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Analysis of Thermal Operating Conditions of 3D Printers with Printing Chamber

Jacek Zaburko[1], Arkadiusz Urzędowski[2], Joanna Szulżyk-Cieplak[2], Anton Trnik[3], Zbigniew Suchorab[1], and Grzegorz Łagód[1]

[1]*Lublin University of Technology, Faculty of Environmental Engineering, Nadbystrzycka 40B, 20-618 Lublin, Poland*

[2]*Lublin University of Technology, Fundamentals of Technology Faculty, ul. Nadbystrzycka 38, 20-618 Lublin, Poland*

[3]*Constantine the Philosopher University in Nitra, Faculty of Natural Sciences, Tr. A. Hlinku 1, 94974 Nitra, Slovakia*

Introduction

In recent years, 3D printing has gained immense popularity. Aesthetic appearance and faithful representation of details which can be obtained with 3D printing became especially desired in certain applications, from biomedicine to specific implementations in industry and civil engineering (Fig. 1). Although the mechanical properties of the used thermoplastic materials are usually lower, compared to standard engineering materials, the possibility of quickly printing complex prototypes and their low cost compared to a traditional steel form are significant advantages.

Fig. 1. 3D models made of PLA and ABS filaments

Materials and methods

The study used polymer materials acrylonitrile-butadiene-styrene (ABS) and polylactide (PLA) as two most commonly used copolymers in 3D printing. The laboratory setup for conducting investigations was equipped with MonkeyFab Prime 3D and acrylic glass chamber allowing closing the workspace as well as maintaining elevated temperature when printing. The temperatures were read with NTC measurement probes connected to a FLUKE 1586A temperature scanner (Fig. 2).

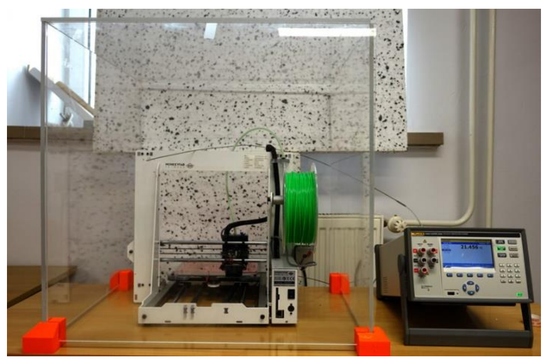

Fig. 2. Laboratory setup

TABLE 1. Characteristics of operating parameters of selected filaments

Filament	Melting point (°C)	Hot pad temperature (°C)	Head temperature (°C)
Rubber TPU	225	40 – 55	245 – 275
PET	200	65 – 75	230 – 255
PLA	150	0 – 60	185 – 230
ABS	230	95 – 100	210 – 280

Results and discussions

The models printed at ambient temperature were presented in Fig. 3(a). In turn, the models printed using the heating chamber, are shown in Fig. 3(b). The values of temperatures obtained for particular samples and materials are shown in Table 2.

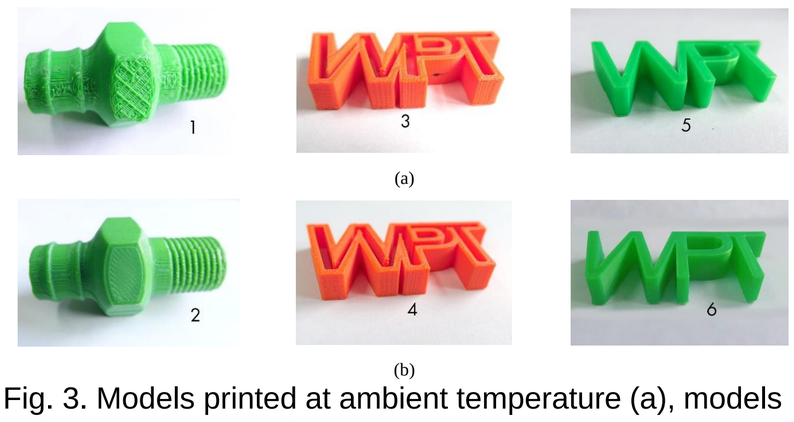

Fig. 3. Models printed at ambient temperature (a), models printed in the heated chamber

TABLE 2. Temperature values for individual printed specimens

Model	Material	Set temperature (°C)		Ambient temperature (°C)		Chamber temperature (°C)	
		Hot pad	Printer head	Hot pad	Printer head	Hot pad	Printer head
5a(1)	PLA	30	195	31.421	194.734	–	–
5a(3)	ABS	95	235	95.431	235.675	–	–
5a(5)	PLA	30	195	32.456	195.256	–	–
5b(2)	PLA	30	195	32.473	194.234	37.365	198.234
5b(4)	ABS	95	235	95.461	235.775	95.456	242.234
5b(6)	PLA	30	195	30.436	196.234	36.354	197.234

In each additive manufacturing technology, the shrinkage phenomenon occurs. Its level for PLA material was determined based on the measurements of the selected reference sample (5b(2)) and representative sample (5a(1)) using PROMA 0–25 mm, 25–50 mm, 50–75 mm with the accuracy up to 0.01 mm. The nominal dimensions and the dimensions measured from the printed elements were presented in Table 3. The level of shrinkage for ABS was determined for a reference sample (5b(4)) and a representative sample (5a(3)). The values of nominal dimensions and those collected from the printed models are presented in Table 4. (b)

Table 3. Shrinkage level of the selected reference samples (PLA)

Nominal dimensions (mm)	3D model	5b(2)	5a(1)
L	60.00	59.98	59.41
Øin	18.60	18.59	18.41
Øout	16.40	16.38	16.33
½ L	30.00	29.98	29.75

Table 4. Shrinkage level of the selected reference samples (ABS)

Nominal dimensions (mm)	3D model	5b(4)	5a(3)
L	62.76	62.62	62.55
Height	10.00	9.84	9.81
Width	25.00	24.56	24.49

The dimensional deviations: PLA models - 0.02 – 0.7 mm.
ABS models - 0.14 – 0.51mm.

Summary and conclusions

Research results indicate that the thermal properties of the employed composites are affected by the factors which should be taken into account already at the designing stage. While printing using ABS, closed printing chamber and constant inner temperature enables obtaining uniform surface structure of the model. The PLA models printed in an open chamber had uneven edges with clearly visible printing head movement paths when printing consecutive layers. Measurement of PLA models indicated that using the chamber enabled to achieve the dimensions close to the nominal dimensions of computer models. The situation was different in the case of the models printed at ambient temperature. On the basis of the performed investigations, it can be assumed that the temperatures enabling to avoid undesirable blemishes during printing should be 15° C higher for ABS and PLA than the values recommended by the manufacturer.