Driving vehicle production

With electric cars in production and new automotive component designs made from strong, lightweight materials, the laser is in increasing demand in automobile manufacture, as **Greg Blackman** finds out

At the end of July, as part of its green initiatives, the Obama administration announced a 2025 target Corporate Average Fuel Economy (CAFE) standard of 54.5 miles per gallon – almost double what it is today in the US. On display, as President Obama set forward the proposals, were the latest fuel-efficient vehicles, including the battery-powered Nissan Leaf and GM's plug-in hybrid electric Chevrolet Volt. The CEOs of General Motors, Ford, and Chrysler, as well as the heads of many other auto manufacturers, were present, nearly all of which are developing hybrid or fully electric lines.

Electric cars seem to be what we'll all be driving in the future – one of President Obama's goals is to have one million plug-in electric vehicles on America's roads by 2015 – and the proportion of electric vehicles would have to increase to meet these CAFE targets.

A report published in June 2011 by the Center for Automotive Research (CAR) in the US, states: 'To achieve a CAFE target of 56mpg [one of the scenarios posited by the authors], the estimated market penetration by each technology type [stop/start, hybrid, plug-in hybrid, compression-ignited, and battery electric] would exceed most expectations of a 2025 market, and would require a significant advancement in battery manufacturing technology beyond what is known today.'

Most electric vehicles rely on standard lithium-ion batteries similar to those found in laptops, which can be mass produced in large quantities using standard manufacturing procedures. Pouch-bag battery cells can also be used to power a car; this technology has a higher energy capacity, but is more expensive to manufacture.

As part of the Fraunhofer System Research for Electromobility (FSEM) project, the Fraunhofer Institute for Laser Technology (ILT) in Aachen, Germany, has developed laser welding parameters for the serial electrical interconnections between cells in pouch-bag battery packs. The crux of developing a laser welding process for making the connections, according to Dr Alexander Olowinsky, group leader microjoining at Fraunhofer ILT, is that it can be automated. 'If you consider the quantities of batteries for electric vehicles predicted for 2015, it has to be an automated process,' he says. 'Manual manufacturing of batteries for one million cars on German roads won't be possible.'

Pouch bag cells have two electrodes, one made of a copper alloy and the other an aluminium alloy. The electrodes are typically mechanically screwed together, which uses space, and the resistance is higher than with a welded connection. 'Welded battery packs could be manufactured smaller and lighter than current designs,' Dr Olowinsky states.

Laser welding the electrodes is complicated by the fact that copper and aluminium have completely different melting points (aluminium: 660°C; copper: 1,084°C). In addition, the overlap seam of these materials in a standard weld construction would be around 400-500µm thick aluminium, welded to 200-300µm thick copper. 'The challenge is to melt the copper through the aluminium without overheating the aluminium,' Dr Olowinsky says, adding that the alternative seam geometry of layering the copper on top would not be suitable, as the laser would create a number of pores in the copper.

In addition, the coefficient of thermal expansion for aluminium and copper is completely different, leading to the risk of stresses and cracks occurring from the heating and cooling cycle. 'Even during welding, these problems can occur,' Dr Olowinsky notes. 'You can't avoid this completely, but through selecting the proper laser parameters in terms of

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power, feed rate, and focusing conditions, you can minimise the amount of material required for the interconnect and reduce the problem, not to zero, but to an acceptable value.'

Fraunhofer ILT is also working on laser welding electrical connections within cylindrical lithium-ion battery cells, which involves connecting a steel can either with a steel or copper plate, depending on the module design. This work, according to Dr Olowinsky, has had interest from industrial manufacturers of cylindrical lithium-ion batteries. 'It's a very hot topic right now and a lot of people are trying to automate the production of battery packs for electric vehicles.'

Fibre power

It's not just the development of the electric vehicle on which the CAFE standards are having an impact; auto manufacturers are refining their production processes for combustion vehicles coming off the line as well. According to Mike Klos, general manager at IPG Midwest Operations, the higher CAFE standards have produced a whole new cottage industry of laser processing techniques. Welding and joining of exotic lightweight materials, cutting of high-strength materials for lightweight roll cages, aluminium joining and brazing techniques, are three areas he identifies where the laser is now prominent.

IPG provides fibre lasers for the automotive sector and sells directly to General Motors, Ford and Chrysler, which, Klos says, was unheard of even as recently as five years ago. In addition, Ford, GM and Chrysler all carry out R&D testing at IPG's laboratories in Michigan, US.

Klos identifies vehicle seats as one structure that, over the last three years, laser technology has almost completely changed. Laser remote welding has taken over from resistance spot welding in joining seat frames, and most manufacturers, Klos says, use IPG lasers. The frames are constructed from lightweight materials using remote laser welding to provide higher rigidity in the structure. This is, in part, to adhere to regulations on withstanding vehicle impact. Old frame designs might have had around 15-20 spot welds, explains Klos, whereas the same seat geometry today has more than 50 contact points made by remote laser welding.

The big difference between laser welding and spot welding, says Klos, is in identifying whether the weld is good or not. Spot welds require a peel test to determine this, which destroys the join – if the weld holds and the material tears, then the weld was good, whereas if the weld pulls apart then it can be deemed bad. Laser welds, on the other hand, can be monitored throughout the process, a practice accepted by the US National Transportation Safety Board (NTSB).

Laser welded connectors for serial interconnection of pouch bag cells, battery technology for electric vehicles. The welds were made by Fraunhofer ILT

In addition to weld monitoring, remote laser welding only uses one robot with a weld head that manipulates the beam around the part using galvo mirrors. This is opposed to spot welding, which requires a separate robot for each welding machine and a station of up to four robots to make 20 spot

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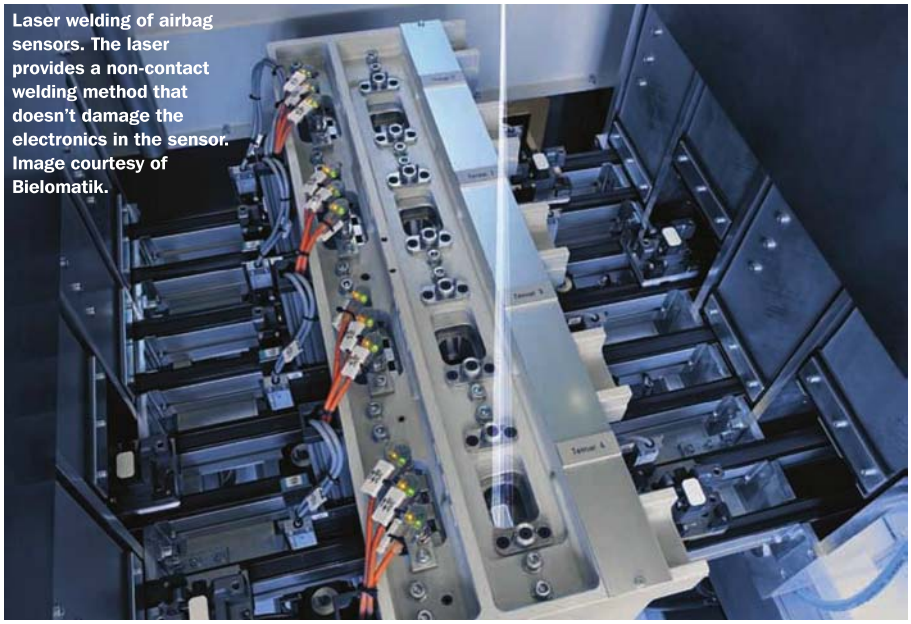

Laser welding of airbag sensors. The laser provides a non-contact welding method that doesn't damage the electronics in the sensor. Image courtesy of Bielomatik.

welds. 'You've reduced the footprint, you've increased the number of welds and the weld strength and repeatability, you can use lighter materials, your overall production cell is considerably smaller, and the time to make the welds is reduced,' states Klos. 'In some cases, it can be one fifth of the time taken using remote welding compared to spot welding. There are huge advantages, with no downside other than the initial cost of the laser system.' Remote laser systems can cover large surface areas of $1m^2$ and make 80 welds in 30 seconds.

Lightweight materials

The seats are just one part of a car where the structure has changed to accommodate lighter materials and different manufacturing methods. Fraunhofer ILT has also been working on laser cutting processes for fibre-reinforced plastics, as potential materials for making lightweight car body parts that can better withstand the impact from a collision. Commercial trials of using the material to produce seat backs have shown up to 40 per cent weight reduction when metallic parts were substituted for reinforced polymer materials.

Laser cutting and welding of reinforced polymers is made more difficult, because the matrix and reinforcement have completely different melting points, especially for carbon fibre-reinforced plastics. 'You want to have clean cuts without freestanding fibres,' explains Dr Olowinsky at Fraunhofer ILT. The institute has been investigating using ultrafast lasers to sever the material, the results from which show a good edge quality without freestanding fibres. However, Dr Olowinsky comments that the process speed has to be improved, which is slow due to the relatively low power of the laser. There is also research into joining these materials using transmission laser welding.

Plastic fantastic

A lot of a car will be plastic; interior parts like the dashboard and glove box, engine pieces like the air intake manifold, and exterior parts like rear lights and sensors are all comprised of plastic or have a plastic component to them. Laser welding in their construction has the advantage of being non-contact and producing clean, precise, neat joins. Manufacturing vehicle instrument panels, for example, comments Andreas Rau, sales engineer at Bielomatik, has to have a very clean finish to the weld. 'Joining the transparent window onto the rigid frame of the dashboard requires a neat and aesthetically pleasing weld, for which the laser is an ideal tool,' he says. The plastic welding division at Bielomatik (Neuffen, Germany) builds plastic welding equipment based on a range of technologies, including lasers, and 70 per cent of its turnover is in the automotive sector.

> **There are huge advantages, with no downside other than the initial cost of the laser system**

Alternative joining methods include gluing and ultrasonic welding, or the part can be mechanically fixed in place. 'The handling is difficult with gluing and it's not a cheap method,' explains Rau. 'It's also a relatively dirty method. Ultrasonic welding works, but the line isn't clean and precise.' In addition, he says, automotive sensors, which have an electronic component inside the plastic housing, can be damaged from the ultrasonic vibrations. Laser welding is contactless, so there aren't any vibrations. 'Whichever method is used depends on the part,' he adds.

Bielomatik integrates both fibre and diode lasers in its machines. The diode lasers utilised are mainly provided by Dilas, although Bielomatik uses other suppliers. 'The fact that diode lasers can be coupled to an optical fibre gives a lot of freedom in machine design,' comments Rau. 'With an Nd:Yag laser, machine design was restricted because of the laser. Smaller machine cells can be engineered using a fibre-coupled laser, and these in turn can be integrated into an automated production line with greater ease.'

High beam quality

Laser processing is well established in automotive production and has been present in some form for almost three decades, according to Klos of IPG. 'There have been tens of millions of vehicle transmission parts welded with CO_2 lasers over the past 30 years,' he says. 'We're replacing a lot of those lasers now, because of the lower complexity, higher repeatability, and the better beam quality of fibre lasers, as well as not having to use an assist gas, which is the case with CO_2 lasers. Fibre lasers are also more efficient.' IPG also provides fibre lasers for most manufacturers of batteries for vehicle power trains which, Klos says, is simply because of the beam quality.

Disk lasers also exhibit excellent beam quality and Volkswagen has recently signed a substantial order for Trumpf's TruLaser Cell 8030 series, based on solid-state disk laser technology. The machine will be used in high-volume production of hot-formed car body parts, with the laser cutting the pressed parts to remove the trim. Lasers are ideal for this task as they are non-contact, whereas mechanical tools wear out quickly.

'These parts tend to be pressed in large volumes, so it's not only the quality of the cut that's important, but also the speed,' explains Gerry Jones at Trumpf's Luton, UK, facility. 'The volume of pressed parts can outstrip the capacity of a single machine, and so production lines will often run a number of these machines alongside the part forming equipment.'

The TruLaser Cell 8030 series is specifically designed for shearing hot-formed parts. It includes a high-speed index table that automatically transports the part, so that the operator or automated system can load the next part while the first is being processed.

While the laser is now integrated into many manufacturing procedures, Dr Olowinsky warns that it is important to consider laser processing early in the design stage of a new part or when working with new materials.

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