

# Mechanical Properties and Microstructure of the Pre-Dried and Undried PLA Filaments in Additive Manufacturing

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**ABSTRACT** – Pre-drying the filament before printing may remove moisture and improve surface quality, restoring its original performance and eliminating waste. This paper aims to present the influence of filament drying on the moisture-exposed PLA filaments and compare the undried and pre-dried filaments' mechanical properties, porosity, and microstructure. A new filament was set as a control specimen, and a different exposure time with the humidity was varied for the analysis. The parameter setting for drying and 3D printing was constant for all conditions. As a result, pre-drying the filament resulted in better tensile and flexural strength, less porous microstructure, shorter interlayer gaps, and better interlayer adhesion. The increment of 5.73%, 12.67%, 56.45%, and 5.40% was calculated in the tensile, flexural, interlayer gap, and density, respectively, in the pre-dried control specimen, compared to the undried.

## 1. INTRODUCTION

PLA filament is hygroscopic and improper storage of the used thermoplastic filaments creates room for moisture absorption, affecting the performance and quality of the printed part, causing bubbles and poor printing quality. Drying the filament before printing may be an alternative to eliminate moisture and restore the original performance of the filament and prevent it from being disposed of as waste which simultaneously supports sustainability. Poor environmental conditions such as humidity may cause warping, poor layer adhesion, and uneven portions [1]. Moisture in the thermoplastic causes the filaments to expand, boil, and break as they are extruded, influencing the surface quality, layer adhesion, and mechanical performance [2]. Moisture absorption increases elongation upon break, lowering elastic modulus and stresses [3], and the absorbed water may create microcracks, which is thought to be the primary reason for these property decreases. In humid conditions, the strength of the 3D-printed item was decreased due to an aging impact. Absorbing water molecules destroy plastic polymer chains which produce printing issues.

Heat treatment is typically effective and improves polymers' mechanical and tribological properties, increasing density by improving interfacial bonding [4] and enhancing the tensile strength of 3D printed parts by decreasing porosity [5]. According to Bhandari et al. [6], heat treatment improves the tensile characteristics of 3D-printed materials and enhances the surface bonding and crystallinity of polymers. More research is needed to understand how heat drying the filament

influences mechanical behavior and microstructure. Therefore, this study aims to analyze the mechanical properties (tensile, fracture), examine the porosity, and observe the cross-sectional microstructure of the pre-dried and undried 3D printed PLA filaments.

## 2. MATERIALS AND METHOD

Three conditions were established: (i) new filaments as the reference, (ii) used filaments stored in the vacuum bag with 50g desiccant, and (iii) used filaments stored in an open environment and exposed to a humidifier for a variant of 48 hours, 96 hours, and 150 hours. Then, three groups were subsequently created from the conditions mentioned above: (i) undried samples, (ii) pre-dried samples using a dehydrator, and (iii) pre-dried samples using an oven. Table 1 shows the setting of the pre-drying and process parameters for the 3d printer, which were constant and applied to all groups. Shimazu AGS-X Universal Testing Machine (UTM), Scanning Electron Microscope (SEM) machine, and a densimeter were employed for the mechanical testing, microstructural and porosity analysis.

Table 1 Parameter setting for drying and 3D printing

Process	Parameter setting
Drying (oven/dehydrator)	Baking temperature: 50°C Time: 6 hours
3D Printing	Printing temperature: 220°C Bed temperature: 60°C Printing speed: 60 mm/s Filling percentage: 100% Layer thickness: 0.1 mm

## 3. RESULTS AND DISCUSSION

Figures 1-2 illustrate the tensile and fracture maximum force for all conditions. The highest strength was observed in the reference sample for all groups. Among all conditions, the specimens humidified for 150 hours recorded the lowest tensile and fracture strength. When the filament is humidified, tensile and fracture strength decrease due to the propagation of a crack in the filament. Pre-drying the filament with both dehydrator and oven increases the maximum force and reduces the fracture strain. Figure 3 depicts the tensile stress and strain graph for the reference filament. The pre-drying filament shows a lower strain hardening than the undried filament as the failure strain increases when the polymer absorbs humidity [7-8]. Thermoplastic's moisture serves as a plasticizer, reducing molecular entanglement and bonding and increasing volume and mobility [8].

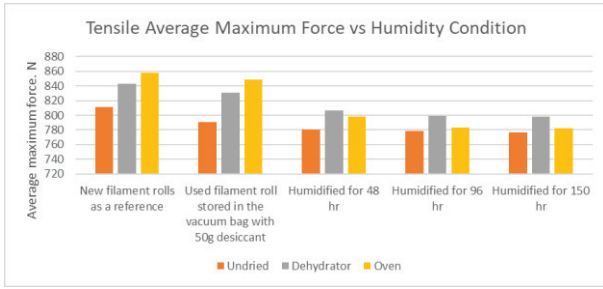


Figure 1 Tensile max force for all conditions

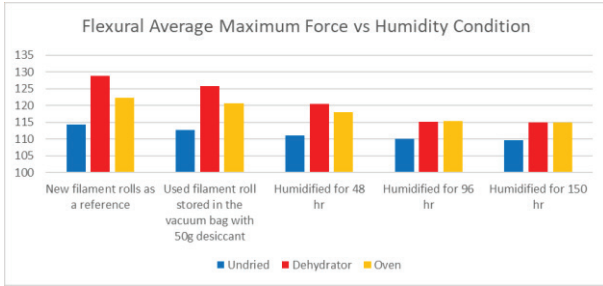


Figure 2 Fracture max force for all conditions

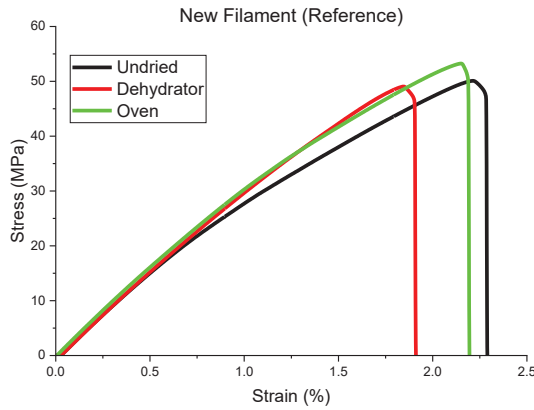


Figure 3 Stress-strain graph for the reference specimen

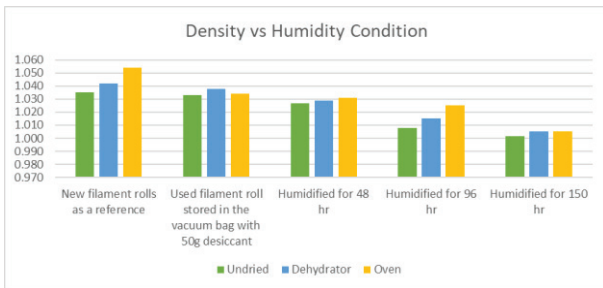


Figure 4 Density for all conditions

Figure 4 shows that the density decreases when the filament is exposed to humidity, resulting in a porous microstructure. The density of the PLA filament for undried specimens is lower than the pre-dried specimens for both drying methods (oven/dehydrator). Larger pores produce a lower mechanical strength as the pores initiate and propagate cracks, causing a lower tensile and fracture strength. The density measurement validated the tensile and flexural results, showing that the drying process has successfully reduced the water absorption, creating a denser printed specimen, resulting in a better mechanical strength.

Figure 5 depicts the SEM images of the undried and pre-dried reference filament (a-b) compared to the undried and pre-dried humidified for 150 hours filament

(c-d). The cross-sectional tensile fractured surface of the reference shows fewer voids, a smooth surface, good interlayer adhesion, and shorter interlayer gaps compared to the longer humidified filaments for both undried and pre-dried, resulting in higher tensile strength. A good interlayer adhesion and a short interlayer gap result in higher tensile strength than weak interlayer adhesion and a large interlayer gap [9-10].

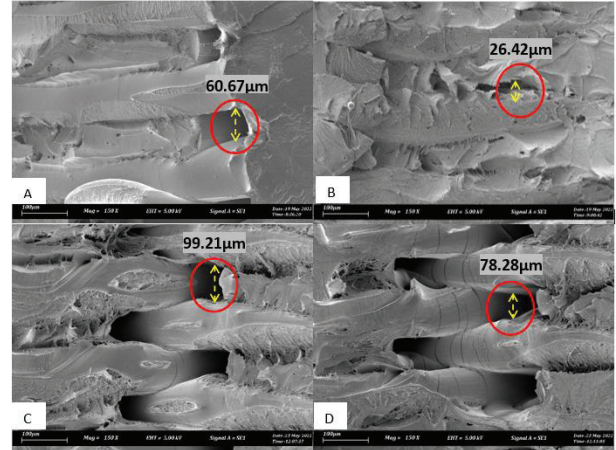


Figure 5 SEM images (150x mag): (A-B) reference (undried, pre-dried), (C-D) humidified 150 hrs (undried, pre-dried)

#### 4. CONCLUSIONS

Pre-dried filament samples produce higher mechanical properties, dense microstructure with fewer voids, good interlayer adhesion, and shorter interlayer gaps.

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