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Effect of Ru addition on the mechanical properties and microstructure of 316L austenitic stainless steel weld metal

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Abstract

The addition of Ru to the weld metal of 316L austenitic stainless steel (ASS) by Gas tungsten arc welding (GTAW) button welds has shown superior mechanical properties. In the present investigation, the effect of Ru additions on the physical properties of 316L weld was evaluated by investigating the microstructural and mechanical properties of weld metal. The microstructure and mechanical properties of the alloyed button welds were analyzed using optical microscope, scanning electron microscopy (SEM), EDX and Vickers hardness test respectively at 0.1%, 0.5%, 1% and 2% Ru addition. Primary ferrite (FA mode) solidification resulted in primary δ-ferrite and eutectic γ-austenite in the button welds, while hardness values increased to 198 HV with increasing Ru addition up to 2% Ru.

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1 Introduction

Austenitic stainless steels (ASS) are widely used in high performance pressure vessels, nuclear, chemical, process and medical industry due to their very good corrosion resistance and superior mechanical properties [1]. The 316L stainless steel is a Mo bearing austenitic. Welding is a common technique used to join 316L ASS which results in

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the solidified weld metal behaving as a miniature "casting". The welding procedure influences the mechanical properties and the microstructural morphology of the 316L ASS. The L-grades ASSs are generally recognised as resistant to sensitization in short-term exposures or heat treatments such as welding. However, 316L still remains susceptible to other forms of corrosion such as pitting corrosion to a lesser extent compared to conventional Ni -Cr stainless steels such as 304 ASS. Corrosion has cost the stainless steel industry extensively in maintenance and mechanical failures particularly at the welded joints of ASS's. Chernova and Tomashov (1978) showed that a small addition of Platinum Group Metals (PGM) to the weld metal of ASS's caused the cathodic potential to spontaneously move to the passive region through a phenomenon known as "cathodic modification" thus protecting the ASS from corrosion [1,2,3,4]. This work compromised tests validate the potential benefit that Ru addition would have on the corrosion resistance of the weld metal based on microstructural and mechanical properties. Additionally the increase in availability and affordability of Ru in South Africa makes it more feasible as an alloying element in the weld metal of 316L ASS. The microstructural evolution of 316L ASS when it undergoes gas tungsten arc welding (GTAW) and the impact on mechanical properties with increasing Ru addition to the weld metal were investigated. The microstructures of all GTAW button samples exhibited γ-austenite phases with δ-ferrite at the dendritic boundaries. Bulky δ-ferrite phases extending to thin dendrite arms were observed at 0.1 wt% Ru while a skeletal δ-ferrite microstructure was observed with 2 wt% Ru addition. The FA solidification mode suggested that an incomplete solid-state transformation had occurred due the melting of the 316L in water cooled conical shaped copper mould [5,6]. The hardness results revealed that 316L ASS had an increase in hardness as Ru addition was increased due to grain refining nature of Ru. Overall, it was concluded that the addition of Ru exhibits no detrimental effect of the solid state transformation but rather strengthens the alloy as Ru increases. Moreover, it can be deduced that the Ru additions in 316L weld metal not only improve the weld metal mechanical properties but can additionally improve the corrosion resistance of the weld metal [2].

2 Experimental methods

2.1 Generation I welds-GTAW Button on welds

Button melted welds were prepared using GTAW then a variety of tests were performed on button-melted samples. Buttons with total weight of 10 grams were made by gas tungsten arc melting 316L and Ru feed material under argon and then air cooling. The following compositions were added to the button welds: 0.1% Ru, 0.5% Ru, 1% Ru, and 2% Ru (all compositions given as percentage of the 10 grams buttons). Since Ru is a form of powder and can be easily blown away by the arc, the powder was compacted and compressed and placed beneath a piece of 316L parent material. The GTAW button welds were fabricated using a button-arc furnace at Mintek (South Africa) under an argon atmosphere using titanium as an oxygen-getter, and were cooled in the furnace, on a water-cooled copper hearth as shown in Figure 1(a).

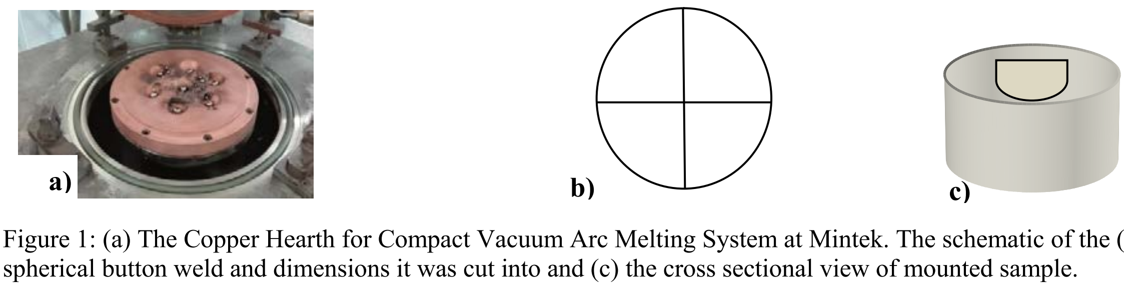

Figure 1: (a) The Copper Hearth for Compact Vacuum Arc Melting System at Mintek. The schematic of the (b) spherical button weld and dimensions it was cut into and (c) the cross sectional view of mounted sample.