THE INFLUENCE OF PRINTING TEMPERATURE ON MECHANICAL PROPERTIES OF 3D-PRINTED PETG-CF SPECIMENS

Jan Krmela, Vladimíra Krmelová, Rastislav Hruškovič, Terézia Matejíková

Introduction

This work focuses on additive manufacturing, specifically the FDM (fused deposition modeling) 3D printing method. The effect of carbon fibers (CF) on the selected properties (mechanical and thermal) of a polyethylene terephthalate glycol (PETG) specimen prepared by utilizing the FDM method, is investigated. The aim of the work is to optimize 3D printing parameters to achieve high-quality printed products and analyze the influence of 3D printing settings on the resulting mechanical characteristics.

Materials

Three materials of filaments for FDM 3D print are used. One is standard material PETG + CF PTG03CF100750BK00 with 20 % vol. of CF (marked as 1), and two own materials with 10 % vol. of CF (150 μm) prepared in different ways - on a twin-screw extruder Theysohn BTSK 60/36 D with side dosing for CF (marked as 2), and a single-screw extruder Labtech LE30-30/C, L/D (marked as 3).

3D printing

First, the effect of 3D printing temperatures (from 220 °C to 265 °C in 5 °C increments) on the quality of FDM-printed PETG-CF temperature and bridging tower is studied. Subsequently, the specimens with a thickness of 4 mm and a width of 10 mm are manufactured using two 3D printing orientations (horizontal and vertical) with a shape and geometry for tensile tests according to the standard ISO 527-1B. The nozzle (printing) temperatures are chosen to be 230 and 260 °C with a heated bed temperature of 90 °C. A nozzle with a diameter of 0.4 mm is used. The 3D printers Prusa MK4 and Prusa MK3 are used with settings: layer height is 0.2 mm, number of wall layers is 3, fill type is lines (diagonal (45°) lines that overlap each layer), and fill percentage is 100 %.

Methods

Tensile tests are realized on the Autograph AG-X plus 5kN - Shimadzu testing machine. The loading speeds are 2 mm/min for vertical specimens and 1 mm/min for horizontal specimens with force preload 0.05 N. Specimens produced with nozzle temperatures of 230 °C and 260 °C are selected for comparison. Example from tensile tests is on Fig. 1. It is obvious where the crack started to spread.

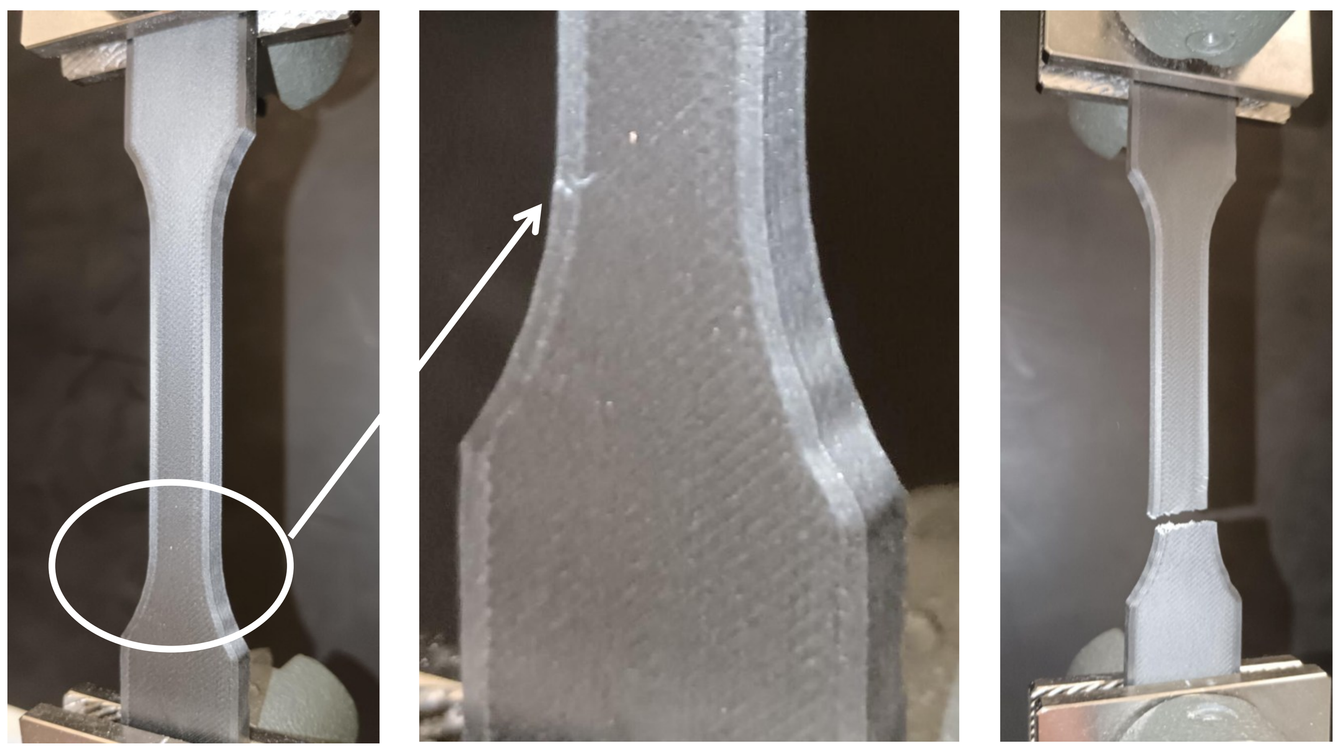

Figure 1. Tensile test – process of crack: start, crack, failure

Results

The specimens from filament No. 1 have strength of 17.03±0.96 MPa and ductility of 1.67±0.18 % for vertical orientation and nozzle temperature (t_N) of 230 °C, and strength of 41.95±1.27 MPa and ductility of 3.71±0.21 % for horizontal orientation and t_N of 230 °C, and strength of 42.5±0.77 MPa and ductility of 4.09±0.21 % for horizontal orientation and t_N of 260 °C.

The specimens from filament No. 2 have strength of 23.34±1.37 MPa and ductility of 1.49±0.13 % for vertical orientation and t_N of 230 °C, and strength of 47.38±0.47 MPa and ductility of 4.64±0.43 % for horizontal orientation and t_N of 230 °C (see Fig. 2 an example of dependences), and strength of 47.38±0.47 MPa and ductility of 4.64±0.44 % for horizontal orientation and t_N of 260 °C.

The specimens from filament No. 3 have strength of 20.27±0.39 MPa and ductility of 1.32±0.02 % for vertical orientation and t_N of 230 °C, and strength of 47.56±0.61 MPa and ductility of 4.75±0.91 % for horizontal orientation and t_N of 230 °C.

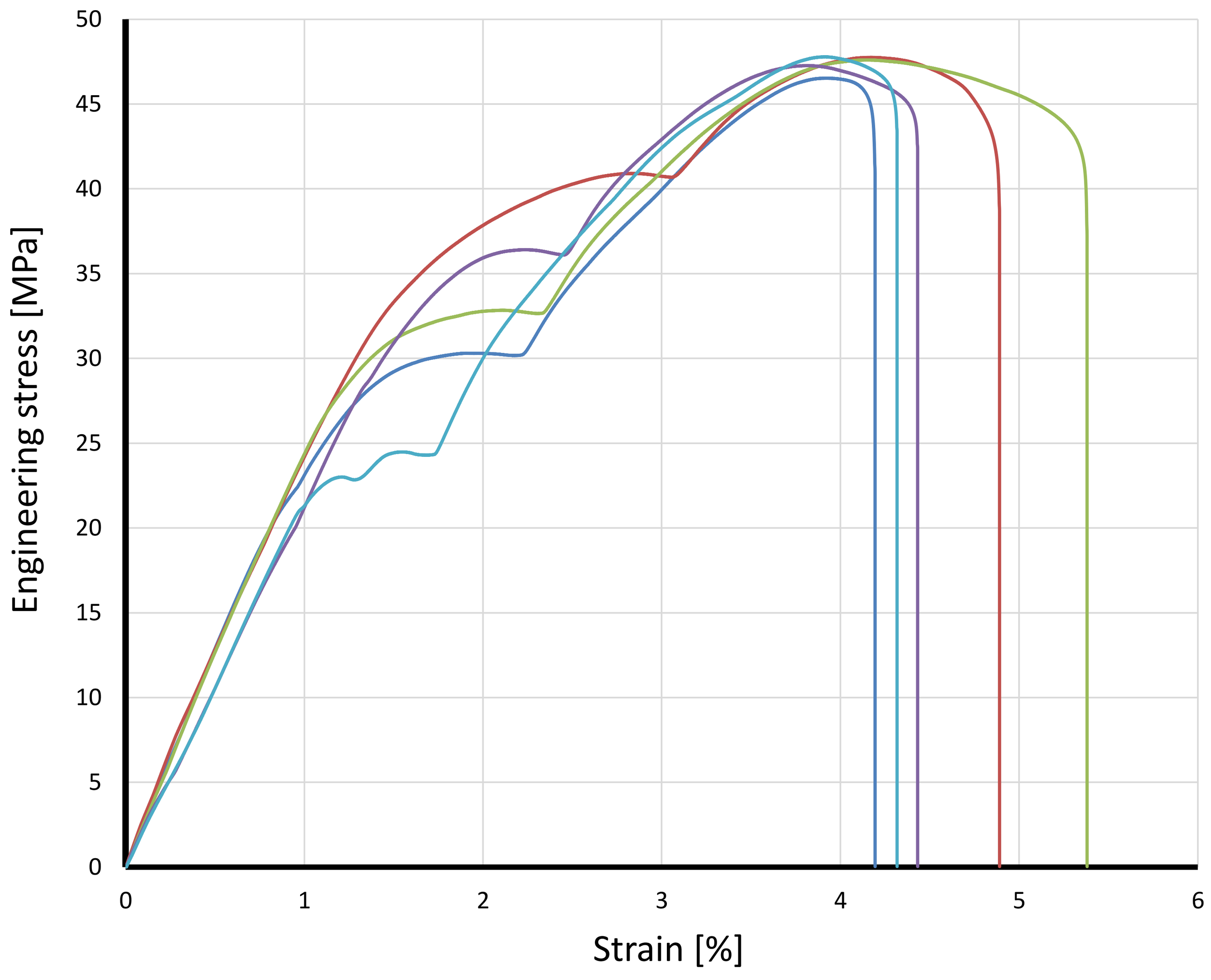

Figure 2. Engineering stress-strain dependences with yield strength for specimens from filament No. 2 for horizontal orientation of 3D printing with nozzle temperature of 230 °C

In some cases, it is possible to observe the emergence of the with yield strength without significant plastic deformation and without the formation of constriction during tensile tests.

Conclusion

Based on the quality of 3D printed specimens and tensile test results, the nozzle temperature of 230 °C is better than the nozzle temperature of 260 °C. The printing is unstable at 260 °C for all filaments, with material accumulating behind the nozzle. 3D printing the material in the horizontal orientation shows better properties than 3D printing the material in the vertical orientation.

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Alexander Dubček University of Trenčín,
Faculty of Industrial Technologies in Púchov,
Ivana Krasku 491/30, 020 01 Púchov, Slovakia;
jan.krmela@tnuni.sk
https://laborator.sk/
http://krmela.wz.cz/contact.html

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