Műszaki Tudományos Közlemények vol. 13. (2020) 118–121.
DOI: Hungarian: https://doi.org/10.33895/mtk-2020.13.21
English: https://doi.org/10.33894/mtk-2020.13.21

THE IMPACT OF ACTIVE COOLING ON HEAT RESISTANT PLA

Norbert László LUKÁCS,[1] Péter FICZERE,[2] Gábor SZEBÉNYI[3]

Budapest University of Technology and Economics, Budapest, Hungary

[1] *lukacsnorbert98@gmail.com*

[2] *ficzere@kge.bme.hu*

[3] *szebenyi@pt.bme.hu*

Abstract

In this study the properties of HT-PLA were determined with tensile tests. The influence of cooling was determined and influence of manufacturing environment shown to be predictable. Heat resistant 3D printing materials can be widely used in the manufacturing process but these materials are relatively expensive. HT-PLA is one of the cheapest materials with these parameters.

Keywords: *FDM, high temperature PLA, additive manufacturing, 3D printing, cooling.*

1. Introduction

Due to the spreading and evolution of FDM technologies, 3D printed parts can be applied directly [1]. For this reason FDM technologies are now adopted in quantity production. There are a huge number of different materials with different properties and application fields: UV resistant materials, flexible materials and heat resistant polymers. The new kind of heat resistant filaments are treatable materials which can make the manufacturing process much easier and cheaper, but they have some weaknesses: for example the tempering process can cause warping and size changes. In this study the influence of active cooling was measured and in the future the influence of tempering process will be determined.

2. Method

The material used in this study was HT-PLA from 3dee. Printed parts from HT-PLA have better heat resistance than parts from normal PLA (65-70°C according to the HDT, E2092 standard). This value can be increased up to 100°C after a short tempering: parts or specimens have to be put in an oven heated to 80-100°C for 20 minutes, then cooled gently. During the process, the crystallinity of parts can be increased, which has a great influence on the heat resistance and tensile strength [2].

For the manufacturing process a Creality Ender 3 was used. This is an affordable commercial FDM (FFF) 3D printer.

The specimens were printed in the horizontal and vertical position (**Figure 1**). They were also printed with active cooling, and without cooling.

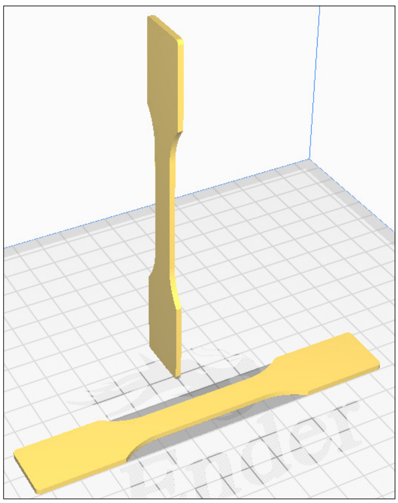

Figure 1. *Standard specimens.*

The common printing parameters were:
– 215 °C nozzle and 60 °C bed temperature;
– 40 mm/s speed;
– 100% infill;
– 0.2 mm layer height.

These specifications were determined as the best parameters for PLA printing several times [3, 4, 5]. The tensile test of 3D printed specimens were made on a Zwick Z005 machine owned by BME Department of Polymer Engineering (Figure 2).

In each case 5-5 standard specimens were measured. Tests were made at a velocity of 5 mm/min (Figure 3).

Figure 2. *Zwick Z005 equipment*

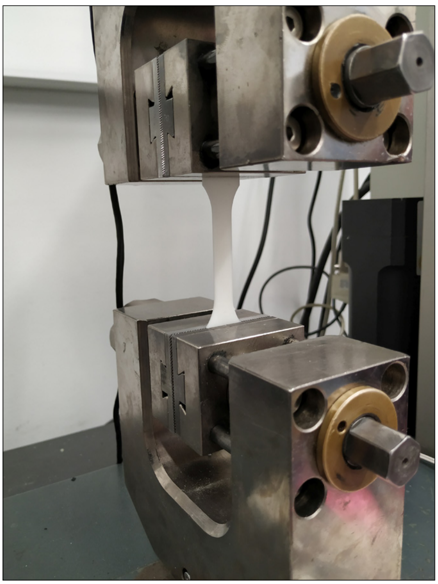

Figure 3. *Measuring of 3D printed specimens.*

3. Results

Figure 4 and Figure 5 show the tensile tests of horizontally printed specimens. As can be observed, the non-cooled specimens have 45 MPa average tensile strength. It is much lower than it supposed to be (66 MPa according to the dealer). This phenomenon can be caused by the direction of layers [6],and by imperfect intralayer adhesion [4].

The cooled specimens have 35 MPa average tensile strength which is 23% lower than the non-cooled specimens.

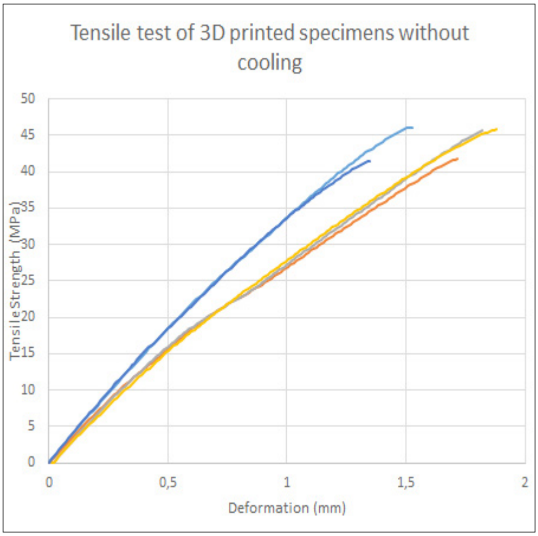

Figure 4. *Horizontally printed specimens without cooling*

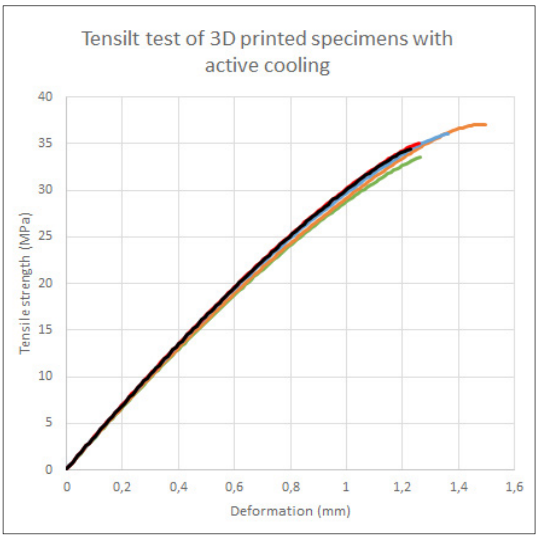

Figure 5. *Horizontally printed specimens with active cooling*

In some cases cooling is needed for the proper surface quality, for example, in the case of parts with overhangs.

The vertically printed specimens were not as strong as predicted [7], but the specimens which were printed without cooling were stronger than the cooled ones. Figure 6 shows the results of non-cooled specimens.

Figure 7. shows the results of 3D printed specimens in the vertical position, with active cooling.

An overall summary of results is shown in Table 1.

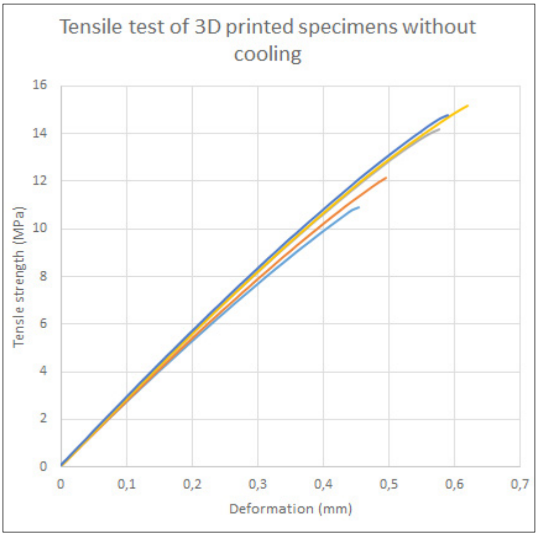

Figure 6. *Vertically printed specimens without cooling*

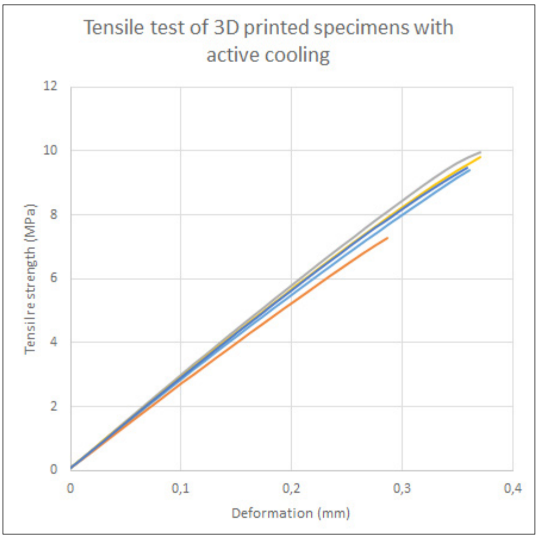

Figure 7. *Vertically printed specimens with cooling*

Table 1. *Overall results*

Specimen	Average tensile strength (MPa)
Horizontally printed with cooling	35.21
Horizontally printed without cooling	44.23
Vertically printed with cooling	9.18
Vertically printed without cooling	13.44

4. Conclusion

According to the results, cooling decreased the tensile strength of 3D printed specimens. The tensile strength of horizontally printed specimens decreased by 20% (from 45MPa to 35 MPa). These effects may have been caused by cooling which may, in turn, have caused the material flow to solidify before it connected to the layers and for this reason the interlayer connection cannot achieve sufficient strength (Figure 8).

The tensile strength of vertically printed specimens decreased by 30% (Figure 9).

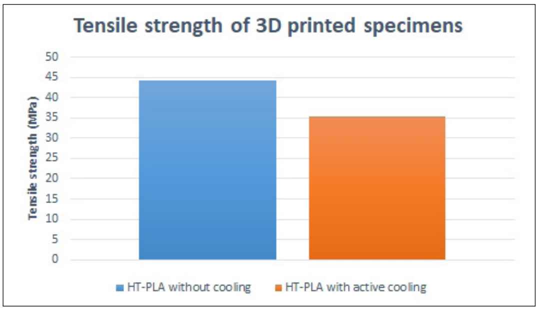

Figure 8. *Horizontally printed specimens compared to each other*

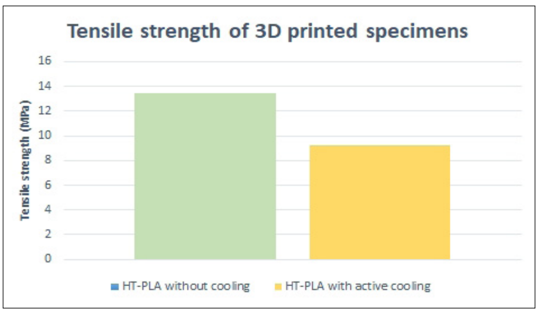

Figure 9. *Vertically printed specimens compared to each other*

5. Conclusions

According to the results the cooling has a negative effect on the mechanical strength of 3D printed parts. Parts made for (FDM) additive manufacturing must be designed to be producible without cooling for better results. Before the serious application of this material the influence of tempering process must be also better known.

Acknowledgement

This study could not have been possible without the participation of Dr. Ádám Török. We are thankful for his assistance.

References

[1] Gerendás P., Károly D., Pammer D., Kiss R. M.: *Egyedi kézrögzítő fejlesztés és gyártása 3D nyomtatással*. Biomechanica Hungarica XI/2., 23–30.

[2] 3DEE Store Budapest (accessed on: 2020.01.28.) https://3dee.hu/termek/ht-pla-001/

[3] Lukács N. L., Ficzere P., Temesi T.: *Gyártási paraméterektől függő rétegközi hibák vizsgálata CAD szoftverekkel.* GÉP, LXX/3, 54–57.

[4] Ogjan L. et all.: *Impact of processing parameters on tensile stength in-process crysallinity and mesostructure in FDM-fabricated PLA specimens*. Rapid Prototyping Journal 25/8. (2019) 1398–1410

[5] Ficzere P., Lukács N. L.: *Evaluation opportunities of SEM pictures by CAD software*. Design of Machines And Structures 9/2. (2019) 20–24.

[6] K. Álvarez C., Lagos R. F., Aizpun M. : *Investigating the influence of infill percentage on the mechanical properties of fused deposition modelled ABS parts*. Ingeniería e Investigación 36/3. (2016) 110–116. https://doi.org/10.15446/ing.investig.v36n3.56610

[7] Ficzere P., Borbas L., Falk Gy., Szebenyi G.: *Experimental determination of material model of machine parts produced by Selective laser sintering (SLS) technology*. Materials Today: Proceedings, 5/13. Part 2, (2018) 26489–26494. https://doi.org/10.1016/j.matpr.2018.08.104.