MECH3660: Rapid Engineering

Laboratory Report

Week/Day: *3/Tuesday*
Time: *2-4pm*
Date: *10/03/2020*

Student's Name & SID:

NAME	SID	Contribution
Dennis Chen	470403767	- Discrepancies
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Introduction

Background

Within the *Rapid Engineering* laboratory session, the project that was undertaken involved the importation of a ready-made 3D CAD model into a printing/CAD software interface. Furthermore, the project encompassed the calibration of the model alongside 3D printing hardware. The model was finally 3D printed with plastic filament material and compared with the CAD model on the software.

Preface

The component that was printed during the laboratory session was a simplified 'rook' chess piece. This report will discuss the comparative features of the CAD model and the physical model that was printed, the material specifications and properties, the key steps taken with the 3D printing and modelling process and finally, the discussion and evaluation of the project performance

Discrepancies

The final product that was printed differed from the CAD model as it had a very dense structural support which resulted in a rougher midsection when these supports were removed. The removal process involved the utilization of blunt and sharp ended pliers, more specifically flat wire cutters and flat nose pliers. A curved and straight surface handheld file was used for the smoothing of any uneven surfaces. This file was employed mainly in the middle section (under the overhang) when the supporting structure was removed. This removal process had resulted in some of the original model being taken off with the support as well as some of the support being left on the model.

The overall model however, was very similar to the CAD model in terms of its shape and form. The model was not warped and was very solid with accurate placement of the filament with no spillages or melted sections. The model was not burnt and was consistent in its filament quality/detail over the whole object. The surface had a very consistent finish through the base and upper section. Parts of the mid section had a rougher finish due to the strong support structure that was printed for the overhang section as reinforcement. Removing this section resulted in an inconsistent finish in the mid section and therefore, would require further sanding to even out the rough layers and inconsistencies.

Figure 1: Final 3D Printed Result

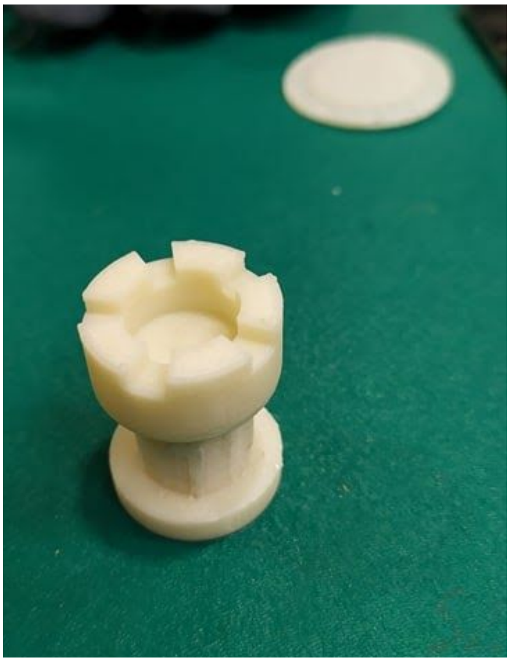

Figure 1: Result with Raft in the Background

Dimensions

The dimensions of the CAD model was measured utilizing the design software. The model was ready-made therefore, the dimensions were previously specified. The physical printed model dimensions were measured using Vernier callipers by a single student.

Overall Linear Dimensions:

Table 1: Dimensions of the Model (all uncertainties ± 0.05mm)

	Width (mm)	Length (mm)	Height (mm)
CAD Model	25.40	25.40	32.50
Actual Dimensions	23.25	23.25	30.70

The discrepancy between the dimensions of the CAD model and the actual dimensions of the printed object most likely arose as a result of the model cooling after it was printed. The extruded filament is extremely hot and coupled with the heated bed, this results in the print being quite hot while it is being printed. While it is cooling down to room temperature, the print gradually shrinks in size, resulting in the slightly reduced dimensions compared to the dimensions of the model.

Change or Optimisation Model

For future attempts at 3D printing using the FDM method, it is recommended that lower density support structure is to be used. Furthermore, calibration is to be performed and checked by observing the printing of the raft. Catching any issues with auto calibration and leveling is critical to have an efficient printing process and a clean model. The model can be better optimised by potentially having a more gradual transition on the overhang section. This may eliminate the need for the mid-section support structure and just have the chess piece itself printed. Furthermore, saving material, time and costs in the long term.

Material

The filament utilized in the 3D printing process can be described as plastic filament. The structure of this material is poly lactic acid (PLA) and is biodegradable plastic. The material is high strength, low flexibility and is fairly durable. This type of material also results in minimal shrinkage and warping as well as insoluble. PLA is produced by a controlled fermentation of carbohydrates such as corn starch or sugarcane. It is a thermoplastic, meaning it can be melted and reshaped with little impact on its mechanical properties (see Table 2 for these).

Table 2: PLA Mechanical properties (Source: Anderson et al 2016)

Properties		Annealed		
		PLLA	PLLA	PDLLA
Tensile strength	MPa	59	66	44
Elongation at break	%	7	4	5.4
Modulus of elasticity	MPa	3750	4150	3900
Yield strength	MPa	70	70	53
Flexural strength	MPa	106	119	88
Unnotched izod impact	J/m	195	350	150
Notched izod impact	J/m	26	66	18
Rockwell hardness		88	88	76
Heat deflection temperature	°C	55	61	50
Vicat penetration	°C	59	165	52

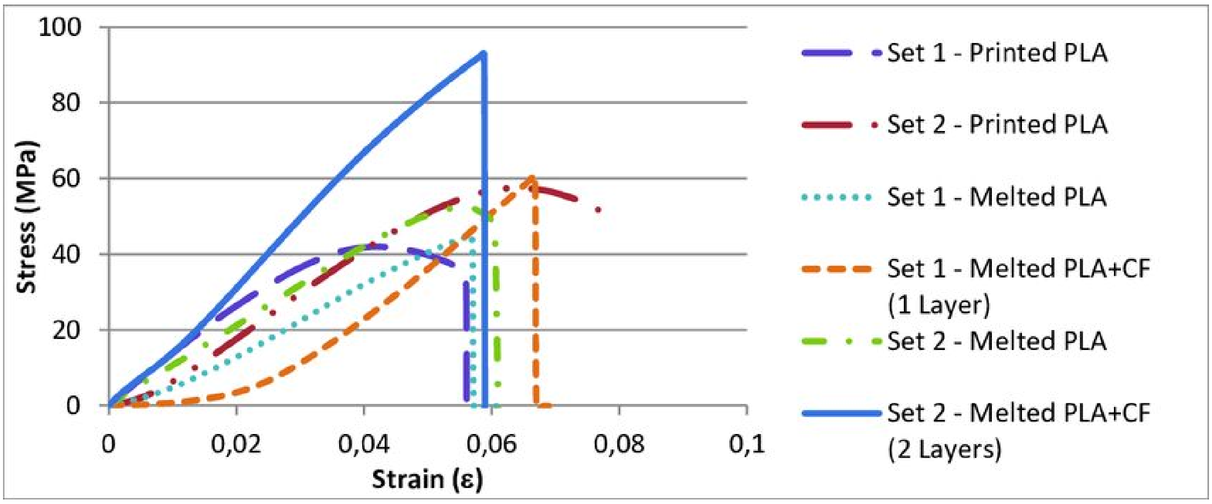

Figure 2: Graph showing tensile strength comparison of PLA, PLA-CF Specimens (Source: Bade et al 2016)

Fused Deposition Modelling Method *(FDM)*

Discuss Fused Deposition Modelling Process. Was this method suitable for printing your group's components?

The steps involved in 3D printing are:

1. Place the printing board or *perfboard* in place (locked in) with both hands.
    a. Ensure that the screw heads are locked in place correctly.
2. Install the filament spool by opening the filament container and feeding the material into the tube.
3. Load the spool onto the holder and cit the end of the fila flat before feeding
4. Load the CAD design into the UP software.
5. Ensure all connections are made with the 3D printer.
    a. Power
    b. USB
    c. Install Printer Drivers
6. Initialize the printer.
7. Auto calibrate the 3D printer and auto level the printer as well.

<u>Note:</u> The auto calibration of the 3D printer involves the arm to travel to nine points as a measurement for the parameters of size and printing area. After this the nozzle high is measured.

8. Load the print head with filament.
9. Let the nozzle reach 260 degrees celsius and therefore, start the printing process.

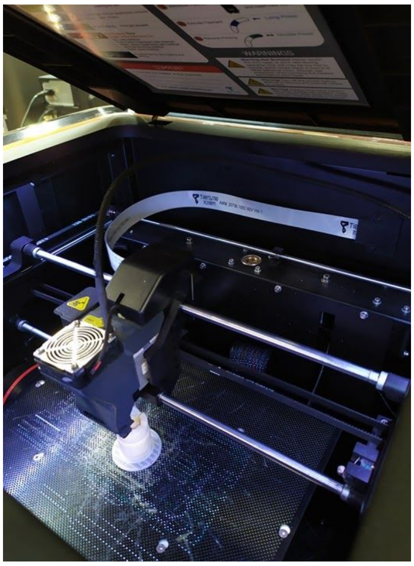

Figure 3: 3D Printer Interior

Figure 4: denotes the nozzle attached to the 3D printer arm which sets the filament once heated in the specified positions addressed in the CAD model/design. The image shows the 3D printer in the printing process (placing the filament).

Note that the piece that is printed at the base with a lower density of material is the raft, which is the base of the structure being printed. This low density allows for the model to be easily broken off the raft hence, separating support material from the model an efficient and clean process.

In summation, the FDM method of 3D printing is very clean and efficient for small prototypes and projects. It allows for customization on the printing style with a versatile plastic that is also recyclable. There is a low level of melting, no damages or impact over time on the nozzle and other components of the printer. This method is very reliable, efficient and clean in creation of most low complexity models. With the project at hand being the chess piece that was printed, the FDM method allowed for a quick print time. Even though the first attempt resulted in melting, the issue was swiftly identified by the nozzle height to be a calibration issue. The printer was easily recalibrated, and the piece was successfully reprinted with no melting or warping. Therefore, the FDM method is a great recommendation of novice users and industry members/consumers.

Finished Product

Ways of improving surface finish:

- Sanding and filing: using filing tools to remove excess material used for support and then using sandpaper with a fine grain to sand back the grooves in the outer layer of the part.
- Vapour smoothing using Acetone: melts the PLA material allowing for the material to morph together and provide a shinier finish. (see figure 2)
- Bead blasting: small beads are blasted at the part to smooth the surface. It is usually used for areas that are difficult to get to so it may be a bit unnecessary for this part since all surfaces are relatively easy to get to

Figure 4: Left to right: 3D print before coating in acetone, after coating

Ways of improving strength:

- Design the print so that the line of filament aligns with the biggest stresses of the part.
- Annealing: plastics used for 3D printing cool relatively quickly when they leave the extruder. This can lead to unevenly cooled parts of the part. As a result, internal stress builds up, especially between layers. Annealing is a technique to even out the internal stresses of the part by heating up the material until just below melting point to reorganise the internal crystalline structure and cause bigger grains to form. This results in a much stronger part but keeps the shape. (Source: Sarcevic, M. 2019)

Ways to improve accuracy (stay within the design tolerance):

- Reduce print temperature and use a lower flow rate:
- Use a smaller Z offset
- Tension printer's belts to minimise dimensional inaccuracies
- Reduce print temperature and use a lower flow rate:

Discussion of Alternate 3D Printing System

Powder Bed Fusion

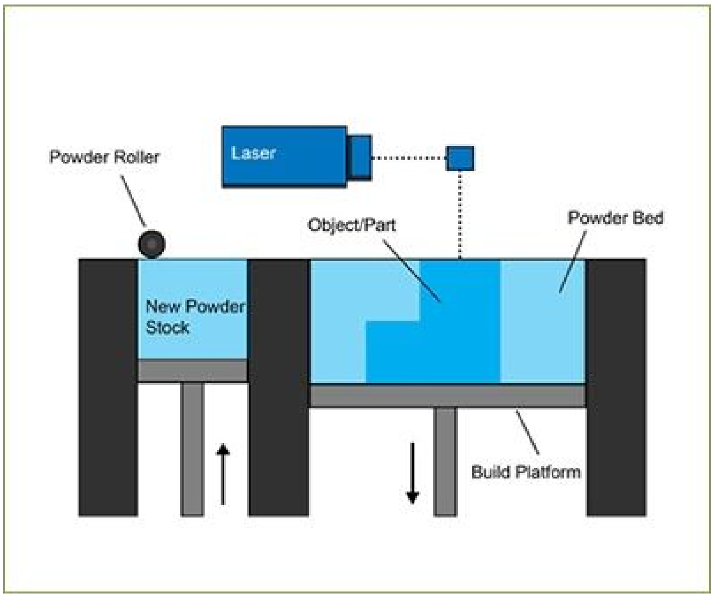

Figure 5: Powder bed fusion (Loughborough University, n.d.)

The Powder Bed Fusion is a 3D printing method that uses lasers to melt and fuse material powder together (Loughborough University, n.d.). One of the popular techniques in this general process is Selective Laser Sintering (SLS). Complex parts can be generated by placing layers upon layers of powder material on top of each other. Focused laser beams are then targeted upon specified locations as calculated from 3D printing softwares on the powder layers to sinter them. These successive layers are typically 20 to 150 micrometers (Kruth, Mercelis, Froyen, & Rombouts, 2005) in thickness which makes it a very detailed manufacturing process. The material powder varies by preference: metal, ceramics and composites (Kruth, Mercelis, Froyen, & Rombouts, 2005).

Figure 6: An SLS printed steering wheel (Koslow, n.d.)

Using the Fused Deposition Modelling Process, the final printed object came out not as we hoped it would. The printed object appeared to have support structures embedded on it that requires a lengthy amount of time and work to remove. Even after removing the support structure, some small bits and pieces were still attached as they were extremely hard to remove. Using extra force would risk the printed object to damage and deformation, therefore it was determined as best to just leave it as it was.

This problem can be resolved by using the SLS machine. As the machine produces the object from the top to bottom, layer by layer, the sintered powder will have adequate support from the powder material throughout the build process (Loughborough University, n.d.).

The possible disadvantages of SLS is that the printed object may have pores which negatively impacts its structure strength but this depends on the powder material used (Jordens, 2014). Additionally, SLS will command high costs as the machineries and equipment for the machine will be expensive.

Conclusion

In conclusion, the laboratory project was successfully carried out based on the physical result that was 3D printed resembles the CAD model. The discrepancies between the two models, in summary are avoidable for future attempts as discussed and overall are not major issues in prototyping. The aim of having the CAD model as close as possible to the physical model therefore, was appropriately achieved. The dependent variables in this project are the printing process while the independent variables are the printing specifications which are recommended to be altered for the future attempts of this project (structure density and support structure density). More accurate measuring instruments and tools for removing the access support structures are recommended for future prints as this will result in better analysis and cleaner, more smooth printed models.

References

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