CHAPTER 1

Introduction

Stainless steels are the most widely used corrosion resistant alloys. They are produced using a variety of manufacturing routes ranging from castings to wrought product forms and welded fabrications for applications as diverse as household utensils to space vehicle components (Baddoo, 2008). In steels with above a minimum content of 10% chromium, a self-healing chromium oxide film is readily formed to provide a protective barrier against further corrosion (Davis, 1994 and Sudesh *et al*., 2006). The various types of stainless steel are generally classified in terms of their crystallographic nature and microstructure typically as ferritic, austenitic, martensitic, duplex, and precipitation hardening grades (Lippold and Kotecki, 2005;Cardarelli, 2008 and Lo *et al*., 2009).

The most commonly used grades are in the 300 series austenitic stainless series, which normally contain at least 18% chromium and 8% nickel. This series is widely used in welded fabrications (Stoenescu *et al*., 2007). The chromium addition provides the protective oxide film, while the nickel addition forms and stabilizes an austenitic matrix (Lo *et al*., 2009). Nickel is not only a more expensive alloy element than chromium, but has also been subject to wide price variations as its availability has varied over the years due to both political and industrial events.

During World War II, increases and variations in nickel prices in the market encouraged research into and development of low-nickel grades of austenitic stainless steel (Charles, 2007 and Quiroz *et al*., 2010). It was found that nickel could be partially substituted by addition of manganese and nitrogen, eventually leading to the market introduction and manufacture of the lower cost 200 Series 200 stainless steels (Kowaka, 1994 and Charles, 2007). Subsequently, copper additions were also included the 200 Series in order to reduce the work-hardening rate and to improve cold working behaviour (Freire *et al*., 2008). For applications that require fabrication by welding, the most suitable of these newer grades to replace the 300 Series are said to be the AISI 204Cu grade or modified AISI 201 (du Toit and Steyn, 2012).

The 300 Series stainless steels are widely used as welded thin sheet fabrication for use in pipeline applications. They can be seam welded without filler addition to obtain complete penetration to 5 mm depth generally by employing tungsten inert gas (TIG)/ gas tungsten arc (GTA) welding process (Koseki *et al*., 1999; Baddoo, 2008;Shiokawa, 2008 and Shyu, 2008). If the 200 Series are to provide an equivalent, but lower cost, substitute for the higher nickel 300 grades then a clear knowledge and understanding of their welding metallurgy is essential to achieve the correct mechanical and chemical properties of welded regions and to ensure effective process controls (Khan, 2007).

The performance of any welding process depends on the control of welding parameters such as shielding gas mixture, weld current mode, heat input, and particularly the solidification cooling rate (Arata *et al*., 1977; Elmer *et al*., 1990-a and 1990-b; Lothongkum *et al*., 1999 and 2001; Durgutlu, 2004; Xu *et al*., 2006; Lee *et al*., 2007; Huang, 2009, and Yousefieh*et al*., 2011).

Lack of control during welding can lead to the formation of deleterious microstructures during or after the solidification process resulting in degradation in properties, notably reduction in toughness, in weld zones. (Koseki *et al*., 1999). Microstructural variations are related to the level of retained δ-ferrite and the presence intermetallic phases (Lothongkum *et al*., 2001). Arc weld methods usually generate a high rate of heat input within the fusion and heat affected (HAZ) zones (Lee *et al*., 2009a). The formation of chromium-rich carbide phases at grain boundaries during cooling can intensify the susceptibility to intergranular corrosion (IGC), particularly at boundaries between different zones in the weld region (Ahn and Kwon, 2005). Welded areas, when exposed to chloride-containing environment, may be sensitive to localized pitting corrosion and stress corrosion cracking (SCC) (Bhadeshia, 2002, Zinn *et al*., 2002, Lu *et al*., 2005 and Alyousif *et al*., 2007). Therefore, during welding, it is important to understand the critical factors that will affect weld quality.

In this study, the TIG/GTA welding process was selected for the fabrication of austenitic stainless steel thin sheets intended for use in pipeline applications, which involve mild corrosive environment and relatively small applied loads. AISI 304 austenitic stainless steels (AISI 304 and AISI 304L) are used as reference steels for comparison with potential, cheaper alternatives from the Mn-substitution austenitic stainless steels (Mn-ASS: 5-7 wt% Mn). Microstructures, mechanical properties and corrosion behaviour have been studied both before and after TIG/GTA welding.