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ANALYSIS OF THE QUALITY OF PRINTED PLA SAMPLES USING VARIOUS 3D PRINTERS AND PRINT PREPARATION PROGRAMS

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Abstract. *The article presents the impact of individual settings of both 3D printers and software dedicated to the preparation of printouts. 3D printing methods are discussed. The individual methods and tools necessary for the implementation of 3D prints are described. Materials that are used in 3D printing technology are also discussed. In addition, the construction of printers on which the samples for the tests described in this work were prepared was discussed. The advantages and disadvantages of using individual slicers for 3D printing are presented. The obtained measurement results of samples made of polylactide (PLA) are presented. The work was summarized with final conclusions.*

Keywords: 3D print, PLA, slicer, 3D modelling

ANALIZA JAKOŚCI WYDRUKOWANYCH PRÓBEK PLA PRZY UŻYCIU RÓŻNYCH DRUKAREK 3D I PROGRAMÓW DO PRZYGOTOWANIA WYDRUKU

Streszczenie. *W artykule przedstawiono wpływ poszczególnych ustawień zarówno drukarek 3D oraz oprogramowania dedykowanego do przygotowania wydruków. Omówiono metody druku 3D. Opisano poszczególne metody i narzędzia niezbędne do realizacji wydruków 3D. Omówiono także materiały, które są wykorzystywane w technologii druku 3D. Ponadto omówiono budowę drukarek, na których zostały przygotowane próbki do badań opisanych w tejże pracy. Przedstawiono wady i zalety korzystania z poszczególnych slicerów do druku 3D. Zaprezentowano otrzymane wyniki pomiarowe próbek wykonanych z polilaktydu (PLA). Pracę podsumowano wnioskami końcowymi.*

Słowa kluczowe: druk 3D, PLA, slicer, modelowanie 3D

Introduction

Three-dimensional objects are created using special 3D printers, which are based on the principle of applying low layers. The surface of the printed model is smoother when the layers are smaller. This can be described as follows: the smaller the layer, the smoother the surface of the 3D print [9].

3D printing technologies include, among others:

- SLS (Selective Lase Sintering) – this is a technology based on selective laser sintering.
- SLM (Selective Laser Malting) – this is a technology that uses the method of selective laser melting [10].
- DPL (Digital Light Processing) – this is a technology that uses the light emitted by the projector to harden the liquid resin.
- EBM (Electron Beam Melting) – this is a technology that uses an electron beam to melt powders [3].
- FDM (Fused Deposition Modeling) – this is a technology based on the use of thermoplastic material and its modeling [9].

This paper focuses on the FDM method [12].

The material in the FDM technology is a filament that is fed into the print head through the extruder [8, 11]. The filament is melted there and then distributed into layers. The printer applies each subsequent layer on top of the previous one and thus creates the entire object. The technology consists in the use of a thermoplastic material, most often plastic.

The concept of 3D modeling is associated with each of these technologies. 3D modeling is a process of creating a mathematical interpretation of the surface of a given object. As a result, a three-dimensional object is obtained [6]. To create it, it need special computer software such as CAD. There are many such programs on the market, among others: Autodesk Inventor, AutoCAD or SolidWorks [12]. Before the object goes to print, a model should be created in such a program, and then the project should be saved in the appropriate format. The standard format is the STL format, which approximates the walls of the designed object to a grid made of triangles, and the software divides the model into layers. This software is a slicer. It is responsible for preparing files for printing. Thanks to it, you can, among other things, change the print speed settings or the thickness of the extruded filament layer. All applied settings will be applied to the processing of the 3D model and dividing it into individual print layers [5]. 3D printing technology is currently the most dynamically developing technology in the manufacturing process.

1. Materials and methods

The quality of the 3D print is affected by many factors, regardless of the technical parameters regarding the parameters of the program, printer, but also environmental factors such as air temperature and air flow.

1.1. ABS i PLA

The most common materials that are used in FDM 3D printing are ABS (Acrylonitrile butadiene styrene) and PLA(polylactide).

ABS is an acrylonitrile-butadiene-styrene copolymer derived from petroleum. Due to its mechanical properties, it is very popular in industry and is used to make all kinds of cases, knobs, handles, etc. This material is found in the creation of various things, e.g. furniture, pipes, car parts, household appliances, washing machines and small kitchen items, whole containers and toys. Lego bricks are the most common use case for ABS. The popularity of this thermoplastic is due to its hardness, impact resistance, wear resistance and high temperature resistance. It retains its properties in the temperature range from -20 to 80°C (some filament manufacturers give temperatures up to 98°C) [12].

PLA or poly(lactide) is especially popular with 3D printer users. This material is a bio-polymer classified as aliphatic polyester. For its production, corn starch and sugar cane. In addition to FDM technology, this material is also used in the production of various types of disposable packaging. Due to its biocompatibility and degradation time within a few years, it can also be used as a scaffold element for absorbable surgical threads, bandages, stents, orthopedic implants and tissue scaffolds. PLA is recyclable. It is believed to be biodegradable, but without special conditions such as composting. It takes a long time to decompose. The main reasons for the material's popularity are that it is easy to use and cheap [12]

Due to the low shrinkage of the material, heating the bed is not required. Does not require a heating chamber. Printing takes place at a relatively low temperature of 190–220°C. It has very good tensile strength and stiffness. All this makes it an excellent choice not only for novice users, but also for those who want to easily obtain large prints with excellent dimensional accuracy. The main disadvantage is the sensitivity to high temperatures – it deforms at 50–60°C. Therefore, items made of this material should not be used in places exposed to high temperatures (boiling water, boiler rooms, dishwashers, etc.). Prolonged exposure to UV radiation will make it brittle. PLA is a stiff material and sensitive to high temperatures, which can make it difficult to process. This applies, for example, to grinding and drilling [1]. It is also not recommended to use solvents to smooth the print surface. PLA does not dissolve in acetone and is sensitive to substances (such as tetrahydrofuran and dichloromethane) that are not recommended for use outside of a fume cupboard.

1.2. 3D printers

The development of the rapid prototyping technique makes 3D printers more and more popular and common [4]. All models printed for the article were created using a Zortrax M200 Plus and Ender 3 V2 printer.

1.2.1. Zortrax M200 Plus

Zortrax M200 Plus is a device based on Fused Deposition Modeling (FDM) technology. Working parameters:

- technology: LPD (Layer Plastic Deposition)
- layer resolution: 90–390 microns.
- minimum wall thickness: 400 microns.
- dimensional accuracy: +/- 0.2%
- X/Y positioning accuracy: 1.5 microns.
- table leveling: automatic.
- maximum table temperature: 105℃.
- working area of the table: 200 × 200 × 180 mm [7].

Thanks to the technology of printing based on layer deposition, Zortrax M200 Plus (Fig. 1) allows you to create precise and complex models in three dimensions. The printer uses a special Z-ABS filament that is resistant to mechanical damage and chemicals, which makes it ideal for printing utility items. Zortrax M200 Plus also has many functionalities that facilitate work, such as automatic calibration of the printing table, filament sensor or intuitive user interface. In addition, the printer is equipped with a cooling system that prevents overheating of electronic components, which affects its reliability. To sum up, Zortrax M200 Plus is a solid and efficient 3D printer that is perfect for business and educational applications, where high print quality and reliability of the device are required.

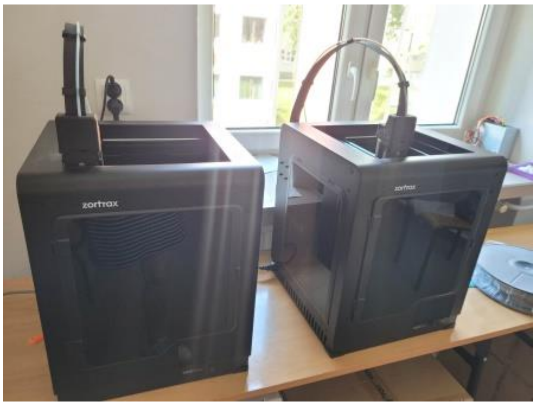

Fig. 1. Zortrax M200 Plus printer station

1.2.2. Ender 3 V2

Ender 3 V2 3D printer (Fig. 2), created by Creality. It is an improved version of the original Ender 3 which introduces several improvements and additional features. Here are the main features of the Ender 3 V2 3D printer:

- stable construction,
- large working surface,
- compatibility with various materials: the Ender 3 V2 printer supports various types of filaments, such as PLA, ABS, PETG and many others (thanks to this, the user has more freedom in choosing materials for his projects [7]),
- working area: 220 × 220 × 250 mm,
- material diameter: 1.75 mm,
- diameter of the print head: 0.4 mm (alternatively 0.2 or 0.3 mm),
- number of printheads: 1 filament: PLA, TPU, carbon filament, ABS,
- device dimensions: 475 × 470 × 620 mm,
- technology: FDM,
- device type: for self-assembly,
- minimum layer height: 100 microns,
- positioning accuracy of the XY axis: no information,
- positioning accuracy of the Z axis: no information,
- maximum table temperature: 110ºC,
- maximum head temperature: 250ºC,
- printing accuracy: 0.1 mm.

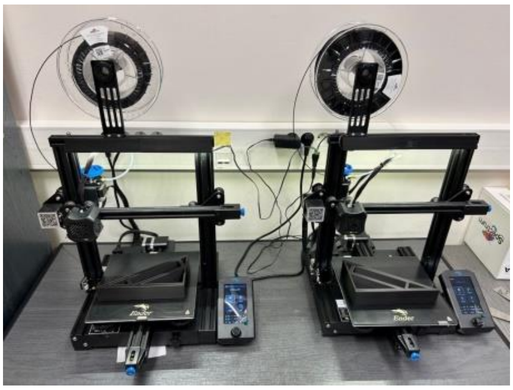

Fig. 2. Ender 3 V2 printer station

1.3. Programs for prepare and slicing a 3D model

In order for the printers to start their work, it is necessary to create a G-code. The G-code language is a programming language used in numerical machine tools. It is based on instructions that control the movement of the tool and the execution of operations on the machine. These functions require input of parameters such as the position on the XYZ axis, turning the coolant on or off, and specifying the spindle speed. Example commands in the G-code language: G91 – incremental positioning, G54-G59 – selection of the workpiece coordinate system. When modeling a 3D object, the resulting file is processed by a slicer that divides the model into layers. The next step is to generate the G-code based on the created layers. Thanks to this, the 3D printer knows, among other things, how it should move or what speed to use. Using specialized software, you can convert the .stl file created in the CAD program to the G-code format [2]. Slicer calculates how much material will be used for the 3D casting process and in what time it will be made. At the end of this process, this command language is produced.

The 3D model was prepared in Autodesk Inventor. A 5×5×5 cm cube was chosen for the settings impact study. Then the model was saved as stl. file. The model was opened in three programs for preparing a 3D print.

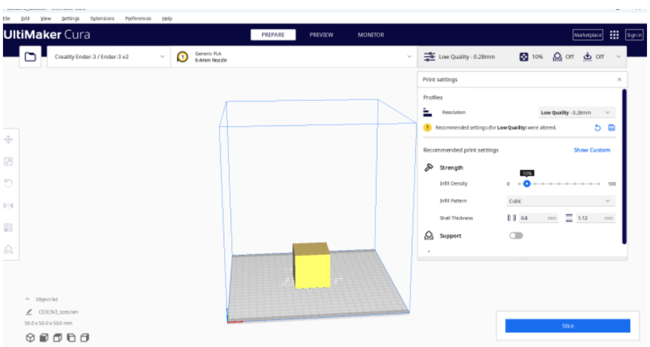

Fig. 3. UltiMaker Cura settings

The first settings were made in the Cura software. Cura is free and open-source software developed by Ultimaker. This slicer offers advanced editing functions, including rotating, cropping and scaling [12]. Cura also allows you to open a preview of the model before printing. All samples were set to 10% infill and 0.28-0.29 mm layer thickness. The settings of the first sample are shown in figure 3.

The second sample was cut in the program dedicated to the Ender 3 V2-Creality printer. Creality (Fig. 4) is the software that comes with the 3D printers of the same brand. The program has specific parameters that can be manipulated, including layer height and thickness, fill density and printing temperature.

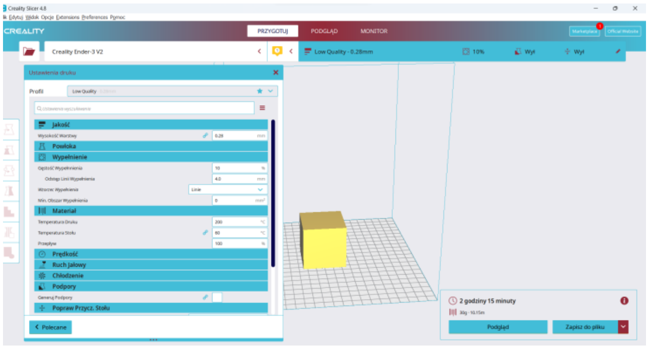

Fig. 4. Creality Slicer settings

Both samples were printed on Ender 3V2 printers. In the case of settings in UltiMaker Cura, the print time was 2h and 15 min. It was the same as in Creality slicer.

The third sample was prepared in the Zortrax – Z-Suite software. The settings are shown in figure 5.

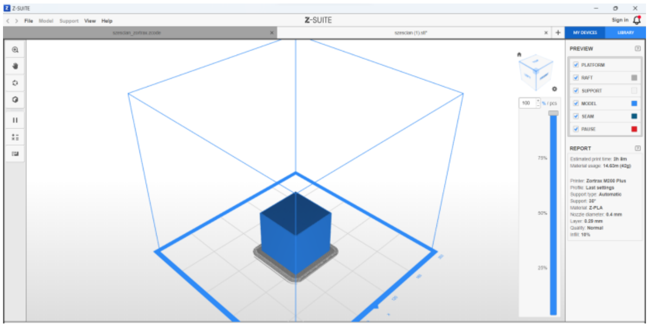

Fig. 5. Creality Slicer settings

2. Results

Table 1 presents the results of the obtained samples set in three different programs and printed on two 3D printers.

Figure 6 an 7 shows the appearance of the samples after printing.

Table 1. Results from 3D printing

3D printer	Ender 3 V2		Zortrax M200 Plus
Slicer	Cura	Creality 3D	Z-Suite
Sample	1	2	3
Material	PLA		
Height of sample	4.95 cm	4.90 cm	4.90 cm
Width of sample	4.90 cm	4.90 cm	4.90 cm
Length of sample	4.90 cm	4.90 cm	4.90 cm
Weight	28 g	28 g	33 g
Color	dark grey	dark grey	light grey
Surface	smooth	smooth	on the first layer, cavities and bulges
Layer visibility	invisible	slightly invisible	invisible

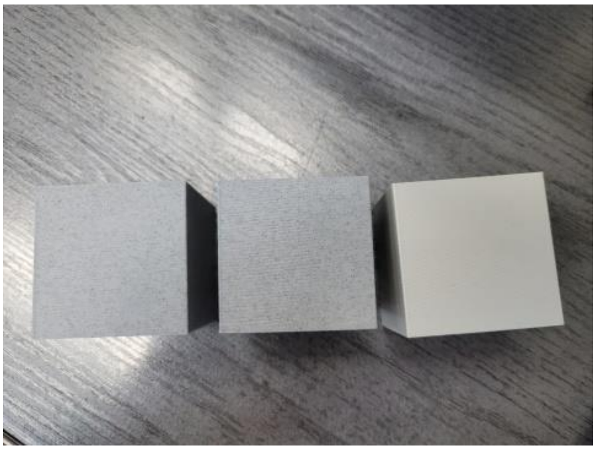

Fig. 6. All samples

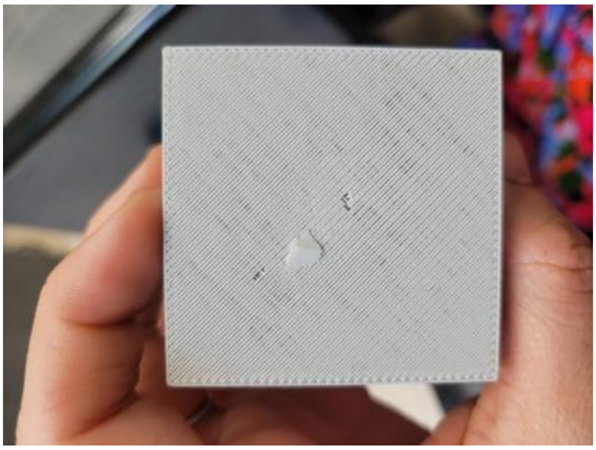

Fig. 7. Sample printing on Zotrax M200 Plus

3. Summary and conclusions

All printed samples are missing about 1mm from the full 5 cm edge of the sidewall. Although the program simulated a printout dedicated to 5×5×5 cm, the final samples have a smaller surface. This is probably due to inaccurate calibration of the printer or shrinkage of the material after cooling down. Samples prepared for printing in UltiMaker Cura and Creality 3D have the same weight. The weight of the sample printed on Zortrax is 5g higher. The samples printed on the Ender 3V2 look practically identical, but the height of the cube prepared in the Cura program is 0.05 cm higher than the other samples. The surface of samples printed on Ender 3 V2 is smooth, while the sample printed on Zortrax has some defects. The last layer has cavities, which was visible in figure 7. The printing time for samples printed on Ender 3 V2 was the same for both the Creality and Cura samples. Although the software showed a weight of 30 g, in the end they weigh 28 g. According to the settings in UltiMaker Cura, the length of material used was 0.07 m longer, but the scale shows that both samples used the same amount of PLA. The sample printed on Zortrax had a shorter print time by 7 minutes compared to samples printed on Ender 3 V2. All the programs used are quite easy to use and have a clear way to change settings. Environmental parameters such as room temperature and humidity also affect the final printout. If the material cools too quickly, the material may crack. To sum up, all the software used fulfill their roles in preparing the model for 3D printing. Economically, less material is used with Cura and Creality 3D sample settings. However, it must be remembered that the Zortrax M200 Plus printer has a different type of data recording in the form of z.code and other components that make up the printer. Selection of the appropriate program depends on availability and user preferences. To sum up, what the final 3D print will look like depends, of course, on the appropriate settings in the software, but also on the correct preparation of the printing device itself.

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