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The effect of ambient temperature on the quality of three-dimensional printer products in FDM technology for ABS material

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Abstract**—**3D printing is a widely used technique for creating three-dimensional solid objects from a digital design. To ensure the production of high quality 3D printed parts, the correct selection of printing parameters is essential. This study aimed to investigate the effect of environmental temperature on the temperature generated by the printer, using the difference between the quality of 3D printer products when closed or open print system. The focus was on how environmental temperature affects this. The results showed that both methods had equal dimensional accuracy, however, the closed printer provided better results in terms of surface roughness and smoothness, while the open printer had a higher tensile strength due to its rapid cooling rate**.**

Keywords: 3D printer, temperature, mechanical properties, ABS

I. INTRODUCTION

The increasing popularity of 3D printing, also known as additive manufacturing (AM), rapid prototyping (RP) [1], or solid free-form technology (SFF) [2], in a variety of applications has led the modern manufacturing industry to seek to replace conventional techniques with this innovative technology where suitable. This is due to the numerous advantages that 3D printing offers in comparison to conventional, energy-intensive techniques, such as the ability to fabricate complex geometries as a single unit with no joints, reduced material and labor costs, improved surface finish, decreased energy demand, single-step processing temperature, simplified processing (CAD model-Print-Install), near-net shape finish, quick production time, short lead time, and lower overall cost.

One of the main benefits of 3D printing is the capability to produce near-net shape products without the need for physical molding to achieve the desired shape of the product. Designs can be created as 3D objects using software such as AutoDesk Products and SolidWorks, which are commonly used for designing prototypes for 3D printing applications. Once created, the 3D soft files can then be converted into the stereolithography (STL) format, a format that can be interpreted by a 3D printer [3].

Fused deposition modeling (FDM) is a widely used method for 3D printing particularly in the medical, aerospace, and automotive industries, where complex geometries are required [4]. This process involves using a 3-D printer (Stratasys) to produce parts made of acrylonitrile-Butadiene-styrene (ABS) plastic. The parts are fabricated in layers composed of fibers and formed through the application of heat to the FDM head, which liquefies the material, which is then extruded through a fine nozzle and deposited onto a platform [5].

FDM parts are exposed to a variety of environmental conditions, with some studies indicating their use in the creation of smart soft composites to cure polydimethylsiloxane [6]. This study aims to verification by experimentally examining the effect of environmental temperature on the mechanical properties of printed products with respect to closed and open print system.

II. METHODOLOGY

2.1. Materials

In this study the ABS material commercially available industrially common 3D printing material was used: Acrylonitrile butadiene styrene (ABS). This filament of 1.75 mm in diameter.

2.2. Experimental procedures

2.2.1 Specimen preparation

Samples shown in Figure: 1 were designed as 3D model according ISO 527 standard with SolidWorks CAD software for tensile test using a designing software and transferred to 3D slicing interface program to be printed.

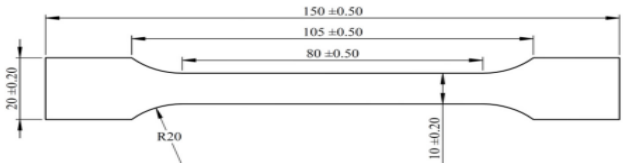

Figure 1. Dimensions of 3D printed Samples

For each type of mechanical test, 3 specimens were prepared and tested, and then the average value was taken for data analysis in order to improve accuracy and reliability of the experimental data. The difference in mechanical properties and surface roughness between two types of 3D printers was studied; one being closed and the other open. The same parameters were used for both printers. Figures 2(a,b) show the 3D printer used in this study, and the printer settings are given in the following table.

infill	100%
Printing temperature	240C^0
Build plate temperature	80C^0
Print speed	55mm/s
Fan speed	100 mm/s
Layer height mm	0.2 mm

Fig:2a, Open 3D printer

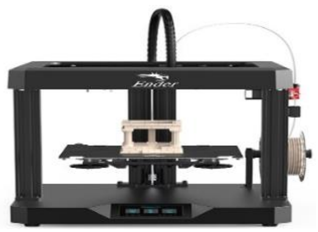

Fig:2b, Enclosed 3D printer

Tensile tests for samples under the same condition were conducted with tensile test machine shown in Figure 3. Hardness tests for samples were conducted with hardness test machine shown in Figure 4.

Fig3. Tensile Test Machine

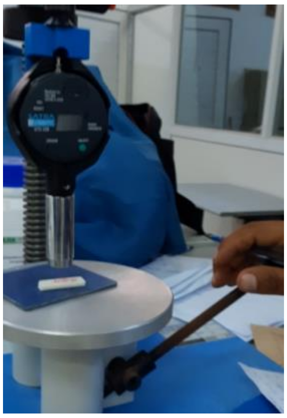

Fig.4. Hardness Test Machine

III. Results

As was detailed in Table 1. ABS specimens were tested and Table (1) and figures: 5(a,b).

Fm: tensile strength
FP: yield strength
Ft: elastic limit

Table1: shows the results of the tensile test

	Fm (KN)	FP (KN)	Ft (KN)	Elong (mm)	Hardness
Closed	0.812	0.797	0.579	1.7772	0.964
open	0.884	0.872	0.601	3.1788	0.953
From closed to open	8.86% ↑	9.41% ↑	3.79% ↑	78.86% ↑	~1% Not changed

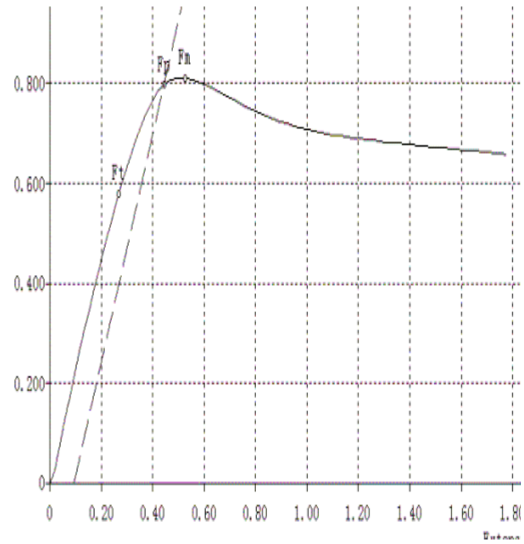

Fig: 5a, Tensile test curve for enclosed 3D printer

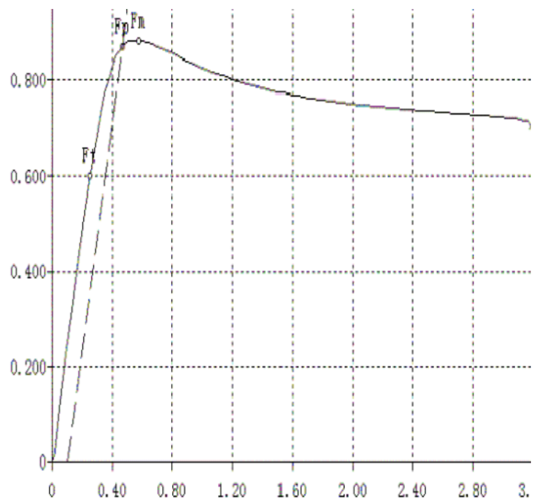

Fig:5b, Tensile test curve for an open 3D printer

The appearance of the 3D printed tensile test ABS specimens with difference environmental temperature are shown in Fig: 6 (a,b,c,d)

Figure 3a. open 3D printed specimens at room temperature

Figure 3b. Closed 3D printed specimens

Figure 6c. Closed 3D printed surface roughness of specimens

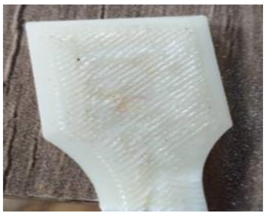

Figure 6d. open 3D printed surface roughness of specimens at room temperature

IV. Discussions

The tensile test results from the closed to the open 3D printer revealed an increasing values of the tensile strength, yield strength, and elastic limit of all samples. The temperature in the printing cell is to be higher in the closed 3D situation than the open one, that's why the mechanical properties were significantly affected as shown in the table 1. This is consistent with what (Eunseob Kim et al) [7] . Specifically, the tensile strength decreased by 8.86%, the yield strength increased by 9.41%, and the elastic limit by 3.79%. In contrast, the elongation decreased significantly by 78.86%. No significant change in hardness was observed when compared to results from an open 3D printer.

After visual observation, the open 3D printer results showed rough surface and geometrical irregularities, as well as strong adhesion between the first layer and bed. The variation in mechanical properties and surface roughness between the closed and open printers is likely due to rapid cooling during printing.

V. Conclusions

1-The samples have the same dimensional accuracy in both methods.
2-The 3D printer with an enclosure gives better results in printing ABS with a smoother surface.
3-The rapid cooling rate has an effect on the surface roughness of the open printer.
4-The higher the temperature, the lower the tensile strength.
5-The cover of the enclosed printer helps to maintain temperature, produce a uniform surface and provide stable mechanical properties

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