Comparison between Joule heating, Microwave heating and Combined heating

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Abstract --Microwave energy has been in use for verity of applications for over 50 years. These applications include communications, food processing, wood drying, rubber vulcanization, medical therapy, polymers, etc. In the last two decades microwave heating has been also applied very effectively and efficiently to heat the different materials. Microwave heating is recognized for its various advantages such as: time and energy saving, very rapid heating rates, considerable reduced processing cycle time and temperature, fine microstructures and improved mechanical properties, better product performance, etc. The most recent application of microwaves has been in the field of industrial heating for different ferrous and non ferrous metals. Geometry of the furnace and crucible for heating made in simulation tool and simulation results of this furnace and crucible by combined heating, microwave heating and joule heating are analyze and discussed by different temperature values at different points of crucible. Comparison of the all three results is done by surface temperature plot analysis. Better method of heating is suggested.

Keywords - Microwave heating, joule heating, combined heating

I. INTRODUCTION

All the processes used in the manufacturing industry that can be little doubt that heating is the most commonplace, widely used in food, chemical, textile and engineering industries for drying, promoting chemical or physical change and many other purposes. Yet it remain one of the most difficult technique to control, being slow and imprecise when practiced in the usual way of heating the surface of the work piece by conduction, convection, radiation or any poor combination of these three methods, and even if perfection is achieved in heating, the process time is limited by heat flow rate into the body of the work piece from the surface[1]. Also in conventional heating all the heat energy required in the work piece must pass through its surface and the heat flow rate is limited by temperature and thermal diffusivity, the larger the work piece longer the heat takes. Due to these limitation in conventional surface heating, it is necessary to find an alternate way of heating work piece to get desired temperature distribution with responsive process time. And by reviewed details briefly microwave heating found best alternate for aforesaid.

Microwave heating is fundamentally different from the conventional one in which thermal energy is delivered to the surface of the material by radiant and/or convection heating that is transferred to the bulk of the material via conduction. In contrast microwave energy is delivered directly to the material through molecular interaction with the electromagnetic field. Microwave wave heating means heating of any substance like, food, material, etc. With the help of microwaves with different frequencies according to need. Now a days it is widely used in manufacturing as well as food processing industries. Since microwave heating has many advantages it can be categorized compared to different conventional heating.

The advantages and applications of microwave in industry as well as domestic level are widespread as, Quick heat penetration in drying of materials and heating of fluids , Selective heating in frozen food tempering modify reactions on catalysts and investment casting, Improvement of product quality in rubber vulcanization, ceramic firing, composite fabrication also Combination with conventional methods for chemical processing.

I. PROBLEM DEFINITION AND METHODOLOGY

In commercial practice, for heating of different materials conventional methods (induction, joule, direct combustion) are used. These methods are time consuming and lack of other advantages compare to microwave heating and also lack in fulfil increasing demands due to slow operations in process and hence production.

At commercial level all conventional heating occurs in furnace, which is a media for our interest. Form overall course study it can be seen that the microwave heating is compensate the lacks of conventional heating media(furnace) with Microwave heating. So, it is supportive to develop a furnace used conventional method of heating assisted with microwave heating. In this course of study attempt is done in this area of heating by simulation of microwave assisted (To Joule heating) heating furnace. For the simulation of such kind of furnace , the dimensions are taken from the CMAT innovation, a U.k based company, which is also a microwave assisted furnace.

Max temperature(°C)	Chamber dimensions (mm)	Radiant heating (kw)	Microwave power (kw)	Microwave frequency(GHz)
1514	232 × 245 × 396	9	1.8	2.45

Geometry of the furnace is developed in the simulation tool, materials for the furnace and target material is cast iron and alumina respectively, this allocation is facilated in simulation tool by it self. Different boundary conditions required for microwave heating and conventional (joule) heating is applied to the furnace and computed it for simulation results.

In addition to this, for comparison purposes. Two other geometry for furnace using only microwave heating and only joule heating is simulated separately . All the results form simulation is compared with each other and better method of heating is suggested for commercial use in the furnace.

I. RESULTS AND DISCUSSION

Simulation results are very important for the analysis of the modelling and also to give conclusion of the feasibility of the model for the occurrence of it. In this study the simulations for three different cases such as combined heating, microwave heating and joule are done. Their results and discussions are as follows,

1. For joule heating,

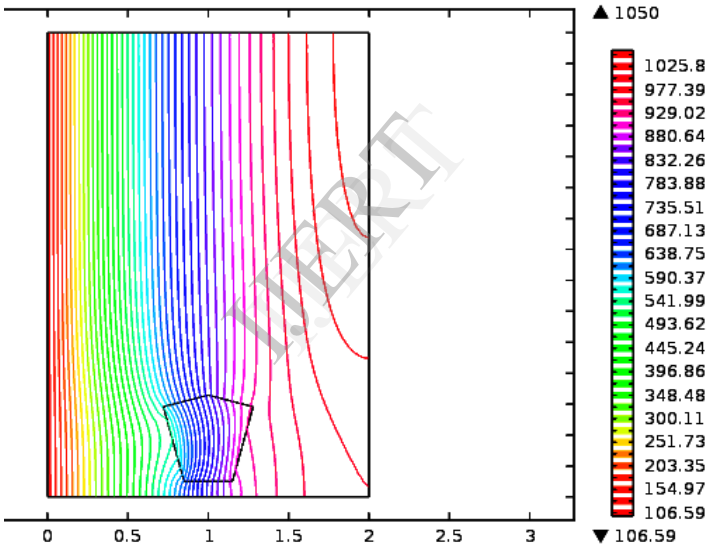

Figure 1 Joule heating

The number of contour lines are 40 for the contour plot of joule heating. The temperature range for the crucible is 400℃ to 850℃. The temperature decreased from left to right. At the middle portion of the crucible the temperature is from 600℃ to 800℃. The maximum value of temperature is 1050℃.

2. For microwave heating,

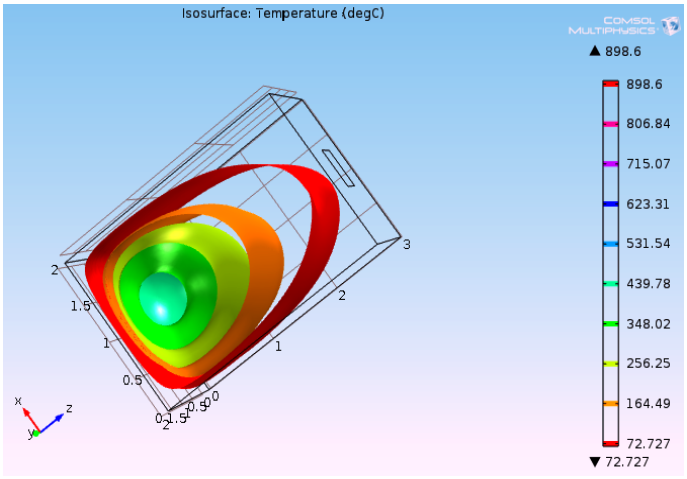

Figure 2 microwave heating

Iso surface plot for the microwave heating with 10 levels of iso-lines is shown in above figure. It can be seen that the temperature at the crucible is about 400℃ to 500℃. From top to bottom the temperature is increased in the range of 100℃ to 800℃. The maximum temperature value in the furnace is 898℃.

3. *For combined heating (microwave and joule heating),*

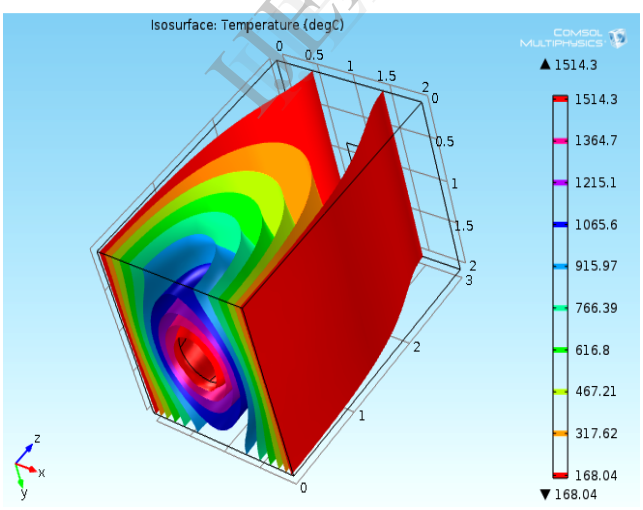

Figure 3 Combined heating

An iso-surface is a three-dimensional analog of an iso-line. It is a surface that represents points of a constant value (e.g. pressure, temperature, velocity, density) within a volume of space; in other words, it is a level set of a continuous function whose domain is 3D-space. There are 10 levels of iso-lines in 3-D represent the temperature variation in furnace with combined heating. The maximum temperature is at the bottom of and middle of the crucible with color code of orange. From inner to outer and the bottom to top the temperature is decreased in the range of 1300℃ to 300℃. The maximum value of temperature in the furnace is 1514℃.

CONCLUSION

In the present course of work an attempt has been made for the simulation of spontaneous wave based microwave assisted heating furnace.

From the overall study following conclusions can be drawn.

- For joule heating the maximum attainable temperature is 1050°C, which can be used for heating and melting of metals have melting temperature below this temperature. Joule heating is supportive for the materials having high value of electric resistance. Only radiation losses takes place in the furnace with joule heating.
- In microwave heating the temperature exceed to the value of 898°C, which is also useful for the heating and melting of materials, but they have good dielectric properties and high value of loss tangent. Only conversion losses in the crucible takes place in this heating.
- With combined effect of microwave and joule heating the temperature value is about 1514°C. This value of temperature is comparable with the reference furnace of microwave assist technology. Also this technology can be useful for melting of commercial ferrous and nonferrous metals within small time limit compare to convention melting in furnace.

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