MICROSTRUCTURAL SIMULATIONS AND PROPERTY EVALUATION OF HEAT TREATED NICKEL FREE HIGH NITROGEN AUSTENITIC STAINLESS STEEL

A THESIS

Submitted by

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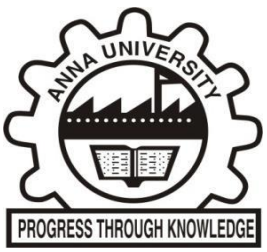

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ABSTRACT

Nickel Free High Nitrogen Stainless Steels (NFHNSS) are a group of high-strength and non-magnetic austenitic steels used in medical and petro-chemical industries. These steels exhibit high strength, toughness along with high resistance to corrosion. Though Ni addition enhances many desirable properties in stainless steels, it causes allergy in human and animal bodies. To counteract these effects, low nickel and nickel-free austenitic stainless steels were developed. Manganese and nitrogen are commonly used as substitutes for nickel in austenitic stainless steels. Addition of these elements promotes the formation of nitrides as well as intermetallic precipitates during various heat treatments. Size and morphology of these precipitates strongly influence the mechanical properties and corrosion behavior of NFHNSS. Thermodynamic, kinetic simulations and microstructural simulations are important approaches to design of alloys along with its precipitates and metallurgical process parameters to obtain better material properties. Phase Field Modelling (PFM) is a new approach to simulate microstructure evolution in various materials. Even though a lot of work on bio compactable behavior of NFHNSS have been carried out, research of CALPHAD aspects of precipitate formations, influence of aging and precipitate phases on mechanical properties and corrosion behavior of NFHNSS are very limited. Microstructural simulation of nitride precipitation by PFM for NFHNSS has not yet been reported.

This research focusses on the microstructural evolution in NFHNSS by PFM, particularly chromium nitride (Cr_2N) precipitation as well as precipitation kinetics under different aging conditions using the CALPHAD approach through ThermoCalc and TC-PRISMA software. Results of the simulation studies were experimentally validated. Effect of precipitate morphologies on the tensile properties, stain hardening behaviour, hardness, toughness and corrosion behaviour of NFHNSS under different aging temperatures has also been investigated.

TC-PRISMA simulations of NFHNSS alloy aged for 14 hours at 700 ^{o}C, 800 ^{o}C and 900 ^{o}C showed the similar volume fraction of Cr_2N precipitates at the austenite Grain Boundaries (GB). However, the size of the precipitate increased with increasing aging temperature. Calculated driving force and nucleation rate for the Cr_2N precipitate formation were found to be much higher in samples aged at 900 ^{o}C. Using Phase Field Simulations, growth kinetics of Cr_2N precipitates was analyzed in 1D and 2D mode. Mn does not favour for the growth of Cr_2N precipitates in austenite matrix. Diffuse interface thickness limits the diffusion of elements into precipitate and hence reduce the growth rate of precipitate for higher time steps.

NFHNSS samples aged at 700 ^{o}C, 800 ^{o}C and 900 ^{o}C showed discrete needle shaped nitrides, lenticular shaped nitrides and disc shaped nitrides respectively at the GBs. Hardness, tensile and impact toughness properties of NFHNSS are significantly influenced by both growth rate and morphology of nitride precipitates in the austenite matrix. Depletion of Cr and N solute atoms in austenite matrix during the formation of Cr_2N precipitates led to a reduction in UTS, YS as well as hardness at higher aging temperatures. A two-stage strain hardening behavior of NFHNSS was calculated using the Ludwigson equation. Strain hardening behavior of NFHNSS was found to be reduce with increasing aging temperature. In NFHNSS, the presence of needle like nitride precipitate at GBs of austenite and coarse lamellar austenite accelerates the rate of pitting corrosion. Disc shaped precipitates at grain boundaries resulted in enhanced pitting corrosion resistance to natural seawater. NFHNSS samples aged at 900 ^{o}C exhibited a higher repassivation behaviour compared to other aged and solution annealed samples.

The results of this research clearly indicate addition of Mn does not favour for the growth of Cr_2N precipitates in NFHNSS. Size of Cr_2N precipitate increased with increasing aging temperature. Size and morphology of Cr_2N precipitate significantly influence the mechanical properties and corrosion behaviour of NFHNSS.