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JOINING OF SS-430F USING MICROWAVE PROCESSING METHOD

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ABSTRACT

Heating of the materials by using the radiations of the microwave is not a new application. Many authors have worked on ceramic materials and their sintering by using the microwave radiations. Now a days the applications of the microwave is being extended up to the sintering of the metallic powders and used them in different applications like cladding as well as joining of the materials. The present work is based upon the joining of SS-430F materials through microwave radiations. Mechanical characterization like tensile testing was performed to see the strength of the joint. Observed results showed that the SS-430F material was successfully joined by the microwave radiations by using nickel as a base powder. The mechanical characterizations of joints shows that mechanical strength was increased due to better metallurgical bonding and diffusion and defects were also less.Observed ultimate tensile strength was 481MPa during the experiment.

Keyword: Microwave, carbide, Strength

I.INTRODUCTION

Demand is changing day by day in every field, so need of such kind of technique is increasing which will not only be effective but also will be efficient and eco-friendly. The processing of different materials like metal, non-metals, ceramics, composites etc. with good quality, less processing time and having less impact on the environment is quiet challenging. Material processing by microwaves is attracting researchers and lot of research is being carried out in joining, cladding and casting of material with the help of microwaves due to its inherent properties like less processing time, volumetric heating, very less heat transfer to the environment etc. Frequency of microwave with range of 0.3Hz to 300GHz [1] is being the part of electromagnetic spectrum. Microwaves are produced by the propagation of electrical and magnetic field which are perpendicular to each other. The vast range of frequency of microwaves allows it to be used for number of purposes like in material processing for medical purposes, communication system, industrial heating and food processing etc. [2]. The basic frequency of domestic oven is 2.45GHz in India and domestic oven is basically used for heating food stuffs. The heaters have been produced for material handling purposes which are utilized as a part of numerous mechanical applications and they chip away at higher frequencies running from 915MHz to 18GHz [3-4] as shown in figure 1.

Figure 1 Different frequency ranges of electromagnetic spectrum

The heating power of microwaves was discovered accidently during the Second World War in 1945 [5]. One day an American engineer called Percy Spenser, was working on a unit to produce high intensity microwaves which can be used in RADAR. During his experiment he observed that the chocolate bar started to melt in his pocket. Then he placed corn near microwaves producing unit magnetron tube was rewarded with flurry of pops after this experiment Spenser got the idea that what microwave can do in the kitchen. After some years of hard work, the first domestic microwave oven came into the market and became very popular for domestic use due to its marvellous feature like higher heating rate, less energy consumption and less processing time and after few years it became the king of kitchen. More research is being carried out in processing of other materials using microwaves. More and more research is being carried day by day to increase the applications of the microwave like processing of ceramics, metallic materials, vulcanization of rubber and chemical reactions etc. [7-9]. The primary characteristics of microwaves material processing are shown in Figure 2.

Figure 2: Characteristics of microwave material processing

All atoms at one time is heated in microwave which leads to faster heating. The volumetric heating coupled to microwaves at the atomic level gives advantage of heating. By using these unique characteristics; many researchers reported processing of ceramics with improved properties [10-12]. Selective heating can be done using microwaves which results in lower heat affected zone and lower defects. The real engineering in the microwave oven lies in creating the magnetron which generates high powered microwaves. The magnetron is made of copper tube (Anode) with a Thorium plus tungsten (Cathode) rod running down the centre and the vacuum is maintained between cathode and anode, then high voltage is applied across the two conductors which causes electrons to move through the vacuum from the rod to the tube but they don't move in straight line. The tube is held in a magnetic field which applies force on the electron and make them to come out in spiral form as the electron spin out, then they pass through a small opening inside the tube. The general description of microwave producing device named as magnetron is given in Figure 3

Figure 3: Description of Magnetron

The transfer of energy at molecular level results is increase in motion of molecules of a substance which results in increase oftemperature.The processing of material which don't couple with microwave at room temperature was very challenging task, to process such types of material with microwaves phenomenon; hybrid heating was used. In this type of heating phenomenon; concepts of conventional heating as well as microwave heating is used. Since material reflects the microwaves at room temperature. Due to this problem suceptor material is used which absorbs the There are certain distinct advantages of using microwaves in heating processes.

There are certain distinct advantages of using microwaves in heating processes. The characteristics of lower energy consumptions coupled with higher heating rates and lower processing times which leads microwave heating as one of the challenging process in material processing. microwaves initially and then heats the material conventionally at elevated temperature. During this process; skin depth of the particles increases.The characteristics of lower energy consumptions coupled with higher heating rates and lower processing time leads microwave heating as one of the challenging process in material processing.Microwave material processing provides better microstructures, lower defects, high efficiency with reduced energy consumption and low cost of heating with respect to conventional heating.[18]. Microwave innovation in the field of metal preparing through microwaves and having assortment of production in various territories of generation like, cladding/Coating, sintering, joining of metallic materials.

Microwave heating prompts vitality sparing and in addition cost sparing. The vitality prerequisite to rise the temperature in heater for liquefying a material is high yet this necessity of vitality can be satisfied effortlessly and inconceivably with microwave vitality. Microwave gives relatively homogeneous microstructures with better grain development and improved properties with lower handling time. The thickness of powder compaction chooses the properties of the completed product. Higher the thickness of prepared material, lower will be the deformities mostly as far as porosity. Because of uniform heating and volumetric heating of an item.

Limitations of the procedure:

(a) Proper sculptor material must be used otherwise chances of fire hazard.

(b) Due to high heat generation it requires high careful handling.

This chapter mainly deals with the up to date happening in the field of microwave joining also the other important works performed in the field of microwave dealing with metals and also gives the information of the work which has been not attempted yet. This chapter also gives the overview of research objectives to full fill the purpose of problem formulation. Srinath et al. [21] worked on joint of stainless steel (SS-316) and mild steel (MS) using microwave hybrid heating method. He applied the nickel powder paste mixed with epoxy resin in between the two substrate with exposer time 450s in homemade microwave oven at 2.45GHz and 900W. Micro hardness of formed joint was 133Hv, porosity was very less (.58%) and measured ultimate tensile strength was 346.6 MPa with elongation percentage of 13.5%. FESEM and XRD was done to study the microstructure of joint with formation of various complex carbides. Srinath et al. [22] worked on a highly conductive material like copper. Earlier it was difficult to join copper but by using microwave hybrid heating method it became simple to join copper. Domestic microwave oven 2.45GHz and 900W was used paste of copper powder mixed with epoxy resin was introduced between the joints of .5mm thickness and charcoal is used as a susceptor material which interacts with microwaves to give heat to the work piece for a time 900s to form a joint. The formed joint was characterised and it shows Micro hardness to be 78Hv, porosity was very less just 1.92%, measured ultimate tensile strength to be 164.4MPawith elongation percentage of 29.2% also FESEM and XRD was done to study the microstructure of joint with formation of various carbides. Bansal et al. [23] investigated the joining of stainless steel-316 microwave hybrid heating method. Domestic microwave oven 2.45GHz and 900W was used paste of stainless steel powder mixed with epoxy resin of 1mm was introduced between the joints and SiC is used as a susceptor material which interacts with microwaves to give heat to the work piece for a time 720s to form a joint. The characterisation of joint shows Micro hardness to be 275Hv, porosity was very less just 0.94%, measured ultimate tensile strength to be 425 MPa with elongation percentage of 9.44% also the concept of skin depth was properly explained by the researcher also FESEM and XRD was done to study the microstructure of joint with formation of various carbides helps in making the joint stronger. Zafar et al. [25] investigated formation of clad on AISI 304 stainless steel of WC-12Co cermet using 1.4KW industrial multimode microwave developed clad was characterised by FESEM, XRD, micro hardness and porosity. Result shows that there is excellent metallurgical bonding of clad material with base metal the microstructure shows skeleton like structure which indicates formation of various complex and stable carbides which indicates high hardness of the developed clad 1135HV porosity was found to be .98%. Research was also carried out on the inside temperature measurement of microwave oven using the pyrometer at small interval of 30s.

A nickel- based powder of particle size 40 μm was utilized as the interface layer for the creation of the joint. The bulk plates of MS were put in such a way, to the point that a butt arrangement and a gap of around 0.5 mm was kept up between both the specimens. The gap was loaded with the slurry, having the blend of EWAC (Ni-base powder) and epoxy. As a result of the microwaves reflection.

II. MATERIALS AND METHODS

Based on literature review SS 430F was selected as a work material for the purpose of experimentation. It has certain inherent properties like good oxidation resistance capacity at elevated temperature, good formability and good corrosion resistance; which makes it suitable for many application like in kitchen utensils, in washing machine parts, in parts of furnace, in heat exchanger and in petroleum refinement equipment etc. Table 2.1 shows the chemical composition of work material. It has chromium to improve the wear resistance capacity, nickel to increase densification, carbon to improve brittleness and manganese to give strength.

Table 2.1 Chemical composition of SS-430F

Microwave hybrid technique was used to join the material SS430F. Microwave applicator (Domestic Microwave), working frequency (2.45 GHz) and working power rating (900W), susceptor material (Fine Graded Charcoal Powder), separator material (99% pure thin Graphite Sheet), interfacial powder (Nickel Powder - EWAC) were used as process material.

Fig 4 Joint Mechanism of Microwave welding

2.1 Skin Depth

To carry out the experiment, nickel powder was used in form of slurry made by mixing with epoxy resin. The combination of both was applied between the work materials. The skin depth is lower at room temperature so nickel is not able to couple with the microwaves; as a result it reflects all the microwaves.

The skin depth of material can be found out by the Eq. 1

$$\delta_s = \sqrt{\frac{2\rho}{2\pi f \mu_0 \mu_r}} \qquad \text{..............................(1)}$$

Where

μ_0 → Permeability constant, μ_r → Relative permeability constant, f → frequencyρ → Bulk resistivity,

δ_s → Skin depth,

Based on the equation 3.1; skin depth was calculated. The calculated value for nickel (considering ρ =8.707 μΩ-cm, =2.45 GHz, μ∘ =4p×10 -7 H/m and μ =600) was approximated 0.12 μm. Nickel particles directly are not able to process with the microwave radiation which results in reflection of the microwaves.

To remove such obstacles related to the skin depth; microwave hybrid heating was used in which firstly the nickel powder was heated by traditional method by using the susceptor material, which will accelerate the temperature of the powder and powder will start to form the bonds with the microwave. Once the process is completed of melting followed by fusing; a solid layer at the joint will be formed which will restrict the reflection of the microwaves.

2.2 Tensile Testing

Tensile testing is mainly done to test the strength of the material in which a suitable load is applied on the work material which gives result in form of ultimate strength after which the failure of the material occurs. During the testing; work material elongated due to which certain cross sectional area of the work material reduced.

These results may be utilized to obtain the material properties like modulus of elasticity, ultimate or yield strength of the work material, Poisson ratio and also the characteristics of the strain hardening. Uniaxial and biaxial tensile testing are carried out. E8/E8 M-09 ASTM standard was used to carry out for tensile testing in the present study. Dimension of the specimen which was used during the experiment is shown in Figure 5(a) and Figure 5(b) also shows the equipment used during tensile testing.

Figure 5 (a) Standard tensile test specimen and (b) Zwick-Roell Z010 tensile testing machine (Chemical department, TU, Patiala)

III.RESULTS AND DISCUSSION

Results on mechanical and physical characterization of Joint of SS-430F by using the microwave are discussed here. Tensile testing of the joint is also presented which was done to calculate the ultimate tensile strength of the work material SS-430F.

Figure 6: Microwave Processed Joint

The observed tensile strength of the joint using UTM was very high as shown in table 2 but there was no elongation as the fracture was brittle. The reason behind the brittle facture of joint might be due to the presence of Ni_3Si. Carbides are also present at joint but they are very low in percentage by volume. Ni_3Si is brittle in nature [37]. It has one amazing property that's corrosion resistance because of formation of high silicon layer. As James studied in his paper that formation of Ni_3C is brittle in nature [38]. Both Ni3Si and Ni3C are present in the welded region and both are dominating in percentage by volume. Since it was seen that Ni_3Si and Ni3C both are brittle in nature so that's how fracture of joint was brittle.

Table 2 Shows the Results of the tensile testing

IV.CONCLUSIONS

Microwave processing technique is being used for joining and cladding of the work materials. The present research work was based on utilization of microwave energy to join the work material SS-430F. Major conclusions drawn from the present study is shown below:

Due to good metallurgical bonding between the work materials; mechanical strength of the joint was observed to 481MPa. Tensile testing proves that the behaviour of the work material was brittle in nature due to presence of Ni3Si with addition of carbon from the graphite sheet.

List of Figures

Figure No. 1

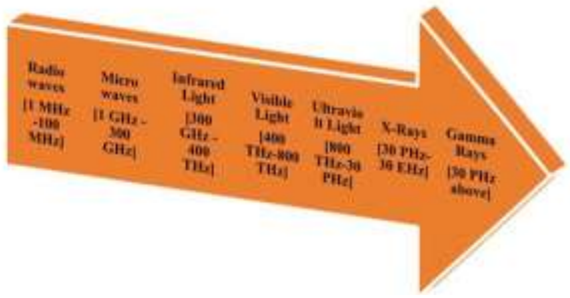


Figure No. 2

Figure No. 3

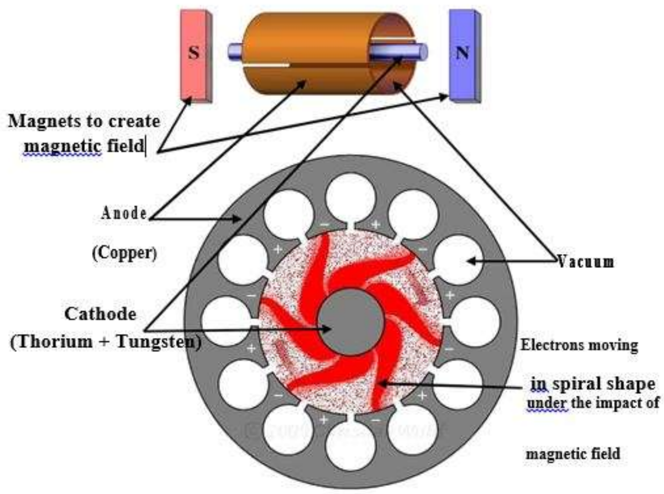
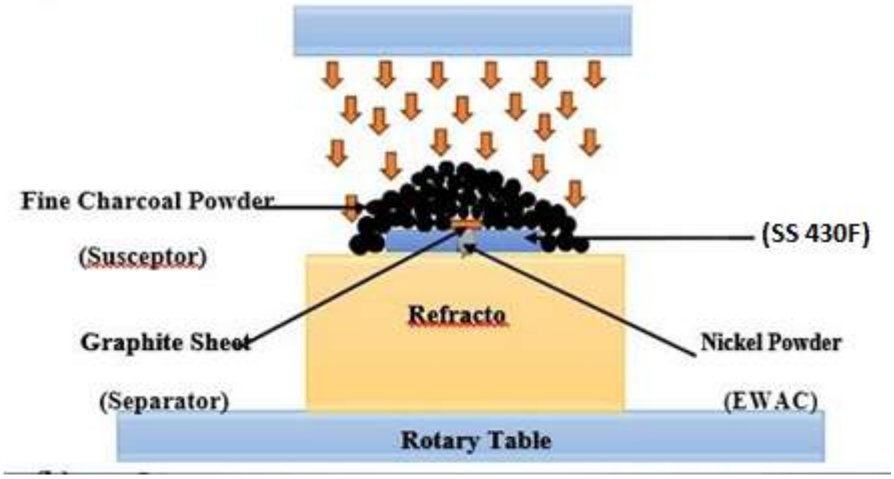


Figure No. 4



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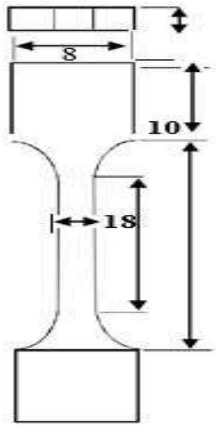

(a)

(b)

Figure No. 6

List of tables

Table No. 1

Material	C	Mn	P	Si	Cr	Fe
SS-430F	**0.12**	**1.25**	**0.06**	**1.00**	**18**	**Remaining**

Table No. 2

Material	Microwave Processed Joint	
	Strength	**% Elongation**
SS-430F	481	No elongation

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