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Time Distribution Analysis of 3D Prints with the Use of a Filament and Masked Stereolithography Resin 3D Printer

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ABSTRACT

The article focuses on the subject of 3D printing. 3D printing technology and currently used solutions are described. The materials used in printing with the use of a filament printer and a resin printer are discussed. The fused deposiotion modeling technique and the LCD-based stereolithography. Printing technology were presented. Samples were prepared using 3D modeling software. The software used to make the models is discussed. The designed models were printed on two types of printers, using different model orientations. Printouts were measured several times. The obtained data was analyzed and the conclusions, proposed solutions and possible improvements to 3D printing were presented at the end. The article deals with the subject of the possibility of accelerating 3D prints due to their location, but also the influence of warming up the printer during subsequent prints was checked.

Keywords: 3D printing, polylactic acid, fused deposiotion modeling, stereolithography), masked stereolithography, resin printing

INTRODUCTION

3D printing technology is currently one of the most popular developing techniques. It is currently used in every area of life [1]. 3D printing is being improved in the mechanical engineering and manufacturing industry [2]. Currently, there are more and more modernized versions of 3D printers on the market. In addition, there are many items that are based on 3D printing. This includes, for example, pens that also use filaments, both acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA). However, it is a technique that is an option for those learning 3D printing. In education, the use of 3D printing is widely used [3]. During educational classes, you can more and more often encounter the use of 3D printing in the form of the aforementioned 3D pens [4]. This form of 3D printing can also be used to connect elements. As the pen heats up to high temperatures, it is possible to connect elements together using a heated filament. The 3D pen is shown in Figure 1.

In education, manufacturing techniques are also combined with programming. In many institutions, classes are conducted with the use of, for example, robots, blocks, and then the missing elements or spare elements are reprinted [5]. Currently, 3D printing technology focuses on the possibilities of accelerating prints, as well as finding appropriate materials resistant to strength as well as perfectly imitating a given real material, eg. medical prints, ie. prostheses, etc. [6]. In industrial printers, it is possible to obtain a quick printing process, but in the case of individual printing without the appropriate model setting and properly calibrated device, quick, but also correct printing may not be possible [7]. With the help of 3D modeling software, you can get the correct dimensions of the model, but you can also maneuver its position during preparation for printing. In the case of some models of 3D printers, the positioning of the object is of less importance compared to the heating time of the printing elements [8]. 3D printing also depends on ambient

Fig. 1. 3D pen for filament

conditions. Therefore, in many printers there is a chamber in order to optimize the temperature [9]. Settings of printer parameters, components, and environmental factors are the most frequently discussed issues related to proper 3D printing. This article also deals with the subject of printing time and the factors influencing this process. 3D printing also depends on the appropriate software [11]. It is not possible to print without a 3D model. In some cases, 3D scanners are used to make the model. They allow for the depiction of even large-format objects [12]. Then the scanned image is processed into a model, and then the object can be printed. Currently, 3D printers are generally available, and their popularity is constantly growing and finding new applications.

MATERIALS AND METHODS

Masked stereolithography resin 3D printer

A filament printer and a masked stereolithography (MSLA) resin printer were used to test the printing time. An Anycubic Photon Mono 2K resin printer was used in the study. This device has a monochrome LCD screen with a diagonal equal to 2.8" and a resolution of 2K (i.e. 2560×1620 pixels), thanks to which it translates into a precision in the XY axes equal to 51 μm. The screen is backlit using a 45W LED matrix that emits ultraviolet light with a wavelength of 405 nm. In addition, this printer has connectivity via the USB port. The resin printer working area allows you to obtain prints with the maximum dimensions of 130×80×165 mm (length × width × height). The stepper motor moving in the Z axis enables printing with a height of a single layer up to a maximum of 10 um. The device enables printing at a maximum speed of 50 mm/h. The overall dimensions of the device are 227×222×383 mm, with a weight of 4.5 kg. The tests were carried out with the use of the standard resin of the manufacturer of the Anycubic Basic Grey device. The resin used has a hardness of 79D and a viscosity of 552 MPa·s. The curing wavelength is 405 nm. The liquid density is 1.1 g/cm^3 and the constant density is 1.184 g/cm^3. The shrinkage is 7.1% and the tensile strength is 23.4 MPa. The approximate composition of the resin provided by the manufacturer is as follows: Polyurethane acrylate: 30–60%, Acrylate monomer: 10–40%, Photoinitiator: 2–5%. The MSLA resin printer used is shown in Figure 2.

Fused deposiotion modeling technology

Fused deposiotion modeling (FDM) is the most popular method of additive manufacturing. The abbreviation FDM is a trademark of Stratasys [13]. In the FFF (used Filament Fabrication) / FDM technology, a thermoplastic material in the form of a polymeric fiber called a filament is fed to an extrusion head, where it is then heated to a state that allows the material to flow [14]. Then the head extrudes and arranges the semi-liquid material layer by layer according to the outline taken from the instructions in the form of a G-code. After a while, the material layer becomes solid and hardens. After making one layer, the extruder is raised by the height of the layer and then the next one is outlined.

LCD-based stereolithography printing

The oldest 3D printing technology is stereolithography (SLA). The production of elements by the SLA method is based on the use of a liquid light-curing resin and a source of ultraviolet radiation, with the help of which the photopolymerization process takes place [15]. Compared to the FDM / FFF technology, these prints are

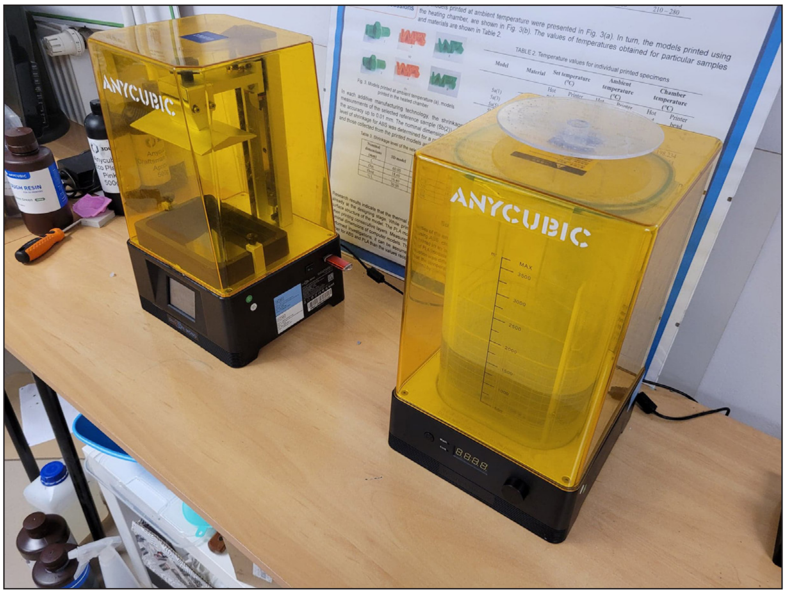

Fig. 2. Anycubic Photon Mono 2K resin printer

characterized by much greater detail and practically invisible layers. The disadvantages of this technology are the smaller working area and the harmfulness of the resins, which can cause burns in the event of contact with the skin [16]. In the SLA printing technology, after printing, the product is not ready, it should be cleaned of residual resin and finally hardened. Isopropyl alcohol is most often used to clean the model from residual resin. Final curing of the model can be done with the use of sunlight or UV irradiation devices of appropriate wavelength.

Filament 3D printer

The study used a beginner's printer model. The Creality Ender-3 3D printer has a working surface of 220×220×250 mm, and the platform is heated to a maximum temperature of 110 °C within 5 minutes. The basic variant, the Ender 3 printer, is adapted to work with PLA filaments as well as TPU, gradient and carbon-enriched filaments. The maximum print speed ranges from 100 mm/s (in the Creality Ender-3 V2 model). LCD displays are used to control the printer, while the Creality Ender-3 V2 3D printer is equipped with a 4.3-inch color graphic display. The Ender-3 v2 supports all the most popular filament types such as PLA, PETG and ABS – thanks to the heating of the table to 100 °C. The layer thickness can be from 0.1 to 0.4 mm, and the printing precision is 0.1 mm. The printer supports filaments with a diameter of 1.75 mm. The 24 V power supply is responsible for the stable operation of the device. The study used PLA material with a diameter of 1.75 mm during filament printing. The printing temperature of this material is 185–215 °C. PLA material was chosen because it is the most practical material to use when starting the adventure with 3D printing, and therefore it is chosen by other people quite often. It is easy to use due to the low shrinkage during printing and does not require a closed chamber or a heated bed. It is odorless during printing and biodegradable. The filament 3D printer used is shown in Figure 3.

Prepare of the 3D model

Photon Workshop and Autodesk Inventor software were used to prepare the model for resin printing. A model with dimensions of 10×10×20 mm was prepared. A simple form of the model was chosen due to the verification of the printing time, and not the accuracy of the printout, eg details of the solid, etc. The printout was checked in two positions of the solid, on the wall 10x10mm. and on the wall 10×20 mm. Resin print setup was done in Photon Workshop. The 3D model shown in Figure 4. The print settings at Photon Workshop are shown in Figure 5.

Filament print settings were made in Ultimaker Cura (Fig. 6). The following parameters were adopted for the filament print settings: nozzle: 0.4 mm, layer height: 0.2 mm, filling: 100%, printing temperature: 210 °C, bed temperature: 40 °C, printing speed 50 mm/s.

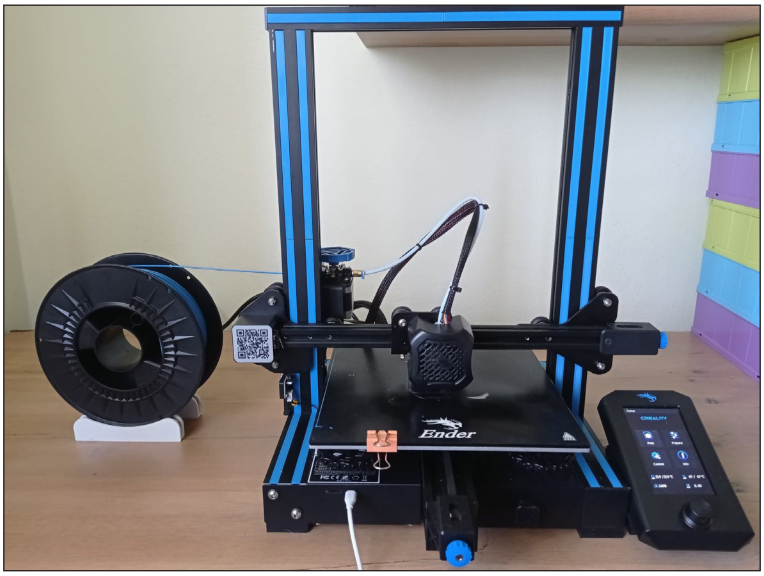

Fig. 3. Filament 3D printer

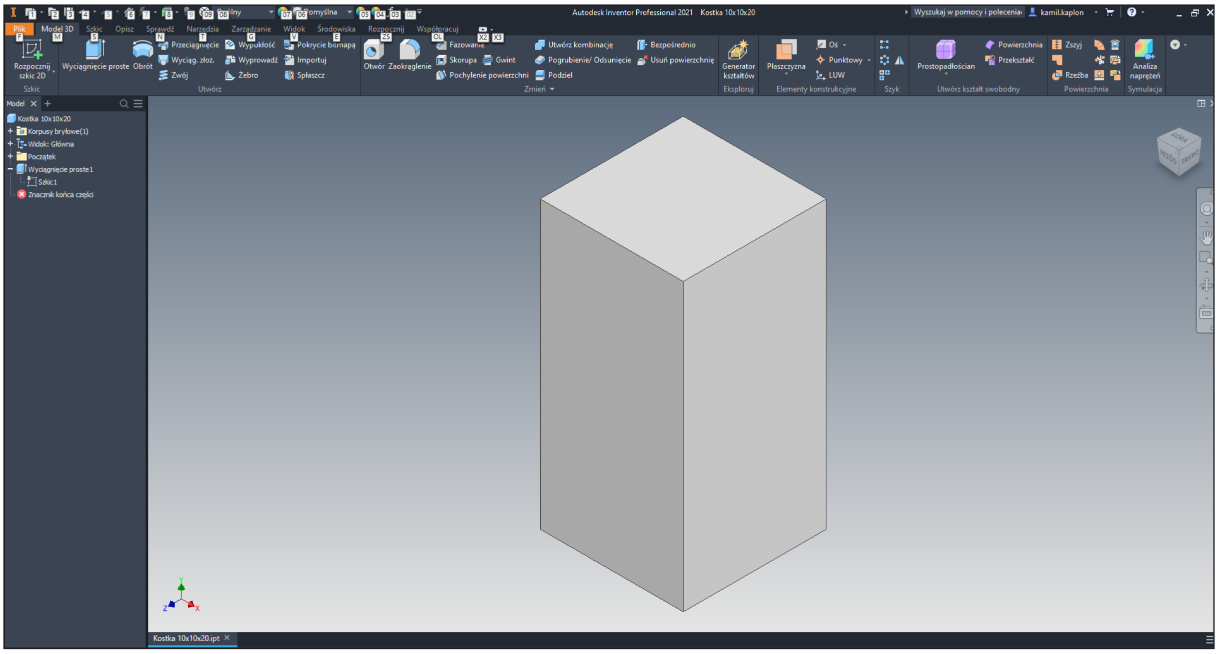

Fig. 4. 3D model in Autodesk Inventor

RESULTS

Results of MSLA resin 3D printing

In order to test the printing time and the repeatability of the results, a single sample was printed, then 3 samples were printed simultaneously on one working area, and finally 5 samples were printed in one working area. The printout was repeated five times. Table 1 shows the results of single sample printouts in two orientations. Tables 2 and 3 shows next printouts. In the case of filament printing, the heating time, pre-printing time and then total printing time were also measured.

Results of filament 3D printing

As in the case of resin printing, in order to test the printing time and the reproducibility of the results, a single sample was printed, then 3 samples simultaneously on one working area, and finally 5 samples were printed on one working area. The printout was repeated five times. The filament print takes into account the heating of the working table, then the initial time and then the final

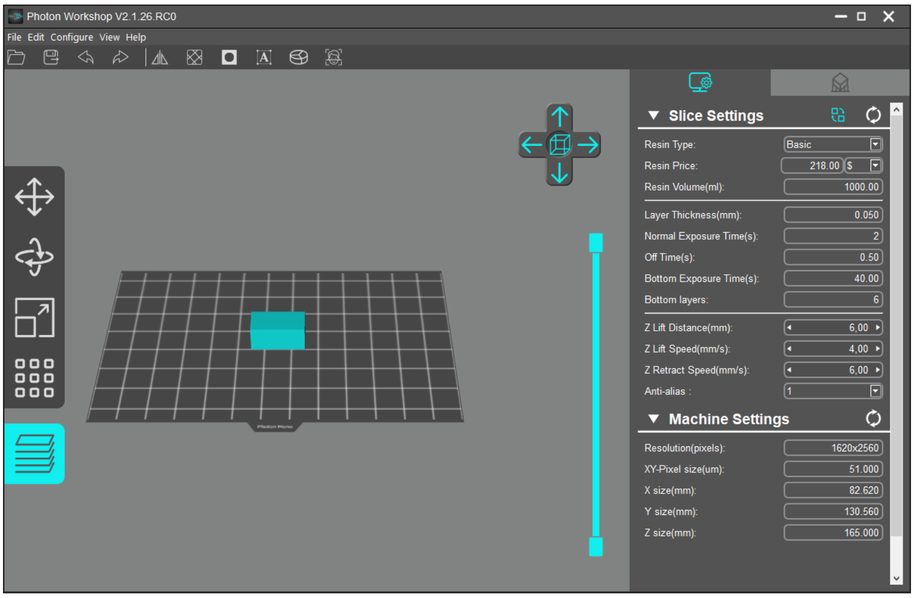

Fig. 5. The print settings at Photon Workshop

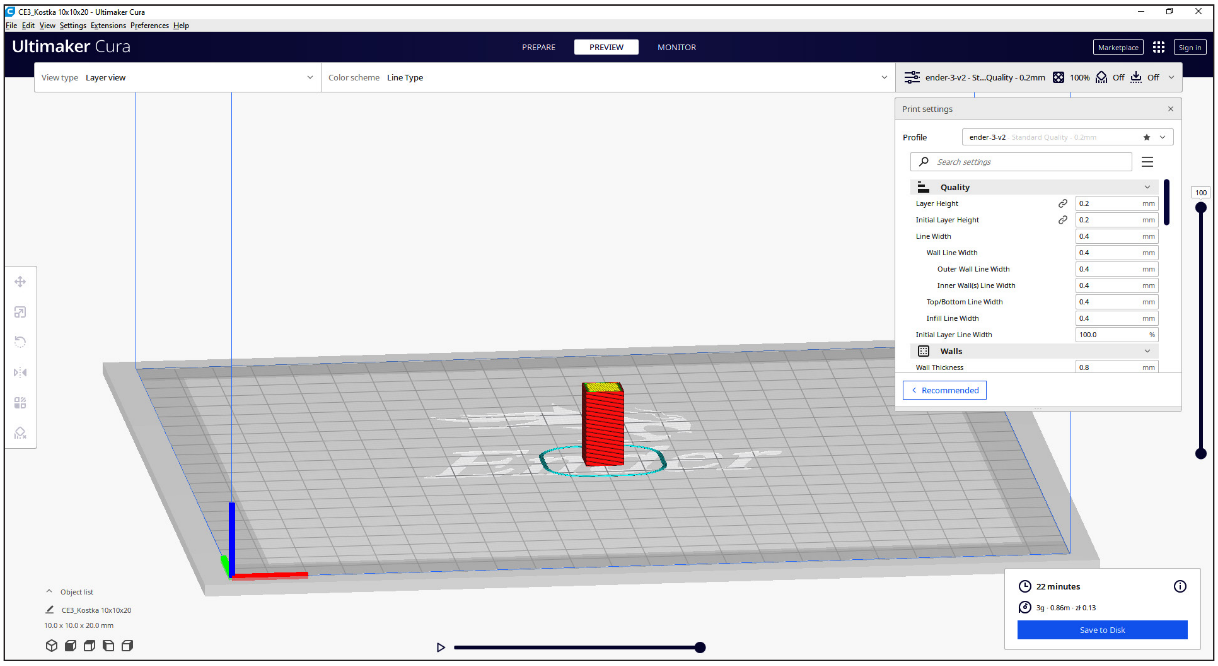

Fig. 6. Print settings in Ultimaker Cura

Table 1. The results of single sample printouts in two orientations

Single sample	Orientation	
	Horizontal	Vertical
Estimated printing time [min]	33	63
Number of sample	Real time of printing [min]	Real time of printing[min]
1	36	66
2	36	66
3	35	66
4	35	67
5	36	67

Table 2. The results of three sample printouts in two orientations

Single sample	Orientation	
	Horizontal	Vertical
Estimated printing time [min]	33	63
Number of sample	Real time of printing [min]	Real time of printing[min]
1	36	66
2	36	67
3	36	66
4	36	66
5	36	67

Table 3. The results of five sample printouts in two orientations

Single sample	Orientation	
	Horizontal	Vertical
Estimated printing time [min]	33	63
Number of sample	Real time of printing [min]	Real time of printing[min]
1	36	66
2	35	66
3	35	66
4	35	66
5	35	66

printing. The obtained results of the printouts are presented in Tables 4–6.

The article focuses on obtaining a properly printed object with a specific shape. The aim of the work was to compare the printing time of an object using two technologies. In the interpretation of the printing times of the samples on the resin printer, it can be noticed that definitely the horizontal position allows for faster obtaining of the sample. The total printing time is also associated with the preparation of the sample, however, if large-scale production is planned, then the preparation time is counted once, because each subsequent sample is a copy of the first one. The difference between the appearance of the sample printed on a resin printer and a filament printer is shown in the Figure 7. However, the shape and size are practically identical. The obtained results

Table 4. The results of single sample printouts in two orientations.

Sample	Orientation					
	Vertical			Horizontal		
	Heating [min]	Preprint [min]	Total time [min]	Heating [min]	Preprint [min]	Total time [min]
1	02:32	03:25	24:16	03:24	04:04	23:49
2	02:54	03:33	24:13	03:14	03:55	23:41
3	02:49	03:28	24:15	02:58	03:38	23:21
4	03:03	03:40	24:28	03:13	03:53	23:38
5	02:58	03:46	24:20	03:06	03:45	23:25

Table 5. The results of three sample printouts in two orientations.

Sample	Orientation					
	Vertical			Horizontal		
	Heating [min]	Preprint [min]	Total time [h]	Heating [min]	Preprint [min]	Total time [h]
1	03:04	03:41	01:09:32	02:54	03:43	01:04:28
2	03:08	03:56	01:07:54	03:24	04:11	01:04:49
3	03:09	03:53	01:09:45	03:29	04:22	01:04:57
4	03:23	04:05	01:09:38	03:09	03:55	01:04:47
5	03:08	03:50	01:09:26	02:58	03:47	01:04:30

Table 6. The results of five sample printouts in two orientations.

Sample	Orientation					
	Vertical			Horizontal		
	Heating [min]	Preprint [min]	Total time [h]	Heating [min]	Preprint [min]	Total time [h]
1	02:51	03:39	01:52:42	02:58	03:48	01:43:35
2	02:49	03:36	01:52:40	03:10	04:06	01:44:41
3	02:49	03:46	01:52:52	03:03	03:54	01:44:36
4	02:51	03:38	01:52:38	03:15	04:08	01:44:50
5	02:50	03:39	01:52:36	03:08	04:01	01:44:49

clearly show that the horizontal arrangement of the modeled cuboid allowed for faster printing. The graph in Figure 8 shows the average time distribution of samples prepared in five copies on one working area on a resin printer and on a filament printer as an attempt at large-scale printing. We can see that even with a large number of elements on one working area, horizontal position of object printing is faster.

CONCLUSIONS

A visually better print result is created when using a resin printer. The edges are smooth. In terms of obtaining a sample with a specific shape, and not necessarily material properties, choosing a resin printer is a better solution. In any case of printing samples, the best and fastest solution is to place the model horizontally. When printing a larger number of items, resin printing is better due to the printing time. Printing time on a filament

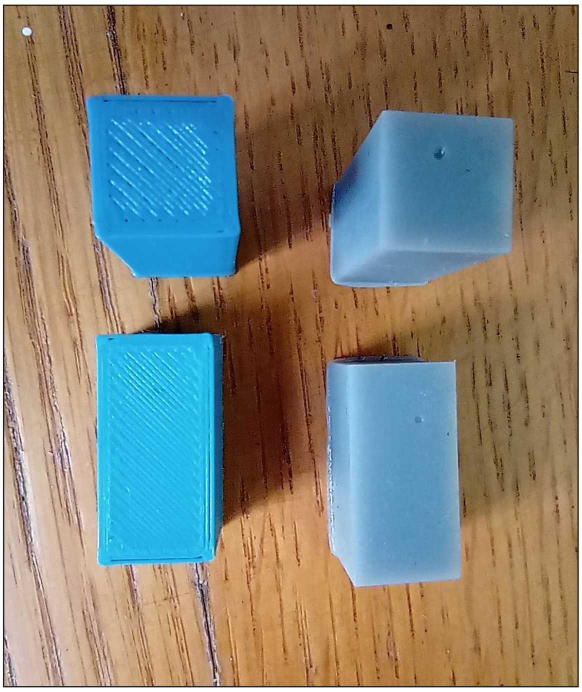

Fig. 7. Printed samples. On the left a PLA filament sample, on the right a resin sample.

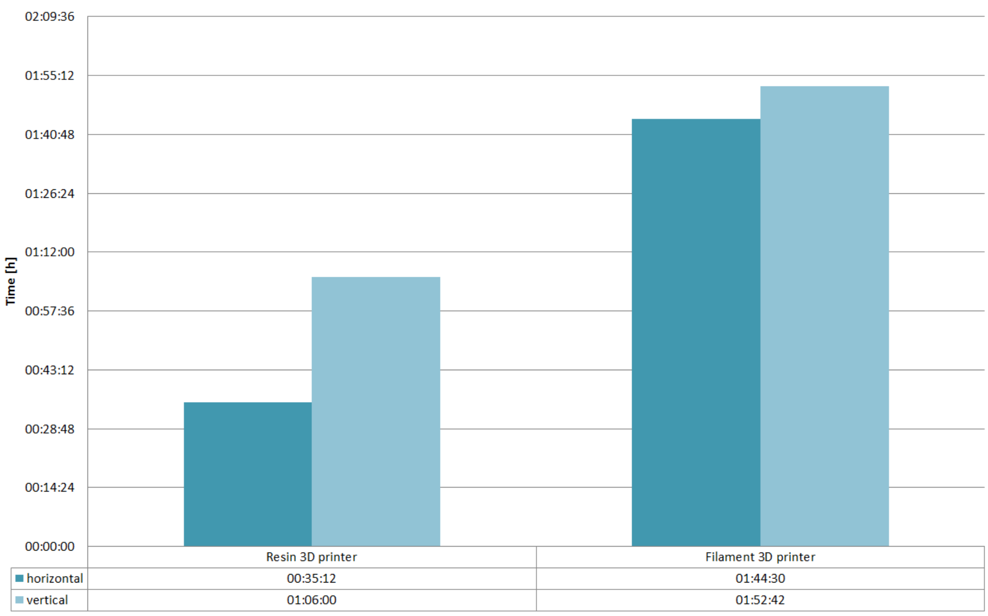

Fig. 8. The average time distribution of samples

printer may also depend on the ambient temperature. In addition, the environment may be a factor affecting the quality of this printout. The printing times on a resin printer are relatively repeatable and close. In the case of unit production, cost is cheaper in the case of printing on a filament printer. In the case of printing with incomplete filling for printing on a resin printer, the time will be constant, while in the case of a filament printer, the time will be shortened. Filament prints are more sensitive to external factors. When printing a larger number of elements on one working area, a faster solution is a resin print. Filament printing is a faster solution for unit production, as shown in the results in the tables. The estimated print time as reported by the printer software was longer than the actual print time. The time of printing one filament sample in the horizontal position differed from the printing in the vertical position by an average of 44 seconds. The average printing time of the filament sample in the horizontal position was 23 minutes and 35 seconds, while the average printing time of the sample in the horizontal position but on the resin printer was on average 35 minutes and 36 seconds. The results were reproducible. The quality of filament and resin printing is a topic for further research.

REFERENCES

1. Siemiński P., Budzik G. Additive techniques: 3D printing. Oficyna Wydawnicza Politechniki Warszawskiej, 2015. (in Polish).
2. Tatarczak J. Overview of modern 3D printing technologies of metal objects. Mechanik, 2017, 7: 612-614. (in Polish).
3. Szulżyk-Cieplak J., Duda A., Sidor, B. 3D printers–new possibilities in education. Advances in Science and Technology Research Journal, 8(24), 96-101., 2014.
4. Micht D., Kaczmarska B, Gierulski W.,Szmidt A. The universality of 3D printing in FDM technology. Politechnika Świętokrzyska, 2017. (in Polish).
5. Urzędowski A., Paśnikowska-Łukaszuk M, Kapłon K. The use of the 3D modeling process and 3D printing in the preparation of entities supporting motor skills and sensory development, Wspomaganie komputerowe w dydaktyce, Wydawnictwo Politechniki Lubelskiej, 2021, (in Polish).
6. Hespel A. M., Wilhite R., Hudson J. Invited review-applications for 3d printers in veterinary medicine. Veterinary Radiology & Ultrasound, 55(4), 347-358, 2014.
7. Zgryza Ł., Raczyńska A., Paśnikowska-Łukaszuk M. Thermovisual measurements of 3D printing of ABS and PLA filaments. Advances in Science and Technology Research Journal, 12(3), 2018.
8. Liu Z., Wang Y., Wu B., Cui C., Guo Y., Yan C. A critical review of fused deposition modeling 3D printing technology in manufacturing polylactic acid parts. The International Journal of Advanced Manufacturing Technology, 102(9), 2877-2889., 2019.
9. Zaburko J., Urzędowski A., Szulżyk-Cieplak J., Trník A., Suchorab Z., Łagód, G. Analysis of thermal operating conditions of 3D printers with printing chamber. AIP Conference Proceedings (Vol. 2429, No. 1, p. 020020). AIP Publishing LLC 2021.
10. Rengevič A., Fúra M., Čuboňová N. Analysis of printing parameters for production of components with Easy3DMaker printer. Advances in Science and Technology. Research Journal, 10(32). 2016.
11. Korga S., Barszcz M., Dziedzic K. Development of software for identification of filaments used in 3d printing technology. Applied Computer Science, 15(1), 74-83., 2019.
12. Barszcz M., Montusiewicz J., Paśnikowska-Łukaszuk M., Sałamacha A. Comparative analysis of digital models of objects of cultural heritage obtained by the "3D SLS" and "SfM" methods. Applied Sciences, 11(12), 5321. 2021.
13. Mazzanti V., Malagutti L., Mollica F. FDM 3D Printing of Polymers Containing Natural Fillers: A Review of their Mechanical Properties. Polymers 2019, 11, 1094.
14. Ćwikła G., et al. The influence of printing parameters on selected mechanical properties of FDM/FFF 3D-printed parts. IOP conference series: materials science and engineering. Vol. 227. No. 1. IOP Publishing, 2017.
15. Wang Jie, et al. Stereolithographic (SLA) 3D printing of oral modified-release dosage forms. International journal of pharmaceutics 503.1-2 (2016): 207-212.
16. Sotov A., et al. LCD-SLA 3D printing of BaTiO3 piezoelectric ceramics. Ceramics International 47.21 (2021): 30358-30366.