Sustainable Steel for Cars

Life-Cycle Carbon Footprint of a Front-End Module

Background

There is a continuous trend in the automotive industry towards greener, safer cars, with ongoing pressure on costs and affordability. Greener in this case is usually associated with maximising fuel efficiency while delivering the lowest possible CO_2 emissions per kilometre. There are many options which are being explored to improve fuel economy and one well recognised method is to reduce the vehicles mass. As a result many designers are working to make vehicles lighter by utilising alternative materials such as aluminium and fibre-reinforced plastics.

Lightweighting, therefore, is a popular approach to achieving sustainability in the automotive industry. But reducing CO_2 emissions during a vehicle's working life by substituting heavier materials with lighter alternatives does not address the overall environmental implications. The environmental impact of the whole product lifecycle needs to be considered, from manufacturing all the way through to end-of-life recycling.

This holistic approach to the environmental impact of car components can be evaluated using Life-Cycle Assessment (LCA). Research by Tata Steel demonstrates that a more environmentally-sustainable solution can be provided using steel rather than aluminium or many composite alternatives.

Life-Cycle Assessment for a front-end module

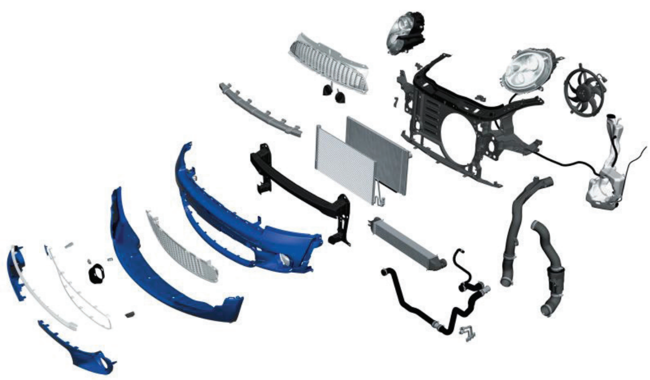
For the LCA, a front-end module (FEM) from a C-class car was chosen to be the study's subject as it is a well-defined component, which could realistically be designed in a variety of materials maintaining the same functions. In order to provide a functionally-equivalent comparison, Tata Steel chose one vehicle platform already providing three alternative FEM carrier designs: a painted, galvanized steel solution and two alternative steel/glass fibre reinforced plastic alternatives (referred to as composite-1 and composite-2). For further reference, the steel solution was redesigned in aluminium with appropriate material selection to achieve the same function with minimum mass.

Mass and cost comparison

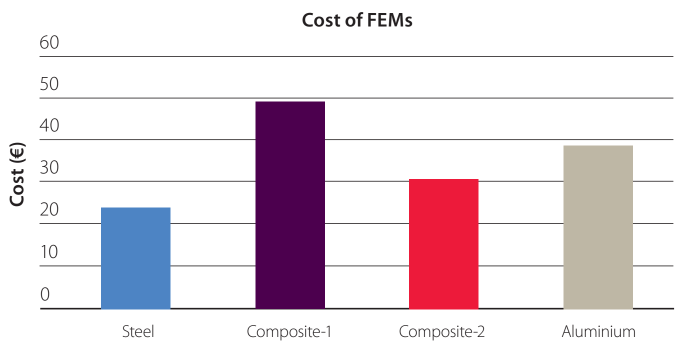
The first step of the LCA was the generation of a bill-of-materials for each design in order to determine the costs for the three FEM production solutions, and the aluminium redesign. The full costing analysis showed that the steel solution at €24 was significantly cheaper than the others, with the composite-1 at €48 being the most expensive, followed by the aluminium redesign at €39.

Composite-1 was also the heaviest component, while the steel and composite-2 models were significantly lighter. The aluminium redesign gave a 19% mass reduction compared to the steel version. Plotting indicative component costs against mass shows a cost of lightweighting for the aluminium redesign, compared to the steel design, of €17 per kg.

Example Front End Module (FEM) carrier and associated components



Cost analysis of FEM carrier solutions



A life-cycle study of a front-end module used across a vehicle platform shows that the steel-based solution has the lowest life-cycle carbon footprint, with a significantly lower cost than either aluminium or composite plastic options.

Environmental impacts

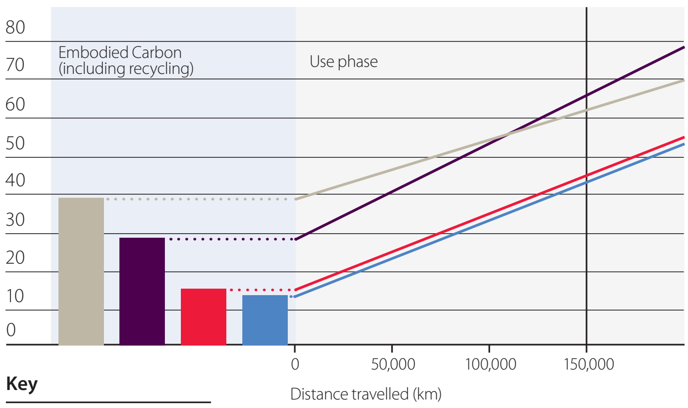
In order to analyse the environmental impacts of the four alternatives, life-cycle models were built in GaBi (a specialist LCA software) based on a methodology developed by the University of California for assessing life-cycle vehicle emissions. The total life-cycle carbon footprint for each solution is made up of a fixed element from manufacturing - including material production and vehicle manufacture - and a variable element from the use phase, which depends on distance travelled. Typical life-time distance for the chosen C-class car is around 150,000 km and this was the value used in this analysis. On top of this, the materials' end-of-life phases have to be taken into account, with a positive impact on carbon footprint if the material is recycled and a negative impact if incineration is needed.

The steel and composite-2 solutions have similar manufacturing impacts and similar mass, giving similar in-use and total life-cycle impacts. Composite-1 uses significantly more material, so both manufacturing and in-use emissions are higher than the steel solution. The aluminium redesign has a significantly higher embodied impact than the steel solution. However, the lighter aluminium component improves fuel efficiency in the use-phase. As the total distance travelled is increased, the improved fuel efficiency gradually pays back the carbon investment made in manufacturing.

This study shows for a typical vehicle with a life-time distance of 150,000 km, the life-cycle carbon impact of the aluminium component is lower than the composite-1 solution but is still significantly higher than either the steel or composite-2 solutions. It was also found that even for a vehicle life-time distance of 200,000 km the steel solution gave the lowest life-cycle carbon impact.

Total life-cycle carbon footprint of FEM carrier solutions

Global warming potential (kg CO_2 equivalent)



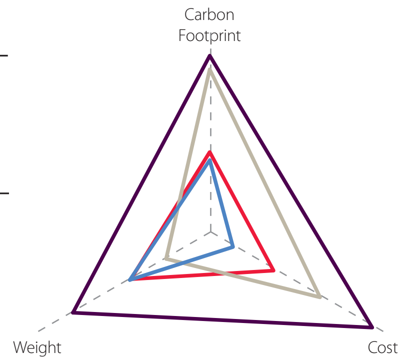
Key

- Steel (4.73kg)
- Composite-1 (6.10kg)
- Composite-2 (4.70kg)
- Aluminum (3.85kg)

Summary evaluation of mass, cost and life-cycle carbon footprint for different material solutions

Key

- Steel
- Composite-2
- Composite-1
- Aluminium



Summary

Steel is competitive on mass, costs less, and over its lifespan leaves a lower carbon footprint than aluminium and composite alternatives. The life-cycle carbon impact of steel is 44% lower than aluminium, and 50% lower than composite one. It is comparable to composite two in terms of LCA, but is 29% cheaper. Similarly, steel is 63% less expensive than aluminium, and 100% less expensive than composite one. Overall, the weight saved by aluminium is not outweighed by the reduced material production and end of life impacts of steel, and across all factors combined the composite solutions cannot compete with steel.

While the steel design is not the lightest it has significant benefits in terms of manufacturing cost and life-cycle carbon footprint, which makes the steel design the most sustainable as well as the most cost-efficient option.

Steel:

- Competitive on mass
- Lower cost
- Lower carbon footprint

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