SETTING OF PROCESS PARAMETERS AND EFFECT OF MOULD QUALITY ON SURFACE ROUGHNESS OF PHARMACEUTICAL CUP OF POLYPROPYLENE

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ABSTRACT

Injection molding and extrusion ranks as one of the key processes for the production of plastics components. It is a rapid process and is bring into utilization to produce bulk of identical products ranging from high precision engineering articles to disposable consumer products. As of late, the production of plastic items has expanded quickly in light of the fact that plastic items are low in price, light in weight and quick for shape framing, along these lines making them more in vogue than the metallic products. As a result of mounting plastics applications, growing customer increased, the quality prerequisites of injection molded items have turned out to be progressively extreme. The setting and optimization of key process parameters are acknowledged as important means to deal with liven up the quality of the molded items. Inappropriate or unseemly settings of parameters normally create quality and production issues. Minute changes of significant molding parameters may give an extensive effect to the plastic product's characteristics and this research paper is also anticipated to lend a hand to the optimization of parameters of vertical plastic injection molding process. In this study, the plastic product has been fabricated using a mould designed in our labs that shows an improved surface roughness which suggests that molding conditions play a vital role in quality of these products.

KEYWORDS: *Process parameters, Polypropylene, Surface Roughness, Optimization, Mould*

INTRODUCTION

Plastic injection molding machines are to a great extent utilized in dealing out of almost all plastics including polypropylene, low-density polyethylene and high-density polyethylene, acrylic, polystyrene and designing plastics and so on. Injection molding machine moulds can be button up in both horizontal and vertical position. The greater part of machines are horizontal machines, however vertical machines are utilized in some applications like insert molding, to take advantage of gravity. Some vertical machines do not require the mould to be fastened. In current time, molding industry weight on great quality items. As to the practical capacity, quality of formed components is imperative. The nature of parts relies upon plastic properties as well as on the procedure parameters or embellishment conditions. Verifiably, ideal process parameters support the quality of items.

Various scientists researched on injection molding machine and proposed distinctive procedures to optimize its parameters for various items having diverse materials. M. V. Kavade and S. D. Kadam applied Taguchi method for improvement of process parameters of injection molding for polypropylene. They took holding pressure and cooling time, barrel temperature, infusion speed, coolant flow rate, injection pressure, holding time, as info factors for productivity as reaction variable (Kavade & Kadam, 2012). Hyoungjun Moon et. al., researched on parameters improvement of injection molding of front board utilizing Taguchi strategy. Taguchi strategy was sent as a computational technique. Vital parameters mulled over to settle deflection issue were cooling pattern and pressing pressure (Moon et al, 2011). Subodh Singh Tomar et al. considered parameters of injection molding utilizing polypropylene of specific grade. Considered process parameters by the researchers were inlet pressure, holding time, infusion speed, cooling time, infusion temperature, and holding pressure. On the other hand, malleable property of the specific plastic was taken into contemplations reaction variable (Tomar et al. 2016). Babur Ozcelik in plastic infusion forming decided the criticalness of injection parameters and mould materials on mechanical behaviors of Acrylonitrile-butadiene-styrene (ABS). The parameters taken were melting temperature, cooling time, injection pressure and packing pressure. Taguchi technique was

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practiced to investigate the signal to noise proportion for mechanical characteristics of ABS and examination of difference was sent to discover the parameters impact on the mechanical properties (Ozcelik et al. 2010)

Wei Guo et. al, did inquire about on the impact of molding conditions on molding process in special molding called micro-cellular injection molding. Time, gas controlling, temperature and weight were considered to reduce weight and dimensional exactness of plastic goods (Guo et al. 2014). Mohammad Sadeghi and Alireza Akbarzadeh dealt with parametric investigation in injection molding sending statistical techniques and IWO algorithm and had the capacity to determine the effects of a range of process parameters as packing time, melting temperature, and packing pressure on polypropylene and polystyrene (Akbarzadeh and Sadeghi, 2011). For thin-shell part Hasan Oktem et. al. utilized Taguchi strategy for streamlining in deciding plastic injection molding process. Distinctive parameters were considered to limit warpage issue identified with shrinkage variety ward of process parameters amid production of thin shell plastic tools (Oktem et al. 2007). S. Rajalingam et. al, discover the ideal embellishment process parameters by utilizing two-level factorial design with focus points. They took injection pressure, mould temperature and infusion speed, which essentially impacts quality, soliciting cost from production and efficiency in injection molding industry (Sokkalingam 2011).

Kuo Ming et. al., took a shot at the response of process variables on lenses optical quality in injection molding. They uncovered that the key procedure parameter that influences the waviness of surface is melt temperature, trailed by packing pressure, mould temperature, and injection pressure (Tsai et al. 2009). Mustafa Kurt et. al. did trial investigation of plastic injection molding. In their test work, impact of a cavity pressure and mould's temperature on quality of conclusive items was tested (Kurt et al. 2009). Shidi Yang acquired 316L stainless steel and 6061 aluminum alloy by using different injection pressure, temperature and speed. After the injection, X-ray tomography was used to scan the green bodies. The reconstruction and projection images shown the different defects obtained by the improper process parameters (Yang et al. 2015). Investigation was carried on the impact of injection parameters for ultrafine WC/12Co carbide powder injection molding on worth of formed compacts. The selected quality characteristics are segregated into flexural quality and thickness and compacts' appearance. Along these lines, the flexural quality was picked as the fundamental quality characteristics for molded compacts. It was proved that the statistical model used to forecast the value of flexural strength of compacts is reliable (Xie et al. 2015). In thin wall plastic injected part warpage is one of the genuine deformities. Here scientists utilized that pressing procedure parameters and dynamic filling are the new plan parameters to play out the streamlining on warpage. By relating with the infusing weight and regular infusion, the upgraded framework shifts with the same recurrence as powerful stream rate during filling, which assumes a fundamental job for the decrease of warpage (Wang et al. 2015). Hence, numerous different researchers have dealt with optimization of parameters of injection molding machine for various materials (Lin and Hsieh 2017, Kitayama et al. 2018, Hamidi et al. 2017, Ozcelik and Erzurumlu 2006, Rosato and Rosato 2012, Chen and Turng 2005).

Up till now, pertinent research studies have been carried out in injection molding process. However, research studies on particular plastic materials are limited. Local manufacturers in Peshawar (Pakistan) were coming across an issue of surface roughness in products of polypropylene (plastic) and none of the optimization technique was being applied to resolve the issue. In this research, optimization of injection molding process is done for polypropylene. Four process variables are taken for this specific plastic in the likes of injection temperature, mould temperature, injection (inlet) pressure and total time for surface roughness which is taken as response. Best possible grouping of process variables is obtained to resolve surface roughness issue. Products were being produced using mould practiced in industry and mould designed and fabricated in our lab, after comparison it has been observed that surface roughness obtained from products that are produced using locally made mould has been decreased in comparison to mould practiced in industry. This suggests that along with process parameters of machine, manufacturing of a mould plays a vital role in quality of these products.

Whatever remains of the paper is requested as pursues: Section 2 delineates the modeling of mould, fabrication and experimental setup while section 3 describes process parameters combinations and their response variable.

Section 4 outlines results and discussion. Section 5 is the last section and it finishes up the paper and features the future prospects.

MOULD MODELING, FABRICATION AND INSTALLATION

Mould is utilized when extensive quantities of parts are to be produced. To satisfy complete product development, mould has additionally been modeled and manufactured. Modeling of a mould has been done by utilizing PTC CREO software. The purpose of modeling and then fabricating a mould is to take in the nuts and bolts of mould making, production of mould models and to gather and assemble the pieces into the mould.

Mould modeling in PTC CREO Software

In the wake of making model, drawings of drag and cope and ultimate drawing of a pharmaceutical glass are likewise generated in CREO Parametric software. Models of drag and cope and the assembly of the generated mould are appeared in Fig. 1, 2 and 3 individually. Cope is planned and designed by the bed of injection molding machine present in our lab. The drag is clamped with the upper part of machine while cope of a mould is clipped with the bed of machine.

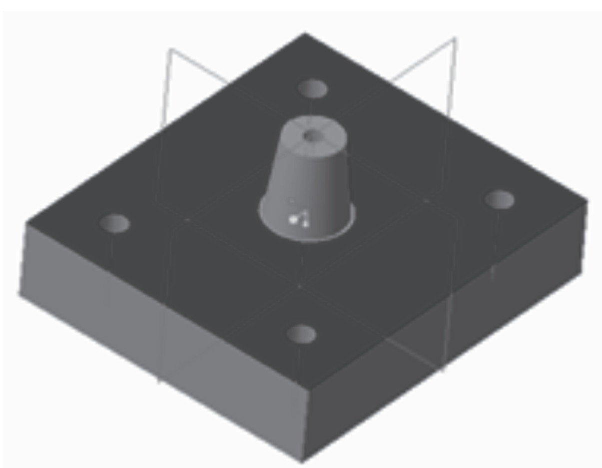


Fig. 1: Model of the cope in PTC CREO

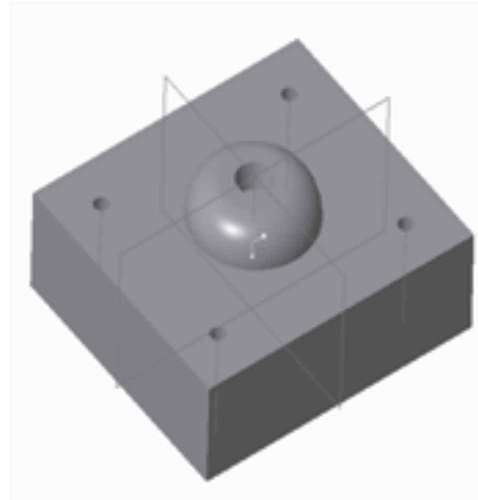


Fig. 2: Model of drag in PTC CREO

Cope and drag are made independently and afterward assembled in software to make a mould.

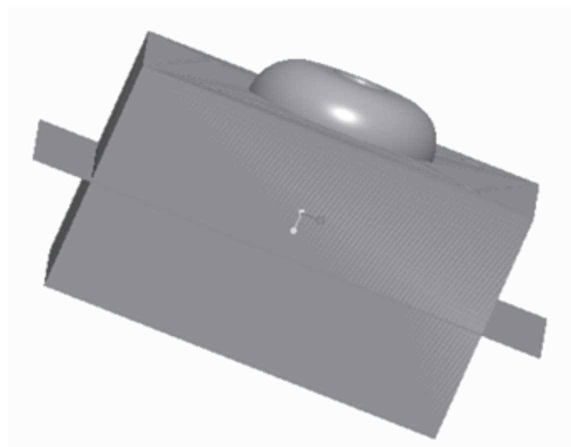


Fig. 3: Complete model of the generated mould

In drag of a mould, different commands are used. Specifically, extrude command is taken into consideration for making various holes and revolve command is used for a dome which will help in holding plunger of the machine. In cope, extrude and numerous different commands are used. Drawings of cope and drag are shown in Fig. 4 and 5 respectively. Dimensions are taken in millimeters (mm).

In top view obviously mould's length is 239.52 mm while its width is taken 212 mm. Bigger diameter of a pharmaceutical glass is 50.8 mm and smaller diameter of the glass is 38.1 mm while its height is measured

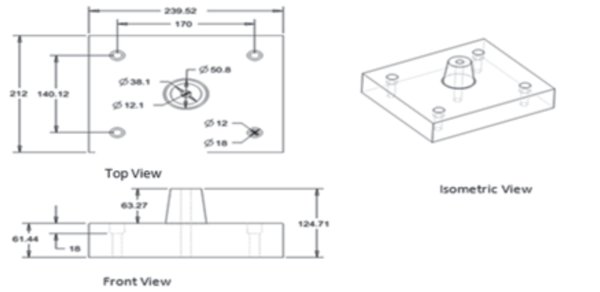


Fig. 4: Drawing of cope of a mould (mm)

as 65.56 mm. Lengthwise distance measured between center holes is 170 mm while widthwise it is measured 140.12 mm. Add up to height of a cope of a mould is 124.71 mm as appeared in front view in Fig. 5. Holes are made where bolts of M-12 is utilized to hold cope to the bed of the machine. Isometric view of cope is additionally given in Fig. 4.

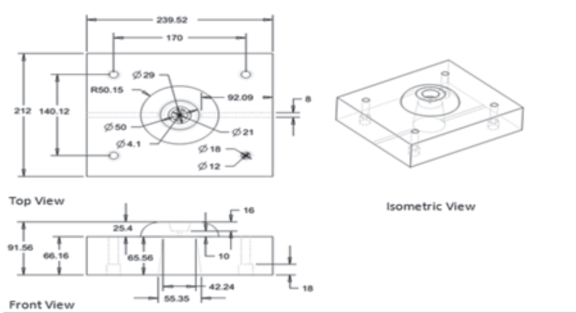


Fig. 5: Drawing with dimensions of a drag of mould (mm) and isometric view as well

In like manner of a cope of a mould, drag of a mould has same width as well as length. Dome in isometric view of Fig. 5 is to grasp plunger of machine and its width is 100.1mm while height is 25.4 mm. Add up to height of a drag of a mould is 91.56. M-12 bolts are utilized for fastening of drag with injection molding machine.

In the wake of making complete shape and developing its drawings, minor changes are brought in the mould to stay away from quality issues in ultimate products. Ultimately, height of glass is diminished, and is then sliced into various parts, and after that drawings of various parts are redeveloped as appeared in Fig. 6 to 10.

Purpose of a base plate/bottom plate is to settle the fabricated mould with the bed of machine just after ejection of an item. Length of this particular part and every

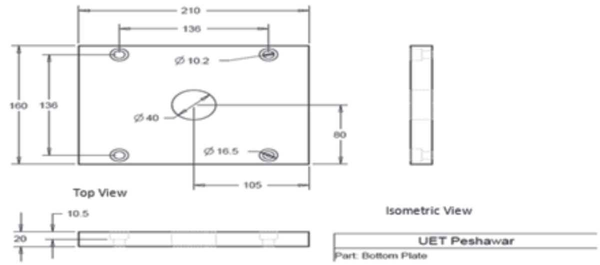


Fig. 6: Drawing of bottom plate of the mould

single other part are planned according to the specifications of the machine. For instance, length of base plate is measured as 210 mm and separation between center holes is taken as 136 mm the long way and widthwise as appeared in top view in Fig. 6. From these four holes, M-10 bolts will pass and brace it with bed of machine. These four openings are in arrangement with the holes of bed. Radius of M-10 bolt is 5 mm. Focus opening or center hole in bottom plate that is appeared in top view is utilized for launch, since power is applied from this hole by ejector stick available in bed of machine.

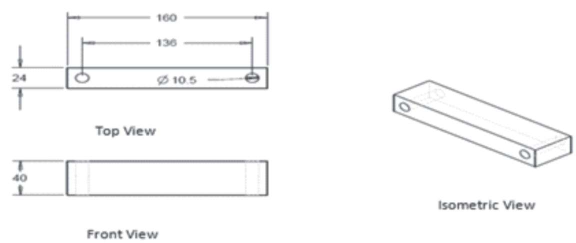


Fig. 7: Drawing of spacer used in the mould

Two spacers are utilized in the mould and their purpose is to keep gap between punch holding plate and ejector plate. Separation between focus openings is 10.2 mm and M-10 bolt is utilized in these plates. Isometric view is likewise appeared in Fig. 7.

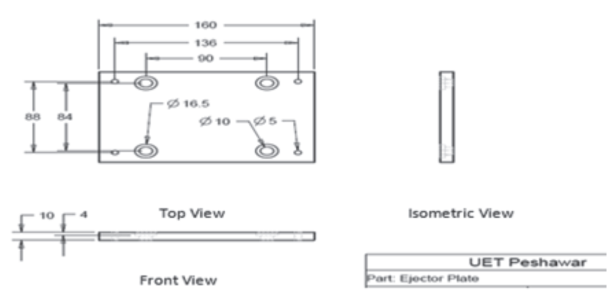


Fig. 8: Drawing of ejector plate used in the mould

This specific plate is set above bottom/base plate and its purpose is to help in ejecting a product and its length is 160mm. In this particular plate four fabricated ejector pins are utilized of breadth 16mm, which ultimately will help in ejecting a product. Height of the four pins is 16 mm. Four littler bolts of 6 millimeter (mm) are utilized in ejector plate to associate it to ejector back plate. It is littler in size than the majority of alternate plates aside from spacer. Also, this plate is balanced in the middle of two spacers.

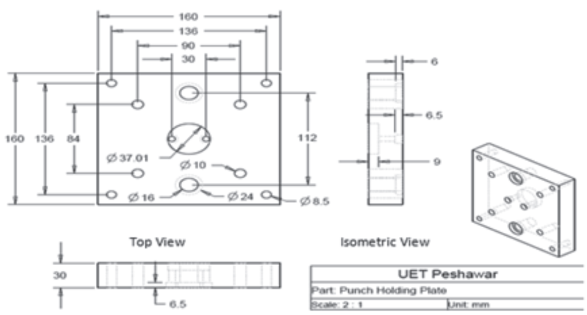


Fig. 9: Drawing of punch holding plate used in the mould

This particular plate is set above spacers as well as ejection plate to grasp a punch and is to be settled in cavity plate. Four M-10 bolts are utilized to hold a plate and two M-6 bolts are utilized in the focal point of punch holding plate to hold punch inside it. Four M-10 pins utilized in ejector plate will likewise go through this plate. Two required holes have been created in punch holding plate for pins which goes through stepper plate. The pins are utilized to hold distinctive parts from one another amid opening of a mould to eject item. Different views are also appeared in Fig. 9.

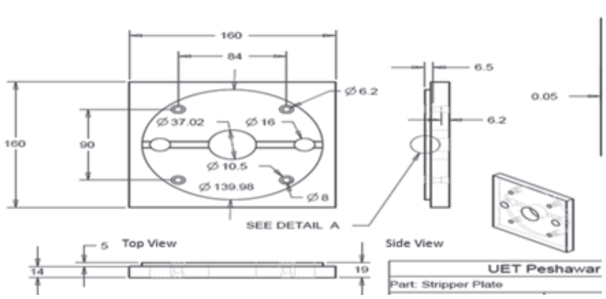


Fig. 10: Drawing of stepper plate used in the mould

Stepper plate is another straightforward part which throws out a piece of core to get ready mould for next shot. Guiding pins going past punch holding plate will likewise go through this plate as well as cavity plate. Stepper plate has similar dimension to punch holding plate. Center point through which punch go inside the cavity plate is 5.25 mm in radius. Four M-8 bolts are settled in external four openings of diameter 8 mm. Side, front and isometric drawings of this plate are appeared in Fig. 10. Thus cavity back plate is settled to the upper piece of a machine after ejection amid opening of mould. Likewise, drawings of cavity back plate and cavity plate are generated.

Ultimate model of the mould is shown in Fig. 11 which is to then fabricated using milling machine and then is to be installed in injection molding machine for parameters optimization for a product made of polypropylene.

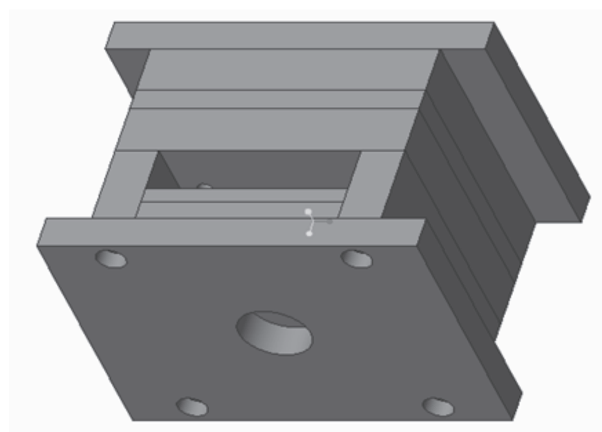


Fig. 11: Complete model of a mould in PTC CREO

The exploded view of the mould with different parts and their arrangement is given in Fig. 12.

The plunger of machine interacts with cavity plate and which is further braced with upper segment of the machine. Material is infused from plunger of machine which goes past cavity plate and gets to punch holding plate. Amid closing of the mould, solidification of products happens. After solidification of product, ejector plate put force on punch holding plate which powers mould to open. Finally the product is launched out.

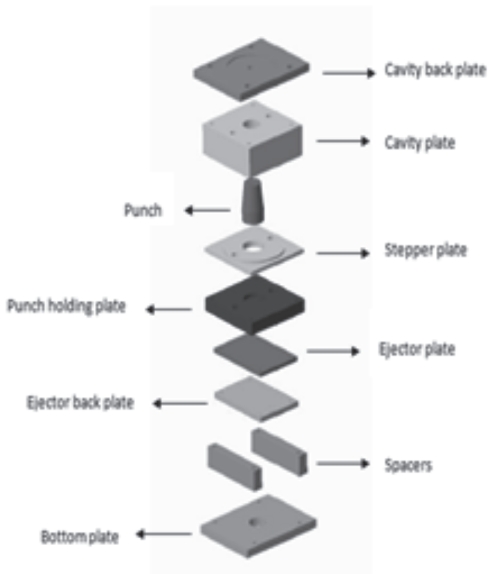


Fig. 12: Exploded view of a mould with parts and their arrangement

Mould fabrication in our lab using 5-axis CNC machine

In the wake of generating drawings in software, same drawings are then communicated with CNC five-axis milling machine through program developed from the drawings. Fabrication of a mould in itself on CNC milling machine is an extremely troublesome activity. After program communication with CNC milling machine, diverse process parameters are chosen. Two process parameters are explicitly focused, cutting instrument's speed is taken as 1500rpm while its feed is taken as 80mm/min while cutter diameter is taken as 20mm and is given in Table 1.

Table 1: Two input parameters and their values

1	Treatment 1	Speed of cutter	1500 rpm
2	Treatment 2	Feed of cutter	80 mm/min

Amid expulsion of extra material, speed and feed of cutting instrument is kept up steady as changes in speed and feed causes vibrations in different parts of a machine. The material of fabricated mould is steel (Mild) which is commonly utilized in market and the reason of choosing steel is the attainability of this specific material in the market. Cutting task of additional material evacuation is appeared in Fig. 13.

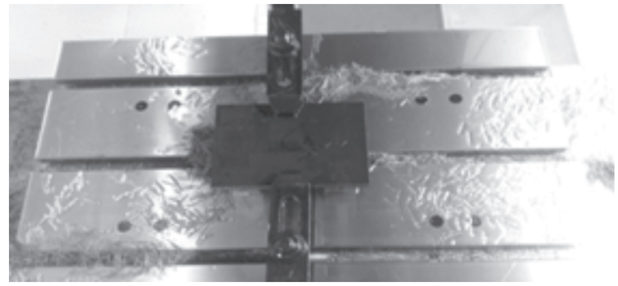


Fig. 13: Removal of excessive material from steel mould

After removal of extra material, the same tool is brought into use for facing of different plates therefore, feed and cutting speed are kept unvarying for facing of almost every plate. Facing of plates can be seen in Fig. 14.

After facing, machining is being done on various components using different cutting tools and the fabricated mould is given in Fig. 15.

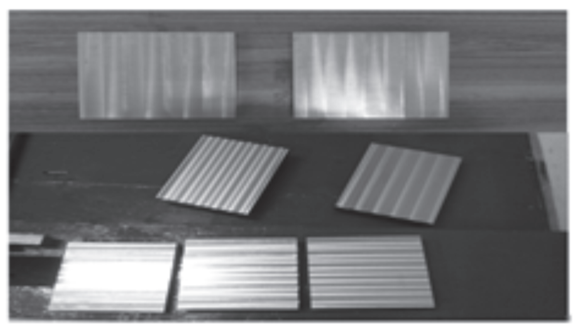


Fig. 14: Facing of various plates of a mould

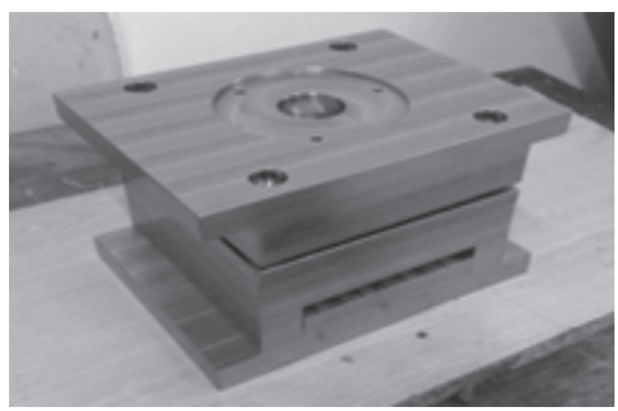


Fig. 15: Mould after fabrication

Mould installation and experiments in Injection Molding Machine

When the mould is manufactured through CNC machine, it is fixed in injection molding machine for development of products and the machine is given in Fig. 16.

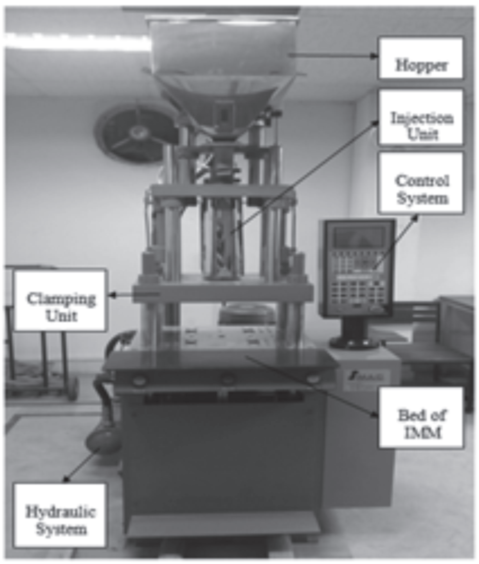
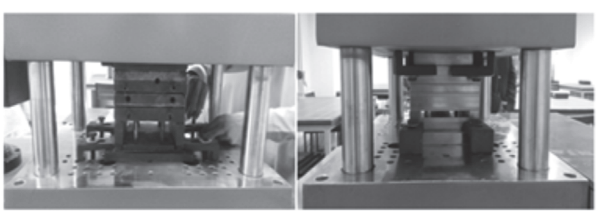


Fig. 16: Plastic injection molding machine

Clamping of both moulds is given in Fig. 17. Injection molding has four different phases in a cycle (Clamping, Injection, Cooling and Ejection).



Clamping of mould practiced in industry Clamping of locally made mould

Fig. 17: Clamping of both moulds in the Injection molding machine

Molten plastic is poured with the assistance of a hopper to the injection part of molding machine. Plastic goes towards the mould and the heat surrounding the barrel and the pressure melt the plastic. It can be observed in Fig. 18 that plunger is prepared to infuse material in a mould. The amount of injected matter is called as shot. Plastic material inside the mould begins to cool and subsequent to cooling it will become hard and will achieve the required profile. Amid cooling, the solidified product might shrink marginally. Cooling time is generally calculated approximately from the wall thickness of the product and thermodynamic characteristics of the plastic material.

Ejection phase is last and final phase and is completed with the ejection system of the machine. As the part sticks to the cavity of the mould after solidification, pressure is applied to drive it out and mould is closed again for further production. In Fig. 19 it tends to be seen that the mould is open and item is being launched out.

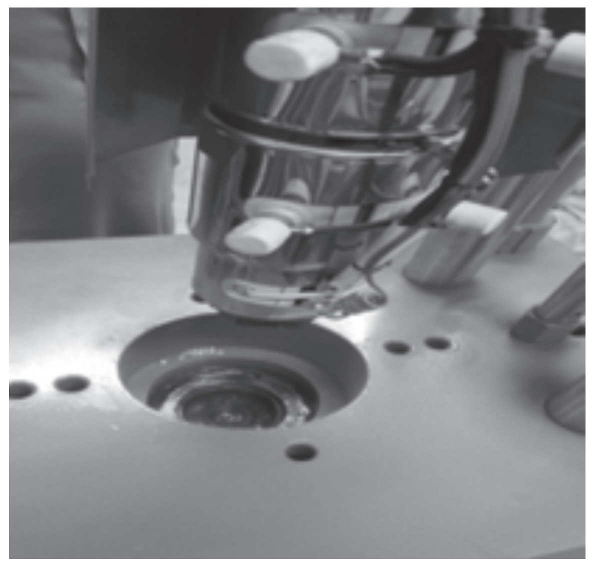


Fig. 18: Injection of plastic in a mould

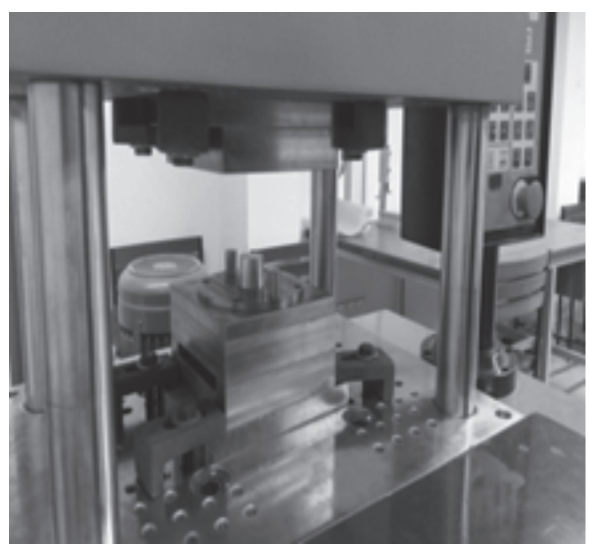


Fig. 19: Ejection of product after solidification

Hence, complete stages of experimental setup are shown in above given figures i.e. injection molding process and its different stages which are necessary for parametric study.

Process Parameters Combinations and their Response Variable

Experiments having two or more than factors usually come across time and again. Full factorial is one of the ways to perform such type of experiments. In this type of cases, all feasible combinations of process variables are investigated in each and every replicate of test. The only way of systematically investigating interactions between different factors is full factorial experiments.

In this research, four parameters are selected for optimization. The number of taken parameters is injection temperature, mould temperature, injection pressure and total time. After that, three levels of each factor are considered, which led to eighty one (81) runs (number of experiments). Surface roughness is treated as a response variable. Result obtained from MINITAB is shown below in Table 2;

In Table 2, Factors 4 suggests that total numbers of factors considered are four and total runs 81 indicate that experiments to be carried out is eighty one and levels of

Table 2: Results deduced from full factorial design technique

Sr. No	Full factorial design
1	Factors: 4
2	Number of levels of each factor : 3
3	Total runs: 81

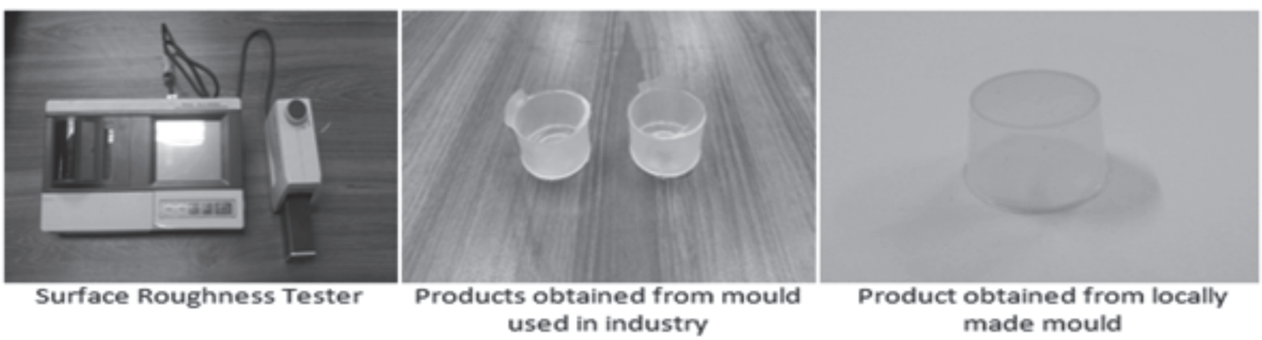


Fig. 20: First picture represent the surface tester, second one is the products fabricated in industry and the third picture is the product fabricated in injection molding machine in our lab

Table 3: Differences in surface roughness of cups made from two different moulds

Sr. No	Treatment-1	Treatmen-2	Treatmen-3	Treat-ment-4	Response of industrial mould	Response of locally made mould
	Temperature (Ċ)	Pressure (bar)	Total Time (Sec)	Mould Temperature (Ċ)	Surface roughness obtained from cups of industrial mould (µm)	Surface roughness obtained from cups of locally made mould (µm)
1	200	50	45	50	0.45	0.4
2	190	50	45	50	10.52	3.21
3	190	55	45	65	1.23	1.11
4	190	45	40	80	0.545	0.51
5	190	45	40	65	0.12	0.05

each parameter taken is three. The required experiments determined are performed on vertical plastic injection molding machine. Surface roughness is measured on portable surface roughness tester. The tool and products obtained from both moulds are shown in Fig. 20.

The measured surface roughness from the products obtained from two different moulds has been shown in Table 3 and for each and every experiment it is given in Appendix 1.

Here it is clear from Table 2 that measured surface roughness of the first five experiments has been highlighted both for mould practiced in industry and locally made mould. Table 3 and appendix 2 provides the complete details regarding the combination of four parameters (input variables) for each experiment and their corresponding surface roughness value for products obtained both from mould practiced in industry and locally made mould.

RESULTS AND DISCUSSION

Graph is drawn for all experiments runs against subsequent surface roughness depicted in Appendix 2. It can be observed that random variation of all the above four mentioned parameters sources a general trend in surface roughness. Hence, there is a random increase or decrease of surface roughness of a product. Experiments are taken on X-Axis (abscissa) whereas surface roughness on Y-Axis (ordinate) as shown in Fig. 21.

The measured minimum surface roughness obtained from a product using portable surface roughness tester is 0.12 µm (Experiment 5) depicted in Appendix 2 and maximum value is 21.5µm (Experiment 29) depicted in Appendix 1. It is clear from Fig. 21 as well that surface roughness is varying very much due to quality issues of moulds used in industries. Similarly, graph is drawn for all the experiments and their subsequent surface roughness of products produced using locally made mould. Taking experiments on X-Axis (abscissa) whereas surface roughness on Y Axis (Ordinate) as shown in the Fig. 22.

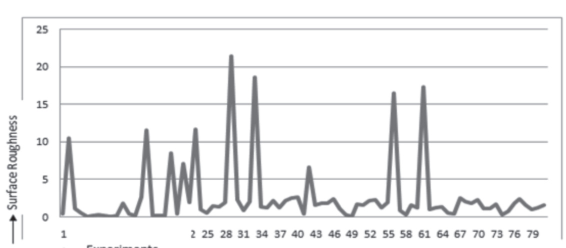


Fig. 21: Variations of surface roughness of products obtained mould practiced in industries

It is clear from Fig. 3 as well that the variation of surface roughness among different experiments are in between 0.05µm and 3.75µm while in products produced using mould practiced in industry, surface roughness is varying between 0.12µm to 21.6µm. Hence quality is improved in terms of variations as well. Table 4 shows the best and worst cases in terms of surface roughness of products.

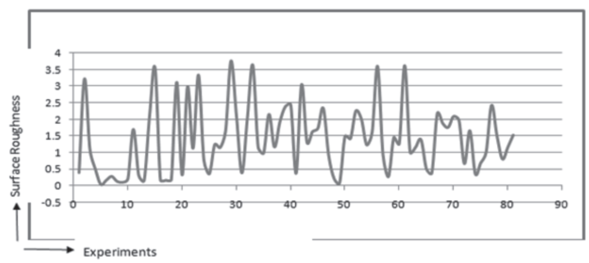


Fig. 22: Variations of surface roughness of products produced using locally made mould

Surface roughness obtained from products produced using industrial moulds is then compared with the surface roughness obtained from products that are produced using mould made locally and is given in Appendix 1. It is concluded that as the quality issues has been resolved in moulds, surface roughness has been decreased for each and every product and larger variations of surface roughness among different products are also resolved. Setting of parameters and their optimization are imperative ways to work with enhancing the quality of the molded items. In any case, the optimization of process parameters is an intricate task, since it relies upon numerous factors, for example, the product and mould design, the material and injection molding machine. The process parameters can influence the quality of produced items. Minute changes of process parameters may possibly give critical effect to the plastic qualities. Experiment 5 and experiment 29 are still the best worst cases in terms of surface roughness respectively. Surface roughness for best

Table 4: Best & worst case in surface roughness

Sr. No.	Treatment-1	Treatment-2	Treatment-3	Treat-ment-4	Response Variable	Response Variable
	Tempera-ture-(Ċ)	Pressure (Bar)	Total Time (Sec)	Mould Tempera-ture (Ċ)	Surface Rough-ness (µm) of products from Industrial mould	Surface Roughness (µm) of products from locally made mould
Experiment 5	190	45	40	65	0.12	0.05
Experiment 29	210	50	45	80	21.5	3.75

case is reduced from 0.12µm to 0.05µm and for worst case it is reduced from 21.5µm to 3.75µm. Hence it is established that quality of moulds also has an impact on quality of products.

Nearby industry making plastic items will profit by the item and process improvement utilizing most recent apparatuses utilized in this task. It is observed that the nearby business isn't utilizing the logical instruments for their items made by injection molding. Mould material would obviously affect the mechanical properties of the items. Distinctive shape materials carry on contrastingly during manufacturing and if the nature of the mould cavity and selection of proper process parameters are not adequate during production, it would positively prompt quality issues during production of plastic items. Hence process parameters have been optimized for specific plastic.

CONCLUSIONS

This research has been taken into consideration to optimize and position the best feasible arrangement of selected parameters and also to find out the effect of mould on quality issues of products. Results reveal that the best likely arrangement of parameters for a pharmaceutical cup of polypropylene by utilizing vertical injection molding machine(IMM) with improved surface smoothness is 190Ċ, 45 Bar, 40 Sec and 65Ċ for injection(inlet) temperature, injection(inlet) pressure, total time and mould's temperature respectively (Experiment 5). And surface roughness obtained from products produced using industrial moulds is then compared with the surface roughness obtained from products that are produced using mould made at our own lab. It is concluded that quality issues has been resolved in moulds, as mould is fabricated on CNC 5-Axis machine as compared to mould practiced in industries that are being fabricated on manual machines. Surface roughness has been decreased for each and every product and larger variations of surface roughness among different products are also being resolved. Hence it is established that quality of moulds also has an impact on quality of products.

Future Prospects

Keeping in mind this research work, in future process parameters of injection molding machine can be set for different plastic materials and quality of mould on different responses can be determined and mould life can be calculated for different materials. Wastage of different plastic materials and different metals can be minimized by latest optimization techniques in injection molding and CNC machining respectively.

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