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A Novel Scheme for Weld Microstructure Control Using Cryogenic Cooling

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Abstract. In this work, the preliminary result on the effect of cryogenic cooling on grain growth in weld is reported. Ferritic stainless steel weld produced under TIG torch in argon environment is cooled in liquid nitrogen. The weld structure is characterized using LOM, SEM and EDX spectroscopy. The results suggest that cryogenic cooling reduced the weld width within 2% to 5% and HAZ to 39% relative to those cooled in normal condition. This ensures that the area of the base metal affected and exposed to the weld thermal cycle is reduced and hence probably generates less metallurgical distortion. The cryogenic cooling also generated 14% to 36% grain refinement compared to welds cooled in normal condition.

Introduction

The heat condition during welding controls the character of the microstructure of the welded joints and hence the properties [1]. The condition is made up of the heating and cooling cycles. The heating cycle is characterised in terms of the heat input and it is established that the heat input invariably determines the cooling rate and hence the cooling cycle [2].

The response of material to weld heat input builds up differential microstructural features relative to the base metal which accounts for the apparent difference in weld section-base metal property. This arises because different areas within the thermal field are heated to different peak temperatures leading to heterogeneous cooling rate [3]. The effect of welding heat in ferritic stainless steel produces grain morphologies in the weld section that are sometimes five folds the grain size of the base metal and columnar in the fusion zone rather than equiaxed grains; and at times the presence of grain boundary martensite in both the HAZ and fusion zone leading to very poor ductility and low notch impact toughness. The refinement of grain size through the conventional technique of thermal treatment is not possible due to the absence of any phase or allotropic transformation. Due to these, the ferritic stainless steel is reported with poor weldability and is less deployed in engineering applications inspite of its attractive economics combined with moderate strength and excellent corrosion resistance in caustic and chloride environments [4].

There is renewed interest in the ferritics due to the increasing cost of nickel which makes the austenitics expensive; and such investigations have been directed towards improving the grain structure of the weld as well as reducing phase in-homogeneity in the weld section which determines the mechanical property of the welded joint [4].

Previous works [4-6] indicate that low heat input welding processes generates lesser metallurgical discontinuity and better microstructural stability relative to high heat input processes; as such extensive works had been undertaken on heat conditions that approximate low heat input welding.

Also the weld cooling cycle is crucial in the control of weld microstructure particularly the time spend above the grain coarsening temperature. This is probably controlled by the heat dissipation mechanism in fusion welds from the peak temperature to the ambient condition. However, the influence of the heat transfer factor in terms of the cooling dynamics on the microstructural features and hence properties of welds have not been well investigated. Additional cooling can assist in the