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Effect of Retained Austenite and Non-Metallic Inclusions on the Mechanical Properties of Resistance Spot Welding Nuggets of Low-Alloy TRIP Steels

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Abstract: The combination of high strength and formability of transformation induced plasticity (TRIP) steels is interesting for the automotive industry. However, the poor weldability limits its industrial application. This paper shows the results of six low-alloy TRIP steels with different chemical composition which were studied in order to correlate retained austenite (RA) and non-metallic inclusions (NMI) with their resistance spot welded zones to their joints' final mechanical properties. RA volume fractions were quantified by X-ray microdiffraction (μSXRD) while the magnetic saturation technique was used to quantify NMI contents. Microstructural characterization and NMI of the base metals and spot welds were assessed using scanning electron microscopy (SEM). Weld nuggets macrostructures were identified using optical microscopy (OM). The lap-shear tensile test was used to determine the final mechanical properties of the welded joints. It was found that NMI content in the fusion zone (FZ) was higher than those in the base metal and heat affected zone (HAZ). Whereas, traces of RA were found in the HAZ of highly alloyed TRIP steels. Lap-shear tensile test results showed that mechanical properties of spot welds were affected by NMI contents, but in a major way by the decomposition of RA in the FZ and HAZ.

Keywords: low-alloy TRIP steel; resistance spot welding; retained austenite; non-metallic inclusions; X-ray microdiffraction and magnetometry

1. Introduction

Advanced high-strength steels (AHSS), particularly transformation induced plasticity (TRIP) steels are increasingly becoming used in the transportation sector due to that their high mechanical properties allowing the use of thinner gauge sheets. Consequently, the total weight of the vehicles is reduced, leading to enhanced safety and fuel efficiency. The typical TRIP multiphase microstructure is developed by the addition of alloying elements such as Al, Mn, P, and Si, in addition to a two-stage heat treatment, and it is composed of a mixture of ferrite, bainite, and metastable retained austenite. TRIP steels mechanical properties are microstructure dependent and they offer an excellent combination of strength and ductility, additionally to high energy absorption during deformation owing to the deformation-induced transformation of RA into martensite (TRIP effect) at elevated strain level [1]. Resistance spot welding (RSW) is the predominant process in sheet metal joining, particularly in the