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Design and Fabrication of Plastic Injection Molding Tool for Pump Gaskets

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Abstract— *This Project gives the information about to design and fabrication of Injection Molding tool or die for Production of pump gaskets by using Plastic material. For Increasing the Production rate, designing and manufacturing the multi cavity die and also Using PP (polypropylene) to overcome the existing plastic material drawbacks. The injection molding tool/die contains the core plate, cavity plate, top and bottom supported plates, channels or runners, sprue, vents, ejector and its pins and horn pins, etc. The gaskets are used to prevent leakages by provide a tight fitting joint between two surfaces. The Greek word of 'Plastic' meaning is 'able to be shaped and molded'; in so many different plastic materials I am using polypropylene material for production of plastic gaskets components. For optimization Process, The selected two bolt oval gasket component is making with injection molding process by controlling parameters of plastic injection molding machine.*

Keywords—Injection molding, injection molding tool, polypropylene, Surface grinding machine.

I. INTRODUCTION

The injection Molding tool/die contains the core designed plate, cavity designed plate, top and bottom supported plates, channels or runners, sprue, vents, ejector and its pins, horn pins, etc. In fabrication process, the considering variables are Temperature, Time, Speed, Pressure and stroke. The gaskets are used to provide a tight fitting joint between two surfaces to prevent leakages. In General the gaskets contains the Properties like Conformity, Resistance, Impermeability, Resistance to chemical attack, Resistance to operating conditions, Provision of apertures, shrinkage, reusability and cost. The Greek word of 'Plastic' meaning is 'able to be shaped and molded'; in so many different plastic materials using polypropylene material for production of plastic gaskets components and analyzing the production rate and production cost. For optimization Process, The selected 2 bolt oval gasket component is making with injection molding process by controlling parameters of plastic injection molding machine.

II. GASKET

The gaskets are used to provide a tight fitting joint between two surfaces to prevent leakages, for example joint between cylinder head and block, between crankcase water pumps etc. And avoid problems like Production breakages, energy.

The selected Gasket design with dimensions is shown in figure 1.

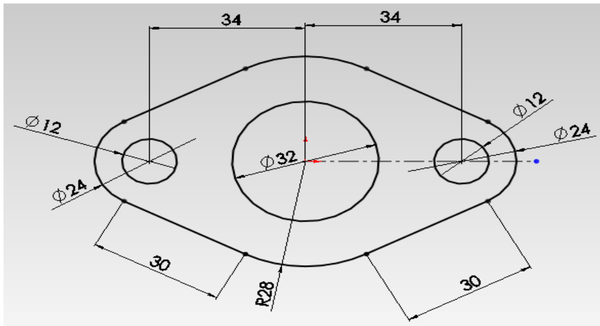

Fig. 1: Gasket with dimentions

III. INJECTION MOLDING TOOL

Injection mold tool also known as die or mold. The dies are two types, fist one is single cavity die and second one is multi cavity die. For increasing the production rate with minimizing the cost purpose, implemented multi cavity injection mold. Tool designed depends on finalized part design dimensions.

For tool designing purpose used software are Solid works, AutoCAD

3.1 DESIGN OF MULTICAVITY DIE:

Injection mold tool is a multi cavity die that means more than one part in a cavity. It contains core plate, cavity plate, spacer, bottom plate, ejector plate, ejector back

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plate, sprue bush, etc. Tool or die designed based on DME and Hasco ejector standers.

3.1.1 DESIGN OF CORE PLATE:

Core designed three gasket parts, air went, guide pillar holes, cooling system, and ejector pin holes. Two ejector pin holes provided for every part of gasket means totally 6 ejector pin hole provided in core plate.

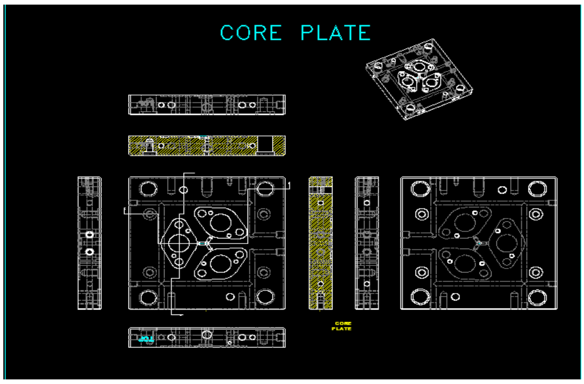

Fig 2: Core Plate

3.1.2 DESIGN OF CAVITY PLATE:

There is no design in Cavity plate because of the total part design happens in core plate itself. Almost all dies contains cavity plate and top supported plate, but in this project, we are providing a thick cavity plate without providing top supported plate

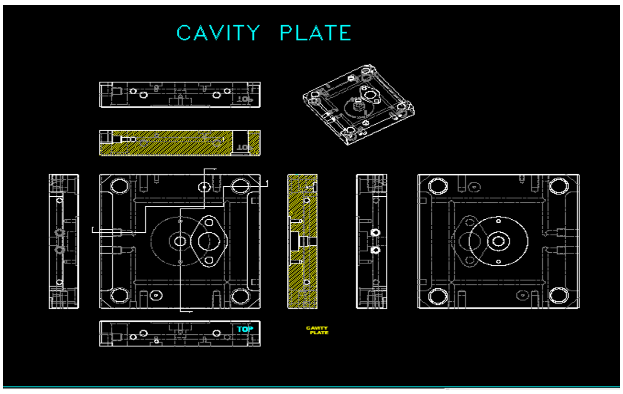

Fig 3: Cavity plate

3.1.3 DESIGN OF SPACERS:

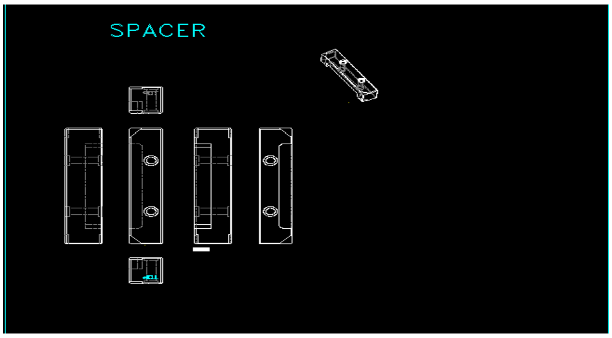

Fig 4: Spacer

3.1.4 DESIGN OF BOTTOM PLATE:

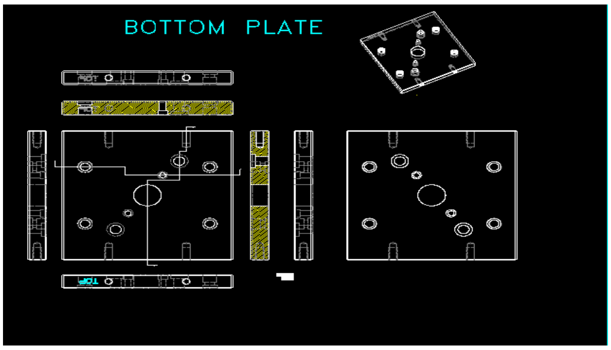

Fig 5: Bottom plate

3.1. 5 DESIGN OF EJECTOR PLATE:

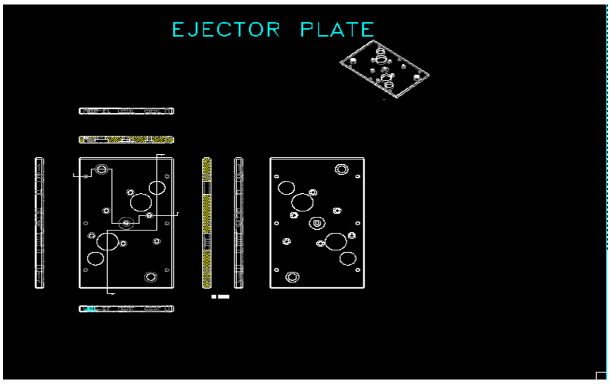

Fig 6: Ejector Front plate

3.1.6 DESIGN OF EJECTOR BACK PLATE:

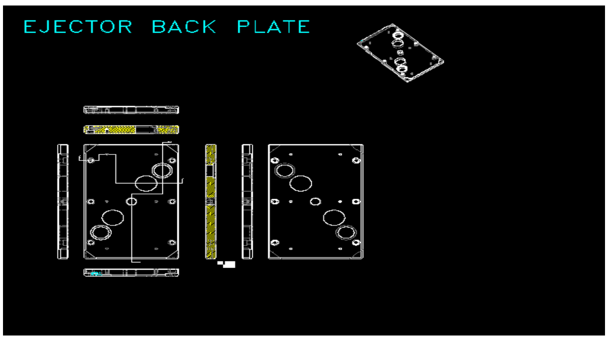

Fig 7: Ejector Back Plate

IV. TOOL MANUFACTURING PROCESS

Some of sequential steps having to manufacturing the multi cavity die; the navigating steps are Raw material selection, Premachining, CNC Milling, Heat Treatment, Surface Grinding, CNC Milling, Sparking, Wire EDM Process, Polishing, and Assembly.

1. Raw Material

Selected Mild steel (MS) raw material **b**ased on the DME and HASCO designed standards to design and manufacturing the tool. In below table contains raw material sizes of components of injection tool.

Material Purpose	Height (mm)	Width (mm)	Thickness (mm)
Core Plate	250	260	40
Cavity plate	250	260	80
Spacer	250	55	55
Ejector Plates	250	150	15
Ejector Back plate	250	150	15
Bottom Plate	250	260	30

Table 1: Raw material sizes of tool components

2. Pre machining: In this process decided the metal sizes and block sizes for maintaining the tool standards.

3. CNC Milling for Rough Surface: Here metal shape is obtained by removing the unwanted material from the Work Piece in the form of chips.

4. Heat Treatment: Heat treatment process is used for hardening the material for better machining.

5. Surface Grinding: Surface grinding divided into two types one is cylindrical grinding (CG) and second one is square grinding. By using this process we will finish ejector pins and bushes, etc.

6. CNC Milling: After grinding once again CNC milling operation done for smooth surface finish of the metal. Here upto 0.1 micron metal cutting shaping process happens.

7. Wire EDM Process: It is used for accuracy in mold component to part design in core plate and also machining the ejector holes.

8. Polishing: It is manual process to remove the waste particles on metal surfaces.

9. Assembly: After finishing all the machining process the assembly of tool look likes the below image

4.1 TOOL OR DIE COMPONENTS:

The tool contains core, cavity, ejector, ejector back plate, bottom plate and spacer, return pins, sprue bush, ejector pins, bushes etc

4.1.1 CORE PLATE:

In injection mold tool core plate is used to attach the entire product design and also attached ejector pins, leader bush and return pins.

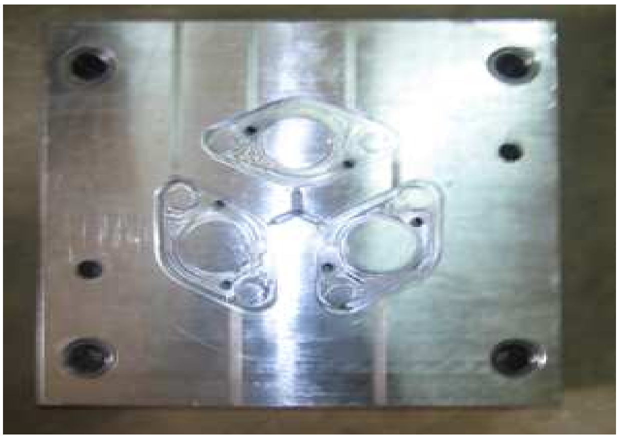

Fig. 8: Core plate

4.1.2 CAVITY PLATE:

Generally in cavity plate is used to hold the cavity side of the product. But here in this project the selected part contains flat surface and thinner because of this nothing is designed about part related in cavity plate, just used as support plate.

Fig. 9: Cavity Plate

4.1.3 EJECTOR:

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It is used to hold the ejector pins sprue, push back pins and support pillars

Fig. 10: Ejector Front Plate

4.1.4 EJECTOR BACK PLATE:

Ejector back plate pushes the return pins and ejector pins, fixed in the plate. Fig no A is the ejector back plate.

Fig.11: Ejector back plate

4.1.5 BOTTOM PLATE:

It is used to hold or handle the remaining mold parts like return pins with bushes...

Fig.12: Bottom plate

4.1.6 SPACER:

Spacer block is placed between bottom plate and the core supported plate to gives space for ejection process.

Fig: Spacer

4.1.7 SPRUE BUSH:

Through Sprue hole molten metal enters into the die.

Fig.13: Sprue Bush

4.1.9 ASSEMBLED TOOL (OR) MOULD:

Tool components assembled by using guide pillars, return pins, ejector pins, ejector back plate return pins, bushes, bolts and with locating ring.

Fig.14: Tool Components

Fig.15: Assembled Die

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V. PRODUCT (OR) PART MANUFACTURING:

Product manufacturing is nothing but plastic part manufacturing by using injection molding process. Plastic is a good engineering material for most products. All plastics materials are polymers, these polymers are divided into two types in that first one is Thermoplastics and the second one is Thermosets. Thermoplastic material melts when heated and reformed again and again.

Thermosets harden when they are heated, later it will lose their properties. Using Thermoplastic type material for product manufacturing, because these type materials are **softer**, **flexible** and it contains low **melting point temperature**.

5.1 PROPERTIES OF PLASTIC MATERIALS:

In the below table mentioned short term properties of some important plastic materials

Material	Density kg/m3	Flexural modulus GN/m2	% elongation at break
ABS	1040	2.2	8
PVC	1300	0.007	300
PTFE	2100	0.5	200
PEEK	1300	3.8	4
Epoxy	1200	3.0	3
Nylon 66	1140	2.8	60
Polythene	920	0.2	400
Polyimide	1420	2.5	8
Polypropylene	905	1.5	150
Polycarbonate	1150	2.8	100

Table 2: General properties of plastic material

On density/weight basis, I have selected the PP (Polypropylene) material for part production.

5.2 PROPERTIES OF PP MATERIAL

In Polypropylene material, identified some of the satisfactory properties for production or molding. In this density, percentage elongation at break, shrinkage percentage there are the considering properties to take for the production.

Material	Polypropylene
Density (kg/m3)	905
Wall Thickness (in)	0.025 – 0.150
Max. Operating Temp ("C)	100
Thermal conductivity (w/m/k)	0.20
Tensile Strength(MN/m2)	33
Flexural modulus (GN/m2)	1.5
% elongation at break	150
Impact Strength (ft-lb/in)	0.4 – 1.2
Melting point Temp("C)	175
% of Shrinkage	1.5

Table 3: PP Material properties

5.3 STANDARD INJECTION CLCLE TIME:

Mold Close : 1-2 sec
Injection : 2-5 sec
Pack and Hold : 8-10 sec
Part Cooling : 10-20 sec
Screw return : 2-5 sec
Mold open : 1 sec
Ejection : 1 sec
The total injection cycle time: 25 – 44 sec
This time changes depends on product complexity

5.4 PRODUCTION PROCESS:

After loading the tool into injection molding machine the material pellets are melted and injected into the mold. Under the pressure, the molten material is forced in to mold through sprue. The mold is held under pressure until the material cools and hardens. Once the material hardens, the mold is opened and the part is removed. And the process can be repeated. The standard injection cycle time is 25 to 44 sec, this time will vary depends on part design.

Fig.16: PP Material Pillets

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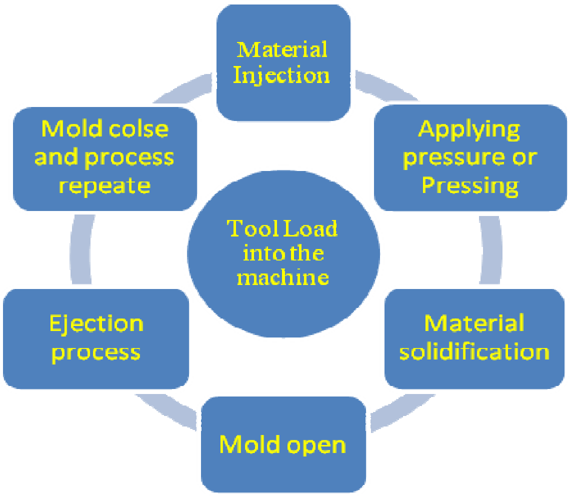

Fig.17: Production Process cycle

Part designed according original dimensions with including shrinkage percentage of PP material that is 1.5%, with respect to part thickness, length and width

Fig.18: Tool loading into machine

That, The Final dimentions of the core design dimentions are original dimentions with includes 1.5 % of part sizes

Fig.19: Three cavity tool with material filling

Fig.20: Combination of multiple parts and single part

In figure number 20, is the final fabrication product of gasket application, in this first one referring expected fabrication result for multiple cavity parts and another one is single part of gasket. Total output product weight is 19.1 grams, in total weight single part density is 6 grams remaining 0.1 grams is related to waste material.

Process parameters		**Specified**	**Actual**
Temperature ()	Zone-1	200-210	205
	Zone-2	180-200	190
	Zone-3	170-190	180
	Zone-4	160-180	170
Injection parameters	Inj. Pressure	90-110	100
	Inj. Speed	08-11	9
Refill Parameter	Refill speed	70-90	80
Cycle time	Injection time	03-06	5
	Cooling time	10-20	15
Total time		28	28
Raw material	PP - CP MI 3530		

Table4: Fabrication process parameters

VI. OPTIMIZATION

In this project optimization process can divided into three ways. First one is Process Optimization and second one is Production rate final process is Cost optimization

6.1 PROCESS OPTIMIZATION:

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A change happens in machining process of core and cavity plate. Total part design machining core plate itself there no design cavity plate it is used doe supported plate for pack and holding process.

6.2 PRODUCTION RATE:

For increasing the production rate, manufacturing multiple part die for producing multiple parts per cycle.

6.3 COST OPTIMIZATION:

The important cost effecting parameters are injection molding cycle time, metal and material cost, tooling cost and production cost.

For cost optimization selected some factors these factors are:

6.3.1. TOTAL MANUFACTURING COST

TMC = M + T + P

TMC = Total Manufacturing Cost
M = Material
T = Tooling
P = Processing

6.3.2 MATERIAL COST PER PART

c_M = M/q
= (cost/weight x weight) / number of parts
c_M = $c_w (w_p + w_w)$
= $c_w (w_p + \alpha\, w_p)$
c_M = $c_w\, w_p\, (1+\alpha)$

Here,
M = Total materials costs (raw)
Q = production quantity
c_M = [cost/weight] [weight/no of parts]
c_M = (cost/weight) (weight/part)
c_M = cost/part
c_w = material cost per unit weight, and
w_p = weight of finished part
w_w = weight of wasted material, scrap
α = ratio of wasted material weight / finished weight
α = w_w / w_p

6.3.3 TOOLING COST PER PART

CT = T/q

T = Total cost of molds, fixtures per cycle
Q = Number of parts per run

6.3.4 PROCESSING COST PER PART

CP = Ct .t
Where,
C_t = cost per hour, (machine rate + labor)
t = cycle time (hours per part)

6.3.5 TOTAL COST PER PART

Cost per part,

C = $C_M + C_T + C_P$ (OR)

C = $c_w\, w_p\, (1+\alpha) + T/q + C_t\, t$

Cost estimation calculations done by using cost effecting parameters and cost optimization factors

VII. RESULTS

Results entered in the following table format, form this easy to estimate cost differences in between single cavity and multi cavity production process

			Alternative
	Part Per Cycle	**Part Per Cycle**	**Multiple Per Cycle**
Mfg. Process	Injection molding	Injection molding	Injection molding
Material	PVC (Flex)	PP	PP
Part Weight	8.3	6	6
Alpha	0.01	0.01	0.01
Material Cost (kg)	90	90	90
Tooling Cost	32000	32000	35000
Production quantity	50000	50000	150000
Cycle Time	25	25	28
Machine Rate	400	400	400
Per Part Cost	5	5	1.85

Note: Material cost information gathered from market

Table 5**:** Manufacturing cost analysis

In table, for multi cavity column production quantity is 150000 for 50000 cycles (3 parts per cycle).

VIII. CONCLUSION

This research paper gives effective information about design, manufacturing and optimization process of injection mold tool and multi cavity part production.
For an effective part design uses AutoCAD and injection mold tool designed in UG software.
Multi cavity die manufacturing purpose used CNC milling machine, surface grinding machine, Wire EDM profile measuring machine.
Because of no complex profile shape of part design, Entire multi cavity part design done in core plate itself not in cavity plate, it is used as atop plate as well as cavity supported plate. This machining process comes under optimization of tool design.
Maintain the quality of tool uses profile measuring machine and also used to avoiding the macro level differences in edge level.
For part production uses PP material, to overcome the existing material drawbacks
The minimum production cycle time is 25sec; this duration is almost all same for single cavity and two cavity part production. As per experimental results for three cavity production process cycle time is 28 sec. Injection time is causes for this variation of time between single and three cavity part manufacturing.

Experimental production cycle time causes for cost minimization, this has shown in results table.
The following effective conclusions are derived from the project results:
1. Increasing the production rate by developing the multi part die.
2. Machining cost reduced by providing effective tool design
3. Because of this multi part production cycle time is cause to reduce the manufacturing cost.

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