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"Design and Manufacturing of Protection Cap for Stub Shaft Using Plastic Injection Molding"

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Abstract*: In most of the industries the product is manufactured at one place while assembled at other location. So, during transportation and handling, from manufacturing to assembly plant the part might get damaged, due to which it will not fit to assemble, leading to big loss for the company. To avoid this, the part needsto be protected. By manufacturing of product using Plastic Injection Molding (PIM), it will protect the part during transportation and handling. Considering strength as one of the important property of the part, injection molding is best suited for mass production of plastic parts. Hence, injection molding is most widely used in local industry. This paper gives an insight of Plastic Injection Molding process from designing to manufacturing of product, with certain process parameters that need to consider while designing for selection of optimum material for the product.*

Keywords–*Plastic Injection molding, Mass Production, Optimum Material.*

I. Introduction

The most common methods of manufacturing plastic parts include Extrusion, Injection moulding, Blow moulding, Casting, etc. However, injection moulding is most widely used in local industry as it is suitable for mass production. In plastic injection molding process, plastic products are produced by forcingthe resins made of plastic materials by application of high pressure into a mould (hollowed-out block cavity) where it is cooled, allowed to solidify and after that taken out from the mould by opening cope and drag part of the mold. The solidified material ejected from the mould results into final product. Objects having complicated shapes and geometries can be easily manufactured by using plastic injection molding process with great dimensional accuracy.[1] The cooling process in plastic injection moulding is of great importance as it plays a crucial role in determining both the production rate and part quality.[2] In this project a protection cap is being manufactured in order to protect the base of the stub shaft. Stub shaft is used in power transmission systems. It is a small rotating shaft which helps to transmit power from its place of generation to a location where it is applied to perform useful work. It allows side-load to the back of an engine while simultaneously preventing any load transmission back to the crankshaft. Considering the dimensions of the stub shaft a protection cap is manufactured by using plastic injection moulding. The main purpose of the cap is to protect the edges of the stub shaft during transportation from one location to another. Another important parameter that needs to be considered is costing of the process. Higher cost of material will result in expensive product. Hence, selection of material should be considered in order to fulfills the requirements of the customer.[3] Fig. (1) Shows vertical plastic injection moulding machine.

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Fig. 1 – Injection Moulding Machine

Problem Statement

Design and manufacturing of protection cap for stub shaft using injection moulding methodology. Major challenge is to come up with an optimum design to match customer requirements in a cost efficient way and to select best supplier for rawmaterials and ensure smooth manufacturing to match customer demand.

Methodology

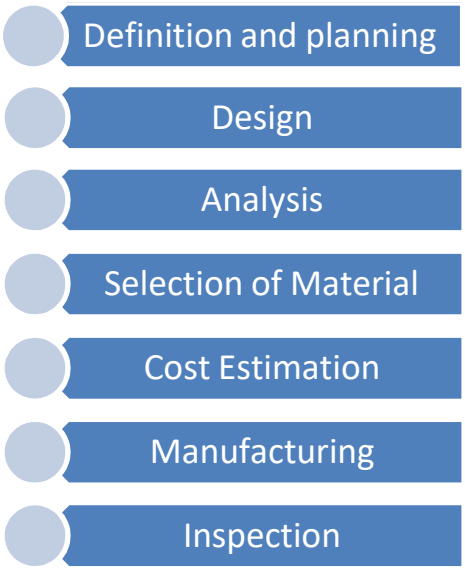

Fig. 2 – Methodology

- **Definition and Planning:** Discussion of problem statement and further planning.
- **Design:** To design the part as per the dimensions of stub shaft.
- **Analysis:** To carry out analysis to select best suited material.
- **Selection of material:** Based on analysis result, selection of precise material.
- **Cost Estimation**: To predict the cost of the resources required to complete the product within theproject scope.
- **Manufacturing**: To manufacture product by using automatic machine.
- **Inspection**: To inspect the final product by considering good quality, accuracy and precision to fulfil customer's requirements.

II. Literature Survey

R.M.Khan et al.[1] , In this paper author studied and identified the factors which are considered to manufacture product with minimum defects. It is concluded that to control defects in manufactured product selection of proper geometry and process parameters are important.

Y.C.Lam et al.[2] **,** This paper states the importance of cooling system in plastic injection moulding. CAE (Computer Aided Engineering) technology is adopted for the optimization of cooling system in plastic injection moulding. From a case study authors have concluded that the genetic algorithm and CAE stimulation is efficient in cooling system. It results in high production rate and good production quality.

P.K.Mulge et al.[3] , This paper gives a brief review on optimization of process parameter used in plastic injection moulding by using Taguchi's methodology. Taguchi's techniques are most widely used in industry to save cost, to reduce experimental time and to improve quality of manufactured product.

G.Singh et al.[4] , In this paper author reviewed and concluded that controlling process parameters leads to improve quality of product. Two most commonly occurring defects in plastic injection moulding are warpage and shrinkage. Use of recyclable and eco-friendly raw material is highly beneficial for environment and society.

K.Jain et al.[5] , This paper highlights the causes of defects in plastic injection moulding components. The product quality of component mainly depends on selection of material, moulds design, setting process parameters and cooling system. In plastic injection moulding, residual stresses leads to formation of shrinkage in components. By using Taguchi's approach shrinkage defects can minimized which helps to reduce warpage of components.

III. Experimental Work

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Design of Stub shaft

1) Stub shaft is small rotating shaft made of mild steel (M.S) used in power transmission systems.
2) The main purpose of the protection cap is to protect the edges at the base of stub shaft.
3) From the sketch below it is observed that:
4) The maximum diameter of base of the shaft 89.7mm The width of the shaft 26.5mm The length of the shaft 144.5mm
5) From the figure-3 the 3-D sketch of stub shaft is shown which helps in determining the center ofgravity of the stub shaft.

Fig. 3 – 3D Model of stub shaft

Design of Protection Cap

1) Design for manufacture (DFM) is a process in which the product is designed by the design engineerin order to achieve best possible results to meet customer's requirements.
2) The product which is being designed is a protection cap which is used to protect the base of stubshaft.
3) In the figure- 4 2-D sketch of Protection cap is shown which is designed on solid works as per thedimensions of the stub shaft.
4) The internal diameter of cap is equal to the maximum diameter of the base of stub shaft.
5) While designing, a flange of 97 mm is provided for easy fitting and removal of the cap from thebase of stub shaft.
6) For cost optimization, minimum required thickness and width of the cap should be taken underconsideration.
7) As per the calculations the thickness and width of cap was 1.5mm and 16mm respectively.

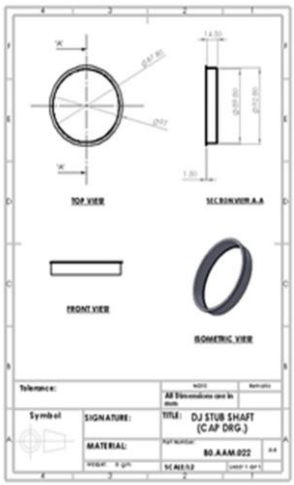

Fig. 4 – Design of cap

Properties of Materials

The common materials used in plastic injection moulding are:
Nylon-6, Polyvinyl Chloride, Polypropylene, Low Density Polyethylene etc.
Few properties of above materials that need to be considered while selection of material is given in tablebelow-
Table (1) shows mechanical properties of different materials. By considering these properties, analysiswill be carried out to select the best suited material for the cap.

Parameter	**Material**			
	NYLON-6	PVC	PP	LD
Modulus of	3500	3230	1450	44
Tensile strength,	186	50	369	64.
Hardness	82	83	83	56.
Mold	95	70	91	65.6
Tangent Modulus	792.52	729.05	947.62	305.

Table – 1 Mechanical Properties of material

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Result and Discussion

Modelling is the first step towards analysis. It acts as a link between designer and manufacturer to create a3D prototype of the product that is to be manufactured. The fig. (5) Shows the 3D model of the protection cap which is modelled on ANSYS Workbench. The cap is designed on software as per the dimensions of the base of the stub shaft.

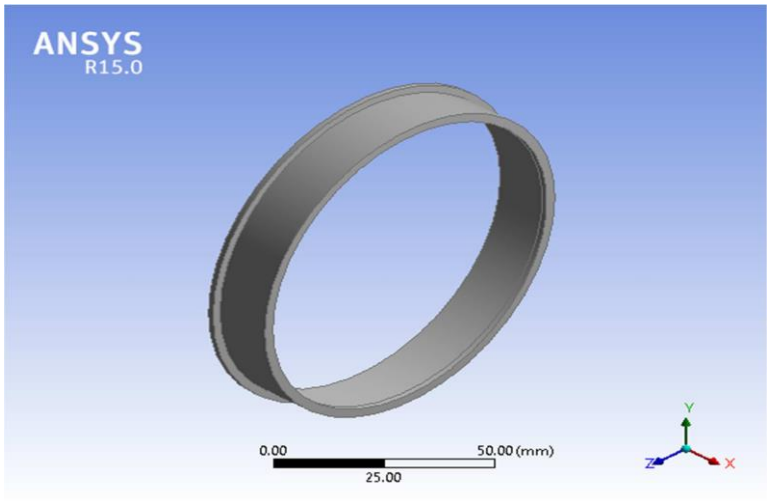

Fig. 5 – 3-D Model of Cap

Analysis

The analysis of 3D model of protection cap was carried out on ANSYS Workbench R15.0. The material properties like young's modulus, Poisson's ratio, tangent modulus and other mechanical properties were defined for all the materials. After meshing of cap, boundary conditions were applied to carry out the analysis.

Meshing

Meshing or discretization is defined as dividing the body into finite number of smaller elements to increase the accuracy up to maximum possible extent. For the protection cap fine meshing was done which created 15555 nodes and 7405 elements.

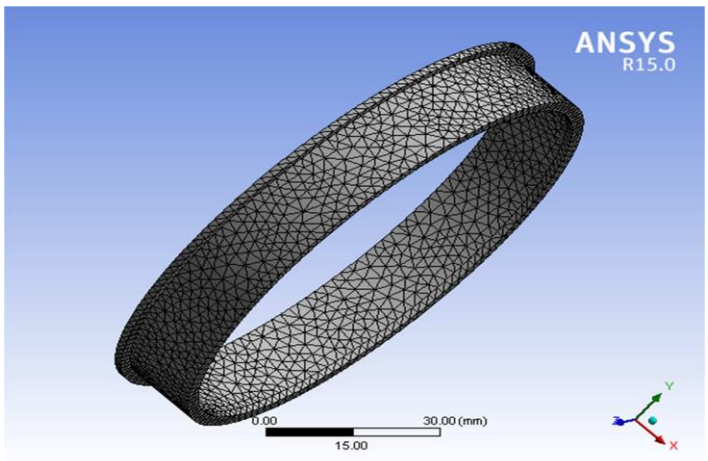

Fig. 6 – Fine meshing of cap

Boundary Condition

The value of variable such as force, displacement, temperature etc. specified on the boundaries of the body or structures are called as boundary conditions. Boundary condition is an important factor of mathematical modelling. They help in determining the flow of problem which leads to a unique solution. As the cap is resting on its base, the fixed support is applied at the base. Remote point is a point in which boundary conditions can be applied from outside of the body. The significance of remote point is that, the force which is applied on the point is equally distributed over the surface of the body. To apply the remote force it is necessary to calculate C.G of the body. Fig. (7) Shows a web projected from remote point to the targeted surface.

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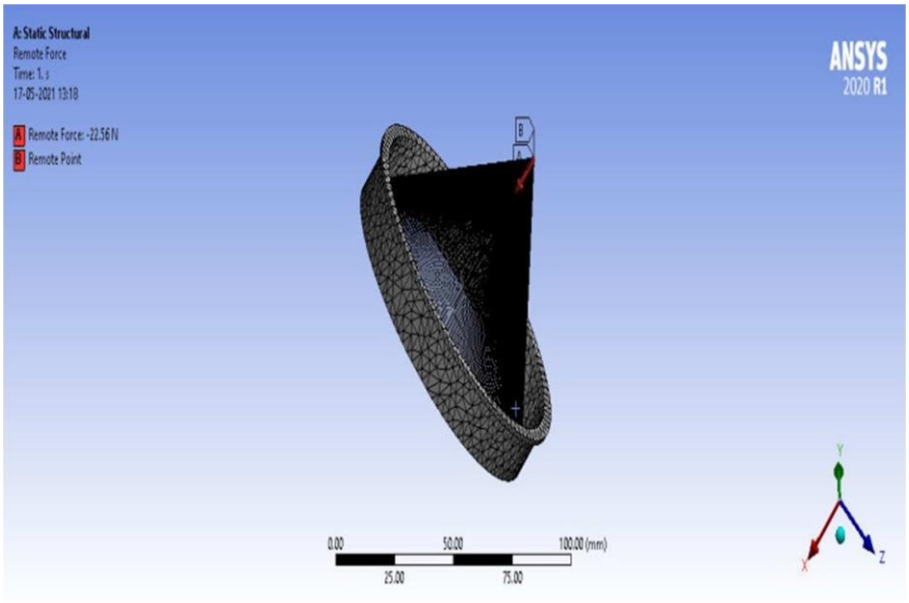

Fig. 7 – Remote force applied on the cap

Results and selection of material
LDPE

Deformation

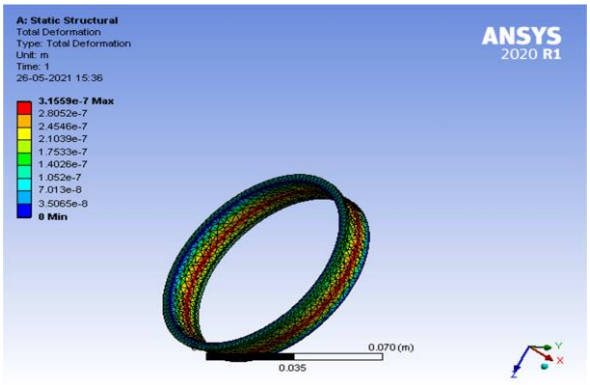

Fig. 8 – Total Deformation of LDPE

Stress

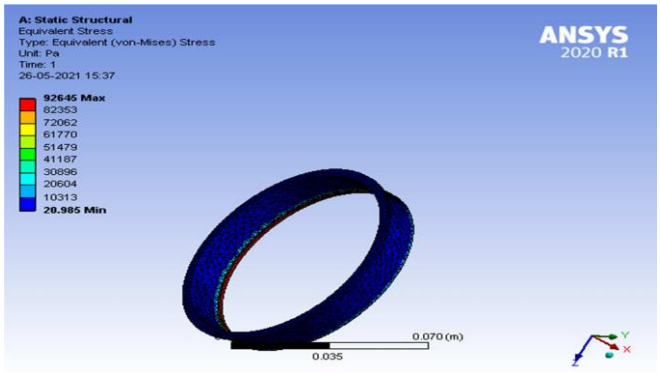

Figure 9: equivalent stress of LDPE

- From above figures the deformation of cap under a certain load and stress induced on the cap areshown.
- The table (2) shows comparison of various materials with respect to different parameters.

Parameters	LDPE	PVC	PP	NYLON-6
Stress	92645	83495	83096	83561
Cost	120	115	140	260
Mold Temperature	65	70	91	95
Young's Modulus	449	3230	1450	3500
Ultimate Tensile	$97.2*10^6$	$156*10^6$	$80*10^6$	$80*10^6$

Table 2 – Comparison of Materials

Analytical Calculation of Stress:
σ = F/Awhere,
F= Load acting on body in Newton.= 22.56 N
A= Cross sectional area in mm2=278.973 mm2
σ = Stress acting on body.= 80.868 KN/m2
The following scale shows variation in property of different materials for selection of optimum material.

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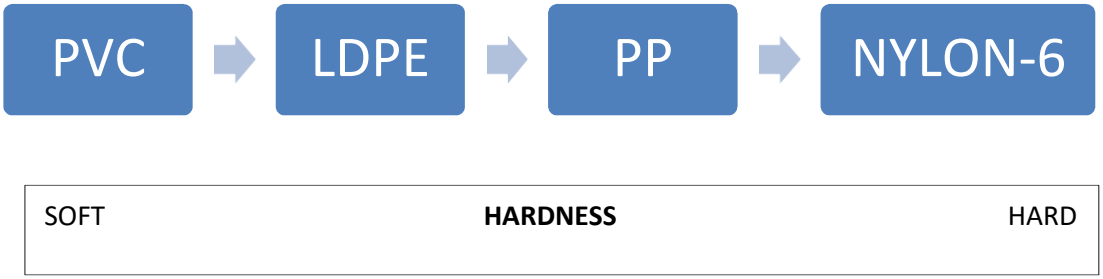
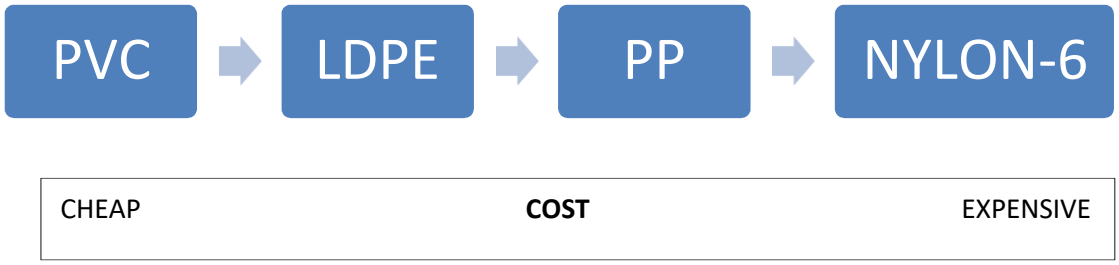
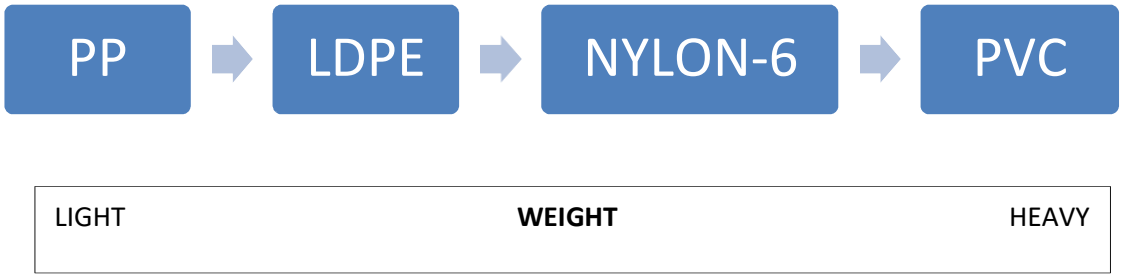
HARDNESS



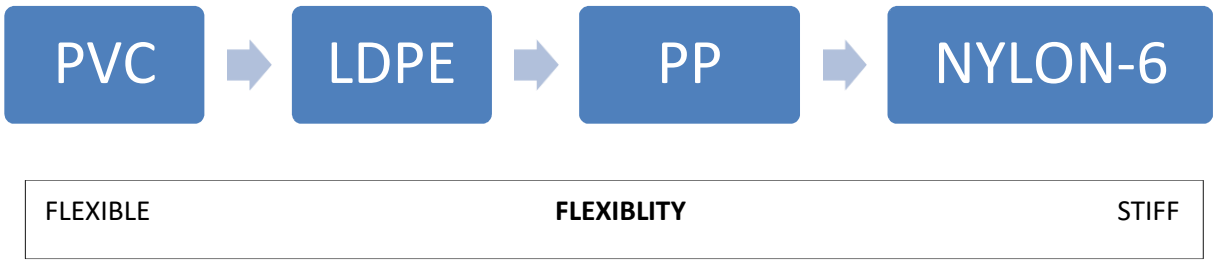
COSTING



WEIGHT



FLEXIBILITY



From charts, comparison of different materials with respect to various parameters is shown. To select theoptimum material for the cap all the parameters must meet the customer requirement. The cap material must withstand the stress induced due to force acting on the cap and at the same time it must be cost effective.

1. STRESS: Analytical value of stress induced in the cap is calculated in analytical stress calculation section. So, by comparing the actual value and the experimental value the best suited material can be selected for the cap. Actual value of stress induced in the cap due to force is 80.868 KN/m^2.This is the minimum value of stress the cap should withstand.

2. DEFORMATION: The deformation values of all compared materials are almost equal. Therefore, these values will not

be considered as the main comparing parameter for selection of material.

3. MOULD TEMPRATURE: Mould temperature has a profound effect on final properties of the product. The actual surface temperature of the mould is called the mould temperature. Perfect mould temperature results in reduced unit cost of plastic product and improves the quality of moulded product. Higher the mould temperature, higher will be the cooling time which will indirectly increase the cycle time of the product. Therefore, the mould temperature should be as low as possible.

4. COST: Cost is one of the important parameters that need to be considered while selection of material. Increasing cost of material gradually increases the final cost of the product. Failing to control the cost of the product results in less demand of the product in competitive market. Hence the selected material should be cost efficient and should have good mechanical properties which match the requirements of the product.

Considering the above parameters, the mould temperature of LDPE is lowest as compared to other materials which reduce the product ejection time resulting in increased production rate. Similarly, in costing the price of PVC is lowest as compared with other materials but it does not fulfil the demands of some mechanical properties required for the cap. Hence the second-best cost-efficient material i.e., LDPE is considered. From the table (2) the experimental values of stresses of all materials meet the maximum value of stress induced. Therefore, by considering all the above parameters LDPE is the best suited material for manufacturing of Protection cap.

IV. Cost Estimation

Cost estimation is one of the important parameters which need to be considered while manufacturing of any product. It gives a brief idea about the inventory cost as well as production cost of the product. The table (3) shows the expected final cost of the cap.

Sr. No.	Component	Weight	Raw Mater-ial	R/M Cost/Kg	Mater-ial Cost	Labour Cost	Over Head Cost	Profit @ 15%	Total Rate
1	Dia 87.8 Cap	200 Grams.	LDPE	Rs. 120/-	2.60	0.55	0.20	0.50	3.85

Table 3 – Cost Estimation

By calculating the weight of the material per Kg required for the production, the material cost can be calculated. The Production cost primarily involves Labour cost and Cycle time. The complex design of the part tends to increase the production cost, which can be minimized by advance mould designs. By using recycled form of material, the cost of the product can be minimized. It possesses same plasticity as that of the virgin material and the cost is 30% less than the raw material which is one of the main advantages of using recycled material. Whereas the cost of the cap can also be reduced by reducing the cycle time of the process, which can be done either by using automatic machines which will indirectly reduce the labor cost or by improving the process parameters. Apart from the production and material cost, the profit parameter is included for the growth of the company. By combining all the discussed parameters, the final cost of the cap is estimated.

V. Manufacturing

Plastic injection moulding process manufacture's products that have good dimensional accuracy, high quality and better dimensional stability. Factors that affect the quality of the moulded product depend on: Design of product, Mould design, Machine performance and efficiency. The basic requirements of injection moulding are plasticization, injection and moulding. Plasticization is a prerequisite which ensures the quality of moulded product and helps to meet the requirements of moulding. Sufficient speed and pressure must be maintained while injecting the molten material into the mould. At the same time to sustain the high pressure generated inside the cavity, there must be sufficient clamping force. Thus, the clamping device and injection device plays major role in injection moulding machine.

Basic steps of manufacturing

In the following figure, the basic steps of plastic injection moulding process are shown:

Step 1 – **Mould Closing:** Mould cavity consists of two parts: Cope and Drag. For the product to be manufactured, both parts of the mould are in closed position to avoid the spillage of material during injection.

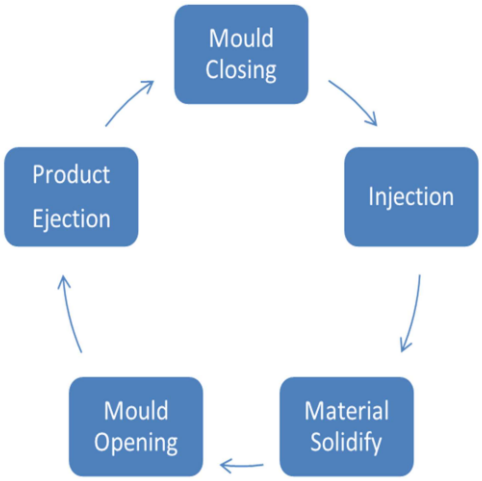


Fig. 10 – Manufacturing Process

Step 2 – **Injection:** The resins are fed into the hopper which passes through the barrel in which heating coils are located. This result in melting of material and the molten resins are dosed through nozzle at high pressure into the mould cavity.
Step 3 – **Material Solidify:** The injected material is kept inside the mould for a certain time period to solidify. Also, water cooled channels are provided for effective solidification of material.
Step 4 – **Mould Opening**: After Solidification of material inside the cavity, the mould is opened for ejection.
Step 5 – **Product Ejection:** After ejection of product from the cavity, post processing is done to get the final-produc
Horizontal injection moulding machine
Horizontal injection moulding machine is most widely used in plastic fabrication companies. The two main units of this machine are clamping unit and injection unit. Both these units lie on the same horizontal centerline.

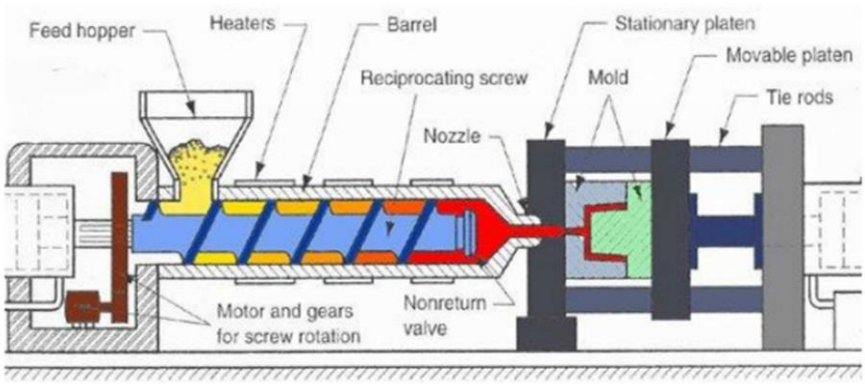


Fig. 11 Horizontal Injection Moulding Machine [3]

Fig. (11) shows schematic diagram of horizontal plastic injection moulding machine. Clamping unit, injection unit and drive unit are the main units of the machine. When the molten resins are injected into mold cavity at high pressure it results in high forces which may lead to opening of the mould to avoid this,clamping unit is used to keep the mould in closed position by the use of clamping devices. Low clamping force may result in material spillage or deformed shape of the product. The function of the clamping unitis to hold, close and open the mould during the operation. Purpose of injection unit is to inject molten granules into the mould cavity using injection nozzles. Power to perform injection and clamping operations is provided by drive unit. Parameters considered in mould designing are runner system, gate location, sprue design, selection and location of the cooling channel.
The plastic resins are fed into the hooper either manually or by automated system. Then the resins flow under gravity through barrel into the heating chamber. The reciprocating screw extends from hooper to the injection chamber. Heating bands are provided along the length of the screw which melts the plastic. Due to the reciprocating motion of the screw, the molten plastic gets injected into the mould cavity. The plasticflows into the mould cavity through sprue, runner and gate. From the injection nozzle the molten plastic flows through sprue into the runner, which then directs the plastic into the mould cavity through gate. Cooling channel is used for rapid cooling to reduce the manufacturing cycle time. When the plastic gets solidified the mould

opens and the final product is ejected.

VI. Conclusion

From this project it is concluded that a protection cap of optimum material is manufactured to satisfy customer requirement. The manufactured cap fulfills the requirement of protecting the edges of the stub shaft while transportation and handling. Considering the mechanical properties of the cap, to make the capcost effective and of good quality, low density polyethylene (LDPE) is the best suited material for the protection cap. Earlier, while transportation and handling the edges of the stub shaft were used to get damaged which leaded to big loss for the company. However, the protection cap served the purpose of protecting the edges of the stub shaft, which minimizes the loss for the company. Although plastic injection moulding is a complex process but the product can be manufactured with lesser defects by controlling the process parameters.

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References

[1] R.M Khan , G. Acharya, "Plastic Injection Molding Process and Its Aspects for Quality: A Review", 3(4):66-70, 2016.

[2] Y. C. LAMY, L. Y. ZHAIY, K. TAIY and S. C. FOKY, "An evolutionary approach for cooling system optimization in plastic injection moulding", Vol. 42, No. 10, 2004.

[3] P.K. Mulge , Dr S.S. Kalashetty, "A Brief Literature Review on Optimization of Plastic Injection Moulding Process Parameters for Various Plastic Materials by using Taguchi's Technique", Vol. 8, Issue 07, 2019.

[4] G. Singh ,A. Verma, "A Brief Review on injection moulding manufacturing process", 5th ICMPC, 2015.

[5] K. Jain, D. Kumar, S. Kumawat, "Plastic Injection Molding with Taguchi Approach – A Review", Vol. 2, Issue 5, 2013.