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Investigation on Effect Oo Abs Filament Extrusion Process Temperature for Fused Filament Fabrication (FFF) 3D Printing

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Abstract: The study highlighted the investigation on effect of temperature on the processing of ABS filaments for Fused Filament Fabrication (FFF) by using a small extruder machine. FFF is easier to set up and utilise than other consumer additive manufacturing methods. It also costs less to run than its competitors. However, producing filaments with a small extruder requires appropriate settings for FFF. Filaments available on the market are produced using commercial extruders that equipped with the establish equipment. Therefore, this study's aim is to investigate the application of Acrylonitrile Butadiene Styrene (ABS) from SONGHAN Plastic Technology (China) pellets to produce filament for Fused Filament Fabrication (FFF) by using a Desktop Filament Extruder machine. The result was obtained by conduct mechanical testing which include tensile and izod impact test by refer to ASTM (D638 and D256).

Keywords: FFF, Rapid Prototyping, Filament Extruder

1. Introduction

Rapid prototyping (RP) is a prominent practice in many sectors for creating low-cost models, prototypes, and unique components. RP is one of the approaches that designers may use to generate better designs. 3D Printing is a sort of RP that speeds up product design and development.

This is one of the main RP procedures that produces functioning prototypes like as the heated extrusion head extrudes molten plastic that end-use engineering material that allows you to conduct functional testing on sample pieces. The FFF method uses acrylonitrile butadiene styrene (ABS), which is a popular plastic [1].

ABS is a thermoplastic polymer used in 3D printing production. This material is popular because of the economic cost and easy to handle. In addition ABS has a good heat resistant, lightweight, formable, and reflective. Depending on the appliance, FFF components may be utilised for minimal to

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thorough functional testing. FFF materials enable the production of actual components for prototype, functional testing, installation, and most importantly, end usage. This research is a first step toward the fabrication of filaments from ABS pellets. The purpose of this research is to examine the use of extruder machines to manufacture FFF filaments. Mechanical and physical properties of the finished product will be evaluated, providing data for further research.

- Effect of Filament Diameter Tolerances in Fused Filament Fabrication

3D printer users face numerous obstacles that can result in incorrect or failed prints. To obtain acceptable prints, Hernandez (2015) claims that "differences in material qualities across manufacturers and even between various materials lots from the same manufacturer can result in radically varied printing results." The volume extruded by 3D printing software depends on the filament diameter, nozzle diameter, and extrusion flow rate. When printing starts, an extruder wheel turns, forcing plastic down the hot end. It will not correct for discrepancies in the filament it is fed and will continue printing. It's called "inconsistent extrusion." Those that extrude filament favor angled extrusion, vertical extrusion, and horizontal extrusion with a pulley to spool the filament. However, preferences do not determine which tactics are acceptable or which are better for the final output [2].

- Moisture effects on the ABS used for Fused Deposition Modelling Rapid Prototyping Machine

A lot of moisture changes, which means there is more relative humidity in the air. This polymer swells, which changes its physical, morphological, mechanical, and thermal stability. Earlier research suggests that these changes may have caused the nozzle to become blocked in the FDM [1]. The blocked nozzle leads to very expensive machine head repairs, which are often not worth it for places with limited funds. Even though it has a huge impact on people who use FDM machines, the issue isn't clear [3]. Temperature also has a big impact on how quickly moisture is absorbed. Despite the fact that moisture may cause physical changes, it doesn't cause ABS to become so big that it's too big for the liquefier's diameter. In the end, it can be seen that moisture makes the ABS bigger, but it doesn't slow down the flow of water through the nozzle.

- Impact behavior of acrylonitrile-butadiene-styrene after temperature and humidity load

Brazilian scientists explored three varieties of commercial ABS: GP (general-purpose ABS), HI (high-impact ABS), and HH (high-impact ABS) (ABS high heat resistance). They investigated the activation energy of all three ABS and discovered that it is significantly higher than previously reported. The penetration test was performed on injection molded ABS samples at a fall height of 100 J before and after temperature and humidity loading, and the findings were analyzed and discussed. ABS was shown to have a decreased impact resistance when subjected to temperature and humidity loads [4].

2. Materials and Methods

2.1 Flowchart

The flowchart of this research is shown in Figure 1

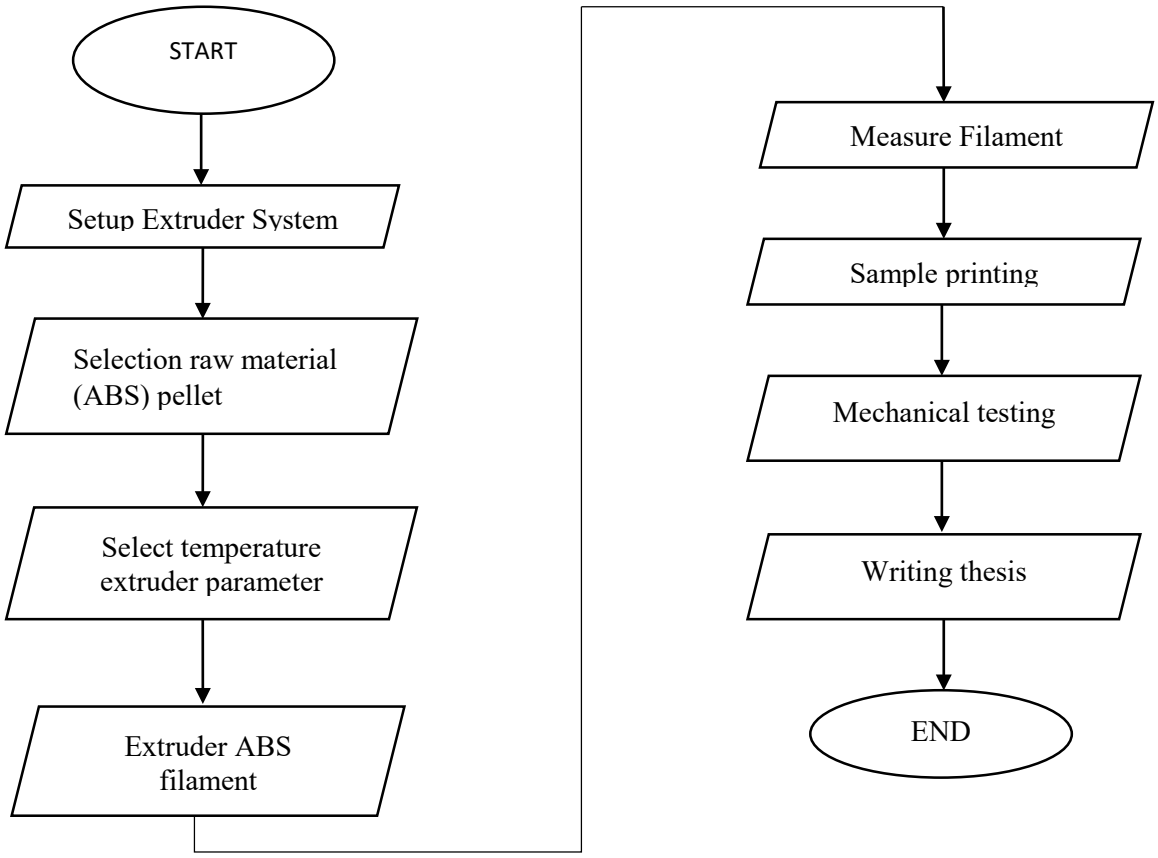

Figure 1: Process flow of the overall project

In this work, ABS from SONGHAN Plastic Technology (China) pellets was selected to produce filament for Fused Filament Fabrication (FFF) by using Desktop Filament Extruder machine. The range for temperature for ABS pellet is between 230 °C – 260 °C [6]. Addition temperature 220°C and 270 °C were selected from out of range to find out the effect of temperature on the ABS filament. The temperature of 220 °C, 230° C, 240 °C, 250 °C, 260 °C and 270 °C will be selected to produce the filament. The produced filament was measured using vernier caliper. The 3D printer will be used to print the specimens by using ABS filament. In order to analyze the effect of temperature towards ABS filament processing, mechanical test in terms of tensile and izod impact test will be conducted.

2.1 Filament wire fabrication process

The desktop filament extruder machine will be used to extrude the raw material from the ABS pellets. The extruder machine's filament discharged into the winder, which caught it. Ultimately, the machine's temperature and speed will determine the filament's output. Diagram of the small extruder system is shown in the following Figure 2.

Figure 2: Layout of mini extruder system

2.2 Temperature setting for Desktop Filament Extruder Machine

Different parameter of temperature extruder has been set to produce the ABS filament in selected temperature 220 °C, 230 °C, 240 °C, 250 °C, 260 °C and 270 °C. The parameter of speed will be fixed to 2.6 mm/s to produce 6 different of extruder temperature in Table 1.

Table 1: Different parameter of extruder temperature

No	Speed	Temperature (°C)
1	2.65 mm/s	220
2		230
3		240
4		250
5		260
6		270

2.3 Measuring fabricated filament size

The range measure for diameter of ABS filament will be used by vernier caliper. The average of inconsistent diameter for ABS filament will be state in Table 2.

Table 2: Average diameter of ABS filament

No	Speed	Temperature (°C)	Ø (Diameter) Range measure of diameter – 66cm										Average
1	2.65 mm/s	220	2.0	1.9	2.0	2.0	1.9	2.2	2.0	2.2	1.9	2.0	2.01
2		230	2.3	2.0	2.1	1.8	1.9	2.0	1.9	2.2	2.0	1.9	2.01
3		240	2.1	2.3	2.4	2.2	1.9	1.8	1.7	2.5	2.3	1.9	2.11
4		250	1.7	2.3	1.8	2.3	1.8	1.7	1.6	1.8	1.5	1.7	1.82
5		260	1.5	2.1	1.6	2.2	1.7	1.6	1.6	2.0	1.6	1.7	1.76
6		270	1.9	2.1	1.6	2.0	1.7	1.9	2.1	1.8	1.9	1.6	1.86

2.4 Fixed Parameter setting for FFF printed sample

Marlin is one of the firmware for runs G-code as robot software on the 3D printer's control board which manages all of the machine's real-time activities. Marlin is chosen for machine setting for 3D printer in the process of printed sample. The difference G-code flavor between Marlin and Ultimaker 2 is printing temperature, build plate temperature and flow can be set and adjust by using G-code flavor for Marlin.

Table 3: Fixed Parameter setting for FFF printed sample

Nozzle diameter	0.4 mm
G – code flavor (Machine setting for 3D printer)	Marlin
Printing temperature	250°C
Build Plate temperature	85°C
Pattern	Lines
Layer thickness	0.15 mm
Infill density	50%
Print Speed	45 mm/a

2.5 Samples preparation

There are 30 ABS specimens that have been produced according to ASTM standards (D638 and D256) for tensile and izod impact test. For measuring tensile (ASTM D638) and impact test (ASTM D256) respective standard specimens having dimensions 63.5 mm × 9.53 mm × 3.4 mm, 63.5 mm × 12.7 mm × 3.17 mm.

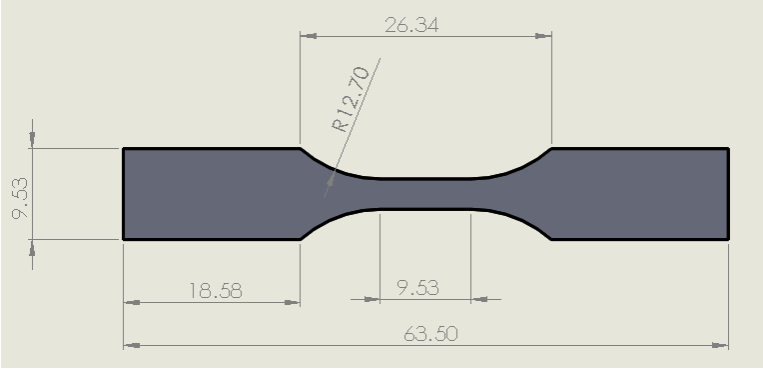

Figure 3: Dimension sample for tensile test type iv

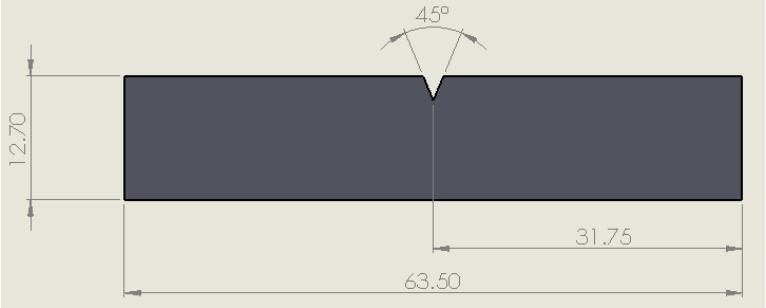

Figure 4: Dimension sample for Izod impact test

2.6 Mechanical Test

After the specimens have been printed, the tensile and izod impact test will be conducted. Figure 5 shows one of the specimens break at top while Figure 6 indicates the izod impact specimens after test.

Figure 5: Tensile test specimens after test

Figure 6: Izod impact test specimens after test

3. Results and Discussion

The desktop filament extruder machine produces ABS filament at 220 °C, 230 °C, 240 °C, 250 °C, 260 °C, and 270 °C. However, only 3 from the 6 temperatures (220 °C, 230 °C, and 240 °C) can be 3D printed. This is because of the inconsistent diameter of filament. Aside from that, the result will be compared to different ABS filament temperatures. The comparison and debate also helped to clarify the ABS filament's mechanical qualities. Before utilizing the filament to print a sample, the diameter of each filament range was measured using a digital vernier calliper. 30 samples were printed at 220 °C, 230 °C, and 240 °C before tensile and izod impact tests.

3.1 Tensile Test Results

The Lloyd Machine produces results like as Ultimate Tensile Strength (UTS), Young's Modulus, percentage strain at maximum load, and load at break. In Table 3.1, the average tensile test result is focused on Ultimate Tensile Strength (UTS) and Young's Modulus.

Table 4: Average Result for Tensile Test

Temperature (°C)	Ultimate Tensile Strength (MPa)	Young's Modulus (MPa)
220 °C	40.146	1691.12
230 °C	35.287	1464.32
240 °C	34.898	1517.24

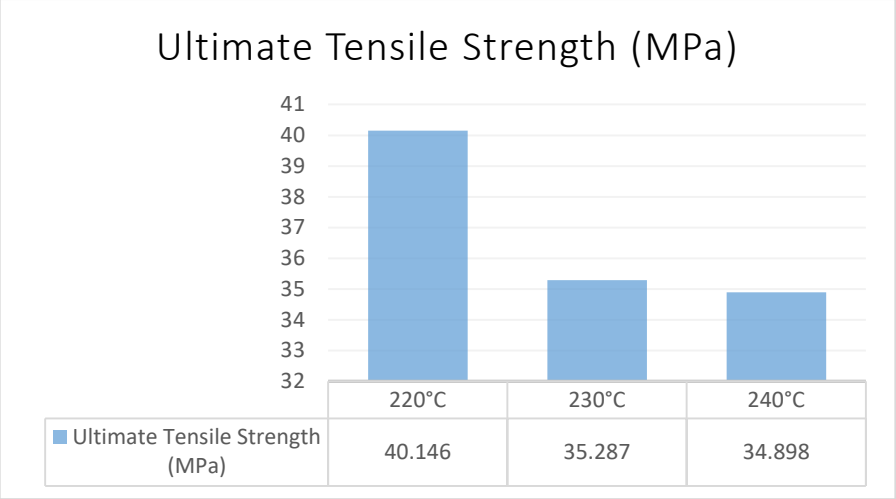

Figure 7: Average result for Ultimate tensile strength

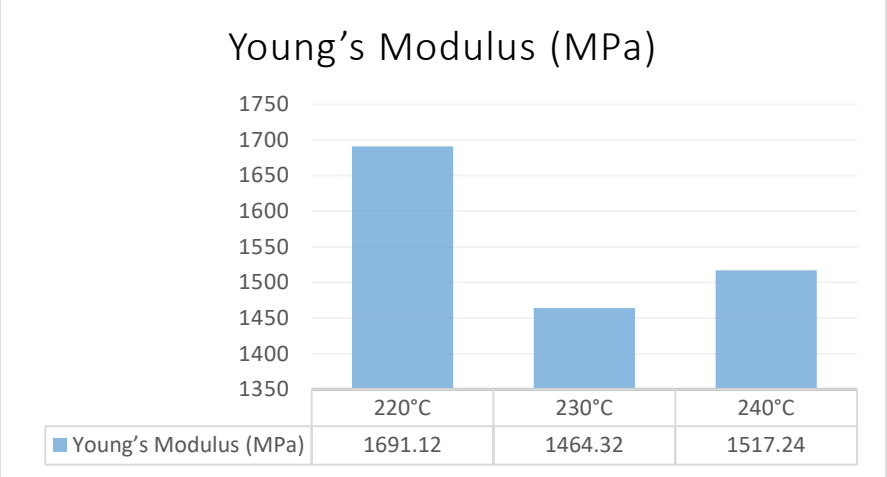

Figure 8: Average result for Young's Modulus

The 3D printer can print at 220 °C, 230 °C, and 240 °C, even though the filament diameter varies when processing ABS filament. Support is needed to feed filament into the 3D printer. Achieved the greatest temperature 220 °C for Ultimate Tensile Strength and Young's Modulus. There are some inconsistency in the tensile result. Due to non-constant environment while the filament was fabricated. In this case, the indoor environment might affect the property of fabricated filament. On other hand, fracture propagation moves inside the weak part of the specimens, which is the bonding between two beads, in the specimens [5].When tested, some specimens break at the top, not at gauge length. The specimens slip in the Universal Testing Machine's jaws, influencing the reading. To avoid errors in the tensile test result, the specimens must be appropriately placed.

3.2 Izod Impact Test Result

According to ASTM D256, the results obtained from a pendulum impact testing equipment are shown in (Table 5, Figure 9 and Figure 10).

Table 5: Average result for Izod Impact Test

Temperature	impact strength, kJ/m²	impact energy, J
220°C	11.01	1.84
230°C	8.28	0.28
240°C	6.69	1.069

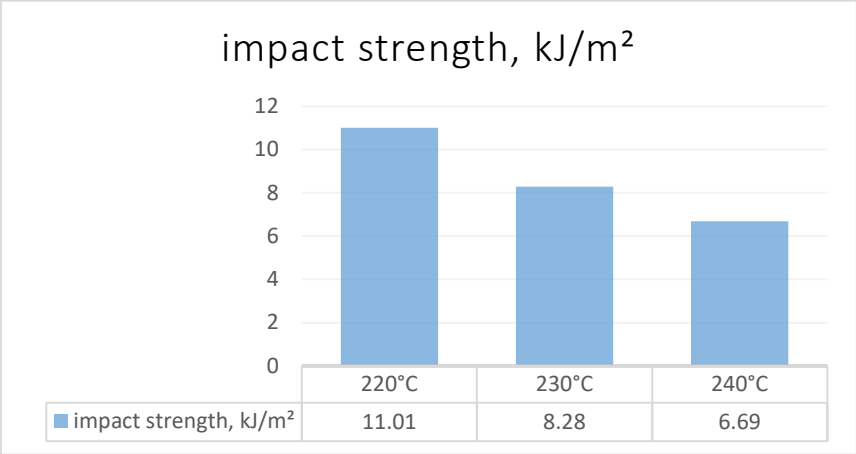

Figure 9: Average result for impact strength

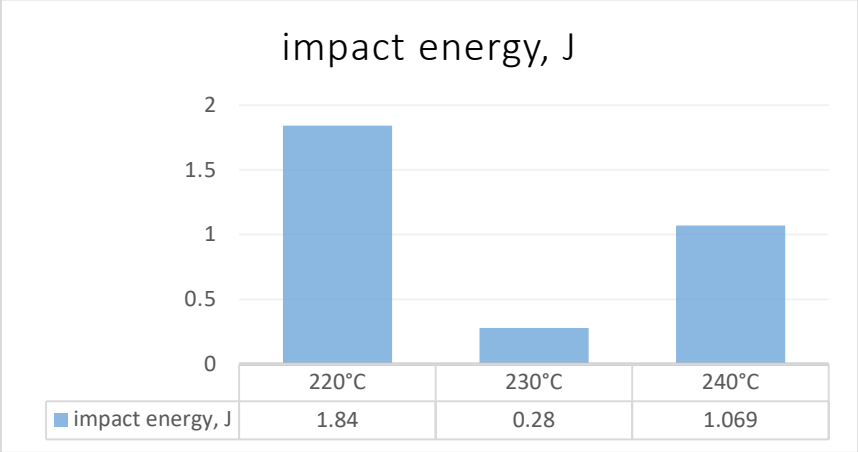

Figure 10: Average result for impact energy

The average result of the Izod impact test clearly indicates that the temperature 220 °C has the greatest outcome of any temperature sample. There were some unexpected findings from the Izod impact test. Because the impact test measured the amount of energy that polymers could absorb, it indicated whether ABS temperature fracture was more ductile or more brittle based on the amount of energy that material could absorb. When specimens are tested, the clamped of the specimens are not properly, resulting in an incorrect vertical position of the specimens. Another issue arises during the printing of the specimens, when the filament does not travel properly due to the filament's variable diameter.

4. Conclusion

The major goal of the study was successfully achieved which is to investigate the utilization of ABS pellets from SONGHAN Plastic Technology (China) to fabricate filament for Fused Filament Fabrication (FFF) using a Desktop Filament Extruder. 3D printers can print filaments at 220 °C, 230 °C, or 240 °C. The material's mechanical properties were also studied, including Ultimate Tensile Strength (UTS), Young's Modulus, Impact Strength, and Impact Energy. As a result, the filament extrusion temperature 220°C have more strength than other extrusion temperature.

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