UTILIZING FLOW SIMULATION IN THE DESIGN PHASE OF A DIE CASTING DIE TO OPTIMIZE DESIGN PARAMETERS WHILE VALIDATING THROUGH EXPERIMENTATION DURING TRIALS

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ABSTRACT

The Design phase for the Die Casting Die involves discrete selection of Design parameters namely, type of Gate, location of the Gate, Type of runner and its geometry, position for overflows and so on. While the raw material to be processed also plays an important role in the nature of defects in the part, in most of the instances, the Design of the Die is vital in determining the quality of the part produced. This work shall focus on the parameters for designing the Die Casting Die while securing crucial inputs from the `flow simulation' for the casting. The analysis would highlight the problem areas in the geometry and the probable locations where the process defect is likely to occur. Standards would be referred as applicable to the industry for realizing the best design for the case being pursued at the Sponsoring Company. The same shall be validated with identical components in the pilot lot production phase at the Company. Results shall be documented for offering as a quick generic reference for all the other part akin in form and features.

KEYWORDS: *Casting, Design, Parameters, Analysis, Flow Simulation etc.*

I. INTRODUCTION

The Design Engineer works closely to design the gating system. Multiple gating designs are simulated using popular software for the flow of the `Melt'. Designs include balanced filling patterns in the cavity to produce the best quality products. Overflow locations are placed appropriately based on flow simulations. Water cooing and oil line locations are recommended based on solidification result. Numerical simulations have been found to be very useful in many areas which lead many researchers attempting to implement them into die casting process. Considerable research work has been carried out on the problem of solidification including fluid flow which is known also as Stefan problems. Minaie et al in one of the pioneered work use this knowledge and simulated the filling and the solidification of the cavity using finite difference method. Hu et al used the finite element method to improve the grid problem and to account for atomization of the liquid metal.

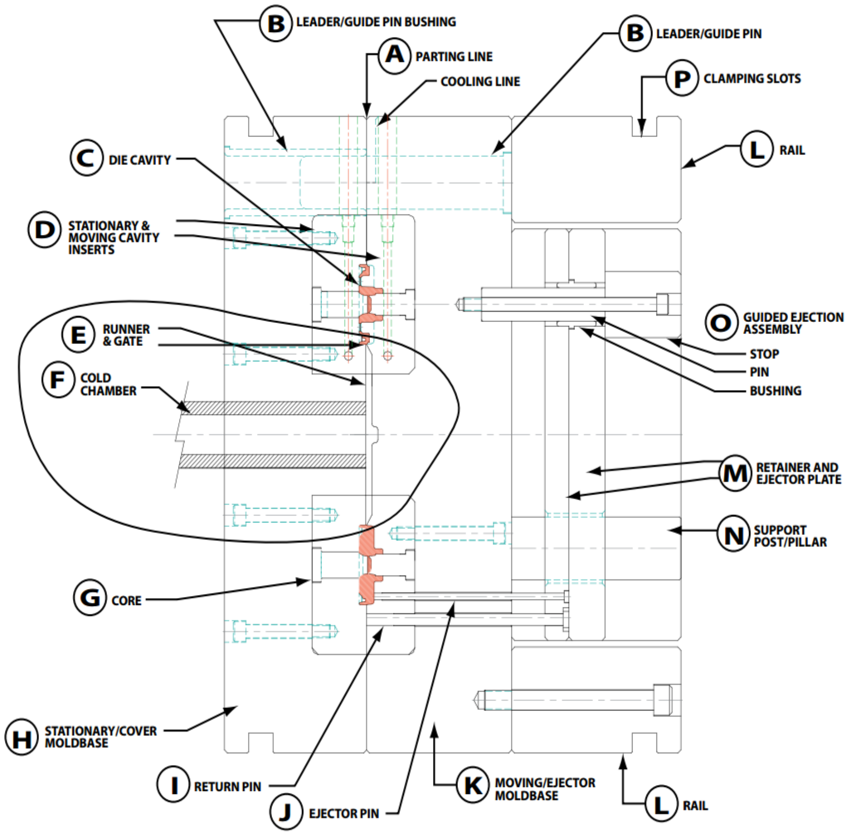

Fig.1- Typical layout of die casting machine.

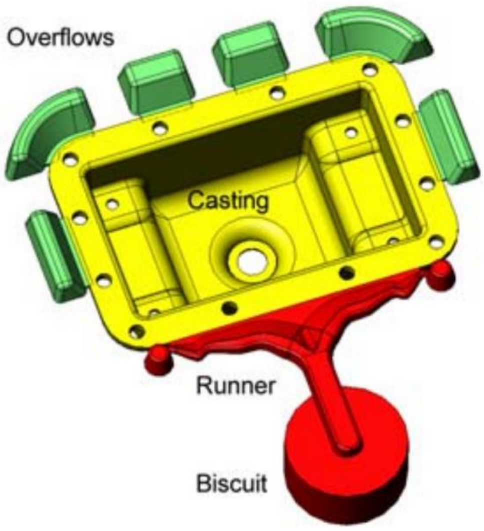

Fig.2- Typical representation of die casting system.

Runner Design - the design and the different relationship between runner segments are studied herein. The first step in runner design is to divide the mold into several logical sections. The volume of every section has to be calculated. Then the design has to ensure that the gate velocity and the filling time of every section to be as recommend by experimental results. For these criteria the designer has to check the runner design to see if gate velocity is around the recommended range.

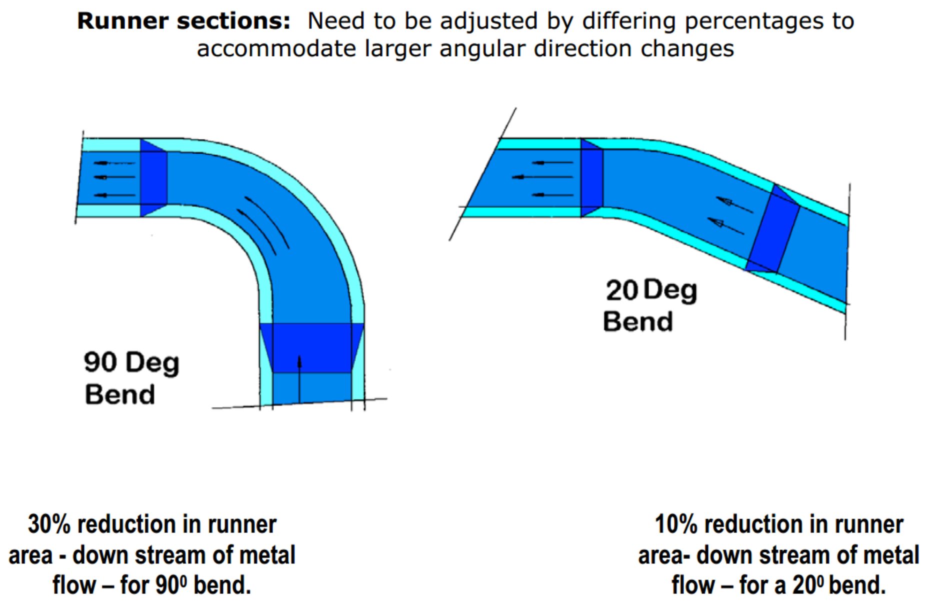

Fig.3-Examples of Runner design.

Venting System Design - Proper design of the venting system is one of the requirements for reducing air/gas porosity. Porosity due to entrainment of gases constitutes a large portion of the total porosity, especially when the cast walls are very thin. The main causes of air/gas porosity are insufficient vent area, lubricant evaporation, incorrect placement of the vents, and the mixing processes. One needs to consider the influence of the vent area on the residual gas at the end of the filling process.
Gate Design - The most common calculations used by die casting engineers to determine the relationship between the die casting machine and gating design parameters, and the resulting metal flow rate.
The gating design includes the following steps:
-Analysis of the metal flow.
-Selection of the best place for the gate on one side of the casting and vents on the opposite side for suitable cavity fill time.
-Division of the casting into gating segments
-Fill time and gate area calculations.
- Gate velocity selection.
- Modifications and a new tryout.

II. LITERATURE REVIEW

-**Alexandre Reikhe (2012)** studied the rate of metal flow in the channel is much higher than the solid-liquid interface velocity. The flow in the thin cavity is treated as two-dimensional after integrating the momentum and continuity equations over the thickness of the channel, while the heat transfer is modeled as a one-dimensional phenomenon in the thickness direction.
-**Bodhayana M. R. et al. (2014)** investigated that die casting was a versatile manufacturing technique in which molten metal is poured into die. The die consists of core and cavity, an impression is formed when these core and cavity are closed together. This impression forms the shape and size of the component. The main challenge in die casting is design and manufacturing of die. Integration of design and analysis yields to better results.
-**Manjunath Swamy et al. (2012)** investigated on conventional gating design casting defects such as shrinkage and gas porosities were found in front axle housing a critical automotive component. This component is generally made out of spheroid graphite iron. A flawed gating system was found to be the reason for improper fluid flow and melt solidification which in turn produced casting defects.

-B.S. Sung et al. (2008) have worked on an automobile body part and performed simulation along with hardness tests their research concentrated on development of the new die casting process method for automobile parts and prediction of the optimal die-casting conditions. Optimal preheating temperature of this product was determined to be 250 ◦C.

-K Maheswari et al. (2013) worked on die casting process which is an effective near net shape manufacturing process for producing geometrically complex components which require a high production rate and an excellent surface finish. However, one problem area has been indicated that die castings are often rejected by die casters as a result of being machined, and the defects for causing the rejections are frequently not clearly defined.

III. PROBLEM STATEMENT

A new variant of a passenger car is being introduced by the client of the Sponsoring Company. This variant comes with new features and functionality unique than its predecessors. The design for the components would carry a focus on aesthetics and/or function. The design and development phase is aimed to be short and effective. For this work, the die cast component named GCM is considered for research over the most suitable design for Die. The Design for the Die holds a key in effecting a good quality product in a lesser turnaround period of development. The problem here would be to identify the design parameters for the Die Casting Die while manipulating the inputs for desirable responses i.e. output parameters. The same shall be deployed through analytical tool for simulation of the Die casting process with the result for key variation made for the best outcome for product quality (minimization of defects through suitable Design). The design parameters namely, the type and location of the Gate, the Runner system and/or the Overflow would be studied for concluding the Design phase for the Die.

IV. SCOPE/ OBJECTIVES FOR THE WORK

-Identifying the Design parameters for Die Design.
-Design for the Die Casting Die with suitable value (level) for the parameter alongwith other standard industrial practices.
-Using CAE (Analytical Methodology) for flow simulation, studying any two variations in the input (Design) parameters on the output (Quality of the component).
-Representation of the Die Design over the Assembly (exploded view) with overall size.
-Validation through representative samples of the component produced during the development stage (prototype or manufactured part).

V. METHODOLOGY

Analytical Treatment

The flow simulation represents the analytical solution for the problem. Suitable CAE software would be deployed for modeling the problem and applying the constraints with the input parameters. The working conditions would be defined over the interface along with application of the properties for the melt (raw material). The simulation would determine the nature of flow, fill time for the Die, occurrence of any defect in the form of blow holes or deflection upon cooling. The comparison of the two variations in the parameters shall be offered by visual representation of the problem. The nature and the magnitude or prominence of the defect would be evident while realizing the solution using this Analytical tool.

This approach of problem solving would deploy CAD and CAE practices for arriving at the most suitable solution to the Design problem at hand. The geometry would be modeled using CAD software like CATIA or Unigraphics for the dimensions of the product / component. For this work, though, this data would be received as an input for the research work; the focus of the work being on Die Casting Die design. This would be imported in the interface of the pre-processor (HyperMesh) for discretizing the geometry. Further, flow simulation would be effected using AutoCast or FlowCast or

Magma Soft or any suitable software available with the Sponsoring Company or its associates. This would be deployed for evaluating the nature of flow w.r.t the time taken during filling as well as identifying potential threats to quality in terms of defects like blow holes, warpage or deflection, shrinkage, sink marks, flash or fins and so on.

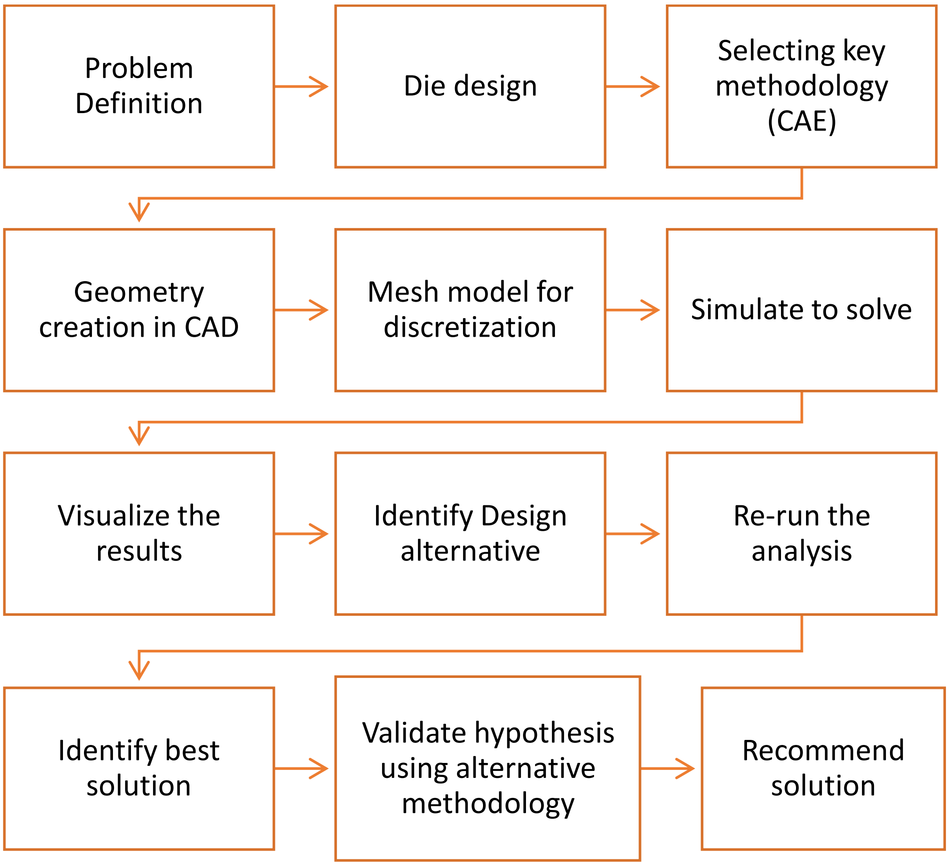

Fig.3-Scheme of implementation.

Physical Experimentation

This alternative methodology would be explored for validating the hypothesis. Upon securing the analytical results the development for the Die would be pursued according to the Design. Upon development (manufacturing) of the Die itself, trials are planned to evaluate the quality of the results. Typically, the strength of the component in terms of Load Vs Deflection shall be verified vis-à-vis the results obtained by the Finite Element Method. Provision would be made for a reasonable error margin based on the nature of the input or the output parameter being correlated.

The setup for experimentation typically include the Die Casting machine of a suitable type and tonnage with the requisite raw material and facility for initializing the process as well as the Die Casting Die that is designed and developed while pursuing the case. The process would be set for the component trials and the sample produced as an outcome of the Design. The characteristics of this component in terms of the aspects of quality would be evaluated for determining the success of the Design phase. Typically, the `absence of defects' especially like the blow holes or short shots (unfilled regions) or weld lines is considered as an indicator of good quality of the component produced. The material would be checked for one of the key output parameters in a Test Lab for determining the presence or extent of the defect.

Table 1- For Experimentation, typical Specs for Die Casting machine can be found below:

Specification Item	Unit		DC250J-MS
Die Closing	Die locking force	Ton	250
	Platen dimensions *(VxH)*	mm	850 x 850
	Tie-bar spacing *(VxH)*	mm	580 x 580
	Tie-bar diameter	mm	110
	Die thickness	mm	600 ~ 300
	Die stroke	mm	360
Injection	Maximum injection force	kN	270
	Intensification ratio		01:01.9
	Plunger stroke	mm	315
	Tip protrusion	mm	230
	Injection port position *(From machine center)*	mm	-125
	Injection speed	m/s	0.05 ~ 8.0
	Tip diameter	mm	60
	Sleeve length	mm	350
Ejection	Ejection force	kN	124
	Ejection stroke	mm	10 ~ 80

VI. EXPECTED RESULTS

Research and development has to be undertaken especially for the casting die to manufacture a part of newly introducing vehicle .The process parameters and technological scheme of die castings would be optimized with the help of proper CAE simulation tool. This will result in the production of die castings of consistently high quality and the lead-time will be shortened greatly. Flow simulation analysis will give satisfactory results. The castings that are produced successfully in production have to be analyzed and the test results of manufactured product will satisfy the quality expectations.

REFERENCES

[1] AlexandreReikhe "Numerical Analysis of Die-Casting Process in Thin Cavities Using Lubrication Approximation" The University of Wisconsin-Milwaukee, Theses and Dissertations, December 2012, Paper 65.

[2] Bodhayana M. R., N. Ramesha "Tool design for pressure dies casting of Housing Component" International Journal on Theoretical and Applied Research in Mechanical Engineering Volume -3, Issue-2, 2014, PP. 30-33.

[3] B.S. Sung, I.S. Kim"The molding analysis of automobile parts using the die-casting system"journal of materials processing technology, 20 1 (2008) 635–639

[4] Chandan Deep Singh, Sukhjinder Singh, VarunPanwar, SheetalBansal "Computer Aided Design Library of Gating System for a Die Casting Die" International Journal of Applied Studies Volume: 1, Issue- 1, Jan 2014, PP. 1-11.

[5] Dashwood R.J., McShane, H.B., Jackson, A., 1988. Computer prediction of extrusion limit diagrams. In: Proceeding of theFourth International Aluminium Extrusion TechnologySeminar, Chicago, IL, pp. 87–95.

[7] H. Ahuett-Garza, R.A. Miller "The effects of heat released during fill on the deflections of die casting dies" Journal of Materials Processing Technology 142 (2003) 648–658.

[8] K Maheswari and G Sureshkumar "Die Designing and molten metal flow analysis for intermediate flange" International Journal of Mechanical Engineering and Robotics Research India, Vol. 2, No. 4, October 2013, PP. 176-182.

[9] Manjunath Swamy H. M., J. R. Nataraj, C. S. Prasad “Design Optimization of Gating System by Fluid Flow and Solidification Simulation for Front Axle Housing” International Journal of Engineering Research and Development, Volume 4, Issue 6 October 2012,PP. 83-88.

[10] Meir, G.B., Eckert, E.R., Goldstein, R.J., 1996.“Pressure die casting: a model of vacuum pumping” Journal of Manufacturing Science & Engineering-Transactions of the ASME 118, 259–267.

[11] Paul W. Cleary, Joseph Ha, Mahesh Prakash, Thang Nguyen “Short shots and industrial case studies: Understanding fluid flow and solidification in high pressure die casting” Applied Mathematical Modeling, volume34,Issue 2010,PP.2018–2033