SIMULATION BASED DESIGNING OF DEFECT FREE PARTS IN DIE CASTING

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Abstract - simulation of die casting process is an important tool to predict the filling behavior of die cast metal in dies and prediction of defects in the die cast parts. The simulation of the die casting filling process is performed to predict defects incurred in producing a die cast part. The results of simulation are examined to analyze the filling behavior of the molten metal and to identify any defects in the part. The model has been updated so as to reduce defects in the die cast parts. The capabilities of the developed system are demonstrated by applying it on sample die cast part model. In the present work, functional requirements of a part were not accounted for and the designer can accept or reject the modified design keeping in mind the functional requirements.

Keywords - Design for manufacturing; die casting, process simulation.

I. INTRODUCTION

During a die casting process, molten metal is initially poured into the shot sleeve and then injected into the die cavity by the plunger. After filling of the die cavity, pressure intensification occurs during the solidification to reduce the amount of gas porosity, air entrapped and dimensional inaccuracies etc. Finally, the die is opened and casting is separated from the die [1]. Fig 1 shows a die-casting process setup.

There are five major phases [1] in the pressure die casting process. During the first phase of pressure die casting process, molten metal is initially poured into the shot sleeve and then injected into the die cavity by the plunger under pressure. The molten metal fills the mold cavity in the next phase. Solidification of the molten metal takes place to form the designed die cast part in the third phase. Pressure intensification occurs during solidification to reduce the gas porosity, feed shrinkage porosity & dimensional inaccuracies. In the next phase, the cast part is ejected from the die with the help of an ejector mechanism and casting is separated from the die. Finally, the mold is closed for the next cycle. The present work is focused on the filling behavior in the die casting process.

II. LITERATURE REVIEW

Yan et al. [2] proposed a numerical simulation of AZ91D magnesium alloy automobile plug in pressure die casting process to predict casting defects e.g. insufficient pouring, cooling separation, crack generation, shrinkage etc. Authors were able to reduce the defects in the work piece by improving the part design by incorporating the design changes suggested after examining simulation results.

Shepel and Paolucci [3] proposed a method for filling and solidification of a casting of an automotive aluminum alloy piston. They concluded that simulation can be used for accurate prediction of various parameter and defects in die casting.

Krimpenis et al. [4] proposed a neural network approach to generalize connecting input process variables, such as gate velocity, mould temperature, etc., to output variables, such as filling time, solidification time, defects, etc. The results of casting simulation were examined for generating design changes suggestions for producing the combination of input and output variable that achieves the best output parameter values.

Fu and Yong [5] proposed a CAE modeling technology for simulation of filling and solidification process in die casting. The CAE simulation has been applied to identify and predict the process related defects and help to propose the solutions to avoid the defects.

Guo et al. [6] developed a methodology to model the material properties for better casting simulation. Authors discussed that effect of changes in the composition of an alloy on the properties during solidification.
Cleary et al [7] discussed applications of SPH and MAGMASoft to model the filling in different automotive parts. It was stated that SPH don't require mesh suited to fluid flows where droplet formation, splashing and complex free surface motion.

Yongbao et al [8] developed a 3D program using FDM approach to simulate the filling process in the die casting. Simple Marker and Cell (SMAC) method was used to solve the full Navier-Stokes equations and track the free surface k-e model to account for the turbulence phenomenon during filling process. The simulation capability and validation of the numerical model was demonstrated by comparing the results with the experimental results.

Colominas et al [9] presented a Galerkin meshless formulation through various dynamic simulations by comparing with the experimental results. It was concluded that proposed method is able to handle severe distortions and complex phenomena. Sulaiman et al [10] developed an algorithm for analysis of flow front movement by combining the network element method and fluid flow analysis. The effects of variation of pressure, velocity and temperature within the cavity for mould filling are studied. The effect of draft angle over metal filling process is also investigated.

### III. METHODOLOGY

Simulation offers a powerful and cost effective way to study the effectiveness of die filling process [2]. Process simulation of the casting system reveals filling behavior in the casting process and identifies the necessary information related to product quality and defect formation. Simulation helps to determine the process routing and process parameter configuration in the die casting process [2]. Simulation also helps to verify the die design based on the revealed filling and solidification behavior of the melt [2]. The simulation helps for quality prediction and defect evaluation in the die casting process. By using simulation, the process can be virtually realized, so it reduces trial and error runs. The mold filling is a crucial step to generate good quality castings. Improvements to both product quality and process productivity can be achieved through better control of the die filling.

The part CAD model is designed in CAD software using feature based modeling. The die casting process is simulated for the designed part and modifications in the design are suggested on the basis of simulation to predict the behavior of filling process. The present system uses the process simulation of the die casting and design changes are proposed resulting into reduction of the defects in the die cast parts.

The following steps has been used for simulation of die casting process has been performed for prediction of defects in the die cast part.

1. The part CAD model of the die cast part is input to the designed system for simulation study.
2. The filling behavior of the melt in the die has been simulated. If the filling behavior in the simulation process is normal, it can be said that the cavity has filled properly.
3. If the filling patterns reveal any abnormality, then there are chances of some defect in the part.
4. The part model is redesigned aiming to reduce the defects in the die cast part.
5. The redesigned model is again simulated to confirm whether the defect has been reduced or not.

### IV. IMPLEMENTATION AND RESULTS

The cast material is AlSi9Cu3 (A380/ADC 10); a widely-used die cast material. The die material is X38CrMoV5, hot working steel. Various physical properties of the cast material are described as pouring temperature-670°C, liquidus & solidus temp. - 593°C & 538°C, tensile & yield strength - 317 & 159 MPa, shear & elastic modulus – 26.54 & 71 GPa, poisson ratio – 0.33, thermal conductivity – 109 W/mK, specific & latent heat - 963 & 389 kJ/kgK, coefficient of thermal expansion - 2.2x10^-5/K, mass density – 2760 kg/m³. The sample die cast part has been shown in fig 2.

The time instances of results of the simulation of the filling process are shown in fig 3. Simulation results of the die casting filling process show that the hollow boss features is difficult to cast and does not fill properly. The molten metal is unable to reach the top surface of the boss.

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**Fig 2: Sample part CAD model**

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In the present study, the thickness of the hollow boss is increased by 10% iteratively and the filling process is again simulated. It has been seen after that the hollow boss features are able to fill almost completely at a thickness equal to approx. 3.993mm. The filling process of the part model is again simulated for any occurrence of defects. The results of die casting simulation on the model are shown in fig 4.

CONCLUSION

The simulation of the die casting filling process is performed to predict defects incurred in producing the sample part. The results of simulation are examined to analyze the filling behavior of the molten metal and to identify any defects in the part. After examining the simulation results, it was found that hollow cylindrical features do not fill properly and lead to defects of air entrapment in the sample part. After studying simulation results, some design modifications are suggested by changing one or more feature parameters of the part. The part model is modified after incorporating the design changes and the model is simulated again to see the effect of design changes on the occurrence of defects. The process is continued in an iterative manner till the defects in the part are significantly reduced. In the present work, functional requirements of a part were not accounted for and the designer can accept or reject the modified design keeping in mind the functional requirements.

REFERENCES