Effect of different PLA filament colours and process parameters towards the tensile strength of 3d printed parts

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ABSTRACT: Fused Deposition Modeling (FDM) has become among the most popular 3d printing technology. PLA and ABS are by far the most used materials in FDM 3D printing. There are many colours of PLA filament which are assumed to have the same mechanical properties. However, different colours need different extrusion temperatures, and it is uncertain how the colour of PLA would affect material tensile properties. In addition, printing parameters are also affecting the tensile strength of FDM parts. Therefore, this study aims to analyse the tensile strength of 3d-printed parts fabricated from three different primer colours of PLA filaments (red, blue, and yellow) and identify the most significant parameters and their interaction on the tensile strength using the Taguchi method. The printing temperature (°C), layer thickness (mm), and printing speed (mm/s) are set as the main factors. Three factors were set into four groups, with the combination of setting for each group is made using the orthogonal array. It was found that the deviation of tensile strength data between groups (1-4) are more significant than within the group itself. To conclude, process parameters are more influential than filament colours, with layer thickness as the most significant factor affecting the tensile strength.

Keywords: *Tensile strength; PLA colours; Taguchi method*

1. INTRODUCTION

Additive manufacturing (AM) plays a significant role in IR 4.0 due to its versatility and low cost. Among all AM technologies, Fused Deposition Modelling (FDM) is the most commonly used 3d printing, which uses thermoplastic polymer as the printing material. Polylactic acid (PLA) is popular among FDM users, which offers various colours suitable for many applications. However, a study on PLA still lacks, which motivates this research to be carried out. In addition, there is another issue concerning this FDM technology where there is a lack of standardization of material and procedures [1], which simultaneously affecting the mechanical properties of the printed parts. Further, a study on the effect of colour pigmentation on mechanical properties is little studied. Tymrak [2] suggested that inconsistencies in FDM process parameters have caused tensile strength to vary and suggested that it may have been due to the colour of the filament. A study by Wittbrodt [3] has shown a significant interaction between the printing temperature and different filament colours (white, black, silver, and blue). Therefore, in this study, the effect of different PLA filament colours towards tensile strength of 3d-printed parts is evaluated, and the most significant factors affecting tensile strength and the interaction among these factors are identified using Taguchi Method.

2. MATERIALS AND METHODS

In this study, the commercial Cixi Lanbo PLA filament of a primer colour (red, blue, yellow), manufactured by Cixi Lanbo Printer Consumable CO., LTD. with a diameter of 1.75 mm was used. PLA samples were manufactured using an Odyssey X2 desktop 3D printer, a low-cost desktop printer that uses PLA material with a 0.4 mm nozzle size. The 3D printed specimens' geometry was modelled using CATIA V5R21 software according to ASTM D638 Type IV standard. CURA 4.0 software is adapted in setting the required parameters and finally generating the G-code. Taguchi method with the L4 Orthogonal Array is used to design the experiment. The main factors are set into three, which are the printing temperature (℃), the layer thickness (mm), and the printing speed (mm/s). The printing temperature was set to 210°C and 220°C, respectively. According to Valerga [1], a better mechanical strength is achieved at a higher temperature up to the maximum of 220°C. Likewise, the manufacturer recommended the use of printing temperature between 195°C to 225°C.

Table 1 Experimental planning for each colour

Parameter	Speed	Layer	Temp.
1	30	0.1	210
2	30	0.3	220
3	50	0.1	220
4	50	0.3	210

Table 1 shows the experimental planning for each colour, with four runs. Replication of two is set for each experiment, making the total number of runs equal to eight. Therefore, altogether, there were 24 runs performed for all three colours. The bed temperature and fill density were set to 60°C and 30%, respectively.

Shimadzu AGS-X is used for the tensile test with a 20kN load. Tensile testing is performed with a testing speed of 5 mm/min. Then, the fractured specimens were sputter-coated using SC7620 Mini Sputter Coater and Carl Zeiss Evo 50 Scanning Electron Microscope (SEM) is subsequently used for the microstructure study. The images were captured at 15.00kV with 25x 50x 100x 200x of magnification power.

3. RESULTS AND DISCUSSION

3.1 Tensile test

Figure 1 shows the stress-strain curve for all 24 specimens. The result for all colours slightly varies according to each parameter setting. The colour of the filament slightly can affect the tensile strength of 3d printed parts, which might be due to the crystallinity of the PLA during the colour pigmentation. According to Aydemir [4], different pigmentations influence some aspects of the parts. Figure 2 shows the max force versus the type of parameters plot. Parameter 3 setting produces higher tensile strength, among others. The deviation between all four groups is significant. However, the deviation of tensile strength within the same group parameter is not too noticeable. As for the interaction between parameters, the layer thickness is the most influential, follows by the printing temperature and printing speed. The finding is supported by the main effects plot for all colours. However, the main effect plot for the printing speed of the blue filament, for example, as depicted in Figure 3, is almost horizontal, which indicates almost no main effect of the speed compared to layer thickness and temperature.

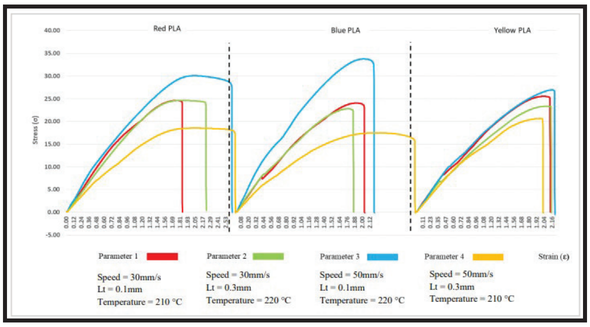

Figure 1 Stress-strain curve for all colours

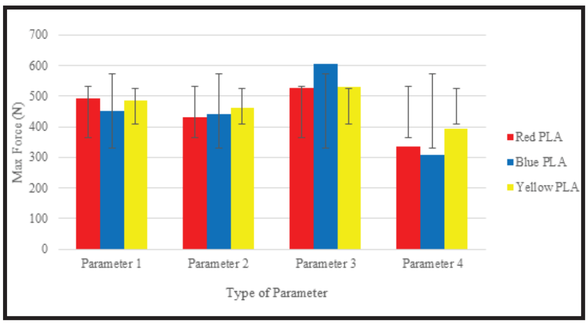

Figure 2 Max force vs. type of parameter for all colours

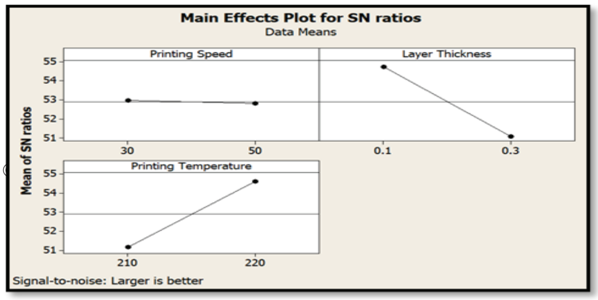

Figure 3 Main effect plot for the blue filament

3.2 Fractographic analysis of the PLA samples

As for the microstructure analysis, the image of the PLA filament for parameter 3 and parameter 4 is compared. According to Figure 4, a significant difference in the cross-section of the layer is observed. A smooth surface with fewer voids is discovered on parameter 3, while more voids are spotted on the rough fractured surface of parameter 4.

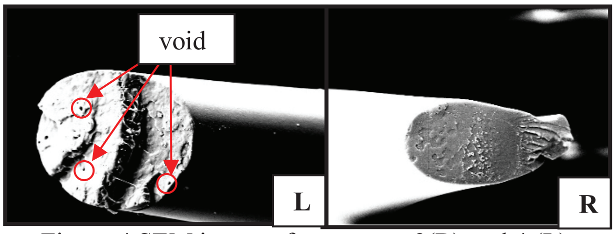

Figure 4 SEM image of parameter 3(R) and 4 (L)

4. CONCLUSION

In conclusion, the tensile strength of 3d-printed parts is affected by the different settings of parameters, which fluctuate the tensile test. The difference tensile strength data between parameter (1-4) groups are more significant than within the group itself.

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