encompasses all CO_2 contributors. (image 2).
In the Assumption table (image 3) at the bottom of this page shows that in the study, on average, favourable assumptions for aluminium have been used, creating more positive LCA results for the aluminium solutions.

Image 2: Holistic view on CO_2 reduction through LCA

All contributing phases

- material and vehicle production
- use of car
- recycling

- Tailpipe emissions are today the major contribution to the environmental impact of car mobility
- Legislation is set out to reduce tailpipe CO_2 emissions
- A holistic approach to CO_2 reduction should encompass all CO_2 contributors
- LCA is a standardised evaluation method to take CO_2 emissions from material production, car manufacturing, use phase as well as recycling benefits into account

With regards to the production phase, the evaluation shows that aluminium production is strongly influenced by the choice of electricity power mix, which is determined by geography. Whereas each aluminium ingot manufactured in the EU produces 11.2 kilograms of CO_2 per kilogram of aluminium due to its high focus on hydropower, the global value is even higher (15.9) as many other manufacturers – specifically in Asia – rely on coal-fired power plants. Steel slabs, in contrast, have a value of only 1.87 kilograms of CO_2 per kilogram of steel. For the study, the aluminium manufacturing impacts were based on the, slightly more favourable, EU electricity power mix. Considering the metal utilisation rate that shows how much of the material really ends up in the car and not as scrap in the vehicle manufacturing process, the chosen 58% is more realistic for aluminium than for steel, which tends to be a bit higher.

In the use phase, the impact of the door assembly is calculated by looking at the emissions of the vehicle without the component. Each additional kilogram for the component is then attributed a CO_2 emission. Secondary weight savings at brakes, wheels or smaller engines are not taken into account. In this assessment, fuel savings as a result of weight reduction are an important factor. The fuel economy data is based on the actual driving test with a compact class petrol vehicle. Fuel economy values are determined for the WLTP (Worldwide harmonised Light vehicles Test Procedures). This is more stringent than the traditional EU driving cycle NEDC (New European Driving cycle) updated in 1997. In terms of distance, a 150,000km payback time was chosen to represent realistic usage and reflect the current EU norm. Concerning fuel reduction value, a potential engine resize was also taken into consideration as it has a strong influence on fuel consumption. By taking this approach, Tata Steel aimed to use data that is as realistic as possible.

When it comes to the recycling phase, the general recyclability of metals compared to other materials like plastics is favourable for the overall Life-Cycle Assessment. To be able to reuse metals they need to be remelted, but this takes less energy than primary metal production. As steel needs to be heated up to 1,300 degrees and aluminium only to 650 degrees, more energy is needed for steel. Regarding the reuse of metal scrap, two different models can be used: recycled content and end-of-life credit. Recycled content implies that the more scrap contained in the product, the lower the impact.

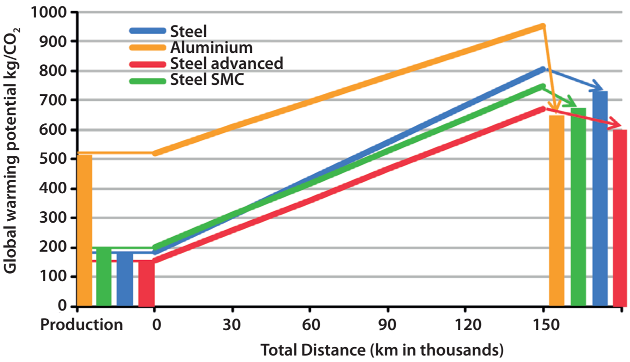
Image 3: Assumption table

Stage	Assumption	Value used in study	Positioning: pro steel	Positioning: pro aluminium
Production phase	CO_2 per kg steel	1.87kg CO_2eq/kg	1.87 kg CO_2eq/kg global data	1.87 kg CO_2eq/kg EU data
	CO_2 per kg aluminium	11.2kg CO_2eq/kg	16.5 kg CO_2eq/kg	11.2 kg CO_2eq/kg
	Metal utilisation	58%	20%	100%
Use phase	Driving cycle	WLTP	NEDC	WLTP
	Distance	150,000km	100,000km	300,000km
	Fuel reduction value	with engine resize	without engine resize	with engine resize
Recycling phase	Including recycling		no	yes
	Methodology	End-of-life credit	Recycled content	End-of-life credit
	Recycling recovery rate	90% steel 80% other	50%	100%

However, this ignores that currently there is almost no end-of-life scrap recycled into metal sheet applications for a vehicle. For the conservative assessment Tata Steel chose the end-of-life credit model that considers the amount of metal scrap that can be recycled into a new product, therefore representing a more realistic recycling practice. The recovery rates used in the assessment are 90% for steel and 80% for aluminium, which reflects the overall efficiency of collection, sorting and remelting.

So far current legislation is focused on tailpipe emissions. As can be seen in image 4, the global warming potential of the aluminium solution is slightly higher than the global warming potential of the advanced steel solution (both just above 800kg CO_2). It shows that the lower CO_2 emissions during the use phase of the vehicle in combination with compensated global warming potential during recycling do not compensate for the high CO_2 emissions during production of the primary product. The lightweighting effect for the use phase can be recognised in the slope of the curves. The slope for aluminium is lower than for steel. However the lines do not cross even up to 150,000km. This is due to the high starting point of the production phase for aluminium. Even taking into account the high recycling benefits of aluminium the full lifestyle view of the door shows that the advanced steel concept has the lowest overall CO_2 global warming contribution.

Image 4: Results for WLTP driving cycle



Cost implications

While the weight and CO_2 savings of each concept tested vary, and suggest virtues of each concept tested, the cost implications for each demonstrate the most effective solution for manufacturers. The multi-material concept had the lowest weight saving (12%) and also resulted in a relatively high cost penalty, around €3 per kilogram of weight saved. This means that the weight saving is only marginal and the cost penalty makes the weight saving unattractive.

The other concepts, using advanced steel and aluminium respectively, both achieved good weight savings. Achieving a weight saving of 31%, compared to 17% for steel, the aluminium concept performed more strongly than the advanced steel when solely considering weight. However, when considering the impact on a vehicle's CO_2 emissions across the entire vehicle life, steel performed more strongly.

When considering the cost implications to a manufacturer, seeking to find a good balance between saving weight and managing the additional costs, the advanced steel concept is the more favourable option. With a cost implication of €1.5 for each additional kilogram saved, the advanced steel solution is in a much better position than aluminium, which causes much higher costs of €6 for each kilogram saved.

Summary

Steel is a responsible solution to the CO_2 challenge. As long as legislation continues to implement a wide range of technologies to minimise CO_2 tailpipe emissions, the contribution of the use phase becomes less and less important for the overall environmental impact of cars. Therefore, the benefits of aluminium cannot compensate for impacts in other lifecycle phases. To assess the lifecycle impact, the LCA method becomes increasingly important. The study shows that advanced steel solutions offer the lowest lifecycle impact in terms of greenhouse gas emissions, regardless of the test cycle, and that steel is an affordable, lightweight, material due to its performance across the vehicle lifecycle, including material production and recycling.

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