ABSTRACT

Super austenitic stainless steels (SASS) are widely recognized for use in modern technology due to their versatile range of mechanical properties and corrosion resistance. SASS belongs to the family of high alloy steels with chromium (19-28 wt %) and nickel (17-24 wt %) being the principal alloying elements. They also contain molybdenum (2- 8 wt %) and nitrogen (0.15-0.5 wt %) as the supplementary alloy additions. Though conventional austenitic stainless steels (304, 316 and 317, etc.) are widely used for corrosion resistance applications, they do not have sufficient corrosion resistance and high strength for some critical applications. With the advent of nitrogen and molybdenum alloying, this notion has changed to give rise to SASS and the newly developed SASS has exceptional strength, toughness and corrosion resistance. Some very common applications of SASS involve piping in gas, oil, pulp and paper industry or structures for heat exchanger and seashore applications.

The main difficulty in the production of SASS is the solubility of nitrogen. Therefore SASS has been processed by several advanced techniques such as AOD, VOD, VIM, ESR, VAR etc. and by a stringent process control. Among the various techniques one common limitation existing is that all these processes have to be processed in controlled atmosphere conditions with specialized equipment, which is highly expensive.

Hence, the present research focuses with the production of high performance super austenitic stainless steel in the low cost conventional air induction melting and to bridge the gap between conventional melting technique and advanced melting techniques on the development of SASS. This work involves production and characterization of high Mo cast SASS in both i) solution-annealed and ii) isothermal aged conditions. The methodology adopted in the present work is discussed briefly in the following chapters as given below:

Chapter 1 gives introduction to SASS, its advantages over the conventional austenitic stainless steels, need for improving the properties of SASS and the means by which the high performance SASS is achieved. A detailed literature review on the types of stainless steels, production, solution-annealing treatment, isothermal ageing treatments, corrosion resistance of the SASS have been reported in Chapter 2. Though extensive work on characterization of SASS have been carried out, the production of high Mo SASS in conventional melting furnace and further processing it by isothermal ageing have not been reported yet. The effect of precipitate phases on the mechanical properties and theoretical aspects of the precipitate formations are not reported for the high Mo SASS. So to bridge the gaps in the literature, this SASS is taken to carry out the detailed investigation.

The main focus of this research work is to understand the role of Mo and N content in improvement of the yield strength, the toughness and the pitting resistance of the solution-annealed SASS. Also, the effect of Mo and N content on the formation of precipitate phases and its consequence on mechanical and corrosion properties of the isothermally aged conditions have been investigated. The scope of the present investigation is also presented in chapter 3. The steps and sequence of alloy addition employed in the production of selected alloys are given in chapter 4. Also, the detailed methodology adopted in analyzing the metallurgical characteristics of the investigated alloys for studying the microstructural analysis, hardness, tensile properties, toughness and corrosion resistance of the both solution-annealed and aged alloys are discussed in chapter 4.

The results and discussion on the findings of the present research work is given in chapter 5 as pertained to production of SASS, characterization of solution-annealed cast alloys and isothermal ageing of solution-annealed cast alloys. In production, the actual nitrogen solubility obtained in the alloys is compared with the theoretically calculated nitrogen solubility of the corresponding alloys using thermodynamic equation. Sigma-solvus temperature (dissolution of sigma in austenite) of the SASS was predicted and the same was experimentally validated to the investigated alloys.

For the cast SASS solution-annealed between 1100 to 1250^{o}C, the results and discussion is made on the microstructure, hardness, tensile strength, toughness and resistance to pitting corrosion. It is observed that the optimum solution-annealing is 1250^{o}C to achieve better mechanical properties with excellent resistance to pitting corrosion.

The results, discussion and detailed analysis of isothermally aged alloys for different time intervals at various temperatures between 500°C to 1000°C are made to study its effect on the precipitate formations, mechanical properties and corrosion properties. The fractography analysis carried out on the impact samples for all the heat treated alloys using SEM are reported. Chi (χ) phase is formed from 500°C to 800°C, and the sigma (σ) phase is formed at temperatures above 900°C. Compared with chi (χ) phase, the sigma (σ) phase contains more Mo. Toughness and pitting resistance decreases with increase in volume percentage of chi (χ) and sigma (σ) phases.

The results of this research clearly indicates nitrogen solubility can be easily achieved up to 0.42 wt % and it gives maximum tensile strength of 789 MPa with 38 % elongation and impact toughness as high as 216 joules. The SASS with higher nitrogen gives better corrosion resistance and pitting resistance is good up to 900°C and above that temperature the pitting resistance decreases by the formation of secondary phases like chi and sigma phases

The results also clearly indicate the fact the formation of chi and sigma phases increase only hardness with reduction in toughness, strength and corrosion resistance.

The conclusion of this research work and scope for the future work has been summarized in Chapter 6.