

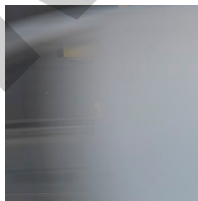
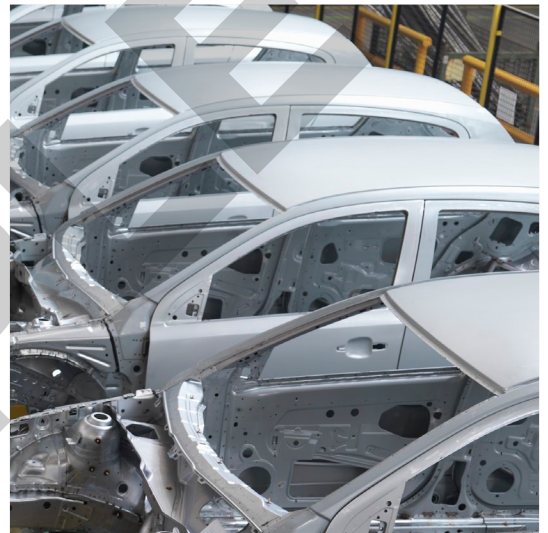
IHS AUTOMOTIVE

The Weight Reduction in Automotive Design Report

Lightweighting, Materials and Manufacture

2016 edition

supplierbusiness.com



SECTORAL REPORT

Lightweighting



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BMW

BMW's lightweighting strategy focuses on using what it regards as the most appropriate material for the component concern, or in the case of the i-series models, the most appropriate material for the platform as a whole. It has chosen not to develop a full aluminium vehicle and has chosen instead to use the material selectively, alongside high strength steels and composites. In all these materials, it is very much at the forefront of industry developments. For example, on the i3 electric vehicle, on which weight-saving was a key factor, given the need to maximise battery range, there is extensive use of composites in the body panels; these are made by SGL, a composites supplier in which BMW holds a controlling stake.

As well as composites from SGL providing a number of weight-saving breakthroughs, BMW has also – along with Peugeot – achieved significant weight-savings through the use of ARPRO. This material is used on the butterfly doors' panels on the i8 plug-in hybrid model. ARPRO is a synthetic rubber copolymer which was used by Magna's interior trim division (prior to its sale to Antolin of Spain) to produce the i8's door panel carrier, which generates a 22% weight-saving over comparable materials used on mainstream BMW models. This material also cut tooling investment by 50% and has allowed enhanced insulation for the door panel as well as improved integration of the wiring cable channels and switches. This was not actually the first time BMW had used this material, having already used it on seat components for the 5-series and the X5/X6 SUVs.

The i8 CFRP body – taking BMW into new areas

The BMW i3 and i8 are at the centre of BMW's path-breaking approach into the sustainable mobility arena. The i3 is an entirely emissions-free electric car, while the i8 is a plug-in hybrid sports car, using an electric engine and three-cylinder 1.5 litre petrol engine. These sit on what BMW calls is Life-Drive Architecture which uses carbon-fiber (CFRP) material for its body. The result is a vehicle which weighs 1,485kgs, and which can still achieve leading performance figures in the sports car segment, such as accelerating from 0 to 100kms an hour in 4.4 seconds; even when using the petrol engine, it produces under 50 grammes of CO₂ per km. Not satisfied with this, BMW is understood to be working on a vehicle which can get as many as 588 miles per gallon. Limited information has come out on this vehicle, which is understood to be a four-door vehicle weighing under 1,200kgs, using a two-cylinder range-extended petrol engine and an electric motor which powers the rear wheels. This vehicle is also believed to use an entirely CFRP body and may form the basis of the

replacement for the i3 due around 2020, or entirely new model.

Development of future i-series vehicles will take place at BMW's Lightweight Design Centre at its Landshut facility, north of Munich, which was officially opened in the summer of 2015. The company has invested €20m here. This facility will house at least 160 engineers focused on continuing to develop BMW's expertise in lightweight design. In addition to future i-series models being designed here, the facility will also provide lightweight design contribution to BMW's mainstream models; the new 7-series for example already contains several CFRP and aluminium body panels and plastic bumpers designed at the Landshut facility. According to Oliver Zipse, BMW's production chief, the importance of this facility is summed up as follows:

"Lightweight construction is one of the key technologies of the global automotive industry and a key differentiating feature ... In addition to dynamic driving benefit, lower weight also provides substantial CO₂ savings. The concentration of light metal, castings, plastics and fiber composite expertise at (Landshut) is unique ..."

"Carbon-core" at the heart of the new 7-series

While the i3 and i8 – and future i-models – will be the main adopters of CFRP within BMW, this material will also be used on the brand's mainstream cars. The 2016 G12 7-series employs a strategic mix of carbon-fiber, aluminium and high-strength steel, creating what BMW calls its Efficient Lightweight chassis. Critically, the 7-series will feature carbon-fiber reinforcements to a primarily steel structure, with BMW referring to this mixed materials approach as "carbon core". This model will use carbon-fiber reinforced plastic in the following areas or components:

- B- and C-pillars.
- Roof bows.
- Centre tunnel console.
- Parcel tray.
- Door sills.

The roof arch which runs from the base of the A-pillar all the way to the rear of the car.

According to Klaus Frolich, BMW board member for R&D, BMW's "innovative combination of carbon-fiber structures with steel, aluminium, magnesium and plastic means that the 750i xDrive is 130kgs lighter than the previous model;

and this is despite having added a wide range of safety and convenience features on the new model, adding weight.

Suspension and engine mountings are made from aluminium, either extrusions or castings; most of the main exterior panels are made from aluminium, with high-strength steel making up most of the rest of the body structure. The result is said to be a weight-saving of around 200kgs over the previous model, with just under one-third of this cut coming in the body structure alone. It should be noted that the 200kgs weight-saving is actually reduced to 130kgs once additional sound deadening material and safety technology have been factored in. Other areas where BMW removed weight on the new 7-series include:

- Suspension arms and other suspension components, made of aluminium.
- Steering knuckles and hubs.

Sound proofing material in the cabin, where nearly 12kgs of weight was cut by insulating the engine itself, ie reducing engine NVH at source.

And doors, which are 10% lighter than on the old model, by dint of being made of aluminium.

The use of CFRP on the 7-series confirms, moreover, that BMW is confident that it can make CFRP components on an “industrial scale”, with 7-series volumes being much higher than the i3 for example. Given the commonality between the old 7-series and the 5- and 6-series, we can expect similar approaches to be adopted on the replacement for the 5- and 6-series models in due course. The next 3-series will also benefit from the lightweighting advances made on the next 7-series.

The new 5-series is expected to use a carbon-fiber roof, similar to the one already used on the M3 and M4 performance vehicles. It is also worth noting how the current 5-series was path-breaking at BMW for using aluminium in its doors, saving 23kgs; other aluminium parts on the existing 5-series include front side walls, the bonnet and front and rear axle parts.

The CFRP production process and manufacturing arrangements

The CFRP parts used on the i3 and i8, and indeed on the 5- and 7-series, are produced using high pressure resin transfer moulding (HP-RTM). This is a modernised and faster process of the original RTM process which was first used in the 1990s to make parts of the Dodge Viper sports car. This difference now is that HP-RTM is much faster

and more efficient than the original RTM process which operated at 10-20 bars pressure, with a cycle time of 30-60 minutes. HP-RTM, by contrast, operates at as high as 150 bars inside the material mixing head and at between 30 and 120 bars inside the mould. HP-RTM is also far more automated than the original RTM process, making it practical to deploy in a high labour-cost location like Germany.

BMW had been using RTM processes for low volume M3 and M6 vehicles for around 10 years, making carbon-fiber/epoxy resin roof parts. However, until the cycle times for this process fell, along with automation for high volume production and improvements to carbon-fiber, it could not deploy it more widely. Developments in all three areas meant that it could be made to work for the complex geometry parts used on the i3 and i8 especially. Manufacturing costs have been cut in half, aided by the use of curing agents which have cut the injection cycle to just one minute and totalling curing, at 120° Celsius, to two minutes. Even faster curing is said to be possible through developments with curing agents undertaken by Dow.

On the original applications on the M3 and M6 models, such long cycle times did not matter significantly, as production volumes were only between 1,000 and 4,000 units a year. Now with i3 volumes heading, hopefully, towards 50,000 units annually and beyond, faster pressures and curing times are essential for the process to be economically viable. Key components for the i3 and i8 are now made, using the fastest curing agents and resin on a Krauss Maffei injection machines at BMW's Landshut facility in southern Germany; similar technology is deployed at the i3/i8 vehicle plant in Leipzig where some of the CFRP components are made.

The carbon-fiber for the i3 and i8 components comes from a BMW-SGL joint-venture plant in Washington State, USA. Having been initially set up with a US\$100m investment, the SGL facility at Moses Lake received US\$200m of investment in 2014-15 to triple capacity to 9,000 tonnes a year, increasing employment to 200 people and making this facility the largest carbon-fiber plant in the world. Initially the plant had two production lines dedicated to producing carbon-fiber for the i3 and i8, each pair capable of producing 3,000 tonnes of fiber a year.

The production of the glass fiber and indeed the finished parts is certainly a very international affair, encompassing Japan, the USA and Germany. The process and geographic division of labour work as follows:

Precursor material, based on polyacrylonitrile fiber is produced in JV plant between SGL and Mitsubishi Rayon in