Aluminium : Lightweight Steel

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Since the majority, if not all, vehicles in present mass production worldwide are sheet-based monocoque structures, it is the substitution of steel by aluminium in these structures that has the most impact on fuel economy and global warming issues. The key question is what developments are required for aluminium to truly to be considered as “lightweight steel”.

It is more than 20 years since Alcan launched its Aluminium Vehicle Technology (AVT) concept as a set of enabling technologies for high volume automotive manufacture. To date, the only significant build that uses AVT is the latest Jaguar XJ saloon, of which there are now more than 40,000 examples on the road or in showrooms.

However, a key part of AVT was not adopted by Jaguar who have made extensive use of self-pierce riveting (over 3000 per vehicle), rather than resistance spot welding, in combination with adhesive bonding. Although the use of these mechanical fasteners offers certain production line advantages, there are issues for the wider adoption of this type of joining technology for more affordable vehicles.

Although Ford/Jaguar decided that steel rivets were the best way to reinforce adhesive bonds for the XJ saloon, subsequently there has been a major advance in aluminium resistance spot welding that extends electrode-life and ensures both joint consistency and integrity.

The key to reliable resistance spot welding of aluminium is frequent electrode maintenance. This is not a new idea but the equipment available today uses hardened steel cutter blades that remove up to 0.5 mm of copper on each operation. For aluminium, it is only necessary to lightly abrade the electrode surface at regular intervals. This can be achieved by using abrasive media or by shot-blasting. If the electrode is maintained in this way every 10 20 welds then electrode-life is extended to more than 6000 welds without any deterioration in weld quality. This means that electrodes do not have to be changed mid-shift.

Presently, there are no commercial welding systems that incorporate this frequent dressing technique. However, the process can be demonstrated in an experimental welding cell that has been set up by Innoval at Warwick University’s International Manufacturing Centre.

General Motors have used a similar approach to manufacture the aluminium tailgate for their Chevrolet Tahoe and Yukon SUV models at a rate of 500,000 units per year. But their line uses traditional electrode cutting rather than abrasion, and some mid-shift maintenance is required.

There is a clear opportunity for development of commercial electrode maintenance equipment designed specifically to address the wear characteristics uniquely associated with aluminium spot welding.

Technology for aluminium vehicles has also advanced in other areas and this has expanded the range of adhesives that can be utilised. In particular, lower modulus adhesives can be used without reduction of vehicle torsional stiffness. There is also a much wider range of pretreatments that are suitable both in terms of ease-of-use and full environmental compliance.

Although the technology now offers the opportunity for the mass production of aluminium structured vehicles; the main issue is still the cost of aluminium automotive sheet compared to steel. Today, all aluminium automotive sheet is made by conventional production techniques based on the casting of large rolling blocks that are processed through hot and cold rolling mills. Although techniques for continuous belt casting of aluminium automotive sheet have been developed, they have not yet been commercialised. Alcan has developed “Flexcaster” thin-belt casting technology that has been adopted by NLM in Japan to enter the market for automotive materials. This production facility sited in Kambara was scheduled to begin production in July 2004, and will be able to supply 10,000 tonnes per month by 2006. This will potentially provide the Japanese automotive industry with high performance, low-cost aluminium structural and closure sheet. In Europe, there are efforts in Turkey, by Assam, and in France, historically by Pechiney, to provide low-cost aluminium closure sheet by twin-roll casting. It will be of great technical interest to follow the impact of these potential lower-cost technologies.

In summary, the Jaguar XJ experience combined with various technology developments have shown that aluminium can begin to be considered as lightweight steel for the mass production of sheet-based bodies in white. The main barriers to its more extensive use and significant impact on fuel consumption and global warming require the adoption of resistance spot welding and the availability of lower-cost sheet.