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INTERNATIONAL JOURNAL OF ADVANCED PRODUCTION AND INDUSTRIAL ENGINEERING

IJAPIE-2018-10-422, Vol 3 (4), 11-14

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Overview of Welding Using Microwave Radiation

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Abstract : *The application of the microwaves is increasing rapidly in material processing due to its unique characteristics of volumetric and rapid heating. Volumetric heating means that materials can absorb microwave energy directly and internally and convert it to heat. Its characteristic leads to controlled, selective, uniform and rapid heating. Microwave energy can be used for the processing of a wide variety of materials, where heat is generated from within the material instead of via radiation heat transfer from external heating elements. This paper introduces microwave heating, its characteristics and effect of process parameter on welding. In this review paper, the work carried out by the researches in the field of microwave joining of similar and dissimilar materials in the past decade by various researchers.*

Keywords: *Hybrid Heating, Process Parameter, Welding Time, Refractory Brick.*

1. INTRODUCTION

1.1. Brief History and Applications of Microwave Heating

Microwaves are part of the electromagnetic spectrum with frequencies ranging from 300 MHz to 300 GHz and corresponding wavelengths between 1 m and 1 nm respectively, Amit et al [2013]. There was need of Microwave technology during Second World War due to the demand for better radar technology for detection of enemy aircraft and submarines, Wong and Gupta [2015]. In 1945, Dr. Percy Spencer from Raytheon filed a patent for using microwaves to process food leading to the introduction of commercial microwave ovens in 1947 but due to its large size and high cost, found limited usage in industries, Gupta and Jain [2015]. Originally, microwaves were used for communication. In 1950, microwave energy was used to heat materials. After that, microwave heating had been successfully used in the following fields: tempering meat, precooking bacon, preheating rubber slugs, vulcanizing rubber, drying pasta, drying crushed oranges, etc., Wong and Gupta [2015]. In 1960s, a smaller and cheaper domestic microwave oven was introduced and the sale of microwave ovens grew rapidly in 1970s and has since become a common kitchen appliance in many households, Karanbir et al [2015]. Microwave heating is used most commonly for the heating of food due to the good microwave susceptibility of water molecules in the food and has been increasingly applied for processing of polymers, ceramics, metals, minerals, chemicals, composites and biological subjects, Srinath et al [2011]. In the late 1980s, there was growing interest in high temperature microwave processing of materials, with some successful applications at laboratory scale, for example, sintering of ceramics, microwaves are justified as a potential heating mechanism to replace some conventional heating methods, Srinath et al [2015].

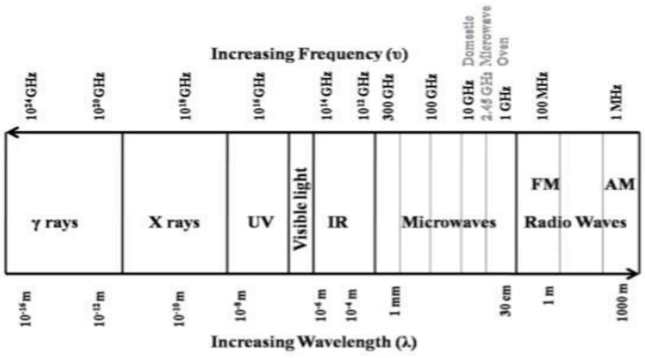

Fig 1 classification of electromagnetic waves

1.2 Fundamentals of Microwave Heating

One of the descriptions of the characteristics of microwave heating was in a Scientific American article in 1943 where it was mentioned that heat was generated from within the object and involves no transfer of heat to it. This is fundamentally different from conventional heating where heat is usually transferred to an object via conduction, convection or radiation. In conventional heating using an oven or furnace, the heating source first, has to heat up the entire volume of air and walls of the container before thermal energy is transferred from the surface of the object to the interior through conduction. But in microwave heating, due to the penetrative nature of microwaves, the object directly

absorb the microwave energy and heat is generated from within the object and do not require substantial heating of the environment.

1.3 Introduction to microwave materials processing

Microwave heating is a process which uses electromagnetic energy in the frequency range of 300 MHz to 300 GHz. In microwave heating the material is subjected to an electromagnetic wave that oscillates the molecules of material, there by generating heat. Microwaves are directly absorbed by the material thus causes volumetric heating. This volumetric heating is only obtained by microwave processing and it reduces time, energy as well as it is eco-friendly.

1.4 Characteristics of Microwave heating process

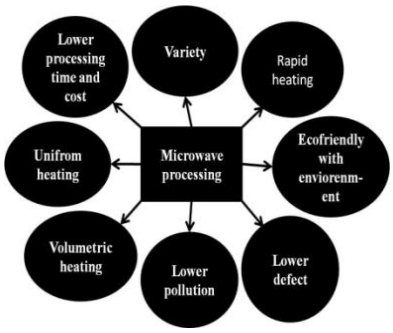

Fig 2 characteristics of Microwave Heating

a) **Clean energy:** It does not require medium, it propagates by only changing the electric field and magnetic field. It can propagate even in vacuum. It reaches the object and penetrates without heating air.

b) **Internal heating:** Microwave will reach the object to be heated at same speed of light, then it enters into the object as a wave and by getting absorbed, the object generates heat therefore microwave heating is internal heating.

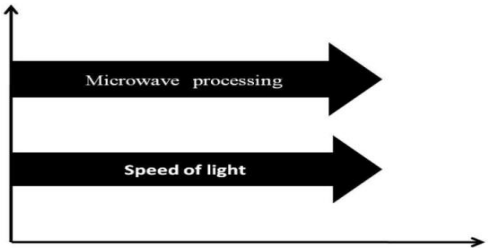

Fig 3 Comparison of transmission speed of microwave same as light

In microwave heating, the heat will be generated in the object by absorption of microwaves which has inverse heating profile. It heats the object internally and heat flows from inward direction to outward direction which reduces heat loss and rapid heating is achieved.

c) **Rapid heating:** It generates heat on their own by penetration of microwaves, not necessary to consider about heat conduction that is why rapid heat is possible by microwaves.

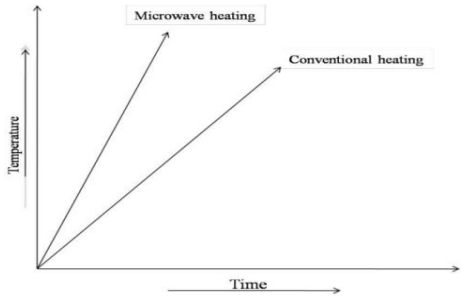

Fig 4 Microwave heating vs. conventional heating

d) **Heating uniformity:** It heat uniformly i.e. it gives volumetric heating effect can. Each part of heated object generate heat, so even for those object with complicated shape, it can be heated relatively uniform.

e) **Lower power consumption:** The microwave heating of material involves direct absorption of radiations by material, it provides higher rate of heat transfer in comparison of conventional methods and attains higher temperature in shorter time, this reduce overall consumption of power.

2. METHODOLOGY

1. Selection of specimen which is to be joined (Both the specimen can be similar or dissimilar)
2. A cavity is made on the refractory brick of the size of the specimen. Then specimen is cleaned with emery paper and acetone.
3. The joint is applied with the slurry (mixture of epoxy and nickel powder).
4. The specimen is placed in the cavity.
5. Graphite sheet is placed on the specimen.
6. Charcoal power is poured above the graphite sheet.
7. The whole refractory brick is placed in the microwave oven.
8. The microwave oven is set to 900W.
9. The time is calculated using stopwatch to determine the time required for the formation of joint between the two specimens.

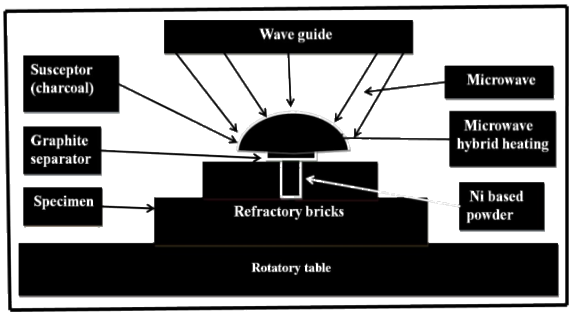

Fig 5 Schematic microwave hybrid heating processing

3. EFFECT OF PROCESS PARAMETERS

3.1 Effect of time

- It is important parameter to consider time for which specimen is kept in the in microwave. It was observed that:
- For stone charcoal melting point was not reached after 12-15 minutes and even red hot condition was not observed.
- For wooden charcoal melting point was observed after 10-12 minutes.
- For graphite powder red hot condition was observed after 2-3 minutes and melting point was observed around 6 minutes.

3.2 Positioning of Work Piece

Intensity of microwaves varies from point to point inside the microwave oven. So it is necessary to position the work-pieces at a point where maximum amount of microwaves reach to the work-pieces to achieve the proper melting in least time. After number of experiments it was observed that 16 mm height at the center of base plate was appropriate for the maximum intensity of microwave energy.

3.3 Length of Specimen

Length is also one of the major parameter which was observed during experimentation. No melting was observed in all the experiments conducted on specimen having more than 10 mm length. So it was tried to keep the specimen length as short as possible and the average length of each specimen was 8mm.

3.4 Thickness of Slurry

Very fine thickness is required for good quality joint. If the thickness applied is more than the appropriate value (0.2-0.3mm approx.) then there will be gap at the joint and the possibility of mismatching occurs because slurry burns within 10 to 15 sec.

3.5 Susceptor Material

The basic purpose of susceptor material is to prevent the direct exposure of material in microwaves. When it comes in contact with the microwaves, it absorbs the microwave energy, burns and raises the temperature of work-pieces up to its melting point.

4. CONCLUSION

In the present paper, it was concluded that, microwave processing is emerging as a innovative technology with many advantages over conventional processing. There is, therefore, increasing industrial application of microwave energy for heating, drying, curing and sintering of materials. Until 2000, microwave processing of materials mostly was confined to ceramics, semimetals, inorganic and polymeric. The most recent significant development in the microwave processing has been the sintering, brazing, joining and melting of metals also.

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