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Influence of fusion zone size and failure mode on mechanical performance of dissimilar resistance spot welds of AISI 1008 low carbon steel and DP600 advanced high strength steel

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ABSTRACT

The work here addresses the investigation of the effect of the welding parameters (welding time, welding current and electrode force) on the overload failure mode and mechanical performance of dissimilar resistance spot welds between drawing quality special killed AISI 1008 low carbon steel and DP600 dual phase steel. Mechanical properties of spot welds are described in terms of failure mode, peak load and energy absorption during the quasi-static tensile-shear test. Three distinct failure modes were observed during the tensile-shear test: interfacial, pullout and partial thickness–partial pullout failure modes. Correlations among failure mode, welding parameters, weld physical attributes and weld mechanical performance are analyzed. Effect of expulsion on mechanical performance of welds is also investigated.

1. Introduction

There is an increasing demand for high strength steel sheets in the automotive industry, in order to improve the fuel efficiency, occupant's safety and reduction of auto body weight. Due to the combination of excellent strength and formability, advanced high strength steels (AHSS) offer the potential for improvement in vehicle crash performance without the addition of excess weight. Dual phase (DP) steel is one of the most common AHSS steels. DP steels exhibit a composite microstructure of martensite and ferrite [1,2]. Considering the development and commercialization of new DP steels for applications in automotive bodies, there is a need to study the spot welding behavior of these materials.

Quality and performance of resistance spot welds (RSWs) are very important for determination of durability and safety design of the vehicles. Generally, there are three measures for quality evaluation of resistance spot welds including physical weld attributes (e.g. weld nugget size, electrode indentation, etc.), mechanical properties and failure mode [3,4]. Significant works have been carried out on the welding behavior and mechanical properties of low carbon and HSLA steels [5–10]. Moreover, valuable information on the resistance spot weldability of dual phase steels, particularly DP600, is published, recently [1,2,11–15].

In many studies the effects of process parameters including welding current, welding time, electrode force, holding time and electrode geometry on the physical weld attributes and mechanical properties were studied for a given steel base metal. Through these researches, it is well established that the geometrical attributes of spot welds, particularly weld nugget size, are the most important controlling factors determining the mechanical strength of RSWs [1,4]. In this regard, weld nugget size has been included in several empirical relations. For example, Heuschkel [5] developed empirical relations among the tensile-shear strength (P), weld nugget size diameter (D), base metal tensile strength (σ_{BM}), sheet thickness (t), and base metal chemical composition (C, Mn):

$$P = Dt[\alpha - \beta(\mathrm{C} + 0.05\mathrm{Mn})]\sigma_{BM} \quad (1)$$

where α and β are material dependant coefficients. Similar relations have been developed by other researchers. For example, the following relation is developed by Sawhil and Baker [6] for the tensile-shear strength of spot welds:

$$P = ftD\sigma_{BM} \quad (2)$$

where f, is a materials dependent coefficient, with a value between 2.5 and 3.1.

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