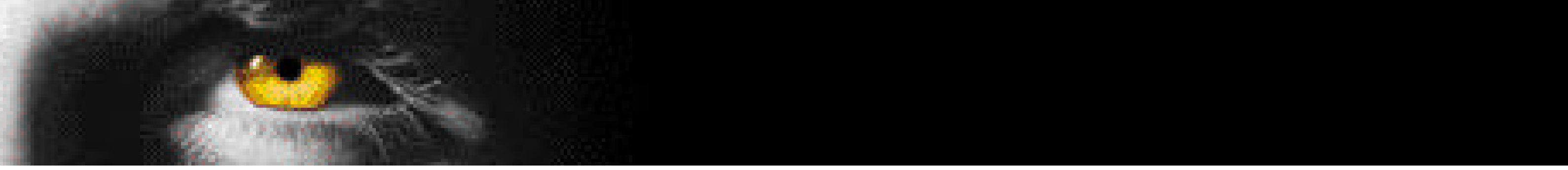


Feeding optimization in gravity casting using ProCAST simulation

e-Tips
Nr. 20

The goal of this e-tip is to illustrate the simulation methodology in case of gravity casting. In order to optimize a casting design in an efficient way, it is recommended to proceed the simulation step by step:

1 casting solidification only

2 positioning of the risers

3 filling study

4 experimental validation

Solidification shrinkage

Let's consider as shown in Figure 1 a simple steel bar during solidification (sand casting). As the metal goes from liquid state to solid, i.e. as the temperature reduces, there are three different contractions to be dealt with: a) liquid contraction, b) solidification contraction and c) solid contraction. The contraction occurs at the freezing point, because (most of the time) of the greater density of the solid compared to that of the liquid. The final stage of shrinkage in the solid state can cause other types of problems linked to the final shape of the casting and to the stress and strain distribution in the casting. At this first stage we will concentrate on the way the casting solidifies and the main questions are: 'Should we have a riser at all in order to compensate for solidification shrinkage?' and 'How large should it be?'. Nowadays simulation software as ProCAST or PAM-CAST are valuable tools for the foundry man and should help to answer to these questions. According to feeding theory (see for instance «Castings» by John Campbell, Butterworth-Heinemann Ltd), a feeder modulus (volume/cooling area) of around 1.2 times the modulus of the casting should ensure a sound casting. In addition, one should make sure that: a) the riser solidifies at the same time as, or later than, the casting, and b) the riser contains sufficient liquid to meet the volume-contraction requirements.

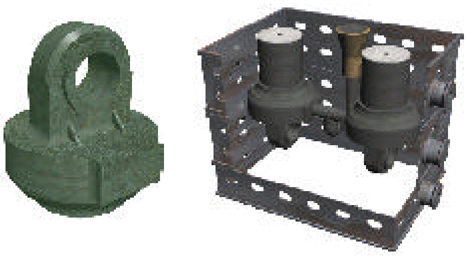


Figure 4: Steel casting part (68 Kg) and its position in the sand mold (Courtesy of DSB Blansko).

Need of Risers

Figure 2 shows the evolution of solid fraction (below 0.7%) in the same bar as shown in Figure 1 when feeders are added. The feeding distance L_d between carbon steel cast plates into sand moulds depends on the section thickness T of the casting: castings should be made sound for a distance from the riser edge of 4.5T. Figure 2 where a 0.8 ratio between riser and casting volumes is obtained shows that the risers are not efficient enough to compensate for solidification shrinkage. Figure 3 shows the same bar with larger risers and confirms the 1.2 ratio rule between riser and casting volumes. However one should keep in mind that the riser size is increased further, so the casting solidification is progressively delayed by the nearby mass of metal in the riser. Thus while this excessive feeder is no disadvantage in itself, the solidification delay of the whole casting increases the time available for further precipitation of gas porosity. However, it is clear from this demo work that an undersized riser will result in very serious porosity, whilst an oversized feeder causes less problems (although, of course, it does adversely influence the economics!).

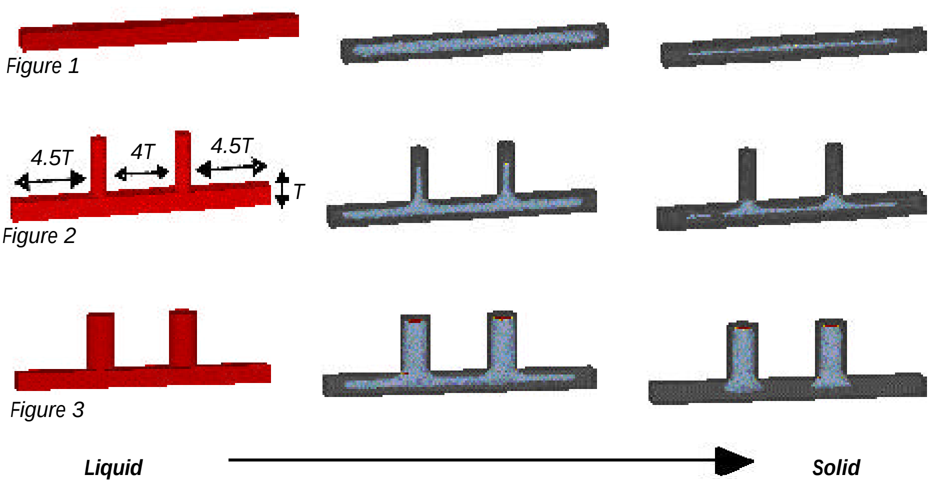
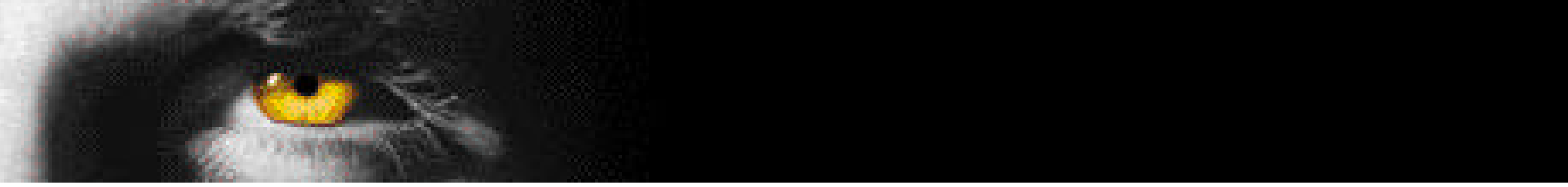


Figure 1-3: Evolution of the Fraction of Solid in a bar (sand mold) 1) Due to metal contraction during solidification, shrinkage porosity is observed in the center of the bar, 2) The risers in this case are not efficient enough, i.e. does not prevent solidification shrinkage in the casting bar as they solidify before the casting (in this case Mfeeder = 0.8xMcasting), 3) The risers are well designed as no liquid pockets remain in the bar (in this case Mfeeder = 1.2xMcasting).



Industrial application

Let’s consider a steel casting part (68 Kg) as shown in Figure 4 (Courtesy of DSB Blansko). A thermal calculation shows, as illustrated in Figure 5, that the riser is not enough effective. The riser is indeed solidifying before the casting and is thus not able to feed the casting part with liquid metal in order to compensate solidification shrinkage. Good agreement obtained between the shrinkage prediction of ProCAST and the experimental observation which confirms that this riser design is not optimal. The modulus of a riser can be artificially increased by the use of an insulating or exothermic sleeve.

In Figure 6 the use of an insulating sleeve is moving the remaining liquid pocket in the riser and is thus improving the efficiency of the feeder. Experimental observation confirms the predicted results as shown in iii). The simulation of an exothermic sleeve would show a better efficiency of the riser, and allows one to reduce the volume of the riser.

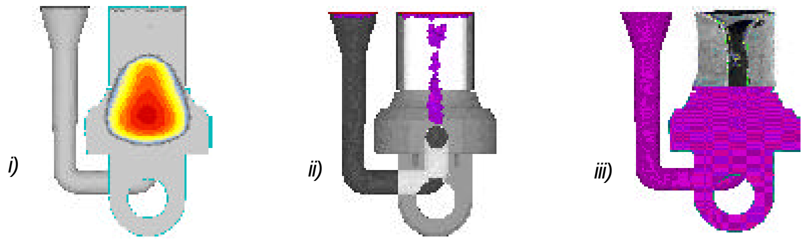


Figure 5: i) Fraction of solid showing the remaining liquid pocket ii) porositiy prediction, iii) experimental observation. (No insulating sleeve)

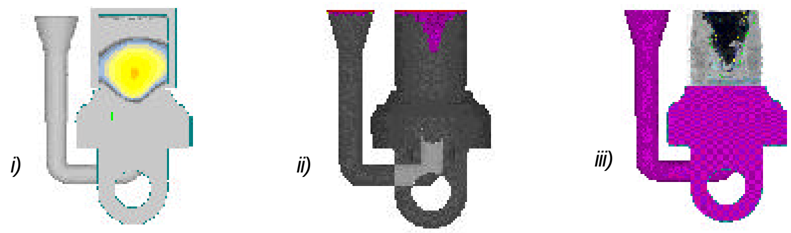


Figure 6: i) Fraction of solid showing the remaining liquid pocket in the riser ii) porositiy prediction, iii) experimental observation. (With insulating sleeve).

This brief study demonstrates that thermal simulation is an efficient tool for the optimization of the size and the positioning of the risers. The last step in order to validate this casting and riser geometry design is to run a fluid flow calculation in order to make sure that the heat distribution induced by the filling sequence is well controlled and does not change the efficiency of the risers.

Filling Simulation

Figure 7 is showing the filling simulation results of the casting. The evolution of the fraction of solid is confirming that the risers are playing correctly their role, i.e. allow the shrinkage porosity defects to be moved out of the casting.

This note demonstrates that thanks to simulation:

1. the solidification of the casting can be evaluated.
2. the optimal design and position of the feeders can be investigated.
3. the capacity to use the metal available in the risers can be investigated as a function of the shape (modulus) of the casting.
4. the influence of the gating system and of the filling sequence can be checked in order to ensure the good use of the riser.

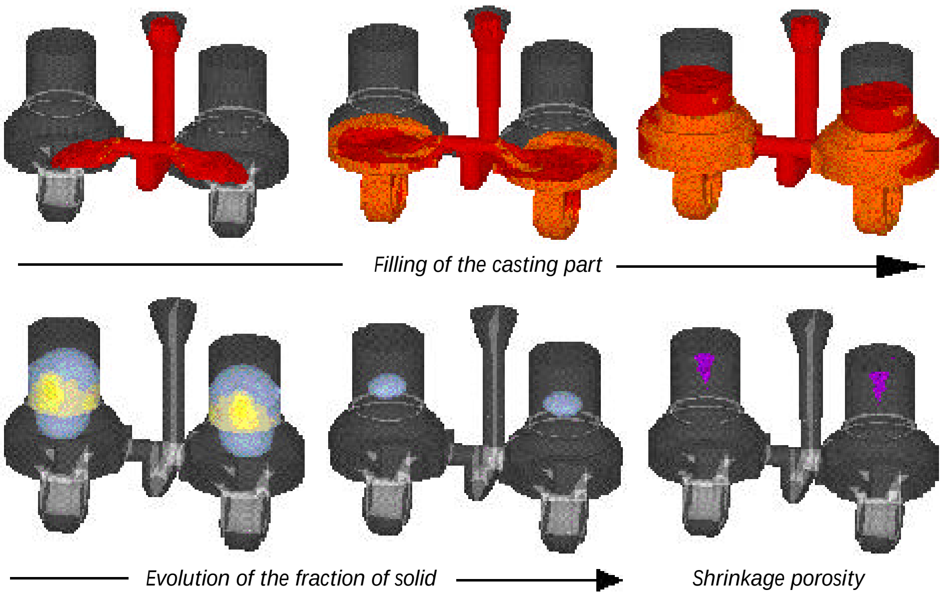


Figure 7: Filling simulation of the casting part in order to make sure that the thermal distribution during this sequence is well controlled and does not change the efficiency of the risers. The evolution of the fraction of solid is confirming that the risers are playing well their role, i.e. allow the shrinkage porosity defects to be moved out of the casting.

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