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Experimental and Numerical Investigation of Case Gear Meter Casting Die

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ABSTRACT

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mold cavity. The function of casting die is to hold the molten metal in the shape of desired casting so that the molten metal get solidify and finally removed out of die as a solidified casting. The design of the die is vital in determining the quality of the part produced. This paper mainly focus on the design phase for the die for an automobile component made of aluminium alloy (AIDC12) for a newly launching vehicle The design phase for the 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. Also the raw material to be processed also plays an important role in the nature of defects in the part. Work involves designing the 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— **Analysis, Design, Die Casting, Flow Simulation, Parameters etc.**

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I. INTRODUCTION

Die casting has increasing application in automobile aerospace,household appliances industriesdue to high strength and good performance.Four Basic Functions of The Casting Die-(1) Hold the molten metal in the shape of desired casting. (2)Provide a means for the molten metal to get into the space where it is to be held in the desired shape. (3)Remove heat from the molten metal to solidify the metal. (4)Provide for the removal of the solidified casting. Hence quality of casting component is determined by the die with which the component is formed.[6]

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. The Design Engineer works closely to design the gating system because it will affect subsequent design procedure and influence the overall quality of the die casting.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. The solidification process is also very complex it is extremely difficult to accurately examine and control.[6]

Die casting enterprises need to produce high quality die castings in shorter period with lower cost. The production period of casting can be significantly reduced by introducing CAD/CAM/CAE system with computerized casting analysis that will reduce the cost and time required. Due to the complex shape of casting components large scale CAD/CAM software is required for 3D solid modeling. Widely used CAD/CAM softwares are Pro/ENGINER, CATIA, Unigraphics. IDEAS. The CAE simulation packages available for casting are CAP, FLOW-3D, Pro/CAST, MAGMASOFT etc. The principle of CAE simulation of castings is solving equations of fluid dynamics and heat transfer such as Continuity equation, Navier-Stokes equation and the Fourier equation etc.[3]

II. LITERATURE REVIEW

-**AlexandreReikhe (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.

-**ManjunathSwamy 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) carried out computer simulations to analyze the flow of molten metalto analyze effective mould design. Optimal conditions are calculated through simple equationsand examined using experimental outputs.

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. 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

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.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.

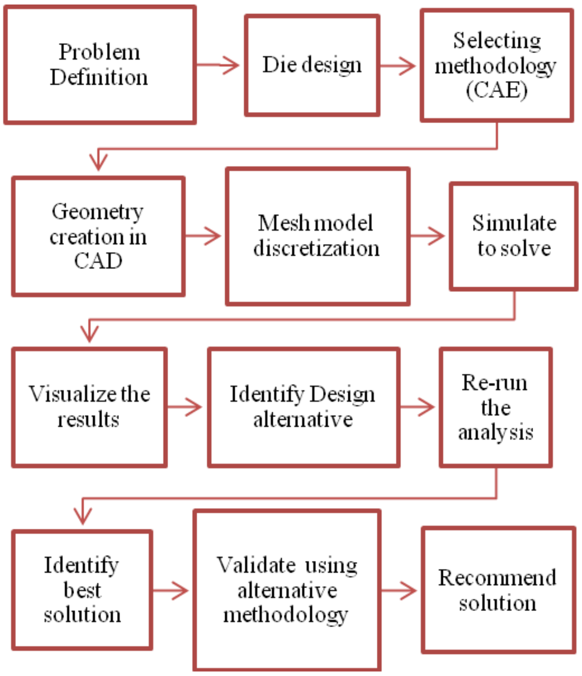

Fig.1-Scheme of implementation.

VI. DESIGN

Product information

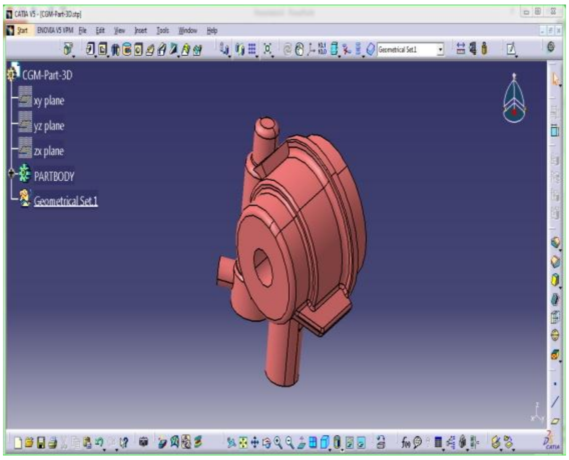

Fig.2-3D diagram of product to be manufacture

Material of Case Gear Meter is an aluminium alloy-AIDC12

Chemical Composition of AIDC12[8]

Table No.I

Content	Wt(%)
Sillicon(Si)	9.6-12.0
Iron(Fe)	1.3 max
Cupper(Cu)	1.5-3.5
Maganese(Mn)	0.50
Magnesium(Mg)	0.30
Nickel(Ni)	0.50
Zinc(Zn)	1.00
Tin(Sn)	0.30

Mechanical properties of AIDC12[8]

Table No. II

Density(gm/cm3)	2.7
Heat Capacity(J/g.K)	0.963
Thermal Conductivity (W/m.K)	92
Melting Range(^{0}c)	516-582
Ultimate tensile Strength(Mpa)	331
Yield Tensile strength(Mpa)	165
Elongation(%)	2.5

Design of Case Gear Meter Casting Die System

Die Material: Hot Die Steel H-13 .Principal Design Feature of this alloy is one of the Hot Work, Chromium type tool steel. It also contains molybdenum and vanadium as strengthening agents. The chromimum aontent assists this alloy to resist softening if used at higher temperature .[8]

Chemical Composition of H-13[8]

Table No. III

content	Wt.(%)
carbon	0.32-0.45
chromium	4.75-5.5
molybdenum	0.2-0.5
Phosphrous	1.1-1.75
Sillicon	0.03 max
Sulpher	0.8-1.2
Vanadium	0.03 max

Physical properties of H-13[8]

Table No. IV

Density(lb/cu.in.)	0.283
Specific Gravity	7.8
Melting point(^{0}F)	2600
Modulu of Elasticity Tension	29

Calculations:

1) Part Projected Area: 2428.00mm^2
2) Overflow Projected Area:364.00mm^2
3) Slide Projected Area= (π*6*6*2*tan 10)[6] =19.93mm^2
4) Total Part Projected Area=(Part Projected area)+(Overflow Projected Area)+(Slide Projected Area)[6] =(2428)+(364)+(19.93)=5623.86mm^2
5) Runner Projected Area=(Part Projected Area)+(30-40% More)[6]=3797.00mm^2
6) Total Projected Area[6]=(Total Part Projected area) +(Runner Projected Area)[6]=9420.86 mm^2

7) Tonnage of Machine[6]=(Total Projected Area)+(Casting Pressure)+(Die Locking Force)
=(94.21)+(0.8)+(90.44)=185.45Tonnes
Selecting Nearest Available value from standard seies availabl is 210 Tonnes[7]

8) Shot Weight=(Weight Per Cavity) + (Runner+Biscuits) [6]
Weight Per Cavity=116.00gm
As we want to design twin cavity die Weight Per Cavity=116.00*2gm
Runner+Biscuits=313.00gm
=(116.00*2)+(313.00)= 545.00gm.

9) Filling Ratio=$\frac{\text{Shot weight}}{(\text{Plunger Area})*(\text{active length})*(\text{Density})}$ [6]
=$\frac{545.00}{(\pi*2*2)*(4.3)*(2,7)}$=3.73

10) Cavity Fill Time (t) =K*T*$\frac{(Ti-Tf+Sz)}{Tf-Td}$. [6]

Where,
K-Emperical constant=0.034 sec/mm.
T-Casting thickness =4 mm
Ti-Temperature of molted metal as it enters the die =680^{0}c.
Tf-Minimum flow temperature =630^{0}c
Td- Temperature of die cavity surface =120^{0}c
S-Allowable percent solid fraction
Its selection depends upon casting thickness, per 4mm thickness its 20.
z-Units convergion factor =3.8

t=0.64*4*$\frac{(680-630+76)}{630-120}$ =0.034sec

11) Gate Area=$\frac{\text{Weight after gate}}{(\text{Cavity Fill time})*(\text{Dencity})*(\text{Gate velocity})}$[6]

=$\frac{232}{(0.034)*(0.0027)*(40000)}$=63.180 mm^2
Hence,
Gate length=32 mm
Gate Thickness=2 mm

12) Flow Rate = $\frac{(\text{Cavity weight})}{(\text{Filling time})*(\text{Dencity})}$ [6]

= $\frac{232}{(0.034)*(0.0027)}$=2527233.115 mm^3/sec

13) Plunger velolcity=$\frac{\text{Flow Rate}}{\text{Area of Plunger}}$[6]
=$\frac{2527233.115}{(\pi*20*20)}$=2011.10 mm/sec
Plunger velocity=2.01 m/sec

VI. MODELLING AND MESHING

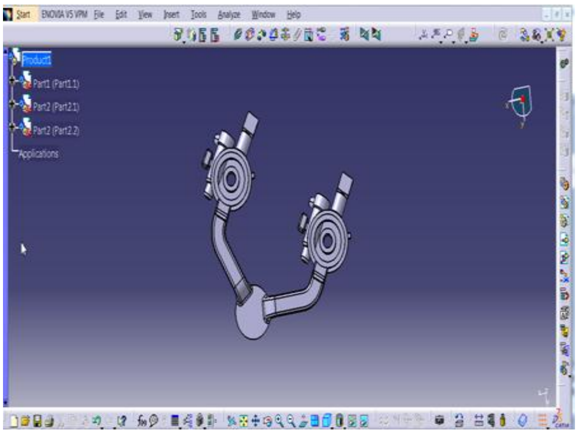

Fig.3- Layout of Case Gear Meter die

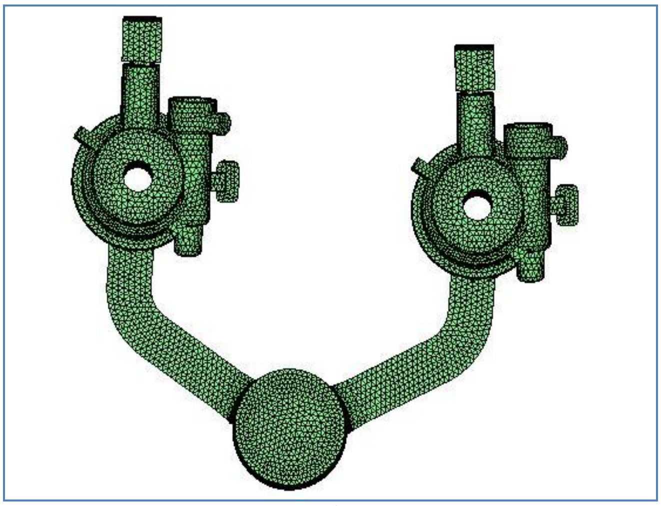

Fig.4- Mesh disgram of Case Gear Meter die

Above diagram shows the meshing diagram of Case Gear Meter die. Solver used for meshing is Magmasoft version 5. Total number of elements are 83328. Solid mesh type mesh is chosen.we have chosen this type of mesh as per the geometry.this is mapped mesh. Element type is tetrahedral. Element size is 4. Accuracy of mesh quality is confirmed on basis of following criteria:
Warpages > 5.00
Aspect ratio > 5.00
Skewness > 60.00
Net collaps < 0.5
Jacobian < 0.7 and trial faces: Minimum angle <20 and Maximum angle > 20

VII. EXPARIMENTATION ANALYSIS WITH MAGMASOFT

Magmasoft is a three dimensional solidification and fluid flow package used extensively in the die casting industry, particularly in foundary appications, to model molten metal flow. Magmaoft employs the finite difference method to solve the heat and mass transfer on a rectangular grid it is a useful tool of simulating molten metal flow in a permenant mould since it can provide useful informationabout the filling pattern and has strong material properties capability.It produces reasonably accurate data on casting related features such as prematuare solidification air entrapment, velocity distribution, runner and gate effectiveness.

Here, analysis are performed on die by selecting calculated parameters as input boundary conditions with increasing number of air vents from 1-4

Physical properties of H-13

Table No.V

Parameters	values
HighVelocity (m/sec)	2.0
Switch over point (mm)	339
Gate area (mm^2)	62
Gate Velocity (m/sec)	41
Cavity FillTime (sec)	35
Material temp (^oc)	680
Die temp (^oc)	150

VIII.RESULTAND DISCUSSION

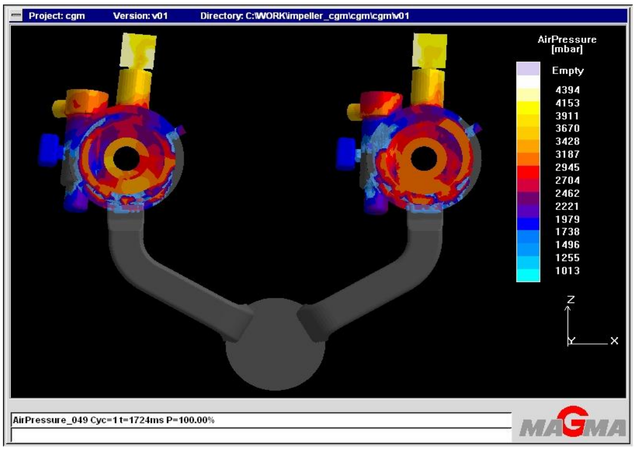

Fig.5- Air pressure analysis result

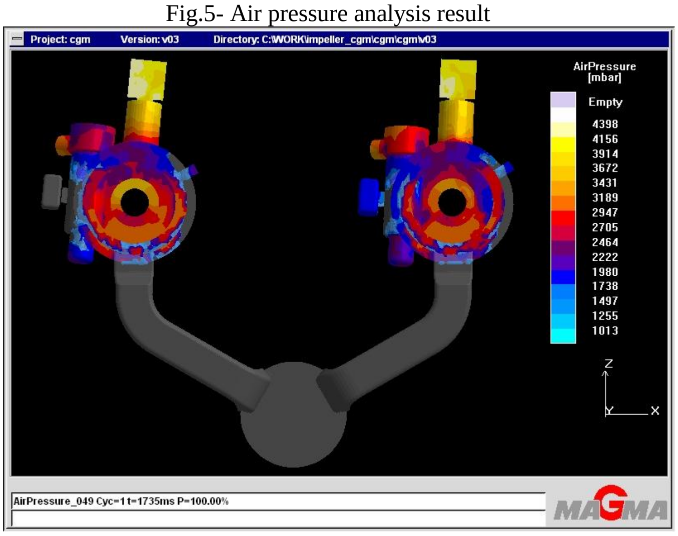

Fig.7- Air pressure analysis result

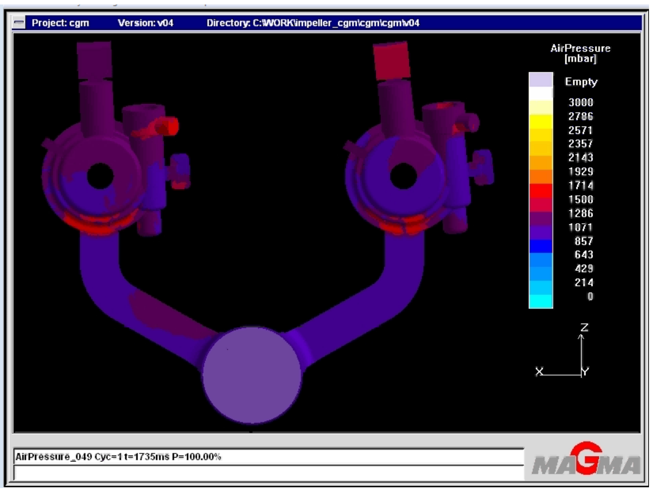

Fig.8- Air pressure analysis result

This result shows the back pressure of entrapped air in casting cavity. If this value is more than 2 bar then will lead to air porosity after machining of casting. Fig.5,6- Air pressure value is 4.1 bar max by adding Venting in further analysis in fig.7- Air pressure value reduced to 1.3 max.

IX.CONCLUSION

[1] From above disscusion Design parameters are calculated as gate velocity 41 m/sec, metal temperature 680 deg.Gate area 62 mm^2 and cavity fill time 35 sec.

[2] It have been seen that value of maximum back pressure should be less than 2 bar to avoid air entrapped and gas porocity hence we have finalize our maximum back pressure reduced upto 1.3 bar with aditional venting.

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