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Joining of Bulk Metallic Material Using Microwave Energy: A Review

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Abstract: *In the final few existence, the uses of microwave energy is flourishing day by day. It is one of the novel techniques of joining bulk metallic material. The unconventional method of microwave heating is particularly fascinating due to its advantages i.e. improved yield strength, energy saving, less pollution etc. The rudimentary difference from other type of welding is interaction with electromagnetic waves at molecular level ensuring volumetric heating. Most of microwave energy has been confined to microwave absorbing materials, i.e. ceramic and ceramic composites. Very few works has been implemented on metallic material due to its high thermal conductivity. In this process charcoal powder is used for hybrid heating. Graphite plate is used as a separator. Nickel can be used as interfacing material. Substrates such as mild steel, stainless steel, brass, copper etc. can be used for research. Microwave energy can be worn for a variety of purpose such as microwave joining, microwave sintering, microwave cladding etc. Study in this pasture can actually motivate the novel academicians and researchers for superior results.*

1. LITERATURE REVIEW

Osepchuk (1984) concluded the basics of microwave heating. Author also stated that the possible areas of its application in his study [1]. **Sutton (1989)** analyzed that the microwave energy can be utilized for the processing of ceramics which is relatively new invention in this field [2].

Siores and Rego (1995) prepared joint of 0.1 to 0.3 mm thin steel sheet. Author concluded the localized arching was enough to melt such thin sheets [3]. **Jacob et al. (1995)** stated that dielectric heating inside a compound is caused due to dielectric polarization. The author also stated that dielectric polarization is a combined effect of the four factor i.e. electronic polarization, atomic polarization, dipole polarization, interfacial polarization. [4]

Agrawal (1998) examined the use of microwave energy for the sintering of powered meals, fabrication of transparent ceramics and the design of continuous microwave systems [5].

Rodiger et al. (1998) reported that the sintering of iron, copper and graphite composite using microwave energy for 30 min resulting in exceptional density [6].

Yarlagadda et al. (1998) explained that the cause of localized heating mechanism is friction associated with oscillation of dipoles in polymers [7]. **Yarlagadda et al. (1998)** stated that microwave energy absorption by a material is dependent on electric field intensity, permittivity, frequency and loss factor [8].

Aravindan and Krishnamurthy (1999) explained the sintering by hybrid microwave heating ceramic matrix consisting of alumina and zirconia. Author stated that the process was done using sodium silicate glass powder as sandwich layer and 2.45 GHz, 700W microwave radiation [9]. Ahmed & Siores (2001) performed microwave joining of alumina, silica, zirconia ceramics. Author concluded that the excess of strength of yielded joint as compared to base material. They also recorded the elimination of impure inner layers further increasing the strength [10].

Ku et al. (2001) stated various industrial applications and process methods using fixed and variable frequency microwave (VFM) facility. Author introduced these applications for better understanding of microwave energy [11]. **Das et al. (2008)** concluded that the main focus of research on microwave processing is now centered for industrial applications, and study is being undertaken to understand the heating performance of materials exposed to microwaves [12].

Prabhu et al. (2009) observed that activated tungsten sintered powder using microwave shows better densification as compared to conventionally sintered powder due to reduced particle size and higher specific surface energy [13]

Mondal et al. (2009) concluded that smaller particle size and higher porosity leads to rapid heating due to high absorption rates of microwave. Study was done with different particle size of conduction material such as copper [14].

Cha et al. (2009) stated that the heating of bulk of material in microwave processing is due to penetration of microwave irradiation through the volume of material [15].

Sharma and Gupta (2010) patented the use of microwave energy for cladding of metallic and non metallic powders on metallic substrates [16].

Srinath et al. (2011) performed and examined the joining of bulk copper by microwave energy at 2.45 GHz and 900W, with charcoal to enable microwave hybrid heating. Author resulted in dense uniform microstructure, with preferential orientation (1 1 1), hardness 78± 7 Hv, 1.92% porosity and ultimate tensile strength of 164.4 MPa [17].

Bajpai et al. (2012) examined the bonding of natural fiber (nettle and grewia optiva) by microwave energy using suitable susceptor. This was then compared to adhesive bonding and the supremacy of bonding by microwave energy was established [18].

Rajkumar et al. (2012) examined the life characteristic of copper–graphite composite by using high temperature pin-on-disc tribometer, concluding life at mean and 99% reliability are 18,725h and 16,950h respectively [19].

Gupta et al. (2013) resulted that mild steel and stainless steel plates can be joined by the microwave energy at 2.45 GHz and 900 W. The characterization of joint has been carried out through microstructural analysis, tensile strength, elongation, and microhardness. The results revealed that the joint formation is clearly visible in microstructure. Tensile strength, elongation, and microhardness are 340.16 MPa, 11.67%, and 130 Hv, respectively [20].

Gupta and Kumar et al. (2014) discussed joining of the stainless steel plates. The characterization of joint has been carried out through microstructural analysis, XRD analysis, tensile strength, elongation and microhardness. There are no cracks at the joints. Very small amount of porosity has been observed. Hardness decreases towards the joint. As the exposure time and percentage of nickel based powder increase, tensile strength also increases. Tensile strength, elongation and microhardness of joint are 323.16 MPa, 11.30% and 145.3 Hv respectively [21].

2. EXPERIMENTAL SETUP

Fig. 1 shows the microwave joining setup. Experiments can be carried out using mild steel, stainless steel, brass, copper etc. Butt joint is used for joining the pieces due to its simplicity. Specimen is cleaned with the help of acetone. After cleaning, the interfacing material is placed uniformly on the joining faces of the metal.

Charcoal is used for hybrid heating. Graphite plate is used as a separate. Refractory bricks are used to protect the magnetron from reflected microwaves from the specimen. As the microwave comes in contact with the charcoal, the temperature at the joints starts increasing. Ni based powder starts coupling with the surface of the specimen. After wards, coupling takes place. Hence, the raised temperature in specimen affects a very thin layer which gets fused with the molten particles in a sandwich form layer. The faces of metallic material get completely wet, so the melting of the material takes place. The molten area forms the weld bead after cooling at atmospheric conditions.

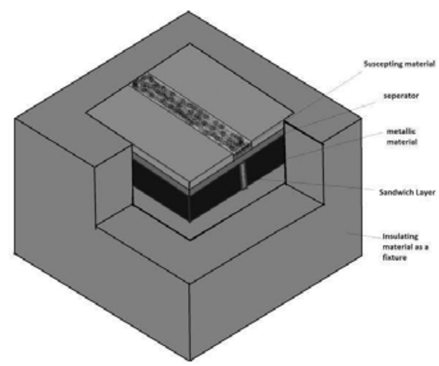

Fig. 1: Microwave Joining Setup

3. ADVANTAGES OF MICROWAVE JOINING

Microwave energy has various advantages over other welding techniques. It is mainly used due its energy saving capability, unique microstructure, improved mechanical properties etc.

4. CONCLUSIONS

Microwave amalgamation is the novel practice for joining different types of materials. Combination of bulk metallic material having high thermal conductivity can be successfully achieved using microwave hybrid heating process. Ultimate tensile strength of the joint is approximately 75 - 80 % of the base metal. This process can further be used for improving the strength of the joints. Different parameters can be varied to get better outcome. Optimization of various process parameters can enhance the novel invention in this field.

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