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Joint Characterization of SS 304 Processed by Microwave Radiation

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ABSTRACT

The feasibility of fabrication of 304 stainless steel through microwave energy using new technique which includes susceptor is conveyed throughout this paper work. The intersection was welded in household IFB microwave oven multimode operated at frequency of 2.45GHz and 900W. Mixture of Nickel-cobalt based fine powder with resin was placed uniting the clean surfaces and using the atmospheric conditions, samples were exposed to microwave radiation for obtaining the joint. Welded joints were analysed by tensile test, X-ray diffraction (xrd) for intermetallic compounds, Micro structural analysis, Field emission scanning electron microscopy (Fe-sem), Porosity test, Micro hardness test and surface temperature measurement. Tensile strength found 390Mpa which is about 70% of the base metal. Micro structure images showed the welded edges were fused properly & got melted on sides of the parent material and porosity found to be negligible through Fe-sem result. The average observed microhardness on weld metal area and base metal were to be 65-66 HRB and 71-72 HRB respectively. The surface temperature of weld zone area was found to be 926oC.

Keywords: Microwave hybrid heating; Interfacing material; Susceptor; Stainless steel.

INTRODUCTION

Fabrication is a vital unit of the raising industry. Therefore, researchers are trying to enhance the stability of joint. Newly, microwave treatment has turn up as a narrative means in order of processing of numerous materials like ceramics, polymers, composites and metals. Microwave heating is recognized for the various parametrical advantages like lessen processing cycle time & temperature, magnificent microstructures, very rapid heating rates and other improved mechanical properties, etc. Being an eco-friendly and ease in processing, this versatile cleaner energy source is building up a huge market for itself [1,2,3,4]. Microwaves form a small segment of the EM spectrum, with frequencies bandwidth from 300 MHz-300 GHz. Microwave usages is vastly assorted, with demand in heating, radar, communication, industrial purpose, science & medical technology and for power transmission. Mostly microwave appliances & equipment utilized 915 MHz and 2.45 GHz of ISM bands. Microwaves can be generated by magnetrons, tubes of power grid, travelling wave tubes, gyrotron, amplifiers having crossed-field and klystrons [5,6,7,8]. Kanwerjeet and satpal Sharma, investigated on cladding process, they used EWAC 1006 EE, Co-based alloy to succeed clad on tool steel substrate of P20 grade by application of microwaves with hybrid & susceptor technique. The trials were supported by LG private microwave with 2.45 GHz frequency & input 900 W power. After investigation he concluded that cladding area was uniform & crack free and there was presence of hard carbide particles having Vicker's microhardness as 761± 1.5Hv[9]. Amit Bansal et al investigated micro structural & mechanical properties of fused pieces of Inconel grade718 and austenitic SS-316L using microwave method and concluded the presence of various carbides and inter metallic compounds by analysing X-ray diffraction test of the fusion zone. Micro structural study let out metallurgical bonding of the two welded surfaces having negligible interfacial cracking. The elementary investigation of unite area affirm proper mixing of powder in between the effective joint. The observed microhardness was 230 HV on joint interface; the porosity was found 0.94%. The average value of tensile strength of welded pieces monitored as 517.5MPa, having elongation 18.18%. A combined mode of collapse of weld joint observed during tensile testing which revealed fractography study [10]. Dheeraj gupta et al focused on joining of bulk material of cast iron using frequency of 2.45GHZ and 900 W input power applicator microwaves. They further investigated micro structural properties of joint using SEM, EDS and XRD and results revealed that proper fusing of interfaying surfaces, uniform distribution of elements were there and porosity was less [11]. Luchy bagga et al obtained a process which shows effect of different interfacing material on stainless steel. The resulted specimen was characterized by X-Ray Diffraction, Microstructure test and hardness test using Rockwell HRC scale. The fact-finding results revealed that the 99.9% pure powder of Nickel had poor quality than EWAC Nickel powder in expression of weld ability [12, 13]. Sahil Nandwani et al reviewed the effect of exposure time, different interfacing powders, type of material and their sizes, blumer ratio of slurry on various characterization factor which further helped researcher to select important factor for welding using hybrid technique [14].

SELECTION OF MATERIAL

The Stainless steel 304 has wide application in manufacturing industries. Trials were conducted using grade 304 Stainless Steel plates having dimension 40mm×20mm×3 mm. Square butt configuration is chosen for joint preparation. Slurry of nickel-cobalt powder of particle size of 20 µm squeezed as layer between faying surfaces.

Table 1. Chemical composition of stainless steel 304

Chromium (Cr) %	Nickel (Ni) %	Manganese (Mn) %	Silicon (Si) %	Carbon (C) %	Phosphorous (P) %	Iron (Fe) %
18.29	8.05	1.14	0.25	0.058	0.041	71.13

Table 2. Process Parameters used in experiment

Parameter	Specification
Microwave oven	Multimode at 2.45GHz frequency
Power Rating	900 W
Interfacing Material	Nickel- Cobalt based powder mixed with resin
Base Metal	Stainless steel 304
Susceptor	Fine charcoal powder
Seperator	Graphite sheet of 1mm

Table 3. Selection of Ni based powder with resin in percentage

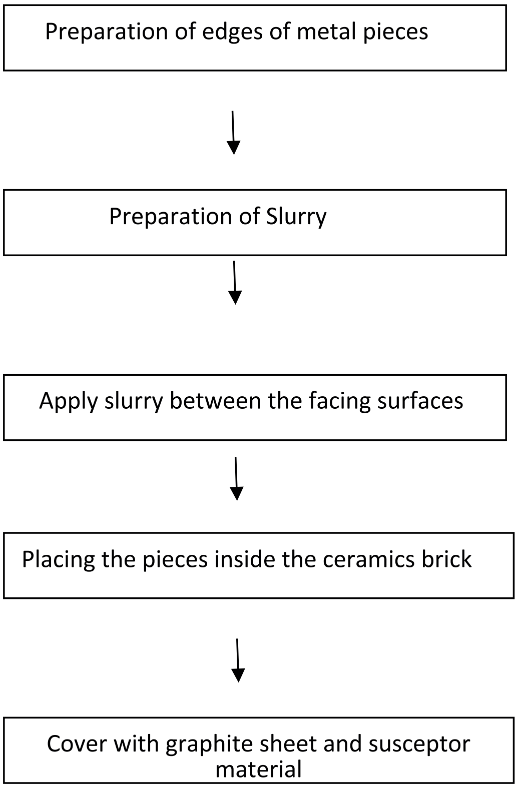
S.No	Ni based powder/ Resin%	Response
1	70/30	No joint
2	75/25	No joint
3	80/20	Little joint

4	85/15	strong joint
5	90/10	Strong joint
6	95/5	little joint
7	100/0	No joint

EXPERIMENTATION

Emery paper of different grades(150 to 1000) were used to polished the edges of specimen mechanically, then dip into acetone solution for degreasing purpose, sometimes ultrasonically cleaned surfaces can be used for better result and then dried prior to joining process. Slurry was prepared using nickel-cobalt based powder and epoxy resin, after that slurry was evenly spread out over the facing edges of two pieces. Graphite sheet of 1mm was placed over the facing surfaces which separate slurry with charcoal powder to avoid diffusion process of carbon into joint. Fine stone charcoal powder was utilized being susceptor material for primary associated with microwave radiation. Whole setup placed inside the refractory brick. The metal pieces reflect microwave radiation at room temperature. In order to solve this problem, microwave hybrid heating principles were used in which metal pieces were set down inside a cavity of insulator brick so that there is no contact between the metal pieces and microwaves. Demonstrations were supported in multimode IFB microwave having frequency 2.45GHz with input power of 900W. Surfaces of metal pieces were exposed to microwave up to 15 min. Atmospheric condition were chosen for cooling during experiment.

A detailed stepwise procedure was used to describe the whole process, showing in Fig 1.



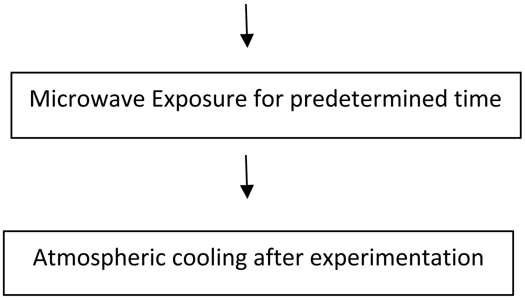


Figure 1. Detailed Description of Hybrid Heating

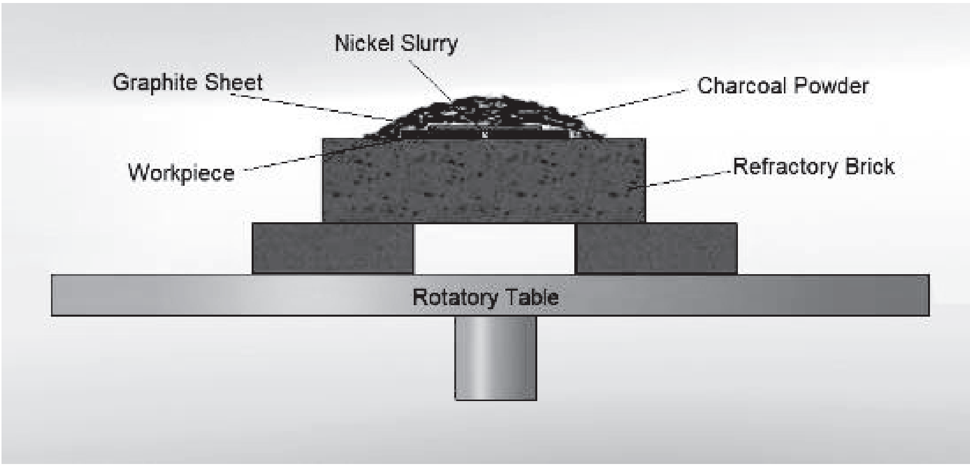


Figure 2. Experimental setup [6]

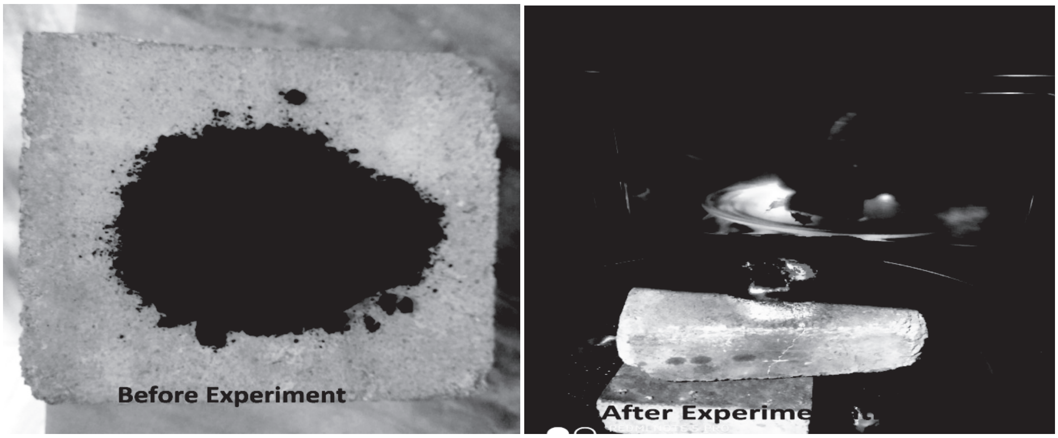


Figure 3. Setup of before and after Experimentation

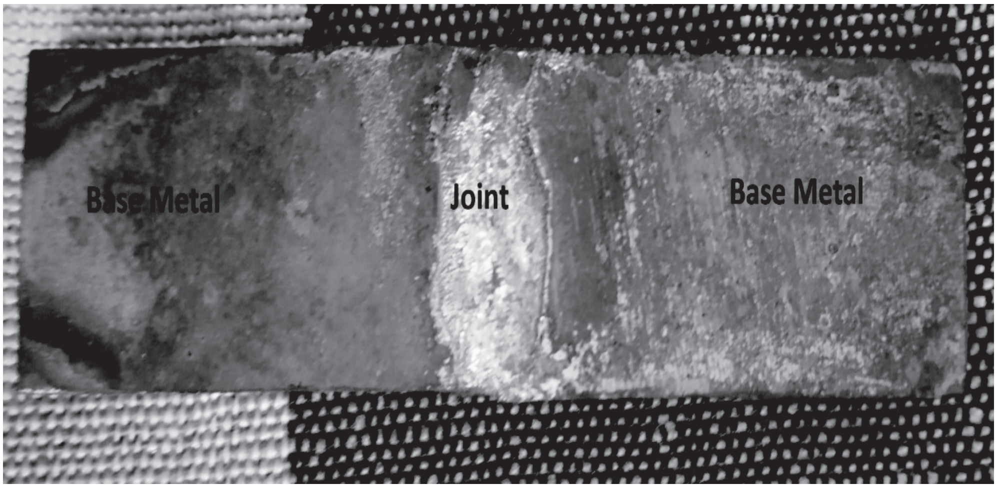


Figure 4. Metal pieces after Joining Joint Investigation

The joints were investigated through X-ray diffraction, FE-SEM, Tensile strength, microstructure, microhardness, porosity measurement and surface temperature. Examination of microstructure metallic joint conducted through field emission scanning electron microscope. Microwave joined pieces brings into sections over the joint then mechanical treatment and etching were carried out for better result. The micro hardness on base metal and weld area surfaces was evaluated on HRB scale. Fig.3 shows the before and after welding setup through hybrid heating.

RESULT & DISCUSSION

The micro structural and mechanical analysis of joint section was carried out and results are discussed in this section.

XRD Analysis

The purpose of XRD analysis is to identity the various phases and elements present in the interfacing powder and weld zone area of welded metal by microwave welding. The XRD analysis confirms the existence of Ni, Si, Co & Cr elements. The percentage of Nickel is highest followed by cobalt and chromium. The presence of FeNi, Fe3C, CoN and FeN shown in the weld joint by XRD analysis.

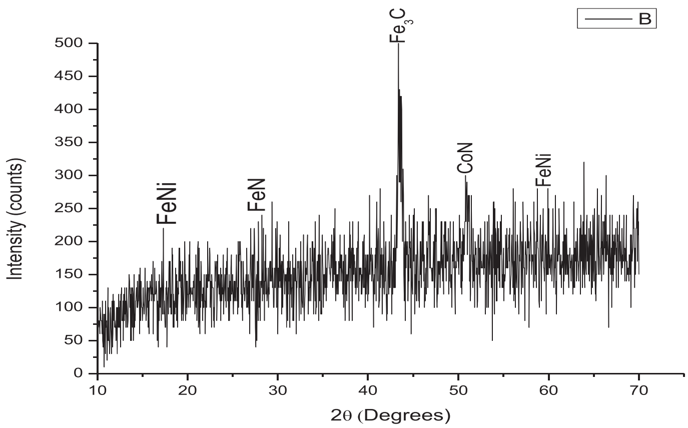


Figure 5. XRD Analysis of weld joint

Rockwell Hardness Test

Rockwell hardness test is done on the base metal surface & weld area joint to evaluate the hardness of joint using Rockwell B- scale. The micro hardness found to be 71-72 HRB on base metal and 65-66 HRB on welded area.

Porosity Test

Porosity of joints induced through microwave was evaluated and observation showed that the porosity was negligible in the intersection region. There are faintly any pores remarked at joint area zone. A uniform and volumetric heating characteristic of microwave hybrid heating is mainly responsible for negligible porosity on the weld area. It is very difficult to obtain uniform volumetric heating in the entire weld zone using conventional techniques, whereas using microwave with hybrid heating it can be easily obtained.

Microstructure Analysis

The microstructures shown in Fig.6 indicate acceptable metallurgical fusing with metal pieces & uniform melting of Ni-Co powder particles. At first charcoal used as receiving material, couples with microwave radiations which initiate heating. Within a very short time, this warmth effect is pass on to powder particles spread in the interfacing layer, the interfacing material begins coupling with microwave at elevated temperature. The outcomes in uniform volumetric heating in the metallic material, which melts the edges of substrate. A fully fused weld interface can be clearly seen from the fig 6.

Figure 6. Microstructure of welded joint

FE-SEM

Field emission scanning electron microscopy (FE-SEM) provides topographical and elemental information at high magnification. It brings about clearer, little electrostatically distorted images. FE-SEM image of Nickel based powder of SS-304 joints are shown in Fig. 7. It shows complete fusing of powder particles at allying metal surfaces and also shows well dispersing of Ni based powder with parent material. A well diffusion of Ni based powder particles and SS-304 can be seen. Volumetric heating responsible for homogeneous joints.

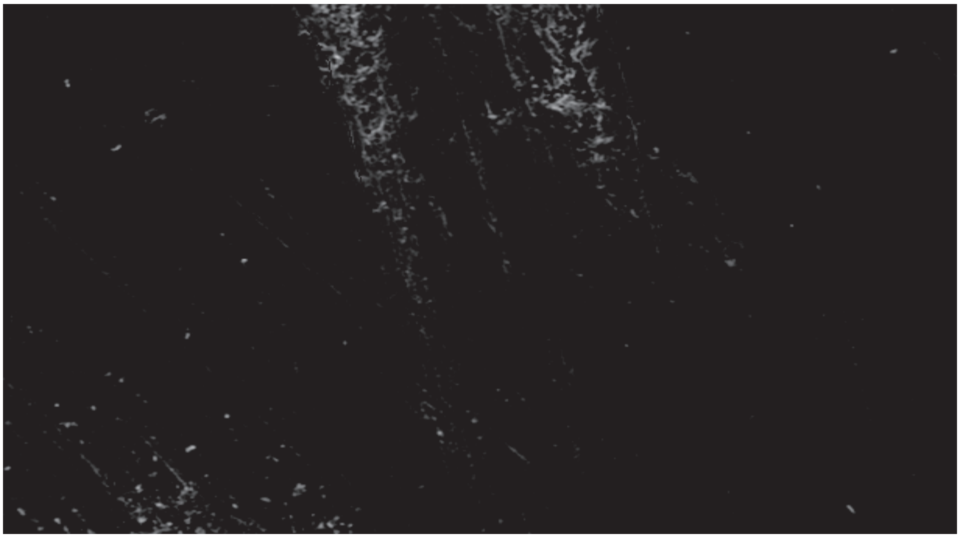


Figure 7. FE-SEM image of SS 304 joint

Temperature Measurement

Temperature of weld joint area was measured by the non contact temperature gun which works on principle of Infrared radiation. An IR thermometer is a device which deduces temperature from thermal radiation throws out by the heated metal being measured from a distance. A contact less IR thermometer was used to quantity temperature under conditions where thermocouple or other kind sensors unable to produce precise data

Figure 8. Temperature of weld joint

CONCLUSION

Microwave radiation for fusing of metallic material in majority is crucial because metal reflects microwave at ambient temperature. The present effort describes the microwave hybrid heating process to join stainless steel pieces.

Following are some major conclusions out of the present study:
1. Metallurgical bonding of two pieces of stainless steel 304 attained in present work.
2. Volumetric and uniform heating throughout the joint is responsible for absolute fusion of faying surfaces and acceptable metallurgical bonding with metal.
3. Formation of intermetallic elements through XRD has been confirmed during microwave heating.
4. Negligible porosity was observed in the weld zone area.
5. Tensile strength found to be 390MPa, which was about 70% of base metal.
6. Surface temperature of weld joint was found 9260c.
7. Bulk joint with Rockwell microhardness around 65-66 HRB has been obtained with a negligible porosity.

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