Development of ferrite powders for inductive heating

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This study investigates the development of polycrystalline ferrite micro-powders to be used as heating agents in chemical reactors in relation to the inductive behavior of their toroidal counterparts. The objective of this work is to correlate the magnetic performance between the sintered core state and the powder state with regard to their chemical composition and microstructure. Mn-Zn ferrite and Mg-Mn ferrite materials were prepared following ceramic processing. The prepared ferrites were properly sintered, both in the state of compacted toroidal cores and free-standing granulated powder. The evaluation of the magnetic performance, heating ability and morphological characteristics of the sintered ferrites revealed a direct correlation between the loss performance of sintered cores and respective granulates. At the same time, the crucial role of the chemical, structural and morphological parameters involved in the matrix is highlighted. Optimization paths towards further improvement of the heating ability on the best-performing carriers are proposed.

Keywords: ferrites; magnetic powders; inductive heating

1. Introduction

There is growing interest in the heating capabilities of magnetic materials in recent years, aiming to assist in the design of thermally activated processes and applications. Several advancements in nanotechnology, biomedical applications and energy-efficient processes have enhanced this demand [1]. In the case of soft ferrite particles in the micro-range and depending on the application frequency and field, the generated heat may be due to either hysteresis and/or due to resonance losses. Both types of losses strongly depend on the chemical composition and crystal structure of the basic unit cell, as well as on the morphology of the particles. Additionally, the Curie temperature can act as a temperature control mechanism (as a safety switch) [2]. The present study focuses on the relations between the inductive behavior of conventional polycrystalline ferrite materials and inductive ferrite micro-powders to be used as heating agents. The work aims to define guidelines towards the design of effective ferrite micro-powders on the basis of the magnetic performance of their polycrystalline core-shaped counterpart, an aspect that remains insufficiently explored in the current literature.

2. Results and discussion

Mn-Zn ferrite materials of the general formula (Mn_x Zn_{1-x} Fe_2O_4, group I), x=0, 0.2, 0.4, and Mg-Mn ferrite materials of the general formula (Mg_y Mn_{1-y} Fe_2O_4, group II), y=0, 0.2, 0.4 and 0.6 were prepared following the solid-state reaction method. After mixing, prefiring and milling at optimal process conditions for each ferrite group, the granulated powders were properly sintered as either compacted toroidal cores or as free-standing granulate. The magnetic performance of the sintered cores was evaluated via initial permeability, saturation magnetization and BH loop measurements. The sintered granulated powders were magnetically evaluated via VSM tests. The heating ability of the powders was evaluated on an in-house built-up module. All sintered cores and powders were structurally and morphologically investigated via XRD and SEM, respectively.

The trend of densification as a function of chemical composition is consistent in both sintered states. Both magnetic coercivity and loss area (extracted from the respective BH loops) show a decrease as Zn increases in group I and as Mn increases in group II. A direct correlation between the loss performance of the sintered core, the powder, and the measured heating ability is revealed. $MgFe_2O_4$ powder exhibits the highest heating potential as a result of its highest loss performance (Figure 1), which can be further improved through the selected granulation process and size optimization, defined by the application requirements.

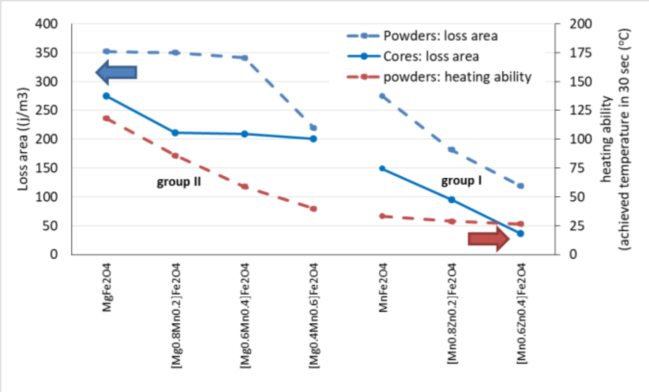

Figure 1: Loss performance and heating ability of prepared cores and powders.

According to SEM, similar grain growth takes place in the two states of core and powder, in both ferrite groups.

Conclusively, inductive ferrite powders can be designed based on systematic core-based investigations and successfully meet application requirements of heating performance.

References

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