DEFECT ANALYSIS METHODS OF DIE-CASTING COMPONENTS: A REVIEW

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Abstract— The casting defects that is induced through molten alloy, were entrapment of gas, air and inclusion and through solidifying pattern, were shrinkage porosity. The assurance of less casting defects have been based with the experience of the engineers in foundry. In present time, with the help of computer simulations, analysis of solidification pattern and molten metal's flow can be done. For solidification process and flow pattern, optimized process parameters can be achieved. The results from simulations for hardware component to check the die-casting process, have found better agreements with the experimental records in terms of quality and reliability, showed satisfactory results.
This paper gives review on various techniques to analyze the casting defects and Variation in simulations is stated, which is helpful for detection and elimination of defects rapidly and accurately.

Index Terms— casting, simulation, defect, solidification

I. INTRODUCTION

Die casting follows specific variation from metal casting as molten metal is pushed into a permanent steel Mold, or say die, very rapidly with large pressures. Reusable steel Mold and the injection of molten metal with large pressures makes die casting different from the other metal casting processes.

Die-casting produce parts at high speed of a list of durable metals & it's alloys with reliably catching the most complex design details.

"Captive" die casting is a process that entirely produce die-castings for their own use. "Custom" die caster produces casting for their customers' order, not themselves. Mainly there are two types of die casting processes, hot chamber die-casting process and cold chamber die-casting process. They acquire these names by the temperature of the alloy(metal) that pumped, comparative to the temperature of the alloy(metal).

- In hot chamber die casting, the metal pump, or gooseneck, is submerged in the metal and is the same temperature as the metal.
- In cold chamber die casting, the metal pump, cold chamber or shot sleeve, is outside the furnace, and is cold relative to the metal ladled into it.

The optimal die-casting configuration is:

- Fill entirely by alloy(metal).
- Solidifies rapidly without defects.
- Release readily from the die.

II. DIE-CASTING PROCESS

Basic cycle:

The fundamental steps of the die-casting cycle include:

- Die spray/die inspection
- Die closing
- Ladling (cold chamber)
- Injection
- Dwell/casting inspection
- Die opening
- Ejection
- Casting removal/inspection

Machinery:

Each DCM consists of several systems:

- Structural -The structural system and its components form the foundation of the machine, providing support.
- Electrical-The electrical systems and its components provide power to the machine and control it.
- Hydraulic-The hydraulic system and its components Utilise a fluid, fire-resisting oil to force the cylinders that do the DCM actuate.
- Safety-The safety components help prevent injuries and accidents while using the machine, when used appropriately and coupled with safety-conscious actions
- Casting dies-
    - Mold base
    - Stationary half Mold base
    - Moving half Mold base
    - Ejector box
    - Ejector system
    - Die cavities

Alloys:

Die casting designers consider a list of issues when producing a die-casting. Each alloy has different mechanical properties: tensile strength, yield strength, elongation, and MOE. The alloy chosen must be appropriate to the die casting's application. Alloy selection is based on the characteristics and properties of the alloys in nine categories.

These include:

- Cost by volume
- Process cost
- Structural properties
- Weight - light
- Impact strength/dent resistance
- Surface finish
- Corrosion resistance
- Bearing properties/wear resistance
- Machinability

Quality:

Die castings make high quality components. The process is often described as the smallest distance b/w raw material and the completed component. The quality of die-cast component, as judged by the end user, is determined by its appearance and ability to do the job it was designed for. However, quality of die casting is more than skin deep. The quality of die casting is also determined by its dimensional and internal integrity.

A quality casting is free of defects. So in order to decide the quality of casting, you must be capable to identify the defects. There are 3 primary types of defects.

1. Surface defects
2. internal defects
3. Dimensional defects.

There are two subcategories of surface defects: flow and other. There are many types of flow defects. These result from how the metal flows to and within the die. They may be related to die temperature, alloy temperature, the casting's geometry, etc. There are two subcategories of internal defects: inclusions and porosity. Inclusions are when something is included in the alloy (metal) that shouldn't be there. Porosity is a void in the casting either caused by trapped gas or shrinkage.

Dimensional defects are related to die temperatures, die condition, and the injection force. Die temperature is the most important variable related to dimensional precision.

III. LITERATURE REVIEWS

In 2013, Quang-Cherng Hsu and Anh Tuan Do [1], In this paper, the optimum process parameters values predicted for casting of minimum shrinkage porosity and the most suitable combination of parameters given as follows:

- Furnace alloy temperature
- die temperature
- Plunger velocity, 1st stage
- Plunger velocity, 2nd stage
- multiplied pressure

The model proposed in this paper gives acceptable results in the optimisation of pressurized die casting process. The expected values of the process parameters and the calculated are in convincing agreement with the experimental data. The experiments which is carried to decide the most effective levels, is based on "Orthogonal Arrays," and is well-balanced with respect to each control factor and though minimum in number. This in turn implies that the resources (materials, saving time, and money) required for the experiments are also minimized.

In 2016, Vinod Kumar Verma, Rohit Rampal, In their investigation, trials will be carried through altering holding furnace temperature, die's temperature, plunger velocities in the 1st and 2nd stage, and increased pressure in the 3rd stage applying L27 orthogonal array of Taguchi method. The experimental data by the orthogonal array can be used to measure the relationship of process parameters and Defect in the die cast component and to analyse the breaking load behaviour of various level of porosity formation in HPDC process.

Bosello high technology industrial x-ray machine can be used and comparison between previous process parameters and optimized process parameters can be analyzed and their results also analyzed. Lowest Porosity noted after process parameter optimization .After optimization of porosity formation in HPDC porosity observed and break load improved.

In 2013, Dasaratha Prabhu B., Ramesh Babu K.[3],In their investigation, experiments are being performed through collection of different parameters affecting the causes for defects in the component, in which the affecting parameters are tool temperature, pouring temperature, pouring time and cooling medium (air and oil).

The data has been recorded at different trails and is being interrupted for statistical analysis software to determine the effect of various parameters affecting the defect in the component. Design of experiment by Taguchi method is used by generating "orthogonal array". A response for defect is being input into the worksheet and analysis can be carried out.

The S/N (signal-to-noise ratio) graph indicates the various parameters affecting to each defect such as bubble, blowhole and flash defect .Taguchi method is evident to resolve that a great significance will be induced by pouring Temperature for blowhole defect, pouring time will influence the major bubble defect in component and the flash defect will be signified by major parameters like tool temperature and cooling medium.

In 2010, V.V. Mane, Amit Sata and M. Y. Khire [4], in their investigation, they introduce a 3-step method to casting defect, that is identification, analysis and rectification. The defects are classified in terms of their appearance, size, location, consistency, and discovery stage & inspection method. This can be useful in precise identification of the defects. For defect analysis, the potential causes are classified into design, material and process parameters.

The outcome of predicted cause parameters on casting quality can be determined through computer simulation. Based on the results and its interpretation, the optimal values of the parameters are determined to eliminate the defects. Casting defect analysis can be accomplished by methods like cause-effect diagrams, DOE (design of experiments), if-then rules & Artificial Neural Networks (ANN)

In 2015, - E. Anglada, A. Meléndez, I. Vicario, E. Arratibel, G. Cangas [5], The industrial procedure follows sequential manufacturing cycles that must be taken into consideration in the simulation. Moreover, the component geometries use to be complex and liquid metal is injected at very high velocities. All of that usually implies long calculation times that in complex cases may lead to several days.

Sometimes, the circumstances require to have available a fast solution despite involves loss of accuracy. The inclusion of the pre-heating cycles in the computer simulation is highly advisable. The only reason is the difficulty to estimate the Mold average temperature in other case.

Relating to bound the computer simulation to the heat-transfer analysis, is good alternative when the interest is only focused in thermal behavior. · Execute first one simulation of the preheating cycles but restricting the analysis to the heat transfer only. Then execute second simulation considering the thermal and the flow analysis.

Mold temperatures obtained as result of the first simulation must be assigned as the initial temperatures of Mold for this second simulation. · On the place of original models, the usage of pseudo-2D models are advisable only in these cases where the accuracy must be sacrificed to keep lower computation times. (10 times compared with detailed one). These alternatives have been validated by its utilization during the preliminary phases of the adjustment process of a HPDC model.

In 2000, B.H. Hu, K.K. Tong, X.P. Niu, I. Pinwill [6], an adequate runner and gating design is very crucial to manage best quality die-castings through providing homogenous Mold fill pattern. Numerical simulation is more cost-effective tool for the designing and optimisation of runner and gating systems. Generally 2 types of gating systems are designed.

The design of split gating system will lead to swirling filling pattern and poor central-flow, which prematurely blocked the edges and left the last filled areas falling into the inside portion of the part. It will result to more possibility of air-entrapment into the casting and this design will not be suitable for the component.

The design can improve through use of continuous gating system as well as bigger size runner. The gate area will increase and the gating speed will slightly reduce. Numerical simulation shows that the design provides homogenous mould filling pattern with the endmost filled areas being situated at the upper edge of the part, where overflows and vents are being attach conveniently. The short shot filling tests proved that the simulation results matched the real casting results very well. Good quality parts with sound microstructure were produced based on the optimised design.

In 2008; B.S. Sung, I.S. Kim [7]; the casting defects which will cause due to molten metal are: cold shut formation, entrapment of gas, air and inclusion. Computer simulations can be accomplished to analyse the flow pattern of molten metal. As the ingate velocity in the thin plates castings increased, resulted in cold shut has decreased.

The runner shape parameters that affected the optimal conditions that are estimated using simple equations and examined using the experimental data. The derived results to control the die-casting process has achieved well agreements with the experimental outputs in terms of tensile strength and hardness test, and material structure showed satisfactory results.

Thermal stability for the Mold has been shown after several cycles based on the calculated results by the use of "virtual thermocouples" because the Mold needs preheating in which the optimized preheating temperature for the product can be determined.

In 2013, chul Kyu Jin, Chan Hyun Jang and Chung Gil Kang [8], in vacuum die-casting. It requires best quality die-design to overcome unfilled phenomena, turbulence in flow, and porosity. The tangential gating design for the thin plate has no interference with the gates, and ensured continuous and homogenous filling of molten metal flow.

More overflow entrances can be added at the end portion of the cavity to eliminate the premature freezing of the molten metal. Moreover, for thin component die casting, Overflow at side-wall the cavity may be needed to solve problem of turbulent flow by inducing high velocity molten metal at the overflow.

In 2016, Vinod V Rampur [9], in their investigation, they identify defects i.e. gas defects, mould material defects, pouring material defects, metallurgical defects and shrinkage cavities and take measures to reduce flaws by using CAE software.

To reduce the volume of entrapped air in the mold by changing the gating design, runner and overflow placement and optimise the gating design as well as process parameters for best quality product and improved productivity. Defects will be induced easily at crucial location during HPDC process. It will cause defective effect on the casting. Mold filling pattern and solidification process of a part can be simulated.

- Increase the quality of part by reducing air present in the shot sleeve during casting process.
- HPDC machines can be used to decrease set-up time before casting process starts.
- Optimizing of casting process through control flow of molten metal in process of die-casting by plunger movement.
- Less time for tool design process and minimum time will be required for casting process and wastage of material will be less. · Simulation which gives the information to the user about the quality of the product whether acceptable or not.
- By the use of HPDC, according to the simulation outputs which will lead to reduce scrap, wastage, production time as well as improve the quality of product.
- By using simulation result manufacturer can design the gates, runner and riser position, where to give overflow. By this to get best solution for filling up of molten metal in to mold cavity.

In 2008, Zhao Haidong, Ohnaka Itsuo, Zhu Jindong [10], In the Mold-filling computer simulation, element parameters will be

- Ratio of volume filled
- surface dimensionless distance
- Ratio surface filled.

Those will propose to identify the shape as well as location of free surfaces in Direct Finite Difference Method (DFDM) elements. With the special X-ray apparatus, in-situ observation and record filling process in the actual Mold of the casting can be carry out. The results of simulation can be validated and analysed by comparing with the observation. Volume filled ratio, surface dimensionless distance, and surface filled ratio for the DFDM elements can be aimed to determine the shape and location in the Mold filling simulation of the free surfaces.

In The filling process model, particularly taking into consideration the transfer of momentum, mass and energy in the neighbourhood of free surfaces, will be established. Both the simulation and observation indicated that the back pressure from gas (or air) in the Mold cavity has minor effect on changing the liquid melt flow when using pressurized feeding system and sand mould with good air permeability.

IV. CONCLUSION

Computer simulation packages give solutions which has well agreements with experimental results. Hence by providing sequence of casting simulation operations, optimization of casting process can be achievable accurately within the short span of manufacturing cycle. Optimization of casting process shows the best combination of process parameters so that effect of parameters on defect can analyse without restriction of other parameters to be constant.

Computer simulations process modification gives very less computation time with sacrificed of level of accuracy.so it is helpful in detecting defects in each portion of casting process i.e. solidification process, molten metal flow process etc.

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