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Use of 3D Printing Technology to Print Wax Pattern for Investment Casting

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ABSTRACT

Already 3D printing technology has gained wide importance for producing decorative plastic equipments, but hasn't built good platform in industrial sector. Thus to achieve the same the project is undertaken where we are introducing 3D Printer to print wax patterns for investment casting. To print these patterns we have used machinable wax filament as extruding material. In 3D printing there is necessity to set various parameters considering suitability of chosen material to obtain excellent print results. To get optimum parameters we had chosen trial and error method after incorporating optimum parameters it is easy to get desired patterns for investment casting.

Keywords: Investment casting, machinable wax filament.

1. INTRODUCTION

Any invention or innovation cannot be praised until it is globally introduced for application purpose. So far till date this technology is being used for various purposes, but hasn't proved its importance in the field of manufacturing at industry level. Thus the project is so chosen to bridge this gap.

This project work can be subcategorized into two parts: one is development of 3D printer and another is creating wax pattern for investment casting. First part i.e. developing a 3D printer is a combination of mechanical and electronics fabrication, which is bit critical to employ its use in the field of at manufacturing at industrial level. As design demands more sturdy, durable and precise parts, assembly and modification is done at great care. Working style and construction of 3D printer divides 3D printer in various types. We have employed FDM i.e. fused deposition modeling method, which best suits for chosen application.

Further as mentioned another part is creating Wax Pattern. It is first time in, history of the 3D printing, where machinable wax filament is used for printing wax pattern as desired in Investment casting. This was big challenge because material was new for printing, and yet there were no suitable printers for printing this kind of material. Also there were no any default parameters were present in software, therefore there was need of employing trial and error method to get suitable parameters for excellent printing.

2. OBJECTIVES OF PROJECT

Objective behind this project is to introduce this 3D printing technology in the field of manufacturing. So that it will leads to reduce lead time, reduce material from being wasted, reduce material & labour cost which will result in increased Productivity.

3. PROBLEM OUTLINE

As discussed earlier, wax patterns are generally produced using an injection molding process. The injection molding is time consuming and expensive process. The cost of this process ranges from $5,000 to $20,000 and Generally lead time for this process ranges from 6-9 weeks.[1] Another problem is it goes difficult to produce prototype casting until the injection mold is completed. Also this creates disturbance to other components in the assembly. Sometimes there may be necessary to scrap the original tool, which is again costly affair. Through injection molding process there is limitation in producing patterns of smaller thickness and of complex shape, which can be well produced by aiding 3D printer. Some attempts using plastic material for patterns are already done by aiding 3D printer. But this has created great issue of leaving ash content and blackish plastic layer because of improper burnout of plastic. Thus in this project work intentionally machinable wax material is chosen for printing wax patterns, which takes out the problems associated with plastic like materials.

4. LITERATURE REVIEW

4.1 3D PRINTING TECHNIQUE

As mentioned earlier, 3D Printing works by receiving a digital data file. The actual process starts from developing a CAD model. A CAD model can be generated by using any design software like CATIA, Solidworks etc. The developed CAD model is fed to slicing software like Slice3r, Cura etc. Slicing software slices the 3D CAD model into thousands of 2D layers. Separate G-Codes for each layers are generated through this software which are further given as input to micro-controller. The microcontroller further gives signals to ramp circuit, which drives stepper motors through pulses. Thus the movement obtained is incorporated for triaxial motion of extruder and nozzle through which part is printed as per the design fed.

4.2 INVESTMENT CASTING

This method of casting is popular for creating both non-metallic and metallic parts, with excellent surface finish and good dimensional accuracy. The process of investment casting requires a wax pattern also known as master pattern which is same as that of final product in all geometrical aspects. This wax pattern is further covered with ceramic slurry of required thickness. This wax patterns were developed with the injection molding process in early days. Once ceramic is deposited at required conditions, then it is heated to melting point of wax, to melt down the wax from the ceramic shell this process is known as de-waxing and thus this is also known as lost waxing casting. Further this ceramic shell is heated to certain temperature, and then molten metal is poured into this shell. Once the metal cools, the ceramic shell is removed by aiding vibrations and blasting technique. Thus in this way a casting of required object is obtained.

5. METHODOLOGY:

The parts of geeetech prusa were bought first for assembly. We were provided with assembly manual for building printer structure. It took us nearly 2 weeks for assembly of the same. After finishing the assembly heating bed was aligned the 3D printing process starts with creation of a 3D CAD model of required object. For trial purpose a CAD model of an impeller was created using CATIA software. Through CATIA a file with extension .CAT was created which was further converted to .STL file to upload it in slicing software. This file was imported into slicing software named as CURA.

In CURA software, model was aligned considering the suitability for printing. For maintaining proper dimensional stability automatically supports were generated in the software. Various parameters like printing

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speed, infill, print bed temperatures, extruder temperature etc. were kept changing for attaining different results. The generated G code file was given as input to the microcontroller. The signals from microcontroller were used to drive the stepper motors. These stepper motors controlled the tri-axial motion of the nozzle. By setting different parameters numerous patterns were printed of the impeller.

As this project work is application oriented, for investment casting printing patterns of wax material only, was the main task. So far there is no anywhere such attempt with wax filament was recorded, thus it was big challenge to print the same so that it could be used as master pattern for casting purpose. There was need of 'machinable wax' instead of regular wax so as to satisfy the conditions of investment casting. After searching worldwide a machinable wax filament was imported from USA. The recommended parameters as per the filament manufacturers were[2]:

a. Extrusion temperature = 140ºC to 150ºC
b. Bed temperature = 80ºC to 90ºC
c. Printing speed = 20 to 70 mm/sec

At the time of very first trial above parameters were set in CURA software. Due to values were given in range format, difficulty in setting right value for each parameter was arisen. There was need employing Trial and error method to overcome the problem. At first we took extrusion temperature as 140ºC but we found that the material didn't melt, then we chosen extrusion temperature as 150ºC, 160ºC, 170ºC, 180ºC. Further we varied bed temperature between temperature 80ºC to 90ºC in steps of 2ºC. Same process is followed for printing speed. Printing speed is varied between 20 to 70 mm/sec in steps of 10mm/sec.

6. RESULTS & DISCUSSION:

We got following results after doing above experiment:

a. Extrusion temperature = 180ºC
b. Bed temperature = 90ºC
c. Printing speed = 40 mm/sec

Above parameters proved to be suitable for printing wax material. Printing results obtained at these parameters were appreciable. CAD model of an impeller was given for trial purpose. Resulted part was nearly same as that of CAD model.

When parameters were set to values as provided by wax filament manufacturer's catalogue, following problems occurred:

i) Insufficient Heating: The wax filament didn't come out of extruder when temperature was set between 140ºC to 150ºC.

ii) Overheating: When temperature was set to 200ºC drops of molten metal were formed instead of stream.

Above both problems were overcome by employing Trial and error method. By this method suitable extruder temperature for proper printing was fixed to 180ºC.

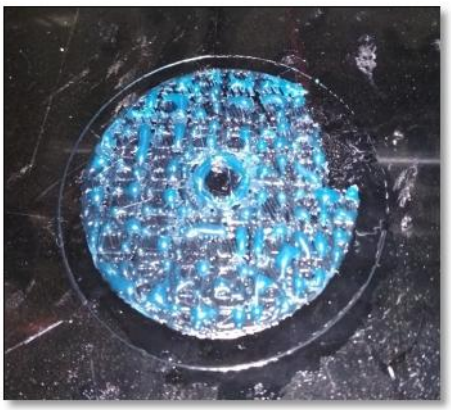

Fig. 6.1 Overheating

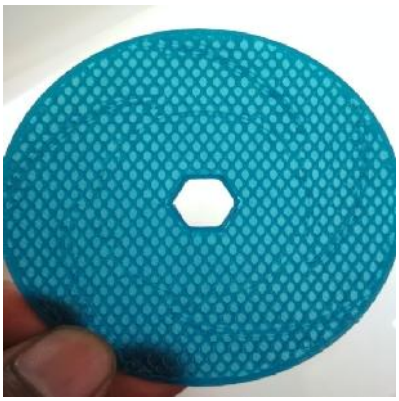

Fig. 6.2 No Overheating

iii) Warpage: The very first layers weren't properly adhered to heated bed, and thus dimensional stability of the model was disturbed.

This problem was overcome by providing Raft through CURA software and in some cases painters tape was stuck on heating bed.

Fig. 6.3. Warpage

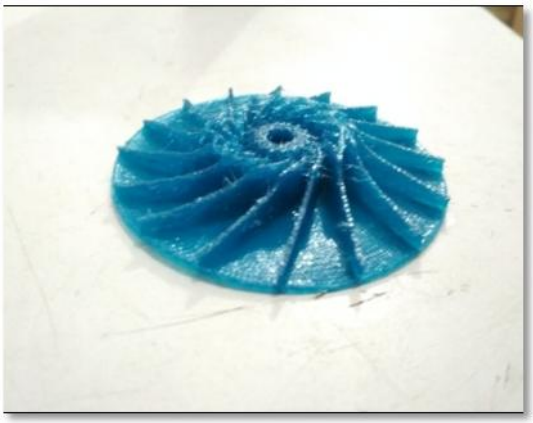

Fig.6.4. Successfully printed part without any defect

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7. SCOPE FOR FUTURE WORK:

There is good scope to incorporate IoT in 3D printing technology, so that there is no need of giving design input to printer manually. From start to end all printing associated things can be done from any place.

8. CONCLUSION

Table 8.1: Comparison of 3D Printing & Injection molding for generating wax pattern[1]:

METHOD	COST (in $)	TIME
1. Injection molding	5000 to 20,000	Upto 9 weeks
2. 3D printing	1,250	Max 1 week
SAVINGS	3,750 to 18,750 (75% to 94%)	7 weeks (88%)

Machinable wax proved to be best material for an Investment casting process as it does not leaves any ash content or blackish layer after melting out. It can be reproduced after melting which saves material and also cost. The 3D printer which is used to print wax pattern can produce patterns with high dimensional accuracy, good surface finish. After conducting numerous trials finally we obtained excellent pattern which proved to be best suitable pattern to draw casting, which was confirmed by a casting expert from investment casting industry.

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