Analysis of software for FDM additive manufacturing

Juraj Beniak [*1], Marko Bednárik [1], Peter Križan[1], MilošMatúš[1], Michal Holdy[1]
[*1] *Faculty of Mechanical Engineering, Slovak University of Technology in Bratislava, Slovak Republic*
Corresponding Author: Juraj Beniak, juraj.beniak@stuba.sk

Abstract

Additive manufacturing is a very important means in the field of innovative production of parts for different uses and from different materials. One of the technologies of additive manufacturing is FDM (Fused Deposition Modeling) - modeling by molten deposition. It uses a wide range of thermoplastics as building material. Different types of materials are used for different uses. They differ in material properties but also in the simplicity or complexity of their processing. A very important element that affects the quality of the manufactured parts is also the software (slicer), which we use to prepare the model for production and generate the g-code. The subject of the article is an overview of existing software for FDM technology with a description of advantages and disadvantages, as well as a comparison of the software with each other.

Keywords: *additive manufacturing, 3D printing, FDM, Fused deposition modeling, slicer*

I. INTRODUCTION

The software for processing the model for the needs of FDM additive manufacturing is called a slicer. Slicer is a tool that converts a digital 3D model to G-code. A digital 3D model is usually in .stl or .obj format. The task of the slicer is to create individual horizontal layers from the 3D model (Figure 1). G-code is a detailed list of commands readable by a 3D printer, which allows to optimize everything it needs during the process. [1] There are 3 key sections of the interface and they are the graphics area, the slicing settings panel and the general settings. [2]

- Graphics area – the slicer offers a 3D graphics area where you can visually monitor how the model is transformed into a layered display. [2]
- Panel of settings for creating cuts - through specific settings and commands, we can set specific parameters during printing. Most slicers can automatically generate optimal settings for a given 3D model. The key criteria in setting are layer height, extruder temperature, print speed, cooling setting, support structure setting, etc. [2]
- General settings – primarily import and export options, display settings, help panel, back and redo options, etc. These settings vary depending on the software used. [2]
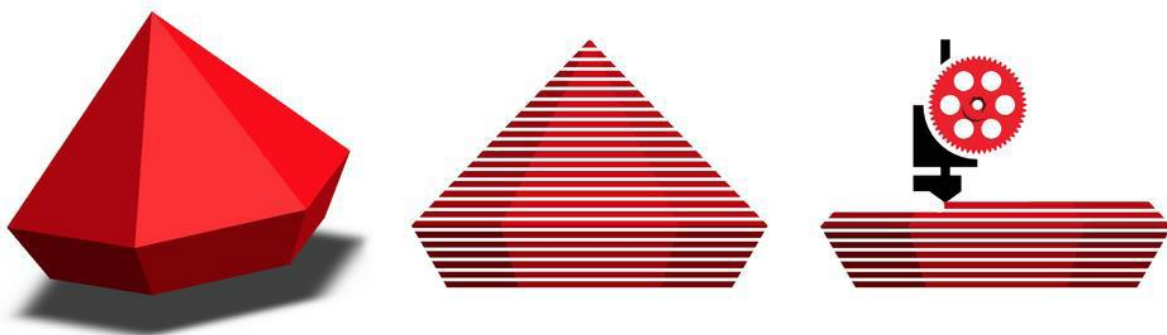

Figure 1 3D printing process [1]

II. SOFTWARE FOR G-CODE PREPARATION

There is a large amount of software on the market and new ones are being added all the time. The most used and most accessible ones were selected for comparison.

2.1 Cura

The software was created by David Braam in 2014. He later became an employee of Ultimaker, a company that makes 3D printers and various other software that is compatible with both their printers and the Cura software. [3] [4]

This software is free, but it is also an open source software called open source. Although Cura is part of Ultimaker, printers from other manufacturers can also use it. There are 15 languages available in the settings. Cura has a very simple interface that allows you to choose from two basic settings: recommended mode and custom mode. The recommended setting is suitable for beginners as there is no need to make any manual changes to the settings. Custom settings allow the user to choose from more than 400 different setting options. It also offers integration of CAD plugins with SolidWorks, Siemens NX, Autodesk Inventor, etc. Cura is still in development as Ultimaker regularly updates this software to constantly improve features. [3]
Ultimaker also introduced Ultimaker Cura Enterprise, which is designed for professionals. It allows adding licensed add-ons from the Ultimaker Marketplace, adds technical support and additional security features for an annual fee of $300. [3]

- Compatible file types: 3MF, AMF, DAE, STL, PLY, OBJ, X3D, GLB, GLTF, BMP, GIF, JPEG, PNG
- Compatible operating systems: Windows, Mac and Linux.
- Suitable for beginners, intermediate and advanced.
- Price: free.

2.2 Netfabb

Originally developed by the German company netfabb GmbH, this software was acquired by Autodesk in 2015. The software has since been divided into four products: Netfabb Standard, Netfabb Premium, Netfabb Ultimate and Netfabb Simulation. Standard, Premium and Ultimate are tools focused mainly on model optimization and preparation for production. Simulation is specially optimized for powder bed melting and direct energy beam deposition processes. Autodesk also offers the Fusion 360 tool, which combines the entire product development process into one cloud platform. [5] [6]

Fusion 360 with Netfabb software includes capabilities for efficient assembly preparation along with design optimization tools for additive manufacturing, additive metal process simulation, and CNC post-processing planning (Fig. 13). We can divide most of the functions of this software into 4 categories: the first is assembly preparation, the second is design optimization for additive manufacturing, the third is machine integration, and finally simulation. [6]

Preparing a report includes functions such as: importing; analysis; repair of 3D models; modification of the model using wall thickness, smoothing out irregularities, etc.; identification of areas that need a support structure; optimal placement of parts; advanced changes for tool path.

Design optimization includes: creation of internal grid structures, topology optimization, integrated performance analysis, optimization module, selective spatial structures.
Machine integration includes: integrated print engines and solutions for machine manufacturers.
The simulation makes it possible to predict the thermomechanical response of additive parts during the use of production processes. [6]

- Compatible file types: almost all 3D file, image and CAD formats.
- Compatible operating systems: Windows.
- Suitable for intermediate and advanced.
- Price: 30-day trial version, then the annual price is $240 for Standard, $4415 for Premium, $13,790 for Ultimate, and the price for the Simulation version is not listed.

2.3 Prusa Slicer

The software was originally based on Alessandro Ranellucci's Slic3r software. In 2016, it split off and released its own internal version called Slic3r PE (Prusa Edition) via GitHub. As Slic3r PE deviated more and more from the idea of the original software, Prusa officially renamed it in May 2019. Since then, PrusaSlicer has been continuously developed and updated. [18]

The software is free and open source. It can also be used by printers from other manufacturers. The first time you start the software, the PrusaSlicer configuration wizard opens, showing basic settings such as selecting a printer and materials. Once complete, the selected configurations will be saved and accessible on the main screen. PrusaSlicer has a very clean look and easy to use. Most of the tools that are placed on the screen can be controlled using keyboard commands. In the basic interface, by grouping similar settings, PrusaSlicer makes it easy to customize and save different profiles. Thus, it is possible to switch fiber profiles without affecting the printer settings. PrusaSlicer allows you to save a file in 3MF format, in which all objects, settings, modifiers and their parameters are saved. Thus, it is easy to go back to your projects and see which profile was used. The software offers the ability to repair modelsthrough Netfabb software (only available for Windows). There are 14

languages available in the settings. Main features: adjustable support structures, automatic profile updates, variable layer height, color change option, Octoprint integration, production time analysis, etc. [7]

- Compatible file types: 3MF, STL, OBJ and AMF.
- Compatible operating systems: Windows, Mac and Linux.
- Suitable for beginners, intermediate and advanced.
- Price: free.

2.4 Slic3r

The Slic3r software emerged from the RepRap community in 2011. It was mainly created by Alessandro Ranellucci, and other contributors helped in its continuous development. Slic3r has released 48 official versions since its inception and all are available on the official website. Slic3r is a non-profit project based on a community of people working together on Github, where they discuss new features and test them. It is generally accepted that many features that exist in 3D printing software today were first tested, developed and implemented in Slic3r software. [8]

The software is free and open source. After the first launch, a window will open to calibrate the 3D printer and define the correct configuration parameters. The user interface is not as well graphically processed as with the other mentioned software. However, the advantage of the user interface is the presence of descriptions in the menu. They provide quick help and clarify the functions of the selected parameter. The software is also fully usable through the command line. Key features include: auto-correction and re-export capability, Octoprint integration, fast G-code generation for FDM printers and more. [8]

- Compatible file types: STL, OBJ, AMF, 3MF.
- Compatible operating systems: Windows, Mac and Linux.
- Suitable for intermediate and advanced.
- Price: free.

2.5 Craft Ware Pro

The software was founded by Craftbot. Craftbot is a Hungarian company that was founded in 2014. It focuses on the development, innovation and production of 3D printers. On their official website, they offer standard, premium and premium enterprise versions (this version is still under development and not available). [9]

Key features include: interactive print management, automated presets, CAD functionality (allows you to edit and customize objects), grid modification, support structure and more. It also includes a function to select different settings for different nozzles in the print heads. It has a choice of three modes Smart, Easy and Expert, which can be chosen based on experience and the need for advanced functions. According to the manufacturer, the software uses an algorithm that generates the best possible tool path for the 3D printer. [9]

- Compatible file types: STL, OBJ.
- Compatible operating systems: Windows, Mac and Linux.
- Suitable for beginners, intermediate and advanced.
- Price: free for the standard version, 3-month trial period for the premium version (the price after the trial period is not indicated).

2.6 Tinkerine Suite

Tinkerine is a Canadian technology company that focuses on manufacturing 3D printers for education. In addition, Tinkerine has also created its own software, Tinkerin Suite, which is free. [10]

This software has a very simple interface and is also very easy to use. This makes it usable even for children who can get basic information about 3D printing. In addition to print parameters, the software also includes tips that explain how changing individual settings will affect printing. Basic features such as: 3D visualization, basic model manipulation, multi-model printing, support structure and more are available. Overall, this software is primarily aimed at education. [11]

- Compatible file types: STL, OBJ.
- Compatible operating systems: Windows and Mac.
- Suitable for beginners and intermediates.
- Price: free.

2.7 Octoprint

Rather, this software serves as a software platform that enables simple and effective remote monitoring of printing in progress. Monitoring is possible through a web browser or through the Raspberry Pi application, which is also available on a smartphone. Thanks to its cloud operation, it is possible to directly load STL files into the 3D printer without the need to use an SD card. It is possible to remotely monitor progress, temperature, estimated remaining printing time. It is also possible to install a webcam, with which it is possible to obtain video recordings or directly check the printing whether there were any printing errors. It includes an integrated software that is based on CuraEngine so it includes all the main functions as well as the other mentioned softwares. [12]

- Compatible file types: STL.
- Compatible operating systems: Raspberry Pi, Windows, Mac and Linux.
- Suitable for intermediate and advanced.
- Price: free.

2.8 Simplify3D

Simplify3D was founded in 2013 and focuses only on the development of its software. It works with 3D printing companies so the software is compatible with almost any printer. [13]

The software is available for a one-time fee of $149. They offer a 25 percent discount for students and teachers at the university. The software is available in 7 languages. The user interface is very simple and easy to use. It contains many settings such as: extruders, layer control, different filling methods, temperature and cooling settings, automatic or manual addition of support structures, it is also possible to modify the G-code or scripts and more. Simplify3D provides a pre-print simulation that will allow you to see the steps that the 3D printer will take before the 3D model starts printing. The simulation contains information about the speed, sequence and settings used when printing. [13]

In the settings, there are two modes: basic and advanced. In the basic mode, it is possible to select basic parameters such as material, print quality, generation of support structures and others. When choosing a more advanced setting, all software settings are available, from setting temperature, cooling, speed to editing the G-code itself. The software is very fast when importing models, generating G-codes and also during simulations. [13]

- Compatible file types: STL, OBJ, 3MF, JPEG, PNG.
- Compatible operating systems: Windows, Mac and Linux.
- Suitable for intermediate and advanced.
- Price: 149$.

2.9 Self CAD

The software was designed by Aaron Breuer in 2015 and launched in 2016. Since its release, SelfCAD has been continuously improved and new features added. It is an online software that allows users not only to generate G-codes, but also to model and shape objects. The software does not need to be downloaded, it is browser-based, so it only requires an internet connection. All documents can be stored in the cloud, but offline mode is also available. [14]

The software has a very simple and unique user interface. It is compatible with almost all 3D printers. Both 2D and 3D drawing and sketching tools are available to design the entire 3D model. SelfCAD also includes a function to create simple animations. The software can also be modeled using sculpting tools. SelfCAD has a built-in tool for creating 3D print sections based on Cura, which allows you to generate G-code. There is also a Magic Fix tool that allows you to fix models before printing. It contains all basic settings such as: filling, material selection, print quality, support structures and more. [14] [15] [16]

- Compatible file types: almost all 3D file and image formats.
- Compatible operating systems: Windows, Mac and Linux.
- Suitable for beginners, intermediate and advanced.
- Price: free for the SelfCAD version, $14.99 per month for the SelfCAD Pro version, you can also purchase a lifetime version for $599.

2.10 ideaMaker

The software was founded by Raise3D. Raise3D is a FFF 3D printer manufacturer and focuses on 3D printing technology research and application. The California-based company was founded in 2014. [17]

The software is free and compatible with almost all 3D printers available. Provides advanced settings for printing with a compatible 3D printer that has dual extruders. It has built-in support for the Raise3D ecosystem, which includes 3D printers, the ideaMaker library for the 3D file sharing community, and RaiseCloud. RaiseCloud is a web-based 3D printing platform (also available as a mobile application) through which it is possible to remotely manage, monitor and have an overview of the entire progress of print production. [17]

Key features include: easy texture creation, automatic parameters for optimization, tool for optimizing parameters of specified sections, integrated basic functions for carving, splitting, combining models and more. [17]

- Compatible file types: STL, OBJ, 3MF, OLTP.
- Compatible operating systems: Windows, Mac and Ubuntu.
- Suitable for beginners and intermediates.
- Price: free.

III. COMPARING THE QUALITY OF SELECTED SOFTWARE

In this section, we will compare the resulting quality of 3D models printed through different software on an FDM printer. For comparison, we chose Cura, PrusaSlicer, Simplify3D and Slic3r software. We have a test 3D model available (Figure 2):
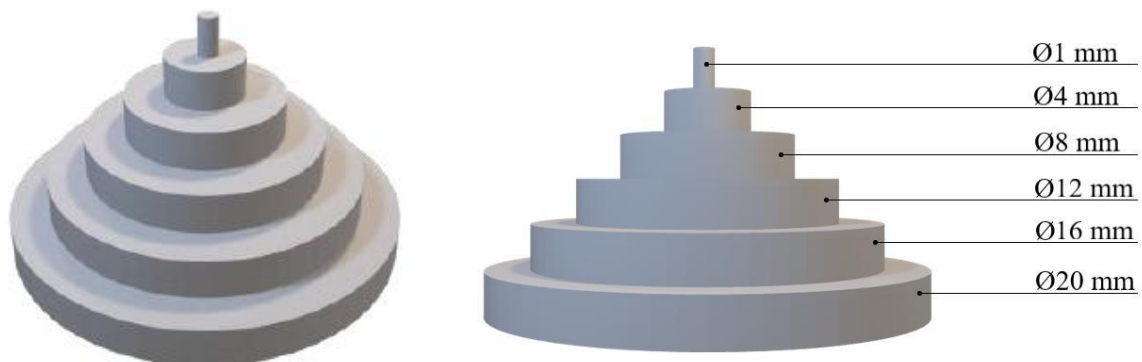

Ø1 mm
Ø4 mm
Ø8 mm
Ø12 mm
Ø16 mm
Ø20 mm

figure 2 Model for the purpose of comparing the print quality of different diameters

From the measured values from tab. 1 we can see the accuracy of individual software and also how the height of the layer affected the accuracy of the given software. In the table, we subsequently determined the ranking of the software 1st - best and 4th - worst. Depending on the measured values, the largest deviations of the software were recalculated and, according to the result, were placed in the accuracy categories of individual averages. Placement in the second category of print quality of the smallest diameter of 1 mm also included the largest deviations and also the visual side of the print of the smallest diameter of 1 mm (Figure 3). According to the results from the first and second groups, the overall ranking of the software was determined.
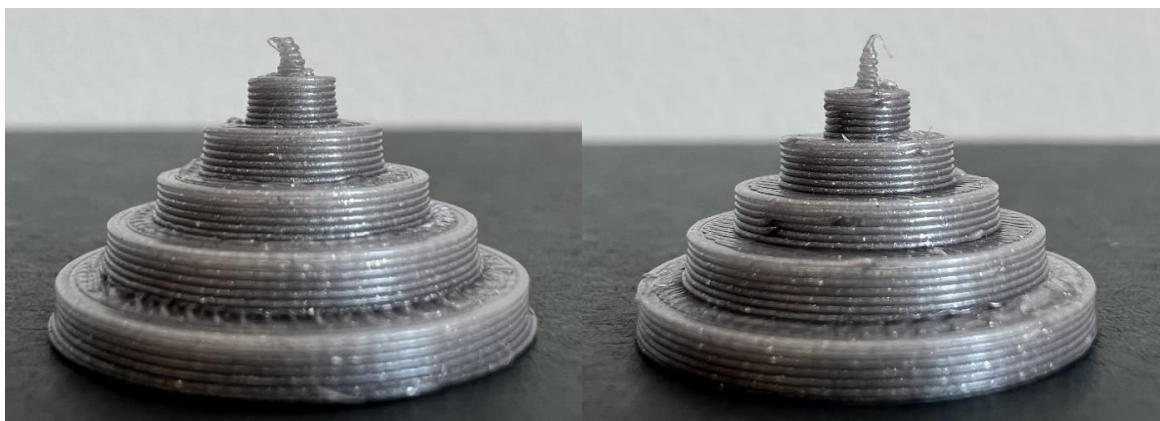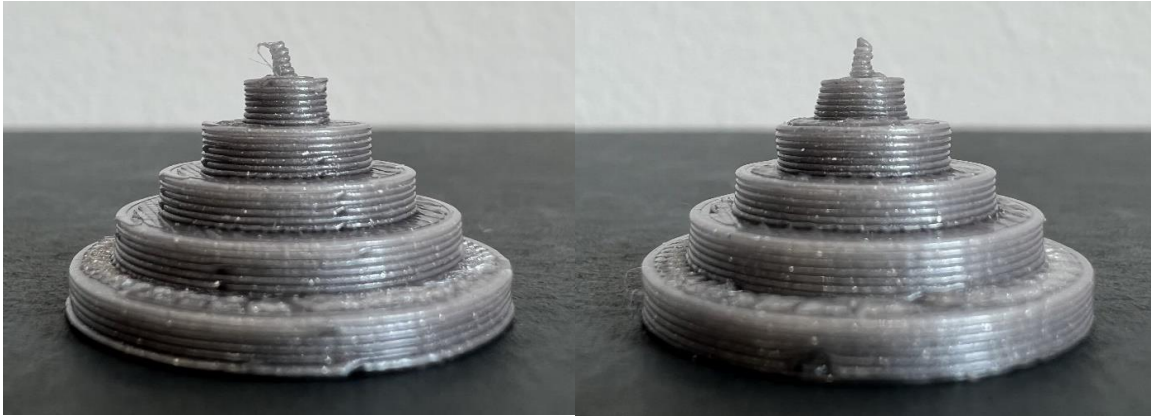
figure 3 Print quality of the smallest diameter of 1 mm - the second group 1 mm
(top left Cura, top right PrusaSlicer, bottom left Simplify3D and bottom right Slic3r)

The PrusaSlicer finished in first place based on the most accurate dimensions, although it has the worst print quality in the first group with the smallest diameter of 1 mm. Simplify3D and Slic3r had similar results, therefore finishing in second place. Cura took the last place based on the worst results from the measurement and also in the print quality of the smallest diameter of 1 mm. From the result, it can be concluded that printing with a diameter of 1 mm is unsatisfactory for all software, and the recommended printing diameter should be at least 2 mm.

Tab.1 Evaluation of the printing quality of models made in different software

	Firstgroup – layer 0.15 mm		Thesecondgroup – layer 0.3 mm		Overallplacement
	Accuracy of individualdiameters	Printquality of thesmallest diameter of 1 mm	Accuracy of individualdiameters	Printquality of thesmallest diameter of 1 mm	
Cura	4	3	4	4	3
PrusaSlicer	1	4	1	1	1
Simplify3D	2	2	3	2	2
Slic3r	3	1	2	3	2

IV. CONCLUSION

From the obtained comparative measurements and the evaluation of the order of success of individual software, it can be concluded that the PrusaSlicer software took first place. It is the software that achieved the best results in comparison criteria. Two software, Simplify3D and Slic3r, took second place. The Cura software took the last place.

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