# Middle East Technical University

## Department of Metallurgical and Material Engineering

### Mete215 – Materials Processing Laboratory

**Experiment 8: 3D Printing**

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## ABSTRACT

A 3D object was printed with the 3D printer MakerBot Replicator Mini in the duration of 45 minutes. The printed object that can be considered as a sphere that was inside a cage which it could not get out of was drawn in openScad and was converted to G-code in slic3r. The different functions used in openScad was observed and used. Polylactic acid (PLA) was the material that 3D printer used. The fragment number was kept relatively small and the advantages as well as disadvantages of 3D printing were observed and discussed.


## INTRODUCTION

The normal printing is known by everybody and it is the putting of any image to a paper with the use of ink. In this day this printing can be seen as a daily occurrence an it can be considered as 2D printing. With the advancement of technology, a new dimension has been added to printing. It is now possible to print 3D shaped objects with a printer. This printer is called a 3D printer. 3D printing can be seen as a method that exists under additive manufacturing, a method that enables the construction of complex shapes (William K. Durfee, 2019).

Before the additive manufacturing came to light, the materials were let undergo processes such as milling, molding or grinding. This was done to shape the material by removing the extra material and it is called subtractive manufacturing. However, in subtractive manufacturing the removed parts of the materials were considered as surplus and was not very useful. Moreover, by removing of the material there are times where to create a solid structure this way is either very hard or impossible. Therefore, for subtractive manufacturing it can be said that it was a wasteful and inefficient type of manufacturing where it also limited the possible manufacturing of certain complex 3D shapes.

To compare additive manufacturing with subtractive manufacturing; for 3D printing, a method of additive manufacturing it can be said that any complex solid structure only limited by the users imagination can be created faster, by using much less energy and in any place that the 3D printer is set up (makerBot, n.d). With such advantages of 3D printing can been used in variety of industries. Namely, construction, automotive, aerospace, medical and may more (Thabiso Peter Mpofu, 2014).

There exists more than one technique that the 3D printer can use to obtain an end product. Stereolithography (SLA), Digital Light Processing (DLP), Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Selective Laser Melting (SLM), Electronic Beam Melting (EBM) and Laminated Object Manufacturing (LOM) are some of them (TechPath, n.d).

There are certain types of 3D printing. The type of 3D printing is dependent on what type of additive will be used in the process of printing. To give an example if polymers were used as an additive than the type of 3D printing can be said to be polymer based. Polymer based 3D printing is one of the most popular type of 3D printing as the additive material which is the polymer is lightweight and is more processible in relatively lower temperatures. This is important as in our experiment the Fused Deposition Modeling technique is used. This technique uses materials where it is melted such that its viscosity is enough for the printer to be able to print it out. As soon as these materials are out of the printer they solidify. Therefore, the material must be relatively easy to melt for better efficiency where polymers show this exact property.

Apart from polymer-based 3D printing, there are Bio and Metal based printing which are also very important. In bio-based 3D printing it enables to print skin and tissue which may enable to print human organs in the future (Murr, 2016). This is very important as even now there are many people waiting organ donors to undergo organs transplant surgery. In the future, it is seen that there may be no need to wait as custom organs may be printed. The advantages of 3D printing has been mentioned. The possibility of constructing complex solid shapes opens many doors for new innovation. This is more the case in metallic based 3D printing. With the manufacturing of durable and strong complex metal structures, it may enable the breakthrough in many engineering areas.

## EXPERIMENTAL

In this experiment MakerBot Replicator Mini 3D-Printer, Polylactic acid (PLA) filament as well as openScad and Slicer was used as softwares and equipment to conduct the experiment.

**Figure 1.** Image of MakerBot Replicator Mini 3D-Printer

**Figure 2.** Image of Polylactic acid (PLA) filament

To begin the experiment the 3D shape of what will be 3D printed was drawn on the software openScad. To draw the shape, first a 3D shape was created with the properties of 9 width, 9 depth and 15 height using the cube() function of openScad. From this cube a cylinder that had 13 height and 5 radius was extracted using the cylinder() function to create the cylinder and the difference() function to extract the intersection volume from that of the cube. To this shape a sphere with a radius of 4 was added with a sphere() function which was then shifted 2.5 distance downwards from the origin with the use of translate() function. After these steps the 3D shape that was desired was drawn. For the 3D printer to print this structure, the structure needed to be concerted to g-code. To do this a program called slic3r was used.

To end the experiment, the computer was plugged into the 3D printer and the process of printing started. An initial increase of temperature was observed to about 215 $^{0}$C where after the polymer-based filament was used to start the printing of our 3D object. The printing occurred at around 250 $^{0}$C and lasted roughly forty minutes.

## RESULT&DISCUSSION

The shape of the desired object was drawn with the help of the software openScad. In figure 3 the screenshot of the drawn shape and its code can be seen. To create this shape the functions; difference(), cube(), cylinder(), translate() and sphere can be seen.

cube([9,9,15], true) function implies the creation of an cube with 9 width, 9 depth and 15 height that is centered on the origin. Similarly the function cylinder(13,5,5, true) means a cylinder of height 13 and a radius of 5. The function difference uses both the cube and the cylinder function by extracting the volume of cylinder from the cube. The resulting shape can be seen as the part where the sphere is in in figure 3. The sphere(4) function was used to create a sphere with a radius of 4 which as can be seen from figure 3 shifted 2.5 units downwards with the help of translate([0,0,-2.5]) function.

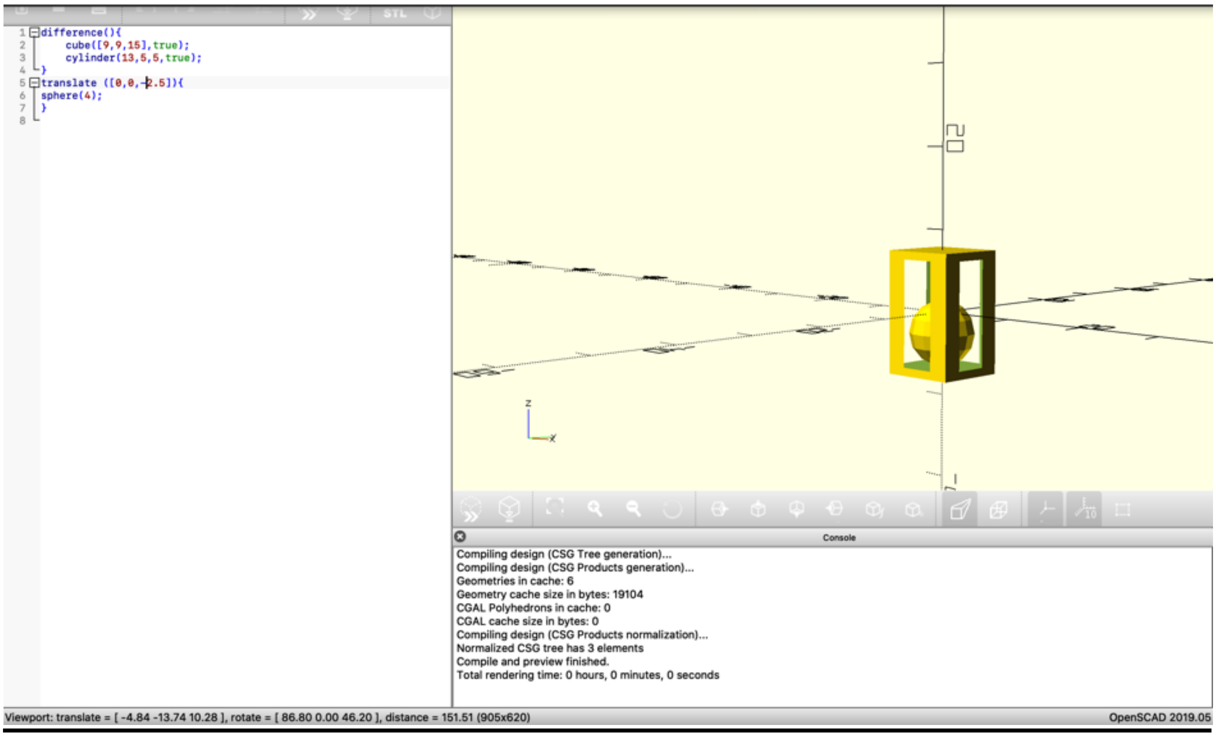


**Figure 3.** Screenshot of the code and image of desired 3D shape

For the created object to be printed, it must be turned into G-code which the printer can understand. This was done by the help of the software slic3r.To use slic3r the shape that was drawn in openScad and was turned into a stl file, which was then added to slic3r. Some of the properties of the drawn shape can be seen in the bottom right corner in figure 4. The layer form can also be seen in figure 5. Slic3r also has features such as the ability to add support material to our structure.

It is important to note that there is a small distance from the bottom of the surface and the sphere. This is to let the cylinder be free inside the structure. If it were to be touching the bottom surface than the sphere would be fixed at the bottom and it would not be able to move.

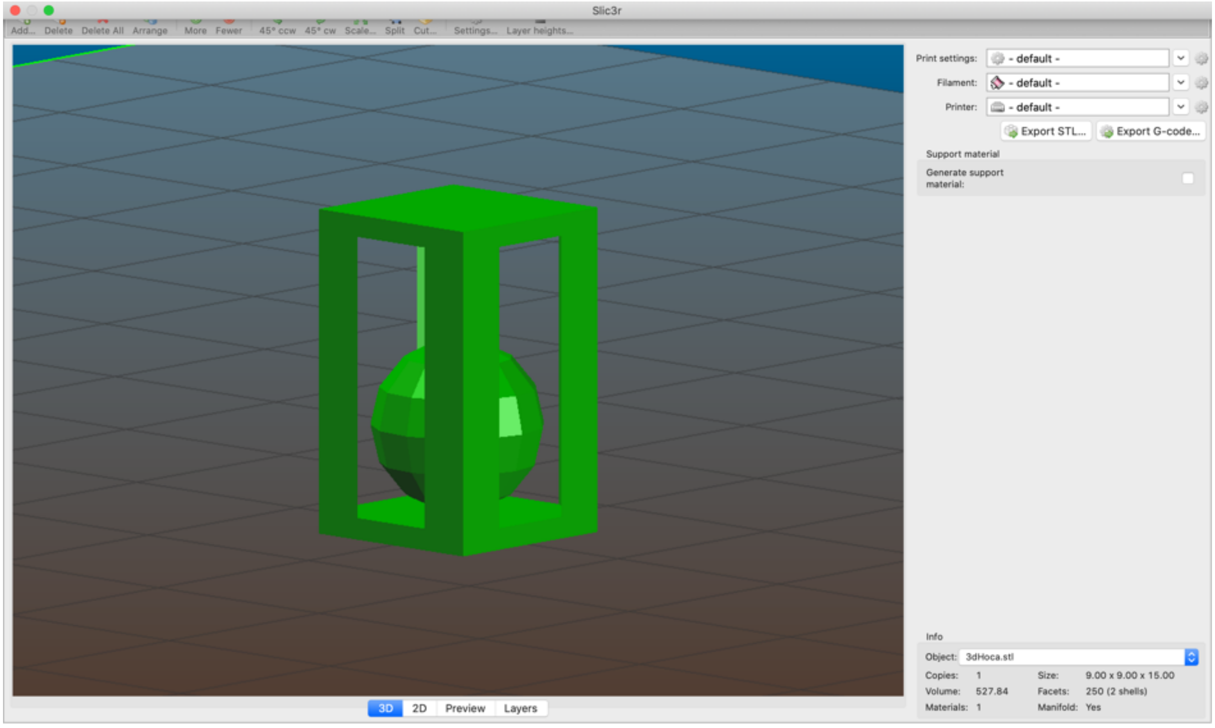


**Figure 4.** The image of the created shape in slic3r

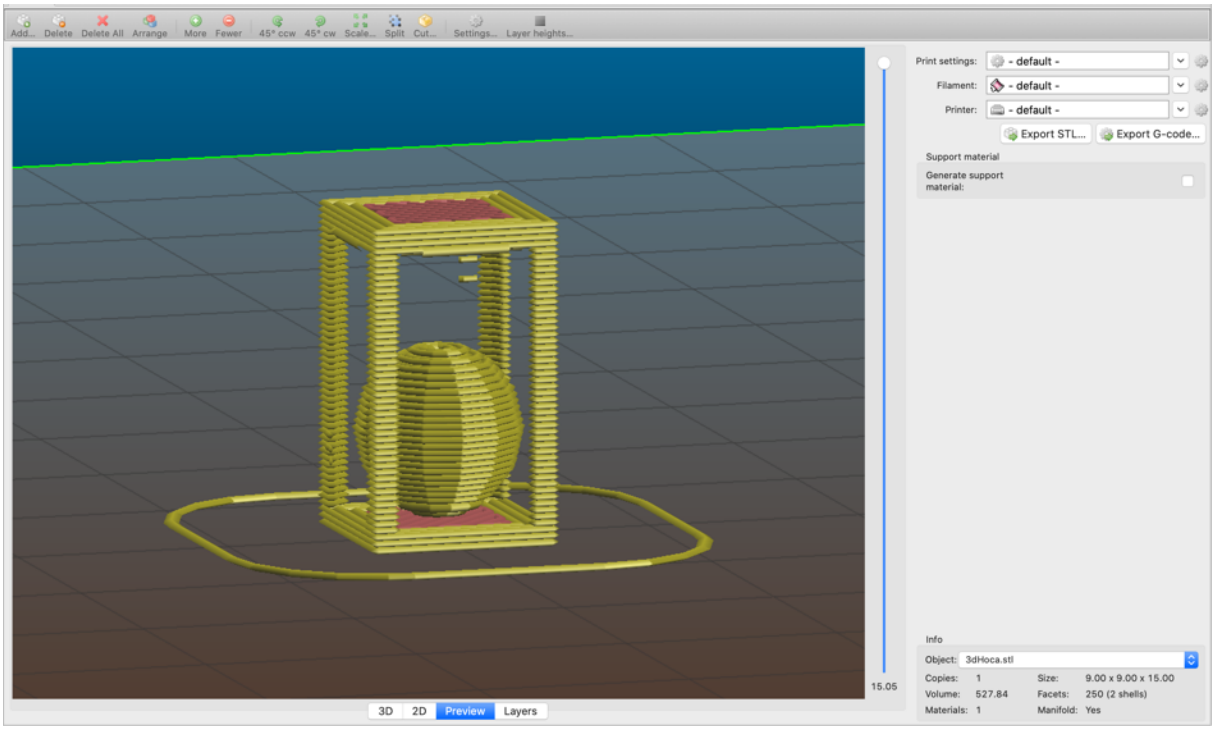


**Figure 4.** The image of the created shape in slic3r where the layers can be seen

Once the G-code was created the printer was connected with the printer for the printing process to start. Before using the filament there is an initial heating to about 215 $^{0}$C. This is to allow the filament to stick to the surface properly. After the printing with the filament starts the temperatures reach about 250 $^{0}$C.

The final thing to note is the number of fragments. In figure 4 the sphere can be considered as relatively non-smooth. This related with the number of fragments which can be altered with more fragments resulting in smoother surface. However, with the increase of fragment number the time it takes to complete the 3D printing also increases. Therefore, to save from time in this experiment a relatively low number of fragments were used.

It can be said that 3D printers when compared to production with traditional methods has more efficiency in time and material. It makes it possible to create structures that could not be manufactured before.

## CONCLUSION

In this experiment the 3D image of a desired shape was drawn in openScad which was then turned into G-code with the help of slic3r. The experiment shows the power of additive manufacturing as the complex shape that was printed with the 3D printer used much lesser material, energy and time than if the same shape was produced with traditional methods. The ability for anyone to print anything they can create results in a faster prototype creation which can result in more innovation which is also a critical factor in additive engineering. The different types of 3D printers also expand the scope of innovation.

To add to the experiment, in the future different types of filaments can be used to observe any differences that can arise.

## REFERENCE


makerBot. (n.d). *10 Advantages of 3D Printing*. Retrieved from makerBot: https://www.makerbot.com/stories/design/advantages-of-3d-printing/

Murr, L. E. (2016). Frontiers of 3D Printing/Additive Manufacturing: from Human Organs to Aircraft Fabrication. *Journal of Materials Science & Technology*, 987-995.

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## APPENDIX

Homework

From us a structure that was similar to what was drawn in the experiment was wanted. The cage structure was wanted with the properties of 23 width and 23 depth. Inside our cage three spheres were needed to be put and two of these structures was wanted to be put on top of each other to create a final shape that consisted of two cages and six spheres where no space existed between each cage.

```
difference(){
     cube([23,23,70],true);
     cylinder(66,15,15,true);
}
translate ([0,0,-22]){
sphere(11);
}
translate ([0,0,0.0]){
sphere(11);
}
translate ([0,0,22]){
sphere(11);
}
translate([0,0,68]){
difference(){
     cube([23,23,70],true);
     cylinder(66,15,15,true);
}
translate ([0,0,-22]){
sphere(11);
}
translate ([0,0,0.0]){
sphere(11);
}
translate ([0,0,22]){
sphere(11);
}
}
```

**Figure 5.** The code of the Homework

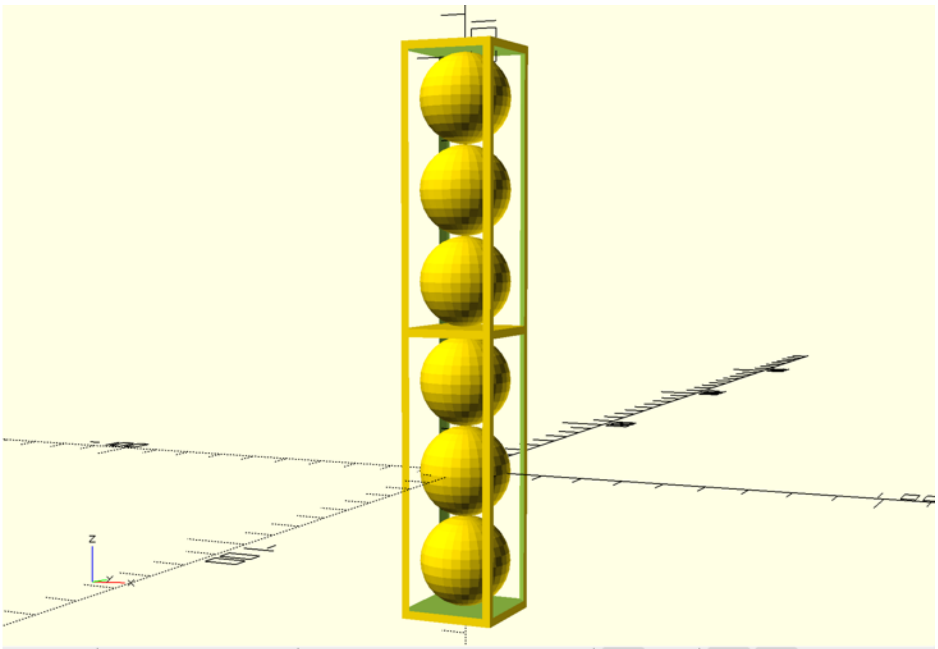

**Figure 6.** The structure of the Homework shape in openScad

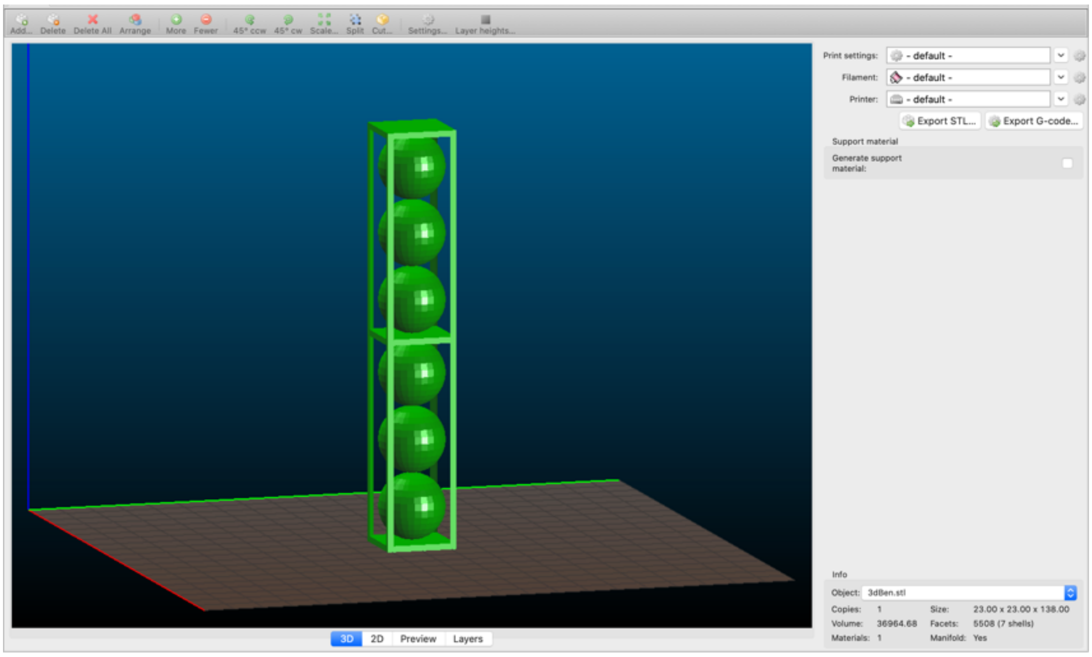


**Figure 7.** The structure of the Homework shape in slic3r

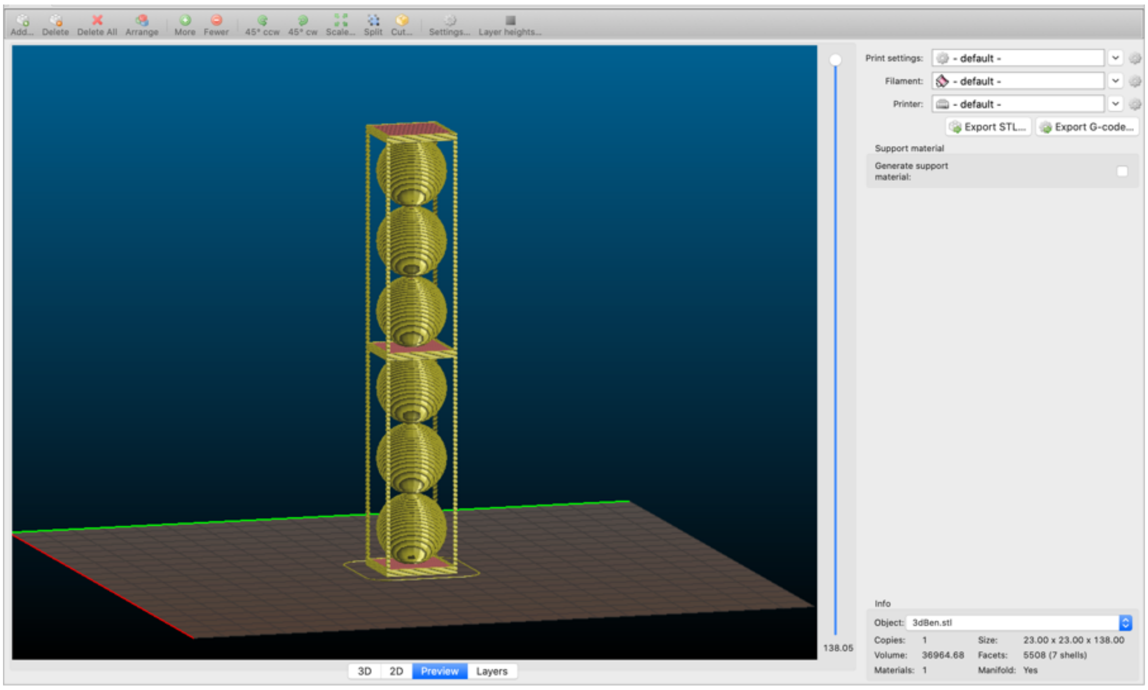


**Figure 8.** The image of the Homework shape in slic3r where the layers can be seen