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Characterization of resistance spot welded transformation induced plasticity (TRIP) steels with different silicon and carbon contents

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ABSTRACT

This research work examines the influence of chemical composition and microstructure of 6 different transformation induced plasticity (TRIP) steels on the mechanical behavior of resistance spot weldments. The microstructure of the spot welds was characterized by means of scanning electron microscopy and X-ray diffraction techniques. The mechanical properties were assessed under lap-shear tensile and hardness testing. Results indicated that the nugget width is strongly correlated with the type of failure mode of the spot welds. The mechanical properties exhibited by the spot weldments are related with the partitioning behavior of chemical elements specially Si and C present in the steels during the cooling stage of the resistance spot welding process. X-ray diffraction study indicated traces of retained austenite in the heat affected zones of the spot welds of those steels with Si-enriched chemical composition where intercritical annealing temperatures were closer to Ac_1.

1. Introduction

High levels of pollution generated by CO_2 emissions have led the automotive industry to get involved in the production of fuel-efficient vehicles. Among the main proposed solutions, net weight reduction of vehicles is a promising one. This purpose is properly achieved by the introduction of advanced high-strength steels (AHSS), which are lighter owe to thinning of gauge sheet. Additionally, AHSS offer enhanced mechanical properties if compared to their predecessors (i.e. HSLA), in a way that the passengers safety is not compromised. Transformation Induced Plasticity (TRIP) steels highlight among AHSS due to the carefully designed microstructure composed of a ferritic matrix, bainite, fine islands of retained austenite (RA) and additions of martensite. TRIP steels offer an excellent combination of strength and ductility owe to transformation of RA into martensite (hardening rate) at elevated strain level. The stability of RA depends on the carbon enrichment during austempering because presence of Si acts as a carbide growth suppressor during bainitic transformation, thus, carbon enrichment increases the thermal stability of austenite that is to be retained upon cooling to room temperature [1].

Resistance Spot Welding (RSW) is the predominant welding process by which TRIP steels are joined for auto-body construction, RSW develops rapid weld thermal cycles (i.e. elevated heating rate followed by extremely high cooling rates), which causes the original steel microstructure to be locally transformed. Further microstructure transformation is strongly dependent on the steel chemistry and cooling rate [2]. For this reason, the resultant mechanical properties are of vital importance and must be assessed with the purpose of obtaining sound joints.

According to AWS D8.1M [3], failures in welded joints joined by RSW can occur in three modes: i) interfacial, ii) partial-interfacial, and iii) button failure. Each of these failures occur in different zones of the joint, either in the heat affected zone, which causes the complete detachment of the nugget as in the case of plug failure (button) or the partial detachment of the nugget as in the case of partial plug failure (partial-interfacial), a detachment along the nugget is characteristic of an interfacial failure. There are some factors associated with the failure modes in AHSS steels, in which the influence of the geometry, hardness and metallurgical phenomena generated by the welding process are highlighted. The size of the nugget directly influences the failure mode that the weld joint experiences, so the area available to support loads is a function of the nugget width, for this reason interfacial failure will occur more easily in small diameters, while larger nuggets involve partial or plug failures [4,5]. The metallurgical factors, as well as the hardness, both are intrinsically related to the chemical composition of TRIP steels, high percentages of alloying elements will cause the welded joint to be more susceptible to the segregation of harmful elements in the initially formed austenitic grain boundary, which will generate an

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