CAE Techniques for Casting Optimization

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Abstract: *During recent years the application of some popular commercial software as computer simulations tools has become widely accepted within the foundry industry, leaving the idea of the simulation as luxurious tools. The application of casting simulation has been most beneficial for avoiding shrinkage scrap [1], improving cast metal yield, optimize the gating system design [2,3], optimizing mould filling [4] and finding the thermal fatigue life in permanent molds [5]. Several case studies demonstrate the benefit of using these tools under industrial conditions [6]. Nowadays, in Finland, the foundries that covers around 90 % of the production of the cast machine components use casting simulation as an everyday tool [7]. This paper will demonstrate the application of the ProCAST software. Simulation resulted in gating system and moulding changes that reduced the weight of the total casting from 59 kg down to 46 kg. Maintaining casting quality the yield has increased by 9 %. Some experiments were carried out under foundry conditions to compare the results.*

Keywords: *CAE, Casting, Optimization*

1. Introduction

This paper describes a demonstration work that was done to Ferespe, a Portuguese foundry in order to show the capabilities of ProCAST software to optimize the gravity system of castings (GS70 alloy steel) produced by no bake silica sand moulds. The goal of this study was the improvement of the casting process using the software ProCAST, which is tailored to casting simulation and solves the heat transfer problem by the finite element method (FEM). The aim of the foundry was to reduce the remelting and refinishing metal but obtain at same time a high quality casting. In the present case they had a lower amount of saleable casting from a given amount of liquid metal, driving a yield of 34 %.
In order to evaluate the applied methodology, the foundry has done a new model and several castings were produced. To compare the quality of the parts some cuts were made at the castings.

2. Methodology

Figure 1 shows a flowchart, in which 3D CAD and simulation tools are utilized to improve the system design of the casting.
The castings geometries presented here were meshed with MeshCAST, which requires the generation of a surface mesh before meshing the enclosed region with tetrahedral elements.
The computational conditions used in all simulations were the same.
Figure 2 shows a flowchart, where is represented the steps needed to make a simulation.

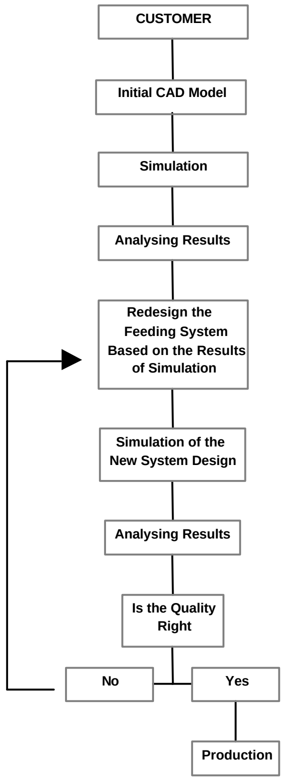


Figure 1 – Procedure to improve the design of new casting.

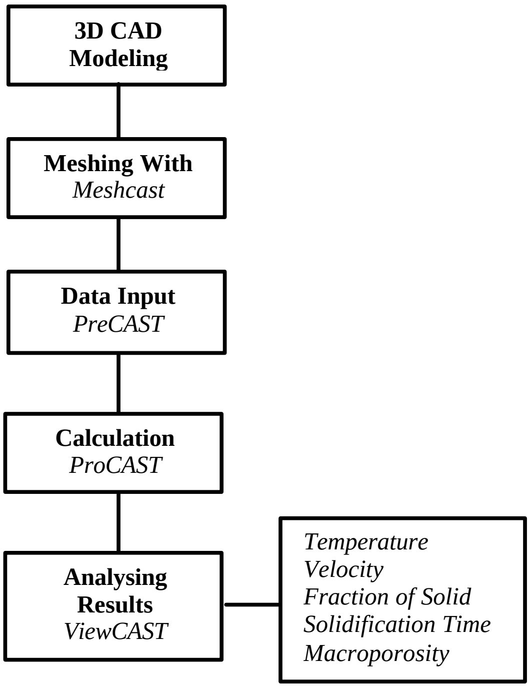


Figure 2 – Steps needed to make a simulation.

3. Numerical Simulation

3.1 Original Casting

The geometry was received from the foundry with original assembly 3D CAD model in Parasolid format shown in Figure 3.

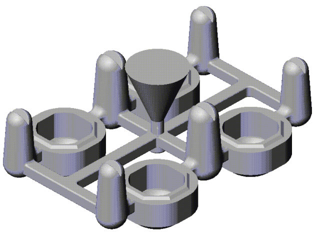


Figure 3 – Original 3D CAD casting.

Table 1 – Initial Conditions

Mould Temp	Metal Temp	Fill Velocity
25 ºC	1634 ºC	0.08 m/s

Figure 4 shows a finite-element mesh of the original geometry by *MeshCAST.* The existence of symmetry planes allows the simplification of the geometry.

In the pre-processing, a virtual mould was created. The material properties of the metal - GS70 - and mould [8] were applied to the respective model, as well as the interfaces, boundary conditions [8] and the initial conditions of the model, Table 1. After the pre-processing, the finite-element model was solved using the software *ProCAST*.

The results of simulated filling and solidification time were confirmed by their practical agreement. The quantitative analyses of macroporosity (Figure 5) showed values (0.02 % - 0.08 %), which are not in agreement with the good real casting sanity.

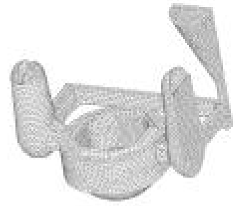


Figure 4 – Simplified finite-element mesh of original geometry.

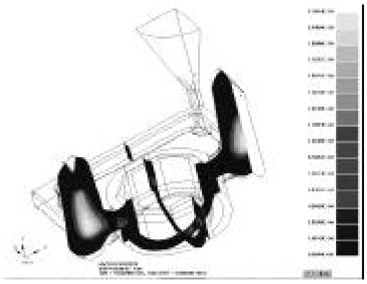


Figure 5 – Macroporosity prediction in the original geometry.

The analysis has shown that it is possible to simulate realistic filling and solidification time by the finite element method with reasonable results. However, there are some uncertainties associated with thermophysical properties or boundary conditions that drive at unrealistic macroporosity results. So, we assumed that in this case the input numerical parameters give some safety margin.

3.2 Modified Casting

In order to perform a reduction in the poured metal some modifications were made in the feeding system. The achieve solution in terms of results closely approaches with the simulation of the original casting. The proposed geometry is presented in Figure 6. Figure 7 shows a finite-element mesh of the modified geometry by *MeshCAST*. The existence of symmetry planes allows the simplification of the geometry.

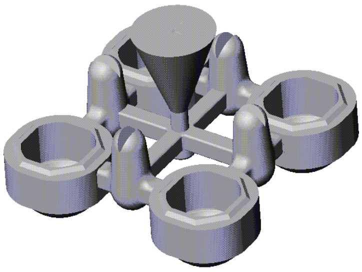


Figure 6 – Modified 3D CAD casting.

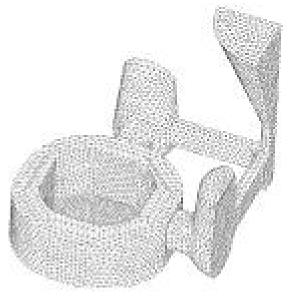


Figure 7 – Simplified finite-element mesh of the modified geometry.

Figure 8 presents the fill flow distribution 38 seconds after pouring. With this analysis type it is possible to detect turbulence and unsteady flow behaviour. Also it is possible to analyse the optimal filling sequence. Figure 9 presents the prediction of shrinkage hot spots. By making the solidified metal transparent, users can easily see the remaining liquid pool. An isolated region of liquid thus suggests a potential hot spot and macroshrinkage indication.

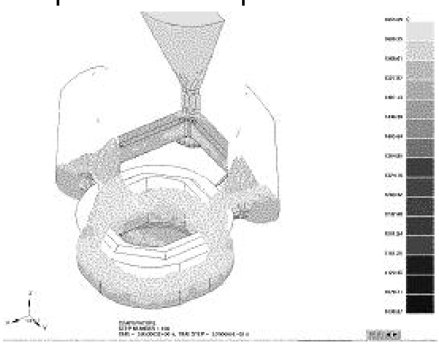


Figure 8 – Temperature distribution 38 seconds after pouring.

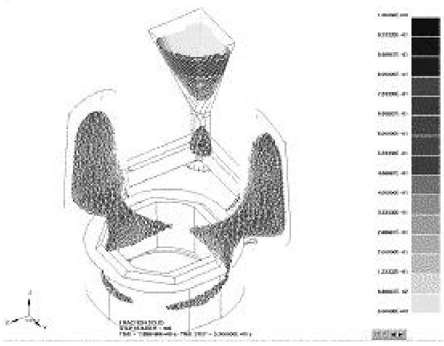


Figure 9 – Prediction of hot spots.

Figure 10 shows the macroporosity prediction results at the modified geometry for two cross-sections, we can see a macroporosity range at about 0.02 - 0.08 %, at the same level previously detected at original geometry. This location and macroporosity percentage don't seem to have great influence in the acting of the piece, once a simulation was made with the original casting and was verified after simulation, similar results Figure 5.

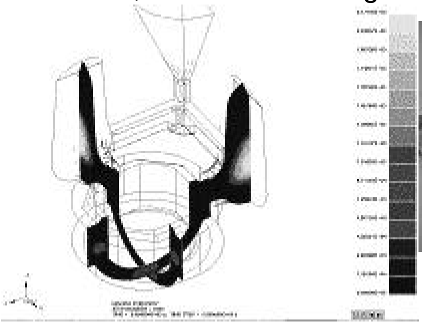
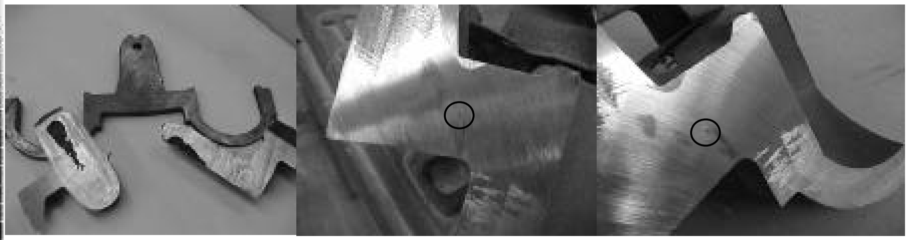


Figure 10 – Macroporosity prediction in the modified geometry.



a) b) c)

Figure 11 – a) Cuts done in the casting, b) and c) cuts done in the pieces.

4. Experimental Validation

After the results obtained by the simulation, the foundry made a new layout in agreement with the modified casting and some pouring tests were made. The casting was sectioned approximately down the middle of the riser, to see if the macroporosity is visible. Figures 11.b) and 11.c) shows the cuts done in the pieces and we can see no signs of macro shrinkage or porosity inside them, but after polish some micro porosity points were found out of the pieces.

5. Conclusions

With this new layout, we can improve the total process:

?? Increasing yield by 9 %;

?? The modified casting is clearly a better proposition since it increases productivity while at same time decreasing production costs;

?? The mould dimensions are significantly smaller (~22 %).

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