Critical Issues in modelling investment casting

Reduce part development lead-times by a better knowledge of process and an early confirmation of metallurgical capabilities is one of the main topics for investment casting technology. Numerical simulation is one of the major tools which can be used to face this goal. This e-tip illustrates a simulation methodology usable to optimize a casting design in an efficient and rapid way.

The Investment Casting Modelling Methodology

At the early stage of a development process, the final shape design of the part is not totally defined. Thus, we have to put in place a numerical modelling approach that takes into account this parameter.

A 'standard' modelling approach for the investment casting process is shown on Figure 1. Each step of the methodology will be described and the benefits industrials can get will be discussed.

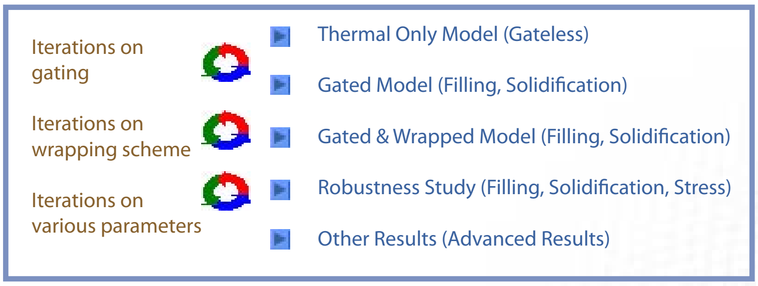

Figure 1: Investment casting modelling methodology

Step 1: Thermal Only Model

Here, the final casting design is not always totally defined. Nowadays, customers require casting houses to help them to verify and optimize their part design.

Is the design castable? If not, what geometry changes are necessary? What can be optimized to match customer's needs and founder's process?

This is the Concurrent Engineering approach that can be done first with a thermal only model. For this type of model, we only consider the casting design and the ceramic shell around it (Figure 2). These types of models are very easy to set up and very fast to run (a few hours). Thus, we can run several models with different part designs and then analyze which design is the best for the customer's need and for the investment casting process.

Figure 2: Thermal only model set up

Step 2: Gated Model

This step consists in analyzing the filling and the solidification of the model with the final part design and several gating designs. Effectively, one has to build now an efficient gating design which allows:

- a good filling of the casting (top filled, bottom filled, ...);
- a good solidification scheme which will have to be improved later (step 3) with wrapping process;
- an economical approach which is acceptable.

Figure 3 shows two gating designs for the part geometry we have set up at step 1. These models can be built, set up and run simultaneously. Then, one has to make a filling and solidification scheme comparison between the two approaches :

- design #1 has 4 very high hot spots near each arm/feeder junction
- design #2 has 2 hot spots at the interface between the part and the gate. Level is lower, and localisation should facilitate the removal of the associated porosity from the part. Moreover, from an economically point of view, this design requires 10% less alloy.

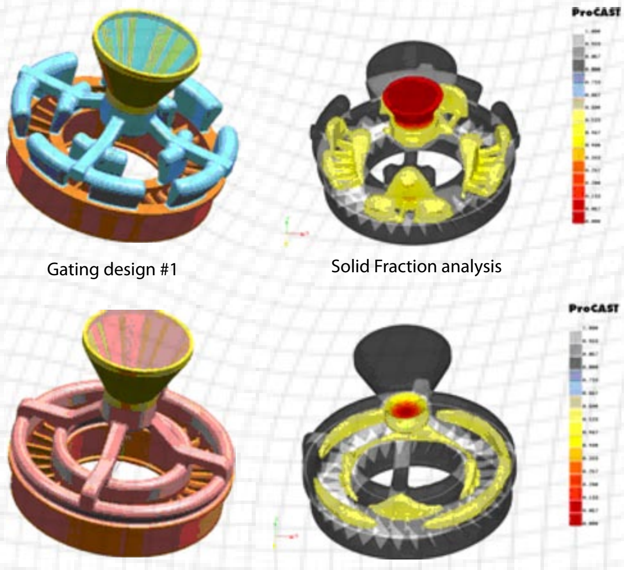

Figure 3: Hot spot localisation with different gating designs

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As the filling has not a big impact here, it is clear here that one has to choose gating design #2 to proceed to step 3.

Step 3: Gated and Wrapped Model

Here, one has to run several models with different wrapping schemes (Figure 4) in order to get a good part from a solidification point of view. Looking at the solidification behaviour, we are able to conclude that scheme #2 seems better. Effectively, modelling shows some isolated hot areas near each 'arm' for scheme #1 (macro porosity prediction confirm this), whereas there are no such areas with the second scheme.

At this stage, one can say that we get a process which normally allows us to process a manufacture (from the filling/solidification point of view). Thus, the die tooling can be manufactured (several weeks/months), while more modelling investigation can be done (step 4).

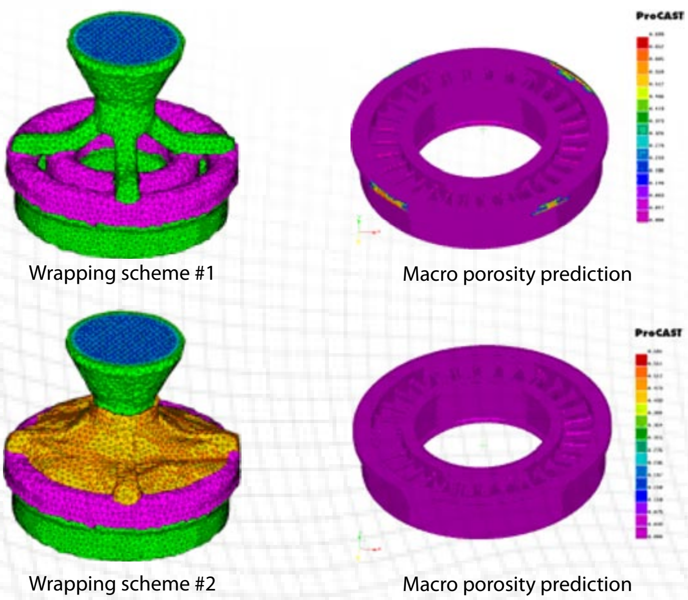


Figure 4: Result study with several wrapping schemes

Step 4: Robustness Study

The goal here is to see more precisely the impact of chosen parameters and thus, to get a more robust process. One has to know that achievement time is longer when geometric parameters are modified (Figure 5). Physical parameters are easier to change and allow testing a great variety of process parameters.

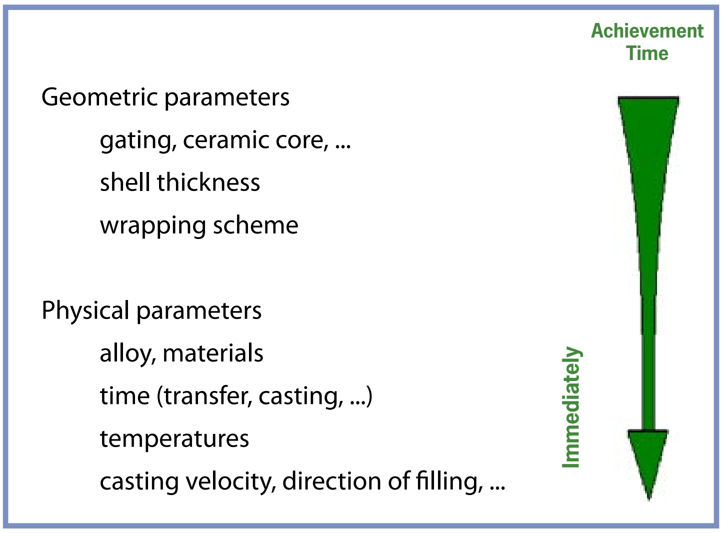
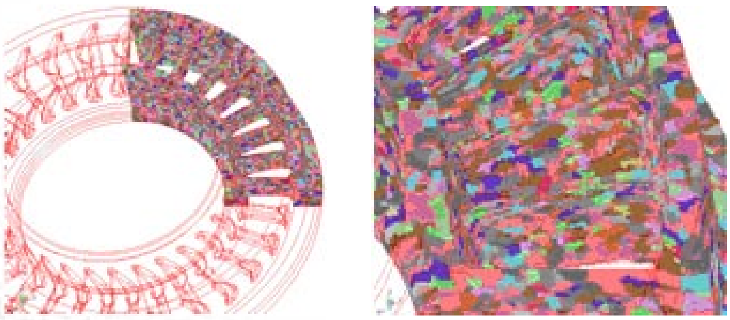


Figure 5: Achievement vs. parameters modification

Step 5: Other Results

Some investigations can be made also on some specific topics, depending on the process used and/or on the customer requirements. For instance, if grain size and orientation is a key criterion, one can model it (Figure 6).



Grain size and orientation (CAFE module of ProCAST)

Figure 6: Grain modeling

Conclusions

Shorter development times and cost reductions (scrap costs, re-engineering costs) are required to the investment casting houses. Modelling is an efficient tool to achieve these goals, as it can be used at the very beginning of the design conception (concurrent engineering with customers). Modelling the investment casting process step by step (thermal only, filling, solidification) allows founders to get a robust process in a short time and results can be shared by all engineers with a Product Data Management software.