PREFACE

Superalloy IN718 is a popular nickel-iron based superalloy designed for application as turbine components of different types. It finds extensive application in aerospace and petro-chemical industries due to excellent combination of good strength up to high temperature of 650°C, corrosion resistance and ease of fabrication. Because of these attractive properties, it has been extensively used in critical gas turbine engine components like compressor blades, discs, shafts, and casings, etc. Two precipitating phases, gamma prime (γ') and mainly gamma double prime (γ'') are responsible for strengthening of the austenitic gamma (γ) matrix.

Although Ni-base superalloy IN718 possess good strength at the operating temperatures of turbines, but suffer from hot corrosion from salts like NaCl, Na_2SO_4, and V_2O_5. In marine gas turbines, filters are used to remove NaCl particles suspended in air, however, since volume of the air used is too large, NaCl particles invariably remain there in the ingested air. Sulfur and vanadium in the fuel form Na_2SO_4 and V_2O_5 compounds during combustion. Deposition of salts on surface of alloys leads to deterioration of the protective oxides. As the time passes corrosion products penetrate the alloy by diffusion, corrode the substrate repeatedly and roughen the surface. It is well known that in hot corrosion salt/salt mixtures fuse and accelerate the rate of oxidation and sulfidation of superalloys at elevated temperature. There are two types of hot corrosion; high-temperature hot corrosion (HTHC) above 750°C, and low temperature hot corrosion (LTHC) in the temperature range of 550 to 750°C. In the HTHC, Na_2SO_4 undergoes melting whereas in LTHC it forms eutectic of Na_2SO_4-MSO_4 (M = Ni, Co, and Fe).

Several means are being used to modify the surface and develop nanostructure. Ultrasonic shot peening (USP) is a relatively new process of generating surface nanostructure. Mechanical properties of metallic materials are significantly improved by surface nanostructuring without changing their chemical compositions. Enhancement in oxidation and hot corrosion resistance from surface nanostructuring is achieved by the formation of dense chromium oxide layer at the surface of the specimen.

Fatigue properties are significantly affected by the environment of exposure. High cycle fatigue behavior of superalloys in corrosive environment at elevated temperature causes reduction in fatigue life. Formation of pits on the smooth specimen in the corrosive environment causes reduction in the number of cycles for fatigue crack initiation due to high stress concentration at the bottom of the pits. Most engineering components and structures experience both an alternating stress and mean stress during their service life. For a metal, tensile mean stress is usually detrimental and compressive one is beneficial. Tensile mean stress is known to reduce the stress range for the specific fatigue life whereas compressive mean stress increases the allowable stress range for specific fatigue life. Thus the ability to predict the mean stress effect on fatigue resistance is of much importance in engineering design.

The present study deals with hot corrosion and high cycle fatigue behavior of the superalloy IN718. The thesis comprises of **seven chapters**.

Chapter-1 presents a brief introduction along with literature review on properties and applications of the Superalloy IN718. It also presents the details of hot corrosion and hot corrosion resistance in metals/alloys. The objectives of present investigation are listed at the end of this chapter.

Chapter-2 deals with details of the experimental procedure of hot corrosion and high cycle fatigue of the superalloy IN718. USP and characterization of the nanostructure in surface region of the superalloy IN718. The superalloy IN718 was procured from MIDHANI, Hyderabad (INDIA), in solution annealed condition, in the form of rods of 20 mm diameter with chemical composition Ni-53.5, Cr-17.91, Nb-5.22, Ta-3.1, Ti-1.04, Al-0.5 and Fe-balance (wt.%). It was subjected to double aging heat treatment cycle (720ºC for 8 hours, furnace cooled at the rate of 55ºC/hour to 620ºC, held at 620ºC for 8 hours followed by forced air cooling).

Chapter-3 presents the effect of surface roughness and USP on hot corrosion behavior of the superalloy IN718 in simulated salty environment of gas turbine engine, at 600ºC. Samples of varying roughness (400-1000 grit) were spray coated with the salt 1S (100 wt.% NaCl) and salt mixtures 2SM (60 wt.% Na_2SO_4 + 40 wt.% V_2O_5) and 3SM (75 wt.% Na_2SO_4 + 15 wt.% NaCl + 10 wt.% V_2O_5) and exposed at 600^0C in air up to 100 hours. The corrosion products were characterized using different tools such as XRD, SEM/EDS and EPMA. Corrosion kinetics showed that the rate of corrosion was highest for the lS coated sample at all the levels of surface finish followed by that coated with 3SM and was lowest for the 2SM coated. The oxide layer was found to be less protective at higher surface roughness due to larger surface area and enhanced diffusion of corrodants in the material. Ultrasonic shot peening, a novel technique of surface modification was found to enhance the hot corrosion resistance in the salt/salt mixtures at 600ºC by promoting the formation of highly protective Cr_2O_3 layer in the surface region.

Chapter-4 presents the effect of surface roughness and USP on hot corrosion behavior of the superalloy IN718 in 100 wt. % NaCl (1S) and in salt mixtures of 60 wt.%

Na_2SO_4 + 40 wt.% V_2O_5 (2SM) and 75 wt.% Na_2SO_4 + 15 wt.% NaCl + 10 wt.% V_2O_5 (3SM), deposited separately by spray gun technique, at elevated temperature of 700ºC. The weight gain per unit area at 700ºC was increased by 49% for salt S, 153% for the dual salt mixture 2SM and only 8% for the triple salt mixture 3SM, in comparison with that observed earlier at 600ºC. The marked increase in the severity of corrosion at 700ºC was attributed to formation of the highly damaging compound $NaVO_3$ that significantly enhances the oxygen activity, in the 2SM coated samples. The effect of surface roughness on corrosion behavior at 700ºC, however, was found to be similar to that at 600ºC. Ultrasonic shot peening, a novel technique of surface modification was found to enhance the hot corrosion resistance in the salt/salt mixture at 700ºC appreciably due to extensive grain refinement to nanoscale and formation of highly protective Cr_2O_3 layer in the surface region.

Chapter-5 describes the high cycle fatigue behavior of the superalloy IN718 in the air at 600ºC in fully reversed stress controlled mode (R= -1), in the as heat treated condition as well as pre hot corroded in the salt mixture of 75 wt.% Na_2SO_4 + 15 wt.% NaCl + 10 wt.% V_2O_5 at 600ºC for 100 hours. Fatigue life of the pre hot corroded specimens was drastically reduced at all the stress amplitudes studied. The variation of fatigue life with stress amplitude followed the Basquin relationship. The endurance limit of pre hot corroded specimens was reduced by 100 MPa in respect of that of the as heat treated sample. The reduction in fatigue life was found to be associated with pits formed on the surface due to evaporation of chlorides, from the prior hot corrosion in the above salt mixture, which led to early fatigue crack initiation and rapid crack propagation.

Chapter-6 presents the effect of mean stress on high cycle fatigue behavior of the superalloy IN718 at 600°C, at stress ratios (R) -1, 0.5, and 0.7. There was decrease in fatigue life, with increase in the tensile mean stress. At high mean stress, the decrease in fatigue life is found to be associated with multiple crack initiation sites at the specimen surface. The fatigue limit is found to be strongly affected by the tensile mean stress and stress ratio, R=0.7, since the maximum stress approaches near the yield stress and causes cyclic ratcheting.

Chapter-7 presents the overall summary of the present investigation, including important conclusions and suggestions for further work.