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Designing and Fabrication of Polymer Based Injection Molding Die Using 3D Printing

Shivam Singh[1], Sanjeev Kumar Singh Yadav[2]
[1]*M.Tech Scholar, Department of Mechanical Engineering, Harcourt Butler Technical University, Kanpur, India*
[2]*Associate Professor, Department of Mechanical Engineering, Harcourt Butler Technical University, Kanpur, India*

Abstract: ***The purpose of this study is to design and fabricate the injection molding die with help of designing software and fabricating it with the help fused deposition modelling based 3d printing machine. Emphasis on designing of the injection die is given on the size and shape of the specimen to be molded and on giving a proper shrinkage allowance to the injection molding die for getting the desired dimension of the specimen molded in the injection molding die. Draft analysis of the injection die was carried out on the designed injection die for easy separation of the specimen and the polymer based injection die. Acrylonitrile butadiene styrene (ABS) polymer based filament is used in the fabrication of the injection die using Fused Deposition Modelling (FDM) working principle based 3d printer. The nozzle temperature requirement of the ABS based filament is 250 degree Celsius and the bed temperature required for printing ABS is around 90 degree Celsius which is recommended by the company which manufactures the used ABS based filament. The time consumption in manufacturing of the die is recorded and then compared to the time taken in manufacturing metal based die. This study concludes the optimum value of shrinkage allowance and proper draft analysis and time taken in the manufacturing of the die in the recommended parameters for the printing of the die.***
Keywords: designing, fabrication, ABS, FDM, 3D printing, die.

I. INTRODUCTION

The injection molding manufacturing process is a leader in manufacturing plastic parts for the industry. Because of its short cycle time and considerably low production cost, it is used in many manufacturing plastic industries such as electronics, toys, medical, telecommunication, arms, and many more [1-2]. The benefit of using injection molding is the ability to use a variety of polymer based plastic and complexly designed parts can also be made by this process. Reduction in waste and high output production and consistency makes it more desirable for the manufacturing industry. Even though injection molding has many benefits but it has a very big pre-installation cost to be beard for the set up. The tool required in molding is a challenge in itself. it takes very complex tooling and sophisticated methods in making of an injection molding die. It is important to remove all the design flaws before manufacturing of the injection die otherwise it will increase the initial manufacturing cost of the injection molding die. Manufacturing of metal based injection molding die by traditional method is very expensive and consumes a lot of time.For prototyping and low volume production of the parts the cost and time commitment for manufacturing of the injection molding die is very high. This is the only reason the injection molding manufacturing process is not recommended for rapid prototyping [3-4].

Additive manufacturing (AM) also known as 3d printing can overcome the drawbacks of tool making by providing rapid tooling method. In 3d printing the material is added to make a solid part hence the name additive manufacturing. Emphasis is given on design rather than manufacturing process [5]. 3d printing can manufacture injection molding die with complex design in short period of time. Comparatively 3d printing consumes less time in manufacturing of injection molding die than traditional method of injection molding die making. Costing of ABS based additively manufactured injection molding die is more economical as compared to the metal based traditionally manufactured injection molding die. 3d printing provides a flexibility of design for the parts to be printed in the 3d printer. Though 3d printing is a superior technology and perfect way to manufacture injection molding die but it too have some drawbacks. Plastic based mold behaves differently than the metal based injection mold die. So proper modification should be done in the design phase of the injection molding die manufacturing process. Shrinkage allowance must be modified for the ABS based mold taking the solidification time of the molded part in the ABS based mold into consideration [6]. The proper draft analysis must be carried out for the injection molding die so that a proper separation may occur during the end of the injection molding cycle. For the fabrication of the mold a proper parameterization of the 3d printer must be done to get the best quality die with the help of fused deposition modeling methodology and post processing is done on the die to get a functional mold.

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II. METHOD AND MATERIALS

A. Additive Manufacturing

Additive manufacturing is a technology of making any solid objects by adding material to the part with the help of digital information or data (CAD) using a 3d printer or additive manufacturing machines. The biggest benefit of additive manufacturing is zero to less wastage of material as the material is added to make a whole part hence there is zero to no scrape. The cost of prototyping is much less as compared to the other methods of manufacturing. For a small production run it is proven to be faster and more economical compared to the other manufacturing technology.it is very easy to modify an existing part which are running in a production line. It is a link between computer aided design (CAD) and computer aided manufacturing (CAM). Fused deposition modelling (FDM) is the most commonly used methodology of additive manufacturing in the industry right now. FDM uses a 3D printer with a hetted nozzle that melts the filament fead to the heated extruder that prints the object layer by layer. Many materials that can be drawn into a filament can be printed by this FDM methodology workin 3d printer [7].

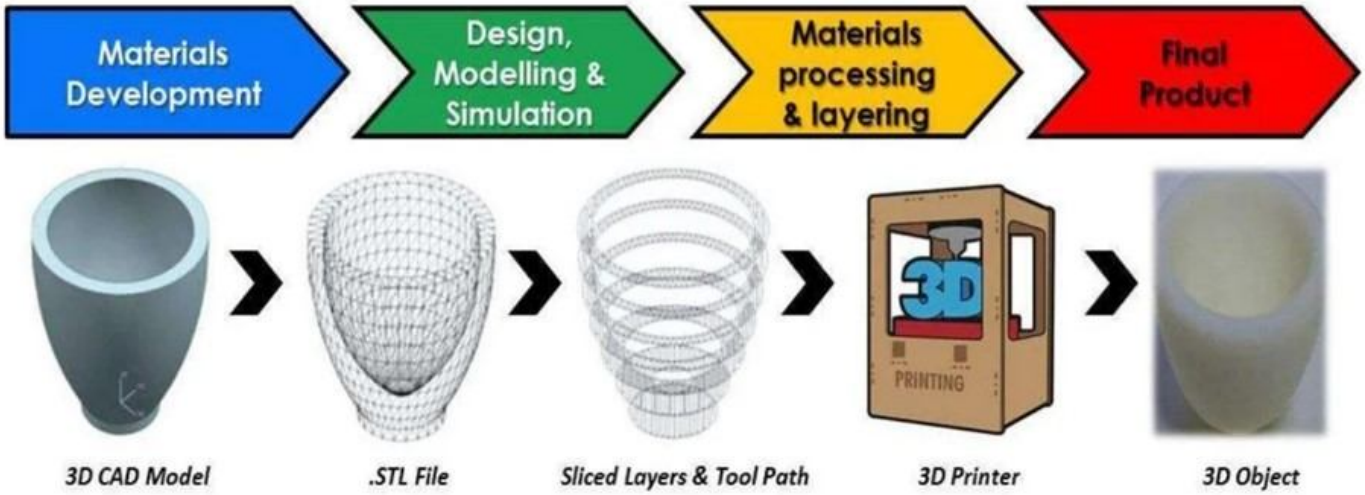

Fig. 1- Steps of 3d prining

Steps of 3d printing are as follows: -

1) Designing of part on CAD software.
2) Converting it into STL file format.
3) Slicing the STL file object into layers with the help of slicing software.
4) Getting a g-code for the 3d printer.
5) Feeding the g-code to the 3d printer.
6) Finished 3d object.

B. Acrylonitrile Butadiene Styrene (ABS)

ABS or Acrylonitrile butadiene styrene is a thermoplastic polymer most commonly used for additive manufacturing and injection molding applications. The advantage of low production cost and high machinability makes it the most desired thermoplastic material in the plastic manufacturing industry. This material is easily available and affordable. the ABS material's has a superior property such as high Impact Resistance, high Structural Strength and Stiffness, Chemical Resistance, Excellent High and Low Temperature Performance, and Great Electrical Insulation Properties as compared to the other thermoplastic material. Though printing of ABS is a challenge in itself. Because of its wrapping when rapidly cooled. This problem is solved by using an enclosed box for the 3d printer to maintain a elevated temperature of the object so that the wrapping is minimised. ABS PRO+ filament by WOL 3D is used for printing of the injection molding die. This additive reinforced ABS filament has superior properties as compared to the generic ABS filament. ABS PRO+ delivers high impact strength with high-temperature.

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Fig. 2- ABS filament.

Resistance and superior finish as compared to the generic ABS. heat resistant property helps the mold in the molding of high-temperature plastics with ease. In this study the printing of ABS-based mold using ABS PRO+ filament [8].

III.DESIGN OF EXPERIMENT

In this study, the specimen for which the mold has to be designed must be selected. Stress-strain testing metal based injection mold was available so by taking the reference. The mold was designed with the help of SolidWorks designing software. The die was divided into two parts one is the core and the other one is the cavity. The core contains the surface of the specimen which holds together both parts of the die. The cavity contains the indent of the specimen to be molded in the ABS based injection molding die [9-10].

A 2-degree draft was given to the die for proper separation of the specimen and the die. The dimensions of the specimen indented in the die were increased considering a 3 percent shrinkage allowance. The shrinkage allowance was increased considering the increase in the solidification time because of the poor heat conduction property of the ABS material of which both the parts of the die were manufactured. The draft analysis was conducted for the die after the completion of the designing phase of the mold. The compatibility of both the core and the cavity was checked by keeping both parts in the assembly mode of the same designing software [11].

The core and the cavity were saved in STL extinction for the slicer software to slice it layer by layer making the complete part. The STL file of both the core and the cavity is then imported into the Ultimaker Cura slicing software for the segmentation of the parts. The slicing software generates the g-code of the design layer by layer for the 3d printer for printing the part [12].

The parameter on which the mold has to be printed is fed in the 3d printer which was recommended for both the creality ender-3 3d printer and the ABS PRO+ filament by the Wol3D company. And the time taken in manufacturing or printing of the mold was recorded and compared to the metal based mold available. The time taken was matched by the Ultimaker Cura slicing software for double verification of time [13].

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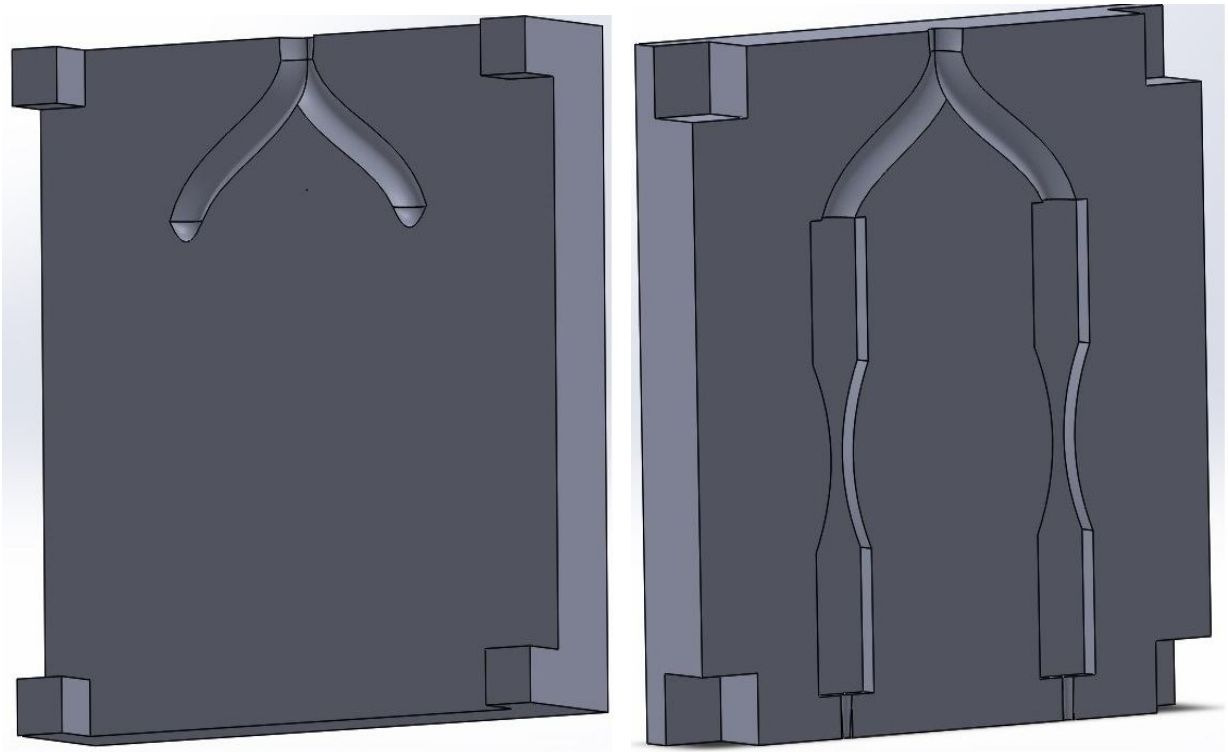

Fig. 3: designed core and cavity of die.

IV. RESULT AND DISCUSSION

The parameters for the fabrication of the die using the 3D printer were kept as recommended by the filament company but the injection molding die must have a greater surface finish without compromising the time duration for 3d printing of the injection molding die.

TABLE I
Parameters for 3D printing of the injection molding die.

S.No	Parameters	Units	Value
1	Layer height	mm	0.16
2	Printing speed	mm/s	60
3	Filament diameter	mm	1.75
4	Nozzle diameter	mm	0.4
5	Bed temperature	°C	90
6	Nozzle temperature	°C	250
7	Infill percentage	%	20
8	Infill pattern		Cubic

The mold manufactured by 3d printing appears to be of good quality and functional for the injection molding process. The assembly of the mold was quite compatible as it was in the design in the Solidworks CAD software. The feasibility of the ABS mold is considered by the final product is seen.

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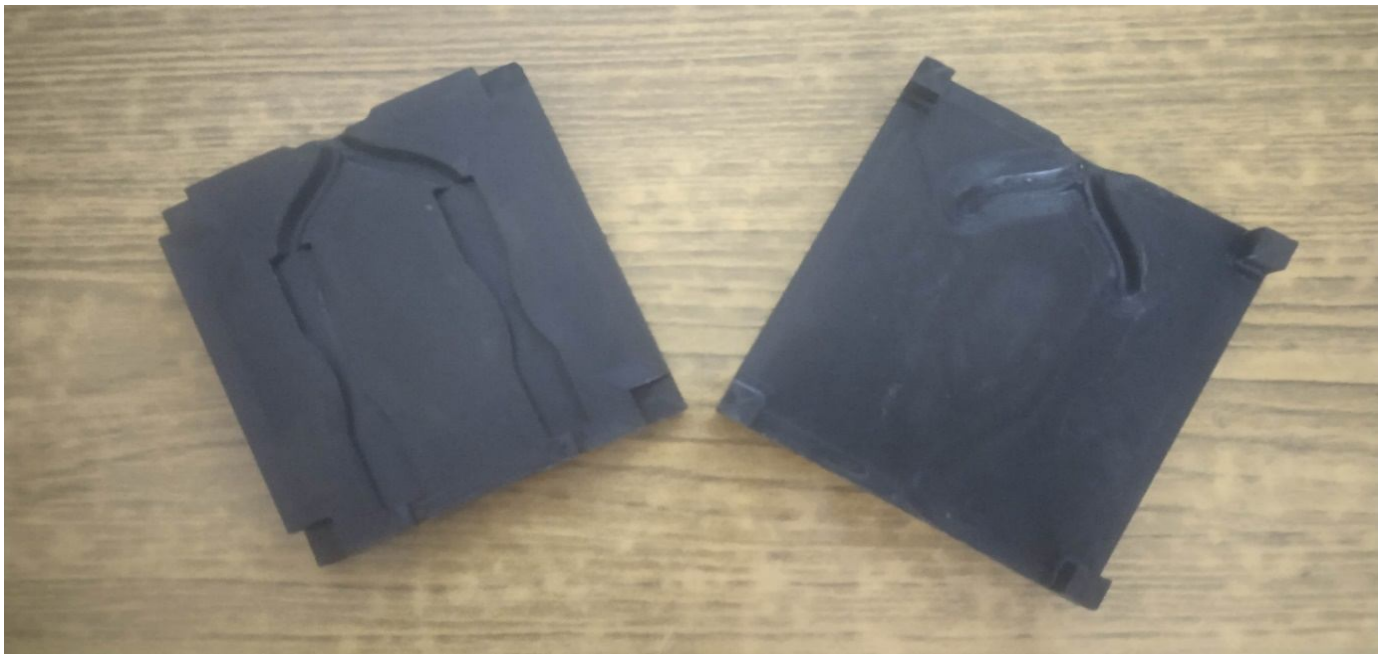

Fig.4: 3d printed injection molding die.

The recorded time consumption of additively manufactured of ABS based injection mold was much less compared to the time consumption of traditionally manufactured metal based mold. The same goes for the time commitment of the manufacturing of injection molding die. The time consumption was much less in the case of Additively manufactured ABS based injection molding die when compared to the time consumption of traditionally manufactured metal based injection molding die.

TABLE 2
Cost and time consumption of injection molding die.

S.No	Material type	Total cost	Printing/machining time
1	ABS based 3d printed mold	250 Rs.	9 hours
2	Mild Steel conventional machined mold	10000 Rs.	2 week

V. CONCLUSIONS

This study shows that the time consumption of additively manufactured ABS based injection molding die is very less as compared to the traditionally manufactured metal based injection molding die. The same results are seen in the case of processing cost of the injection molding die. The processing cost of the additively manufactured ABS based injection molding die is much less when compared to the traditionally manufactured metal based injection molding die. The study also shows the exact parameters for manufacturing of ABS mold using a 3d printer. The study also gives the exact value of draft angle and shrinkage allowance for the proper functioning of the ABS based injection molding die. This study concludes that additive manufacturing is a superior manufacturing technology as compared to the traditional mold manufacturing processes

VI. ACKNOWLEDGMENT

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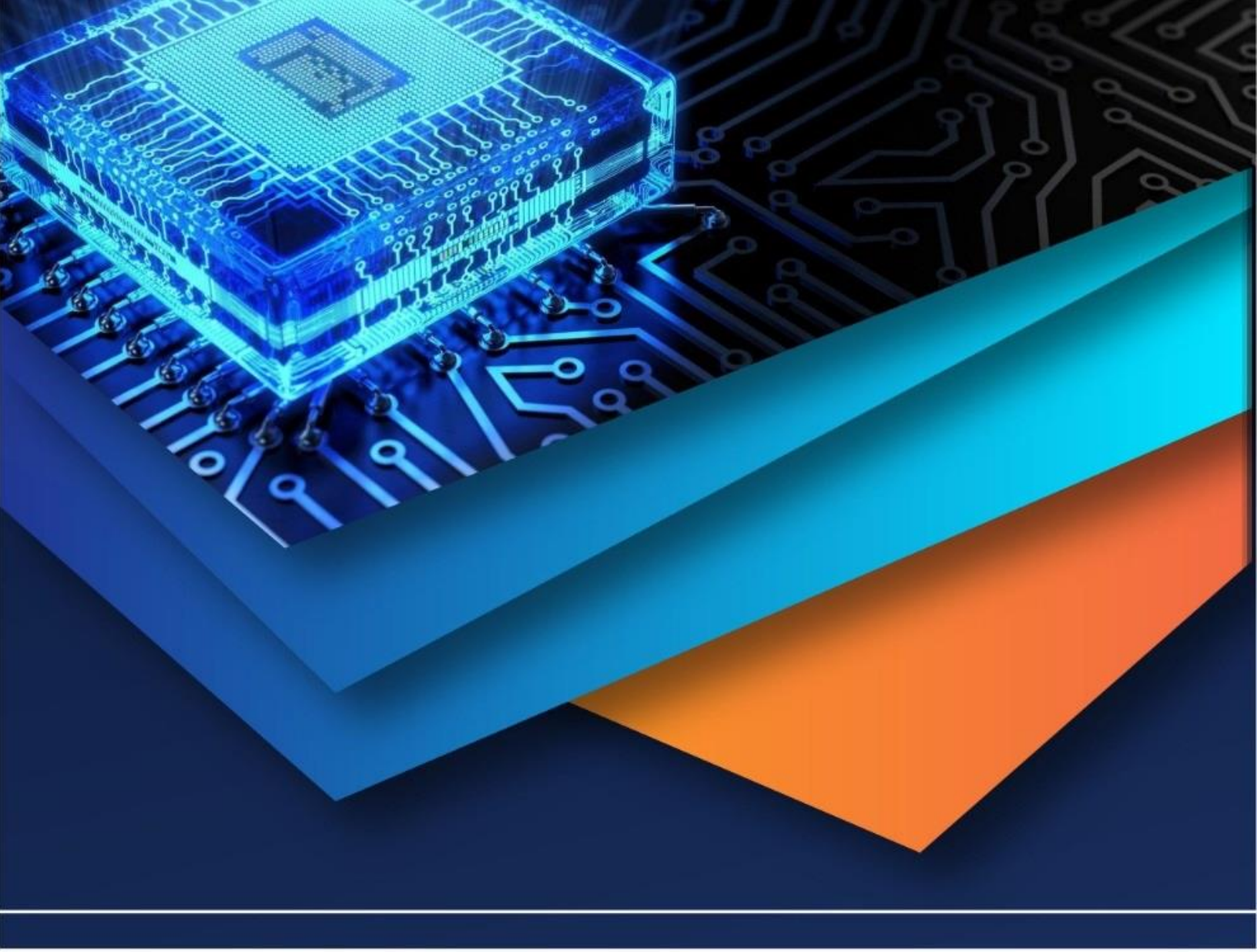

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