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Methods to Improve Cross-Tension Spot Weld Strength of Quenched and Partitioned Steel Spot Welds

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ABSTRACT

Mechanical properties of Resistance Spot Welds (RSW) in Quenched and Partitioned (Q&P) steels have been shown to be reduced under traditional spot-welding conditions. These challenges have been noted in both zinc coated and uncoated grades during quasi-static tensile tests. Reduced spot weld strength of Q&P steels is primarily attributed to the brittle microstructure observed in the fusion zones of these spot welds. To improve the fracture toughness of Q&P 1180 spot welds, four different post-weld process modification parameters were added to the spot weld schedule. Compared to the baseline spot welds made without any process modifications, spot welds made with these four post-weld process modifications exhibited 30-60% increase in the cross-tension spot weld strength. Microhardness tests, microstructural characterizations, and elemental segregation analyses were performed on these spot welds to understand the underlying microstructural evolutions that resulted in an increase in the spot weld strength of Q&P steels. Results indicate reduction of phosphorus segregation at the edge of fusion zone has been the predominant strengthening mechanism that resulted in maximizing the strength/ductility of spot welds.

INTRODUCTION

Advanced High Strength Steels (AHSS) have been used in automotive structural applications for almost three decades. Compared to the conventional mild steel grades, these multi-phase steels provide significant improvements in strength and ductility. Implementation of these steel grades in the automotive body structures has helped the automotive OEMs in reducing the overall body weight, thereby increasing the energy efficiency of vehicles without compromising the crash safety requirements [1]. Quenched & Partitioned (Q&P) steels, classified as 3rd generation AHSS, are multiphase steels with varying amounts of retained austenite. These steels are useful to automotive structural applications because of the enhanced formability these steels offer, compared to that of the 1st generation AHSS [2].

Due to the ease of automation, and the economic viability for mass production, resistance spot welding (RSW) is the predominantly used process for joining steel parts used in the automotive Body in White (BIW) structural applications. In a modern-day vehicle, thousands of spot welds are made connecting different body structures [3]. In automotive assemblies, groups of spot welds act as fold initiation sites to manage impact energy during crash. Therefore, the performance of spot welds is an important design criterion in determining the crash worthiness, and structural integrity of the vehicle [4].

The resistance spot weld process involves subjecting the AHSS materials to a wide range of thermo-mechanical processing conditions. This multitude of processing conditions results in the modification of the carefully designed microstructures around the spot weld regions of these materials. In general, the quality of resistance spot weld is evaluated based on the weld size, and the strength failure location. For a given spot weld size, Q&P steel spot welds exhibit lower cross tension strength compared to that of the Dual Phase (DP) steel spot welds. Consequentially, Interfacial mode of failure (IF), where fracture occurs through the fusion zone, was observed in the Q&P spot welds, while plug failure (PF), where fracture occurs outside of the spot weld fusion zone was observed in the DP spot welds [5]. Reduced fracture toughness in the fusion zone of Q&P spot welds is mainly attributed to three factors: (i) inability to achieve critical spot weld diameter (D_c) needed for plug failure (PF) without experiencing expulsion [3], (ii) high hardness associated with martensite microstructure in the fusion zone due to the relatively higher degree of alloying elements like carbon [6-8], and/or (iii) grain boundary embrittlement caused by the segregation of elements like phosphorus during non-equilibrium solidification associated with spot welding [9-10].

