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# Finite Element Analysis of the Influence of Cold Crucible Design on Electric Performances of Induction Furnaces

V. Fieteanu<sup>1</sup>, P. Brun<sup>2</sup>, E. Sauvage<sup>2</sup>

1: POLITEHNICA University of Bucharest, Romania

2 : CEA,DES,ISEC,DE2D, SEVT Centre de Marcoule, F-30207 Bagnols-sur-Cèze, France

**Abstract.** Based on finite element models, this paper studies the influence of the cold crucible (CC) configuration, on the charge induced power, on Joule losses and electric efficiency of the induction furnaces for molten glasses. The influences of the ring connecting the CC segments are evaluated. A new horizontal segmentation of CC is studied.

## 1. Introduction

The crucible is the component of cold crucible (CC) induction furnaces with important Joule losses contribution and the most influent related to the furnace efficiency. Results of finite element analysis of furnaces with different CC configurations are analysed in this paper.

## 2. Finite Element Models of common Vertical Segments Cold Crucibles

### 2.1 Cold crucibles with disk bottom or six-box bottom

The 3D finite element model of a CC furnace, Fig. 1, operating at 1.4 MHz, includes the molten glass CHARGE and a non-magnetic steel COLD\_CRUCIBLE - the assembly of 67 circle cross-section vertical segments and the disk, or six-box shape bottom. Copper conductors, parallel or series connected, compose the One-turn or Eight-turn INDUCTOR.

The maps of Joule power/losses density in Fig. 2 correspond to the design (1), Table 1, respectively to the One-turn inductor furnace, cold crucible with circle cross-section segments and disk shape bottom. In the designs (2), (3) and (4) the Eight-turn inductor replaces the One-turn inductor variant and in (3) the circle cross-section of segments is replaced with trapeze cross-section. In the design (4) the disk bottom is replaced with the six-box shape variant. This is the most advantageous of all four variants, the power induced in charge is the highest, Table 1, all three components of the Joule power losses are the lowest that leads to highest value of the furnace electric efficiency.

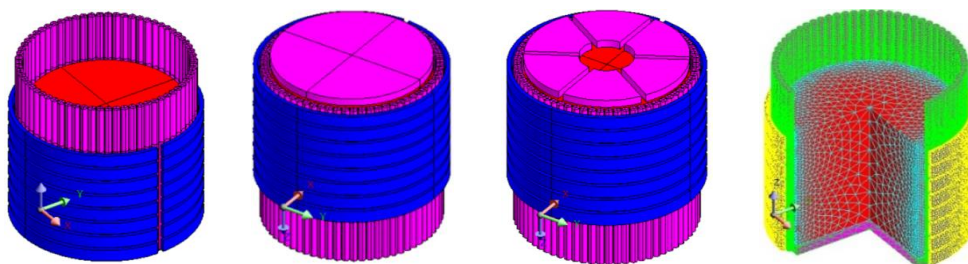


Fig. 1. Induction furnaces / Cold crucibles with circle cross-section segments and disk or six-box bottom

Table 1. Comparison of furnace designs for the same value of the total inductor current

Furnace design	CHARGE Joule power [kW]	COLD_CRUCIBLE Joule losses [kW]	BOTTOM Joule losses [kW]	INDUCTOR Joule losses [kW]	Supply voltage [V]	Supply current [A]	Furnace efficiency [%]
(1)	111.08	12.48	1.523	0.739	1098	700	88.28
(2)	126.26	13.85	1.204	0.785	9201	87.5	88.93
(3)	95.83	18.94	1.254	0.774	7435	87.5	82.05
(4)	143.1	11.44	1.148	0.704	8643	87.5	91.50

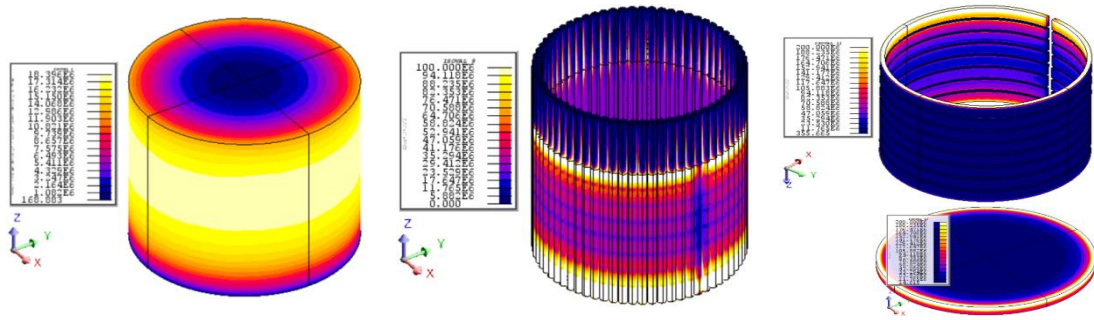


Fig. 2. Density of Joule power in charge and of the Joule losses in the inductor and CC segments and bottom.

## 2.2 Cold crucibles with ring connected segments

The rings in Fig. 3 connect the upper or lower extremities of the CC circle segments. The most advantageous is the azimuth discontinuous variant RING3, Table 2, with four sections, since the power in the charge increases and Joule losses decrease Table 2.

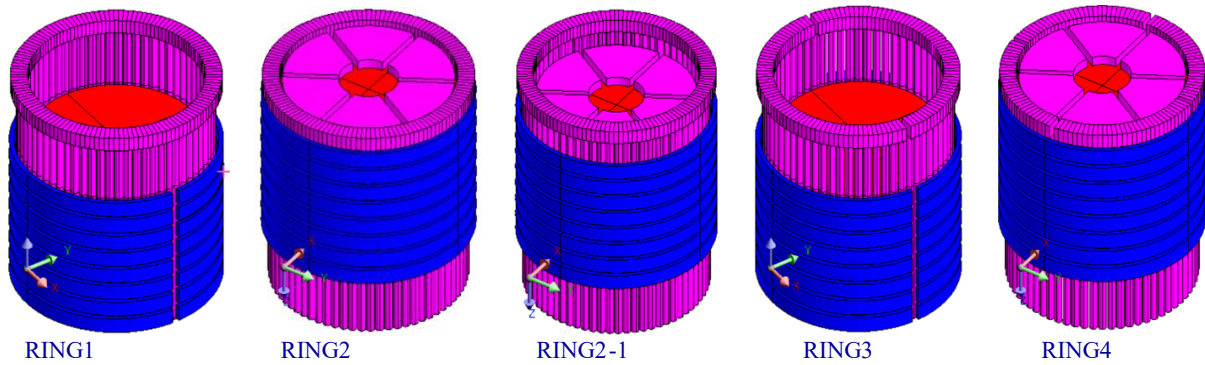


Fig. 3. Furnace geometries with a RING connecting the cold crucible segments

Table 2. Different designs of the cold crucible RING designs.

RING	CHARGE Joule power [kW]	COLD_ CRUCIBLE Joule losses [kW]	BOTTOM Joule losses [kW]	INDUCTOR Joule losses [kW]	Supply voltage [V]	Furnace efficiency [%]
No RING	143.1	11.44	1.148	0.704	8643	91.50
RING3	166.34	10.55	1.309	0.725	9854	92.97

## 3. CC with horizontal segments

In the new CC, with annular horizontal segments, rectangle cross-section, the induced current flows in one direction on the external faces of segments and in the opposite direction on the internal faces. The comparison of the finite element results for a vertical segmented CC furnace with 67 vertical circle cross-section segments and a new furnace with the same data 350 kHz, 600 kW, with 39 horizontal CC segments, emphasizes the decrease with 11.4 % of the Joule losses and a slightly increase of the electric efficiency.

## 4. Conclusions

This paper proves the positive impact of the simulation driven finite element assisted design in the improvement of performances of CC induction furnaces, since the CC configurations able to decrease the losses and to increase the device efficiency can be very efficiently evaluated.

## References

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