International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
Index Copernicus Value (2015): 62.86 | Impact Factor (2015): 3.791

Analysis of Microwave Welding of Stainless Steel

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Abstract: ***Welding is a process in joining of metals which are done by using or without using of filler materials. Generally this is done by melting the work pieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat to produce the weld. A more versatile, faster and cleaner process could have a huge impact on production. Investigations reveal that application of microwave energy as a tool in materials processing is not only a green manufacturing process, but also significantly faster at relatively low investment. Microwave welding is a form of electromagnetic welding, similar to radio frequency, laser, induction and IR welding, using a radiation frequency of typically 2.45 GHz. Ease of processing and environmental hazards, are some of the issues that need to be addressed, so this type of welding . Microwave materials processing can give an alternative to high energy consumption heating techniques that are commonly used in industries In microwave processing, energy is directly transferred to the material through interaction of electromagnetic waves with molecules leading to volumetric heating. Heat is generated internally within the material, instead of originating from the external sources, and gets transmitted outward. In the present work, microwave joining of two similar and non-similar materials has been successfully carried out using a multimode applicator at 2.45 GHz and 900 w and mild steel in plate forms have been successfully joined through microwave heating within 660 s of exposure time.***

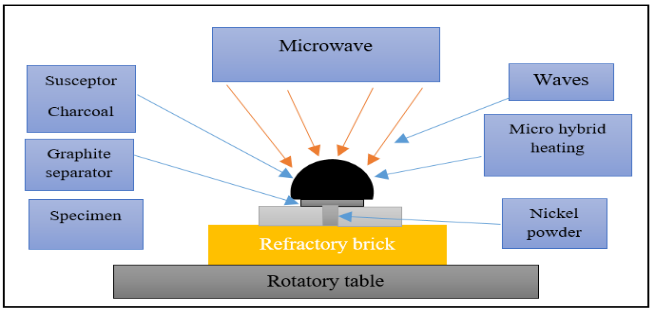
Keywords: welding; microwave; stainless steel; interface layers

1. Introduction

Welding is an essential process used for joining basic parts. It is almost used in every industries, railway, ship buildings, cars, aeroplane, civil construction etc. It is likewise broadly utilized for the manufacturing and repair of machine tools, farm equipment. Therefore the cost and quality of a finished product depends upon the quality of welding joints and its structure. Microwave joining of materials is a new non-conventional technique emerged in the recent years. The unique characteristics of microwave radiations like volumetric heating, less power utilization, eco-friendly with environment, highly quality products etc. are attracting numbers of researches in this field. These techniques in not fully developed as compared to other joining techniques but results of this technique are relatively better in terms of hardness, HAZ and tensile strength. Many materials which are extensively used in industries like aluminium, stainless steel, cast iron, etc. have been joined by microwave joining process. In case of stainless steel, the interface materials used for microwave joining includes nickel based powder or nickel based EWAC powder. These two materials are in powder form made from same parent material i.e. nickel but show different results in microwave joining. In this research, work-pieces of stainless steel 304 are joined by microwave joining with the help of both nickel based EWAC powder (50µ in size) and nickel based powder (50µ in size) as interface material. Microwave heating is a procedure which utilizes electromagnetic vitality as a part of the frequency scope of 3 to 300 MHz's. In microwave heating the material is subjected to electromagnetic waves that oscillate the molecules of material, there by producing heat. Microwaves are directly absorbed by the material in this manner thereby causing volumetric heating.

2. Microwave Joining

In microwave joining process domestic and industrial microwaves are used for bulk material joining. Thesedomestic and industrial microwaves works on stranded frequency 2.45GHz. Refractory brick with cavity is used to hold the work piece. Epoxy resin blumer and bisphenol-A are used to hold the interface powder. Charcoal powder are used as a susceptor which suscepts the microwave radiations and concentrate them at the interface of the joint. Graphite sheet is used as a separator to separate the interface powder and susceptor powder as show in Figure.



Bansal et alstudied joint fabrication of mild steel- mild steel through microwave hybrid heating in domestic900 watt microwave. The gap was filled with interfacing slurry of nickel based powder and epoxy resin bisphenol-A and blumer 1450XX. The joint was characterized using XRD, EDS, SEM, Rockwell hardness etc. Gupta et al. investigated butt joint of tungsten carbide bearing alloy through microwave joining. Mild steel and stainless steel were joined by used of nickel based EWAC powder. Gupta and Kumar worked on welding of SS420 with SS420 used nickel based EWAC (empowering welding and cutting) powder as an interface material. Slurry is made by 95% nickel based powder and 5% blumer 1450XX. The joint was characterized by XRD, SEM, micro tensile tester etc. Badiger et al. worked on joining the Inconel-625 alloy through microwave hybrid heating in domestic 900 watt microwave using Nickel based powder as an interface material. The experiments were carried out in domestic microwave and characterized by XRD, SEM and UTM etc. Bansal et al. investigate on Inconel 718 structure – properties in microwave joining. The butt joined Inconel 718 plates were joined by the microwave hybrid heating technique. Inconel 718 powder as filler material was used for microwave welding. Singh et al. worked on joining aluminium-aluminium through microwave hybrid heating. Aluminium powder was used as an interface material. SiC powder is used as a susceptor.

3. Experimental Setup of Microwave Welding

EXPERIMENTAL SECTION

The experiments have been carried out on stainless steel of dimensions length (50 mm), width (12 mm), and thickness (4 mm). Butt joint is used to join pieces. Now, the pieces are cleaned with acetone and emery paper to avoid unwanted contaminants. After that, specimen is placed on the table in the microwave. Ni-based powders (95%) with resin (5%) are used as the interfacing material. Now, Slurry (Ni-Based Powder þ Resin) is applied on the faces of the substrates to be joined. Graphite plate is used to separate slurry and charcoal powder. Charcoal provides extra heating at a particular place. After applying the slurry between the faces, the specimen has been surrounded by the refractory bricks, which are shown. These bricks are used to avoid direct interaction between the microwaves and magnetron. After that 900 W power is setup, with the exposure time of 700 s. As, the exposure time increases from 0 to 700 s, magnetron generates more microwave radiations. These radiations produce the heating effect at the joints. Now, charcoal powder starts to burn when it has been exposed to microwaves and thereby the temperature increases at the joint. Resin is present in the interfacing materials, which heats up as the temperature rises. Thereby, the surface of the substrates starts coupling with Ni-based powder. It affects a very thin layer, which bonds with the molten particles in sandwich layer. The substrates faces get completely wet which in turn forces the materials to melt. The molten area turns into a form of weld bead after cooling at atmospheric conditions.

Parameters

Parameters play a drastic role in joining of metals using microwave energy. There are various process parameters of microwave welding which are explained below.

Exposure Time

With the help of pilot experiments, various process parameters of microwave welding have been selected. For the selection of time period, the number of trials has been carried out. It has been varied from 300 s to 900 s. Power and frequencies have been kept constant for all experiments. The results are to be presented in Table 1 format.

Selection of time period.

S.no	Time	Effect
1	300	
2	400	
3	500	
4	600	
5	700	
6	800	
7	900	

Percentage Of Interfacing Material

Nickel sulphate, nickel carbonate, zinc Sulphate, cast iron, copper powder, and EWAC (Ni-based powder) were used as interfacing materials. Most of them were not suitable to weld stainless steel metal because they have low weld ability and coupling property. Out of these interfacing materials, Ni-based powder (EWAC) has excellent weld ability and formed good weld. So, this has been selected as a best interfacing material. The different combinations of Ni-based powder and resin have been used. The results are to be presented as in Table 2 format

Selection of percentage of interfacing material.

S.no	Ni powder/ resin	Effect
1	70/30	
2	75/25	
3	80/20	
4	85/15	
5	90/10	
6	95/5	
7	100	

Susceptor

The susceptor has been used to transfer microwave heat from microwave radiations to the joint. Due to this, selective heating takes place. For this purpose, charcoal powder is used. It is also easily available.

Substrates

Stainless Steel is used as substrates because it has wide applications in industries. Experiments were carried out on stainless steel having the dimensions, i.e., length (50 mm), width (12 mm), and thickness (4 mm). Properties and chemical composition of SS are shown in Table 3.

Element	Percentage by Weight Maximum Unless Range is Specified		
	304	304L	304H
Carbon	0.08	0.030	0.04 – 0.10
Manganese	2.00	2.00	2.00
Phosphorus	0.045	0.045	0.045
Sulfur	0.030	0.030	0.030
Silicon	0.75	0.75	0.75
Chromium	18.00 20.00	18.00 20.00	18.00 20.00
Nickel	8.00 10.50	8.00 12.00	8.0 10.5
Nitrogen	0.10	0.10	0.10

Types of Configuration

- Based on welding type

On initial analysis and peer discussions we selected 2 weld test configurations:

- Square groove weld configuration
- Double v groove weld configuration
- Based on specimen slots on refractory bricks

On initial analysis and peer discussions we selected 2 weld test configurations:

- Single slot- dual substrate
- Single slot- single substrate

4. Experiment Procedure

The experiments have been carried out on stainless steel of dimensions length (25 mm), width (12 mm), and thickness (4 mm). Butt joint is used to join pieces. Now, the pieces are cleaned with acetone and emery paper to avoid unwanted contaminants. After that, specimen is placed on the table in the microwave. Ni-based powders with resin are used as the interfacing material. Now, Slurry (Ni-Based Powder Resin) is applied on the faces of the substrates to be joined. Graphite plate is used to separate slurry and charcoal powder. Charcoal provides extra heating at a particular place. After applying the slurry between the faces, the specimen has been surrounded by the refractory bricks, which are shown in. These bricks are used to avoid direct interaction between the microwaves and magnetron. After that 900 W power is setup, with different exposure times. As, the exposure time increases from 0s, magnetron generates more microwave radiations. These radiations produce the heating effect at the joints. Now, charcoal powder starts to burn when it has been exposed to microwaves and thereby the temperature increases at the joint. Resin is present in the interfacing materials, which heats up as the temperature rises. Thereby, the surface of the substrates starts coupling with Ni-based powder. It affects a very thin layer, which bonds with the molten particles in sandwich layer. The substrates faces get completely wet which in turn forces the materials to melt. The molten area turns into a form of weld bead after cooling at atmospheric conditions.

5. Results and Inferences

The following table describes the best possible exposure time to obtain credible welding

Results of selection of time period.

S.no	Time	Effect
1	300	No joints
2	400	No joints
3	500	No joints
4	600	Partial joint (weak)
5	700	Complete joint
6	800	Partial joint (weak)
7	900	No joints

From **Table 3** it is understood that the proper welding is possible only at exposure temperatures between 600s – 800s. This is due to the observation that the samples are not heated enough below 600s while the above 800s the interfacing material overheats and melts completely.

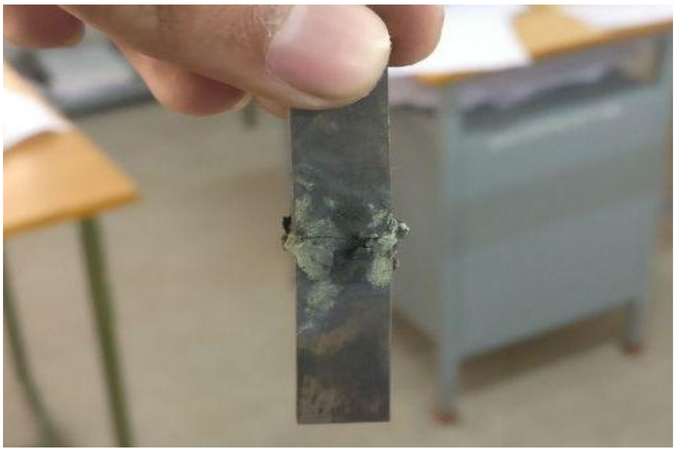
The following table is result obtained after performing trials on the combination of nickel powder –resin for credible welding.

Results of selection of percentage of interfacing material.

S.no	Ni powder/ resin	Effect
1	70/30	No joints
2	75/25	No joints
3	80/20	No joints
4	85/15	Partial (weak)
5	90/10	Partial (better but weak)
6	95/5	Complete joint
7	100	No joint

From **Table 4** it is understood that for the best joining to take place the interfacing material must have a combination of nickel based powder and epoxy resin as 95% and 5% respectively. This is because if the percentage of resin is increased if affects the welding process as it evaporates completely before reaching the required temperature level for welding to take place.

From the above trials that are performed the welded samples that are obtained have weak weldments and are very brittle. This may be due to use of ewac-1004en (nickel based powder) which is mostly recommended for cast iron.



6. Conclusion

From the above trial and analysis of microwave welding using stainless steel as substrates it is concluded that this technique of welding requires more fine tuning before it can be commercially exploited.

This new welding technique has high potential in the years to come as new materials are found for which new manufacturing processes has to develop.

Hence more research has to be done min this area for this technology to fructify.

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