# Creative Die Corrections Based on Realistic Casting Simulation of Gravity Die-Casting

**S. Shamasundar**
ProSIM R&D Pvt. Ltd., Rajaji Nagar, Bangalore – 560010, E-mail: shama@pro-sim.com

Author is involved in sensitising the management and engineers of Indian industries in general and casting industries in particular, (as well as casting users) to adapt simulation-based design procedures for more than a decade. Today, many industries in India are quite well aware of the casting simulation although the routine usage in design process is still low.

Once the user gets a feel for the usage of software, simulation software can be used in a variety of ways to solve casting problems. In this paper, a case study relating to die correction of a GDC process is presented. An unconventional and creative solution was found and delivered by trying multiple corrections on the existing die and validating the same using a casting simulation software ADSTEFAN. Solution considered the batch size, time constraints and the constraints of existing die (that was wrongly designed by a third party- obviously who did not use any simulation procedure).

## Introduction

Sequence of activities of a typical conventional trial-and-error-based die design procedure is compared with a simulation-assisted design procedure in Fig. 1.

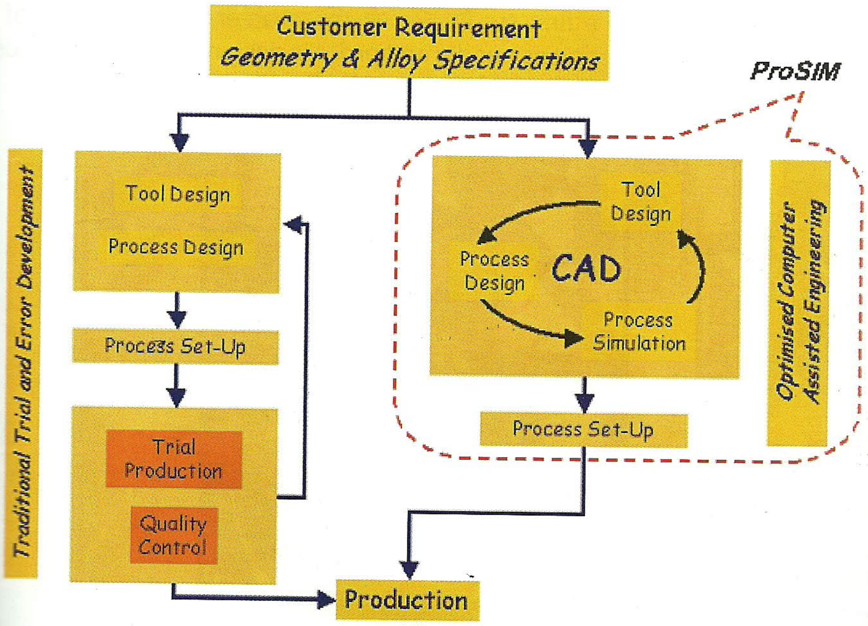


**Fig.1**: Trial & error-based design compared with Simulation-based casting process design.

Benefits of casting simulation in terms of predicting the defects such as shrinkage porosity, air entrapment, under-filling, die erosion, hot tear, cold shut, residual stress, distortion, die wear etc., are well-known and proven. While using the simulation, the computer screen becomes a virtual casting floor. Designer can conduct multiple experiments without resorting to physical production of dies. Metal flow, cooling of melt and solidification can be visualised in 3D component giving complete information. Several Indian casting industries are engaged with ProSIM for such simulation-based prediction of defects and gating development. Development cycle time can be drastically reduced by using simulation. Many times, the entire development is done within a week. Reduction of scrap and yield improvement are major benefits resulted from using simulation. ProSIM has worked with customers to increase the yield from a low of 40% to more than 65%. Rejections are reduced to as low as 3 to 6%.

ADSTEFAN is a casting simulation software from Hitachi Industry & Control Solutions Ltd., Japan. ADSTEFAN originated at Tohuku University in Japan, with Prof Niyama, who is known as the father of solidification science. (Solidification factor is named after him as 'Niyama Criteria'). Hitachi is investing on continuous development of ADSTEFAN. As a result, ADSTEFAN has very fast and robust solvers, which give very accurate and reliable results.

## A Wrong Die is Designed and Fabricated

Figure 2 shows a brass casting to be produced. The shape is intricate and has sharp features and cross-sectional changes. Third party pattern maker and designer were not aware of the simulation-based die design for gravity die-casting. They were also very confident of their expertise and developed a die design. Figure 3 shows the die produced for the casting production. The die design yielded very bad castings, with air entrapments in multiple locations as shown in Fig. 4. Several corrections were tried and no solution was found. After several dozens of failed attempts, the caster approached ProSIM for a simulation-based solution to overcome the problem of air entrapment and *shrinkage porosity in the brass casting.*

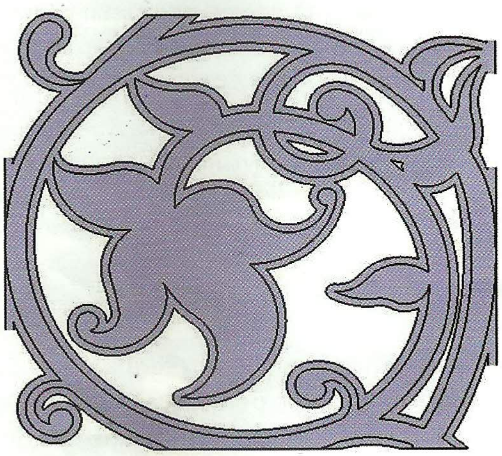

**Fig. 2** : Features of casting to be produced.

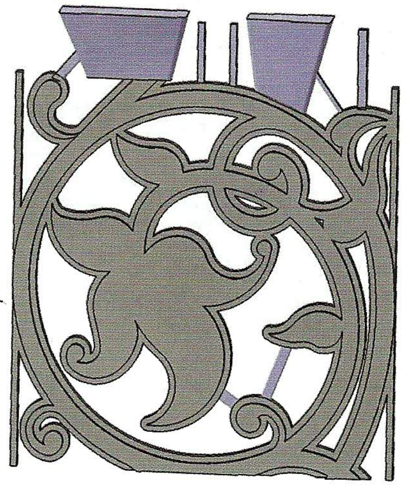

**Fig. 3** : Die designed by third party for GDC of the component in Fig. 2.

## Diagnosing the Die Design Problems using ADSTEFAN Simulation

As a first step to solve the problem, a simulation of the casting as per die and process design was carried out using

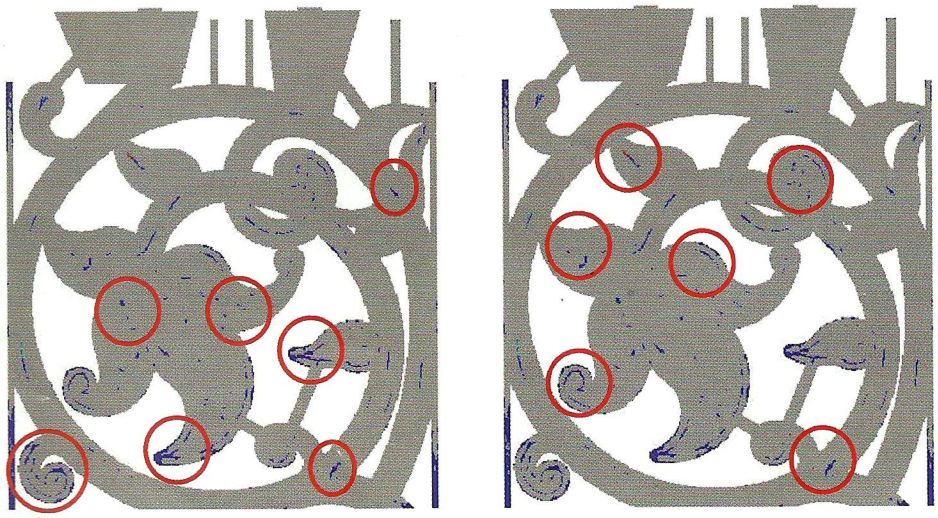

**Fig. 4**: Defects generated in the dies developed without using Simulation (surface porosities).

ADSTEFAN software. Melt flow simulation (coupled flow and heat transfer) and solidification simulation (coupled heat transfer and solidification phase change) were carried out.

Process conditions are as given below:

Material: Brass (60Cu-40Zn)

Solidus temperature: 899° C

Liquidus temperature: 905 ° C

Weight of finished casting: 89 kg

Pouring temperature: 1050-1080 °C

Die preheat temperature: 280-300 °C

Figure 5 shows the images of progressive die cavity filling by the molten metal. Colour contours show the temperature distribution. From the figure at 100% filling it is seen that the temperature of the melt, in the last regions to fill is less than, 450 °C, which is lesser than the solidus temperature. This means, the solidification will have got initiated before the die cavity filling is complete.

Melt temperature at the end of cavity filling is very important for the designer. This information is available only by simulation. Using ADSTEFAN simulation, it was realised that temperature of the melt has to be increased. It was decided to preheat both the faces of the dies (instead of only one face pre-heated earlier), and also insulate the feeder sprues to reduce the heat loss.

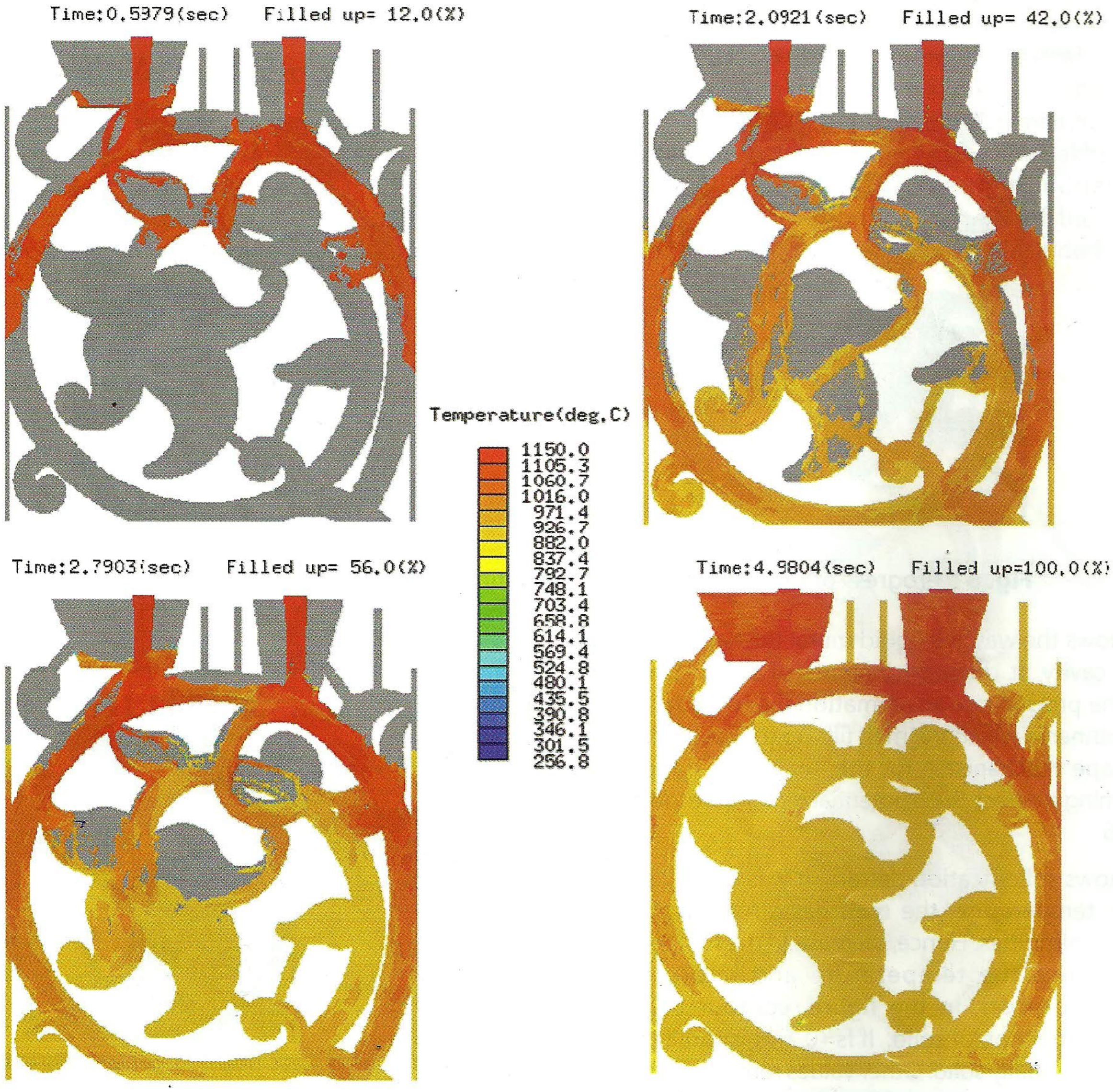


**Fig. 5** : Molten metal filling the die cavity depicting the melt temperature distribution.

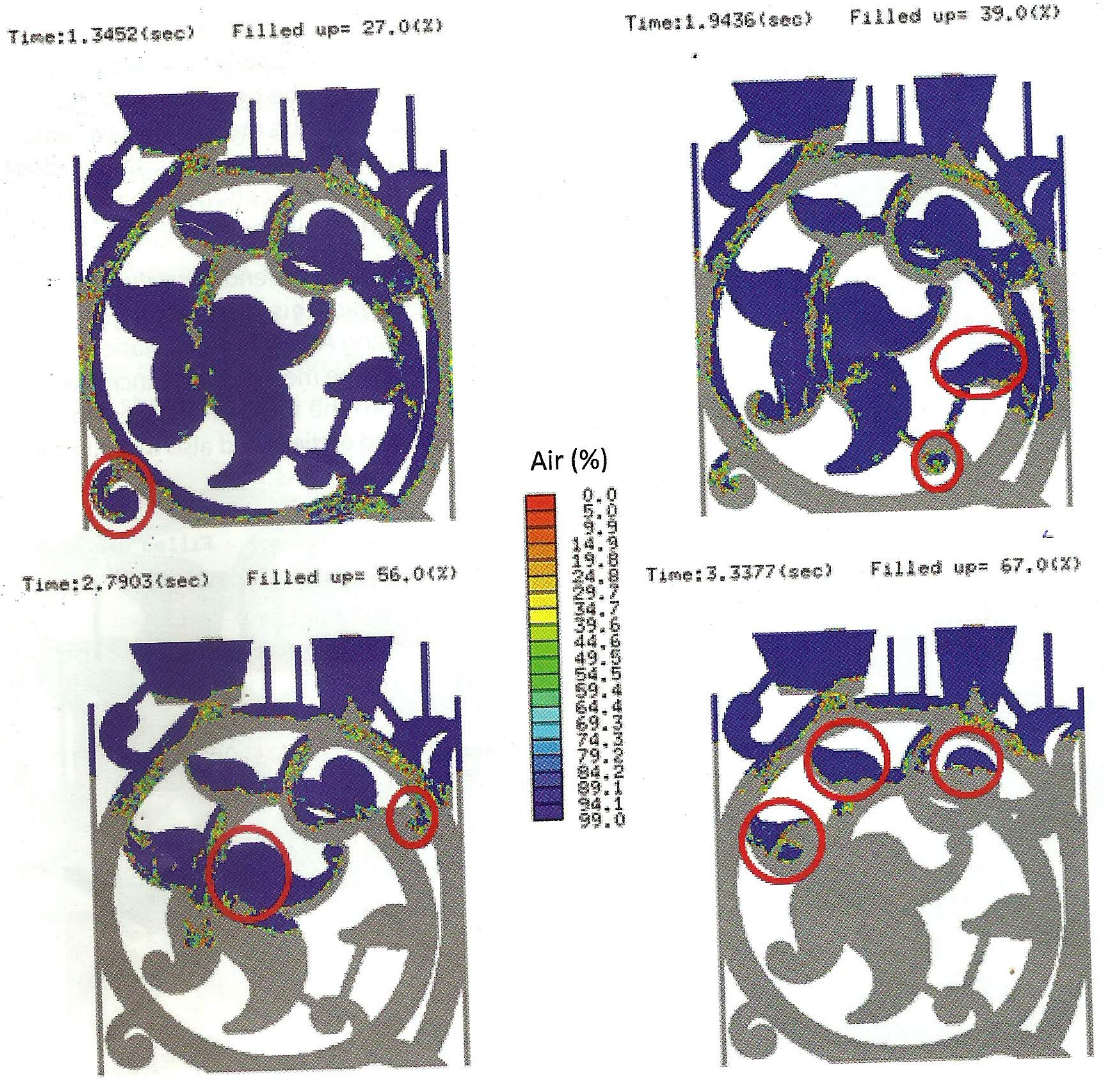


**Fig. 6** : Progress of die cavity filling and formation of the air entrapments in casting.

Figure 6 shows the way the liquid metal flushes the air out of the die cavity at different instants of time. User can generate the progress as an animation file to visualise the dynamic manner in which the melt fills up the cavity. If there are no escape mechanisms for the air, it gets trapped in the die, forming a defect. Such potential regions are identified in the Fig. 6.

Figure 7 shows solidification pattern. It was observed that due to low temperature, the melt has already solidified causing discontinuities. Hence, increase in die temperature should stabilise the temperature and improve the solidification process. In the figure, contour band 'fs' represents the fraction of solid. If fs=0, this is totally liquid melt and fs=1 is totally solid. Other values represent a mushy zone with different fractions of liquid and solid.

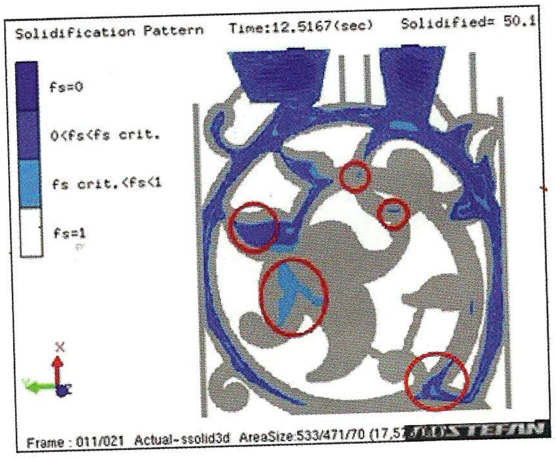


**Fig. 7** : Solidification pattern after fluid flow.

## Analysis of the Defective Die Design:

From the simulation studies of the casting, the following inferences are drawn.

- By the time the molten metal fills entire die cavity, the temperature of the melt has gone below the solidus temperature. (During pouring in the foundry, it was observed many times that the filling would not be complete, and solidification would prevent flow and lead to under-filling).
- There are multiple spots of potential air entrapment.
- Some sharp corners of the design are not getting the feed of liquid metal.
- There are shrinkage porosities in multiple locations as identified in Fig.7.

## Creative Engineering Solutions Based on ADSTEFAN Simulations

It was very clear that the die design at hand was not based on sound die design practices. From a practical business perspective, there was not enough time to design a new die and prove it. As per the business commitments, certain number of castings had to be shipped each month. A creative engineering solution had to be obtained to solve the problem. Several options (more than 22) for the process and die design change were explored, in a span of 1 week. Trying such many options by physical melting would take several months with spending of several lakhs of Rupees. Using simulation and engineering judgement, and considering practical business needs of the situation, a solution was obtained. The solution included:

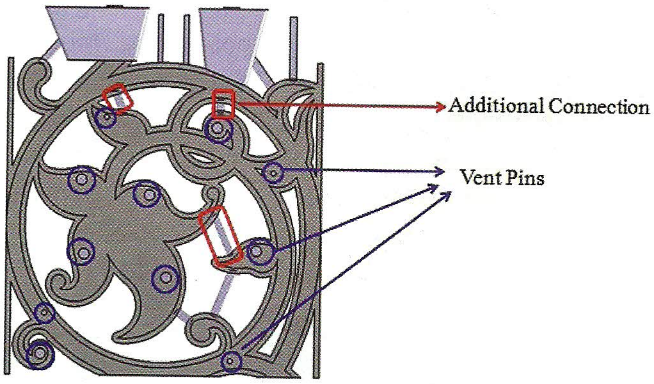


**Fig. 8**: Schematic of modifications in the die.

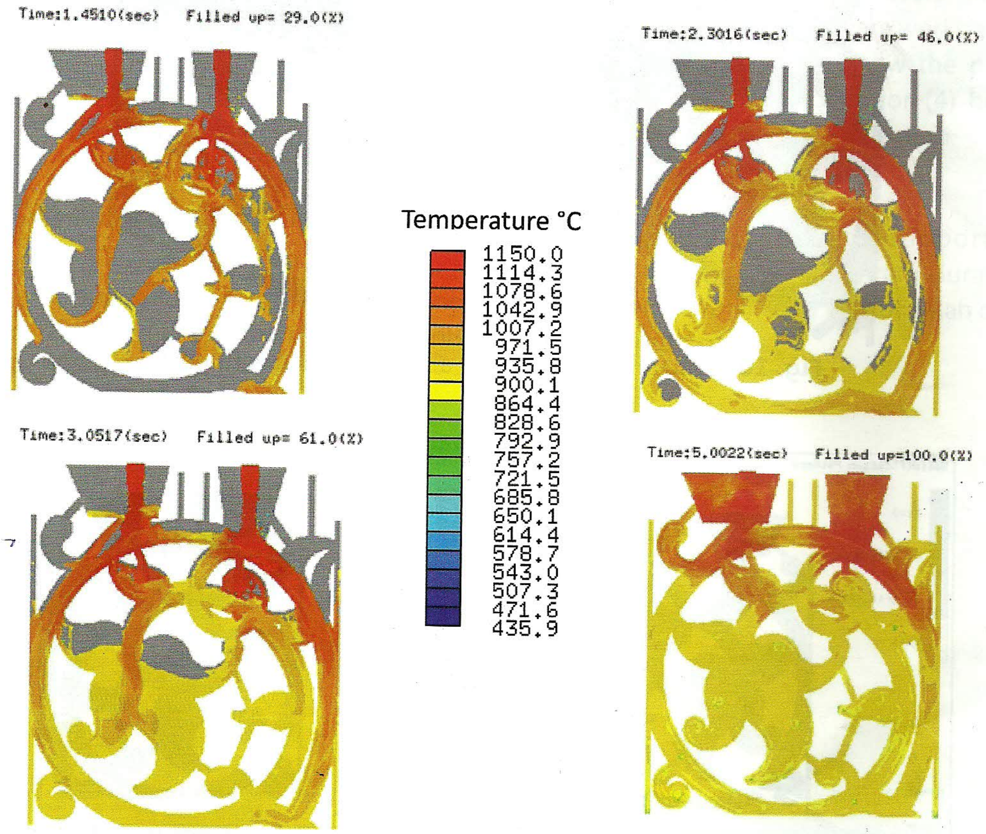


**Fig. 9**. Temperature distribution at the end of die filling for modified design.

- Providing connector channels to feed the melt flow to the region where the metal was not flowing. This could be accomplished by cutting the dies which was very much feasible.
- Inserting air vent pins /plugs to allow the air to escape from regions of last filling.
- Providing the pre-heating to both halves of the die.
- Insulating the feeder sprues.

Figure 8 shows the proposed modifications to the die based on the simulations.

Figure 9 shows the temperature distribution at the end of

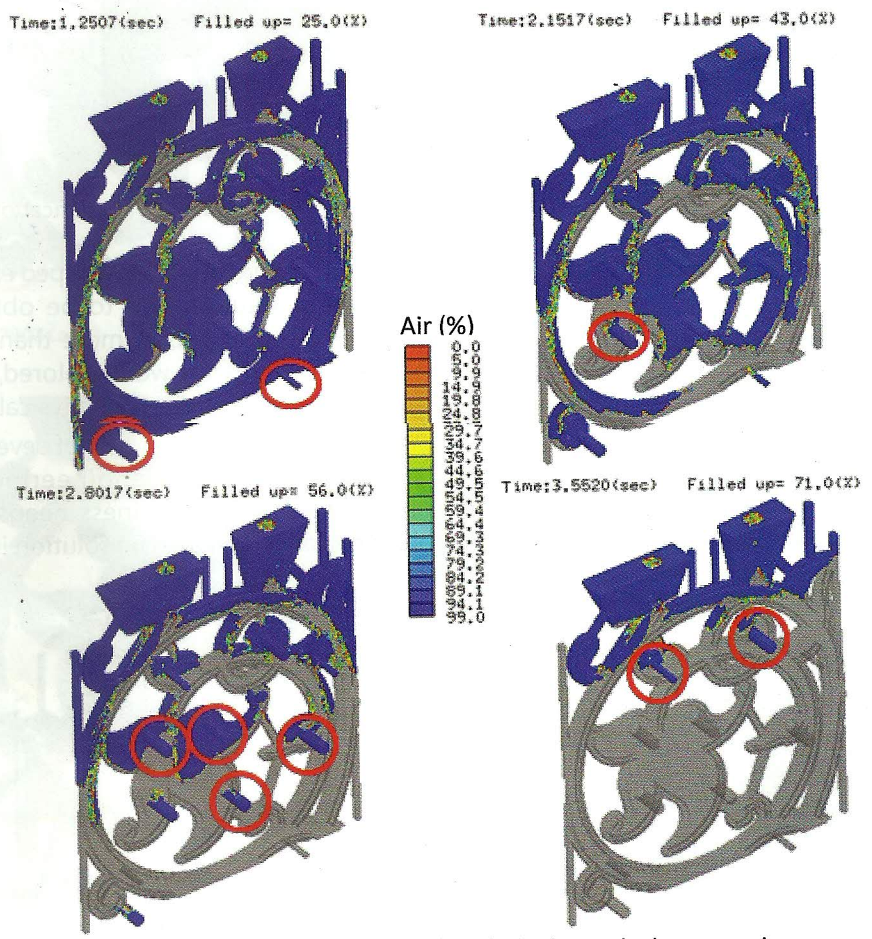


**Fig. 10** : Evacuation of trapped air through the vent pins.

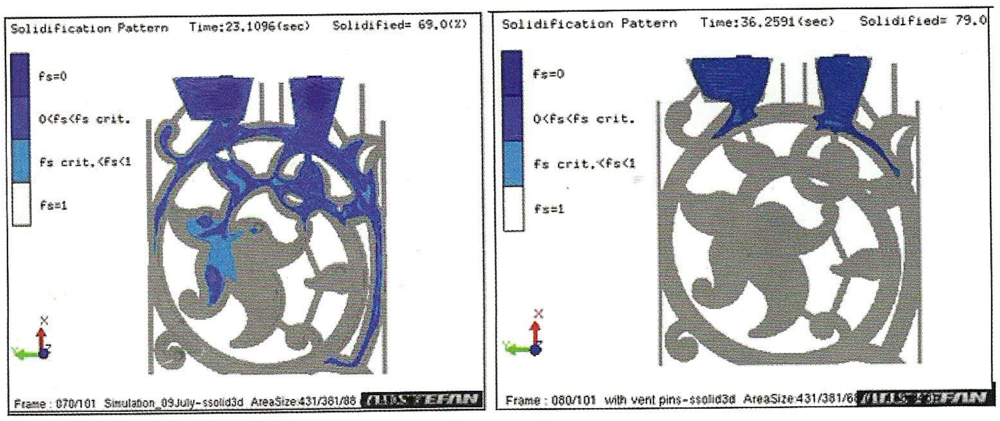


**Fig. 11** : Solidification pattern after fluid flow.

the die cavity filling. It is seen that the temperature is above the liquidus temperature.

Figure 10 shows the evacuation of air through the vent pins justifying the locations on the die. (Blue colour indicates air and transparent indicates liquid metal).

Figure 11 shows the improved stabilised solidification process with less discontinuities resulting due to increased die temperature and pre-heating of both halves.

**Fig. 12**: A sound casting using simulation results.

## Discussion and Conclusions

Author has presented a case study on die correction, for a gravity die-cast non-ferrous component using the casting simulation software ADSTEFAN. Simulation software tools are generally proposed to be used at the early stage of die design and process development. In this case study, author demonstrates the ability for die corrections to suit specific (and urgent) business needs of the caster. ProSIM has assisted their customer to keep the confidence of end customers by supplying the component, without delay. If the die design was to be started from scratch by using the benefits of simulation, a more elegant die design could have been achieved. But due to the business (time) pressures from the end customer, it was not even remotely acceptable. What is achieved, is an optimal solution keeping all the constraints and considerations in mind to ensure end customer's satisfaction.

What has been demonstrated in this paper is a non-ferrous gravity die-casting process. Same principles can be applied in casting of any type of material (steel alloys/ cast iron/ ductile iron/ aluminium alloys/ titanium/ nickel alloys etc.) or any type of process (sand casting/ shell moulding/ pressure die-casting/ investment casting/ centrifugal casting or tilt pouring). Key issues for successful deployment of simulation software are (1) software must be based on sound scientific principles (2) users must have a good appreciation of how the software works and (3) users must have good appreciation of how the particular casting process works in the shop-floor (4) how the material behaves during flow and solidification.

## Acknowledgement

Author acknowledges the support provided by Mr. Padmanabh Shetty, Mr. Shriram Gurav and Mr. Shyam Bhanushekar of ProSIM and Mr. Punnaiah of Vision Castings for his suggestions.