A STUDY AND DESIGN ANALYSIS FOR INJECTION MOULD FOR PLASTIC BEARING

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Abstract - *Any products to be manufactured invariably require tools. Tool design and development is a specialized and critical area. Since tool is an aid for mass production, it should be accurate and economical for successful life of a product. Tool making is combination of art and science. Moulds are used to produce three-dimensional components. The economy and life of mould reacts entirely on the designer and his role is very important. The main objective is to have the detailed knowledge of the mould making techniques, tool processing in a properly planned and progressive manner. This presents an idea of fundamental necessary for processing the tool and to give a clear picture of manufacturing process.*

Keywords: Injection, Toughness, Tensile, Ejection and Hardened

1.INTRODUCTION

This paper gives a detailed knowledge of mould making and designing in step-by-step and also difficulties involved and skill of toolmaker. It is helpful for toolmaker by providing basic knowledge about design, raw material selection, manufacturing process etc. The information present in this paper can be asset not only to a toolmaker but also to any one concerned with tool making and production. The aim of this paper is to explain the tooling aspect involved starting from basic designing to finish stage of the injection mould in similar and clear manner. Any products to be manufactured invariably require tools. Tool design and development is a specialized and critical area. Since tool is an aid for mass production, it should be accurate and economical for successful life of a product. Tool making is combination of art and science. Moulds are used to produce three-dimensional components. The economy and life of mould reacts entirely on the designer and his role is very important. The main objective of the paper work is to have the detailed Practical-knowledge of the mould making techniques, tool processing in a properly planned and progressive manner. This presents an idea of fundamental necessary for processing the tool and to give a clear picture of manufacturing process, i.e., sequence of machining operations involved during manufacturing and assembly of moulds. The main purpose of choosing this component is, this component was different from other component which was manufactured earlier in that company and I have got more exposures to learn different operations which was involved in it so I have choose this tool to do my paper.

2. LITERATURE SURVEY

Nowadays almost an infinite variety of materials are available often specialized for a particular application. In most cases, the selection is unique and manufacturer's assistance need to be taken. Bearing materials can be metallic or non-metallic. Metallic bearings are made of white metal, bronzes, aluminum based, porous metals, and coated metals. Non-metallic bearings are made of polymers, ceramics, and composites. Bearings can also be classified based on their geometry, half-round sleeves called as bearings and full round sleeves are called as bushes.

Table 1: Relative comparison of bearing materials

Property	Babbitt metal	Al-based	Cu-based	Polymer based
Compatibility	1	2	3	2
Conformability	1	2	3	1
Embeddability	1	2	3	2
Fatigue Strength	3	2	1	2
Corrosion Resistance	Varies	1	3	1
Compressive strength	3	2	1	Varies
Density	1	2	1	3
Cost	1	2	2	3

* All the numbers shown are arbitrary scale 1-High, 2-Moderate, 3-Low.

Teflon, nylon, phenolic, are used in the manufacture of polymer bearings. These are less in cost compared to metal bearings. Solid lubricants can be blended in their manufacture to improve their lubrication properties. Recent advances in manufacturing engineering polymers and understanding their properties has increased their use in the recent past. Polymer based composites were developed which combine high wear resistance, low friction and wear rates and good thermal conductivity. There is flexibility, like blending solid lubricants, mixing various polymers in the melt phase, can be combined in layers, interwoven, impregnate into porous materials, to exactly suit the application. When compared to metals, Polymers are less rigid. So, they have conformability, good vibration absorption, good embeddability, high corrosion resistance, low wear rate. However, they have a high coefficient of thermal expansion about 5-10 times more than metals, have low melting points that limit their use to light load applications. They adhere to materials like aluminum, so their use is also limited by shaft material. Polyamideimide coatings are widely used on aluminum-based linings with the addition of graphite or MoS_2 as solid lubricants. These coatings are alternatives to the above electro-deposited and sputtered layers. These coatings poorly conduct heat. So, heat transfer from the bearing is less compared to metal coatings that limit the use of these bearings.

3. PRESENT WORK

3.1. COMPONENT ANALYSIS

The successful design of a component and the relevant tool to produce such component largely depends on how one analysis it. That is both on technical and commercial aspects. A brief analysis of the component “BEARING” is given below. The component analysis depends upon:

1. Component Details
2. Function of component
3. Properties of component materials
4. Critical dimensions of component

3.2. COMPONENT DETAILS:

1. Name: Bearing
2. Material: NYLON 66
3. Shrinkage: 0.4-0.7%
4. Melting temperature: 55-65^{0}C
5. Component weight: 120gms
6. Mould temperature: 80-90^{0}C
7. Finish: Glossy finish
8. Weight of mould component with runner: 123gms

3.3. BRIEF SPECIFICATION OF MOULD:

1. Type of mould: Injection mould.
2. Type of injection mould: Two plate mould
3. Number of cavities: Single cavity
4. Material of the component: Nylon 66
5. Type of Runner: Half-Round Runner
6. Type of gate: Spoke gate
7. Shut Height: 350mm
8. Machine used: SHINE WELL Servo 120E
9. Clamping Force: 95 tones

Fig 1: Mould

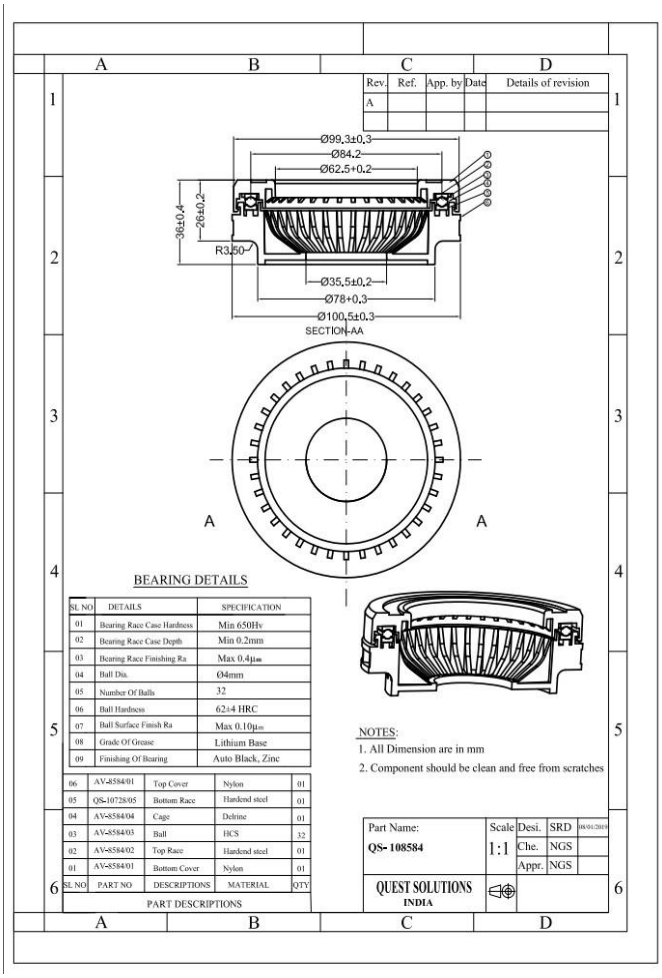

Fig 2: Specification of Mould

3.4. TOOL DESIGN ANALYSIS

The product drawing is the basis for construction mould. Designing requires a lot of planning and visualization of what can be accomplished by the resources at hand in a given time. A design with proper implementation and good workmanship can produce accurate parts.

This design is to construct a mould of 300X250mm size and a shut height of 215mm, because of the availability of machine size and the maximum and the minimum, adjustment of the machine platen .

The important factors to be considered while designing the injection mould are:

1. Parting line
2. Feed system
3. Cooling of mould
4. Ejection of component

3.5. FACTORS TO CONSIDER WHILE DESIGNING:

1. Costing
2. Gate location
3. Machine requirement
4. Easy to manufacture
5. Material consideration
6. Draft
7. Mould shrinkage
8. Wall thickness
9. Special features

Fig 3: Cavity Insert

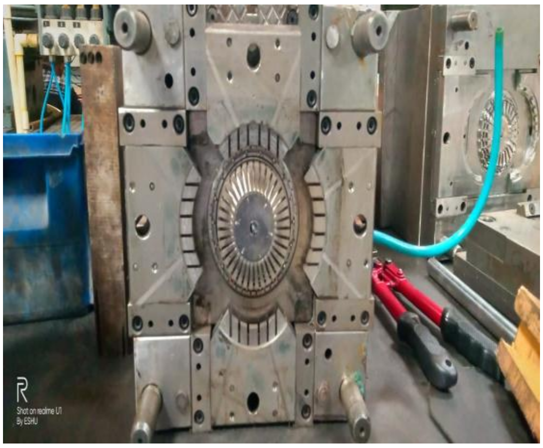

Fig 4: Core Insert with side cores

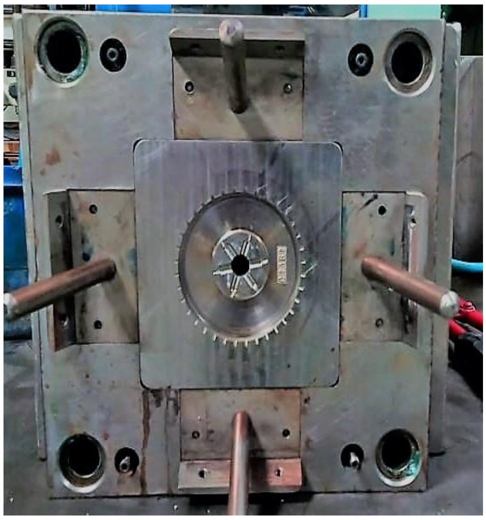

Fig 5: Cavity Half

3.6. RAW MATERIAL SELECTION

The selection of raw material plays a vital role in the manufacturing of the mould, which has a direct impact on the life of a mould. Different applications require specific characteristics for the material to be used. To select the material that provides the most economical overall performance and imparts necessary quality required is very important. The selection of material for a particular application is governed by the working condition to which it will be subjected. The raw material for tool can be chosen from the following-steel, cast steel, aluminum and copper.

Generally, mould makers use the following 4 kinds of steel with different composition:

1. Low carbon steel (<0.2% carbon)
2. Low carbon steel (<0.2% carbon)
3. Medium carbon steel (0.2 to 0.6% carbon)
4. High carbon steel (0.7 to 1.3% carbon)
5. Alloy steel

The raw materials used in this mould are mainly tool steels. The raw materials distinguished by their special physical and mechanical properties influenced by the addition by alloying elements like Nickel, Vanadium, Chromium, Molybdenum silicate etc.

3.7. PURPOSE OF ADDING ALLOYING ELEMENTS:

1. Greater wear resistance for cutting/abrasion
2. Greater toughness or strength.
3. Higher hardness.
4. Increases harden ability.
5. Hot hardness.

According to IS method a steel may be designated by a group of symbols indicating the important characteristics in the following order:

1. Tensile strength
2. Carbon content
3. Alloy content
4. Sulphur and phosphorous limits
5. Weld ability
6. Surface condition
7. Surface finish
8. Steel quality
9. Treatment

3.8. EFFECTS OF ALLOYING ELEMENTS ON STEEL

1. CARBON - This is very much essential for heat treatment. The carbon content of die steel generally does not exceed 0.3 to 0.35%.

2. MANGANESE - Addition of more than 0.5% of manganese increases hardens ability and strength of steel. It is an excellent deoxidize. It increases the cooling rate.

3. SILICON - The increase in silicon content will raise the critical temperature, increases susceptibility to de-carbonization and graphitization and when combined with other an alloy promotes resistance to high temperature oxidation. Gives strength and toughness to steel.

4. NICKEL - Nickel permits lowering of carbon content to achieve a given strength level thereby increasing toughness and fatigue resistance.

5. CHROMIUM - It improves hardness, wear resistance, toughness, corrosion resistance and it helps in retaining high surface finish. It varies from 0.25% to 14% depending upon the properties required.

6. MOLYBDENUM - It restores hardness at elevated temperatures. It improves hardness; polish ability, toughness and mach inability. It eliminates temp brittleness in steels. It acts as a grain growth inhibitor

7. When steel is heated to high temperatures, molybdenum also intensifies the effects of other alloys.

8. TUNGSTEN - Increases hardness, strength and toughness up to 1.5% tungsten in steel increases wear resistance, retains hardness unto 600ºC to 650ºC.

9. VANADIUM - It is quite expensive, where as it increases the strength, hardness and impact resistance. It inhibits the grain growth during heating, permitting high temperature. The percentage of vanadium in steel varies from 0.15-2%.

There are different types of mould materials like Hot die steel, Cold work die steel, Cast steels, Aluminum, Copper etc.

In this mould the different materials used are:

- Mild Steel
- Oil hardened non shrinkable steel
- Pre Harden steel

MILD STEEL:

1. Trade name: MS (Mild Steel)
2. IS Codification: St-42
3. Tensile Strength: 42kgs/mm^2
4. Carbon: 0.22%
5. Silicon: 0.65%
6. Phosphorus: 0.05%

This has high toughness and shock resistive property so it is used in plates, locating ring, male hose ends etc. this material withstands the clamping force, injection and ejection pressure and economical.

OIL HARDENED NON-SHRINKABLE STEEL:

1. Trade name: OHNS
2. IS Codification: T110 W2 CR1
3. Carbon: 1.1%
4. Manganese: 0.65%
5. Chromium: 0.05%

This is a cold working tool steel whose important properties are good mach inability, high wear resistant and temperature resistant properties combined with remarkable toughness. This is used for Sprue bush, ejector pins, Guide rills, etc.

PRE HARDEN-STEEL:

1. Trade name: P20
2. IS Codification: T55 Ni2 Cr65 Mo30
3. Carbon: 0.24%
4. Manganese: 0.5%
5. Chromium: 13.3%
6. Nickel: 1.40%
7. Molybdenum: 0.35%
8. Vanadium: 0.35%
9. Silicon: 0.3%

3.9. MOULD TERMINOLOGY OF DIFFERENT PARTS

Injection mould is an assembly of parts containing within it an impression into which the plastic material is injected and cooled. It is the impression, which gives the moulding it's required from. The impression may be defined as the part imparts into the shape with accurate dimensions to the moulding.

3.9.1. Top plate:

The Top plate is made of mild steel. This plate should be thick enough to prevent bending; it will be bigger in width than the cavity plate. This plate is used for clamping the fixed half to the machine platen. It incorporates a hole for sprue bush, locating ring, guide pillar and a screw hole for arresting the cavity plate and wedge housings.

- Material: St-42
- QTY: 1 no.

3.9.2. Cavity plate:

This plate is used for fixing the cavity in position. In this plate component profile, are usually sparked on it. In this plate sprue bush hole is incorporated

- Material: St-42
- QTY: 1 no.

3.9.3. Core plate:

This is a plate where core profile is machined so that it is in alignment with the cavity. It also provides provision for incorporating guide bush, core back plate channel for arresting wear plates, guide rails and also a provision for push back pins and ejector pins.

- Material: St-42
- QTY: 1 no.

3.9.4. Side core:

Side core is a local core that is normally mounted at right angle to the die axis for forming profiles in the side face of a component. It gives the internal and external profiles to the component; it has critical profiles, which are sparked.

- Material: OHNS (T110W2Cr1)
- QTY: 04 Nos
- Hardness: 54-56HRC

3.9.5. Push back pins:

These pins are fitted in the ejector plate and ends in the mould parting line. This is used only to retain the ejector assembly back into its position before the mould closes.

- Material: OHNS(T110W2Cr1)
- QTY: 04 Nos
- Hardness: 54-56HRC

3.9.6. Locating ring:

This is a disk-shaped part seated into a recess in the top plate on the cavity half of the tool. It locates the mould on the fixed platen. Being accurate it ensures alignment of the sprue bush with the centerline of the injection unit nozzle.

- Material: St-42
- QTY: 01 No

3.9.7. Sprue bush:

It is a headed cylindrical component about a tapered polished bore. The bush is positioned in the cavity half of the mould and provides an entry point for the machine injection unit to feed the mould.

- Material: OHNS (T110W2Cr1)
- QTY: 01 No
- Hardness: 54-56HRC

3.9.8. Finger Cam:

This are the 2 pillar's which will be fitted in an angle in the cavity half and the front portion will be of 15^0 taper and slight radius is made for the easy penetration and for the actuation side cores

- Material: P-20 (pre hardened steel) (T55Ni2Cr65 MoV30)
- QTY: 04Nos
- Hardness: 44-46 HRC

3.9.9. Guide rails:

They are provided for guiding the side core perpendicular to core axis without distortion, step is ground in these rails to arrest collar in the side core.

- Material: OHNS (T110W2Cr1)
- QTY: 08Nos
- Hardness: 54-56HRC

3.9.10. Ejector pins:

These are cylindrical moving pins used for ejecting the component. It is housed in the ejector plate.

- Material: OHNS (T110W2Cr1)
- QTY: 18 Nos.
- Hardness: 56-58HRC.

3.9.11. Ejector plate:

This plate houses all the ejectors pins and push back pins within it.

- Material: St-42
- QTY: 01 No.

3.9.12. Ejector back palate:

It is back supportive plate for the ejector assembly.

- Material: OHNS(T110W2Cr1)
- QTY:01 No.

3.9.13. Guide pillar and Guide bushes:

These are used in the tool to get accurate components and align moving half with fixed half when it is loaded on the machine. These are made up of oil hardened steel.

- Material: OHNS (T110W2Cr1)
- QTY: 4 Nos
- Hardness 62-64HRC

3.9.14. Spacers:

These blocks are used in the mould to facilitate the ejector assembly to be positioned and actuated.

- Material: St-42
- QTY: 02 Nos.

3.9.15. Bottom Plate:

This plate is incorporated next to the spacer. It provides enough room for the moving half to be clamped to the machine platen. It will be of more thickness to prevent buckling.

- Material: St-42
- QTY: 01 Nos

3.9.16. Screws:

Screws are used to hold the parts together of mouldings.

- Material: STD

3.9.17. Sub core insert:

These inserts are press fitted in the holes provided in the main core insert as per the design and the insert are screwed in the counter bores provided at the back side of the main core insert.

- Material: P-20 (pre hardened steel) (T55Ni2Cr65 MoV3
- Hardness: 44-46HRC
- QTY: 01 Nos

3.9.18. Wedge

This part is used to hold the side core rigidly against the injection pressure when the molding is at working

- Material: MS (St 42)
- QTY: 04 Nos.

3.9.19. Wedge Wear plate

This part is used to wear resistance of rubbing part of wedge and side core to with stand that rubbing the wear plate is used

- Material: P-20 (pre hardened steel) (T55Ni2Cr65 MoV30)
- QTY:04 Nos.
- Hardness: 44-46 HRC.

3.10. MANUFACTURING PROCESS:

3.10.1. Part Name: Cavity plate :(1 no)

Material: Mild Steel (St-42)

Cavity block was pre tooled and sized with allowance for further operation.

1. Cavity plate was surface ground for reference; the holes are drilled as per drawing then moved for profile machining and spotting of screw holes etc.
2. Boring of guide bush holes and reaming sprue bush holes were done in one setting as per drawing.
3. In the next setting collar for sprue bush was machined and holes spotted as per drawing.
4. The spotted holes were drilled and tapped as per drawing.
5. Cavity plate is moved to CNC for milling the housing for cavity insert and wedges
6. The cooling cooling hole are matched with respect to main cavity insert
7. The cavity was assembled along with the finger cams, sprue bush, cavity insert, wedge, finger cam and top plate.
8. Sprue bush was matched to the cavity face by grinding.

3.10.2. Part Name: Core plate :(1 no)

Material: Mild Steel (St-42)

1. Core block was pre tooled and sized with allowance for further operation.
2. Core plate was surface ground for reference; the holes are drilled as per drawing, then moved for profile machining and spotting of screw, ejector holes etc.
3. Drilling, boring of guide pillar holes and reaming of pushback pinholes were done in same setting as per drawing.
4. The plate is moved to CNC for milling the housing of core insert
5. After completing the operation on CNC, the cooling hole are matched with respect the cavity inserts.
6. Finger cam relief slots were opened in the core plate as per the drawing.
7. The spotted holes were drilled and reamed as per drawing.
8. The guide rails and wear plates were assembled to the core plate holes were transferred to the core plate.

3.10.3. Part Name: Guide Rails (8Nos)

Material: EN31

1. Four P-20 blocks were pre tooled by keeping 0.6mm stock with a grinding allowance per side. Right angle grinding was done on all sides.
2. Spotting and drilling of screw holes, and reamed as per drawing.
3. The parts were heat-treated and inspected.
4. The blocks were ground according to the drawing to make sliding for side core assembly accurately.
5. Relief was provided at the side of the guide rails for preventing rubbing of side cores.

3.10.4. Part Name: Side core (04 No)

Material: P-20 (pre hardened steel) (T55Ni2Cr65 MoV1)

1. The Side Cores are pre tooled and are sized with allowance for further operation.
2. Surface grinding of thickness and right angle is done on all sides.
3. Step milling with allowance for grinding as per drawing.
4. The side cores were then moved for profile machining.
5. The side core steps are ground accurately to the dimension and are made to slide easily through the guide ways.
6. Side cores were angle drilled and angle milled as per the drawing.
7. Side cores were then blue matched to the mating profiles

3.10.5. Part Name: Ejector plate

Material: Mild steel (ST-42)

1. The Ejector plate is pre tooled and is sized with allowance for further operation.
2. Surface grinding of thickness and one side right angle for reference is done and the required size is maintained.
3. Drilling of tapped holes as per drawing.
4. Ejector pin and push back pin collars were machined and relief holes were spotted and drilled.

3.10.6. Part Name: Retainer plate (Ejector back plate)

Material: Mild steel (ST-42)

1. The Ejector back plate is pre tooled and is sized with allowance for further operation.
2. Surface grinding of thickness and one side right angle for reference is done and the required size is maintained.
3. Transferring of free hole and counter bore hole from tapped hole from ejector plate as per drawing.
4. Drilling and machining of collar and relief holes in ejector back plate as per drawing for the purpose of assembling a positive retraction bush.

3.10.7. Part Name: Spacers (2 no)

Material: Mild steel (ST-42)

1. The Spacers are pre tooled and are sized with allowance for further operation.
2. Surface grinding of thickness and two sides right angle is done.
3. Transferring of free holes from tapped holes from core back plate.
4. Drilling of tapped holes in spacers for the purpose of screwing.

3.10.8. Part Name: Bottom plate

Material: Mild steel (ST-42)

1. The Bottom plate is pre tooled and is sized with allowance for further operation. Surface grinding of thickness and one side right angle for reference is done and the required size is maintained.
2. Drilling of relief hole for retraction bush as per drawing.
3. Transferring free hole and counter bore hole from free hole of spacers.

3.10.9. Part Name: Sprue bush

Material: OHNS (T110W2Cr1)

Hardness: 54-56HRC

Turning of the bush is done with allowance for grinding,

1. Through hole having a less diameter than the minimum diameter of the taper hole was drilled.
2. Bush was sent for heat treatment, after which cylindrical grinding of fitting area was done to have push fit in cavity block.
3. Then the collar and total height was maintained by surface grinding.
4. Then sprue bush is sent for WEDM where the sprue hole was wire cut and the cut portion was polished.
5. After every operation stage inspection was done and finally inspected prior to assembly.

3.10.10. Part Name: Sub core insert

Material: P-20 (pre hardened steel) (T55Ni2Cr65 MoV1)

Hardness :44-46 HRC

Turning of the insert is done with kept allowance for further operation

1. After turning we send it for CNC because we can't manufacture the rib portion of component in conventional machining
2. The insert has to move to CG to get accurate OD because it is fitted in the main insert and the plastic material has do not enter into the main insert.
3. The Barffel cooling hole has to be drilled to the insert as per drawing
4. Drilling core drill for M8 threads

After completing all operation, it will inspect for prior assembly

4. CONCLUSION

Bearing single cavity mould was completed successfully and the components produced in the trials were excellent, which satisfied the requirement of the customer. The intension of this paper is to give a clear picture of general procedure of mould manufacturing and machining process involved in mould making. Working on this mould has been greatly beneficial in more practical knowledge and has acquired the spirit of team work and discipline. This paper will be a reference for my future endeavors.

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