MODELING RESISTANCE SPOT WELD FAILURE IN MARTENSITIC BORON STEELS USING A CRITICAL J-INTEGRAL FRACTURE CRITERION

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ABSTRACT

The load bearing capacity of welding joints during crash tests under complex loading conditions is of great interest to the automotive industry. Among all existing technologies, resistance spot welding is the most popular joining technique. In recent years, advanced high strength steels (AHSS) have been introduced to a large extent to reduce the total weight of new generation car body structures while maintaining or even improving their safety performance. Martensitic boron steels belong to this type of steels providing a significant improvement in their mechanical behaviour (UTS=1500 MPa). Consequently, the fracture behaviour of AHSS spot welds in these steels is drastically affected and becomes critical in the design of new car bodies. The bearing capacity of the joints mainly depends on the combined sheets' materials and thicknesses; the resulting spot weld diameter, and the imposed loading angle. Altogether, these features make the characterization of resistance spot welds in AHSS time- and money-consuming. The 22MnB5 boron steel in a fully hardened grade showing a fully martensitic microstructure is used in this work. The welding process alters significantly the initial microstructure around the joint producing distinct zones with different mechanical properties. The joints bearing capacity in common ductile steels is typically restricted by the base material mechanical properties around the weld nugget and is usually linearly dependent on the steel fracture strength. Unlike in the case of common ductile steels, the failure in AHSS generally initiates at the notch tip around the joint nugget. The strain-based fracture criteria normally used to predict the failure of welding joints in ductile steels fail in this case, given the stress concentration and high strain gradients occurring around the notch tip. A non-intrusive method based on the J-integral applied to the simulation results gathered from conventional finite element (FE) models is proposed in this work to predict the maximum bearing forces of resistance spot weld joints for the 22MnB5 boron steel. The local material properties of the different spot weld zones are introduced in the FE model. All the simulations are run by using the commercial software VPSPAMCRASH and the J-integral is computed by the equivalent domain integral method [1]. The J-integral is used here as a fracture criterion to evaluate the severity of stress concentration around the notch tip. When it reaches a critical value a crack nucleates and the joint fails [2-3]. An experimental matrix considering different sheet thicknesses combinations and spot welds diameters is used to calibrate and validate the method. The developed approach predicts the maximum forces of these welding joints by using a unique critical J-integral value depending on the fracture mode [4] (a material parameter obtained from independent experiments), providing promising results to reduce to a large extent the time- and money-consuming experimental characterization.

References

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