HEATING OF EN9 STEEL BY USING MICROWAVE ENERGY AND COMPARING WITH CONVENTIONAL HEATING TECHNIQUE WITH THE HELP OF MICROSTRUCTURE

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ABSTRACT

The microwave heating technology began with heating foodand later on extending applications to the processing of a widevariety of materials, like ceramics, polymers and composites;now offers wide applications in the area of metallic materialprocessing too. The microwave processing of materials is a relatively new technology that provides new approaches to improve the physical properties of materials; provides alternatives for processing materials that are hard to process; reduces the environmental impact of materials processing. Thegrowing interest is partly the result of increased awareness among scientists, processing engineers, and potential usersabout the benefits of microwave processing. Microwaves formetallic material processing are a challenging area of researchowing to reflection of electromagnetic waves by most of themetals at ordinary conditions.

Keywords: ***Volumetric Heating, Electromagnetic Spectrum, Potential Heating Mechanism, Microwaves*.**

I. INTRODUCTION

The spectrum of electromagnetic waves spans the range from a few cycles per second in the radio band to 10^{20}cycles per second for gamma rays. Microwaves occupy the part of the spectrum from 300 MHz (3×10^6 cycles/s) to 300 GHz (3×10^{12} cycles/s). Within this portion of the electromagnetic spectrum there are frequencies that are used for cellular phones, radar, and television satellite communications. For microwave heating, two frequencies, reserved by the Federal Communications Commission (FCC) for industrial, scientific, and medical (ISM) purposes are commonly used. The two most commonly used frequencies are 0.915 and 2.45 GHz. Recently, microwave furnaces that allow processing at variable frequencies from 0.9 to 18 GHz have been developed for material processing. [1] Originally, microwaves were principally used for communication. In 1950, the use of microwave energy to heat materials was discovered. Now microwave ovens have became common for heating food products in the home. The potential advantages of microwave heating have led researchers to design and implement new processes for industrial use. Although some non-thermal microwave effects have been observed and claimed by researchers, the main application of microwave processing of materials is in heating. The most prominent characteristic of microwave heating is volumetric heating, which is quite different from conventional heating where the heat must diffuse in from the surface of the material. Volumetric heating means that materials can absorb microwave energy directly and internally and convert it to heat. It is this characteristic that leads to advantages using microwaves to process materials. Beginning 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 [2].

Melting metals in traditional furnaces such as cupola furnace, blast furnace, crucible furnace etc. consumes significant amount of energy along with possibilities of material and energy losses and some safety risks. In order to overcome the inherent disadvantages of conventional melting, one or more of the advanced melting technologies such as electron beam melting, infra red melting, plasma melting, microwave melting, solar melting etc. are preferred according to the specific requirements and applications. Microwave heating receives considerable attention due to its major advantages such as high heating rates, reduced processing time, low power consumption and less environmental hazards. During microwave heating, large amount of heat may be generated for a lossy material throughout the volume, whereas for conventional heating, the material is heated via an external heat source and subsequent radiative transfer [3].

In recent years, microwave processing of metal/alloy powders have gained considerable potential in the field of material synthesis. Microwave heating is recognized for its various advantages such as: time and energy saving, rapid heating rates, considerably reduced processing cycle time and temperature, fine microstructures and improved mechanical properties, better product performance, etc. Microwave material interactions for materials having bound charge are well established, but for highly conductive materials like metals, there is not much information available to interpret the mechanism of microwave heating and subsequent sintering of metallic materials. In heating how the thermal profile of electrically conductive powder metal like copper changes with particle size and also with porosity content; in other words, initial green density when the material is exposed to 2.45 GHz microwave radiation in a multimode microwave furnace [4].

Microwave hybrid heating is the most important example of mixed-absorbed heating that is used to sinter material which has low dielectric loss at low temperature and high dielectric loss at high temperature. The microwaves are absorbed by the component that has high dielectric loss while passing through the low-loss material with little drop in energy [5-6]. This can be performed by using material, which is called susceptor, and has high dielectric loss at low temperatures around the green part. At low temperatures, susceptor material absorbs microwave and reaches high temperatures. Then, it can transfer heat to the sample via conventional heating mechanisms. Thus, the sample which has high dielectric loss at high temperatures will be able to absorb microwaves per seconds. A combined action of microwaves and microwave-coupled external heating source (microwave hybrid heating) can be utilized to realize rapid sintering from both inside and outside of the powder compact [7]. The hybrid heating system will heat the sample more readily at low temperatures and at high temperatures will flatten out the temperature profile inside the sample

II. EXPERIMENTATION

Two trials were carried out in a 1050 W domestic microwave oven which was modified later with glass wool insulation to reduce heat loss. This oven was then fixed with a thermocouple along with PID controller. Also two trials were conducted in muffle furnace of 3500W capacity for conventional heating. Metallurgical heating of EN9 steel in bulk form has been achieved in this work. Suitable susceptor was used for initial coupling of microwaves with metallic materials in MW heating. Bulk pieces were exposed to microwave radiation for 14 minutes in a multimode applicator and 136 minutes in muffle furnace. Photograph of red zone inside the insulation box of microwave oven and muffle furnace as shown in Figures 1.1 and 1.2 respectively.

Specification of microwave oven is given in Table 1.1.Tables 1.2 and 1.3 give the properties of EN 9 steel. Table 1.4 shows the specifications of the muffle furnace used. Samples were heated at 875°C, and soaking time of 20 minutes was maintained. After heating, the specimens were removed from both the furnaces and were subjected to air cooling, oil quenching and water quenching respectively.

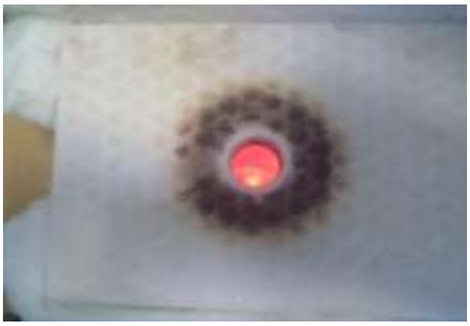


Figure 1.1 : Photograph of Red zone inside the insulation box

Figure 1.**2 : Photograph of Red zone in Muffle furnace at 875°C**

Table 1.1: Microwave oven specification

Model number	KJ17Gww2-mmz
Product	Grill microwave oven
Capacity	17 Litres
Power output (MW)	700 Watt
Power input (MW)	1050 Watt
Power input (Grill)	1000 Watt
Dimensions (cm)	44 x34x25.8
Weight	10.5 kg

Table1.2: Chemical composition of EN9 steel

Carbon	Silicon	Manganese	Sulphur	Phosphorous
0.50%	0.25%	0.70%	0.05%	0.05%

Table1.3: Physical Properties of EN9**steel**

Density kg/m^3	Coefficient of Thermal Expansion Per °C from 20°C	Modulus of Elasticity N/mm^2
7800	11.6x10-6	206000

Table 1. 4: Muffle Furnace specification

Manufacturer	Biotechniques India
Sl. No.	148
Volt (V)	230
Watts(W)	3500
Model	BTI

III. RESULTS AND DISCUSSION.

fter experimentation we got the following results in term of microstructure. They are illustrated in following figures. Figure 2.1 shows the microstructure of the sample before heating which reveals ASTM Grain size 7 to 8 and appearance of Elongated & Equiaxed Grains with 55 to45% ferrite.

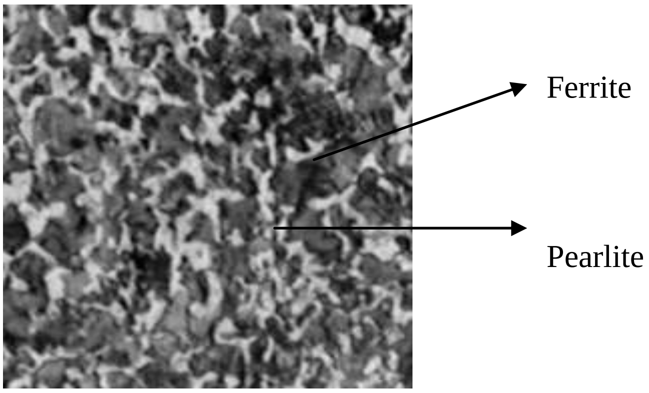
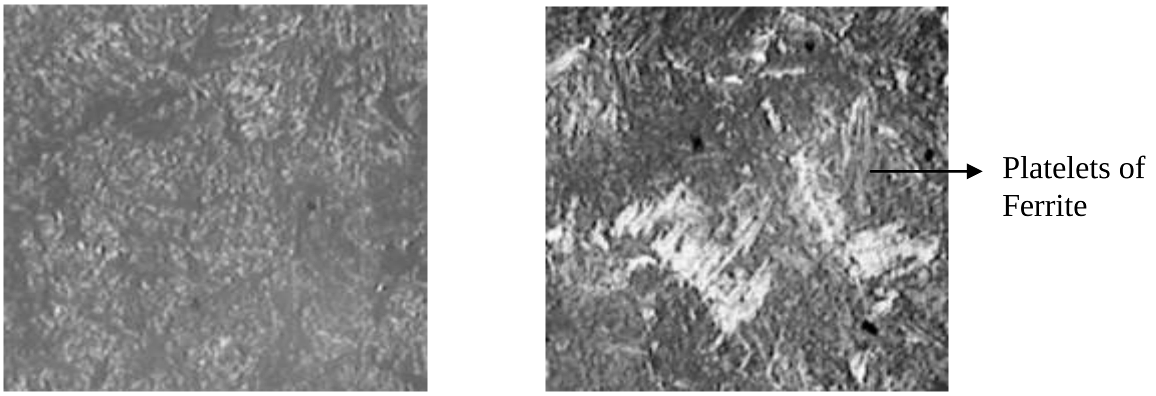


Figure 2.1: Micrograph oforiginal specimen at 250X

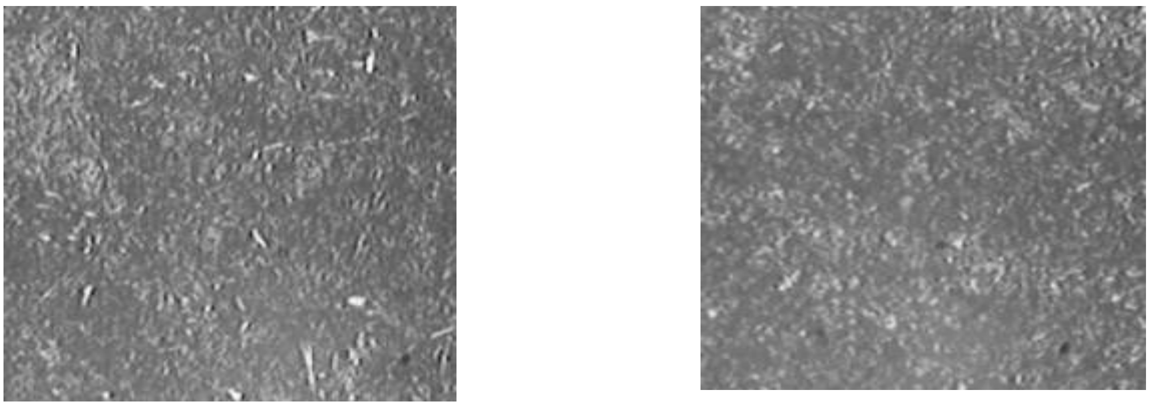
Figure 2.2(a) shows the microstructure of Oil quenched specimen (Trial 1) of muffle furnace having coarse structure of martensite and Figure 2.2 (b) shows microstructure of oil quenched specimen of microwave heating having fine bainite structure which gives better machinability properties. Widmanstatten platelets of ferrite at prior austenite Grain boundary and within grain in a matrix of martensite in fig 2.2(b)



(a) **(b)**

Figure 2.2: Micrograph of oil quenched specimen at 250X. (a) MF Heating, (b) MW Heating.

Figure 2.3(a) shows microstructure of the water quenching specimen(Trial 1) of muffle furnace, martensitic structure is observed. Figure 2.3 (b) shows microstructure of the water quenched specimen of microwave heating, coarse structure has been observed. Specimen has fine structure, along with high toughness**.** Hardness value increased in MW heating.

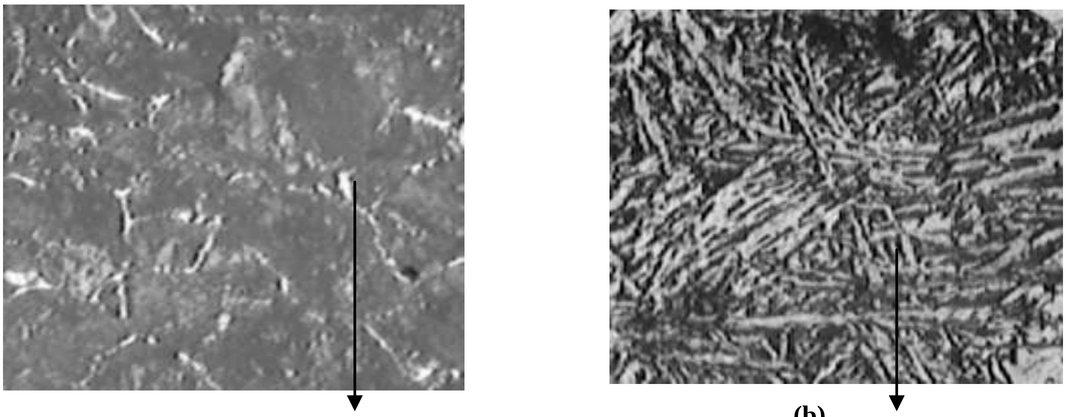


(b)

(a)

Figure 2.3: Micrograph of water quenched specimen at 250X. (a) MF Heating, (b) MW Heating.

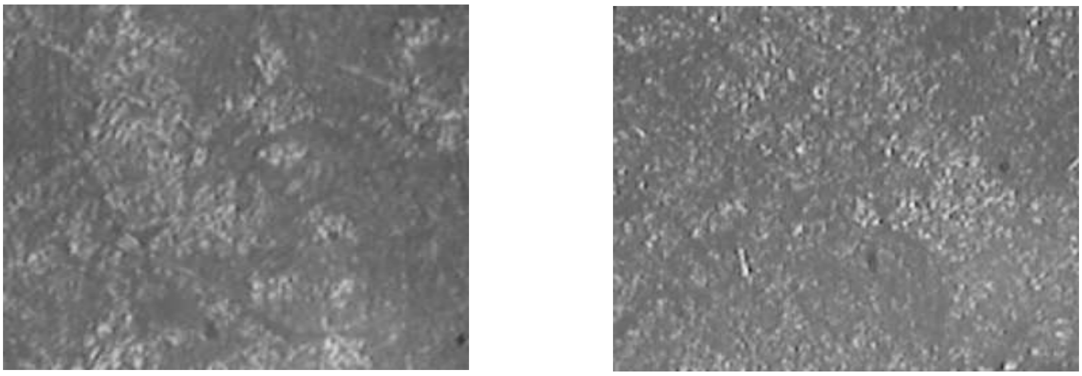
Figure 2.4(a) shows microstructure of the muffle furnace, air cooled (Trial 1) specimen, ASTM Grain size 7 to 8 elongated & equiaxed. Grains predominantly pearlitic matrix with grain boundary ferrite is observed. Air cooling requires maximum time and therefore grain size reduces. Figure 2.4(b) shows microstructure of the air cooled specimen of microwave heating, Widmanstatten platelets of ferrite at prior austenite grain boundary & within grain in a matrix of martensite. From above microstructure coarse structure obtained also machinabilityhas been improved.



(b) Pearlite (a) Platelets of Ferrite

Figure 2.4: Micrograph of air cooled specimen at 250X. (a) MF Heating, (b) MW Heating.

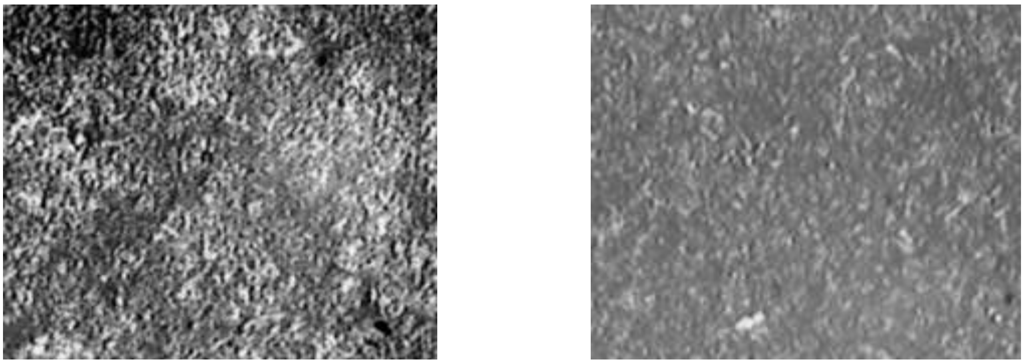
Figure 2.5 (a) shows the microstructure of oil quenched specimen(Trial 2) of muffle furnace having coarse structure of martensite and Figure 2.5(b) shows microstructure of oil quenched specimen of microwave heating having fine bainite structure which gives better machinability properties. Widmanstatten platelets of ferrite at prior austenite grain boundary and within grain in a matrix of martensite in Figure 2.5 (b)



(a) (b)

Figure 2.5 : Micrograph of oil quenched specimen at 250X. (a) MF Heating, (b) MW Heating.

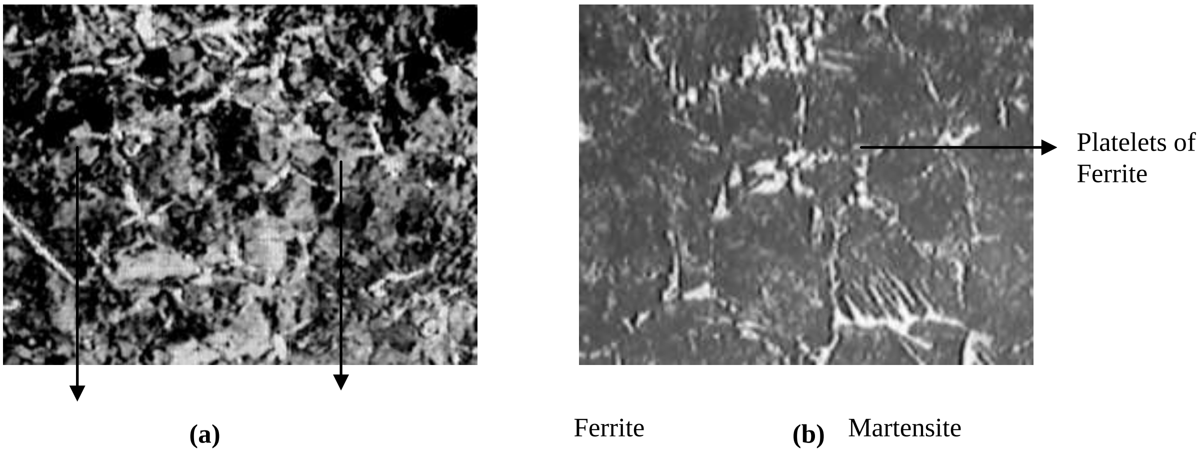
Figure 2.6 (a) shows microstructure of the water quenching specimen (Trial 2) of muffle furnace, martensitic structure is observed, coarse structure is seen..Figure 4.6 (b) shows microstructure of the water quenching specimen of microwave heating, which shows >95 % martensite with fine structure and high toughness**.** Hardness value increased in MW heating.



(a) **(b)**

Figure 2.6: Micrograph of water quenched specimen at 250X. (a) MF Heating, (b) MW Heating.

Figure 2.7(a) shows microstructure of the muffle furnace, air cooled specimen, Martensite with grain boundary ferrite is observed. ASTM Grain size 7 to 8 Elongated & Equiaxed. Grains Predominantly pearlitic matrix with grain boundary ferrite is observed. Air cooling require maximum time that's why grain size reduces. Figure 2.7 (b) shows microstructure of their cooled specimen of microwave heating, Widmanstatten platelets of ferrite at prior austenite grain boundary & within grain in a matrix of martensite. From above microstructure coarse structure obtained also machinability has been improve



(a) **(b)**

Figure 2.7: Micrograph of water quenched specimen at 250X. (a) MF Heating, (b) MW Heating.

IV. CONCLUSION

In experimentation we have taken various heat treatment processes. From that experimentation we concluded that results of microstructure getting from microwave heating technique are far better than conventional heating technique.

V. ACKNOWLEDGEMENT

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