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Benefits of Molybdenum Use: Ford Fusion B-Pillar

Automotive Steels & Molybdenum

The past two decades have seen growing pressure on vehicle manufacturers to reduce the environmental impact of their vehicles as governments, consumers and other stakeholders have become increasingly concerned by the impact of transportation on climate change, air pollution and resource use.

Air pollution in China: Concerns over emissions from vehicles have led to increased emissions controls

The EU estimates that around one fifth of the region's greenhouse gas emissions come from road transportation, with cars alone responsible for 12% of the total. In China, the world's biggest vehicle market, concerns over air pollution in urban areas have seen significant controls introduced in the past two years, culminating in the adoption of the Euro IV emissions standard to control the release of significant air pollutants such as carbon monoxide (CO), nitrogen oxides (NO_x) and particulate matter (PM).

At the same time, rising oil prices have made fuel efficiency a key consideration when purchasing a vehicle.

One of the most effective ways to improve fuel efficiency and lower emissions is to reduce the mass of the vehicle, a process known as *light weighting*. One way to achieve this is to 'down gauge' the material used to form the car body by reducing the thickness of the metal. However, this could weaken the structure and reduce the safety rating of the vehicle. A preferable alternative is to substitute for a material offering equal strength and crash resistance at a lower mass.

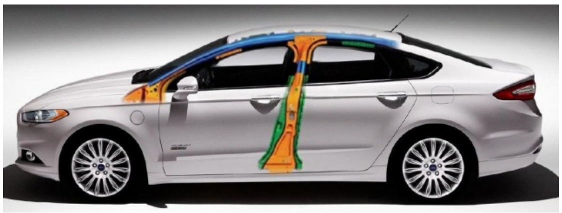
With the majority of car bodies worldwide being produced from steel, there has been a significant drive to develop steels that offer the high strength demanded for crash performance at lower thicknesses.

Known as advanced high strength steels (AHSS) these new steel grades combine higher concentrations of alloying elements with innovative steelmaking and treatment techniques to deliver the properties required by automotive manufacturers.

For many of these AHSS grades the use of molybdenum as an alloying element plays a key role in ensuring that vehicle components can be made lighter and stronger, while remaining economically competitive.

Redesigning the B-Pillar

A vehicle's B-Pillar acts as the vertical support between the front and rear sections of the vehicle and, as such, is one of the most critical components of the entire structural body. In particular, the B-pillar must protect the occupants and help maintain the structural integrity of the vehicle during a side impact.



Ford Fusion with A-pillar/roof rail and B-pillars highlighted: The B pillar plays a pivotal role in side-impact crash protection (image courtesy of Ford)

In designing the new Fusion model, Ford's development team aimed to produce a body structure with class-leading safety while also reducing the overall mass. For the car's B-pillar, the previous press-hardened boron steel design was replaced with a hydroformed part made from a mix of DP800 and DP1000 dual-phase steels with average molybdenum contents of 0.18% and 0.33% respectively, resulting in a 4kg weight saving.

Assessing the Benefit

When assessing the relative environmental performance of the old and new B-pillar designs it is important to take into account the complete lifecycle of the part from production and manufacturing, through its use in the vehicle through to end of life.

Life cycle assessment (LCA), a widely used method for assessing the total lifetime environmental impacts of products, has been used to analyse the two parts.

Lifecycle of a vehicle: LCA can assess the overall environmental impacts of products or components

As defined in ISO 14040, "*LCA is the compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.*"

In assessing the environmental performance of the B-pillar, four major lifecycle stages were identified: Steelmaking and casting, rolling, finishing and forming, vehicle use and end-of-life.

For vehicles with combustion engines, the use phase is the dominant lifecycle stage and it is clear that light weighting will have a significant impact on fuel consumption and emissions during the use of the vehicle. However, as the two parts use different steel grades and manufacturing processes, it is also important to take into account the manufacture and end-of-life phases to identify any potential "trade-offs" between lifecycle stages.

A number of environmental metrics relevant to the performance of vehicles have been assessed as part of this study. These cover climate change, air pollution and energy resource use. Addressing a range of potential impacts leads to a more complete understanding of the overall environmental performance of the product. The metrics assessed are:

Global Warming Potential: used to quantify climate change, which is generally the primary environmental concern related to vehicles for governments and legislators. CO_2 emissions are increasingly subject to strict limits and are used as a basis for vehicle taxation

Acidification Potential: used to quantify atmospheric acidification, which leads to acid rain. Acidification is driven by emissions of sulphur and nitrogen oxides (SO_x and NO_x). NO_x emissions are regulated as part of the European Emissions Standards and acid rain remains heavily associated with vehicles by consumers.

Smog Creation Potential: used to quantify "summer smog" (such as those experienced in LA or Shanghai) and heavily associated with vehicle emissions by stakeholders.

Eutrophication Potential: used to quantify algal bloom, eutrophication is linked to airborne emissions (particularly nitrogen oxides)

Primary Energy Demand (Total): reports the total energy consumption of the lifecycle of the component (from both renewable and non-renewable energy sources) and is often used as a proxy measure of energy efficiency.

Primary Energy Demand (Non-renewable): reports the energy demand from non-renewable resources such as oil, natural gas and coal. This is a key impact category for vehicle manufacturers using internal combustion engines.

Data and Assumptions

Data from a number of industry sources were used in the development of the LCA model developed to assess the environmental performance of the B-pillar.

Data from the World Steel Association (worldsteel) were used to model the production and galvanising of the steel components. This data related to steel produced in the EU-27. The alloy mixes used were adapted to account for differences in the compositions of the individual steel grades. Data on alloy production was related to global production for molybdenum and the majority of other alloys. Notable exceptions were ferrovanadium and ferromanganese for which only data for South African production were available. The new B-pillar comprises 76% DP800 and 24% DP 1000 as estimated from technical drawings provided by Ford. The sensitivity of the results to the use of different proportions of these grades has been investigated as part of the analysis. DP 800 and DP 1000 are estimated to have molybdenum contents of 0.18% and 0.33% respectively.

The composition of the individual steel grades was determined from data provided by steel producers. The composition data used were a mix of publically available data and data provided directly to PE INTERNATIONAL, who were responsible for developing the lifecycle models. Alloy compositions stating average or typical values were used wherever possible. Composition data stating maximum alloy contents (e.g. alloy standards) were also considered and used to cross-reference other data sources.

Data on the hydroforming technique which allowed DP800/DP100 to be used for the new part was not available. Consequently a conventional stamping process is modelled for both parts. The potential effect of this exclusion on the results is discussed in the analysis. Similarly, any differences between the two B-pillar designs related to assembly have not been included.

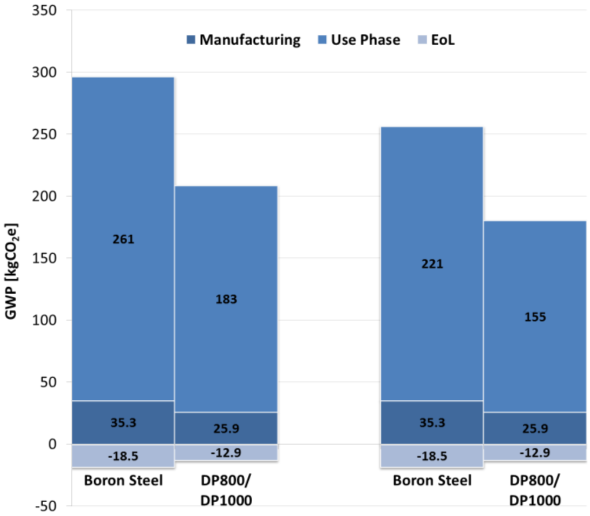
The fuel consumption attributable to the B-pillar has been estimated using Fuel Reduction Values (FRV) commonly used in the European automotive industry for calculating the benefit of light weighting vehicle components (0.35 l/100kg•100km and 0.28 l/100kg•100km for petrol and diesel vehicles respectively). Estimates of lifetime vehicle mileage vary according to the class of vehicle and between manufacturers. This study uses an estimate of 200,000 km.

The recycling rate of steel from cars is close to 100%. A “net scrap” approach taking into account the scrap input required to produce new steel has been used to calculate the benefit of recycling steel at end-of-life. Both products are modelled as being produced by via BF/BOF route, the main production route for automotive strip/coil products, with average scrap inputs of 11.9%. The worldsteel dataset for the value of scrap has been used to calculate the overall environmental benefits/burdens attributable to recycling at end of life.

Background datasets related to alloys, materials and fuels have been sourced from the GaBi database developed by PE INTERNATIONAL.

Environmental Assessment Results

Results generated for the full life cycle of the vehicle B-pillar indicate that the new DP800/DP1000 design has a lower impact for all six environmental metrics assessed. The graph below illustrates the results for global warming potential (GWP) for one B-pillar. These show a significant reduction in GWP between the baseline boron design and the new DP800/DP1000 design incorporating molybdenum.



Lifecycle GWP for one B-pillar. Results are shown for both diesel and petrol drivetrain.

The graph shown above also illustrates that the use phase is the dominant contributor to a vehicle's lifecycle impacts due to the emissions from fuel combustion. Based on the assumptions described previously, the use phase accounts for around 93% of the life cycle GWP impact of the B-pillar.

Consequently, the reduction in fuel consumption resulting from the 4 kg weight saving accounts for the majority of the difference in impacts between the two B-pillar designs. However, as the use of alternative low-emission powertrains become more widespread, the proportion of impacts attributable to material manufacture is set to increase.

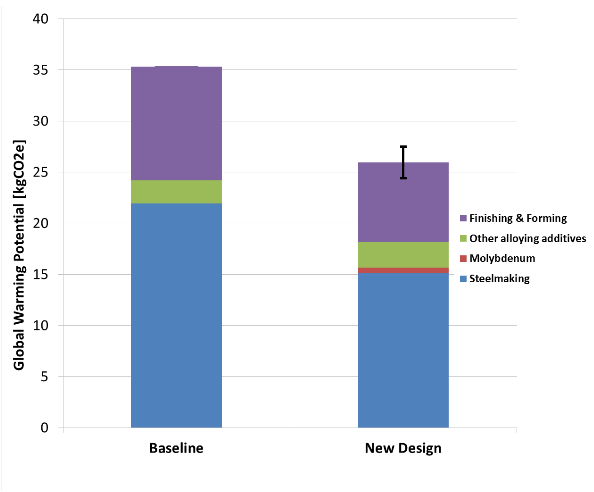
A credit at end-of-life related to steel recycling is shown in the graph as a negative value below the x-axis. This represents the reduced environmental burden in the next life cycle due to the reduced requirement for steel from virgin material.

The table shown below presents values for one B-pillar for all six of the impact categories assessed and demonstrates the significant reduction in environmental impacts with the switch to the new B-pillar design.

Results for the two B-pillar designs indicate that the new design has a lower environmental impact during production as well as in the use phase. The small increase in impacts due to the use of alloying elements including molybdenum in the DP800 and DP1000 steel grades is more than compensated by the significant reduction in the material required for the B-pillar and the consequent reduction in ironmaking and secondary steelmaking impacts.

	Petrol Drivetrain		Diesel Drivetrain	
	Baseline - Boron Steel	New Design - DP800/DP1000	Baseline - Boron Steel	New Design - DP800/DP1000
Global Warming Potential [kg CO_2 eq.]	278	196	238	168
Acidification Potential [Mol. H^+ eq.]	0.715	0.513	1.08	0.767
Eutrophication Potential [kg P eq.]	3.68E-04	2.57E-04	2.55E-04	1.79E-04
Smog Creation Potential [kg NMVOC]	0.273	0.197	0.433	0.309
Primary Energy Demand (Total) [MJ]	3915	2753	3426	2410
Primary Energy Demand (Non-renewable) [MJ]	3760	2643	3289	2313

The graph below illustrates the global warming potential due to production and shows the contribution made by molybdenum and other alloying elements. Similar results were obtained for all the other metrics assessed with the new design having a lower impact in all cases.



GWP for the production of the two B-pillar designs, with error bar to indicate uncertainty surrounding the hydroforming impact of the new design.

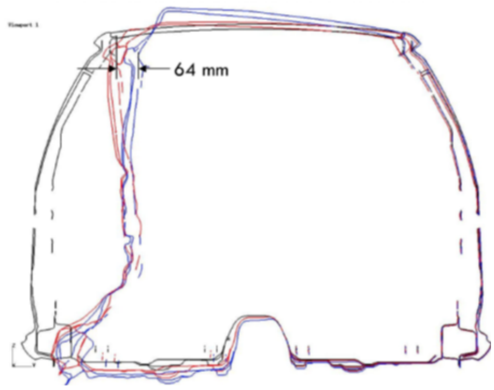
As mentioned in *"Data and Assumptions"*, data on the impacts associated with the hydroforming process used to manufacture the new part were unavailable. For the purposes of this study, forming for both parts has been estimated with a conventional forming process, but an error bar has been included in the graph above to show the potential effect of a ±20% change in the impact of finishing and forming. Given the significant difference between the production impacts of the two designs, even a doubling of the impact (i.e. a 100% increase) from forming would not result in the GWP of the new design being higher than the original boron steel design.

Another aspect investigated as part of the sensitivity analysis was the impact of a change in the proportion of DP 800 and DP 1000 being used in the B-pillar. DP1000 was found to have a marginally higher impact than DP800, but assuming that the part was 100% DP1000 resulted in an increase of less than 5% in the production impacts of the B-pillar for all metrics assessed (less than 1% over the full lifecycle of the part).

Summary and Conclusions

The assessment of the lifecycle impact of selected environmental metrics relevant to the automotive sector indicates that the new hydroformed DP800/DP1000 B-pillar design has significantly lower impacts than the previous boron steel design. The 4 kg weight reduction leads to considerable use phase savings, which drives the difference in impact between the two parts. The GWP saving for both B-pillars in the Ford Fusion over a 200,000 km total driving distance is 165 kg CO_2e for a petrol drivetrain and 141 kg CO_2e for a diesel drivetrain. This is equivalent to driving the vehicle over 1,000 km.

Looking solely at the impacts of production, the small increase in impacts due to the increased use of alloying elements including molybdenum is far outweighed by the savings in ironmaking and secondary steelmaking. Additional impacts from the hydroforming process that have not been taken into account might increase the overall results, but are unlikely to cancel out the reduction impacts associated with the new part.



Crash performance of the Fusion B-Pillar: In a side impact, the new design (shown in red) has a lower intrusion at the top of the passenger compartment (image courtesy of Ford)

Crucially, these environmental improvements have been achieved while also improving the crash performance of the B-pillar during side impacts, as illustrated in the image below. Ford also estimates that the redesign has yielded a significant cost saving.

Overall the results of this study indicate that switch to a DP800/DP1000 B-pillar design has yielded a benefit on an environmental, economic and a social level - in other words all three pillars of sustainable development. This demonstrates the potential improvements that can be achieved by using advanced high strength steel grades (AHSS) with innovative manufacturing techniques and the contribution that molybdenum can make in supporting similar innovations in the future.