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FDM 3D Printing as an Alternative form of Making Pattern for Metal Casting: A Comparison with Wood-Based Pattern

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ABSTRACT: The problem with the wood-based design is that it changes size when it absorbs water, which can make the pattern grow and shrink, and the surface goes away, making it unsuitable for mass production. Plastic is the most common 3D printing raw material, and it can be used to build practically any form of object. Fused Deposition Modelling (FDM) is a type of 3D printing prototyping that may be used to make a plastic design for metal casting. In this project, the metal casting product were evaluated by casting quality and surface roughness for both 3D printed- based pattern and wood-based pattern. For the quality of their castings, both generate the same shape based on the dimensions specified by their respective patterns, but both have experienced gas porosity. For the surface roughness produced from the wood-based pattern, an average Ra value of 1.965 micrometres was recorded, while the average Ra value recorded from the 3D Printed-based pattern was 2.357 micrometres. The findings revealed that wood-based pattern produces a slightly better surface than 3D Printed-based pattern, but 3D Printed is still relevant to be used as a pattern because it is more durable and easier to produce with good time consuming.

KEYWORDS: Metal casting, FDM, wood pattern, plastic pattern, surface roughness

INTRODUCTION

Casting, or the process of foundry is a very efficient and effective manufacturing process that can transform raw materials into discrete output. 3D printing is popular due to its printing capability, near-zero material waste, and high precision in producing standard products in a short amount of time [1]. Additive manufacturing (AM) is increasingly being employed in the development of mechanical components, enabling for the creation of complex structures that would be impossible to create using traditional methods. Indeed, numerous scientific investigations of the literature have identified patterns and opportunities related to this process, as well as some potential benefits for a variety of businesses[2]. Additionally, quick prototyping has a broad range of applications in various disciplines of human endeavour. Plastic is the most popular raw material for 3D printing and can be used to make almost any type of item. Because the process of 3D printing is handled by a computer rather than by hand, the manufacturing speed is higher. It can quickly and easily create any form of complex geometric object.

Traditional sand casting requires 2D drawing and fabrication by a highly skilled pattern maker, which can be slow and expensive. Some use CNC milling to produce patterns, but it is not suitable for complex shapes and wastes a lot of materials. Compares to 3D printing in its ability to print with low costs of materials and the high precision of producing standard products in a short period of time [3-4]. Sand casting uses patterns made of wood, metal, or plastic. In the preparation of metal castings, mould patterns made from wood have often been used in recent years. The size, complexity, dimensional precision, and volume of the casting that must be made from one pattern also affect the pattern of material that has been chosen. Mould patterns from wood have their own advantages, but the disadvantages of the wood-based pattern are the distortion of dimension due to the absorption of moisture, which can make the wood-based pattern swell and shrink, and abrasion can occur on the surface, making it unsuitable for large-scale production. Thus, the wood-based pattern will crack and cause the casting result to have a damaged, uneven, and non-smooth surface. The goal of this work is to develop and produce a pattern for metal casting using FDM 3D Printing for the casting process, as well as to compare the casting quality and surface roughness of wood-based and 3D printed-based patterns.

FDM 3D machines can also produce plastic patterns for sand casting. Because they are as light as wood and as robust as metal, several types of plastic are preferred for pattern making because, when compared to wooden designs, plastic patterns are more dimensionally stable. Besides, plastic patterns also have excellent surface finishes, and they are affordable, lightweight, and low-cost. In this work, plastic patterns from PLA material were produced by using 3D printing and the casting product was compared with the wood-based pattern product. The product of casting was studied and comparisons between wood and plastic pattern were analysed in terms of visual inspection and surface roughness in order to produce a better pattern for metal casting.

METHODOLOGY

The project's methodology comprises four components. The first step is to design a floral pattern in SolidWorks using the exact dimensions of the wooden flower pattern from the foundry workshop. The second step is to manufacture the SolidWorks-created design using a Fused Deposition Modelling (FDM) 3D printing machine. The third step is to cast the 3D-printed flower pattern to observe the finished product. Lastly, perform the observation procedure and surface roughness tests to determine whether the plastic pattern is effective and suitable for the casting process.

To design floral patterns, SolidWorks software was used to design the flower, sprue, and runner patterns. The structural integrity of the finished product, as well as the dimensions, have been designed according to the same pattern as the original wood-based pattern. The length of the new designed pattern from the top of the flower's petal to the bottom of the flower's stem was 200mm, the width from left leaf tip to right leaf tip was 145 mm, and the thickness of the new designed pattern was 50mm. The design that has been made from this SolidWorks software, which is a CAD model, was converted to 3D printable format (STL file type) and assembled on a deposition modelling machine (FDM) able to print flower patterns according to size and measurements as specified.

The results that have been printed through a FDM 3D printing machine have been photographed. The following is evidence and results that can be recorded in the production of a plastic-based pattern as a new pattern. The shape and specification of the new pattern follow the old shape in order to facilitate the comparison process in terms of visual inspection. This plastic-based pattern printing takes 3 hours and 45 minutes to complete. Figure 1 shows the final part of the flower, from which the base has been removed and used for the casting process.

Figure 1. Flower Pattern that has been removed from the base layer

In casting, the mould is contained in a frame called a flask. Green sand, or mould sand, was inserted into the flask around the flower pattern produced by the FDM 3D printer. After the sand was tightly packed, the flower pattern made by polylactic acid (PLA) was removed and cast. To produce metal products from castings, the metal is melted in crucibles. After the metal melts, it is poured into the mould cavity and left to solidify for around 4 hours. Once solidified, the shaking process begins to remove sand from the cast product. The casting was polished to produce a useful surface for its final purpose, which is to test the surface roughness depending on the planned usage of the finished product by using a vertical grinder machine. Figure 2 shows the product produced from wood-based patterns and 3D-printed-based patterns after the surface is smoothed.

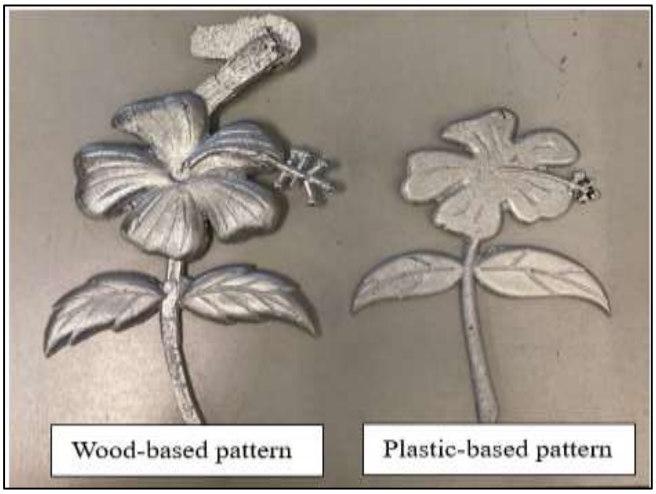

Figure 2. Products after the surface finishing

RESULTS AND DISCUSSIONS

The results of casting have been evaluated by casting quality and surface roughness. Through the visual inspection, the product has been evaluated in terms of its casting quality and its aspect in terms of shape and size. From this method, the casting product can also be evaluated to see whether it has defects or not. Besides, through the surface roughness method, the product can be evaluated based on the type of surface produced after going through the casting process. Every step in the process of metal casting, from patternmaking to heat treating, is done carefully to avoid problems with the soundness, surface finish, mechanical properties, and final dimensions of the finished casting. Small problems can arise unexpectedly, and many castings have mechanical requirements that may be undermined by a hidden defect. Casting inspection allows the foundry and clients to feel confident they have a quality casting.

Visual Inspection

Based on Figure 3(a), there is a noticeable difference in terms of the shape of the resulting product casting. This is because of the defect found in the wood-based pattern, which causes the shape of the "pollen tube" not to be straight and flat. The product casting that results from the 3D-printed-based pattern is neater, flatter, and straighter on the "pollen tube" component as opposed to the right side in Figure 3(b). This is due to the fact that the PLA pattern was

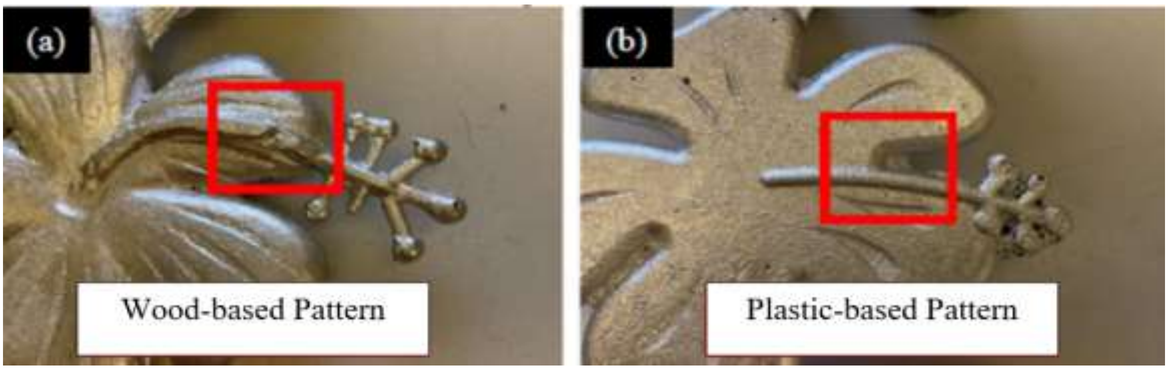

Figure 3. Comparison in terms of shape changes found on "pollen tube" pattern between product from (a) wood-based pattern and (b) plastic-based pattern.

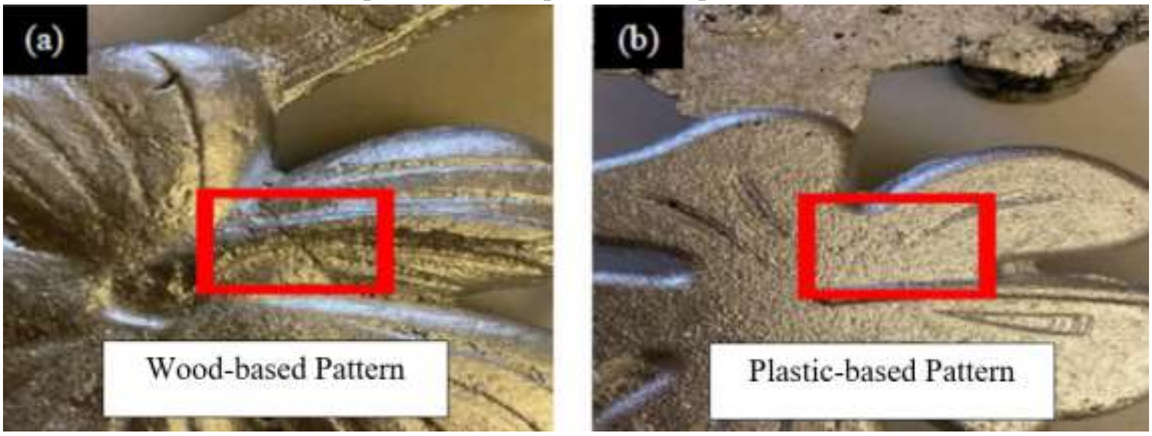

Figure 4. Comparison in terms of cracks found on pollen tube pattern between product from (a) wood-based pattern and (b)plastic-based pattern

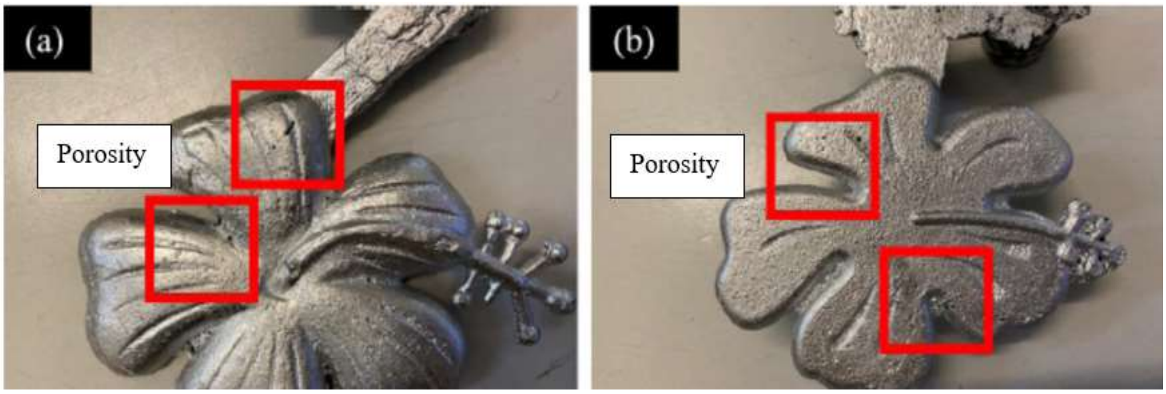

Figure 5. Porosity effects that occur in product of metal casting from (a) wood-based pattern and (b) 3D printed based-pattern.

Created using a SolidWorks software shape that was sketched out. 3D printing is a fast development method that works by adding layers of material to make 3D things that are controlled by a computer. Therefore, the mould filled the space and followed the pattern. The cavity is formed by packing sand around the pattern, about half each in the cope and drag, so that when the pattern is removed, the remaining void has the desired shape of the cast part. Figure 4 shows the comparison in terms of cracks found on pollen tube pattern between product from (wood-based pattern and plastic-basedpattern.

In both casting products that have been produced, there is a defect in the product, which is gas porosity as shown in Figure 5. Different scholars have done different kinds of study to find out what might cause porosity to form in different kinds of steel. They conducted several studies on various mold-making materials, mold-metal interface reactions, air interactions, pouring temperatures, melt handling functions, and other environmental factors that are likely causes of gas defects [5]. Due to the fact that molten metal may store more dissolved gas than the solid version of the material, gas porosity develops. For example, when it reacts with binders used to make moulds for no-bake systems, different amounts of dissolved gases are often made. Since these gases can get stuck in a metal and cause gas porosity [5]. Figure 5 shows the defect that occur on the both product from wood-based pattern and 3D Printed-based pattern.

Surface Roughness

For measuring surface roughness, a Mitutoyo SJ-410 machine is used, using Roughness Average, Ra, as a parameter. The Surftest SJ-410 surface roughness measuring instrument provides both skidded and skidless measurements. The unit's high-resolution detector and drive unit provide a wide range of highly accurate measurements and ultra-fine steps. Using the unit's skidless measurement and curved compensation functions, straightness, waviness, and the evaluation of cylinder surface roughness can be easily measured and evaluated [6]. There are numerous measurement methods that can be used to determine surface roughness. The many categories of measurement techniques include touch method, non-contact method, comparison method, and in-process method. The touch approach is employed in this project to evaluate the surface finish. While sketching on the surface, the stylus is parallel to the surface [7]. The registered profile generated by this process is then used to determine the roughness parameters. To use this method, the machining process must be stopped. A sharp stylus may produce microscopic scratches on testing surfaces.

According to the material ratio curve (BAC) shows the curve of load length ratio determined as the cut level c function. BAC's interpretation, the proper number would represent the percentage of solid contact at a certain height if the surface had worn down to that level. For many surfaces, the bearing curve appears to be in the 'S' shape. It displays the height distribution histogram's cumulative form [8]. Figures 6 show the surface roughness values from original pattern sample which is wood-based pattern that have been tested using a Mitutoyo SJ-410 machine

Figure 6. Surface roughness values from Mitutoyo SH-

410 machine

After taking three reading samples from the Mitutoyo SJ-410 surface roughness machine, the average value of Ra was plotted on the histogram graph as stated in Figure 7. The average Ra reading obtained from the wood-based pattern is 1.965 micrometres. The surface roughness testing method was carried out in the same way as the wood-based pattern, where three reading samples were taken to obtain the average value of Ra on the "leaf" part. The reading found on the 3D Printed-based pattern was slightly larger when compared to the original pattern made of wood, which recorded an average value of Ra 2.357 micrometres based on Figure 6. This is because the surface of the pattern made of PLA material resulting from the FDM 3D printer produces a surface that is not as smooth as the original wooden pattern. This affected the molten metal that was poured into the mould cavity that was formed.

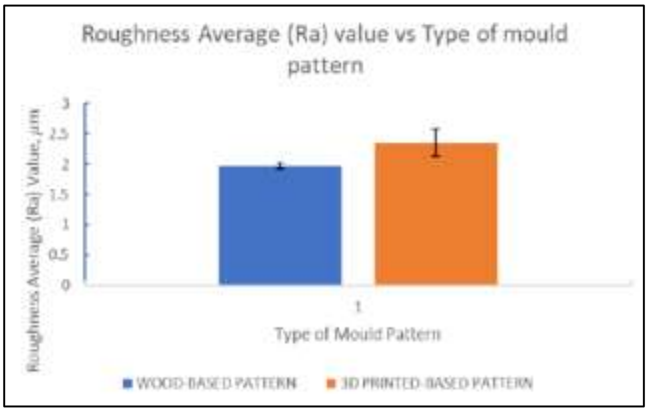

Figure 7. Roughness Average (Ra) value vs type of mould pattern.

CONCLUSIONS

In conclusion, the outcomes of a visual inspection of the product that was generated from a pattern that was based on wood or a design that was based on 3D printing are comparable. Both produce the shape of the flower as it has been fixed according to the shape. In addition, both also have the same defect, which is gas porosity, and there is no defect in the shape. According to the data that has been compiled, the typical value of Ra when tested against designs made of wood and those made of plastic yield slightly different results when compared to one another. This demonstrates that the use of PLA material as a pattern for metal casting provides a result that is practically equivalent, which indicates that it may replace the pattern that is based on wood. The average Ra value that has a difference where the product from the wood-based pattern produces a smaller Ra value (1.965 micrometer) compared to the product from the plastic-based pattern (2.357 micrometres) proves that the wood-based pattern produces a product that has a slightly better quality than the plastic-based pattern. Plastic-based patterns can be used as a substitute for previous patterns made of wood because plastic-based patterns offer superior durability and lower manufacturing costs compared to wood patterns. This is important since patterns for metal casting are intended to be used for an extended period of time. In addition, in contrast to the use of a wood template, the use of 3D printing makes it much simpler to create and then cast a complicated shape.

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