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Jerzy BARGLIK

Silesian University of Technology, Katowice, Department of Industrial Informatics

Induction melting - modeling and practical application

***Abstract**. Induction melting is applied in the ferrous and non-ferrous industries for many years. But it is also used in various non-metallic applications, like melting of glasses or crystal growth of semiconductors. The paper deals with mathematical modeling of two kinds of inductor furnaces: crucible induction furnace and cold crucible induction furnace.*

Keywords: induction heating, induction crucible furnace, cold crucible

Introduction

Induction furnaces for melting, holding and casting of materials are based upon heat generation in the charge. It is mostly a direct heat generation within the charge, but sometimes, more rarely indirect one.

In the first case the contactless power transmission between an inductor and an electrically conductive charge is realized. In the second case the power is transmitted directly to the conductive crucible (for instance made of graphite) and heat generated there is retransmitted to the conductive or non-conductive charge. The inductor is often equipped with the magnetic flux concentrator.

The induction furnaces are divided into three main groups:

- Crucible ICF
- Channel CIF
- Special like for instance Cold Crucible Induction Furnace CCIF.

The paper concentrates on a description of mathematical modeling and practical application of two kinds of induction furnaces: ICF and CCIF. Mathematical modeling of the ICF or CCIF devices are very complicated because of necessity of solving triply coupled electromagnetic-temperature-flow fields mostly in 2D, but sometimes as well in 3D formulation.

Induction crucible furnace ICF.

The ICF is mainly used for melting as well as holding or combined melting and holding. In the ICF the melt is usually charged by pieces into a crucible built from refractory and insulation materials. The water cooled inductor encircles the crucible and the melt. It generates the electromagnetic field which is necessary for the direct power transfer to the charge. The 2D sketch of mathematical model of the ICF with cylindrical crucible and inductor is presented in Fig. 1a. It corresponds to the real ICF installed in the aluminum plant located in the southern Poland [1]. Electromagnetic field produced by a periodical current has to be calculated as an open boundary task. The artificial boundary ABCD (see Fig.1) is taken in a sufficient distance from the inductor 4 - charge 6 system. The inductor is equipped with the magnetic core 5. The crucible 7 is covered by the ceramic lid 1. Space 2 represents inert atmosphere or sometimes vacuum areas. Due to non-uniform distribution of Lorentz forces the convex meniscus of the free surface 3 is observed (Fig.1b).

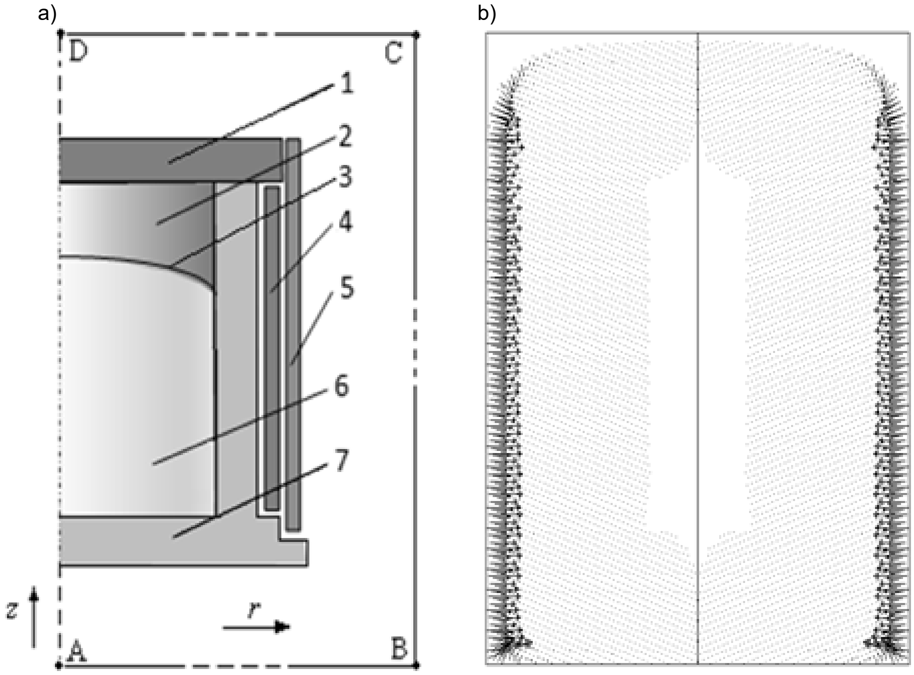

Fig.1. Sketch of the mathematical model (a) 1 – lid, 2 – inert atmosphere, 3 – free surface, 4 – inductor, 5 – magnetic core, 6 – charge, 7 – crucible. Distribution of Lorentz forces (b).

High values of volumetric Lorentz forces are observed near wall of the crucible only.

Cold Crucible Induction Furnace

Melting of extremely reactive materials in the conventional ICF with ceramic crucibles at high temperatures leads to a contamination of the melt. It does not allow melting of such high purity metals like titanium. But it possible to melt them without any contamination by ceramic materials in the CCIF. The modeling of such a furnace is even more complicated. The inductor and copper crucible (both water cooled) are consisting of several mutually insulated segments (so no significant eddy currents are induced in the segmented walls). Due to cold walls of the crucible a thin layer of melt forms the skull preventing remaining melt from contacting the crucible

Conclusion

Mathematical modeling and practical application of two types of induction furnaces are discussed in the paper. Illustrative examples are presented. The convex meniscus of free surface is observed in both kinds of presented furnaces. The ICF is often used in industry, however the CCIF is applied for melting of high purity metals only,

References

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Author: *prof. zw. dr hab. inż. Jerzy Barglik, Silesian University of Technology, ul. Krasińskiego 8, 40-019 Katowice, e-mail: jerzy.barglik@polsl.pl*