MICROWAVE HEATING – AFFECT OF VARIOUS MATERIAL PROPERTIES ON HEATING RATE

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Abstract:

This article discusses the possibility of using microwaves for heating materials in the steel industry. Initially, basic theoretical aspects and properties of electromagnetic radiation were discussed and were compared with conventional heating. The second section of article shows results of laboratory tests, which were focused on heating of graphite, pure oxides of iron and hematite iron ore under various conditions (grain size, power input).

Keywords: heating, microwave, electromagnetic radiation, iron oxides, graphite

1. Introduction

Production of pig iron and steel demands a huge amount of raw materials and energy. This process is also associated with formation of a significant quantity of solid, liquid wastes and gaseous pollutants: especially nowadays much discussed carbon dioxide. For that reason, there are possible innovations of production associated with a reduction in CO_2 production. Reduction in consumption of raw materials, fuels is highly desirable. One possible innovation may be the utilization of microwave radiation for drying, defrosting, low temperature reduction and also for heating of raw materials, which deals with this article.

2. Microwave radiation characteristics

Microwave radiation is an electromagnetic radiation with frequency of 0.3 to 300 GHz and wavelength 1m – 1mm. In common practice is the microwave radiation with frequency 2.45 GHz and corresponding wavelength of 12.23 cm most used. As the title „electromagnetic " suggests, the wave is composed from electric and magnetic component (Fig. 1).

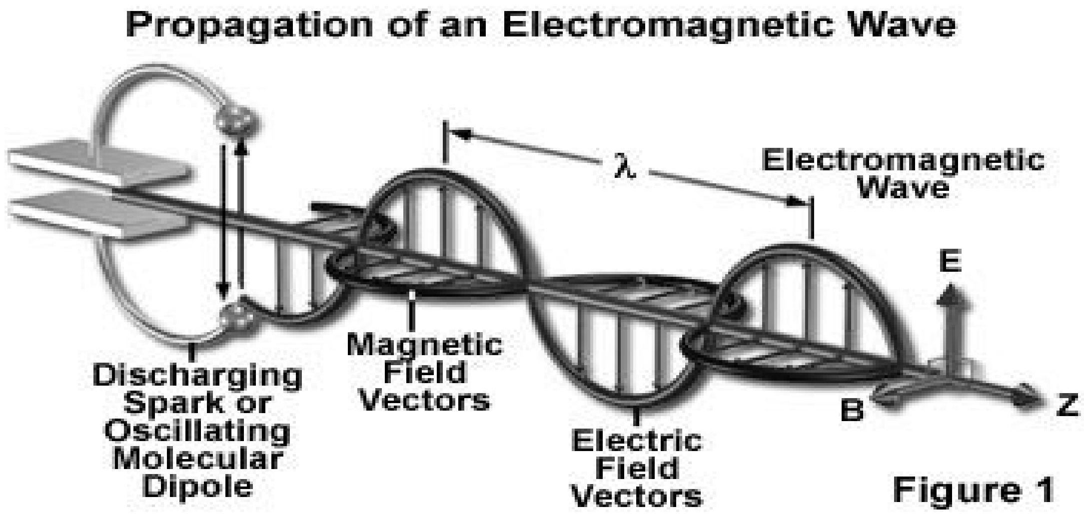

Fig. 1. Electromagnetic wave [1]

Microwaves are a kind of no-ionizating radiation with low energy (10^{-3} eV), which is not dangerous for living organism. Microwaves cause formation of internal electric field in the heated material. This cause vibration and rotation of particles (electrons and ions) and the result is volumetric heating of material. Three types of materials with different behavior in microwave field are discriminated:

I. Microwaves cross material with no effect (water, air)
II. Microwaves penetrate into material
III. Material reflects microwaves (metals)

2.1 Microwave thermal effects

Specific microwave effects are those effects that cannot be emulated through conventional heating methods. Examples:

I. Superheating effect: - rating to a temperature above normal boiling point (liquids)
II. Hot Spots: - in-homogeneous microwave field
III. Volumetric heating: - microwaves penetrate into material
IV. Selective heating: - only materials which absorb microwaves can be heated
V. Thermal runaway: - refers to a situation where an increase in temperature changes the conditions in a way that causes a further increase in temperature

3. Experimental part

All experiments listed below were held in 2010 at the Department of Metallurgy Technical University of Ostrava. In the text below there are given only summary tables and charts, each measurement was performed repeatedly (3 identical measurements) to reduce possible errors and then we used the average results.

3.1 Experimental device

Experiments were held in a conventional microwave oven Whirlpool JT 369SL with controllable microwave input power in the range 80 – 1000W (7 power degrees). For experimental use the microwave oven was modified:

I. Resistive heating elements were removed from upper wall
II. Input for ceramic tube in the upper wall was drilled and isolated
III. Rotary drive in the bottom of oven was unplugged
IV. Workspace was isolated by two layers of Sibral Super with total thickness of 4 cm

Microwave oven is located in an area of the hood, because there is the possibility of CO generation. Temperature measurement is realized by sheeted thermocouple, which is inserted directly into the sample. The sample is placed into the Al_2O_3 crucible, again isolated by Sibral layer. Prerequisite for maximum efficiency is to find a place with the highest concentration of microwaves (as mentioned before, the microwave field is inhomogeneous).

3.2 Microwave heating

Experimental heating measurements were made for graphite, Fe_2O_3, Fe_3O_4 and hematite ore. All samples were weighted with accurate 0,1 g and placed into isolated Al_2O_3 crucible

3.2.1 Heating characteristics – milled samples

The results are displayed at Fig. 2. Before measurements the samples were mashed in laboratory mill to grain below 0,1 mm. Measurements were carried out at the same power input for samples with same weight.

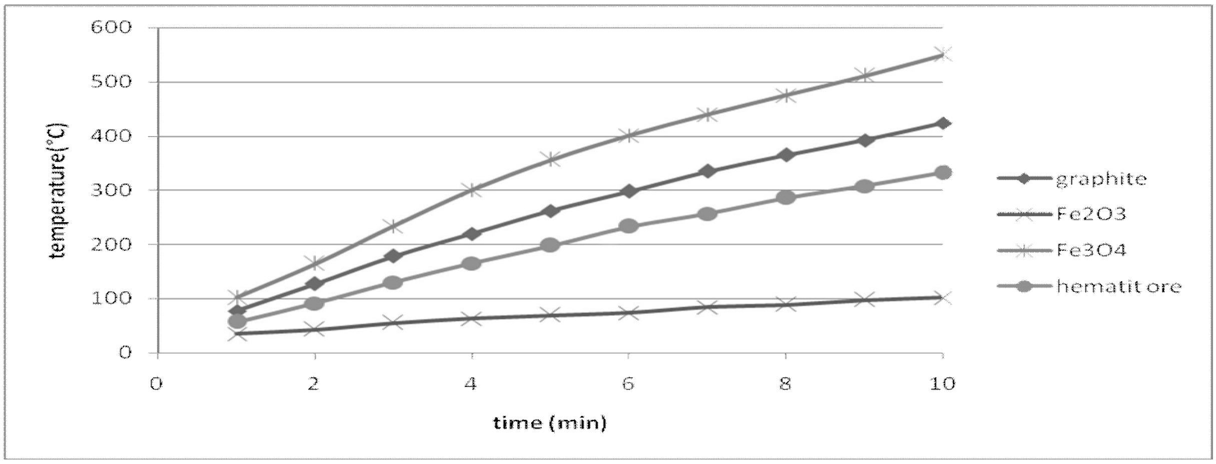

Fig. 2. Heating characteristics of milled samples

The experiment results showed that the most suitable material for microwave rating is Fe_3O_4. The worst rating speed has Fe_2O_3. As can be seen on the results of hematite ore (57% Fe_2O_3) heating, compounds contained in the ore (SiO_2, MgO, Al_2O_3, CaO…) significantly affected the rating rate. In the observed temperature range is the rating almost linear.

3.*2.2 Heating characteristics for materials with various grain size*

Before measurement were the samples crushed and divided into different factions. Other conditions were identical to previous measurements.

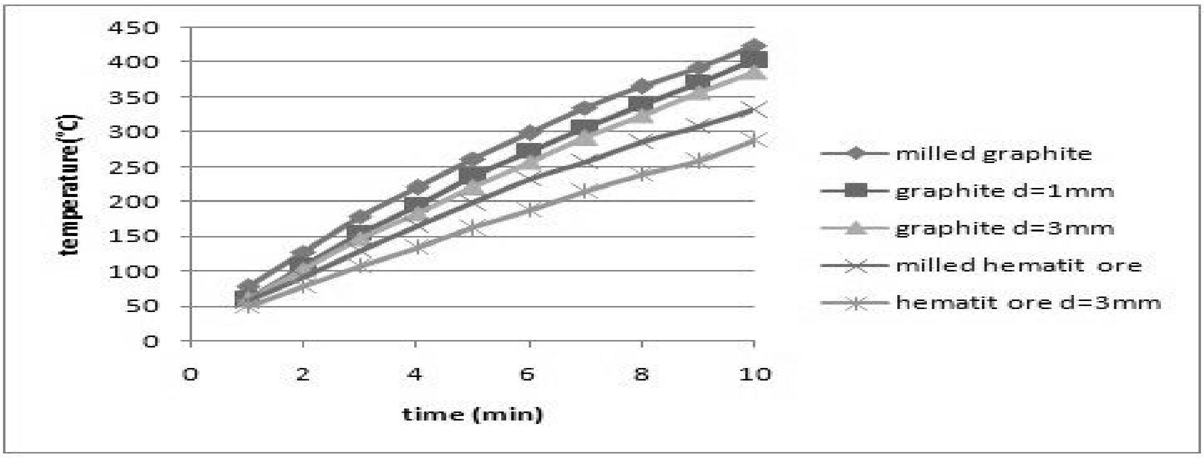

Fig. 3. Heating characteristics for various grain size

The results clearly show that the heating rate is decreasing with the growth of grain size. Amount of decrease is depending on the type of material and grain size. In our measurements was the rate of decline from 5 to 14 percent (Fig.3).

3.*2.2 Heating characteristics for different power inputs*

Measurements were performed for 2 different power inputs (500W, 1000W). Other conditions were identical to previous measurements. The results are showed on Fig. 4.

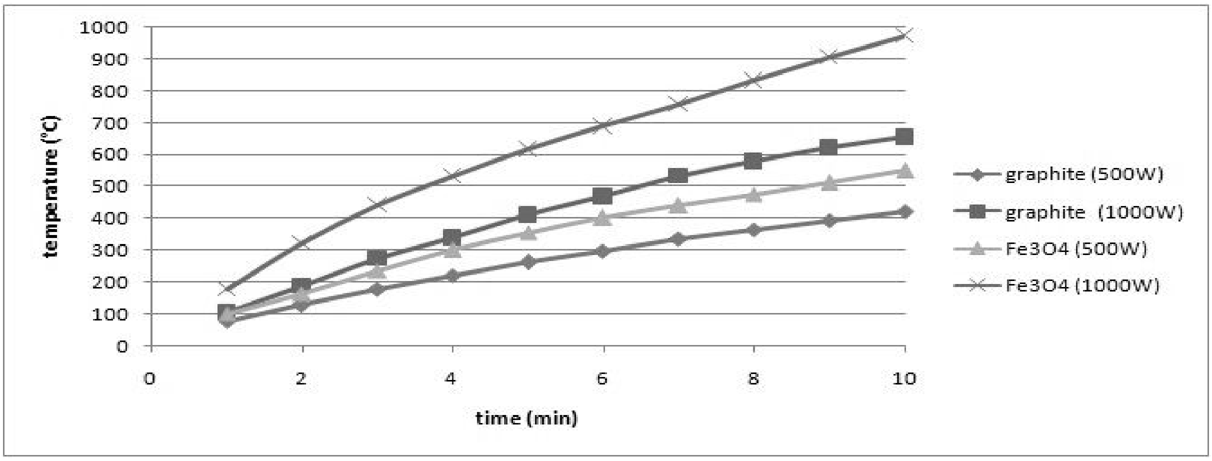

Fig. 4. Heating characteristics for different power inputs

As we have expected, the heating rate has significantly accelerated on the higher power input. The power input was increased twice and the final temperature increased by 77% for Fe_3O_4 and 55% for graphite.

Conclusion

The published results of laboratory measurements suggest that microwave radiation can be used for heating these materials. The average energy efficiency reached 15%. If a focused microwave field or larger samples will be used, we can reach greater efficiency. Nowadays we are focusing on the low temperature iron ore reduction in microwave field.

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FI-IM5/119.

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