View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by Elsevier - Publisher Connector

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 64 (2013) 1310 – 1319

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference On DESIGN AND MANUFACTURING, IConDM 2013

Design and Fabrication of an Injection Moulding Tool for Cam Bush with Baffle Cooling Channel and Submarine Gate

S.Selvaraj[a]*, P.Venkataramaiah[b]

[a] *Research Scholar, Department of Mechanical Engineering, Sri Venkateswara University College of Engineering and Senior Lecturer, Department of Tool & Die Making, Murugappa Polytechnic College,Chennai, ,India-600062*

[b] *Associate Professor, Department of Mechanical Engineering, Sri Venkateswara university College of Engineering, Tirupati, Andhra Pradesh, India-517502.*

Abstract

This research works is focused on design and fabrication of an automatic injection moulding tool for production of CAM BUSH which is used in electrical engines as a connector. An injection mould is a tool which is used for production of plastic components in large numbers in a short span of time. The moulding tool consists of the Top plate, Cavity plate, Core plate, Spacer blocks, Ejector plate and the Bottom plate. In this work, six core pins and six ejector pins are provided on injection mould because the required cam bush has six indexing holes. The material, Oil Hardened Non-shrinking Steel(OHNS) for the core and cavity, EN353 for the guide pillar, guide bushes, core pins, ejector pins, locator ring and the sprue bush and Mild Steel for other plates are selected. The elements of injection moulding tool have been designed, fabricated and assembled. Submarine gate and Baffle circular hole cooling system has been provided in the moulding tool to increase the productivity and good surface finish. The required Nylon-66 Cam bush component is produced with this moulding tool by properly controlling the various parameters of injection moulding machine.

© 2013 The Authors. Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and peer-review under responsibility of the organizing and review committee of IConDM 2013

Keywords: Injection Moulding Tool, Injection moulding machine, core plate, cavity plate, baffle cooling, submarine gate;

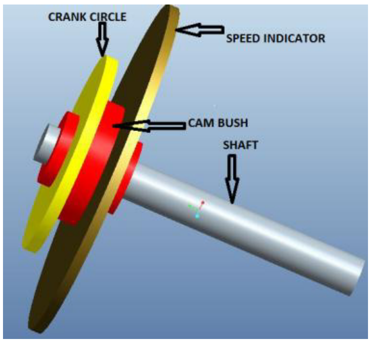
* Corresponding author. Tel.: +91-944-410-4753;
E-mail address: selvas99@gmail.com

1877-7058 © 2013 The Authors. Published by Elsevier Ltd. Open access under CC BY-NC-ND license.
Selection and peer-review under responsibility of the organizing and review committee of IConDM 2013
doi:10.1016/j.proeng.2013.09.212

1. Introduction

Plastics are man-made materials. They are less brittle than glass, yet they can be made equally transparent and smooth. They are light weight and at the same time possess good strength and rigidity. They resist corrosion and the action of chemicals. They can be easily moulded to different shapes. Commonly used thermoplastic materials are Polystyrene, Nylon 6,Nylon 66,P.V.C ,Polypropylene, etc. Mould making is an important role in plastics industries because the related products constitute more than 70% of the components in consumer products. Injection moulding is a complex but highly efficient means of producing a large variety of thermoplastic products and has many advantages, such as short production cycles, excellent surfaces of the products, and has no secondary operations, good results in moulding of complicated shapes[1-3]. The design and fabrication of injection moulding tool for complex plastic products is play a wider role to meet the industrial demand especially in plastic industries. Hence, there is a demand in the industry for plastic injection moulding techniques capable of producing plastic parts[3-6]. Literature review reveals that there is a lack of research on design and fabrication of injection moulding tool for complicated plastic components. Hence, this paper focused on design, fabrication of Injection moulding tool with baffle type cooling channel and submarine gate for production of cam bush.

Cam Bush is used as a indexing device in ON/OFF Load Tap changer device of high voltage transformer and serves as the connector between the indexing head and the power changing gears. The indexing head is connected to the gear by means of the shaft which is attached with the Cam Bush as shown in Fig 1. The cam bush has two tail ends, one side is press fitted to the indexing crank circle and the other side is fitted to the driving mechanism. Each hole has different driving mechanism, when the indexing circle rotates and the crank pin engaged in the first hole the first driving mechanism turns on. The different type of power is obtained by means of changing the index position. Cam bush serves as the connector between crank circle and the gears. It is provided in the power changing indexing mechanism. The indexing crank circle has many indexing holes, but the mechanism has 6 drive, so the cam bush with 6 holes is provided in between the crank circle, speed indicator wheel and the shaft which is intersected in center and connected to the gears. So the cam bush ensures proper indexing. NYLON-66 is selected as a component material because NYLON-66 has good toughness, high tensile strength, elasticity, good heat resistance, excellent wear resistance, wrinkle proof and excellent chemical resistance.



Crank circle Cam bush Speed indicator Shaft

Fig 1 Cam bush

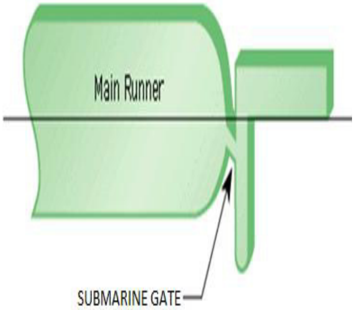


Fig 2(a) Submarine gate

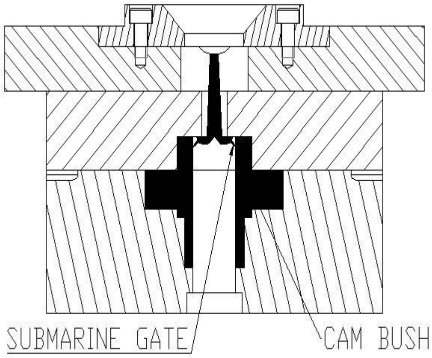


Fig 2(b) Mould with Cam bush and submarine gate

2 Design of injection moulding tool for cam bush

2.1. Modelling and design of Cam bush

It is decided to design and fabricate fully Automatic Injection moulding tool with ejectors assembly, baffle cooling channel and submarine gate. First, cam bush is modelled using ProE according to standard specifications as shown in Fig 4(a) and Fig 4(b).Based upon the model of cam bush, the different parts of the injection moulding tool is identified and a model of injection moulding tool is created in ProE 5 wildfire. For design of injection moulding tool for cam bush, the following steps are used.

i) Volume and Weight of cam bush

Volume of the component (from ProE model) = 57.89 cm^3
Density of plastic material (Nylon66) = 1.14g/cm^3
Weight of the component = Volume X Density= 57.89 X 1.14 = 66g

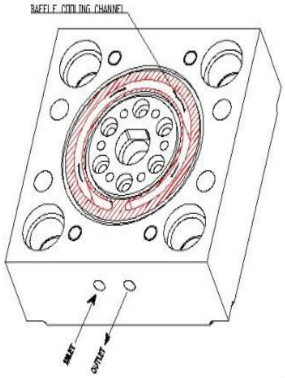


Fig 3 Baffle cooling in core plate

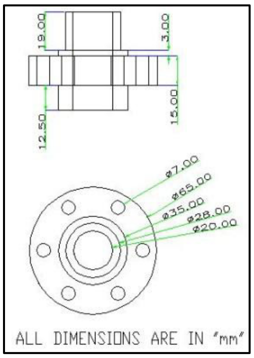


Fig 4(a) Cam bush in 2D with dimension

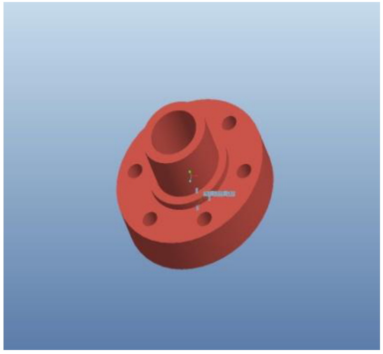


Fig 4(b) model of Cam bush in 3D

ii) Shot weight

Shot weight of the mould = Total weight of the component + Total weight of the feed system
Total weight of the component = (weight of component x No. of cavities) = (1 x 66) =66g
Total weight of the feed system = 10% of the component weight = [(10/100) x 66] = 6.6g
Thus the shot weight of mould = (66+6.6)g = 72.6g

iii) Injection Moulding Machine

The 'Optima 75' fully automatic injection moulding machine was selected based Mould base size, Maximum daylight, Shot weight and Injection pressure to produce Nylon66 Cam bush components.

2.2 Shrinkage allowance

Shrinkage is inherent in the injection moulding process. Shrinkage occurs because the density of polymer varies from the processing temperature to the ambient temperature. The shrinkage factor will depends on Plastic material, Processing condition, Product design, Mould design. Shrinkage allowance of Nylon 66 is 0.5% considered. The dimensions of the cam bush has been modified with considering shrinkage allowance as shown in Table 1. This total dimensions are incorporated in the mould designing of core and cavity plate.

Table 1 Dimensions of Cam bush with shrinkage allowance

S. No	Component Details	Actual dimension in mm	0.5% shrinkage allowance in mm	Total dimension in mm
1	Diameter 1	65	0.325	65.325
2	Diameter 2	35	0.175	35.175
3	Diameter 3	28	0.14	28.14
4	Diameter 4	20	0.10	20.10
5	Diameter 5	7	0.035	7.035
6	Length 1	15	0.075	15.075
7	Length 2	15.5	0.0775	15.5775
8	Length 3	19	0.095	19.095

2.3 Design of feed system

The flow way that connects the nozzle of the injection moulding machine to the cavity is called "feed system". The feed system consists of a sprue, runner and gate. The design of feed system is discussed in the following

2.3.1Design of runner

The main consideration for the designer to design a mould is the shape and cross section of the runner, the size of the runner and Layout of the runner. The different shapes of the cross section of the runner are fully round, semi-circular, trapezoidal, modified trapezoidal, hexagonal, square and rectangular. Semi-circular cross section type runner is selected because it is easy to machine.

Runner diameter calculation:

$$D= (\sqrt{W} \times \sqrt[4]{L}) / 3.7$$

L- Length of Runner = 20mm; **W**- Weight of Cam Bush= 66g

Hence, **D**- Diameter of runner = 4.65 mm

2.3.2 Submarine Gate:

Submarine gate is a type of edge gate where the opening from the runner into the mould is located below the parting line or mould surface, whereas conventional edge gating has the opening machined into the surface of the mould. As shown in Fig 2(a) and Fig 2(b), the angular pin shaped electrode is sparked in the core pin on both sides for equal material flow. The gate is at the angle of 45 degree, even though the gate has a large opening, the gate diameter is angularly decreasing and at the tip, it is 1.25mm. The submarine gate is selected because the gate mark on the component is comparatively lower than the edge gate. The minor diameter of the component is sliding area if the gate marking is higher the sliding is difficult.

2.4 Details of injection moulding tool

Mould or die are the common terms used to describe the tooling used to produce plastic parts in moulding. The various types of injection moulds are Two plate mould, Three plate mould, Split cavity mould, Stripper plate mould and Hot runner mould. Here for these component two plate moulds is selected by considering cost and economical factors. The different parts of injection moulding tool with materials is listed in Table 2.

Table 2 Bill of materials of Injection Moulding Tool

S.NO	MOULD ELEMENT	MATERIAL	QTY
1	CAVITY PLATE	EN 353	1
2	CORE PLATE	EN 353	1
3	CORE BACK PLATE	MS	1
4	EJECTOR PLATE	MS	1
5	EJECTOR BACK PLATE	MS	1
6	SPACER BLOCKS	MS	2
7	BOTTOM SUPPORT PLATE	MS	1
8	TOP PLATE	MS	1
9	BOTTOM PLATE	MS	1
10	CORE PIN	EN 353	6
11	GUIDE BUSH	EN 353	4
12	GUIDE PILLAR	EN 353	4
13	SPRUE BUSH	EN 353	1
14	LOCATOR RING	EN 353	1
15	EJECTOR GUIDE BUSH	EN 353	1
16	M6 ALLEN SCREW	STD	6
17	M10 ALLEN SCREW	STD	8

I Fixed half

The mould parts are fall into two section or halves. The half attached to the stationery platen of the machine (cavity half) is termed as fixed half. Cavity plays as a fixed half because it has the flow system. It consists of following elements or parts.

2.4.1. Top plate

It is the front face of the mould, in which the locator ring and the sprue bush, is fitted as shown in Fig 7(a). It is fastened with the cavity plate. Mild steel material is selected because it just serves as the support to the mould.

2.4.2. Cavity plate

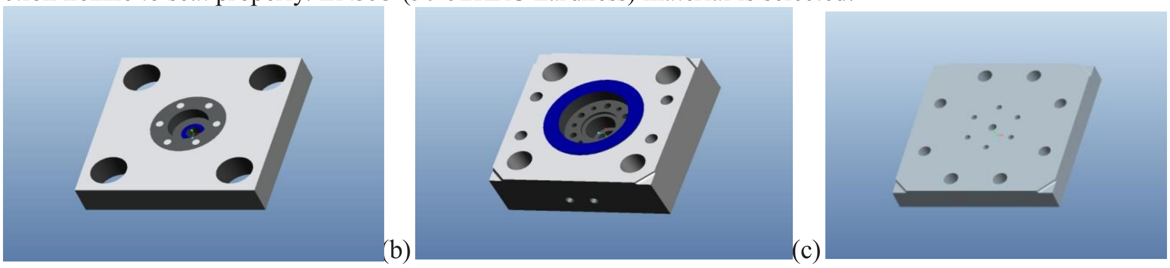
As shown in Fig 5(a), the shape of the component is formed on the cavity plate. The molten plastic enters into the cavity and forms into its shape. Guide bush is fitted on the four corners of the plate. OHNS (35-38HRC hardness) material is selected, because it has to withstand the high heat.

2.4.3. Sprue bush

During the injection process plastic material is delivered to the nozzle of the machine as a melt: It is then transferred to the impression through a passage of 3mm. This passage is a tapered hole within the bush. EN353 (50-52HRC hardness) material is selected

2.4.4. Locator ring

It is provided on the plate to ensure the proper location of the injection machine nozzle. The bottom of the ring is fastened to the top plate and the top portion is fixed to the machine. It has a taper passage within the ring for the injection nozzle to seat properly. EN353 (50-52HRC hardness) material is selected.



(a) (b) (c)

Fig 5 Model of (a)Cavity plate (b) Core plate (c) Core retainer plate

II Movable half

The other half of the mould attached to the moving platen of the machine (core half) is known as the moving half. It has the ejection system in it. It consists of following:

2.4.5 Guide bush and Guide pillar

To mould the even walled component it is necessary to ensure that the cavity and core are kept in alignment. This is done by incorporating Guide pillars on core plate and Guide bush on the cavity plate.EN353 is selected and hardness for guide bush is 50-52HRC and for guide pillar is 20-25HRC.

2.4.6 Core plate

The inner profile of the component (holes) which projects from the core as shown in Fig 5(b). It has Guide pillar arrangements reference to the guide bush on cavity plate .It also has push back pin holes, reference to the ejector plate. OHNS (35-38HRC) material is selected, because it has to withstand the high heat and shrinkage.

2.4.7 Core retainer plate

This plate is assembled on the back of the core plate to arrest the degree of freedom of the core pin as shown in Fig 5 (c). It has the push back pin and ejector pin holes, to give the movement the ejection system. Mild steel material is selected because it just serves as the back plate to core plate.

2.4.8 Push back pin

It is provided on the ejector plate for the easy movement of the ejection system. It also ensures the ejection stroke is fully completed and prevents the ejector pin breakage. EN 353 material is selected and hardness is maintained at 50-52HRC.

2.4.9 Core pin

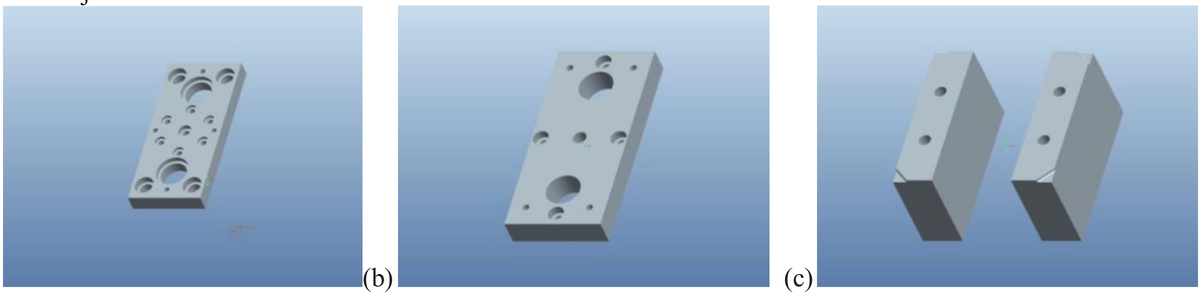
Core pins are used to produce holes in the component. In this mould Centre core acts as a runner system. EN 353 material is selected and hardness is maintained at 50-52HRC.

2.4.10 Spacer block

Spacer blocks are provided on the two sides between core back and bottom plate. The thickness of the spacer block determines the length of the ejection stroke as shown in Fig 6(c). It leave 3mm gap from the ejector plate on both the sides. Mild steel material is selected as it has no working other than providing ejection gap.

2.4.11 Bottom plate

It is the base plate of the mould. It is fastened with the spacer blocks, core retainer plate, and the core plate. In the block center it has a 28mm hole for the ejection rod to go through it as shown in Fig 7(b). M.S material is selected because it just serves as the bottom of the mould



(a) (b) (c)

Fig 6 Modeling of (a) Ejector plate (b) Ejector retainer plate(c) Spacer blocks

III Ejection system

It has ejector plate, retaining plate and the ejector rod. Ejector assembly is the part of the mould to which the ejector element is attached. This system is placed between the spacer blocks.

(i) Types of ejection

When a moulding has internal form the moulding as it cools will shrink on to the core and some positive type of ejection is necessary. The basic ejection techniques are Pin ejection, Sleeve ejection, Blade ejection, Valve ejection and Stripper plate ejection. Pin type ejection is selected because it is easy to incorporate in mould.

(ii) Pin Ejection

This is the most common type of ejection. It is simplest to incorporate in the mould. With this particular technique the moulding is ejected by the application of a force by a circular steel rod called an ejector pin. The ejector pin is headed to faciliate its attachment to the ejector plate assembly. The ejector retainer plate and ejector plate is fastened together. The hole is provided in the bottom plate. The length of the ejector pin is machined equal to the cavity surface as the molten plastic enters and solidification takes place. One end of the ejector rod is screwed to the ejector retainer plate and the other end to the machine. The ejector rod pushes the ejection system forward and thus the ejector pin pushes the moulding from the cavity

2.4.12 Ejector pin

It is a lengthy pin provided on the ejector plate to the core plate for the ejection of the component.EN353 material is selected for the ejector pin and hardness is maintained to 50-52HRC.

2.4.13 Ejector rod

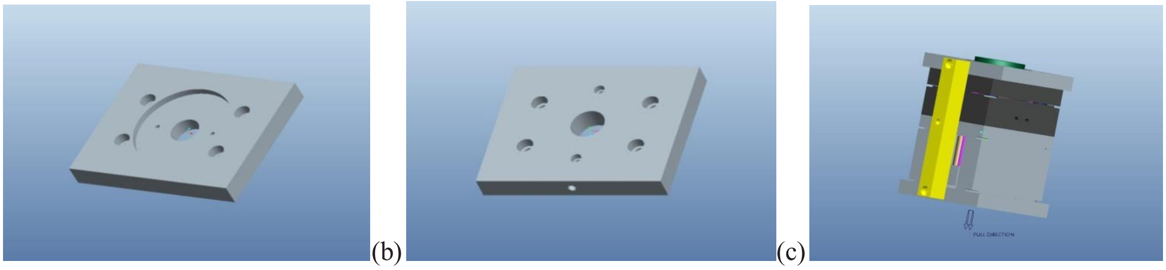
One end of the ejector rod is threaded and screwed into the ejector plate. In this design the ejector rod functions as the actuating member. The other side of the ejector rod is fastened to the machine.EN353 material is selected to avoid cracking.

2.4.14 Ejector plate

This plate has the arrangements for ejector pins and push back pins. The purpose of this member is to transmit the ejector force from the machine to the moulding via ejector element. The ejector plate is 16mm thick to avoid bending as shown in Fig 6(a). Mild steel material is selected because it is not has main function.

2.4.15 Ejector retainer plate

This plate is securely fastened to the ejector plate as shown in Fig 6(b). The bottom of the ejector plate has the proficiency for rest buttons to prevent bulging. The ejector rod is screwed to the retainer plate. Mild steel material is selected because it just serves as the back plate to ejector plate.



(a) (b) (c)
Fig 7 Modelling of (a) Top plate (b) bottom plate (c) assembly

2.5 Selection of mould material

2.5.1 Mild steel

Mild steel is the most common form of steel because its price is relatively low. Mild Steel has relatively low tensile strength, but it is cheap and malleable. Surface hardness can be increased through carburizing and its easy machinability. Hence, mild steel is used for top plate, bottom plate, core back plate, ejector plate, ejector back plate, spacer blocks and tie bars.

2.5.2 OHNS

Oil Hardened Non-shrinking Steel(OHNS) has a chemical composition of 1% carbon, 0.9% manganese, 1%chromium and 0.2% of vanadium. It can be used in high heating areas. So as we using OHNS material as a core and cavity plate to withstand the heat and dimension changes. It has good surface finish. OHNS is selected for core plate and cavity plate.

2.5.3 EN 353

EN-353 is a Nickel chromium case hardening steel. It gives a very hard surface and retaining a high degree of toughness. It also having a very high wear resistance. So it is used as a material for guide bush and guide pillars. Good dimensional stability.EN353 material is used for Ejector pins, core pins, Push back pins, Sprue bush, guide pillars and guide bushes.

3. Fabrication of injection moulding tool

3.1 Machines used

The following machines are used for making the various elements of the injection moulding tool.

3.1.1 Conventional machine

Milling machine is used to make core back plate, ejector plate, ejector back plate, top plate, bottom plate, and spacer blocks. Surface grinding machine is used to maintain dimension and for finishing operations. Grinding machine is used for grinding works on all plates of injection moulding elements to maintain dimension after shaping. Lathe is used to produce guide pillars, Guide bushes, Core insert, Locator ring and Sprue bush.

Fig 8 EDM
Model : 55-35 (Electronica)
Capacity : 50 Amp
Spark Gap : Min 0.14, Max 0.2

Fig 9VMC
Model : MCV 720 CNC
Travel : 720 X 460 X510
Spindle Motor: X=0.8 N.P, Y=0.8 Np

Fig 10 Injection moulding machine
Model : Optima-75
Shot Weight : 123 Gms
Injection Pressure : 1486 Bar

3.1.2 Electrical Discharge Machining

Electrical Discharge Machining (EDM) sometimes colloquially also referred to as spark erosion, spark eroding, burning, die sinking or wire erosion is a manufacturing process whereby a desired shape is obtained using electrical discharges (sparks) as shown in Fig 8. This machine was used for producing of core pin sizing, ejector pin sizing, and to produce runner and submarine gate on the core pin.

3.1.3 Vertical Machining Center (VMC) MACHINE

Vertical machining center (VMC) is a computer numerical control machine used to fabricate any type of complicated jobs as shown in Fig 9. This machine was used to machine core plate, Ejector retainer plate, cavity plate and top plate.

3.2. Machining process for moulding parts

3.2.1 Cavity plate:

Raw material is taken and dimensions are inspected. The length, breadth and thickness of the plate is maintained by shaping machine and the thickness is maintained by grinding machine. Profile is made using CNC machine. Guide bush and sprue bush are suited in the plate and finally the ends are chamfered to avoid sharp corners. Diamond polishing is done on the profile to get good surface finish on plastic component as shown in Fig 11.

Fig 11 Cavity plate

Fig 12 Core plate

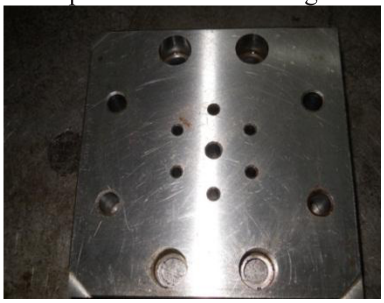


Fig 13 Core back plate

3.2.2 Core plate:

Raw material is taken and dimensions are inspected. The length, breadth and thickness of the plate is maintained by shaping machine and the thickness is maintained by grinding machine. Profile is made using CNC machine. Cooling channel is provided on the backside of the plate. Guide pillar, core pin and Ejector pins are assembled in the plate and finally the ends are chamfered to avoid sharp corners. Diamond polishing was done on the profile as shown in Fig 12.

3.2.3 Core back plate, Ejector pate, Ejector back plate, top plate and bottom plate

Raw materials are taken and dimensions are inspected. The length, breadth and thickness of the each plate is maintained by shaping machine and the thickness is maintained by grinding machine. Each plate is clamped on the DRO milling machine and drilling & reaming works were done on the profile. Counter bore for some of the plates are produced and finally the ends are chamfered to avoid sharp corners as shown in Fig 13,14,15,16 and 17.

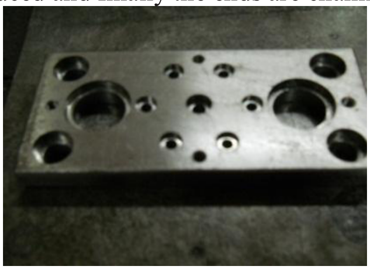


Fig 14 Ejector plate

Fig 15 Ejector back plate

Fig 16 Bottom plate

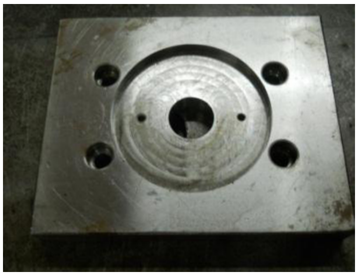


Fig 17Top plate


Fig 18 Push back pin and Elector pins

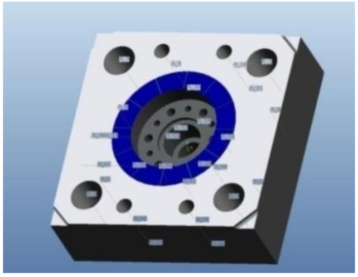


Fig 19 Vents on core plate

3.2.4 Core pin and ejector pin

Raw material is taken and dimensions are inspected. Lathe and Cylindrical grinding works are done on the pin as shown in Fig 18. The thickness is maintained by grinding machine and the pin is clamped in the EDM machine. Runner and submarine gate is sparked on the plate using electrode.

3.3 Relief on parting surface

The purpose of this relief is to increasing the parting surface, if there is any deviation on the plate the flash may occur on the parting surface. By because of the relief the deviation will not affect the parting surface. Relief was provided on the cavity and core plate to increase the parting area. The relief in the cavity plate, diameter of 110 mm, 0.5 mm deep was machined on the top of the cavity plate and core plate.

3.4.Venting

Venting is provided on the mould to release the air from the mould after injection. Ground recesses on the parting line of 0.05 deep by 6 to 12mm wide, extended fully from the cavity. The depth of the vent is slightly increasing as it diverges from the cavity, so that the vent will be self-cleaning. Installation of vents on the parting line improves moulding quality. As shown in the Fig 19, the air vent is machined on the relief of both the core plate and cavity plate of 0.7mm wide and 0.05mm deep at the starting point from the cavity, at the end of the relief air vent is 0.7mm wide and 0.2mm deep.

3.5 Baffle circular cooling channel

It is the typical cooling channel which is often used to cool the cylindrical components. As the drawing shown in Fig 3, the water enters into the inlet port and reach the cooling channel, cooling water circulates around and leaves at the outlet port. The water is circulated continuously. The slot is machined on the channel, ‘O’ ring is provided to prevent leakage of the component.

3.6 Assembly of injection moulding tool elements

As shown in Fig 7(c) and Fig 20, all the elements of injection moulding tool are assembled with suitable type of fit as mentioned in the Table 3 and blue matching is done by applying ink on any one sides of parting surface of the moulding elements to check the clearance between moving half to fixed of the tool.


Fig 20 Movable half of moulding tool


Fig 21 Fixing the moulding tool

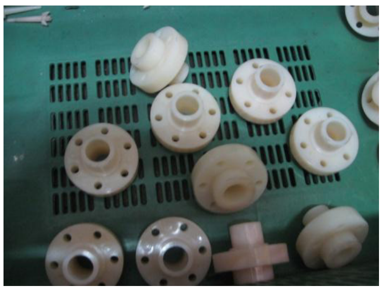


Fig 22 Cam bush components

Table 3 Fits and Tolerance

S.No	Description	Type of Fit	Tolerance
1	Main Guide pillar – Main guide bush	Close running fit	H7 / g6
2	Sprue bush – Cavity plate	Medium drive fit	H7 / m6
3	Core pin – Core plate	Slide fit	H7 / h6
4	Push back pin – Core plate	Close running fit	H7 / g6
5	Ejector pin – Core plate	Close running fit	H7 / g6
6	Ejector Guide pillar – Ejector guide bush	Close running fit	H7 / g6
7	Register ring – Machine platen	Running fit	H7 / f7

Table 4 Process Parameters in Injection Moulding Machine

S.No	Controllable parameters	Value
1	Injection speed(mm/s , %)	90
2	Injection pressure, (Bar)	100
3	Holding pressure (Bar)	40
4	Holding speed (mm/s , %)	30
5	Clamping pressure (Bar)	60
6	Clamping speed (mm/s , %)	80
7	Injection time (Sec)	1.5
8	Holding time (Sec)	2
9	Cooling time (Sec)	60
10	Nozzle temperature (0C)	295

4 Production of cam bush components

The fabricated injection mould tool is fitted as shown in Fig 21 and trial components are produced as shown in Fig 22 by the controlling the various input parameters on OPTIMA 75 Injection moulding machine as mentioned in Table 4. The other conditions are maintained as Refill speed is 90 mm/s, Refill pressure is 140 bar, Shot weight is 65 gram and Pre heat temp is 120^0 C .

5 Conclusions

In this work, cam bus is produced with the use of fabricated injection moulding tool. The following conclusions are drawn from this work.

- The dimensions of the cam bush are checked by 3 D Coordinate Measuring Machine which are in acceptable limit.
- As baffle type cooling channel is provided in the moulding tool, no blow hole defect occurred during the production of Nylon 66 cam bush
- No flash mark or flow line defects were occurred due to selection of proper controllable parameters.

Acknowledgements

The authors would like to acknowledge the staff and engineers of M/s Nutech CNC Private Limited, Athipet, Chennai for their help in preparation of experimental set up.

References

[1] Tang SH, Tan YJ, Sapuan SM, Sulaiman S, Ismail N, Samin R, 2007. The use of Taguchi method in the design of plastic injection mould for reducing war page. J Mater Proc Technol, 182:418–26.

[2] Fu MW,Fuh JYH, Nee AYC,1999. Undercut feature recognition in an injection mould design system. Computer Aided Design,;31:777–90.

[3] Zhai M, Lam YC, Au CK, Liu DS,2005. Automated selection of gate location for plastic injection moulding processing. Polym Plast Technol Eng ;44:229–42.

[4] Rahman WAWA, Sin LT, Rahmat AR, 2008. Injection moulding simulation analysis of natural fiber composite window frame. J Mater Proc Technol,197:22–30.

[5] Huang M, Tai C, 2001.The effective factors in the warpage problem of an injection moulded part with a thin shell feature. J Mater Proc Technol ,110:1–9.

[6] Hassan H, Regnier N, Lebot C, Pujos C, Defaye G. 2009. Effect of cooling system on the polymer temperature and solidification during injection moulding. Appl Therm, Eng;29:1786–91

[7] Selvaraj.S, Venkataramaiah.P, September - Dec (2012). Production of Nylon-6 FR Lever using An Injection Moulding Tool and Identification of Optimum Process Parameter Combination, Inter Jl of Mechanical Engg and Tech (IJMET), Volume 3, Issue 3, pp. 270-284