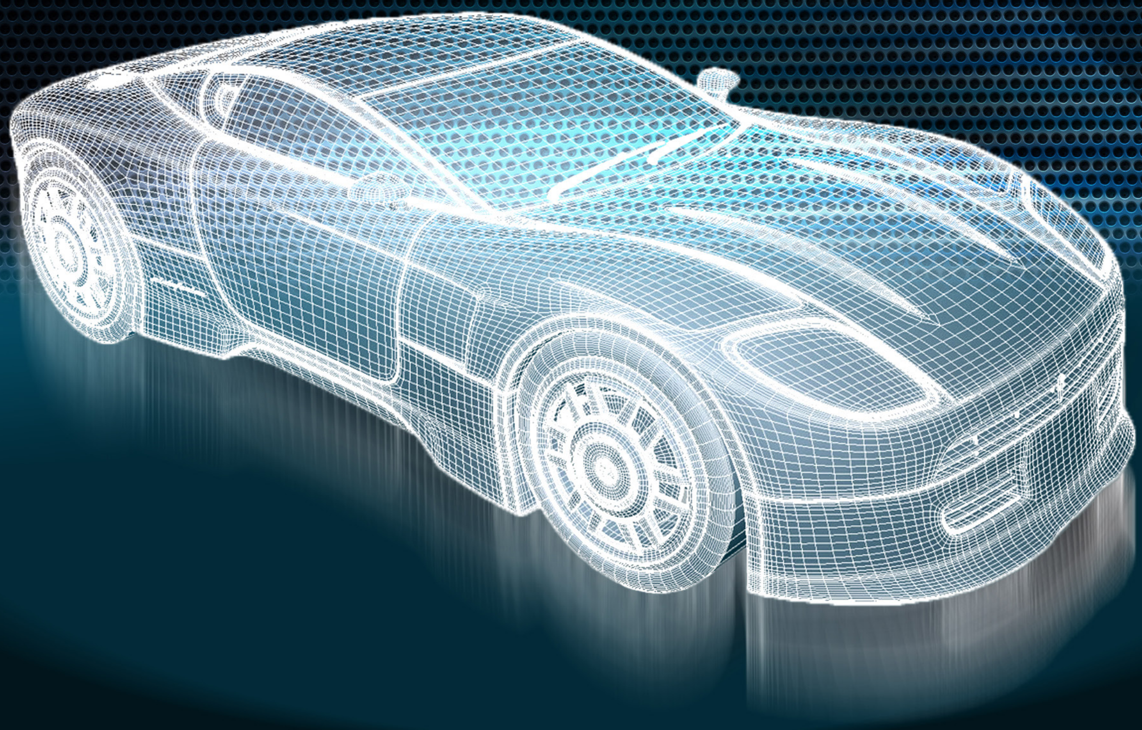
WEIGHT REDUCTION TECHNOLOGIES

IN THE AUTOMOTIVE INDUSTRY



Thematic Report by
Mayur Mhapankar
Analyst, Technology & Patent Research

Image Source: CarBodyDesign.com

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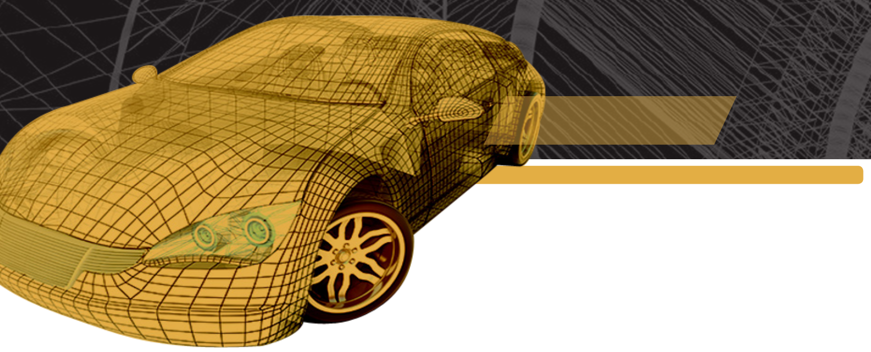
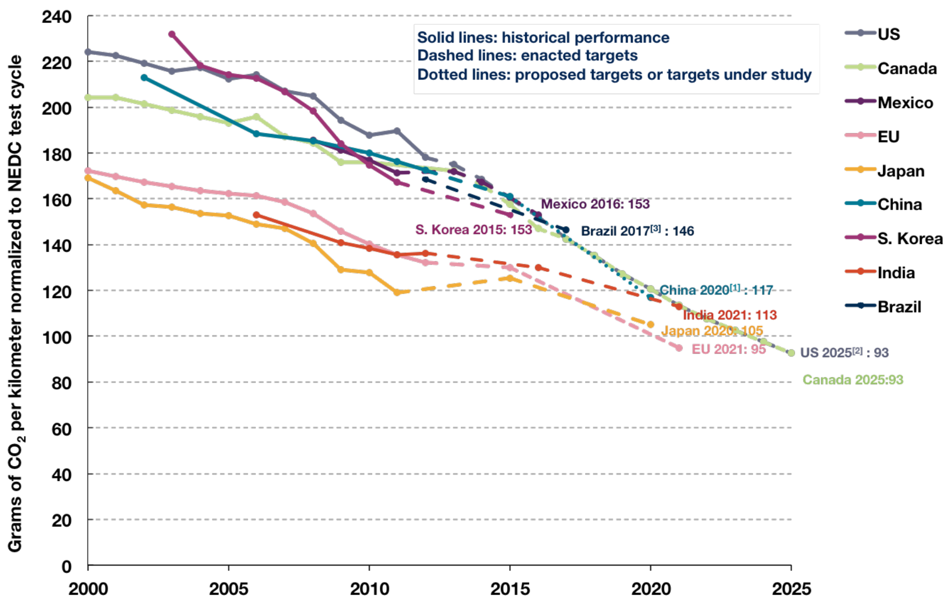


Weight Reduction: A Need in the Automotive Industry

Over the decades, harmful vehicular emissions have shown a negative impact on the environment and human health. The increasing air pollution from the transportation sector has led many government agencies to lay strict regulations on the automobile manufacturers to curb the harmful emissions under permissible limits.

One such example is the European agency (EU), which has set mandatory emission reduction targets for automakers in Europe. According to EU rules, the fleet average by cars to be achieved by 2021 must be 95 grams of CO2/ kilometer, which works out to a fuel consumption rate of around 4.1 liter/100 km of petrol or 3.6 liter/100 km of diesel.

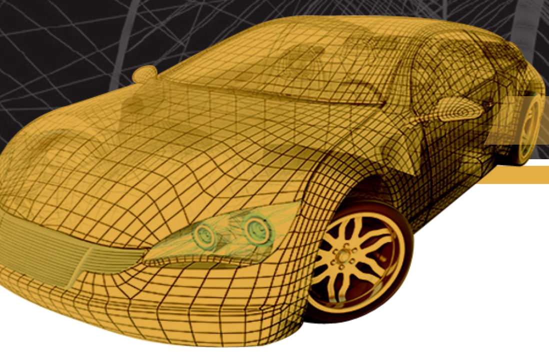


[1] China's target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.
[2] US standards GHG standards set by EPA, which is slightly different from fuel economy stadards due to low-GWP refrigerant credits.
[3] Gasoline in Brazil contains 22% of ethanol (E22), all data in the chart have been converted to gasoline (E00) equivalent
[4] Supporting data can be found at: http://www.theicct.org/info-tools/global-passenger-vehicle-standards.

Source: Transport policy.net

Stringent regulations and heavy penalties imposed by government agencies have put immense pressure on automakers to scout different methods and technologies that help curb vehicular emissions.

A popular strategy adopted by automakers and different OEMs is to reduce a vehicle's weight, which can significantly reduce fuel consumption and CO2 emissions. A lighter car consumes less fuel because it needs to overcome less inertia, reducing the power required to move the vehicle. Losing weight is the easiest way to increase fuel economy; reducing a car's weight by just 10% can boost its mileage by almost 6 to 8 percent.

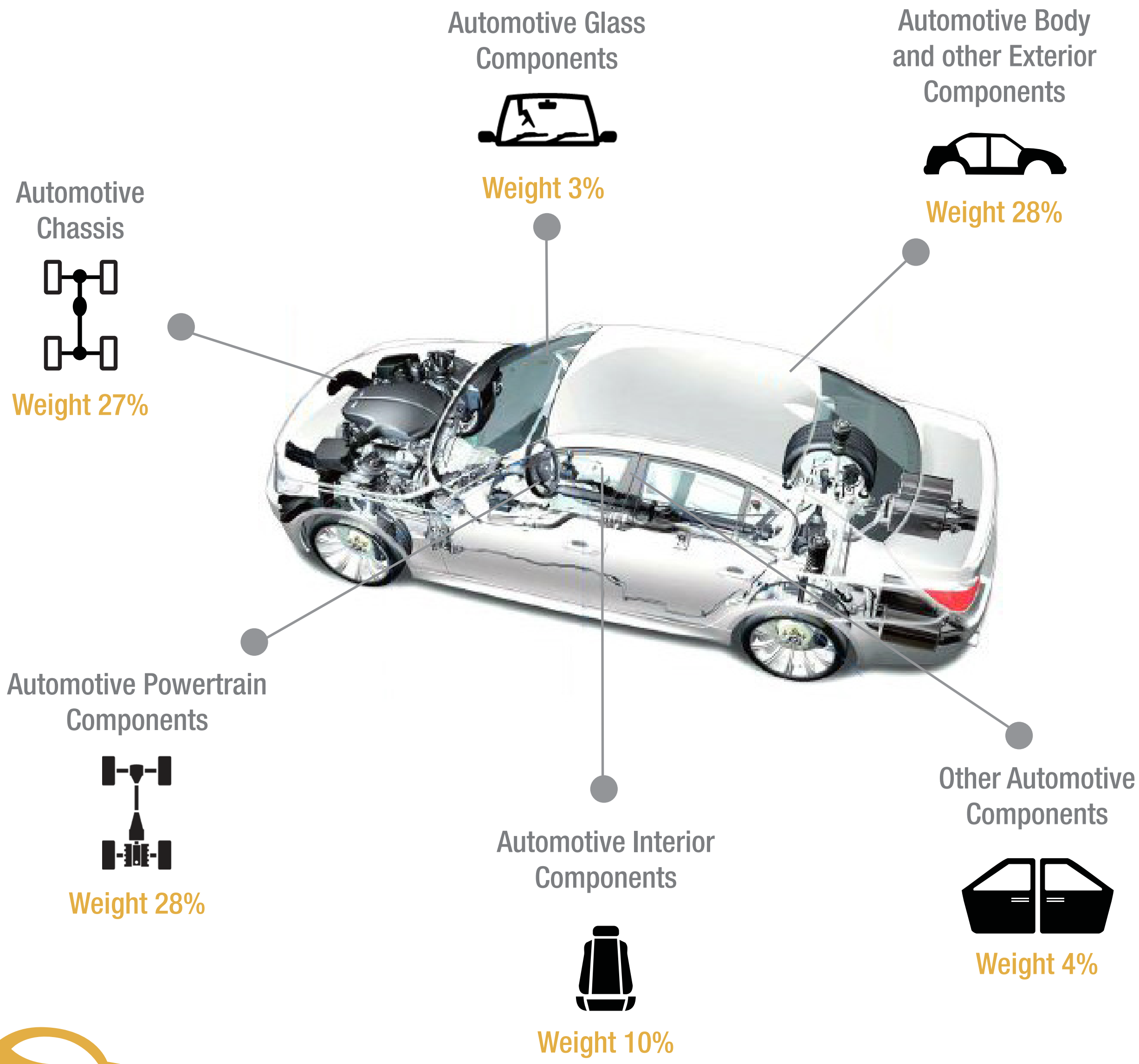


Automobile Weight Statistics and Weight Reduction Strategies

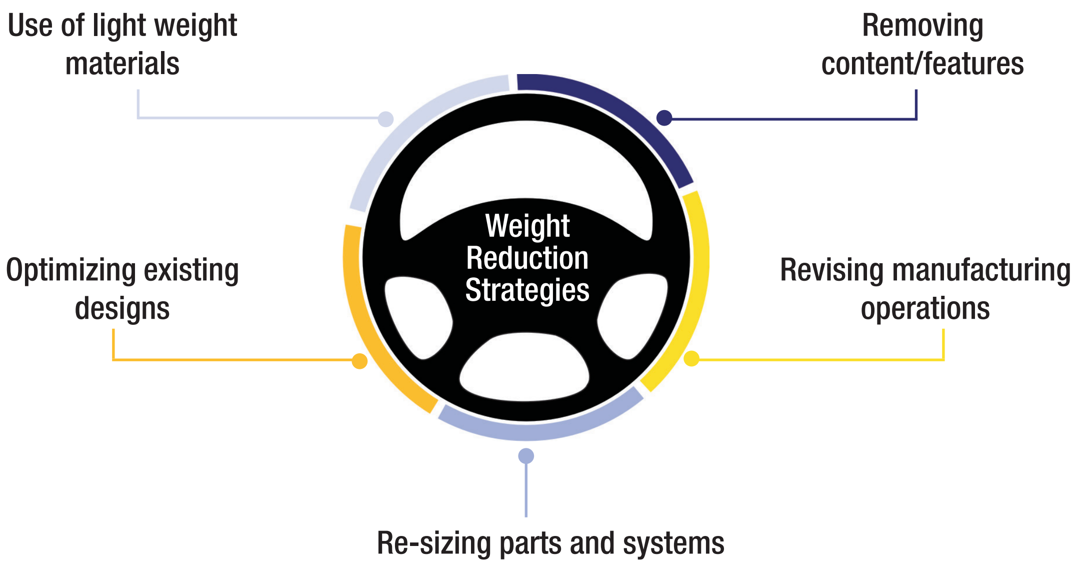
For an average vehicle, about 80% of the weight is shared among chassis, powertrain, body and other exterior components. Consequently, most automakers and OEMs are shifting their research focus towards these components to achieve overall weight reduction.

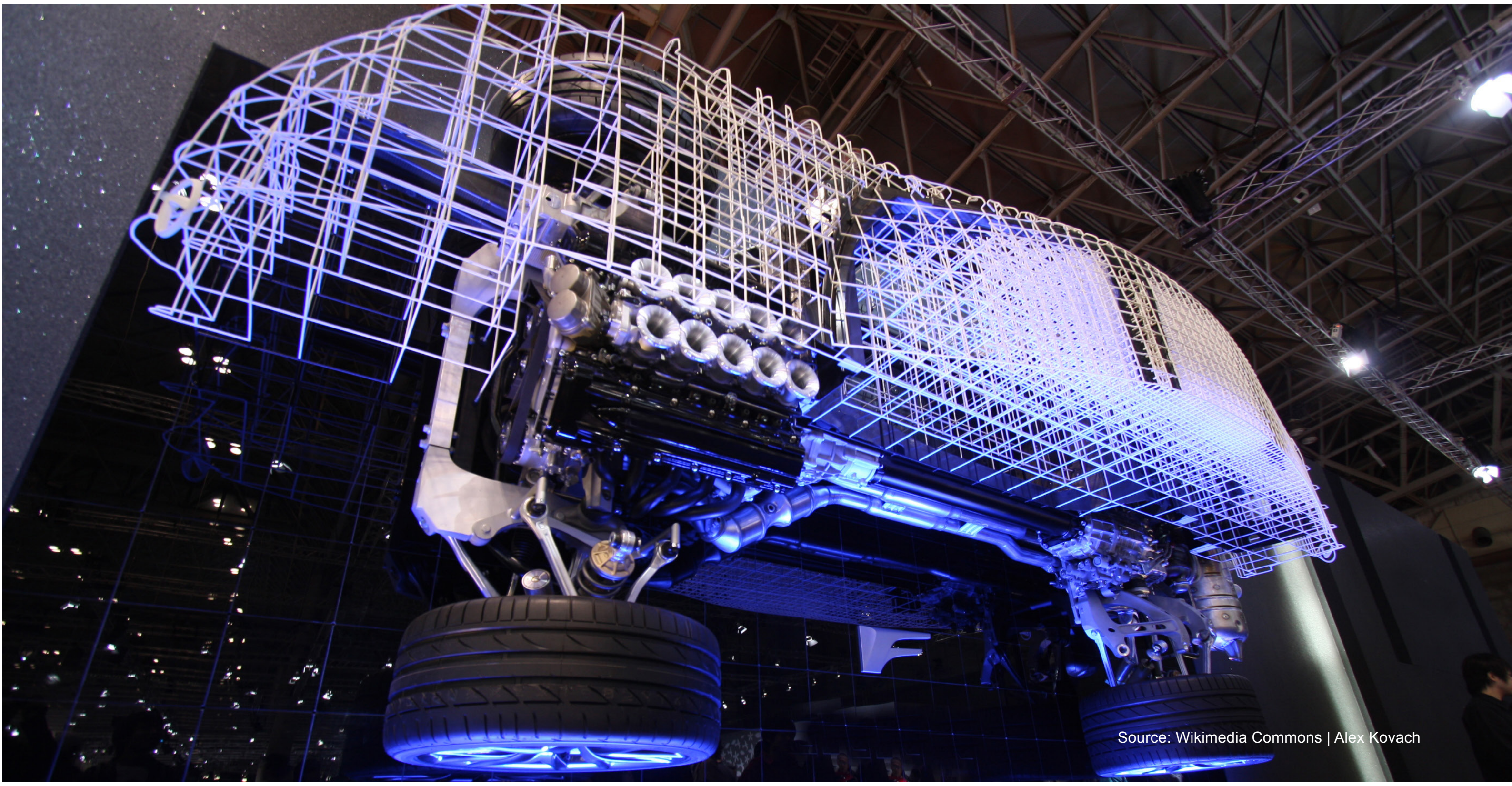
Research by OEMs such as Faurecia and Lear Corp. are also making significant strides in automotive interior space; covering components such as instrument panels, glove boxes, and seating structures to achieve potential weight savings.

Automotive Component Weight Statistics



A variety of weight reduction strategies are adopted by different automakers to minimize weight in automobiles. Using lightweight materials such as aluminum and carbon-fiber or optimizing existing vehicle designs are some of the key strategies adopted by manufacturers in the automotive industry.





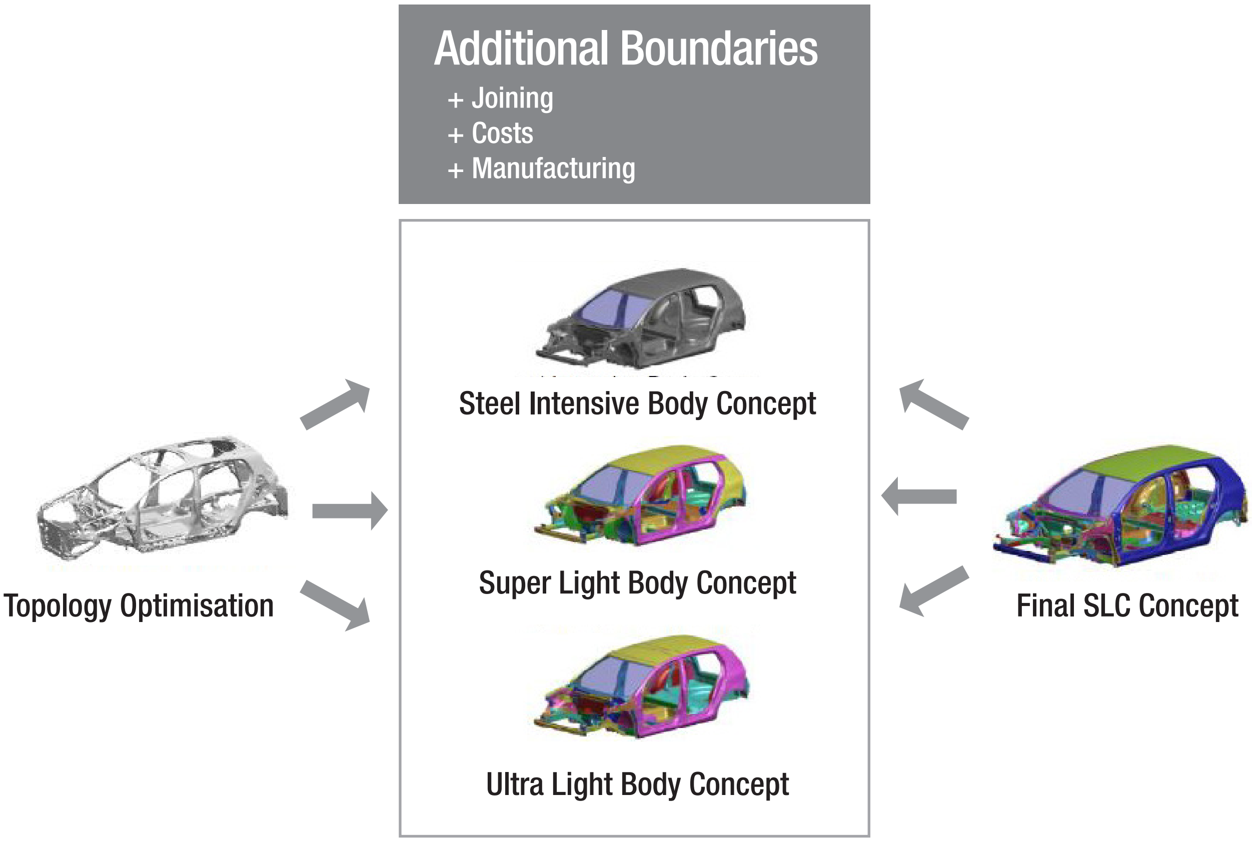
Source: Wikimedia Commons | Alex Kovach

Weight Reduction Technologies

Several governments and regulatory bodies are actively and aggressively lobbying for environmental responsibility. Increasingly stringent requirements for improved fuel economy and reduced emissions have led to developments that could very well reduce a vehicle's average weight by 10 to 15 percent in the coming decade.

Volkswagen-led European Super Light Car

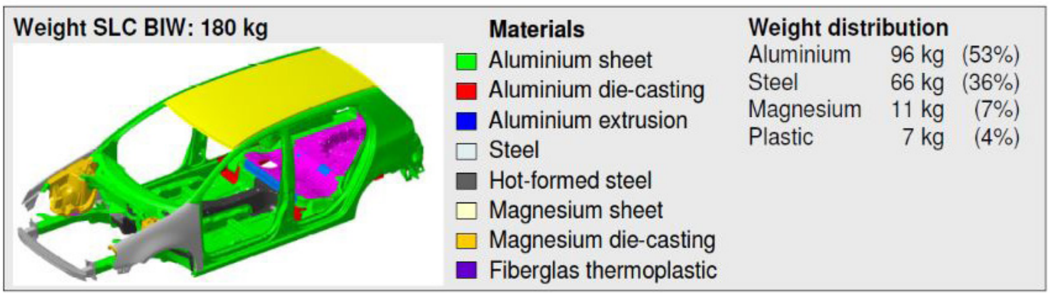
The Volkswagen led European super light car was one several major projects undertaken to decrease fuel consumption and CO_2 emissions. A multi-material approach was adopted to reduce weight in a vehicle's body structure by 85 Kg.



Different materials were selected for different parts of the body structure based on criteria such as energy absorption, structural integrity, stiffness, formability, surface quality, and cost. Computerized simulations and other relevant factors were considered to generate an output of the final weight and material distribution.

Aluminium was the most used material, contributing 53% of the body structure's weight. Aluminium sheets and cast Aluminium extrusion profiles were used as well.

Steel and hot formed steel made up about 36% and magnesium about 7% of the overall weight. Minor parts designed using thermoplastic materials comprised a small 4% share.



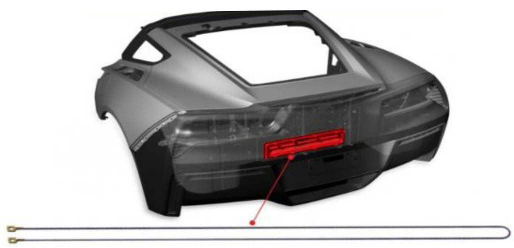
Source: Dynalook.com

The project yielded in major weight reductions of 32-42% in body structure including body, front end and floor.

Heat Activated Smart Materials for Weight Reduction

With an increase in stringent fuel economy requirements, weight reduction has played a major role in a vehicle's design process. The Chevrolet Corvette, which features a shape memory alloy developed by General Motors, is a good example of such design.

Chevrolet and General Motors have experimented with the use of a shape memory alloy wire that opens the hatch vent when the deck lid of the car is opened. The shape memory alloy wire contracts when it is energized by an electric current which further activates the lever arm to open the vent. This reduces the internal air pressure and allows the trunk lid to close easily. The alloy wire returns to its original shape once the hatch is closed and the electric current is ceased. This change closes the vent to maintain the cabin temperature. The use of the less expensive smart material saves about 1.1 pounds of the total vehicle weight as compared to heavier motors normally used to serve the same purpose.



The new 2014 Chervrolet Corvette uses a lightweight heat-activated shape alloy wire in place of a heavier motorized part to open a vent that allows the trunk lid to close more easily.

Source: Gizmag.com

An automobile on an average comprises of 200 such such motorized movable parts that could be replaced with lightweight smart materials, which can further be used to achieve potential weight savings. General Motors have protected this technology with a US patent 8,821,224.

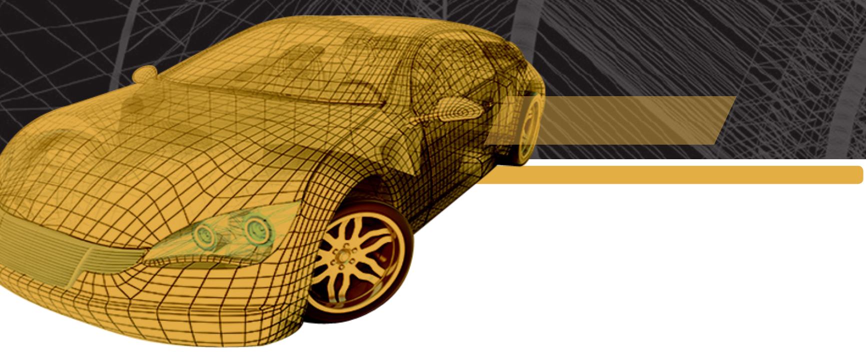
Other such examples of shape memory alloys use can be seen in technology developed by the Japanese company Furukawa. In collaboration with DaimlerChrysler, Furukawa has designed a SMA-NT (NiTi) alloy spring that is used in the Mercedes Benz A class and B class. The SMA-NT (NiTi) alloy spring is used to activate the continuously variable transmission (CVT) of an automobile. The SMA-NT spring is used in a valve system where it automatically senses temperature changes and exerts a significant force to actuate the valve, which automatically changes the direction of oil flow.

Faurecia's "Lightweight & Roominess" Seat Concept

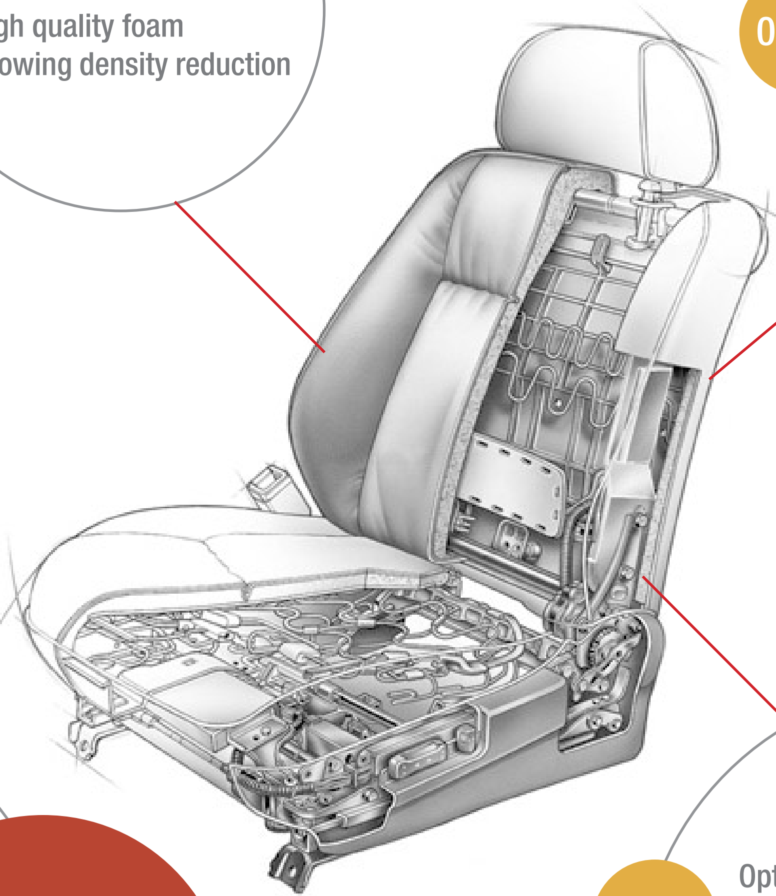
Faurecia, a leading automotive parts supplier, has recently introduced a lightweight seat concept that makes seats about 2.5 Kg lighter than models on its current production line.

Source: faurecia.com

Faurecia has worked on all aspects of the seat's structure in order to achieve a potential weight reduction of 2.5 kg. The seat is designed such that it offers much more passenger legroom.



Here are some of the different technologies used in the seat's design:



Foam

0.4 Kg

High quality foam allowing density reduction

Backrest

0.4 Kg

Sculpted light panel

Frame

0.7 Kg — Optimized mechanisms and components such as tracks, racers, etc.

0.6 Kg — Thinner side-members and risers using HSS

0.3 Kg — Materials: Steel + Thermoplastics

Total weight savings ~2.5 Kg

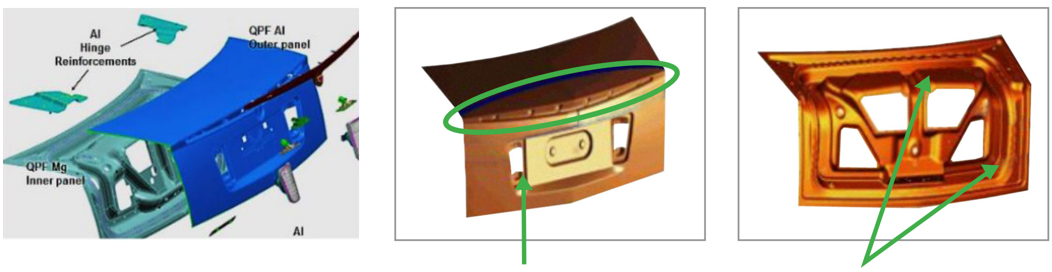
Quick Plastic Forming Process for Aluminum Component Production

Vehicle weight can be reduced by replacing steel with aluminum in components such as trunk lids and door inners. However, manufacturing processes' current abilities to form complex shapes from aluminum are quite limited. To solve this issue, General motors collaborated with VTP and Kaiser Aluminum to develop a Quick Plastic Forming (QPF) process capable of producing aluminum closure panels at high volumes. The technology has been successfully implemented for automotive lift gates and deck lids with complex shapes.

The Quick Plastic Forming (QPF) process is used to replace steel with Aluminium to produce individual components that are 35% lighter. This technology is protected by 59 US and 16 non-US patents by General Motors.

The process is explained as follows:

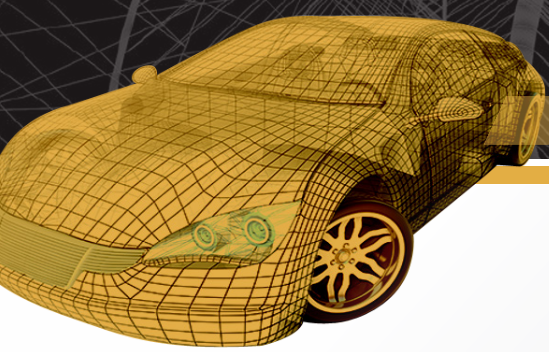
- Light Aluminium metal sheet blanks are placed on a fixture near the press. The blank is then lifted by a robot and placed in a platen heater for 60 seconds.
- After heating the sheet at a determined temperature, the robot transfers the hot sheet into an electrically heated tool.
- The die press closes such that electrically heated tool forms an air-tight seal along the binder periphery.
- Compressed hot air is then blown against the die to blow-form the Aluminium sheet to the required shape.
- After the cycle is complete, the press opens and raises the upper chamber of the die.
- The formed part is then extracted from the lower die with pick-in-place type automation system.
- The hot panel is placed onto a specially designed cooling fixture. The partially cooled panel is then transferred onto a cooling conveyor.



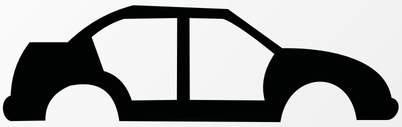
- Sharp feature lines
- License & CHMSL pocket are part of outer

- Deep draw can't be stamped
- Results in stiffer ASM

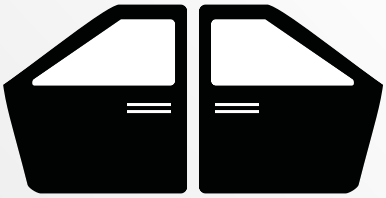
Source: ipcomgrp.com



Advantages Of The Quick Plastic Forming (QPF) Process

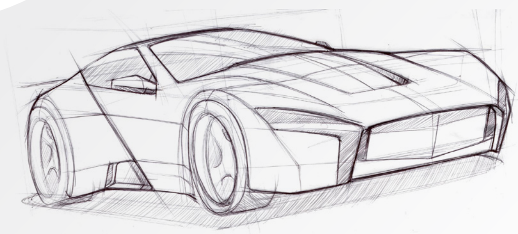


Reduced number of parts in a vehicle

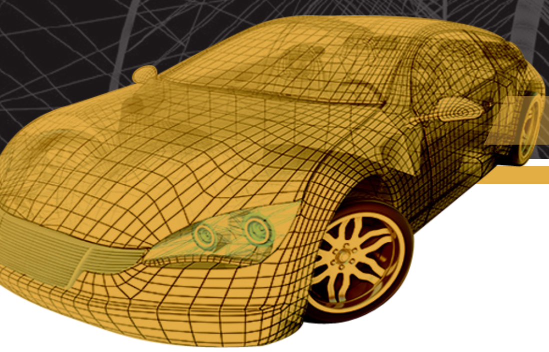


2-3 dies are used to make a closure panel rather than 4-6

The time and cost for a die design is reduced by using advanced virtual modeling techniques



Ultra lightweight and complex metal surfaces can be produced to meet designer goals



Low-cost Carbon Fibre Production Technology by Oak Ridge National Laboratory (ORNL)

The use of carbon fiber composites has been thoroughly explored by various manufacturers and OEMs due to their ability to reduce weight while meeting stringent safety requirements.

The high price of carbon-fiber is a deterrent however, preventing many automakers from using them to their fullest potential. Many research institutes and laboratories are investing heavily into research towards producing carbon-fibers composites at a lower cost.

Traditional carbon fiber manufacturing uses polyacrylonitirile (PAN) as a precursor, which requires a lengthy and energy intensive oxidative stabilization process. This process is crucial to ensure that the carbon fiber can resist the high temperatures to which it is subjected in the subsequent carbonization step. After the carbonization step, the carbon fiber undergoes a surface treatment that improves its ability to bond with composite matrix materials.

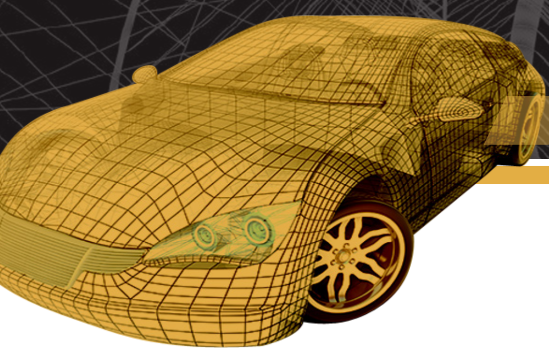
Carbon fiber composite wheels

Oak Ridge National Laboratory (ORNL) has done a lot of research into various solutions to manufacture carbon-fiber at low costs. The laboratory's research goals are to make strong carbon fiber (250 Ksi) economically (at a rate of $5-7 per pound) among other specifications. According to research findings by ORNL, plasma oxidation, microwave assisted plasma carbonization, and advanced surface treatments are the key technologies to reduce production costs.

Carbon fiber composite leaf springs

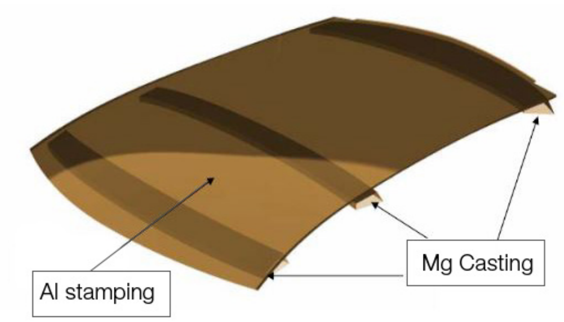
The plasma oxidation process has the potential to reduce the cost of carbon fiber through lower energy requirements, smaller floor space requirements, and reduced processing times. For example, the technology has the potential to reduce the processing time to 20 minutes as compared to 90-120 minutes required for conventional processing.

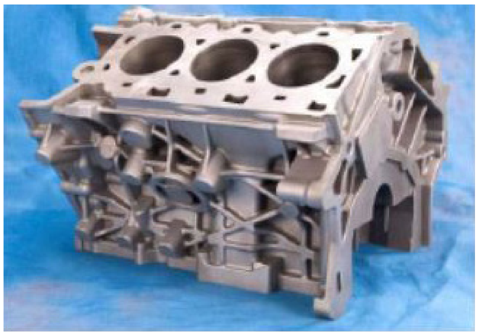
Microwave assisted plasma carbonization process has the potential to reduce costs through reduced energy requirements, faster processing times, and reduced surface treatment needs.



Other Minor Improvements Contributing to the Weight Reduction

Many other automakers such as Nissan, Mazda, Ford and OEMs such as Lear, Robert Bosch and Denso are making minor changes in various automobile components such as their powertrain, body, exterior components, and interiors, in order to achieve potential weight savings.





Magnesium engine block and roof assembly of Aluminium and Magnesium

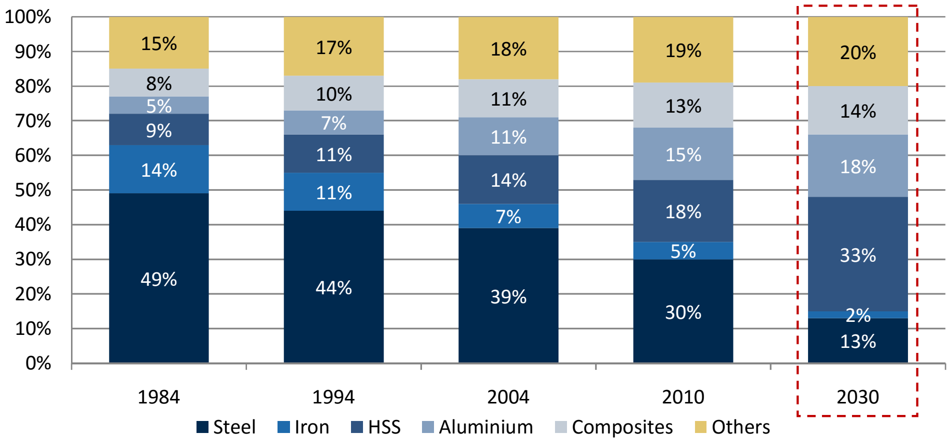
Some of the developments are as follows:

- Magnesium (Mg) engine block, bedplate, oil pan, and engine cover which is 28% lighter than the Aluminium (Al) version.
- Composite materials for drive shafts to achieve potential weight savings of up to 3.5 Kg. The composites are currently used in models designed by Nissan, Mazda, and Mitsubishi.
- Aluminium stamped roofs and rod-like support structures beneath that makes the roof structure 11 Kg lighter.
- Magnesium steering wheel and steering column, achieving potential weight savings of about 2 kg.

Conclusion

Most of the research has been taking place on use of lightweight materials such as Aluminium, Magnesium, high Strength Steel (HSS), and polymer composites to replace heavier materials and achieve a lightweight vehicle.

The majority of research by automakers and OEMs is focused towards developing low-weight solutions in automotive powertrain, chassis, and body components, which constitute up to 80% of total vehicular weight. It is forecasted that High Strength Steel (HSS) and Aluminium will be the most widely used materials in automotive manufacturing by 2030.



Forecast - Overall Material Weight Trends (2030)

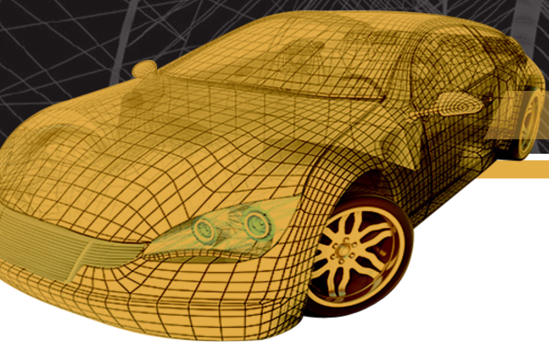
Research by automakers has been towards optimizing their designs for various components of an automobile using a mix of lightweight materials, a trend expected to persist in the years to come.

The use of carbon fiber reinforced composites has proven to be effective in reducing vehicle weight, although its high cost is a major hindrance for automakers. There's definite scope for research institutes and labs such as Oak Ridge National Laboratory (ORNL) in this space to develop low cost carbon composites.

Although other substitute materials such as Aluminium, High Strength Steel (HSS) and Magnesium are high on the manufacturers' list of preferred materials, companies need to grapple with major challenges such as the time taken for production, costs incurred to make changes in their production lines, and durability of the final product.

The automotive sector is highly conducive to patents as most companies protect their innovations in order to gain a competitive market edge. However, keeping in mind the new regulations enforced by different government agencies, competing companies need to collaborate towards making the car of tomorrow a featherweight champ. Tesla and Toyota's recent decision is one such example of collaborative open source automotive innovation.

Adopting an open source model and sharing patents among competitors can be a lucrative strategy to meet the regulatory standards and reduce R&D costs.



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