Abstract

The present study aims to investigating the effect of electron beam processing (surface melting and welding) and laser processing (surface melting and welding) of Inconel 718 on its microstructure, mechanical properties and electro chemical properties. The study has been divided in to four parts: (1) electron beam surface melting, (2) laser surface melting, (3) electron beam welding, and (4) laser welding of Inconel 718. Electron beam surface melting has been carried out at using an indigenously developed conventional electron beam processing unit (with a capacity of 80 kV acceleration voltage & a power of 12 kW) at a constant voltage of 40 kV with varying scan speed from 500 mm/min to 1000 mm/min. Electron beam welding of Inconel 718 alloy was carried out using a constant acceleration voltage of 70 kV, welding speed of 2000 mm/min under varied currents of 45 mA, 58 mA and 67 mA, respectively. Laser surface melting and welding of Inconel 718 was carried out using 2 kW continuous wave Yb-fibre laser. Surface melting has been conducted with a power of 400 watts, scan speed of 500, 750, and 1000 mm/min and with a spot diameter of 3 mm. Laser welding was carried out at constant power 1800 watt with a varying scan speed of 1400, 1200 and 1000 mm/min, respectively. The detailed study involves understanding of the effect of process parameters on surface morphology, bead geometry, microstructure, residual stress, microhardness, wear resistance, and electrochemical properties.

Electron beam surface melting forms a defect-free microstructure with the depth of melting varying from 240 μm to 720 μm and the depth of melting decreases with increase in scan speed. The microstructure of the melt zone is having dendritic morphology and consists of gamma (γ), gamma prime (γ') and small fraction of gamma double prime (γ'') along with few precipitates. Electron beam surface melting introduces residual compressive stress (-180 MPa to -1000.21 MPa) which varied with process parameters. Due to electron beam surface melting, there is increase in surface hardness from 278 VHN for as received Inconel 718 to 950 VHN for electron beam melted Inconel 718. Maximum microhardness is observed at a depth below 100 to 200 μm from the surface. Microhardness was also found to vary with heat input parameters. The optimum process parameters of electron beam surface melting corresponding to development of defect free microstructure with presence of compressive residual stress below yield strength. Due to

electron beam surface melting, there is a significant decrease in corrosion rate with a maximum decrease observed for the samples melted with a scan speed of 1000 mm/min. The pitting corrosion resistance remained unaffected because of electron beam surface melting. Electron beam surface melting caused a marginal decrease in wear kinetics and wear coefficient.

Laser Surface melting offers a defect free melt zone with depth varying from 388 μm to 453 μm. In the microstructure, there is presence of gamma double prime (γ'') phase in addition to gamma (γ) and gamma prime (γ') phases. The microhardness of the melted zone was found to vary from 425 VHN to 475 VHN. A detailed electron back scattered diffraction (EBSD) analysis was conducted to understand the grain size and its distribution, grain boundary rotation angle, and texture. Laser surface melting with the parameters (750 mm/min) shows a minimum wear kinetics under steady state wear. Wear coefficient was also found to vary with laser parameters and a minimum wear coefficient was observed when laser melted using scan speed 500 mm/min and power of 400 watts. Wear rate was found to be reduced due to laser surface melting and decreased with increase in scan speed.

Electron beam welding was successfully applied to weld Inconel 718 of thickness 3 mm. the microstructure was dendritic with the presence of gamma (γ) and gamma prime (γ') and gamma double prime (γ'') phases. There is improvement in microhardness due to electron beam welding (471.6 VHN to 520.5 VHN) as compared to as received Inconel 718. A detailed study of the mechanical properties shows that there is reduction in strength and percentage elongation due to electron beam welding as compared to base metal. Though the corrosion rate in 3.56 wt.% NaCl solution was reduced due to laser surface melting, however, pitting corrosion resistance was improved due to laser surface melting. Laser beam welding leads to marginally decrease in hardness for all the parameters except a few. There is a significant decrease in nano hardness and young modulus but increase in toughness due to laser welding. A detailed crystallographic texture was studied by electron back scattered diffraction (EBSD) analysis to know the crystallographic orientation.

Based on the detailed correlation between microstructure, process parameters and microhardness, the processing region for electron beam surface melting of Inconel 718 were as follows: at constant current of 10 mA, and acceleration voltage 40 kV with varied scan speed between 500 to 1000 mm/min. The most important outcome of electron beam surface melting of Inconel 718 is the increased corrosion resistance of electron beam surface melted specimens in comparison to as received Inconel 718. When processed using a scan speed of 750 mm/min and 1000 mm/min, an improvement in corrosion resistance property is observed for sample melted using a scan speed of 750 mm/min. (0.04 mm/year) as compared to 0.39 mm/year for as received Inconel 718. Laser surface melting of Inconel 718 was performed at constant power of 400 watts and with varying scan speed between 500 mm/min to 1000 mm/min. In laser surface melting the main outcomes are corrosion resistance, due to laser surface melting, there is improvement on corrosion resistance when processed using a scan speed of 500 mm/min (0.17 mm/year) and 1000 mm/min. (0.18 mm/year) as compared to 0.39 mm/year for as received Inconel 718. Electron beam welding of Inconel 718 has been carried out at constant scan speed of 2000 mm/min and acceleration voltage 70 kV with varied current of 45 mA, 58 mA, and 67 mA. Detailed study of the corrosion behavior in a 3.56 wt.% NaCl solution shows that there is no significant variation in corrosion rate due to electron beam welding. However, an improvement in corrosion rate could be achieved by proper selection of process parameters in electron beam welding. Laser welding has been carried out at constant power 1800 watt with varied scan speed 1000 mm/min to 1400 mm/min. However, there was improvement in hardness because of laser welding (278 to 319 VHN)

Inconel 718 possesses good fatigue strength, cryogenic properties, a high temp oxidation resistant and creep resistant properties. As a result, it is commonly used as structural materials over a wide temperature range starting from cryogenic temperature to as high as up to ~700°C. The possible application of the surface melted Inconel 718 will be components in aircraft engine like, spool, combustion casing, turbine disc, gear components etc. and the possible application of welded Inconel 718 will be components of jet engines, jet turbine like forging parts, pump components like stator and rotor, cryogenic storage tank, pressure vessels for rocket, etc.

Keywords: Electron Beam, Laser, Surface Melting, Welding, Inconel 718, Wear, Corrosion, EBSD