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# LOCALIZATION OF MAXIMUM TEMPERATURE STRESSES OF FURNACE ELEMENTS DURING THE METALLURGY PROCESS

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**ABSTRACT**
*Numerical calculation of temperature field in of the furnace with floating slag is realised by using of MAGMASOFT software package. Result of calculation is real image of thermal field in furnace. The method 3D finite elements in static regime has been used in this calculation. Analysis of calculation showed locations of maximum temperature stresses of furnace elements during metallurgy process in order to gain the optimal furnace constructions and to improve energetic work indicators of the furnace in purpose of the most economical work. It is also established that the cristallyzator of furnace with floating slag is the part of the furnace which is the most exposed to the highest thermal loadings, thus this part of the furnace is needed to pay attention from the aspect of its construction and cooling organization.*
**Key words:** furnace with floating slag, temperature stresses, numerical calculation, of temperature field

## 1. INTRODUCTION

In the papier is discussed the numerical calculation of thermal field of the furnace with floating slag with application of contemporary program tools and the method of 3D finite elements in static regime. Extracted distribution of the thermal field made analysis of thermal tension of certain furnace parts possible, and especially analysis of the furnace crystallizer as the most imperilled part of the furnace. The analyses were also made on thermal flux through the surface furnace parts.

## 2. NUMERICAL CALCULATION OF TEMPERATURE FIELD OF FURNACE WITH FLOATING SLAG

Temperature field of electrode is one of the most important part of termophysic examinations. Temperature of surfaces on the sides of electrode is directly dependant about level of its interaction with surrounding.

Temperature field of the slag bath is the most important factor for determination of technical-metallurgicaly characteristics of the furnace. Temperature field in area of ingot is described by equation 1:

$$\Theta_1 = \Theta + \frac{\Phi}{S\lambda_{st}} x \qquad (1)$$

$\Theta_1$-temperature of cristallyzator by ingot side
$\Theta$ - temperature in the cristallyzator wall
$S$- surface of cristallyzator wall im $m^2$
$\Phi$ - steady state heating flux in W
$\lambda_{st}$ – coefficient of heating conduction

Results of solving process of equation 1. are temperature distribution into area of ingot and very important temperature distribution on crystallizator height.
For 3D numerical calculation of temperature fields in steady state regime by finite elements method is used software package MAGMASOFT.
Cross-section of furnace with floating slag is objct of numarical calculation and is showed on figure 1.
Furnace data are:

| | |
|---|---|
| - Power | S = 800 kVA |
| - Current | I = 14,5 kA |
| - Volatge | U = 80 V |
| - Power factor | cos $\varphi$ = 0,8 |
| - Heating time | t = 20 min |
| - Melting velocity | A = 620 kg |
| - Amount of cooling water | 770 l/min |
| - Slag type | $CaFe_3$ |
| - Amount of slag | 100 kg |
| - coefficient of heating transfer by conduction of steel | $\lambda_{Fe}$ = 50 W/m˚C |
| - coefficient of heating transfer by conduction of copper | $\lambda_{Cu}$ = 348 W/m˚C |
| - coefficient of heating transfer by conduction of slag | $\lambda_{š}$ = 98 W/m˚C |
| - coefficient of heating transfer by conduction of air | $\lambda_e$ = 0,0248 W/m˚C |
| - electrode diameter | $d_e$ = 370 mm |
| - crystallizator diameter | $d_k$ = 710 mm |
| | 100 kg |

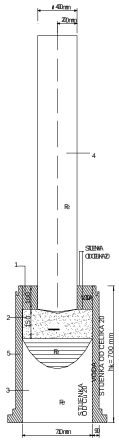

*Figure 1. Cross-section of furnace with floating slag*

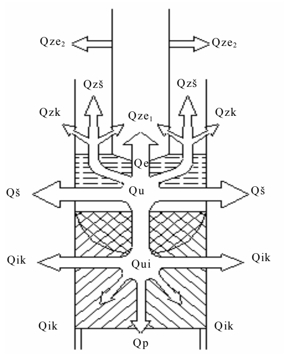


*Figure .2. Heat distribution during furnace operation*

Matematical modelling of melting process include modelling of thermal, electrical and hydrodynamic processes during melting process. Because of simplicity, these processes are analyzed separately. Result is matematical model dependent on one or a few parameters experimentaly determined.
On figure 2. is showed heat distribution during furnace operation.
Heat separeted in slag bath Qu is transfered by:
- conduction on electrode Qc through membrane of liquid metal,
- radiation and convection from slag surface on electrode Qze1, lid Qzs and walls of crystallizator Qzk
- conduction through slag bath on walls of crystallizator and cooling water Qs
- conduction in ingot through boundary surface slag-metal Qi and by liquid metal drops Qk.

Total amount of heat in ingot Qui is consist of Qk and Qi ($Q_{ui} = Q_k + Q_i$).

Analyses of heat distribution of every technology process ensure data for calculation of equipment and evaluation of energetic efficiency.
Usefull spent heat in electro-melting procedure is heat coming in ingot.
Because of forced cooling, temperature of crystallizator worknig surface is much lower then temperature of slag bath and ingot. Big temperature gradient between cooling water and melting area in crystallizator cause intensive heat exchange through the walls of crystallizator.
Clacualtion of temperature field of furnace with floating slag is very complex because of furnace geometry.
Goal of the calculation was to get more accurate temperature field distribution in cross-section of furnace with floating slag, indispensable for analyss of thermal stresses.
Cross-section of furnace is divided on following regions (figure 4):
- outer furnace part, crystallizator, with a fine mesh
- inner furnace part with rough mesh.

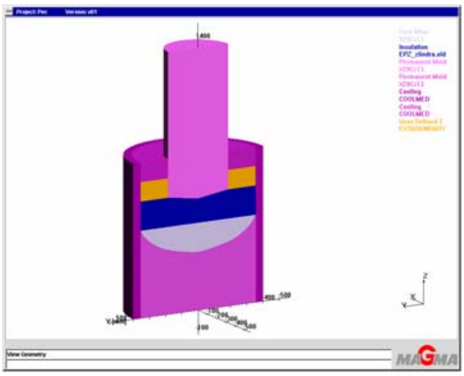

*Figure 3. 3D geometry of furnace with floating slag*

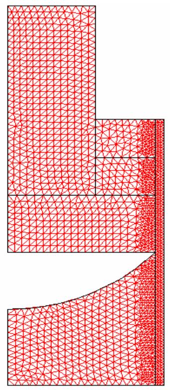

*Figure 4. Mesh of the geometry*

Number of elements is 3310, and number of nodes of the mesh is 1790.

## 3. RESULTS OF NUMERICAL CALCUALTION

On the figures 5 are showed a pictures of temperature fields for different phases of melting process.

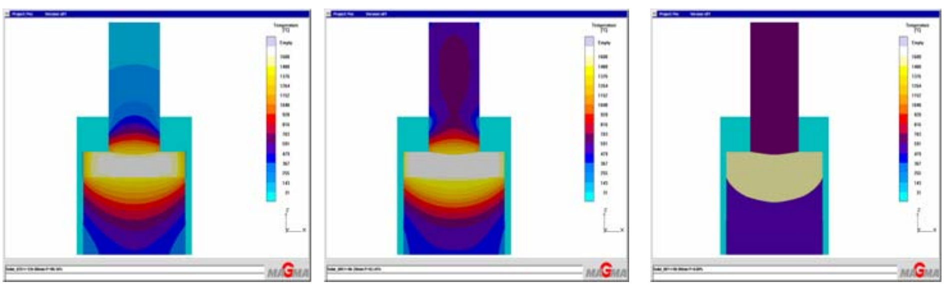

*Figure 5 .Temperature field distribution-phase 1, phase 2, phase 3*

During melting process furnace crystallizator is exsposed to extremly high nonuniform temperature load. On figure 6. is showed temperature distribution in inner side of crystallizator.

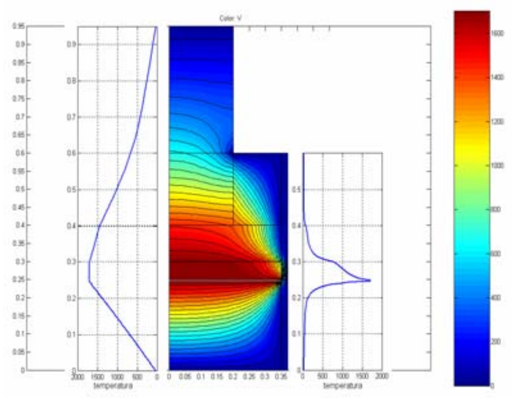

*Figure 6. Temperature distribution in inner side of crystallizator*

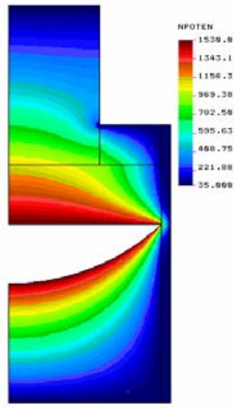

*Figure 7. Temperature field of furnace with floating slag – end of melting process*

As in all melting aggregates, existance of high temperature cause large temperature stresses of some parts of aggregate.Modelling of temperature stresses of some parts of furnace, esspecialy crystalizator is very important. As we can see crystallizator is a heart of furnace.

Value and distribution of temperature on the surface and volume on crystallizator of furnace with floating slag are very important parameters which defined and determined functionability of crystallizator, its defomability, surface quality and a structure of melting ingot. Crystallizator heating during melting process cause its geometry deformation. Depending on construction of cooling channels and crystallizator configuration temperature field of walls could be different.

Crystallizator function is to take-over large heat flux which is measured in millions of kJ/m$^2$ per hour, without burning and deformatios. Crystallizator would ensure obtaining of ingot of needed format.

**4. CONCLUSION**

By analysis of numerical calcualtion of steady state temperature field is possible to:

- locate a places in furnace, during melting process with maximum temperature stress
- have an effect on number of melting periods which could not cause damage of furnace parts exposed to temperature stress
- calculate heating flux during melting process
- improve construction of furnace for more economic work and energetic efficiency of furnace.

**5. LITERATURE**


[1] R.T.Bui,D.Kocaefe, *Mathematical modelling of the metal flow in sidewell furnaces,* Cast shop Technology, Fundamentals and Modelling, Bonn, Germany,1997.

[2] Б.И.Медовар, *Тепловые процессы при элекрошлаковом переплаве* Киев, 1978.

[3] V.S.Taranakov, V.K.Leko, O.V.Mazurov, *Some problems of precise measurements of heat transfer coefficients in glass melts, Measurements of effective conductivity*, Glastechnische Berichte, 1995.

[4] T.Wriedt, *The Generalized Multipole Technique for Electromagnetic and Light Scattering*, Elsevier, '99

[5] M.Huang, F.C.Lai, *Numerical Study of EHD-Enhanced Forced Convection with Two-way Coupling*, ASME Heat Transfer Division, IMECE 2001

[6] A.Mo, H.J.Thevik, B.R.Heriksen, E.K.Jonsen, *Modelling of surface segregation development during D.C. casting of rolling slab ingots*, Cast shop Technology, Fundamentals and Modelling, Bonn, Germany,1997.A.Mo,.