Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 1, No. 3, January : 2024

REVIEW ON MICROWAVE HYBRID HEATING ON INCONEL 625 ALLOYS-

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ABSTRACT-
The Inconel alloy has vast application in the research field, Fabrication of these alloys is complex. Microwave hybrid heating (MHH) in joining of Inconel 625 plays a significant role and eliminated the many limitations of conventional heating -techniques. No optimal Parameter (Para) is defined for the characterization of welded joint. Filler powder size, timing of weld and susceptor is the main aspect of the joined zones. X-Ray Diffraction (XRD), Scanning electron microscope (SEM), Vickers's Micro hardness test, Universal testing machine (UTM) are the major testing and used for characterizations for welded zone. This process is capable to joining of metallic, non-metallic, and bulk materials. Less Heat Affected zone, Environmental friendly, and less power consumption are key features of MHH.

1.INTRODUCTION-
Inconel alloys are nickel-based super alloys. Alloys containing nickel are type of sophisticated material that may be used at both cryogenic and high temperatures up to 1200 Celsius [1]. It has high corrosion resistance, oxidation resistance, and creep resistance at high temperatures. Designations of Inconel-UNS-NO6625, Werkstoff nu-24856, ISO-NW6625, NACENU-MR-01-75.Inconel alloys are utilized in the aerospace sector, the space shuttle, rocket engines, 3D printing technologies, jet engine fuel nozzles, saltwater marine applications, and oil and gas stations. Inconel has the attribute of distinction property of oxidation and weld ability. Welding of this type of alloy is the most critical fabrication [1]. Traditional techniques for welding nickel-base super alloys include laser beam welding, electron beam welding, and tungsten welding [2].They has their own boon and bane. Pros and cons of the welded joint are depended upon filler material, joint design, welding skill, and typical application [3]. It's applied over a wide area but many drawbacks are present in conventional techniques like HAZ is more, high energy consumption, less efficient. Making joint less corrosion resistance and declining mechanical and chemical properties. Considering all of the limitations, an innovative approach that can overcome such fundamental challenges is required.
Microwave hybrid heating is unquestionably one of these types of joining processes. MHH is a new developing fabrication field. Microwaves are non-ionized electromagnetic waves with wavelengths ranging from 1 meter to 1millimetre (mm). The frequency ranges between 0.3 and 300 GHz and at the molecular level, heating occurs from the centred toward the surface, causing dipole rotation and volumetric heating [4]
This review paper presents a comprehensive overview of the detailed procedure for joining Inconel alloys using microwave hybrid heating methods, as well as potential future research directions in the field of microwave energy-based Inconel alloy joining.

2 **Experimental set-ups for joining Inconel-**
Microwaves heating work on the principle of dipolar interaction and ionic conduction. Due to that, there is a conservation of energy rather than transfer. At room temperature, the Metals reflected back the microwave irradiation energy so for joining purposes we have to use a susceptor for joining bulk metal. Major parameters have to be set for it. Joining time, welding zone, filler powder, and susceptor materials play an important role.

3. LITERATURE REVIEW –
3.1. Joining of Inconel 625 through Microwave hybrid heating-

[5]Using Microwave hybrid heating technique welded the joint of Inconel 625 was performed. Delineation of microwave welded joint was done through XRD, UTM, Vickers's micro hardness test, and SEM. The nickel-based powder was used as filler material.1KillowattHome-based multimode microwave oven with a power level was 900W and the frequency was 2.45GHz. The surface where joined has been made in form of a square butt. The microstructure shows the formation of nickel, chromium, and molybdenum carbides. There was additional evidence of nickel oxide and titanium molybdenum oxides. The hardness of interference was also affected and raised due to the presence of chromium carbide near the joint. Norm Vickers's micro hardness and tensile strength of weld were observed at 350±10 Hv, 326MPa.

[6] He also carried out a successful joining of Inconel 625 through microwave hybrid heating. filler material Inconel 625 was used with an average size of 50μm.Coal is used as susceptors material. In the fusion zone, micro structural analysis reveals the structure of the Laves phase along grain boundaries. X-ray diffraction analysis of microwave generated joints reveals the formation of niobium and chromium carbides. As well as inter metallic phases, in addition to the primary-phase ΄Y face-centred cubic matrix. The welded zone of a microwave-induced joints revelled hardness of 245 ± 20 Hv with 0.7 percent porosity. The produced joints' average ultimate tensile and flexural strengths were estimated to be 375 and 377 MPa.

Badiger et al.[7]Experiments have been completed through the usage of Taguchi's L16 factorial layout of the test method. Input parameters selected had been susceptor type, filler powder size, and susceptor. Higher values of tensile strength were gotten from the combination of graphite separator, Silicon susceptor, and a finer filler powder. ANOVA comes about and appears that the molecule measure of interface filler powder is the most compelling parameter in choosing the quality of the microwave actuated joint taken after by the separator and susceptor materials.

The impact of process factors on Inconel625 joining using microwave hybrid heating was investigated (A.sharma et.al[8]).During this research, the impact of four input parameters (the size of the vertical charcoal feeder's drilled hole, the thickness of the graphite sheet, the thickness of the insulation brick, and the surface contact between the refractory and the insulation brick) on the melting region was investigated. This research found that the joint zone melted correctly, that there were no faults such as crater development, and that the charcoal powder did not spread throughout the specimen. The experiment, which used four parameters (Feeder diameter of 8 mm, insulation bricks of thickness 71mm,1.2 mm thick separator, and no surface contact with refractory brick), revealed that the specimen melted only at the interface, with no crater development.

A comparative study was also done on MHH Inconel 625 with Tungsten Inert Gas welding [1]. A commercially available Inconel plate was used in welding through MHH with the Inconel-625 as an interference filler material Average particle size value (50μm). Gap between strip was 1-1.22 mm maintained, and the joint interface was microwave irradiated for 20 minutes. Weld metal's strength through MHH is (53 percent of base metal strength).This experiment was carried out in a home-based microwave oven and also suggests that if this experiment were carried out in an industrial-based microwave -oven in a Vacuum also produce more uniform heating. Maximum hardness is observed that 344 Hv.The uses of finer-based materials with a size of 20-25m may also help to improve the mechanical properties of the MHH joint.

3.2. Joining of other Inconel alloys through MHH –

Bansal et.al. [9]performed the experimental work related to the production of the butt joint of Inconel 718 by using Inconel 718 as a based filler material. The specimen size of 60×10×4 mm and the exposure time was 540 seconds. Because of the [10]In this paper uniform heating involved with the MHH procedure, the joints are devoid of micro-fissures and crack. A field emission scanning electroscopic was used to determine the characteristics of the weld zone. The presence of a strengthening phase in the matrix was found to increase mechanical characteristics. The 981 solutions treated and aged (STA) treatment was also tested for ductility and strength increase.

[11]Joining of Inconel 718 plate dimension(25 × 10 × 4 mm3)butt joint was done through MHH. Power of 900W, 2.45GHz microwave frequency, and processing time for 480s.XRD and SEM test was used to characterize the weld zone. Presence of lavas, δ(Ni3-Nb),carbide phase in weld zone by XRD. Tensile strength and norm micro hardness were 780MPa with 11.11 % elongation and 240Hv.The slurry of Inconel 718 with epoxy resin (Bisphenol-A, Blumer 1450XX) was used with a thickness (of 0.50mm).

3.3 Fabrication of other alloys through MHH-

[12]Bansal.et.al .A bulk junction of stainless steel-316 to stainless steel-316 was carried out utilizing stainless steel-316 as an interference filler powder (50µm size) via MHH in this study. The experiment was carried out in a multimode microwave oven with a frequency of 2.45GHz and power of 900W. Stainless Steel with a dimension of 25×15×4(mm) was used and joints were used to make in the form of a butt joint. The joint has a 425 MPa ultimate tensile strength and a 9.44 percent elongation. The joint's measured ultimate tensile strength was approximately 82.5 percent of the SS-316 base material strength (515 MPa)

[13].The lap joints on specimen SS202 were created in this experiment using selective microwave hybrid heating in a home microwave oven with a frequency of 2.45GHz and a power of 700W. Nickel-based powder (20µm) was used as a filler material. The results reveal that metallurgical bonding between the lower plate metal and the interface material produces greater bonding between the upper plate and the interface material. Exposed time varied from 15 to 20 min. Enactment of welding joint is done through EDS and Electron microscopy. A top-quality joint takes 19 minutes to produce at its best with a lower damping factor. Specimen dimensions of SS202 were 160×31×1 mm.

3.4 Review on Inconel joining through MHH and other techniques-

[14] The various aspects and joining of Inconel alloys were reviewed. The effect of interference filler material size and power input parameters was investigated in this paper. MHH is a volumetric heating phenomenon hence proper utilization of powder size may reduce the timing of joint. The author suggests that because low-rated input power causes rapid cooling and hence a minimal amount of secondary phase at the joint zone, joints formed at low input power may display good metallurgical bonding. Higher joint strength is obtained with finer powder size, resulting in the ductile mode of fracture.

4. CONCLUSION-

The importance of research contributions linked to microwave hybrid heating-based joining of various Inconel alloys has been highlighted in this work. The review concludes that the microwave hybrid heating procedure has been effectively used to link Inconel-625 and Inconel-718 together as well as other metals. Inconel alloy and metals are joined by conventional welding and other techniques but in MHH volumetric heating, Environmental friendly, and less time of joining are key features. Susceptor, filler materials, and timing of joint play important roles in welding. Hybrid microwave heating has a scope of work as there is no more work in this area.

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