Study of the effects of curing time on the mechanical behavior of 3D printed parts with standard resin

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Abstract

The printing of parts with photopolymers like resins is particularly important as it can be used for visual and functional prototypes, medical devices, casting patterns or aerospace and automotive parts, among others. During the printing process there are several variables that could affect the final mechanical performance of the parts, these variables include but are not limited to exposure time, layer thickness, part orientation or light source power. Another determinant parameter regarding the final mechanical behavior is the curing time after printing. In this work the change in the mechanical behavior due to the post-printing curing is studied by means of tensile and torsion tests of 3D printed specimens with standard resins and through SLA method. The curing time varied from 0 to 6 minutes, 3 batches of specimens for both torsion and tensile test were tested in accordance with the ASTM E143-02 and the ASTM D638 standards, respectively.

Introduction

Although several studies related to the evaluation of the mechanical performance of 3D printed parts have been published, it is noteworthy that a large majority of these studies focus on the tensile behavior of thermopolymers processed by fused material deposition methods or on metallic alloys processed by powder sintering methods [1, 2]. Regarding photopolymers there are some studies on its mechanical characterization, focusing on the effect of the printing parameters over its performance. The reported results suggest that one of the most influential parameters over the mechanical performance is the post-printing curing time [3, 4, 5]. Given the above this work is focused on the characterization of the tensile and shear behavior of SLA-printed parts subjected to short post-printing curing times.

Statement of the problem and methods

The problem to be addressed is that of the characterization of the tensile and shear behavior of 3D printed parts with standard resin through SLA method, and how this is affected by the variation of the post-printing curing time. To achieve significant results ASTM E143-02 and ASTM D638 standards were used as guidelines, for the torsion and tensile tests, respectively (Fig. 1). Furthermore, manufacturing conditions such as temperature, humidity and washing time remained within an established range, shown in Table 1, to attain reduce possible alteration in the mechanical behavior of the test specimens.

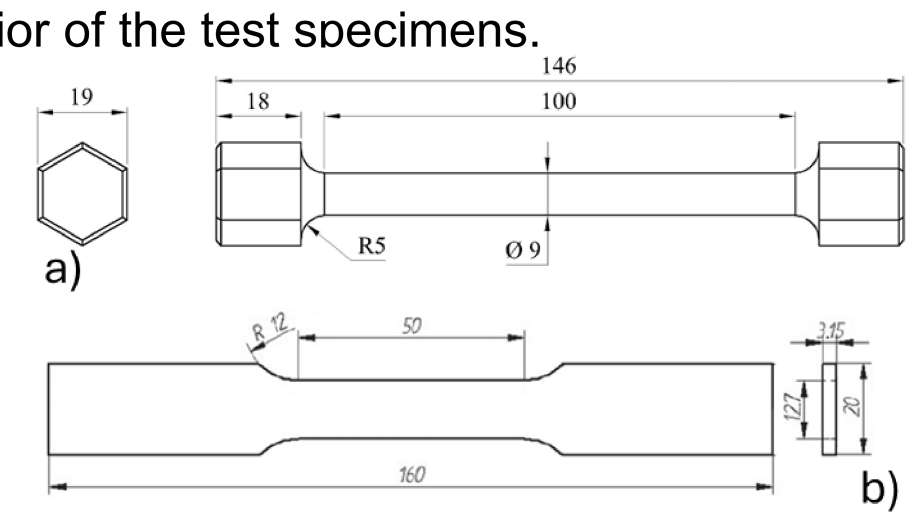

Figure 1 Dimensions of the test specimens used in a) torsion test b) tensile test

Table 1 Ranges for manufacturing conditions

Parameter	value	Parameter	Value
Temperature	32°C	Exposure time	1.8 s
Layer thickness	0.05 mm	Washing time	10 min

Materials and methods

The test specimens were printed with standard resin (density 1.05-1.25 g/cm³, viscosity 250-350 cP*mPa*s) through SLA method (365-405 nm) under conditions showed in Table 1, then the test specimens were cured with a UV led power source of 60 W at 385 and 405 nm, with varying times from 0 to 6 minutes. Three batches for torsion and another three batches for tensile test were manufactured. A visual inspection was performed in each specimen to verify absence of superficial imperfections, along with a dimension verification, diameter variations with average value of 0.15 mm were identified for torsion specimens and for the tensile specimens an average variation of 0.05 mm in width and thickness were identified.

Torsion tests were carried out in an experimental test bench Gunt® Hamburg WP510 with a 200 N.m motor drive, a 50 rpm/min test velocity was used. Changes in torque (resolution of 0.1 Nm) and the corresponding changes in angle of twist (resolution of 0.1°) were measured, then the plot results were obtained.

For tensile test a Shimadzu® AGS-50 universal test machine with a maximum load capacity of 50 kN, a force measurement precision of ±0.5% and a speed range from 0.001 to 1000 mm/min was used. the speed of testing was established at 1 mm/min as it was estimated that at this speed the rupture time of all the specimens would fall between the 0.5 to 5 min of testing time.

Figure 2 a) Torsion test fixture, b) tensile test fixture

Results

From the tests performed it was concluded, as expected, that the better mechanical performance it was obtained when the post-printing curing was done. In Fig. 3a are shown the plot results from the torsion tests comparing the strength for different post-printing curing times from 0 to 6 minutes with step increase of 1 minute. It is noticed that all the tested specimens show a clear linear response, and that the shear strength was increased with the post-printing curing time.

On the other hand, for the tensile test the strength was also increased with the post-printing curing, as with the torsion specimens a linear response it is also present during the first portion of the test and the strength was increased as curing time was increased (see Fig. 3b).

When comparing the different specimens that were cured during the same time the results show consistency, for both torsion and tensile tests.

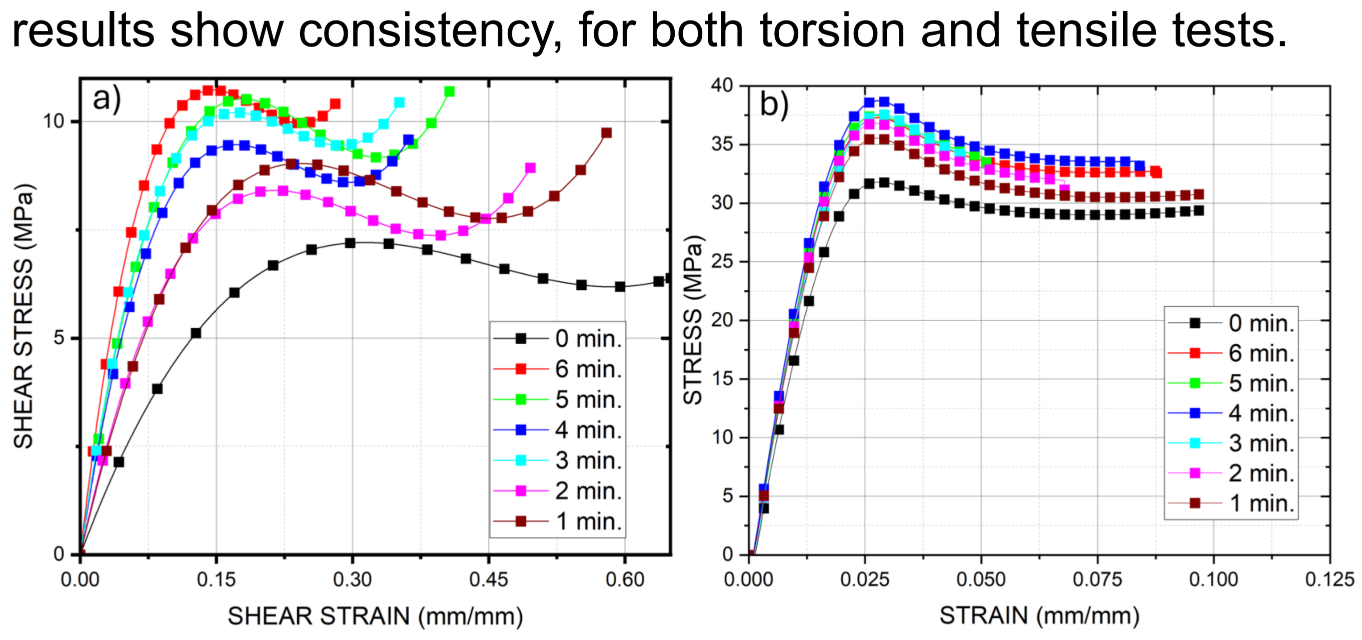

Figure 3 Comparative of test results for different curing times a) torsion b) tension

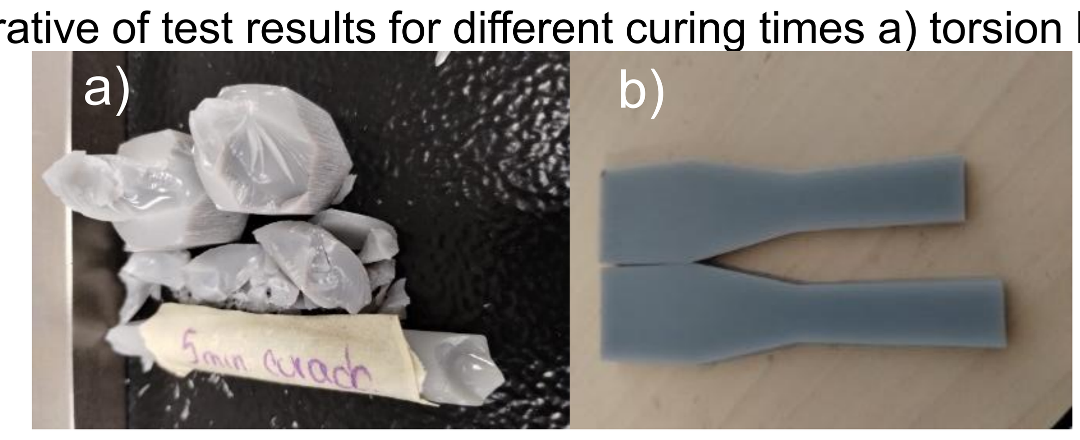

Figure 4 Failure of test specimens a) torsion test b) tensile test

Conclusions

Post-printing curing time has a significant influence on both tensile and shear behavior of the SLA-printed parts, while asserting that even with short curing times a significant increase in shear strength (around 38.33%) and tensile strength (around 15.79 %) are obtained against the strength without post-printing curing, then it can be concluded that short curing times can be suitable to attain better mechanical performance while reducing energy consumption against longer curing times. Also, it is worth noting that the failure of the torsion specimens shown a sudden high speed crack propagation in multiple points, while the failure of tensile specimens was located in a single point in the narrow section (see Figure 4).

References

[1] R. A. T. A. a. K. M. Jemghili, "A bibliometric indicators analysis of additive manufacturing research trends from 2010 to 2020," Rapid Prototyping Journal, vol. 27, no. 7, pp. 1432-1454, 2021. DOI:10.1108/RPJ-11-2020-0274

[2] G. X. F. X. J. T. G. a. L. Z. Gao, "A Survey of the Influence of Process Parameters on Mechanical Properties of Fused Deposition Modeling Parts," Micromachines, vol. 2022, no. 13, 2022. DOI:10.3390/mi13040553

[3] M. Kazemi and A. Rahimi, "Stereolithography process optimization for tensile strength improvement of products" Rapid Prototyping Journal, vol. 24, no. 4, pp. 688-697, 2018. DOI:10.1108/RPJ-05-2015-0049

[4] K. Puebla, K. Arcaute, R. Quintana and R. Wicker, "Effects of environmental conditions, aging, and build orientations on the mechanical properties of ASTM type I specimens manufactured via stereolithography" *Rapid Prototyping Journal,* vol. 18, no. 5, pp. 374-388, 2012. DOI:10.1108/13552541211250373

[5] S. Wang, Y. Ma, Z. Deng, K. Zhang and S. Dai, "Implementation of an elastoplastic constitutive model for 3D-printed," *Additive manufacturing,* vol. 33, 2020. DOI: /10.1016/j.addma.2020.101104

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ACEX 187