INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

# Molybdenum in Transportation

## Car Body and Chassis Construction

**Molybdenum's contribution to sustainable development in:**

- Stainless steels
- **Alloy steels**
- Superalloys
- Cast iron
- Mo metal
- Chemicals

MoRE FOR LESS

Molybdenum makes an important contribution to sustainable development as a metal, as an alloying element, and as a constituent of chemical products. IMOA's 'MoRE FOR LESS' case studies explore, in more depth, how molybdenum is contributing to sustainable development, a pattern of growth in which resource use aims to meet human needs while preserving the environment.

In particular we will look at how a specific use or application is contributing to the three pillars of sustainability:

ECOLOGY — Environmental performance, resource use, energy efficiency & production and recycling

ECONOMY — Supply chain, lifecycle and materials performance

SOCIETY — Health, safety and wellbeing

This case study explores the sustainability benefits of using high-strength steels, particularly those containing molybdenum, to reduce weight in car bodies and chassis, increasing fuel efficiency and reducing emissions.

## The Challenge

Transportation by road vehicles significantly contributes to global energy consumption and greenhouse gas emissions. With more cars than ever on the roads, regulators are imposing increasingly stringent limits on primary energy consumption and greenhouse gas emissions.

By 2015, car manufacturers in the EU will be fined for exceeding an average $CO_2$ emission of 130 g/km across their new car fleet, reducing this value to 95 g/km in 2020. Heavier cars are allowed higher emissions if lighter cars have lower emissions, preserving the fleet average.

The relationship between current vehicle weight and $CO_2$ emissions is shown in **Figure 1**. Reducing vehicle weight is one means of lowering fuel consumption and will increasingly become a priority as emission limits decrease. Field tests indicate that fuel savings range from 0.1 to 0.5 liters per 100 kilometers for a weight reduction of 100 kilograms. This corresponds to a $CO_2$ emission reduction of 8 to 12 grams per kilometer.

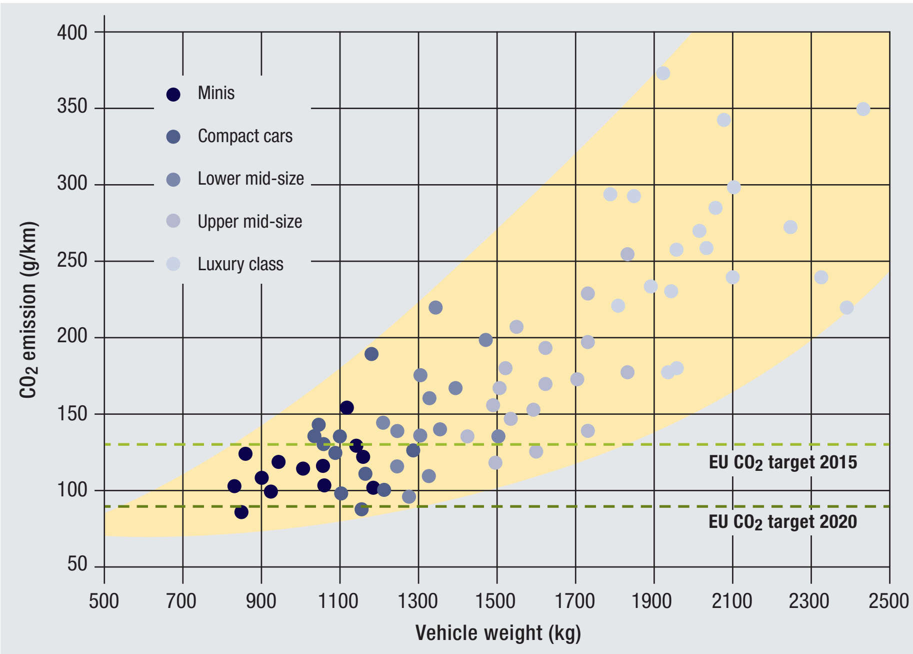


Figure 1: Impact of total vehicle weight on the $CO_2$ emission of European cars.

Lightweighting has therefore been vigorously pursued over the years as a solution to meet decreasing emission targets, in parallel with other initiatives. The challenge for car designers is to reduce weight whilst addressing the growing consumer demand for larger vehicles and increasing strength to satisfy stringent collision safety standards. Cost and manufacturing issues must also be considered.

## The Solution

The conflicting demands of lighter, bigger and safer vehicles can only be satisfied by using materials that have either higher strength and/or lower density.

Steel has been used to construct automotive bodies and chassis for decades. Lightweighting initiatives are replacing mild steel (MS) with high-strength low alloy steel (HSLA), advanced high-strength steel (AHSS) and press-hardening steel (PHS) grades.

Unlike lower density materials, high-strength steel is readily processed using established manufacturing technology and know-how. Furthermore, high-strength steel reduces weight at the same or even a lower cost, whereas low density materials incur very significant cost premiums. State-of-the-art car bodies and chassis are mostly made of high-strength steel, contributing a weight share of 60 to 80%. Compared to a

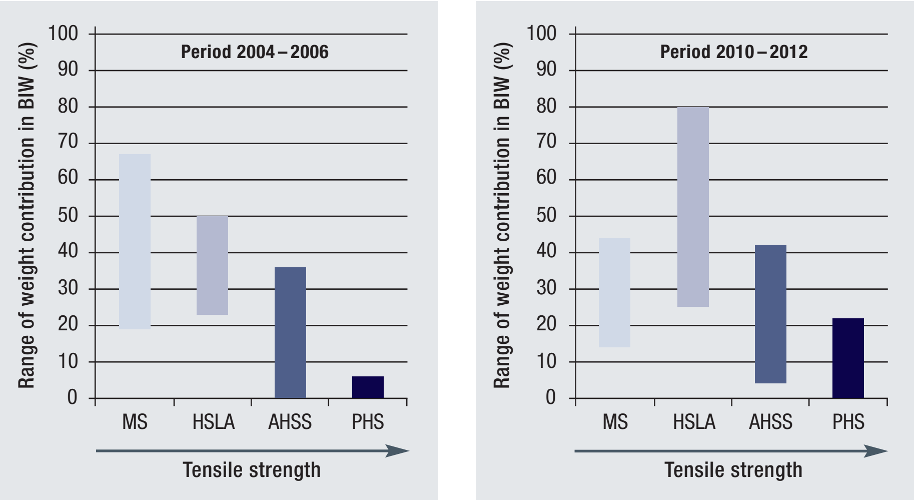


Figure 2: Evolution of high-strength steel application in cars (Europe, Japan)

conventional car body, the intensive use of high-strength steels cuts body weight by more than 100 kilograms.

Increased strength has also helped to increase vehicle safety. A recent study calculated that the likelihood of escaping a crash uninjured has improved from 79 to 82% as a result of improvements in US car fleets assessed in 2008 compared with 2000[1]. The increasing use of high-strength steels (HSLA, AHSS and PHS) compared with mild steel (MS) in vehicle manufacture is shown in **Figure 2**. The different grades and their applications are shown in **Table 1**.

## How molybdenum can help

Making steel of high strength is relatively straightforward. The challenge lies in combining high strength with good formability and weldability, which are necessary for the key processes in automotive manufacturing. Conventional HSLA steels are well established in car making and enable weight reductions of 20–25%. Ultra high-strength steels of up to 2000 MPa strength – which have the potential to reduce weight by a further 20% – require a sophisticated combination of alloying and thermo-mechanical processing to achieve the desired properties.

Molybdenum alloying plays a crucial role when making such steel. Its specific metallurgical effects allow the formation of hard phases that have exceptionally high strength. The mixture of hard and soft phases in the steel matrix provides the desired combination of high strength and good formability in AHSS.

Molybdenum is particularly effective in regulating the co-existence of these different phases in a stable and reproducible manner in a range of production conditions. With the addition of molybdenum, such steels can therefore be made in less sophisticated production lines, giving steelmakers more flexibility in production planning and contributing to wider global availability.

Although other alloying elements can have a similar metallurgical function, molybdenum has the strongest effect per added percentage by weight.

A further important benefit is that molybdenum has no negative effect on zinc galvanization. Molybdenum also provides excellent hardenability in increasingly popular press hardening steels. Used in such steels it can improve component behaviour under crash conditions.

Table 1: The grades and applications of high-strength steel in vehicle manufacture

| Steel type | Grade family | Microstructure | Strength range* | Typical applications | Mo content |
|---|---|---|---|---|---|
| Ferritic-Bainitic steel | HSLA | Ferrite + bainite | 450–600MPa (T) | Wheels, body reinforcements, chassis parts | Max. 0.2% |
| Bainitic steel | HSLA | Bainite (traces of martensite) | 550–800MPa (Y) | Chassis parts, profiles, rails, tubes | Max. 0.3% |
| Dual Phase steel | AHSS | Ferrite + martensite (traces of bainite, austenite) | 600–1000MPa (T) | Body reinforcements, anti-intrusion beams, longitudinals, cross members seat profiles, wheels | 0.1 – 0.3% |
| TRIP steel | AHSS | Ferrite + bainite + martensite + retained austenite | 600–1000MPa (T) | Complex shaped body reinforcements | Max. 0.2% |
| Complex Phase steel | AHSS | Ferrite + bainite + martensite + retained austenite | 800–1000MPa (T) | Body reinforcements, bumpers, anti-intrusion beams | Max. 0.2% |
| Press hardening steel | PHS | Martensite | 1300–2000MPa (T) | Bumpers, anti-intrusion beams, body reinforcements | Max. 0.2% |

* Y = yield strength, T= Tensile

## Key sustainability benefits

| Benefit | Sustainability attribute | | |
|---|---|---|---|
| Increases the strength of steels for car bodies and chassis enabling weight reduction, fuel savings and lower $CO_2$ emissions | ECOLOGY | ECONOMY | SOCIETY |
| Less steel is produced, saving resources and reducing pollution | ECOLOGY | ECONOMY | SOCIETY |
| Molybdenum in alloyed steel can be recycled to a significant degree | ECOLOGY | ECONOMY | |
| Vehicle components made from stronger steel with high energy absorption provide improved safety in collisions | | | SOCIETY |
| High-strength steel has a better total lifecycle carbon footprint than low-density materials | ECOLOGY | | SOCIETY |
| Vehicle construction using high-strength steel is significantly less expensive than using low-density materials | | ECONOMY | |
| High-strength steel readily uses existing manufacturing technology and is globally available – new investments and long distance material shipments are avoided | ECOLOGY | ECONOMY | |
| Lighter cars have more efficient braking and better handling, helping to increase road safety | | | SOCIETY |

## Summary

High-strength steel is the most sustainable material for the production of car bodies and chassis. It is the only material that delivers weight reduction at neutral or reduced cost, while its extra strength increases passenger safety in accidents.

Molybdenum is an essential alloying element, helping to provide higher strength efficiently and simultaneously reducing the processing capability requirements of the steel-making equipment. It contributes to the reliable production of ultra high-strength steel components.

1 "An Analysis of Recent Improvements to Vehicle Safety", National Highway Traffic Safety Administration, US Department of Transportation, June 2012

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