Optimization of Gating System in Die Casting Process: A Review

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ABSTRACT

In the modern generation, there a necessity for casting units & foundry to deliver components with less rejection rate i.e. short lead time. The gating systems is assuming essential part in the field of quality. So, optimization of gating framework in metal casting delivers the error free components. The principle motivation behind optimization of gating systems is growing yield of cast product & overcome the defects like shrinkage, gas porosity, slag, inclusion, etc. Many researchers have been studied on optimization of gating system on the basis of Taguchi method, Numerical Simulation, Mold flow Software, Artificial Neural Network, Genetic algorithm technique and so on to diminish the defects. The objective of this review paper is to optimize gating systems based on statical technique i.e. Response Surface Methodology with the goal of improving casting quality.

***Keywords**: Die-Casting; Gating System; Defects; Optimization; Taguchi Method; 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. Die casting is categorized two types namely- hot chamber and cold chamber as shown in Figure 1.1. Metals like Zinc, tin and lead alloys are casted in hot chamber die casting having melting point below 3900C whereas aluminum alloys are casted in cold chamber die casting machine. Aluminum dissolves ferrous parts in the die chamber and hence preferred to be used in cold chamber die casting. Continuous contact of molten metal is avoided by using a ladle for introducing molten metal directly to the machine.

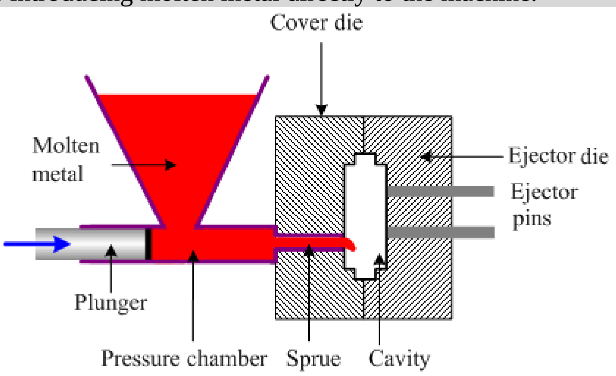

Figure 1. Die-casting process

1.1 General design consideration

The following design guidelines need to be followed for die casting:

- Identify the possibility of incorporating several functions in to one die casting. Full advantages must be taken for the reduction of machining that die casting can afford.
- Before the design and construction of die begin the designer should finalize the design of die casted product and its producibility. Dies after machined undergo heat treatment for hardening.
- The designer must consult die cater about the location of the ejector pin as early as possible in the product design stage itself. If the impression left by the pins are not tolerable or can't be cored out, as an alternative solution rings or sleeve ejection can be opted.

- Abrupt section changes, sharp corners and wall at an acute angle to one another need to be avoided. These features disturb the continuity of metal flow and lead to form a porous structure and surface irregularities. Therefore, it is recommended to provide radii as generous as possible with differing sections blending into one another.
- Blind recesses are needed to be provided in the die to form bosses. Due to trapped air subsurface porosity is developed and this causes the drills to wander and taps to break in secondary machining and hence recommended to be avoided.

II. REVIEW OF LITERATURES

There is extensive literature of review about optimization of gating system in Casting Industry and they brought a various optimization technique used in casting to control defects and maximize the yielding of products.

Yarlagadda and Chiang (1999) developed an artificial intelligent neural network system to generate the process parameters for the pressure die casting process. The scope of his work includes analysing a physical model of the pressure die casting filling stage based on the governing equations of die cavity filling, and the collection of feasible casting data for the training of the network through the use of simulation package MELTFLOW and also from experts in the die casting industry. The multi-layer feed-forward network is trained with data collected directly from the industry using MATLAB application tool box.

Hu et al. (2000) investigated a thin-walled magnesium telecommunication part in hot chamber die cast and a numerical simulation technique was applied for the optimisation of the runner and gating. Two types of runner and gating systems were designed and analysed. It resulted in a high possibility of air entrapment in the casting and the design was not proper for the part. The design was improved by using a continuous gating system and a bigger size runner. The gate area was increased and the gating speed was slightly reduced. For the study, die inserts for both designs were fabricated. Also, a series of casting experiments were conducted. The short shot filling tests proved that the simulation results matched the actual casting results very well. Good quality thin-walled telecommunication parts with sound microstructure were produced based on this optimised runner and gating system.

Myers et al. (2004) studied that Response surface methodology (RSM) is a collection of statistical design and numerical optimization techniques used to optimize processes and product designs. The original work in this area dates from the 1950s and has been widely used, especially in the chemical and process industries. The last 15 years have seen the widespread application of RSM and many new developments. In this review paper we focus on RSM activities since 1989. We discuss current areas of research and mention some areas for future research.

Krimpenis et al. (2006) was studied on pressure die-casting condition of individuals working in production industries. In his work in order to generalise from examples connecting in- put process variables, such as gate velocity, mould temperature, etc., to output variables, such as filling time, solidification time, defects, etc. These examples, or knowledge, are gathered from experiments conducted on casting simulation software, which are designed systematically using orthogonal arrays (DoE). They could also be based on experiments from industrial practice. Neural models derived in this way can help in avoiding excessive numbers of what-if scenarios examined on the casting simulation software, which can be very time-consuming.

Lee and Gokhale (2006) was shown that gas pores can facilitate formation of shrinkage porosity in high-pressure die-castings. Air in the gas pores is an efficient heat-insulating medium that retards heat transfer in the melt as compared to regions without porosity, leading to lower local solidification rate, which can induce shrinkage porosity formation.

Yoshimura et al. (2008) investigated the behaviour and quantity of air entrainment caused by the movement if a die cast plunger in a sleeve and by the tip’s shape are analyzed using a CFD simulator. The optimum shape of the die-cast plunger tip for reducing the amount of entrained air and preventing the occurrence of blow holes in die-cast product is calculated.

Zheng ET AL. (2009) achieved the optimal parameters and the castings with acceptable surface quality. An evaluation system for the surface defect of casting has been established to quantify surface defects, and artificial neural network was introduced to generalize the correlation between surface defects and die-casting parameters, such as mold temperature, pouring temperature, and injection velocity. It was found that the trained network has great forecast ability. Furthermore, the trained neural network was employed as an objective function to optimize the processes.

Swamy et al. (2012) designed and optimized the gating system by fluid flow and solidification simulation for front axle housing. A flawed gating system was found to be the reason for improper fluid flow and melt solidification which in turn produced casting defects. Optimization of the gating and risering system by using casting simulation software ADSTEFAN was carried out. Through several simulation iterations, it was concluded that defect free casting could be obtained by modifying the initial gating ratio 2:2:1 to 2:1.76:1. Also shifting of sprue location from centre to end and providing the risers at location prone to formation of shrinkage porosity led to the decrease in size of the shrinkage porosity about 97%.

Mohanty and Jena (2014) investigated the optimization of process parameters of an aluminium die casting operation. The quality problem encountered during the manufacturing of a die casted component was porosity and the potential factors causing it are identified through cause- effect analysis. An analysis of variance (ANOVA) is conducted to find the factors with significant effects on porosity. A back propagation Artificial Neural Network (ANN) is modelled and trained with these process parameters and porosity in order to predict or control the output by optimizing input process parameters.

Adke (2014) optimized the die-casting process parameters to identify optimized level for cycle time using Taguchi method. There are four machining parameters i.e. melting temperature, Injection pressure, Plunger speed, cooling phase. Different experiments are done based on these parameters. Taguchi orthogonal array is designed with three levels and four process Parameters with the help of software Minitab 15. In the first run nine experiments are performed and Cycle time is calculated.

Panchal et al. (2015) designed and done analysis of gating and risering system for casting of ball valves. CAD model of ball valve has been developed and simulation has been carried out using ProCAST. ProCAST results are compared with the experimental results for validation. Risering and gating parameters are modified to get better yield. It is observed that with new gating and risering system casting yield is improved by 8 % and porosity is decreased by 1 %.

Kulkarni Singh et al. (2017) studied that simulation is now well accepted as a scientific approach to designing the gating, internal quality, optimal yield of casting process. The simulated results can be used to predict the quantity of these defects, optimize the design and take corrective steps to minimize these defects thereby increasing the quality of casting. In the present work, effort is made to optimize the gating design and feeder parameters to obtain quality castings.

Raveendran and Patil (2017) studied that in die casting, the die often has more than one cavity with multiple cavities producing the same or different parts. Multiple cavities require the application of branch runners connecting to a main runner. The design of the runner system has always been a topic for die casting, since it is important for the designer to ensure that multiple cavities start filling at the same time and have the same fill time.

Apparao and Birru (2017) research, the use of the Taguchi approach has been conceptualized to obtain optimal settings of the die casting parameters, in order to increase the Al-Si8Cu3Fe (EN AC-46500) aluminium alloy die casting quality and efficiency by reducing the porosity formation. The effects of the selected parameters on the porosity formation and the subsequent optimal setting of the parameters have been accomplished using Taguchi approach. The final results indicate that optimized parameters considerably affect the porosity formation in Al-Si8Cu3Fe aluminium alloy die castings.

Balikai (2018) carried out to optimize the die casting process parameters using ANOVA and Taguchi method in order to achieve the improved quality of high pressure die casting (HPDC) products, which is the challenge for the small and large-scale manufacturers of HPDC products. Objective was to reduce the porosity in these components which help to obtain the good quality castings. The porosity is the most common defect frequently encountered in aluminium high pressure die castings, which increases the rejection rate and scrap rate and reduces the productivity.

Xavier et al. (2019) experimental study was conducted using air-water and air-water-oil mixtures in a 0.075m diameter pipe. Superficial gas and liquid velocities ranged from 0.03 to 0.13 m/s and 1.26 to 41.58 m/s respectively. Slug flow was the main flow pattern observed. In addition, the transition from churn to annular flow and annular were also observed. Due to the homogeneous nature of the oil-water-air mixture, the three-phase flow was evaluated as a pseudo-two-phase mixture. An Artificial Neural Network (ANN) model developed for the prediction of two-phase and three-phase pressure drop performed better than all models considered during the evaluation. Generally,

III. 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. Many design rules, are developed over the years through experience and studied. But For wide spread application, statical techniques must be easy to use, fast, and reliable. This can be achieved by integrating method. The staical technique has proven its reliability and accuracy in predicting internal defects which help to reduce this defect, and optimization using a single software tool.

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