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Effect of ruthenium additions on the corrosion and mechanical properties of the weld metal of 316L austenitic and LDX 2101 duplex stainless steels

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Abstract

Austenitic stainless steels (ASSs) and duplex stainless steels (DSSs) 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 (Chernova, et al., 1978). The 316L stainless steel is a Mo containing austenitic steel. Welding is a common technique used to join 316L ASS which results in 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-grade 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. LDX 2101 duplex stainless steel was patented by Outokumpu into 2013. Due to its duplex microstructure LDX 2101 offers very good resistance to intergranular corrosion. Duplex stainless steels are less susceptible to this kind of corrosion than austenitic steels. This study explored the impact Ru addition to the weld metal of 316L and LDX 2101 would have on the mechanical and corrosion resistance properties. Corrosion has cost the stainless steel industry extensively in maintenance and mechanical failures particularly at the welded joints of stainless steels. Chernova and Tomashov (1978) showed that a small addition of Platinum Group Metals (PGM) to the weld metal of ASSs caused the cathodic potential to spontaneously move to the passive region through a phenomenon known as “cathodic modification” thus protecting the ASS from corrosion (Chernova, et al., 1978), (Wolff, 1999) and (Potgieter, et al., 1995).This work compromised tests to validate the potential benefit that Ru additions 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 and LDX 2101. The microstructural evolution of 316L ASS and LDX 2101 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 316L 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 ferrite-austenite (FA) solidification mode suggested that an incomplete solid-state transformation had occurred due to the melting of the 316L in water cooled conical shaped copper mould (Baldissin, et al., 2007). The hardness results revealed that 316L ASS had an increase in hardness as Ru additions were increased due to grain refining nature of Ru. The mechanical properties of LDX 2101 were significantly improved as more Ru was added to the

weld metal. The microstructure exhibited a ferrite matrix and austenite region at 1 wt% Ru addition the grain refining capability of Ru was noted. At 2 wt% Ru addition austenite grains were fully refined into thin grains. The hardness verified this improvement as Ru was added the hardness significantly increased from 230 HV to 235 HV. The potentiodynamic polaristion test indicated that as Ru addition increased there was an increase in corrosion resistance for both 316L and LDX 2101. The corrosion resistance was noted to be peak at 1 wt% Ru addition; thereafter 2 wt% exhibited a decline in corrosion resistance. This was due to the spontaneous passivation of the samples cause by 1 wt% Ru addition and cathodic modification. 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. It can be deduced that the Ru additions in 316L and LDX 2101 weld metal not only improves the weld metal mechanical properties but can additionally improve the corrosion resistance of the weld metal, which confirmed the studies by Potgieter et al. (Potgieter, et al., 2014), and Sherif et al. (Sherif, et al., 2009). The comparative study between LDX 2101 and 316L showed that LDX 2101 exhibited superior mechanical properties compared to 316L and higher hardness values; however this required a secondary post weld heat treatment step to be achieved. The comparative analysis of the potentiodynamic polarisation curves of 1 wt% Ru addition indicated that 316L had lower corrosion rate than LDX 2101.