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# Studies on Electron Beam Welded Inconel 718 Similar Joints

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**Abstract**

In the present study, electron beam welding of solution treated Inconel 718 alloy (3 mm thickness) was carried out under varied parameters (50, 60 and 70 kV voltage: 64, 60, and 57.2 mA current:  and 1600, 1800 and 2000 mm/min scan speed) in vacuum (1.6*10-5 mb). The effect of process parameters on microstructure, mechanical properties and electrochemical properties was meticulously studied. It was observed that the shape and size of weld zone and heat affected zone (HAZ) varies with process parameters. The detailed corrosion behaviour shows that there is no deterioration of corrosion resistance property in a 3.56 wt. % NaCl solution due to electron beam welding.


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## 1. Introduction

Inconel 718 alloy is a precipitation hardening nickel-based alloy, which shows exceptionally high yield, tensile strength and creep-rupture properties at temperatures up to 650°C. Apart from superior mechanical properties, the alloy also offers good corrosion resistance, and by virtue of this, considerable research is emphasised on its application as components in aerospace and turbine jet engines. Unlike other precipitation hardening Ni based alloys, the chief hardening phase in Inconel 718 being γ' Ni3(AlTi), γ" (Ni3Nb) and some carbides, the alloy shows good weldability owing to its sluggish precipitation kinetics.  The slow ageing response allows the stress generated during precipitation to be accommodated thereby reducing post welding cracking tendency [1, 2]. This superior weldability in Inconel 718 is attributed to higher Nb content therein. However, higher Nb content  intensifies the segregation phenomenon in the weld fusion zone, which ultimately leads to the precipitation of low melting eutectics in the

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interdendritic region in the form of Carbides and Laves phases [3,4]. Since electron beam welding is characterized by extremely fast heating and cooling cycle, it drastically reduces the segregation tendency in Inconel 718 alloy, thereby making it the most preferable welding technique for such alloy [5, 6]. Furthermore, the quantum of heat input during welding also plays a very important role in the extent of segregation and Laves phase formation. Welding performed with lower heat input ensures a steep thermal gradient during cooling, which inhibits segregation of solutes like Nb, Mo and Ti to the interdendritic region. Thus, lower heat input welds are found to have lower Laves phase content in the fusion zone. However, due to the steep thermal gradient during cooling of weld fusion zone, lower heat input welds may be prone to solidification cracking due to build-up of post weld stresses.

In the present study, electron beam welding of solution treated Inconel 718 alloy has been carried out under varied electron beam parameters in vacuum (1.6*10-5 mb). The effect of electron beam welding on its microstructure and corrosion resistance has also been studied in details.

## 2. Experimental

Initially the uneven plate of 3.5 to 4.5 mm thickness was cold rolled to uniform 3 mm thickness and subjected to solutionizing heat treatment at 980°C for 1 hr followed by water quenching. The solution treated sample was cut into 120 X 40 X 3 mm and then used for bead on plate electron beam welding. An electron beam machine with maximum 80 kV and 12 kW power was used for welding processing. The electron beam machine parameters were designed based on the parameters as selected in earlier EBW studies on Inconel 718 done by Agilan et al [7]. The processing was done in three constant levels of heat input (120 J/mm) with varying voltage (50, 60 and 70 kV), current (64, 60 to 57.2 mA) and scan speed (1600, 1800 and 2000 mm/min) of electron beam (Table 2). Specimens were prepared by cleaning with acetone before processing.

Table 1 – Summary of Chemical composition (wt.%) of Inconel 718 plate used in this study

| Elements | Ni | Cr | Fe | Nb | Al | Ti | Mo | Pb | Others |
|---|---|---|---|---|---|---|---|---|---|
| Wt % | 51.0 | 17.45 | 19.53 | 5.0 | 0.46 | 0.87 | 2.98 | 0.17 | Balance |

Table 2 - Electron beam welding parameters for Inconel 718 alloy

| Sample No. | Accelerating Voltage (kV) | Current (mA) | Weld Speed (mm/min) | Heat input (J/mm) |
|---|---|---|---|---|
| A | As-received Inconel 718 Base Metal | | | |
| B | 50 | 64 | 1600 | 120 |
| C | 60 | 60 | 1800 | 120 |
| D | 70 | 57.14 | 2000 | 120 |

The welds were cut across the welding direction by an abrasive cutter. The cut samples were carefully polished and etched for microstructure observation by Optical microscopy. The samples were then subjected to ageing treatment at 720°C for 8 hrs followed by cooling at 50°C/hr to 620°C where it was held for another 8 hrs thereafter water quenched. The transverse section the electron beam welded samples were polished and etched with the mixture of concentrated acids comprising of HNO3, HCl and HF in the ratio 2:2:1. The microstructures of the melted material (the cross section) were characterized by field emission scanning electron microscopy (SUPRA 40, Zeiss SMT AG, Germany). A detailed analysis of the phase and composition was carried out by X-ray diffraction technique (D8 Advances, Bruker AXS, Germany), respectively. The top surfaces of the welds samples were