# Challenges of Welding Aluminium Alloys for Automotive Structures

by J.F. Hinrichs, J.S. Noruk, WM. McDonald, and R.J. Heideman

**In response to the need for lighter structures, the use of aluminium alloys in transportation vehicles has increased. By reducing weight, vehicle fuel consumption and engine emissions are reduced.**

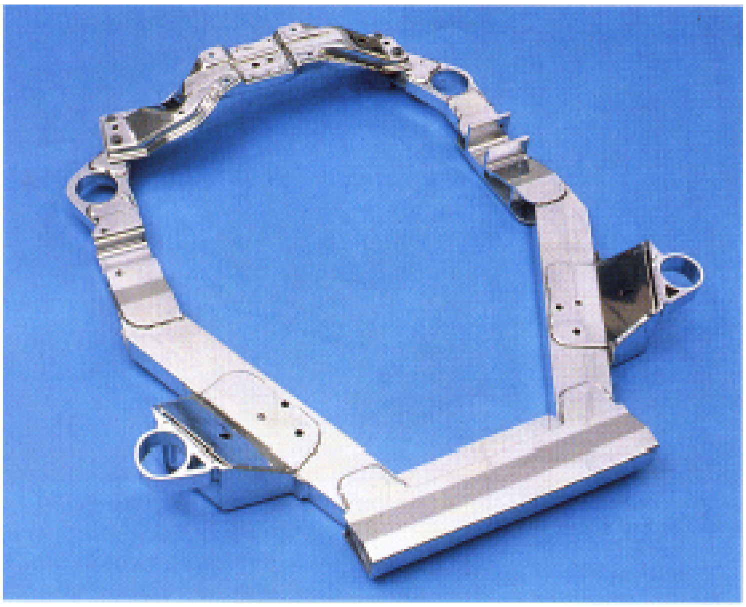

*Figure 1. An all-aluminium passengers car engine cradle assembled and joined by A.O. Smith. The cradle consists of 15 Kaiser Aluminium extrusions, 4 cover plates, and pressed transmission cross-member.*

However, because of aluminium's high cost, it has made only moderate inroads into motor vehicles. This is because the motor vechicle business tends to be cost sensitive, and capital and line operating costs must be kept to a minimum. While aluminium has replaced some body panels, cross members, trim, etc., it has been used in few welded structures. Some examples of welded aluminium structures include: (1) the Audi A8, (2) the spare tire structure on the Chevrolet Corvette, and (3) Honda's Acura NSX. The measure of success of any future high volume welded aluminium structures will be compared in performance, quality, and cost to their steel counterparts. Responding to our customers'requests, A.O. Smith began investigating using aluminium alloys as structural material.

A manufacturing process that interests the A.O. Smith Automotive Products Company (AOS/APC) invoices assembling and joining extrusions to create an automative structure. To join these extrusions, the gas metal arc welding (GMAW) process has received the most attention. This is because GMAW is usually faster than gas tungsten arc welding (GTAW) or plasma arc welding (PAW) processes. Typical travel speeds for GMA welding aluminium and aluminium alloys are 50-100 cm/min. GMA steel welding operates in a range from 125-200 cm/min. The reduced welding speed is a major manufacturing concern. If aluminium alloy welding speeds cannot be increased, production costs, compared to steel structures, will be higher. This will make the justification to use aluminium difficult. A second concern regarding aluminium GMA welding is surface preparation. Recommended practice for most aluminium alloys is to wire brush (stainless steel bristles) the weld surface before welding. This is a concern because it would add production costs and complicate the process. The welding speed and surface preparation issues must be addressed if aluminium alloys are to be cost-effective alternatives for high-volume welded structures.

The first all-aluminium prototype design at AOS/APC was a passenger car engine cradle (see Figure 1) that was joined using pulsed gas metal arc welding (GMAW-P). The design consisted of 15 extrusions and four cover plates that needed to be assembled and joined. Following a finite element analysis performed by AOS that evaluated the cradle design, extrusion cross sections were designed and produced in cooperation with Kaiser Aluminium. Extrusions were then provided in 6 meter lengths, cut to size, machined to the final shapes, and assembled.

The GMA welding process for AOS/APC's first all-aluminium structure utilized a 4043 filler metal and pure argon shielding gas. The fillet leg weld sizes varied from 4-8 mm. The 4043 alloy was selected because other researchers claim this alloy outperforms higher strength 5356 in a fatigue environment. The claim of 4043's improved fatigue perfor-

*The welding cell used to join extrusions for an all-aluminium passenger car engine cradle. The cell contains an ABB IRB2400 robot, an ESAB Digipulse 4SOi power source, and a Binzel WH455 welding torch.*

mance is the subject of another investigation at AOS/APC.

The welding cell used to assemble the prototype cradles contained an ABB IRB2400 robot that was equipped with an ESAB Digipulse 4SOi power source and a Binzel WH455 welding torch (see Figure 2). The ESAB Digipulse 450i power source was specifically tuned by ESAB for welding aluminium alloys. To minimize wire feeding problems. a 10 kg wire spool was mounted on the robot. 1 m from the welding torch. This minimized the push distance and simplified wire feeding. While this setup was acceptable for the prototype builds, it would not be a good manufacturing option because replacing small spools would create excessive downtime.

To reduce downtime in a manufacturing environment, a minimum 100 kg spool would be mounted next to the robot. The increased wire feeding distance resulting from this setup could cause problems; however, to overcome these, a push-pull welding torch would most likely be used. On a robotic push/pull torch. the drive rolls (pushing) are mounted on the robot, closer to the wire spool. The pulling or helper drive roll is mounted on the torch very close to the contact tube. A pulling drive roll keeps the weld wire tight (no slack) during welding and complex robot moves and maximizes weld starts.

Along with the 49 GMAW welds on the prototype cradles, there were two welds that used the friction stir welding process. Friction stir welding is patented by TWI and appears to have promise in joining structural components. By welding below the melting point of aluminium alloys, heat input is reduced. This leads to less distortion. smaller weld grain size. narrower heat affectcd zone (HAZ). and properties closer to the base metal. In addition. the weld profile is nearly flat which could improve fatigue performance. Finally, friction stir welding of 6xxx series alloys requires no surface preparation. Friction stir welding was used to make two full penetration and autogeneous 8 mm but welds. The friction stir welds were made by ESAB AB in Laxå Sweden without surface preparation at about 20 cm/min. The friction stir welds replaced 4 pass GMA welds. Figure 3 shows macro structures of a GMAW sample compared to a friction stir welded sample.

After AOS gained experience welding prototype cradles and talked to non-automotive aluminium fabricators, we concluded that the key to successfully GMA welding aluminium alloys is a eld

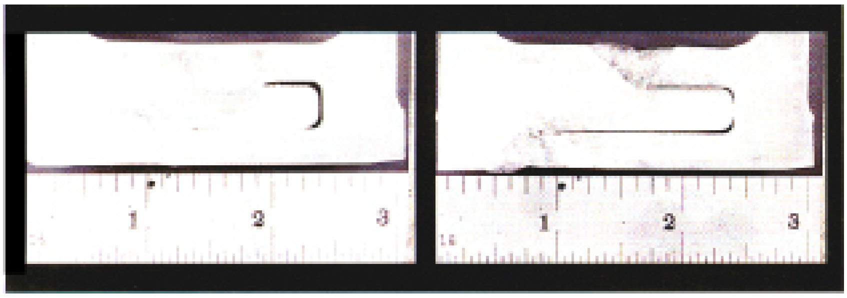


*Figure 3. Cross-sections showing the macrostructures of two welds: (a) friction stir weld and (b) 4pass GMAW welds made with 4043 filter metal.*

filler metal feeding. Aluminium alloys being softer than steel tend to score easily. When the weld filler metal scores, it produces fine aluminium particles (we'll refer to these as flakes). These flakes are then deposited in the wire liner or entrance of the contact tube, constricting filler metal feeding and causing bum-backs.

To compensate for the flaking problem. other fabricators report using oversized contact tubes and liners. This increases mean-time between failures by allowing more flakes to accumulate in the filler metal feed system before becoming detrimental. In non-critical weldments, oversized contact tubes may be an acceptable solution. However, using oversized contact tubes in robotically welded. fatigue-sensitive structures. could cause misalignment of the wire in the joint. Wire misalignment can lead to root penetration problems which could lead to premature failure. In addition, oversized contact tubes can cause inconsistent current pickup resulting in poor starts and burn-backs. The filler metal misalignment concern with oversized contact tubes becomes more serious when welding different fillet leg sizes. For instance. welding a lap fillet with two plates of equal thicknesses in the flat positions presents few problems. However. when two plates of unequal thicknesses are welded togcthcr, fillet leg penetration becomes sensitive to wire position. If the wire moves in the joint, which is more likely with oversized contact tubes, controlling fillet leg penetration could be more difficult.

While using oversized contact tubes is effective, we have not pursued this solution because of the filler metal alignment concern. Rather, we have focused on reducing weld filler metal score. Our observations showed that the contact tube entrance was a significant area for aluminium flakes and slivers to buildup. By deburring the contact tube's entrance, we were able to increase its life and improve arc stability and performance.

In the initial demonstration cradles built by AOS. welding speeds were about 75-90 cm/min. much below the 150 cm/min. common in similar steel structures. Research efforts were reported at the 1995 AWS International Expositions and Conference in Cleveland, OH, where aluminium weld schedules that travel 250 cm/min. and achieve high quality welds without any surface preparation were being developed. This work concentrated on 1-3 mm stock thicknesses and used Neural Nets to develop the initial weld schedules. These speeds along with no surface preparation are attractive for high-volume manufacturing. (1)

Welding of aluminium alloys is not new, but many process improvements arc needed to make aluminium welding in a high-volume automotive manufacturing environment practical. To make aluminium an economical choice for motor vehicle manufacturers, are welding must be automated, friction stir welding technology exploited, welding speeds incrcascd. equipment up-time incrcascd, and surface preparation eliminated. These will be our challenges as we try to make aluminium structures a viable option for our customers.


### *Acknowledgements:*

We wish to acknowledge the Valuable contributions made by many colleagues within A.O. Smith. at Esab AB in Laxå Sweden, and The Esab Group in the USA.


**Reference:**


(1) D.R. White and J.E. Jones, Gas Metal Arc Welding of Thin Section Aluminium with Dissimilar Alloys. Presented at 1995 AWS Convcntion in Clevcland, OH.



**About the authors:**

**John F. Hinrichs** holds a B.S. Degree in Mechanical Engineering and a M.S. Degree in Metallurgical Engineering. He has been employed by A.O. Smith for 40 years and is currently an Engineermg Fellow at the A.O. Smith Corporate Technology Center. He has held many positions within the A.O. Smith Automotive Products Company including Director of Manufacturing Engineering. He also serves on many AWS committees, is an AWS Fellow, and recipient of the 1989 Golden Robot Award.

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