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EMT 2540: PRACTICAL REPORT I

ADDITIVE MANUFACTURING

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1 Introduction

1.1 Additive Manufacturing

Additive Manufacturing (AM) is a manufacturing technology that uses the additive approach in the fabrication of parts. AM significantly simplifies the process of producing complex 3D objects directly from CAD data[1].

3D Printing has become the most commonly used wording to describe AM technologies. This term alludes to the use of a 2D process (printing) and extending them into the third dimension. Significant improvements in accuracy and material properties have seen 3D printing technology become useful in other applications other than prototyping. These applications are: testing, tooling, manufacturing, etc.

3D printing is a rapid and seamless process. It also reduces the amount of resources and processes required significantly. With the addition of some supporting technologies like silicone-rubber molding, drills, polishers, grinders, etc. AM can be possible to manufacture a vast range of different parts with different characteristics. Workshops which adopt AM technology can be much cleaner, more streamlined, and more versatile than before[1].

1.2 Objectives

1. To design a CAD model of a complex 3D part.
2. To fabricate the complex 3D part using an Additive Manufacturing technique (3D Printing)

2 Literature Review

2.1 Additive Manufacturing

Additive manufacturing, referred to in short as AM, is the basic principle of generating a model using a three-dimensional Computer-Aided Design (3D CAD) system and fabricating it directly without the need for process planning. In contrast to other manufacturing processes, AM needs only some basic dimensional details and a small amount of knowledge on how the AM machine works and the materials that are used to build the part[1].

The basic working principle for AM works is that parts are made by adding material in layers, each layer being a thin cross-section of the part derived from the original CAD data. Layer thickness will affect the final output: the thinner each layer is, the closer the final part will be to the original[2].

Additive Manufacturing, commonly referred as 3D printing is a computer-based technology. Like many other manufacturing technologies, improvements in computing power and reduction in mass storage costs paved the way for processing the large amounts of data typical of modern 3D Computer-Aided Design (CAD) models within reasonable time frames. AM takes full advantage of many of the important features of computer technology, both directly (in the AM machines themselves) and indirectly (within the supporting technology).

2.2 Technologies Associated with AM

The most common input method for AM technology is to accept a file converted into the STL file format originally built within a conventional 3D CAD system. There are, however, other ways in which the STL files can be generated and other technologies that can be used in conjunction with AM technology. These are[1]:

2.2.1 Reverse Engineering Technology

Reverse Engineering (RE) is the process of capturing geometric data from another object, commonly referred to as 3D scanning. These data is initially available “point cloud” form i.e. an unconnected set of points representing the object surfaces. These points need to be connected together using RE software like Artec, which may also be used to combine point clouds from different scans and to perform other functions like hole-filling and smoothing.

Engineered objects are scanned using laser-scanning or touch probe technology. Objects that have complex internal features or anatomical models may make use of Computerized Tomography (CT).

2.2.2 Computer Aided Engineering

Direct Digital Manufacture, where AM can be used to directly produce final products, requires Computer Aided Engineering (CAE) tools to evaluate how these parts would perform prior to AM. This ensures that we can build products right the first time as a form of Design for Additive Manufacturing (D for AM).

2.2.3 Heptic Based CAD

CAD modeling systems work in a similar way to Freeform modeling systems to provide a design environment that is more intuitive than other standard CAD systems. They often use a robotic haptic feedback device called the Phantom to provide force feedback relating to the virtual modeling environment. An object can be seen on-screen, but also felt in 3D space using the Phantom. The modeling environment includes what is known as Virtual Clay that deforms under force applied using the haptic cursor. This provides a mechanism for direct interaction with the modeling material, much like how a sculptor interacts with actual clay. Basically, this is CAD for non-engineers for non-engineering applcations.

2.3 Classification of AM Processes

1. Vat photo-polymerization - processes that utilize a liquid photo polymer that is contained in a vat and processed by selectively delivering energy to cure specific regions of a part cross-section.

2. Material extrusion - processes that deposit a material by extruding it through a nozzle, typically while scanning the nozzle in a pattern that produces a part cross-section.

3. Material jetting: ink-jet printing processes.

4. Binder jetting - processes where a binder is printed into a powder bed in order to form part cross-sections.

5. Sheet lamination: processes that deposit a layer of material at a time, where the material is in sheet form.

6. Directed energy deposition - processes that simultaneously deposit a material (usually powder or wire) and provide energy to process that material through a single deposition device.

7. Fused Deposition Modeling (FDM).

FDM uses a heating chamber to liquefy polymer that is fed into the system as a filament. The filament is pushed into the chamber by a tractor wheel arrangement and it is this pushing that generates the extrusion pressure[2].

3 Methodology

The equipment needed and procedures undertaken to carry out 3D printing are described in the following sections. The experiment was done at iPIC (Rapid Prototyping Lab) in JKUAT.

3.1 Equipment

1. 3D Scanning hardware and software (Artec3D, Artec Spider, Artec Studio.)
2. Workpiece shown in Figure 3.1
3. 3D Printing hardware and software (Tiertime Up! Mini)

Figure 3.1: Complex Workpiece

3.2 Procedure

The 3D scanning hardware and software were set up and the workpiece placed on the turntable for scanning. Figure 3.2 shows the workpiece being scanned.

Several scans were performed and the final 3D model was obtained. Some post-processing was performed on the 3D Scan data before processing it into a 3D Model. Some of these procedures are:

1. Aligning the multiple scans using various coincident points and axes on each scan.
2. Denoising - removing noisy areas from the scan.
3. Trimming unwanted parts from the scan.
4. Making adjustments to distorted geometry.

Figure 3.2: Workpiece being scanned

In this practical exercise, FDM was used to come up with a 3D object.

4 Results

4.1 3D Scanning

Several scans were carried out on the object under study, and after post-processing, a 3D model was obtained from the object.

Figure 4.1 shows the 3D model obtained from the scans.

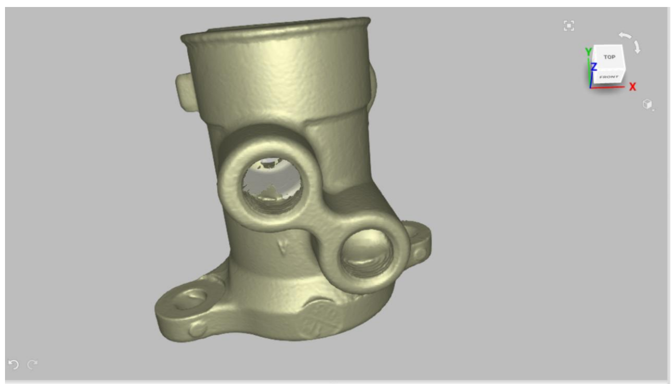
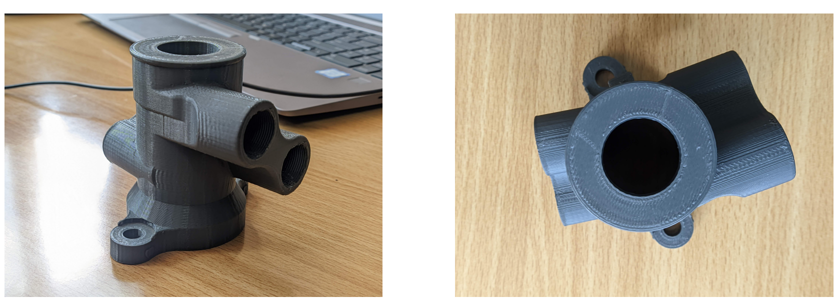


Figure 4.1: Model obtained from 3D scanning

The 3D model was then 3D printed using FDM and the result is shown in Fig. 4.2



(a) Isometric View (b) Top View

Figure 4.2: Reverse-engineered 3D Print

The printed model has exact dimensions and geometries as the original model.

5 Discussion

5.1 3D Scanning

The reverse engineering process is able to replicate an existing object with a great degree of dimensional accuracy and identical geometry. This eliminates the need for accurate measurements and complicated 3D CAD techniques to obtain a 3D Model of an existing product.

While the model obtained is quite close to the original, there are still some inaccuracies in the 3D scan. Some of these are:

1. Distorted screw threads.
2. Blocked holes.
3. Inaccurate internal geometry.
4. Creation of non-existent geometry.

Some of these inaccuracies in the 3D Scan can be minimised by using proper technique and setting up a good scanning environment. Some of the ways to improve the quality of a scan are:

1. Ensuring the scanning area is well lit
2. Scanning dark or non-reflective objects. A thin coating such as fine charcoal dust can be applied to the object to improve scan results.
3. Carrying out several scans to capture geometries on the opposite side of the scanner.
4. Using a turntable to rotate the specimen at a constant speed, as well as synchronising the angular speed with the scanner's polling rate.

References

[1] J. Edgar and S. Tint, "Additive Manufacturing Technologies: 3d printing, Rapid Prototyping, and Direct Digital Manufacturing," *Johnson Matthey Technology Review*, vol. 59, no. 3, pp. 193–198, 2015.

[2] Andanje, "EMT 2540: Advanced Production Technology," *JKUAT Mechatronic Engineering*, vol. 1, no. 3, pp. 121–135, 2022.