CHAPTER 1

INTRODUCTION

Austenitic and austenitic-ferritic (duplex) stainless steels find wide utilization in many engineering applications. These steels present excellent combination of corrosion resistance, ductility, toughness and weldability. They are used as structural materials and components of heat transfer equipment in the chemical and petrochemical industries. In the nuclear industry theses steels are employed as cladding materials in reactor pressure vessels and control rod assemblies as well as cooling system piping.

A serious drawback to the use of such steels and their weldments is the degradation of corrosion and mechanical properties within certain high temperature ranges due to changes in the microstructure.

Welding of austenitic stainless steels 304L, 316L and duplex stainless steels requires a great degree of control. Poor welding practice can result in a severe loss of corrosion resistance. During the weld thermal cycle, relatively narrow region of the material is subjected to a wide range of peak temperatures and cooling rates resulting in a variety of microstructures and changes in the properties of the affected area.

Austenitic stainless steels can be susceptible to intergranular corrosion (sensitization) caused by chromium depletion in the regions next to grain boundaries due to precipitation of $M_{23}C_6$ carbides during usage in the 540°C to 860°C temperature range. In the case of molybdenum- containing austenitic stainless steels, such as AISI 316 and 316L types, long exposure times at temperatures ranging from 650 to 900°C can lead to the precipitation of the intermetallic sigma phase. During solidification or welding delta (δ) - ferrite phase formation might occur which renders the steel even more prone to precipitation of sigma phase.

In comparison to austenitic stainless steels, precipitation of sigma phase in duplex stainless steels occurs, within the ferrite phase at shorter times, at higher temperatures and with large volume fractions. For example, an aging treatment for 3 hours in the 800 to 850°C temperature range is sufficient for the formation of 15 to 20% of sigma phase. In contrast to the carbides that form an almost continuous network in the austenitic regions, sigma phase is finely distributed within the ferrite. The emergence of carbide precipitates and sigma phase in the microstructure of austenitic and duplex stainless steels can render them susceptible to embrittlement since such phases suffer brittle fracture and offer a path for brittle crack propagation thus reducing ductility and toughness. It should me mentioned that the weld metal behavior of these steels is not as good as the base metal by virtue of the relatively higher ferrite and inclusions content in their microstructure.

Pressurized water reactors (PWRs) power control system includes control rod assemblies and a solution of boric acid in the primary coolant. The concentration of boric acid is varied to control long- term reactivity changes such as fuel depletion and fission products. Lithium hydroxide is added to the solution to adjust pH.

In addition, austenitic stainless steels possess unique mechanical properties, which makes them useful at cryogenic (very low) temperature applications. These applications encounter handling and storing liquified natural gases as liquid oxygen and nitrogen with boiling temperatures of -183 and -196°C respectively. At such cryogenic temperatures these steels have tensile strength substantially than at ambient temperatures, while their toughness is slightly degraded. For the design and safety aspects, it is necessary to investigate the low temperature impact properties of weld metals of these steels since weld metals have higher susceptibility to embrittlement than their counterpart base metals.

On the other hand, duplex stainless steels have a two phase microstructure of ferrite and austenite in approximately equal volume fractions and its applications combine pipelines for gas and oil, heat exchangers and pressure vessels. For pressure vessel applications duplex stainless steel provide high tensile yield strength and very strong work hardening capacity by virtue of the beneficial effect of the austenitic phase. However, using duplex stainless steel in the pressure vessel field application has been restricted due to lack of technical experience concerning knowledge of fracture behavior. Since duplex stainless steels contain half as much of ferrite phase, therefore, they have not found wide applications in cryogenic service. Nevertheless, assessment of their fracture mechanism at low temperatures is a requirement since they have readiness to undergo ductile to brittle transition.

The main aim of the present work is to evaluate the effect of aging temperature at 475, 650, 750 and 850°C for 3 hours on the microstructure, ferrite content, mechanical properties (hardness, impact toughness) and corrosion resistance of two types of austenitic stainless steels (304L, 316L) and one type of duplex stainless steel base and weld metals. Welding processes included Shield Metal Arc Welding (SMAW) and Tungsten Inert Gas (TIG). Impact energy of base and weld metals were also determined for the investigated materials between room temperature and liquid nitrogen temperature. Corrosion characteristics were studied in two different media, 2400ppm boric acid solution containing 4ppm LiOH and 1% NaCl solution using cyclic polarization technique.