Design, Analysis and Fabrication of Die Casting Tool for Top Cover Used in Braking System

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Abstract: **The process of forcing molten metal under high pressure into mold cavities (which are machined into dies) is called die casting. Most die castings are made from nonferrous metals, specifically zinc, copper, aluminum, magnesium, lead, and tin based alloys, but ferrous metal die castings are also possible. This method is especially suited for applications where large quantities of small to medium sized parts are needed with good detail, a fine surface quality and dimensional consistency. This dissertation work deals with Design, Analysis and Manufacturing of Die Casting Tool for the component Top Cover. These components are used in braking system for automobiles. The main task of this project is to produce single components in one shot, employing through die casting technique by providing the various design factors on a new concept for the same. Material for this component is Alluminium Alloy ADC 12. The designing of the tool to produce the components as per designing procedure is on conventional lines, based on tested and tried norms developed through expertise and experience over a number of years and reported in literature. The 3D Virtual Model of the tool and the core-cavity extraction is done using the CAD Software Solid works 2013. Structural Analysis of Core Back plate is carried out using CosmosXpress tool. A tool fabrication is included in this report and process planning chart is done for each part, namely choice of machine, operation protocol and estimate of process cycle. Procedure for employing cost of the tool is included here, as it is of utmost important because the cost reflects on the manufactured product.**

1.0 INTRODUCTION

Pressure die casting offers an inexpensive method of producing large quantities of intricate, high-tolerance parts in magnesium, aluminum and copper alloys. The continuous growth of die casting development depends to a large amount on the greater use of die casting in the automotive industry where weight reduction is more and more important. Growing demands on die casting products will make sure continued expansion of die casting alloys with high strength and ductility, weldability, better machinability and corrosion resistance.

Die-casting is the most widely used process of manufacturing net or near net shape components. Pressure die casting is a cyclic process, casting the same parts by injecting melt into metallic molds under high pressure in the order of 560-2100kg /cm^2.This dissertation work covers the design, analysis and fabrication of a die casting die set for the manufacture of an aluminum component 'Top Cover', aimed at high productivity. A new tool with higher productivity and sound castings are the primary requirements.

To accomplish this through careful examination of the casting sample (3D-Solid Model), geometric profiles, surface quality, material specification, and in-service condition was the first step. Design exercise involves choice of parting surface, allowance for shrinkage, draft, gate location, venting, thermal balancing of die and choice of ejection system.

Die casting has been chosen for this project because components made by this process can be used 'as cast' or requires less machining, have superior surface finish, low piece cost at high production rates .

Top Cover, the component under study for this dissertation is used in braking system for automobile. It has intricate geometry and acts as a cover for the fuel pump, which operates at pressures of 2 to 4 bar. Therefore, it should be structurally sound, light in weight for transportation, has good surface quality and close tolerance to reduce post-processing operations.

Alluminium alloy is selected as the material for the component and horizontal cold chamber machine is preferred for manufacturing of the component. Selection of machine depends upon the alloy being cast, shape and size of the casting; also machine parameters such as locking force, shot weight, shut height etc. Total cost of the tool should be as low as can be achieved for a given life, since tool cost affects component cost.

Important features of this dissertation work are implementation of parting surface and side cores, cooling system, ejector assembly to eject component and to achieve sound castings with high productivity.

Structural analysis of the core back plate is performed in order to make sure that the back plate does not deflect due to the injection pressure applied on the tool. Components produced by die casting are used in Engineering, Automobile, Electronic, Aircraft and numerous other industries.

2.0 STATEMENT OF THE PROBLEM

The task of this project is to design, fabricate and validate a single cavity die for pressure die casting to produce a component of “Top Cover “for a brake system in Aluminum - Silicon alloy. (ADC 12)

The component has an intricate geometry comprising of bosses, under cut, hole etc.,
Geometry of the component necessities

1. Flat parting line, two side cores operated by finger cam, a pin ejection system has been adopted to eject component form die.
2. Deflection analysis of ejector housing.
3. Design and manufacturing of the die casting tool should be economical.“Costing" is an integral component of the exercise.
4. Design exercise therefore considers manufacturability assembly and validation aspects before planning fabrication.

The die should have a long life-delivering product with high degree of geometric stability, reliability and consistency through life and be amortized over a production quantity Which allow each component to carry its share of the die cost.

This will be followed by the manufacturing of the tool, proving trial on -Production equipment and critical assessment of the quality of component.

3.0 OBJECTIVES OF THE STUDY

The main objective of the study is

1. Develop a design protocol for the tool of a component such as the” Main frame casting" manufactured by the die casting process employing scientific approach.
2. Material specifies its chemical composition, mechanical properties, machinability, castabliity characteristic such as fluidity structural soundness, hot tearing, typical pouring temperature, heat treatment and related aspect influencing tool design.
3. Die making equipments and methods.
4. Manufacturing aspects - clamping force, type of machine.
5. Constraint of process, tool fabrication resource - equipment, skill set.

In such a complex maze every step was a challenge to integrate experience and common sense, which helped in furthering knowledge and skill.

4.0 SCOPE OF WORK

1. Critical analysis of the component geometry to enable choice making parting surface, tolerance, draft, feeding, venting, cooling and ejecting etc.
2. Study of physical and mechanical properties of the casting alloy and its influence on tool design.
3. 3-D solid modeling of the tool designed.
4. Deflection analysis of ejector housing
5. User validation of component geometry trails under in plant condition.

5.0 LIMITATIONS OF THE STUDY

Design of the tool for the component based on scientific analysis could be validated by limited performance trail on the shop floor. Present shop floor practices use the test-and-fault way to decide die design, when new dies are used. This technique is expensive and outcome in a lot of wasted casting.

6.0 METHODOLOGY

The basic concept involved in this method to attain the objective of the systematic and correct tool design, a well planned approach has been employed. The methodology consists of the following as detailed here and in the subsequent chapters.

- Component analysis.
- Solid modeling of the component.
- Step by step approach to die design.
- Selection of tooling materials.
- Solid modeling of the tool.
- Tool fabrication.
- Tool assembly and tryout
- Tool cost estimation.

7.0 IMPORTANT FEATURES OF COMPONENT

This is a rectangular shaped component. It has no of holes of which the minimum diameter is 3 mm and the maximum diameter is 8 mm. The component has 3 bosses .The component has two ribs at a tangent to the outer radius as shown in isometric diagram. The component holes and slot on three different places which requires a side core to manufacture that hence for one cavity three side cores are required. Allowable draft angle is 1º max.

Fillet radius is 2mm maximum and edge radius is 1 mm. Average wall thickness of component is 2.5mm.Casting weight found from the given sample is 95 gms. As per the customer requirement a die of two cavities is selected.

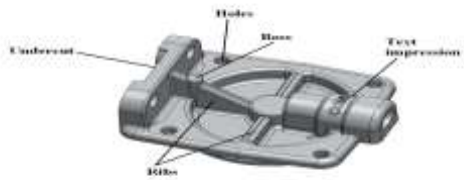


Fig. Features of the component

7.1 MATERIAL SPECIFICATION OF COMPONENT

The component is made of Al-Si alloy conforming to LM2/ADC-12 Chemical composition and mechanical properties are detailed in data book.

7.2 SOLID MODELLING OF COMPONENT

Component was modeled employing 3D Geometry Software (Solidworks-2013). 3D Solid Model of the component created is used to determine Volume, Surface area of the Component, parting surface data etc, projected area, areas of cross section of cores, etc.

8.0 STEP BY STEP APPROACH TO DIE DESIGN

1. Study the component for its geometry, material, its properties and number and quantity to be manufactured etc.
2. Selection of parting surface.
3. Determination of number of cavities.
4. Determination of locking force required.
5. Selection of die casting machine.
6. Design of feeding system.
7. Design of dies.
8. Design of cooling system.
9. Design of ejection system.
10. Design of other parts of the tool.
11. Selection of materials.

9.0 SOLID MODELLING OF THE TOOL:

This was done employing 3D Geometry Software (Solidworks-2013). This software is having tools to perform the operations like extrude, cut, sweep etc. Solidworks is also having tools to assemble parts modeled with suitable constraint. Creating the assembly helps to cheek a prior possibility of interference between mating parts, create 2D drawings and detailing.

10.0 CALCULATIONS

10.1 DETERMINATION OF LOCKING FORCE

Locking force is the force required to keep the die halves together when injection takes place. Locking force (LF) is given by the formula

L.F required = (projected area of (component + over flow+ runner + Biscuit) x n) x P x FOS

Where projected area of single component is= $53.82 cm^2$

- $P = 1000\ kg/cm^2$ Recommended injection pressure for Aluminum die casting
- Factor of safety (FOS) = 1.2
- No. of cavities (n) = 1

To Calculate total projected area (Shot area) assuming 30% of projected area of component for (runner + Biscuit + over flow).

Total Projected area = Projected area of component + 30% of Projected area of Component

= 55.47 + 55.47 * 30/100

Total projected Area = $69.96\ x10^2\ mm^2$

= $70\ x10^2\ mm^2$

On substituting above values in equation

L.F required = $(70\ x10^2 * 1) * 1000x10^2 * 1.2$

= 84 tons

L.F required = 84 Tons

Hence the next higher tonnage capacity is 150tons i.e. ZITAI-150 machine is selected.

Shot weight (Ws) required is given by

Ws = Vs x ρ

Where Vs Shot volume in mm^3

ρ $2.7x10^{-6}\ kg/mm^3$

To Calculate shot volume add 30% of volume of component (Vc) i.e., 10% of component volume (Vc) for overflow and 20% of component volume (Vc) for runner and Biscuit.

Shot volume (Vs) = (Vc + Vc x 30/100)

= $61.66x10^3 + (61.66x10^3\ x\ 0.3)$

= $80.158\ x\ 10^3\ mm^3$

On substituting these values in Equation

Ws = 0.216 Kg

10.2 DETERMINATION OF PLUNGER DIAMETER

Calculating plunger diameter by using shot weight method.

Shot weight = shot volume* density* no. of cavities* f.o.s

= 80.158 * 2.7 * 1 * 1.2

= 259.71gms = 0.260kgs

From machine catalog it is found that the plunger diameter depending upon calculated shot weight for ZITAI-150 = 35mm.

10.3 GATE AREA CALCULATION

1. Volume of metal through gate (Vm) = Vc + Vo, Vo is taken as 10% of Vc

Where Vo =Volume of overflows

Volume of component Vc usually 15-20% extra for runner, gate and overflow.

Vc = Vc + 0.15 Vc

= 61.66 + (0.15 * 61.66)

= $71.02\ cm^3$

Vm = 71.02+ 6.166

= $77.2 cm^3$

2. Fill rate (Q) in mm^3/s =Vm/Tf

Thumb rule 1: Cavity fill time Tf is 0.007 s for every 0.5mm wall thickness of the component. Average wall thickness of the component here is 4mm.

Tf= (t / 0.5) * 7

= (5/0.5) * 7 = 70 milliseconds.

Q = $1102.85\ cm^3/s$

11.0 ANALYSIS

This chapter describes stress analysis of core back plate using Finite Element Method. For current work, Finite element analysis is used to calculate the expected maximum deflection for computed structural loads.

Die casting dies are exposed to a very high mechanical loading but they are only allowed elastic deformation. Since these dies are expected to produce parts that meet the demands for high precision, it is evident, therefore, that any deformation of the core back plate affects the final dimensions of a part as well as shrinkage of the material being cast during the cooling stage. Besides this, undue deformation of back plate can result in undesirable interference with casting process. Thus, the rigidity of a core back plate determines the quality of the castings as well as reliable operation of the dies.

Finite elemental analysis is a simulation tool that enables engineer to simulate the behavior of a structure. Finite elemental analysis is an important part of overall design process, serving to verify or validate a design process prior to its manufacture. COSMOSXpress has been used to predict and simulate the structural behavior of the components used in die casting die.

PROCEDURE

- Geometric modeling of core housing is done in solid works.
- Material is applied to model i.e. SG Iron
- Boundary conditions are applied as per tool assembly & mounting on machine
- Meshing is done by using standard tetrahedral element.
- 150 T load is applied on core housing pocket.
- Above problem is solved by using solid works solver
- Above procedure is carried out for two different conditions

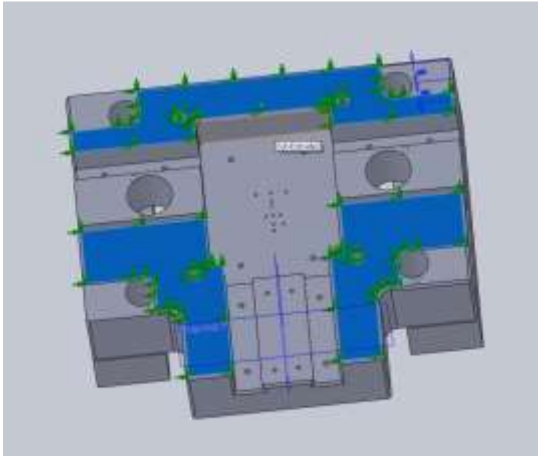


Fig. Boundary conditions, restrain

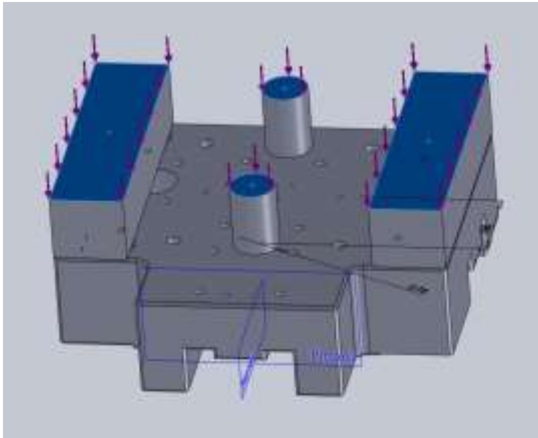


Fig. Boundary conditions, load (with support pillar)

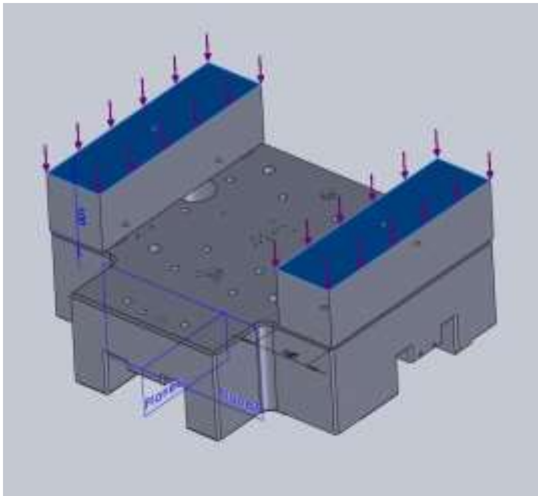


Fig. Boundary conditions, load (without support pillar)

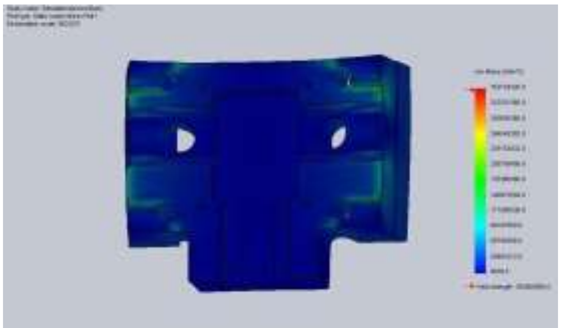


Fig. Without centre support, stress

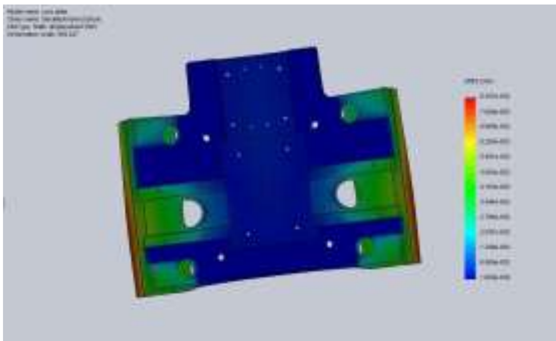


Fig. Without center support, displacement

Fig. With center support, stress

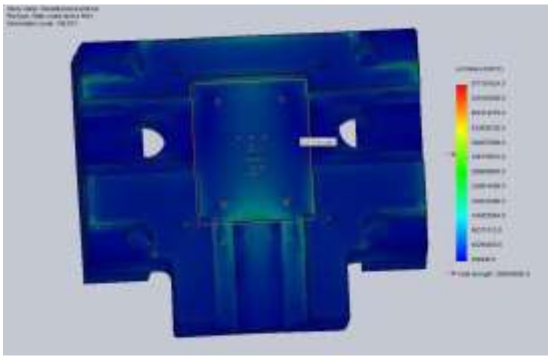
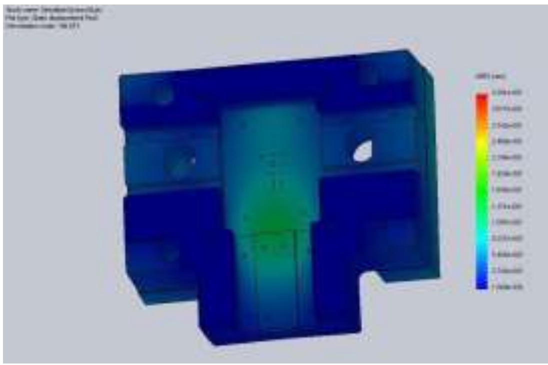


Fig. With center support, displacement



12.0 RESULTS

Without center support we got deflection as 11μ in first case. In second case with center support we got deflection as 5μ. By using center support deflection has been reduced from 11μ to 5μ. Since the deflection is 5μ which is less than desired limit that is 50μ. So design is safe.

13.0 CONCLUSIONS AND SCOPE OF FUTURE WORK

Design, fabrication and user validation through in plant trail of the die set of an Alloy for automotive component – Filter Head manufactured by pressure die casting technique. Design procedure based on standard practices has been involved for designing the tool to produce the casting. Structural analysis establishes the validity of the design protocols employed through this process. A number of lessons were learnt along the way. As indicated below:

• A large number of criteria determined by the

a. Material geometry and functionality of the casting to be manufactured.

b. Quality productivity and cost factors demanded by the user.

c. Equipment and facilities on which the tools are mounted, choice of die materials and fabrication facilities deployed in the in-house Tool fabrication facility.

14.0 SCOPE OF FUTURE WORK

There is extensive scope for carrying out research work in the area of design of the die casting die, i.e., the design to be done by implementation of scientific methods. Fatigue analysis can be carried out for the tool, which results in providing information of the life of the tool.

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