DESIGN AND EXPERIMENTATION OF 3D PRINTED PATTERN AND WOODEN PATTERN FOR SAND CASTING PROCESS

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ABSTRACT:- 3D printing patterns has been considered as an alternative for pattern making but hasn't generally opted as a popular alternative to conventional/traditional casting method. The use of this rapid prototyping technology is to eliminate the material wastage in pattern production, reduce the cost and time management. In traditional method of producing casting with patterns of material like metals are of CNC machined. This CNC prototyping has its own limitation involving the geometric errors due to machine tool accuracy and thermal errors caused due to frictional forces between tool and the workpiece. Other disadvantages include loss of raw material. CNC prototyping may be cheaper but for manufacturing a single product, rapid prototyping pattern would have an upper hand. This work is to enlighten the foundry engineers to make use of rapid prototyping technology to eliminate the material wastage in pattern production, reduce the cost and time in the production of accuracy casting of an acceptable quality. The present work is to replace a wooden pattern with a 3 D printed pattern for which a stepped pulley is designed and taken into consideration for fabrication in rapid prototyping process which thereby used in aluminium sand casting. The casted aluminium will be cross checked for surface finish and geometrical irregularities and compared with aluminium casted with wooden pattern or metal pattern. Any small change in the design will make a huge process for pattern making where as in 3D printing change in design can be easily adopt.

Keywords: *Complex Patterns, Rapid Prototyping, 3D Printed pattern, Sand casting.*

1. INTRODUCTION

Manufacturing is a step by step process through which raw materials are transformed into finished products. These products are availed for further sales or usage by the end users (consumers). The manufacturing process begins with the product design, and materials specification from which the product is made. These materials are then modified through manufacturing processes to become the required part. Manufacturing processes are classified as:

   i.   Casting
   ii. Molding
   iii. Forming
   iv. Machining
   v.   Additive manufacturing

Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

Sand casting is the most widely used metal casting process accounting for a major percentage of total cast in weight. During sand casting process, material is heated to the correct temperature to melt and sometimes treated to modify the chemical composition to achieve the required material properties. Then the molten metal is poured into a mold which has the desired shape cavity to cool down and solidify. Sand castings are produced in specialized factories called foundries. Over 60% of all metal castings are produced via sand casting process.

Since many decades casting process is using pattern made of metals and wood in manufacturing process. The metal patterns and wooden pattern imply defects on the casting obtained in the sense of accuracy and surface finish. Though the

metal pattern contribute to the durability of the pattern, fine and good surface finish of the casting, but it is cost effective and is difficult to modify if any changes are to be made to the casting. In addition the metal pattern is prone to corrosion. In case of wooden pattern, flexibility is possible but it is prone to dimensional changes due to its ability to absorption of moisture. Apart from its absorption property, the surface finish is poor and high dimensional tolerances are needed when compared to metal patterns. For any casted component, further machining is required to get a finely finished product. Lesser the post machining time of a component, faster the output obtained. To reduce the post machining time, the casting needs to be done optimally. Pattern plays a major role for a good casting. The better casting results are obtained by a pattern with good surface and accurate dimensions. In the present work, we tried to compare two casting which were made using a wooden pattern and a 3D printed pattern. Using 3D printing we obtained a pattern with accurate dimensions and with a better surface finish. The material used for the 3D pattern is Poly Lactic Acid (PLA).

Pattern: The pattern is the principle tool during the casting process. It is the replica of the object to be made by the casting process, with some modifications. The main modifications are the addition of pattern allowances, and the provision of core prints. If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product. The quality of the casting produced depends upon the material of the pattern, its design, and construction. The costs of the pattern and the related equipment are reflected in the cost of the casting. The use of an expensive pattern is justified when the quantity of castings required is substantial. Patterns may be constructed from the following materials. Each material has its own advantages, limitations, and field of application. Some materials used for making patterns are wood, metals and alloys, plastic, plaster of Paris, plastic and rubbers, wax, and resins. An ideal pattern should be easily modifiable, strong, durable, light weight, corrosion and wear resistant, ineffective to the climatic conditions and economical. The usual pattern materials are wood, metal, and plastics. The most commonly used pattern material is wood, since it is readily available and of low weight.

2. DESIGN AND MANUFACTURING

In the present work, we have chosen a stepped pulley design for the pattern making as shown in fig.1. The stepped pulley is designed in designing software known as Solidworks.
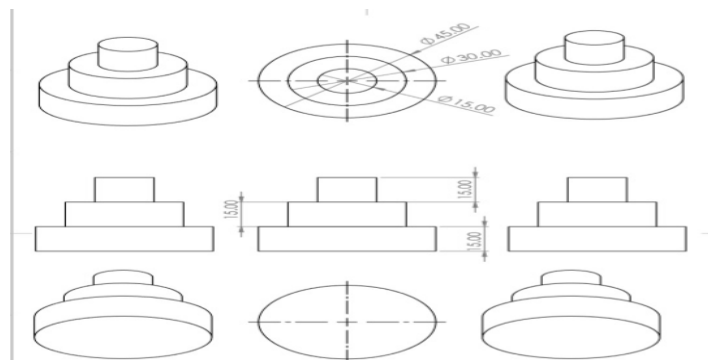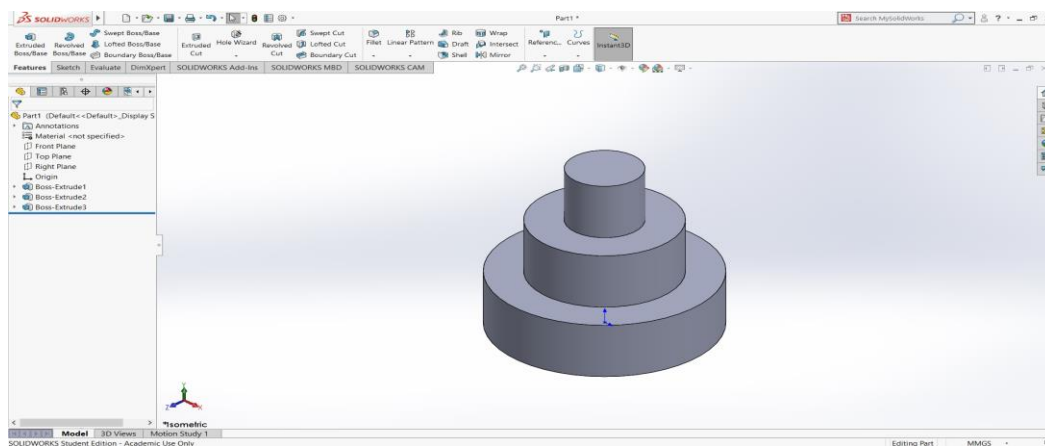

Figure 1 2d view

Figure 2 3D view

Wooden pattern

A rectangular wooden block is taken and chipped out the sharp edges such that it obtains a shape of a cylinder. Fix the block on to the wood turning lathe machine in such a way that the central axis of the wooden block is coincided with the axis of the lathe centres. Mark the required dimensions on the wooden block. Now switch on the machine. The block rotates at certain rpm. Take a chisel and start removing the material from the block gently. Keep removing the material as per the required dimensions. Finally a wooden single piece pattern is obtained with the required dimensions.

Figure 3 wood turning   Figure 4 finished pattern wood

3D Printed Pattern

Poly (lactic acid) or polylactic acid or polylactide (PLA) is the material used for manufacturing components in 3D printing. PLA is biodegradable and bioactive thermoplastic aliphatic polyester derived from renewable resources, such as corn starch , cassava roots, chips or starch, or sugarcane. The name "polylactic acid" does not comply with IUPAC standard nomenclature, and is potentially ambiguous or confusing, because PLA is not a polyacid (polyelectrolyte), but rather polyester.

Table 1: Properties of PLA

Property	Value
Full name	Polylactic Acid (PLA)
Melting point	150°C to 160°C
Glass transition	60°C to 65°C
Injection Mould Temperature	178°C to 240°C
Density	1.210–1.430 g/cm^3
Chemical Formula	$(C_3H_4O_2)_n$
Crystallinity	37%
Tensile Modulus	2.7-16 GPa

The designed model is saved into stereo lithography file format with the file extension of *.stl. Then the slicing operation is performed to the stl format file using the slicing softwares like cura. After slicing the file is saved into a gcode file with the extension of *.gcode. The file is transferred into the memory chip of the 3D printer or the computer is connected to the 3D printer and printing is started.

Figure 5 3D printed pattern   Figure 6 finished pattern

3. EXPERIMENTAL WORK

Fine sand is taken and slurry, known as molasis, is mixed into it. The sand is mixed in such a way that the sand must be moderately sticky and should be good enough to bind. Now take the mould box which consists of cope and drag. The lower part of the mould box is called drag and the upper part is called drag. Now invert the drag on a wooden plank. Place the patter in a position in the drag. Now fill in the drag with the prepared mould sand. Ram the sand in the drag thoroughly so that the sand binds properly. Remove the excess level of sand with a steel rule of a flat plank strip. Now place the cope onto the drag. Take two wooden pieces, one for the sprue and the other for the riser, which are shaped like cylindrical shafts. Place the riser on the pattern and the sprue onto a position at a small distance away from the pattern for designing the gating system. Now hold the sprue and riser tight and fill the cope with moulding sand. Again ram it gentle so that the sand gets binded properly. After the sand in the cope gets binded properly remove the cope and design the gating system .i.e., the runner and choke with the help of the tools available. Once finished the gating system place the cope back onto the drag. In the meanwhile switch on the furnace and melt the metal in it. Once the gating system is finished remove the pattern, riser and sprue from the mould. After the metal is molten, place the mould at a proper position and pour the molten metal into the pouring basin. The level of the metal can observed from the riser and if required more metal can be poured. Once the poured metal gets solidified, the mould can be broken to obtain the casting. The extra parts or projection can be cut off and used for another casting.

Figure 7 mould with pattern   Figure 8 mould box preparation

Figure 9 metal pouring   Figure 10 obtaining the casting

4. DISCUSSION AND VALIDATION

There has been a gradual increase in adoption of 3D printing in various fields including sand of all. The size and structure of any casting depends upon the pattern. Making a pattern includes a lot of time and machining. The time factor plays a major role in production as the pattern takes more time, the production output would be low. Sometimes the pattern making takes a lot of time for complex or contour components. This might lead to delay in casting components which effects the production of the components. Sometimes even material of the pattern affect the lead time of pattern making. If the material used is metal the lead time is high as the metal has to be machined to the desired replica of the component. This machining consumes a lot of time and wastage of material too.

If the pattern material used is wood, even then we need to machine a wooden block and shape it. In addition, the wood dust left over cannot be reused like in case of metal pattern. Wood reacts with its surroundings. It is a good absorbent of

moisture and could react with the moisture content of the moulding sand. Wooden pattern needs high tolerances to be given to avoid shrinkages of the pattern. Wood, being the cheapest material for making pattern, produces casting which requires much machining. Total cost involved in producing, manufacturing and machining is more when compared to that of 3D printed pattern.

The traditional pattern making process involves non CNC machines and involvement of manpower. For making a pattern through conventional means may lack accuracy and involve lot of time. Using means of advance technology like additive manufacturing (3D printing) in pattern making process gives a lot of advantages. The time efficiency of the process is increased as3D printing involves addition of material layer by layer.

3D printing is also called additive manufacturing. As the name suggests, the material is added and layers of a component is formed in a step by step procedure. This reduces wastage of material and hence fore increases the accuracy of the component's dimensions. Unlike wood the 3D printed pattern is independent of temperature effects. Shrinkage allowances are need not be given for the pattern as it does not deform due to the moisture in moulding sand. The material can be also be minimised by variation of the infill pattern like grid, lines, cross linked, etc. which varies pattern strength. Since it is automated, the dimensions are accurate and precise. Apart from dimensional accuracy, the pattern is made such that it obtains sharp edges.

5. CONCLUSION

Ambiguous structures with much sharp corners can be easily printed through 3D printing. The obtained results will make use of 3D printed pattern in many MSME foundry industries. The output after experimentation has given a huge difference on the structure and surface of casting. The overall production time, machining time, and pattern making time has come lower when it is compared to other pattern materials which in turn reduces the usage of raw materials in pattern making. From the above results it is clear that the casting obtained by 3D printed pattern is much superior in surface finish, dimensional accuracy, exactness of shape. The casting obtained by this 3D printed pattern made a huge difference in dimensional accuracy, size and resulted in a matured surface finish.

Table 2 Practical comparison of castings to pattern

Figure 11 3D printed pattern	**Figure 12 final casting of 3D printed pattern**
Figure 13 wooden pattern	**Figure 14 final casting of wooden pattern**

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