

Joining Technologies for Mainstream Vehicle Lightweighting

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Lightweighting of automotive body-in-white (BIW) structures is a key element in the drive for improved fuel economy. The BIW lightweighting initiatives of major automotive manufacturers and tiered suppliers focus on materials, design, and new manufacturing technologies.

Materials for these lightweight body designs include new generations of steels and aluminum alloys. Advanced High Strength Steel (AHSS) grades with tensile strengths up to 1500 MPa continue to extend the potential for down-gauging. Of particular interest are the Generation III steel grades now entering the marketplace. Generation steels are seen to offer compromises in strength, ductility, and cost. The classic steel “banana diagram” indicating strength/ductility compromises for various grades of steels is shown in Figure 1. Generation I steels (C-Mn types) are shown in a group to the lower left of the diagram. Generation II (austenitic grades) are shown the upper right.

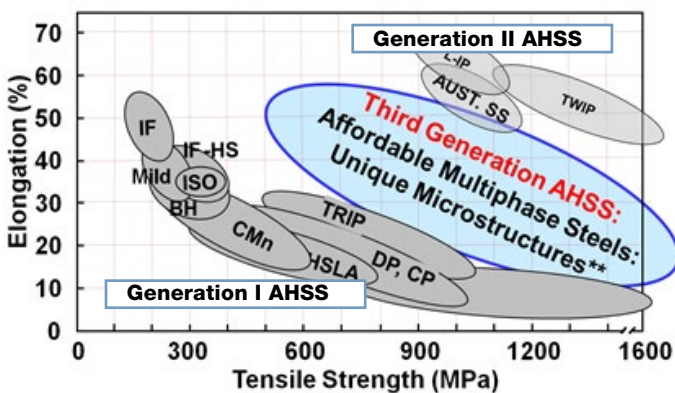


Figure 1: Examples of strength and ductility combinations for Generations I, II, and III types of steels

The higher alloying contents and complex thermal-processing techniques which give these steels their combination of high strength and good formability may present joining challenges. Experience with resistance spot welding of Generation I AHSS grades shows that increased alloy content leads to interfacial cracking due to excessive hardness; however, in-situ tempering via a second heat cycle can mitigate this issue. For underbody components, there is a need for low heat-input gas metal arc welding (GMAW) variations such as reciprocating wire feed GMAW and tandem GMAW (Figure 2) to reduce heat affected zone (HAZ) softening.



Figure 2: Tandem GMAW torch mounted on a 6-axis robot

Aluminum is a major focus for structural lightweighting and although mechanical fastening is common, there is a strong interest in welding to reduce cost. Today’s resistance spot welding innovations address the interaction of the welding electrodes with the workpieces. The introduction of third body elements to the stack-up or the use of tip dressers have both been shown to increase electrical resistance, improving joint quality and reliability. Refill friction stir spot welding (RFSSW) leaves limited disruptions on the original sheet surfaces and while cycle times are not yet comparable with resistance spot welding, avoidance of solidification-related issues make this process attractive (Figure 3 and Figure 4).

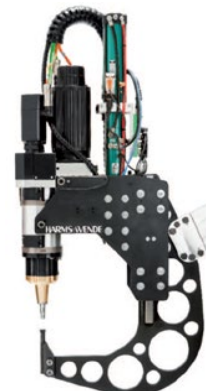


Figure 3: A Harms-Wende refill friction stir spot welding

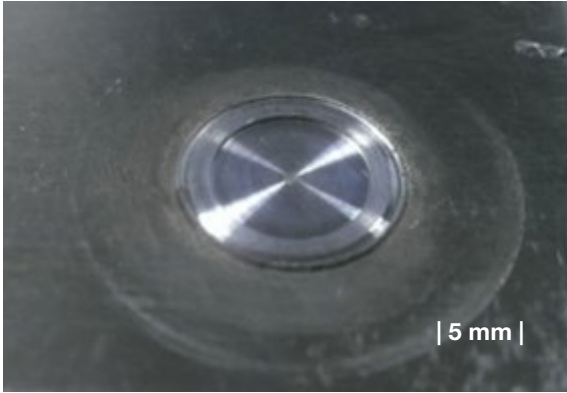


Figure 4: Top surface of an aluminum refill friction stir spot weld

Joining of aluminum to steel has precedent in the automobile industry, particularly with regard to lightweight prop shafts. This work has demonstrated that processing which limits thermal excursions at the steel/aluminum interface is effective in maintaining properties. There is strong interest in extending this understanding to other technologies. Current processes under investigation include friction welding, resistance welding, and friction stir welding. Mechanical fastening methods may also be used to join dissimilar materials; however, applying these technologies to materials with limited ductility is challenging. Localized heating methods developed to enhance formability have been demonstrated on magnesium and high strength aluminum sheet materials (Figure 5 and Figure 6).

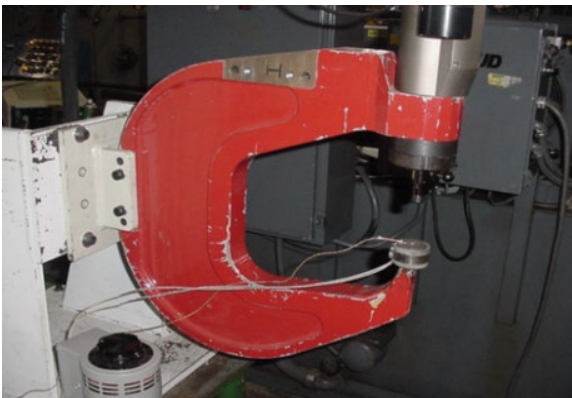


Figure 5: A hot-die self-piercing riveting system



Figure 6: Mechanical joint between Al-6111 and an Mg-AZ-91 alloy

Adhesive bonding provides improved stiffness, the ability to seal joints, and compatibility with varying material systems. Improved joint designs are an ongoing consideration and the combination of adhesive bonding with welding or mechanical fastening offers both structural and manufacturing advantages.

New joining technologies must be integrated into current structural predictive capabilities as structural performance modeling is used extensively in modern vehicle design. State of the art methods for including joints in these models are typically employs empirical failure data for specific material stack-ups. This approach is common for resistance spot welding, but must be adapted for the new range of joining technologies associated with structural lightweighting.