

# APPLICATION OF NUMERICAL SIMULATION ON CAST-STEEL TOOTHED PLATE

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## Abstract:

A three-dimensional Computer Aided Design (CAD) model is established by using Pro/E software. The finite volume method (FVM) numerical model and ViewCast simulation software are used to study both the casting solidification process and filling process of toothed-plate. Based on the simulation, the casting shrinkage and solidification process are forecast visually in the form of images. The mould-filling simulation verify whether the liquid metal pour the mould smoothly and /quietly/evenly. Two optimization schemes are completed based upon the simulation. The production of the casting shows that these optimization methods are very helpful to reduce the casting defect and improve the quality of product.

## 1 Introduction

Numerical simulation and its optimization are effective method to improve the traditional casting technology. Mould-filling and solidification process are the basic components of the casting numerical simulation. Shrinkage defects of steel and iron castings are predicated by the solidification simulation. Mould-filling simulation could test and verify whether the liquid fills the mould smoothly and steadily. It can not meet demand to develop new technology based on the experience of traditional "trial and error" method. Casting simulation has the special advantages of saving the cost and time [1-5]. The cast-steel toothed plates which are the part of crusher of coal mine machinery are used in crushing cinderblock. No casting defects such as shrinkage

porosity, cavity, coldshut and crack exist in the casting and the toothed plate must have the characteristic of abrasion resistance [6,7]. The casting material is 40CrMo cast-steel. The chemical composition of steel is shown in Table 1. Computer aided design commercial software ViewCast developed by the Belgium Metal Processing Center is employed in casting process. ViewCast can be utilized to simulate the solidification temperature field, solidus fraction, the flowing time of the liquid metal, velocity field in the filling process. This software is mainly used for predicting casting defects and for designing gating systems. ViewCast is composed of three following module: preprocessing, numerical calculating and post processing [8].

Table 1. Chemical composition of Cast-steel 40CrMo

Element	C	Si	Mn	Mo	Cr	Fe
Content (wt%)	0.38-0.45	0.17-0.37	0.40-0.70	0.15-0.25	0.90-1.20	Balance

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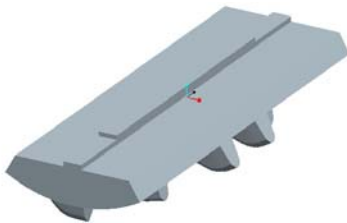
In this paper, casting solidification is simulated by virtue of simulation software, ViewCast. Casting technology optimization is obtained on the basis of the simulation. The technology and structure of the casting are improved in order to decrease the casting defects of toothed plate. The technology parameters of the casting are tested and verified by mould filling with ViewCast.

## 2 Implementation of the numerical simulation and discussion of results

### 2.1 Solidification process of the casting

Mould material is sodium silicate sand. The solid model of the casting is generated by Pro/E software and saved as \*.STL file. The casting part of the toothed plate is shown in Figure 1. Grid subdivision is implemented by ViewCast. Although refining the grid improves the accuracy of results, it needs too long computation time [9]. So, all the cell grid dimensions are set as 5mm. The gating temperature is 1590 °C and the initial temperature of mould is 20 °C. The heat transfer coefficient between the mould and casting is set to 1100 W/m<sup>2</sup>/K. The casting parameters are set before calculation.

(a) View 1



(b) View 2



Figure 1. Three dimensional entity graph of the toothed plate.

The solidification simulation of cast-steel is calculated by ViewCast. Great shrinkage caused by solidification contraction is seen from Figure 2. The transparency in the figure illustrates that the metal content is above 97% and that these parts are deemed as non-defective. The riser is calculated by software and also the pouring system is planned. The simulation results (Fig. 3) demonstrate that the porosities are effectively eliminated and that small scale of shrinkage exists in the bottom of the sprue.

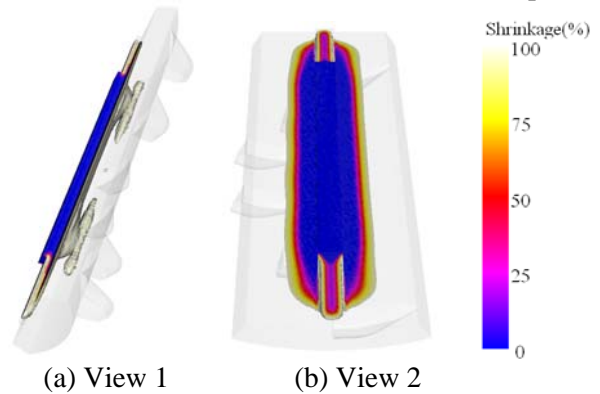


Figure 2. Casting defect forecast map of the plate.

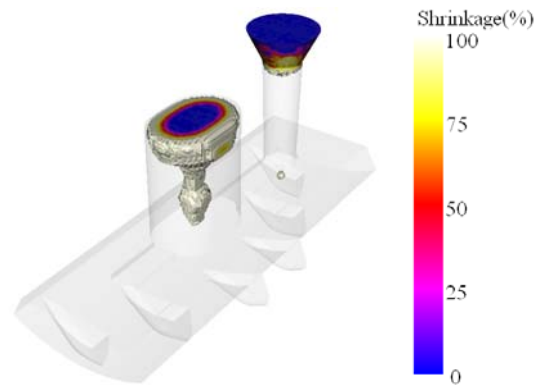


Figure 3. Defect forecast map with riser and gating system.

The solidification process is shown in Fig. 4 and the eight pictures illustrate the representative stages of the solidification. When the solidification time was at 13 seconds, the casting began to solidify. When the solidification time was at 260 seconds, the tooth of plate solidified completely. The whole solidification process covered 2606 seconds. The simulation results show that the riser can fill the shrinkage of the casting.

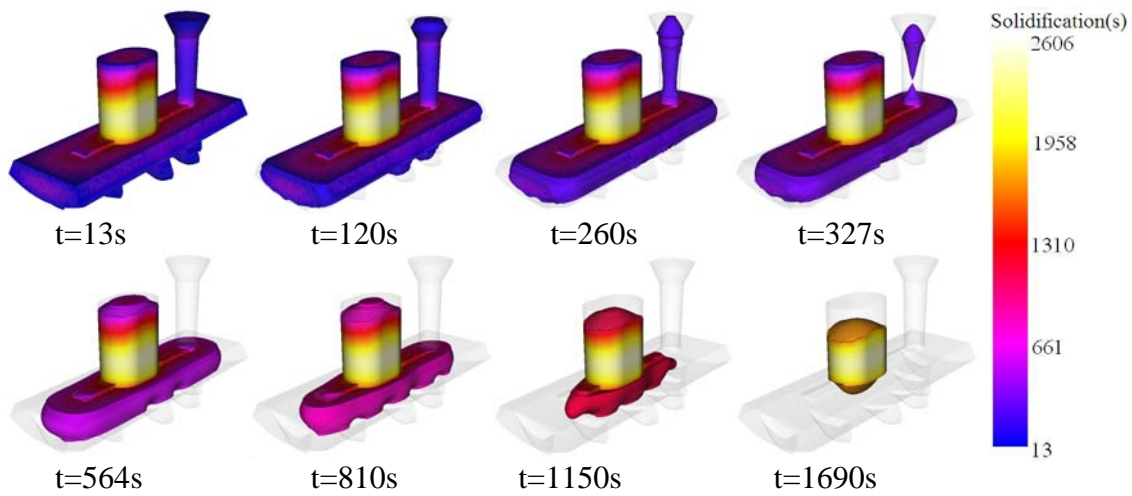


Figure 4. The solidification process of the casting.

## 2.2 Mould filling process

The gating system is tested and verified with ViewCast pouring system simulation. The gating simulation of software could visually examine the behaviour of liquid flow and validate the process of mould filling. Some major results are obtained previously by software [10]. The mould-filling simulation is calculated by ViewCast. Simulation results are shown in Fig. 5. The eight pictures show eight representative stages of the mould-filling. The diagrams demonstrated that the gating process is not smooth and that turbulence exists in the pouring process.

## 2.3 Technology optimization

Aiming at the problem of the initial scheme, two schemes are proposed by ViewCast to improve the casting process. Two runners are designed for gating the casting and two risers are used to feed the casting shrinkage in optimization scheme 1. Two castings are poured into simultaneously and two risers are projected to feed the castings separately in optimization scheme 2. The defect forecast maps of the optimized technology are shown in Fig. 6.

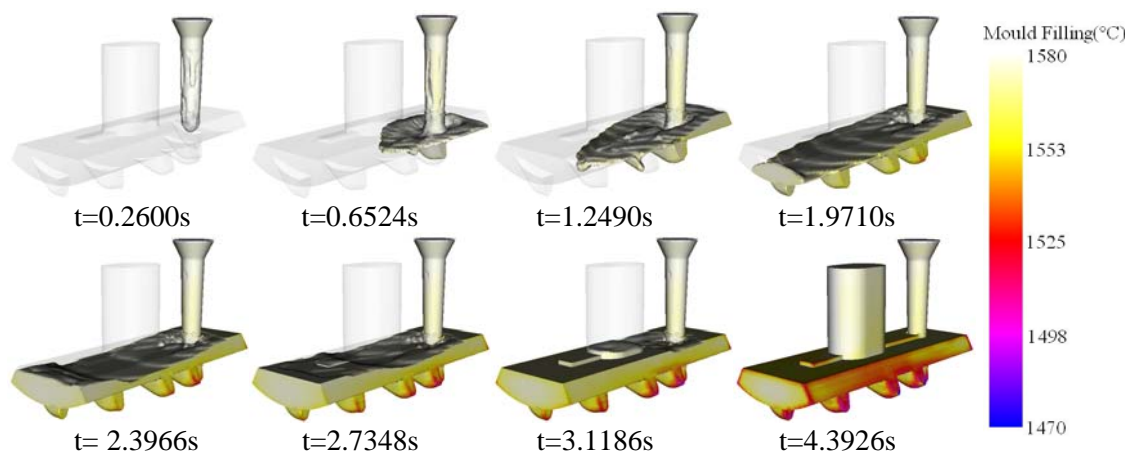


Figure 5. Mould-filling process of the simulation.

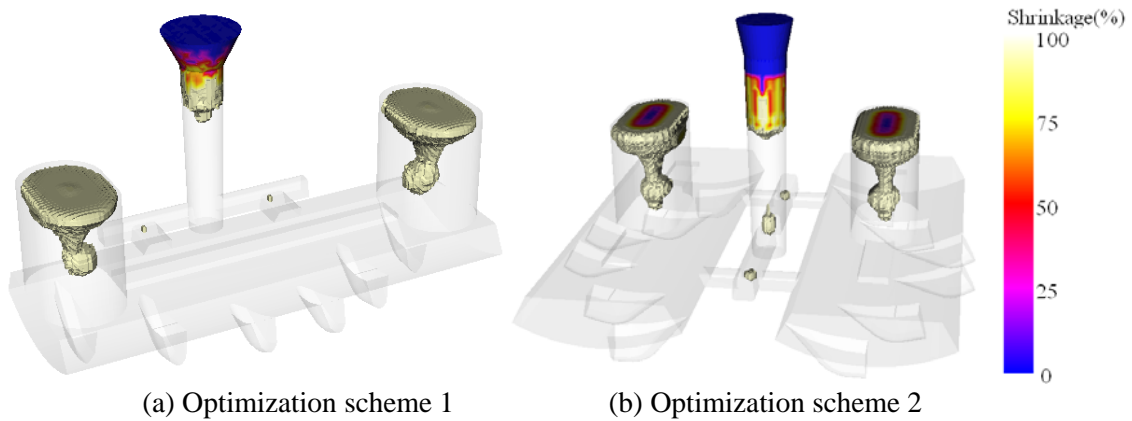


Figure 6. Defect forecast maps of the optimized technology.

**Optimization Scheme 1.** The simulation results (Figure 6a) demonstrate that the shrinkage and porosities are eliminated effectively. The solidification process is shown in Fig. 7. The 8 images show that two risers can effectively feed the casting during the solidification. The mould-filling process is shown in Fig. 8. The simulation results show that the metal liquid does not pour into the casting smoothly and evenly. When the gating time was at 9.1037 seconds and 10.3570 seconds, turbulence existed in the mould.

as the scheme 1. But the scheme 2 has the higher production yield compared to scheme 1 because only one riser is used to feed the casting in scheme 2. The solidification process of scheme 2 is shown in Fig. 9. Two risers can effectively feed the casting separately and the casting achieves progressive solidification. The mould-filling process of the scheme 2 is shown in Fig. 10. The simulation results show that the liquid gates the mould of cast-steel smoothly and /quietly/evenly. The casting is successfully produced in practice so that no defects exist in the casting.

**Optimization Scheme 2.** The scheme 2 has the effect of eliminating casting defects in the same way

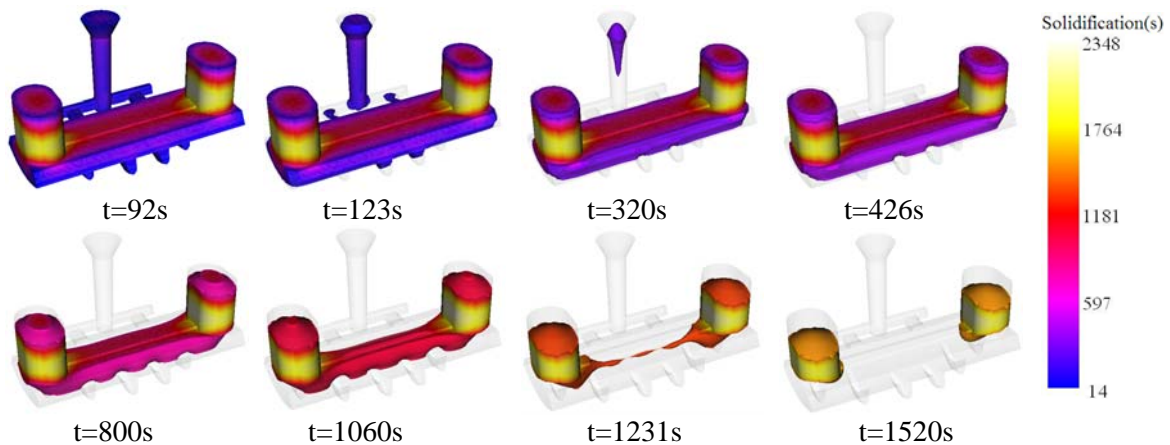


Figure 7. The solidification process of the optimization scheme 1.

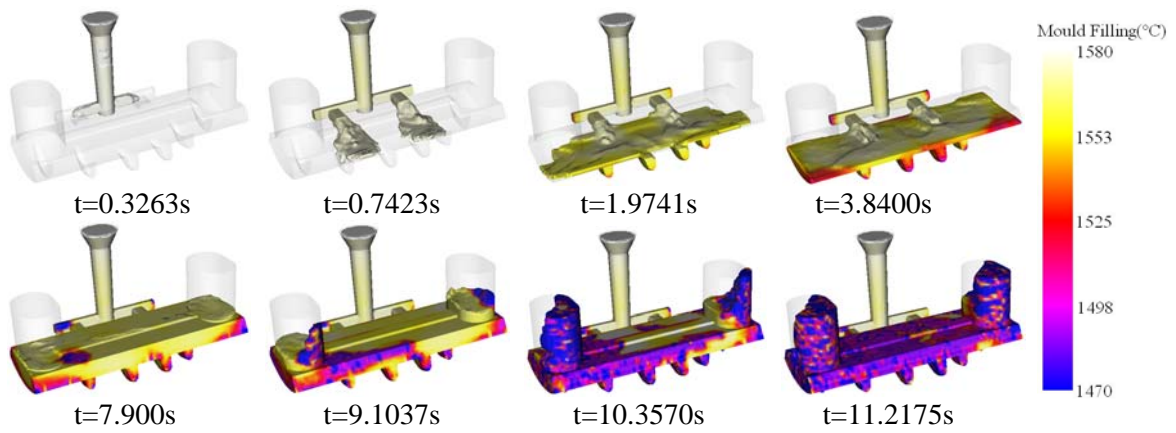


Figure 8. Mould-filling process of the optimization scheme 1.

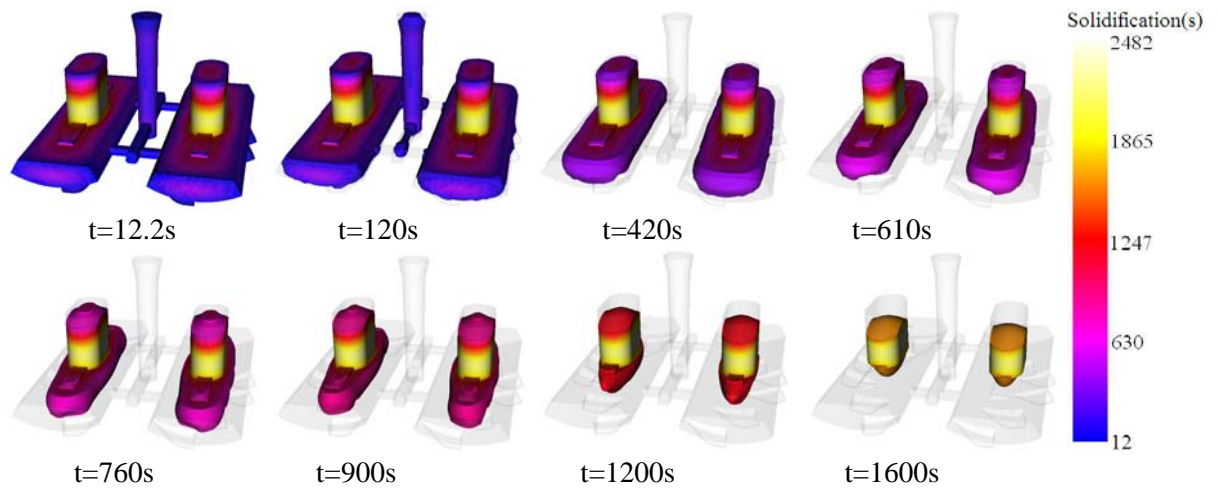


Figure 9. The solidification process of the optimization scheme 2.

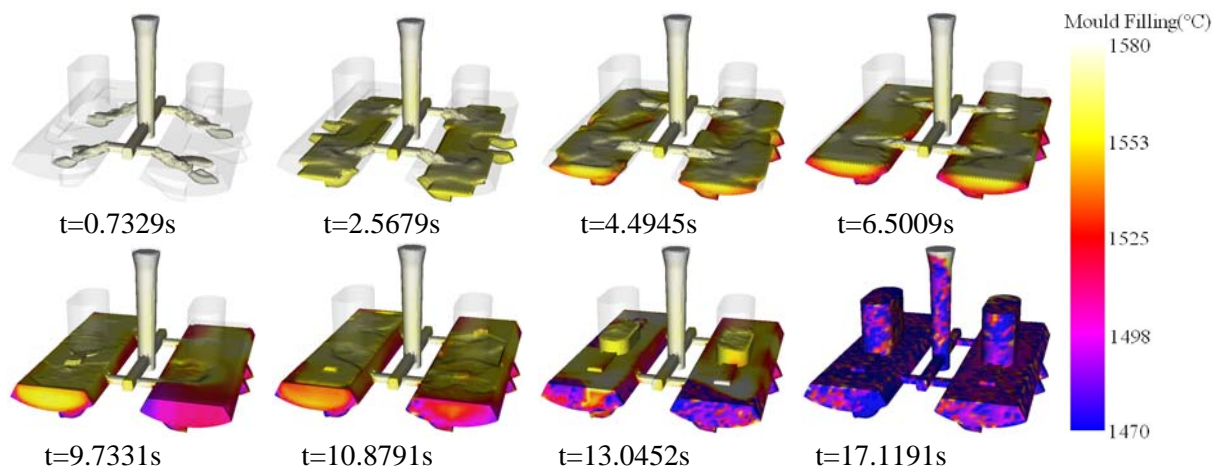


Figure 10. Mould-filling process of the optimization scheme 2.

### 3 Conclusion

The casting technology design is accomplished by ViewCast. The location, size and shrinkage porosities of the casting are easily observed with ViewCast by simulating the solidification process. The solidification simulation could test the progressive solidification of the casting. The mould filling simulation could verify whether the liquid metal fills the mould smoothly, and whether the computer aided design could achieve the parameter plan effectively and expediently. The optimization scheme 2 is in a more reasonable way compared to optimization 1 because the scheme 2 has the higher product yield and metal liquid fills the mould smoothly and quietly / evenly. This research can provide good references of the pouring system designed for the actual production.

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