

COST 526 – Project CZ 5

Final Report

Optimization of Casting of Corundobaddeleyt Material EUCOR

Prof. Dr. Frantisek Kavicka

Brno University of Technology, Faculty of Mechanical Engineering

Technicka 2896/2, 61669 Brno, Czech Republic

1. Introduction

In material production industry there a lot work was done on casting process optimisation of a wide range of metallic materials. The casting technology of ceramic materials is the industry domain, where the aspects of casting processes are not very known and where there is a serious demand of ceramic products casting technology optimisation.

The corundo-baddeleyit material EUCOR is heat and wear resistant material even at extreme temperatures and it is also resistant to corrosion. EUCOR belongs to the $\text{Al}_2\text{O}_3\text{-SiO}_2\text{-ZrO}_2$ oxide ceramics. The melting of this material is done in special electric-arc furnaces lined with material of the same chemical composition. The basic approximate chemical composition of CBM (in weight %) is 13-17% SiO_2 , 49-52% Al_2O_3 , 30-33% ZrO_2 , 0.1% TiO_2 , 0.2 CaO, 0.2% FeO and (1.0-2.0%) alkaline oxides. Mineralogical, i.e. the phase composition of this ceramic material is given in weight % as: 48-50% corundum, 30-32% baddeleyit and 18-20% glass phase.



Fig. 1 *Wide range of wear-resistant EUCOR products*



Fig. 2 *EUCOR products for internal walls of glass furnaces*

Thanks to very good heat and wear resistance at extreme temperatures the material is often used for the internal walls of glass furnaces (see Chyba! Nenalezen zdroj odkazů.), whose needs resistance to liquid glass and the creation of bubbles when in contact with such liquid glass. The second area of application is for products, which are resistant to wear, temperature shocks and which needs a crystalline structure and low porousness (Chyba! Nenalezen zdroj odkazů.).

Successful EUCOR Casting technology needs to take in account and solve several technological problems. The big problem represents the high volume contraction during solidification (6.5 %) thanks to high material thermal expansion coefficient and wide range of solidification temperatures (starting from approx. 1800°C). These

means that there is necessary to ensure the continuous cast product filling during solidification with appropriate technology precautions.

2. Goal of the project

The problems mentioned above are especially significant for products of large dimensions, called “stone”. The shape of such product is on the **Fig. 3**. The dimensions of this EUCOR casting is 400 x 350 x 200 mm. The initial temperature

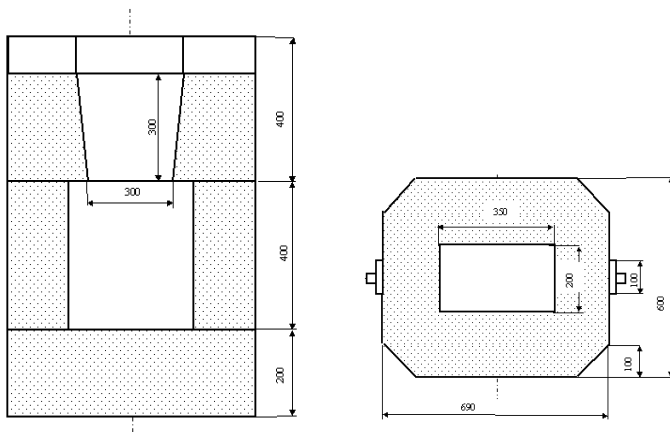


Fig. 3 Eucor product of large dimensions – „stone“

of the mould is 20°C, the pouring temperature is 1800°C, the pouring time is 10 s, the liquidus temperature is 1775°C and the solidus is 1765°C. The mould material is made from a sand mixture with water-glass and the bottom of the mould was made from a layer of magnesite of a thickness of 50 mm. The original riser shape, was a 300-mm-high truncated four-sided pyramid.

Using such casting technology and mould-casting-riser arrangement the production involves a number of defects pieces, especially internal cracks, shrinkage cavities and high porosity. The goal of the project was to optimize the casting technology and prevent defects creation in the production.

3. Simulator, calibration, quality function and optimization algorithms, including assessment with respect to alternatives

For process thermokinetics investigation the appropriate simulation model was build. Thanks to problem symmetry the computational model can cover one quadrant only (**Fig. 4**). For faster computations mapped meshing network generation was used and

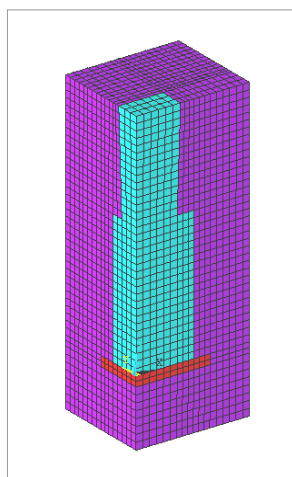


Fig. 4 Computational model network

the solver worked with automatic time step choice. In process simulation material characteristics knowledge is very important. Especially the cast ceramic materials belong to the materials, whose were not very often investigated in detail and that is why required material characteristics were not widely known. That is why material characteristics identification and model calibration a lot of care was given. For simulator calibration and verification the measurement of temperature courses during the solidification was accomplished. They were used special high-temperature thermocouples with housing and for data acquisition from 11 input channels the Grant data-log station was used. The comparison of measured and computed courses show a good correspondence. The measurement arrangement and temperature courses at point T5 in the casting and T10 in the mould are on **Fig. 5**.

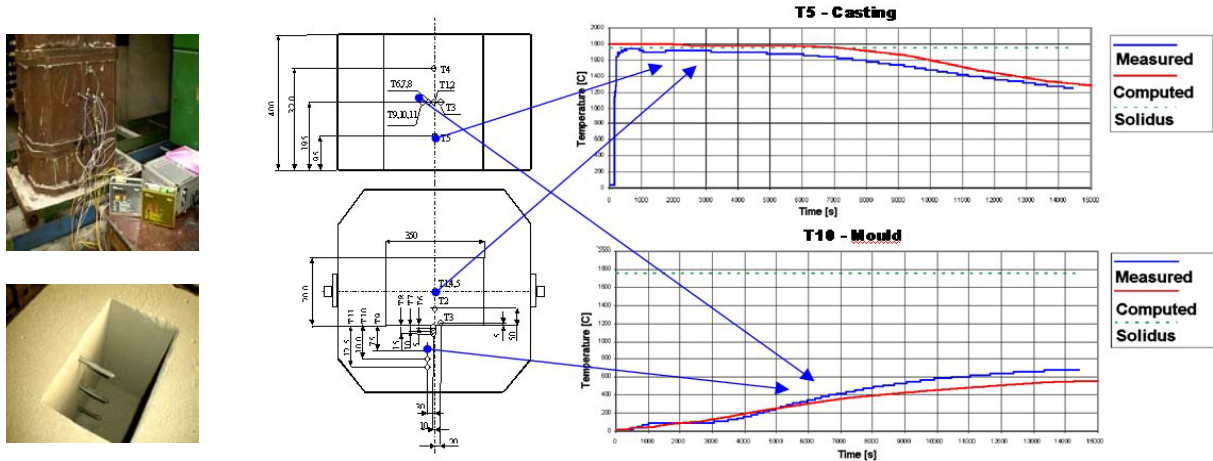


Fig. 5 Experiment arrangement, computed and measured temperature courses comparison

The simulation of the original process arrangement shows, that there is problem with the progress of the temperature field in the system casting-riser. The 3D representation of this is on Fig 6. It shows, that the zone of last solidification was not into the riser but into the cast. It causes “the freezing” of the riser and prevent the cast from molten material refilling.

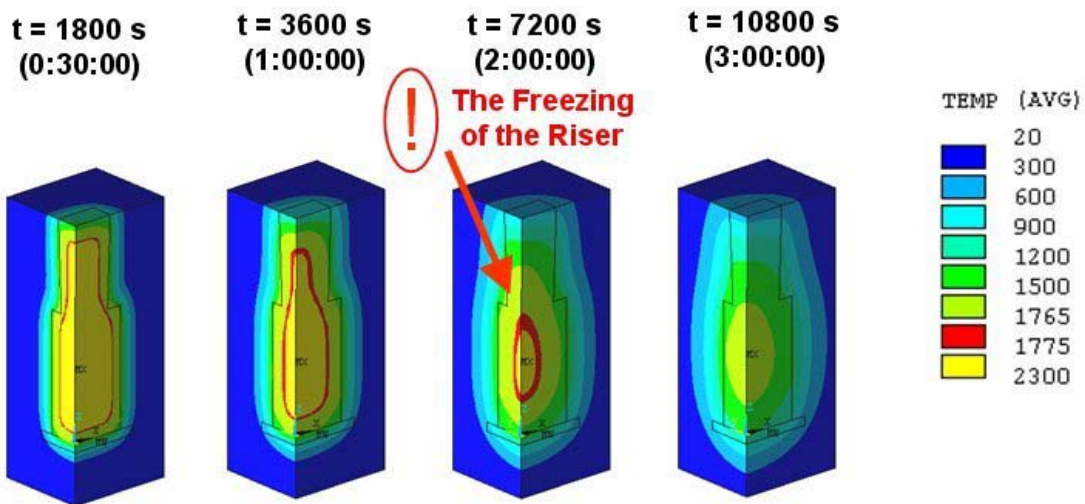


Fig. 6 Original process progress - “the freezing” of the riser

The solution of the problem needs to change the solidification progress by means of appropriate technological precautions. As possible they were modifications of

- dimensions of the riser
- riser cone “jaw” angle
- the shape riser cross section
- the insulation of the riser

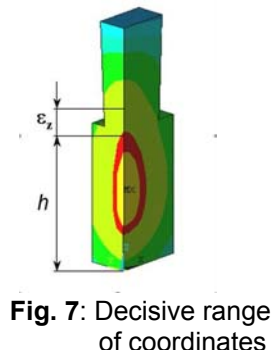


Fig. 7: Decisive range of coordinates

Consulting practically appropriate precautions with the industry partner, considering the experience with insulation problems, the way of changing the riser shape and dimensions was used. There was designed a several riser shapes, among them the riser with elliptical cross section was chosen. The optimization strategy was based on the demand of temperature

course into the cast axis, which represents required “directional” solidification. The principal area is the area from bottom of the casting to the riser/casting boundary plus necessary tolerance ($0, h + \varepsilon_z$) as shown on **Fig. 7**. We can use the constraint (1) involving the temperature course derivation along the axis

$$\forall z \in [h - \varepsilon, h] \cap C_z^*, \forall \tau \in [\tau_S - \varepsilon_\tau, \tau_L + \varepsilon_\tau] \cap T^* : 0 < \gamma \leq \frac{\partial f(x_0, y_0, z, \tau, \mathbf{u})}{\partial z} \quad (1)$$

Using such approach the shape and dimensions of the optimized riser were achieved. The design respects technological parameters variation during practical production. The solidification progress with the optimised riser is given on the **Fig. 8**.

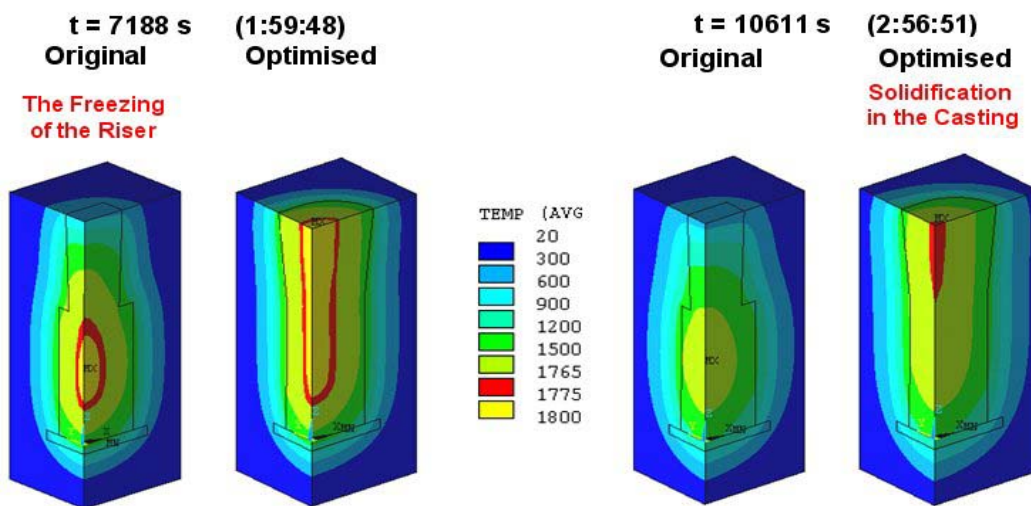


Fig. 8 Solidification progress into original and optimized arrangement

The solidification is directional, the process finish the solidification into the riser, the product is continually refilled, preventing such way cracks and cavities. The amount of scrap during production can be significantly reduced.

4. Main scientific outcome

Main scientific outcome of the project is to build and verify the successful computational simulator for casting process of the ceramic and the conjunction with the mathematical method optimization.

5. Main technical outcome

There are several technical outcomes of the obtained results. For technical application there is valuable the material characteristics identification for ceramic of such kind, the choice of the parameters, whose can be practically optimised and recommendations for risers design for wider range of ceramic products.

6. Collaboration within COST 526

The collaboration within COST 526 makes possible to easily find the appropriate optimization method and the possibility of it's practical realization. The knowledge exchange were realized both electronically form and personally thanks to presentations and common discussions during COST 526 WG Meetings.

7. Cooperation with industry

The industrial partner of this project has been EUTIT Ltd, Cast Basalt and EUCOR, Stara Voda, Mariánské Lázně, Czech Republic. The partner has been opened for cooperation and makes possible to accomplish the necessary steps for project solution as industrial measurements, simulator calibration and results verification as well as practical aspects embedding into optimized variants design.

8. References

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