STUDIES ON CHARACTERIZATION OF NITROGEN ALLOYED DUPLEX STAINLESS STEEL IN THE CAST AND FORGED CONDITION

A THESIS

Submitted by

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ABSTRACT

Duplex stainless steel (DSS) is a material with better corrosion resistance and mechanical properties. Duplex Stainless Steels have widespread use in various industries, particularly in Oil and Gas, Petrochemical, Paper and Pollution Control industries. It is apparent that a balance of ferrite and austenite phase in a microstructure made it realistic for applications which demand better corrosion resistance and improved mechanical properties. Duplex Stainless Steels have the advantage in replacing nickel which is costly. In addition to cast state, Duplex Stainless Steels have also been used in mechanically formed state.

The main difficulty in the production of DSS is the solubility of nitrogen. Therefore Duplex Stainless Steels have to be processed by several techniques and also by stringent process control. Several techniques used for processing involves AOD, VOD, VIM VAR, Electron Beam Remelting etc. Among the various techniques one common limitation existing is that it has to be processed in controlled atmospheric conditions with specialized equipment which is highly expensive.

Conventional induction melting can be opted as a better choice to overcome the above stated limitations when supported by proper alloy design and process control. The work involves production and characterization of nitrogen alloyed Duplex stainless steel in cast and forged condition which is given below in various chapters.

Chapter 1 gives introduction to DSS, its advantages over other types of stainless steels, need for improving thermo mechanical treatment of DSS and the means by which the same is achieved.

A detailed literature review on the types of stainless steels production, Solution treatment temperatures, Corrosion effects and thermo mechanical treatment on DSS has been presented in Chapter 2.

Investigations have confirmed the following observations.

- Increase in nitrogen solubility with increasing volume of elements like Cr, Mo, Mn and an increase in austenite phase with increasing volume of Ni, N, Mn, and Si.
- Formation of secondary phases that are detrimental when aging is done at 850°C for different periods of time.
- Optimum hot working temperature should be greater than 1000° C and less than 1200°C.
- Increase in corrosion resistance in chloride atmosphere depends on appropriate ferrite-austenite phase balance.
- Bulk texture in two phase alloys are generally weak as compared to single phase alloys.

Though extensive work on characterization of duplex stainless steel has been done, the production of nitrogen alloyed DSS in conventional induction furnace and further processing it by hot forging have not been reported. The present work has been taken up to produce DSS with different nitrogen contents using quality tools like QFD and FMEA , to study the effect of solution treatment between 1010°C to 1140°C with increments of 10°C and then hot forging to study the effects of various size reductions.

Interest was particularly focused on understanding the role of nitrogen in improving the mechanical properties like hardness, impact strength, tensile strength and yield strength in DSS specimens before and after hot forging.

The scope of the present investigation is presented in Chapter 3. Chapter 4 discusses in detail the various experimental procedures adopted in the study.

The data on results and detailed discussions on the findings of this research work are given in Chapter 5 under phase 1, phase 2, and phase 3.

In phase 1 the results and discussion of alloy design using QFD and production process control using FMEA are presented. The actual nitrogen solubility achieved is compared with estimated theoretical nitrogen solubility. Actual phase ratios achieved are in agreement with the theoretical phase ratio achieved in Schoefer diagram. Discussion is made on the mechanical properties of DSS alloys with three different nitrogen contents.

In phase 2 the results, discussion and detailed analysis are made on the effects of ferrite volume and micro hardness on solution treatment temperatures ranging from 1010°C to 1140°C with increments of 10°C. Corrosion rate is tested for the same solution treated specimens and discussion is made on the results. It is observed that optimum solutionizing temperature range is 1050°C-1140°C to achieve better mechanical properties without the formation of secondary phases.

The results, discussion and detailed analysis of phase 3 are made on the hot forged DSS to study its effects on microstructure, mechanical properties and texture. Fracture surface analysis carried out on impact specimens for all the three alloys using SEM are discussed with respect to the effect of impact toughness. Increase in ferrite content and hardness are noticed after hot forging. Inverse pole figures and orientation distribution function of 48% reduced specimens of all the three alloys reveals better texture of austenite phase with increase in nitrogen content.

In Chapter 6, major conclusions of this work and scope for future work are summarized.