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Technical Report

Investigation on AISI 304 austenitic stainless steel to AISI 4140 low alloy steel dissimilar joints by gas tungsten arc, electron beam and friction welding

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ABSTRACT

This paper presents the investigations carried out to study the microstructure and mechanical properties of AISI 304 stainless steel and AISI 4140 low alloy steel joints by Gas Tungsten Arc Welding (GTAW), Electron Beam Welding (EBW) and Friction Welding (FRW). For each of the weldments, detailed analysis was conducted on the phase composition, microstructure characteristics and mechanical properties. The results of the analysis shows that the joint made by EBW has the highest tensile strength (681 MPa) than the joint made by GTAW (635 Mpa) and FRW (494 Mpa). From the fractographs, it could be observed that the ductility of the EBW and GTA weldment were higher with an elongation of 32% and 25% respectively when compared with friction weldment (19%). Moreover, the impact strength of weldment made by GTAW is higher compared to EBW and FRW.

1. Introduction

Austenitic stainless steel (AISI 304) and low alloy steel (AISI 4140) possess a good combination of mechanical properties, formability, weldability, and resistance to stress corrosion cracking and other forms of corrosion [1,2]. Owing to these attributes at moderately high temperatures, such combinations of metals are extensively used in the power generation industry [3]. In a nuclear water reactor, dissimilar metal welds are employed to connect the low alloy steel reactor pressure vessel and stainless steel pipe systems. The dissimilar metal weldment joining boiler water reactor nozzles to safe ends is one of the more complex configurations in the entire recirculation system [4]. The problem with the dissimilar metal weld made between low alloy steel and austenitic stainless steel with an austenitic stainless steel filler metal is the carbide formation due to higher carbon content of low alloy steels than that of austenitic stainless steel [5].

As the strength of the dissimilar weldments is generally inferior, most of the in-service failures are reported to take place in the weld region [6,7]. Such failures in the transition zone between ferritic steel and austenitic stainless steel is a perennial problem in fossil-fired steam plants [8]. Li et al. [9] have studied the effect of post weld heat treatment on stress corrosion cracking of low alloy steel to austenitic stainless steel transition weld made by manual metal Arc welding. Raman et al. [10] discussed the prevalence of in-service failures in the welds of chromium–molybdenum ferritic steels. Since it is of great concern in steam generating/handling systems of power plants as well as the components of petroleum/petrochemical industries, studies are required to avoid such failures. Mainly these failures occur either in the heat affected zone or in the weld zone [11–13]. Similar and dissimilar joints involving austenitic steels are susceptible to unexpected phase propagation. As a result of this, a series of negative metallurgical changes such as delta ferrite phase, grain boundary corrosion and sigma phase occurs at the weld interface. Therefore, higher welding speeds are necessary to avoid such effects. Sometimes extensive care and precautions are needed such as pre and post heat treatment processes [14]. The micro-segregation which occurs in weld fusion zones of dissimilar metals leads to a situation where interdendritic regions are enriched in Fe, Cr and C. This segregation within the dendritic structure results in deterioration of the mechanical properties and corrosion resistance of the joints [15,16]. However, such problems can be minimized by judicious selection of the welding process and parameters. In view of the above, solidification during EBW technique is less likely to result in precipitation of unwanted intermetallic constituents. Joining dissimilar metals using EBW has been a subject of interest in recent years. It has been reported that the mechanical properties of dissimilar metals strongly depend on the microstructure of the joints. Thus, studies on the relationship between microstructure and mechanical properties are needed. Notwithstanding the ability of EBW process, friction welding of AISI 4140 and AISI 304 have also found to bring down the severity of segregation associated with solidification and in cutting down the volume fraction of the unwanted phases [17]. Roberto [18] had studied the pulsed Nd:YAG laser welding of AISI 304–AISI

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