Optimization of Gating System Design for Die Casting Process with Minimizing the Casting Defects

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ABSTRACT

Thousands of consumers, commercial, and industrial products can be produced by die casting process with high volume ranging from small to large components and hence die casting can be referred as mass production process. Some of the products produced by die casting was defective and hence needs to improve the performance of the process. The objective of the present work is to evaluate the effect of injection pressure of the molten metal, filling time, gate length and gate width on the dimensional stability of the die cast part. In order to investigate the effect, process parameters such as injection pressure of the molten metal, filling time, gate length and gate width Response Surface Methodology (RSM) with Face Center Design (FCD) has been used. The experiments were carried out according to design matrix of L27 orthogonal array. Two response or defect namely shrinkage porosity (%) and hot tears (%) were considered in this work. The RSM model was developed for each response. Analysis of variance (ANOVA) for each response has been also carried out to find out the influence factors and their interactions. Finally, optimization and confirmation test has been carried out and the optimized input parameters were validated by conducting experiments and predict the optimum response. The modeled and experimental results have been compared and an error of 26% and 24 % has been observed for both responses with 98% of desirability.

Keywords: *Die-Casting; Gating System; Defects; Optimization; Response Surface Methodology.*

I. INTRODUCTION

Die casting is a moulding process in which the molten metal is injected under high pressure and velocity into a split mould die. It is also called pressure die casting. The split mould used under this type of casting is reusable. Hot-chamber die casting, sometimes called gooseneck casting, is the more popular of the two main die casting processes. In this process, the cylinder chamber of the injection mechanism is completely immersed in the molten metal bath. A gooseneck metal feed system draws the molten metal into the die cavity. This process lends itself to higher rates of part production than with the cold-chamber process.

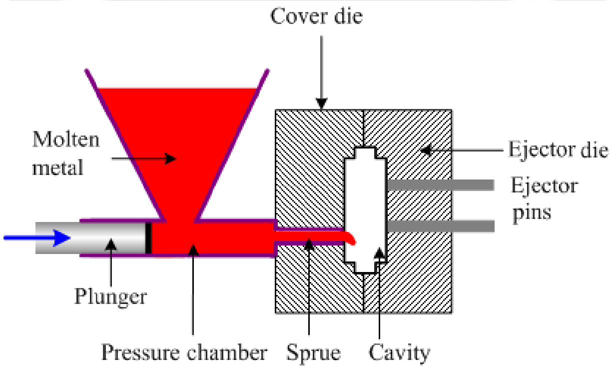

Figure 1. Die-casting process

II. Experimental Setup, Material and Model

The experimental setup of machine that is R38 hot chamber die-casting machine having Tank Capacity: 200L, Weight of machine: 3000kg, Overall dimension: 3000x1050x1550 on which different die-casting process is carried out. Aluminum alloy (as shown in Table 4.1) is considered as a material for die casting and final output of the process completion is shown in Figure 4.2. In this experiment nine experiments have been done as per Taguchi L27 design orthogonal array. The three input variables injection pressure (bar), fill time (sec), gate length (mm) and gate width (mm) considered from which three output response shrinkage porosity and hot tears are to be determined and analyzed.

The main objective of the present work is to minimized the shrinkage porosity (%) and hot tears (%) with optimum gating design. For determining optimum design, the input as well as output parameters, response surface optimization method has been considered.

Table 1. Chemical composition of aluminium alloy

Element	Si	Cu	Fe	Mg	Mn	Ni	Pb	Zn	Ti	Al
Weight %	9.6-12	1.5-3.5	1.3	0.3	0.5	0.5	0.2	1.0	0.3	Balance

Table 2. Process parameters and their setting

Input Parameters/Factors	Range	Low (1)	Intermediate (2)	High (3)
Injection Pressure (bar)	300 – 340	300	320	340
Filling Time (sec)	0.5 – 1.0	0.5	0.75	1.0
Gate Length (mm)	70 – 100	70	85	100
Gate Width (mm)	10 – 30	10	20	30

Table 3. Process parameter (factors) setting in Design Expert software

Factor	Name	Units	Minimum	Maximum	Code Low	Code High	Mean
A	Injection Pressure	bar	300	340	1 ↔ 300	2 ↔ 340	3↔320
B	Filling Time	sec	0.5	1.0	1 ↔ 0.50	2 ↔ 1.00	3↔0.75
C	Gate Length	mm	70	100	1 ↔ 70	2 ↔ 100	3↔85
D	Gate Width	mm	10	30	1 ↔ 10	2 ↔ 30	3↔20

III. Results & Conclusions

In any manufacturing process, there will be two or more process variables that are inherently related and it is necessary to explore the nature of their relationship. A model has been proposed relating the process parameters with the output response. This model can be used for prediction, process optimization or control purposes. In general, there will be response or dependent variables (shrinkage porosity, hot tears) which depend on some independent variables (injection pressure, filling time, gate length, gate width). In this chapter, models have been developed to fit the output responses using Response Surface Methodology (RSM).

The investigative checking of the model has been carried out by using prediction check. In the present work, a prediction check has been made to test the adequacy of the developed models, i.e., construction of a plot of predicted versus actual values. The result of the analysis indicates that good correlation exists between the experimental and predicted values.

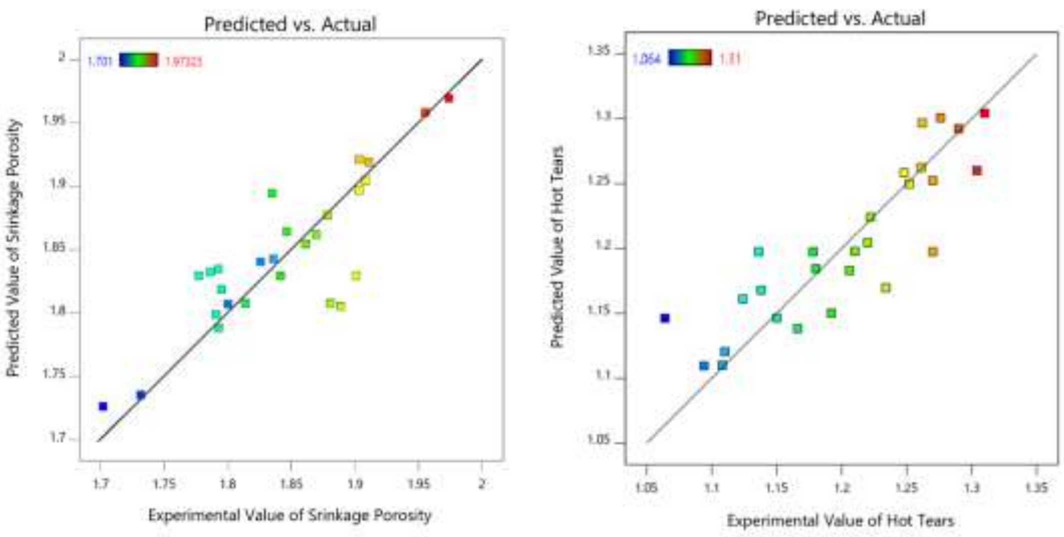

Figure 2. Comparison Plot for shrinkage porosity and hot tears

Table 4. Optimized input parameter for optimum gating design in die casting

Injection Pressure (bar)	**Filling Time (sec)**	**Gate Length (mm)**	**Gate Width (mm)**
340	0.5	99.99≈100	10

Table 5. Optimum output response (shrinkage porosity and hot tears)

Response	**Value**
Shrinkage Porosity (%)	1.456
Hot Tears (%)	1.000

IV. Conclusion

Statical techniques has become an essential tool for casting defect troubleshooting and optimization method. With the use of optimization techniques gating system of the casting are improve and increase the quality of the casting. This would result reduction in cost and material saving. Based on the experimental results, ANOVA analysis and RSM based mathematical model developed for optimization of gating system in die casting process of aluminium alloy, the following conclusion have been drawn to achieved optimal gate design with free defect during die casting process:

- Comparison of the experimental and analytical results has been carried out.
- Empirical relations for the prediction of shrinkage porosity and hot tears using response surface methodology (RSM)
- By incorporating the tool geometry in the model, the validity of the model has been enhanced.
- The accuracy of mathematical model developed using response surface methodology shows the effectiveness of the model.
- The optimization, carried out in this work, gives an opportunity for the user to select the best gate geometry and casting condition so as to get the optimum defects.
- The modelling of the die casting parameters can be done using FEA technique like Creo, ABAQUS, AutoCAST etc., and the computational efficiency can be evaluated.
- The optimization of die casting parameters for multi responses in die casting of aluminium alloy can be carried out using other techniques like genetic algorithm and particle swarm optimization technique and their effectiveness can be evaluated.
- The work can also optimize with considering other defect and for other design or responses.

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