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High Pressure Die Casting Cold Chamber Process

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Abstract: *The lack of effective control of die casting process is the primary reason for the occurrence of defective die cast product. This work focuses on designing of aluminium casting die used for automobile wiper motor casing. The die casting process 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. And also the common defects found in these defective castings were categorized as follows: porosity, cold laps, flow lines, aluminium oxide inclusions, lubricant or mold coating inclusions, and mechanical cracks. Die casting is a manufacturing process that can produce geometrically complex metal parts through the use of reusable molds, called dies. The die casting process involves the use of a furnace, metal, die casting machine, and die. The metal, typically a non-ferrous alloy such as aluminium or zinc, is melted in the furnace and then injected into the dies in the die casting Machine. There are two main types of die casting machines-hot chamber machines (used for alloys with low melting temperatures, such as zinc) and cold chamber machines (used for alloys with high melting temperatures, such as aluminium).Pressure die casting offers an economical way of producing large quantities of complex, high-tolerance parts in aluminium, zinc and copper alloys. The continued growth of the die casting process depends, to a large extent, on the greater use of die castings in the automotive industry.*

Keywords: Die casting, VMC machine, Intensifier, Finishing.

I. Introduction

1.1 What is casting?

Casting is a manufacturing process in which a liquid material is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mould to complete the process. Casting materials are usually metals or various cold setting materials. Casting is a 6000-year-old process. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods. Casting provide better strength to the cast after the manufacturing process of forging.

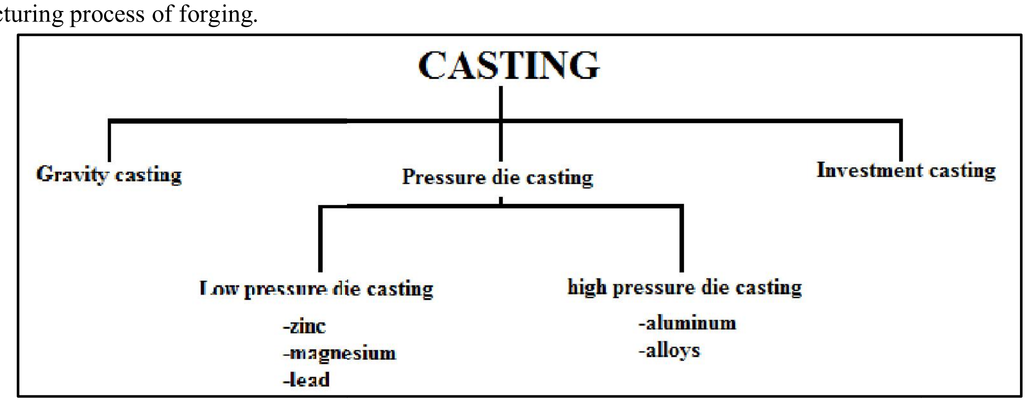

Figure 1: Flow chart for conventional casting

There are two basic die casting process, hot chamber and cold chamber. Hot chamber die casting is preferred for low pressure whereas cold chamber die casting is preferred for high pressure. The primary difference between the two processes is that in the hot chamber process the melt or holding furnace is an integral part of the metal injection system while in the cold chamber process the melt or holding furnace is a separate unit with a ladling unit as a means of transporting the molten metal to the injection unit.

Tool and die manufacturing has long been considered a key industrial sector. A die is a form used to shape metal in forging and stamping operations. Dies also include metal molds used in making plastics, ceramics, and composite materials. Die is a special tool used to shape material mostly using force, dies are generally customised to the item they are used to create.

High pressure die casting is a manufacturing process in which molten metal is injected with a die casting machine under force using considerable pressure into a steel mould or die to form products. The term "Cold Chamber Die Casting" refers to a separate metal melting furnace. Here molten aluminium is forcefully injected into the hardened steel die with the help of shot plunger.

A. Introduction about Die Casting

- Die casting is a manufacturing process in which molten metal is injected, under considerable pressure, into a hardened steel die or also called die casting.
- Die casting is a manufacturing process that can produce geometrically complex metal parts through the use of reusable molds, called dies. The die casting process involves the use of a furnace, metal, die casting machine, and die. The metal, typically a non-ferrous alloy such as Aluminium or zinc, is melted in the furnace and then injected into the dies in the die casting machine.
- In the die casting process, the mould used for making a casting is permanent, called a die.
- If the molten metal is forced into a metallic die under the external pressure, the process is known as 'pressure die casting' or simply 'Die casting'.
- So, Pressure die casting can be defined as a process by which a casting is made by injection molten metal under the high pressure into a permanent mould, called a die.
- Pressure die casting is a widely used process- it is difficult to name a product or appliance where die casting are not used for at least some of the component parts. In every industry there is a steadily rising demand for high quality die castings. Pressure die casting parts are used in Automobile, Auto ancillary (subordinate), electrical equipment, electrical motors, Building hardware's, Toys and home appliances and so on.

B. Limitations of Die Castings

- Only small parts can be made. The maximum practical weight for a die casting is about 200 newton for Zinc, 100 newton for Aluminium and 80 newton for Magnesium. The minimum weight can be low as 0.05 newton.
- Only non-ferrous metals and alloys can be commercially cast. For ferrous metals, the chief drawback to their use in the lack of suitable and strong die materials for withstanding the high pouring temperatures.

C. High Pressure Die Casting Machine

High pressure die casting is a manufacturing process in which molten metal is injected with a die casting machine under force using considerable pressure into a steel mold or die to form products.Because of the excellent dimensional accuracy and the smooth surfaces, most high pressure die castings require no machining except the removal of flash around the edge and possible drilling and tapping holes. High pressure die casting production is fast and inexpensive relative to other casting processes.

High Pressure die casting molds, sometimes referred to as high pressure die casting tooling, are made from steel hardened to withstand high temperatures and extreme pressures. There are many types of high pressure die casting tooling from simple inexpensive inserts to complete high pressure die casting dies that are dedicated to only one part. Once a high pressure die casting tool is produced, the cost to make high pressure die casting parts is very little. We have an in-house toolmaker who can make your high pressure die casting die or fit your inserts into one of our holders at a very competitive price. A die-casting machine consists of four main parts:-

1. The frame
2. The die
3. The mechanism for opening and closing the dies.
4. Apparatus for injecting the molten metal into the die, along with source of molten metal.

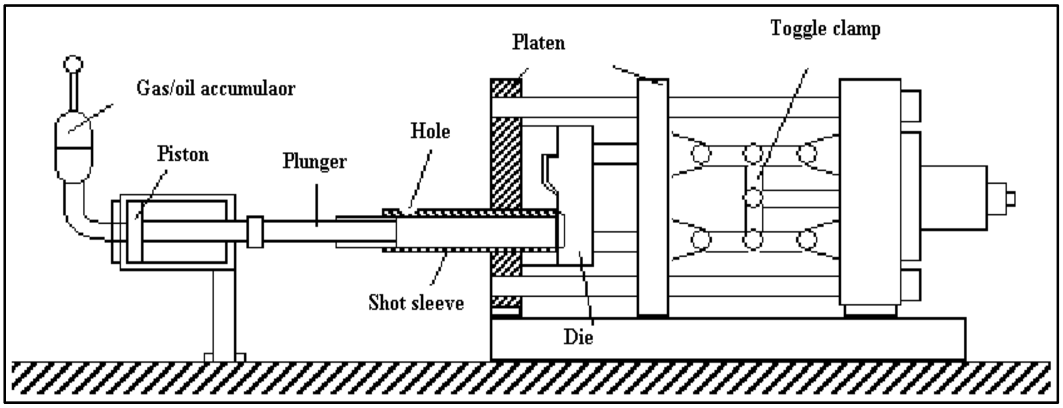

Figure 2: Schematic representation of high pressure die casting machine

Working of the machine shown above is explained as-

1. Die closure, where the die halves are brought together and locked with the required clamping force,
2. Ladling, where the predetermined volume of melt is ladled into the shot sleeve from the holding or melt furnace,
3. Cavity filling, where the superheated molten metal or alloy is injected at high velocities and under high pressure into the die cavity to ensure rapid and complete filling,
4. Melt solidification, where the injected melt is solidified under pressure and under predetermined thermal condition,
5. Die opening, where the die halves are separated and the solidified casting is ejected by pneumatic or mechanical force and
6. Die lubrication, where the open die halves are sprayed with lubrication and anti-solder compounds.
7. The frame must be rigid and strong to support the weight of the dies, since often the weight of an assembled die may exceed several tonnes. The machine frame incorporates a stationary platen and a movable platen to which the die halves are attached (Die is made in 2 halves to facilitate removal of the casting). Die casting machine frames generally are four bar presses, although the solid one pieces frame has gained wide acceptance for small machines.

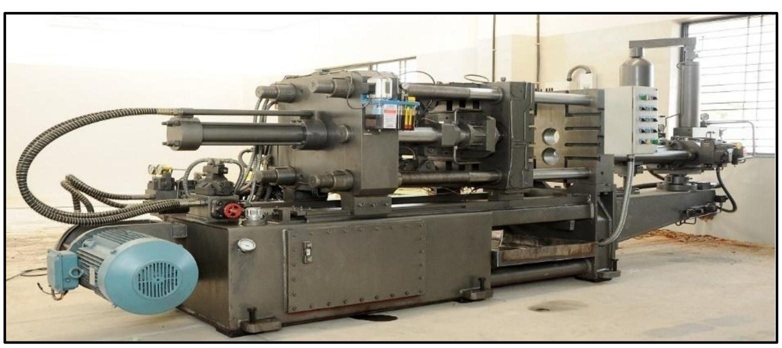

Figure 3: High pressure die casting machine

The basic function of a casting machine is to open and close the die and to hold the two die halves together against the pressure of the metal developed by the injection system. The locking force must ensure leak proof clamping at the die parting. In some modern die-casting machines, locking forces may approach 10 MN, depending on the die size and the molten metal pressure employed. The maximum force tending to open a die will be equal to the maximum molten metal pressure times the total projected area of the mould cavity and gating.

The system is self-locking and will not snap back even if there is a power failure. The system is flexible and the closing speed can be infinitely variable and the locking force can be adjusted to suit the requirements by adjusting the toggle nuts. The other closing systems can be wedge-lock hydraulic, cam lock hydraulic.

To obtain uniformity of die castings and maximum speed of operations, a predetermined and automatically controlled time cycle must be employed. A machine cycle is started by pushing a button and from the onwards the cycle continues automatically, stopping at the end of one complete cycle.

II. Literature Review

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III. Design Calculations

Formula:

1. $Gate\ Area = \frac{w}{t*\rho*v}$

Where W = metal after gate
t = fill time (20 - 60 ms)
Thin section= 20 - 40 ms
Thick section= 40 – 60 ms
ρ = density
Liquid metal density= 2.5
Solid metal density= 2.7
V = gate velocity (35 – 50 ms)

2. Gate area = width x thickness
Thickness = 1.6 to 4.5 mm

3. Locking tonnage = projected area*specific pressure*N
N = factor of safety

	Simple	Leak proof	Pressure tight
Specific pressure	600 bar	800 bar	1000 bar
N	1.2	1.3	1.5

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4. Fill ratio: some standard ratio are following;

70:30 (shot weight)

60:40

50:50

5. Plunder diameter:

$$\text{Weight} = \frac{\pi * r^2 * L * 2.7}{1000}$$

Trail 1:

Theoretical

W = metal after gate = product weight + overflow

= 0.542 + 0.045

= 0.587 kg

Take the minimum fill time = 60 ms

Density = 2.5 kg/m^3

By experience take the gate velocity = 35 m/s

$$\text{Gate area} = \frac{0.587}{0.06 * 2.5 * 35}$$

= 0.1118 m^2

Locking tonnage:

Projected area = 165 mm x 140 mm

= 23100 mm^2

Since our product is water pump casing, then its pressure is tight, therefore assume;

Specific pressure = 1000 bar

Factor of safety = 1.5 for pressure tight

Locking tonnage = 23100 x 1000 x 1.5

= 346.5 tonne

Fill ratio:

Take the fill ratio is 60:50

It means 60% of sleeve is fill by material and 40% of sleeve is empty, because of splashing of hot material are injured the workers and avoid the material wastage.

Trial 2:

a) By using software

1. Information about product

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Information listing created by: NX

Date : 14-04-2017 01:59:18 PM

Current work part : C:\Users\ADMIN\Desktop\Project\pump housing tavera die design.prt

Node name : Pump housing Tavera die design

===

Measurement Mass Properties

Displayed Mass Property Values

Volume = 218972.001488482 mm^3

Area = 56804.887392798 mm^2

Mass = 0.593633096 kg

Weight = 5.821557253 N

Radius of Gyration = 46.570681280 mm

Centroid = 5.189850061, -5.733887024, -20.500336455 mm

===

Detailed Mass Properties
Analysis calculated using accuracy of 0.990000000
Information Units kg - mm
Density = 0.000002711
Volume = 218972.001488482
Area = 56804.887392798
Mass = 0.593633096

==

Error Estimates
Volume = 97.461917190
Area = 6.306145782
Mass = 0.000264219

b) By using Excel sheet calculate the design parameter:

MACHINE SELECTION							
AREA							
Projected Area	231	cm²					
Mechanical Slide Area	0	cm²	0	cm²			
Hydraulic Slide Area	0	cm²	0	cm²			
Overflow Area	1.4	cm²					
Runner	1.6	cm²					
Plunger Diameter (dm)	65	mm	6.5	cm	33.18	cm²	
Area (AIM)	267.18	cm²					
K (1.15 with slide, 1.1without slide)	1.1						
Final Pressure (P13M)	1000	bar					
Opening Force (FLI)	2671.83	KN					
Closing Force (FLN)	2939.01	KN					
MACHINE	**293.90**	**TON**					
MACHINE SELECTED	**250**	**TON**					
GATE AREA							
Active Sleeve Length	300	mm	30	cm			
Shot Weight	1500	gram					
Weight after gate (ma)	600	gram					
Volume after gate (VA)	233.92	cm³					
Gate velocity (VMA)	35	m/s					
Fill time (tf)	60	Milli Seconds	0.06	sec			
Density of Aluminium (p)	2.565	g/cm³					
GATE AREA (SA)	**111.39**	**mm²**					
Metal Flow Rate (QM)	**3898.64**	**cm³/sec**	Molten metal temp				680
Plunger Speed (VC)	**1.17**	**m/Sec**					
Venting Area (Sv)	**19.49**	**mm²**					
Filling Ratio	**58.74**	**%**					
Shot Position	**150**	**mm**					

Table 1: Excel sheet calculation

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IV. Die Manufacturing And Production

4.1 Tool and It's Part Manufacturing

Once the tool design is completed, the manufacturing process can start. The dies used for die casting may be either wrought or cast. The cavities in the wrought die blocks are made by the conventional machining methods including die snickers (special purpose milling machine). The conventional machining methods such as ECM, EDM and USM have gain wide applications in making complex dies. The quality of the materials and equipment we use ensures the high quality of the final product. We also possess the full range of tools and certifications necessary to handle the full mold production process. Once the die cast mold is completed, it's tested and checked by engineer. By using VMC and CNC machine we manufacture the tool and its parts, the following picture shows the machine;

Figure 4: VMC machine

The stage starts with production of the 3D model with the help of dimensions the die cavity is machined. The standard components are bought from the market where they do not need any machining or dimensional modifications. The standard components come in handy at the time of replacement or failure.

- The major components like cavity is machined
- Raw material is pre-machined on conventional machines
- Inserts are machined on VMC (vertical milling centre), they undergo roughing operation in which the inserts are roughly machined up to dimensional tolerance and the semi-finished per side having a stock of 0.7mm. Then the inserts are vacuum hardened or through hardened up to 44-46HRC. Similar method is implemented for machining side core holder. The fix insert and moving insert are needed to withstand forces from the injection of shot hence they are hardened.
- For ejector pin hole, core pin hole, return pin hole wire cut machining is done.
- Guide pillars and bushes are machined on lathe machine on which the cylindrical raw material is held in the chuck and then turning operation is performed with 0.5 mm grinding stock the pillars and bushes are then case hardened up to 54-56 HRC – case depth 0.8- 1 mm. The ejector pillar and ejector bush is also machined and case hardened.
- For the die cavity, the cavity is machined on VMC a part programming is done, the imprint obtained from 3D model is converted to .stml format where the part programming is obtained in hand via software. This part program is fed to the VMC and then the operation is started.
- For electrode manufacturing for EDM, raw material used is copper (forced copper) or graphite.
- The various components are subjected to stresses induced in them during machining these stresses are compensated by heat treatment.

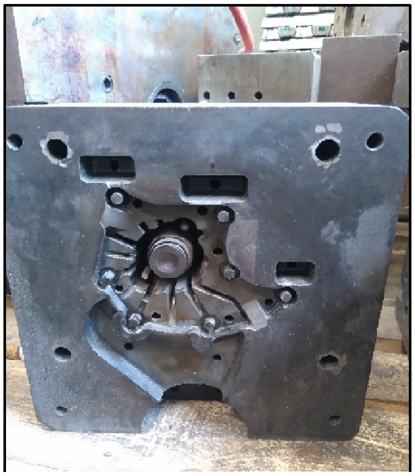

Figure 5.1: Moving inserts

Figure 5.2: Fixed inserts

4.2 Production

Once the tool design and manufacturing is completed, then actually production process of water pump housing will be starts. By using the high pressure die casting machine we will develop the product.

4.3 Components of Machine

The process of die casting and machining required the few mechanical devices of high pressure die casting machine are following;

A. Pump- Vane Pump (Unbalanced Vane Pump)

Principle of working:

- Initially note that the rotor axis and the axis of circular ring is positioned eccentric. This is an important arrangement needed in any vane pump.
- There occurs a positive sealing between the vanes, which can freely move in the slots and the cam ring. The driving force for this positive sealing is centrifugal force, which forces the vanes to make contact with the cam ring.

Advantages:

- Vane pump are self-priming, robust and supply constant delivery at a given speed.
- They have few moving parts, hence gives minimum maintenance.
- Comparative to other pumps, they are lighter in weight and compact.
- Pressure variation

Disadvantage:

- Lower operating pressure
- Wastage of power increases as the vane loading effect increases.

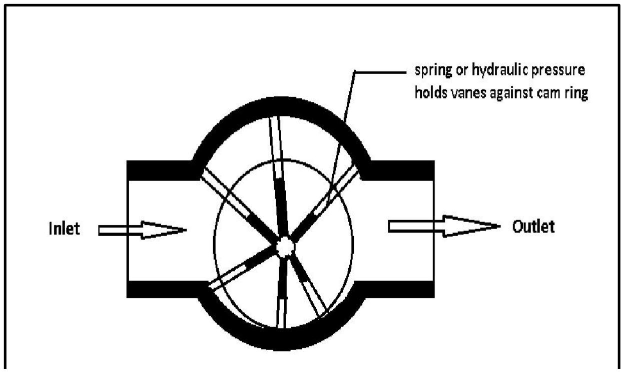

Figure 6: Schematic diagram of unbalanced vane pump

B. Accumulator- Piston Type Accumulator

It consist of a cylinder body and a movable piston. Piston floats between gas and oil. This piston serves as a barrier between the gas and oil and avoids direct contact between two fluids.

Advantages:

- It can be mounted in any position
- It is suitable for both high temperature or low temperature fluids
- Longer life

Disadvantages:

- Pressure supplied by accumulator is not uniform
- More response time

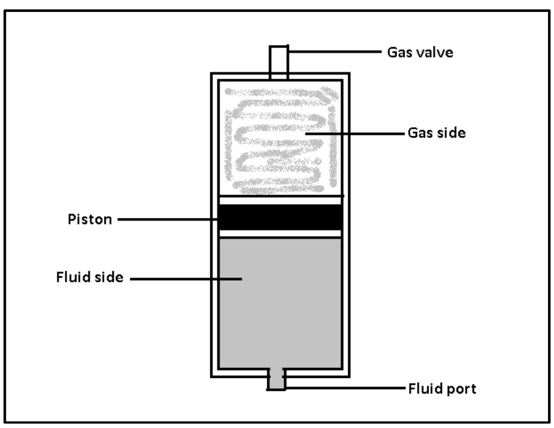

Figure 7: Schematic diagram of piston type accumulator

C. Intensifier- Double acting intensifier

- In case of single acting intensifier the booster action takes place only during forward stroke of piston. However in case of double acting intensifier both stroke gives us booster action and highly pressurized fluid.
- The fluid pressure booster as the fluid enters the either side of big piston. This causes movement of smaller piston in such a way that one piston will be in forward direction and other piston in backward direction stroke. So during either stroke of piston, a highly pressurized fluid is supplied to system.

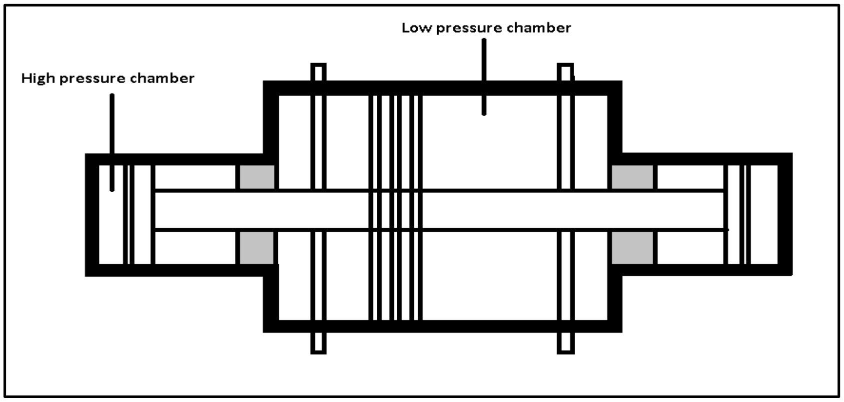

Figure 8: Schematic diagram of double acting intensifier

4.4 Finishing

Once the process of die casting and machining is completed, we can apply a wide range of protective or aesthetic coatings to increase the efficiency and value of the products.

- Vibratory deburring: This type of finish removes all imperfections from the product's surface. It can be used as a standalone finishing option or prepare the surface for painting or application of other coatings. Vibratory debugging is an extremely popular option and the most common "pre-plate" choice for a variety of products. The reasons for this are:
  - Smooth surface provided by this type of finish.
  - Removal of oils, which can coat the surface of the parts during the process of machining.
- Drilling: Sometime components are required hole but in casting process difficult to induce the core, then we used the external drilling operation.
- Polishing, and finishing: This technology provides a quick and efficient metal finishing solution. The finishing they provide is guaranteed to be smooth and bright.by using CNC machine.

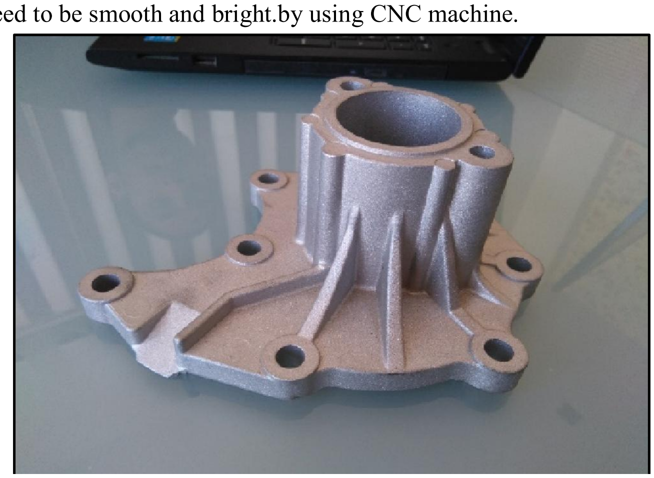

Figure 9: Final Component

V. Summary

By taking into consideration the various material parameters and the product details the project work has been further proceeded to design and analysis phase.

Phase 1: Die components are being designed using software simulation with the help of structural analysis NX software. The monetary expenses are being provided by the OEM.

Phase 2: The material selection is done on the basis of market research and now trending components which are in high demand in the market, the material selected for the die component are hot die killed steel ; since the material properties are favourable for aluminium-zinc castings.

Phase 3: Once we select the material and design is completed then we go to the manufacturing of tool. After the manufacturing we check the geometrical dimension and tolerance of tool and its parts.

VI. Conclusion

The component water pump housing was acknowledged for Die Tool design. The design for housing is completed successfully and sent for manufacturing. Manufacturing will be done at tool making VMC machine in precision engineering company Nashik.

The proposed die tool will help in high accuracy, but also reduce the interval between each consecutive job. Hence leading to increase in production rate. We have implemented new fill ratio of 70:30, where 70 is the article and 30 is the wastage. The life of tool will be high will due to new material selection, also will reduce in wearing of the die tool. The person from industry will definitely be satisfied with the performance of die tool for manufacturing of the product.

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