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Application of innovative mechatronic systems in product design, development and production

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ABSTRACT

The application of mechatronic systems is very topical today. Today, mechatronic systems are applied in all areas, so today systems are also being developed that enable fast and simple production of products. Today's mechatronic systems that are supported by computers enable the development, easy and fast production of prototypes and products. Two technologies that are widely used are 3D printers and scanners. 3D printers allow a virtually developed product to be turned into a physical model, while the application of a 3D scanner allows a physical model to be turned into a virtual model on a computer. In this paper, a comparative analysis of two types of printers and their software was performed. They differ according to their working principle. In addition to the working principle, an example of the difference between the software used to write the G code to drive the printing process of 3D printer.

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1. INTRODUCTION

Mechatronic systems have become one of the main areas in all production processes. Today, mechatronics also participates and contributes in the production of various elements, but also in the development of certain products [1,2]. 3D printers and scanners are increasingly used today. 3D printers are today the main component in additive manufacturing (AM) [3]. Today, AM can be defined as a computer-controlled process that creates three-dimensional objects by applying materials, usually in layers (layer by layer) [4]. 3D printers are mechatronic systems because they have all the components that a mechatronic system has, as shown in [5]. The same is the case with 3D scanners. The difference between a scanner and a printer is that they have a completely opposite function in the process of developing and manufacturing a product. 3D printers have the role of turning a virtual 3D model into a physical 3D model, on the other hand, 3D scanners have the role of turning a real physical 3D model into a virtual model [6-7].

Today, 3D scanners represent one of the systems that are important in reverse engineering [8]. They allow correction and repair of various models, and even their repair [9]. Thus, virtual models are formed from the physical model through these devices, which can be reconstructed in a simple way by software without taking the basic dimensions of an element. This kind of scanning is an excellent method to easily obtain a file for 3D printing or for use in a digital environment in the context of augmented reality [10]. In this way, a product can be easily developed or, by comparing two 3D models, compare the shortcomings of a product using other methods such as CAE methods. Similarly, by scanning an element that was in use, it is possible to determine the wear of some surfaces or deformations using modern methods of 3D model analysis [11]. Thus, scanning today represents a key element of reverse engineering, whether for product improvement, reconstruction, design augmentation, or a variety of other use cases [12].

On the other hand, 3D printers have a completely opposite role compared to scanners. These printers, as they can turn a virtual model into a physical model, have a wide role today [13]. Their widespread role is reflected in the fact

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that they enable easy and fast production of physical models compared to some classical processes of parts production [14]. Today, 3D printers are widely used both in smaller companies, home conditions and some large and serious branches of industry. 3D printers can use different materials for the production of models, from rubber, plastic to metal [15, 16]. In general, the models that are printed have a small mass depending on the material used and the model printing parameters. Today they are used for different purposes and production of different products. Some of the areas, when it comes to industry, are used in robotics, the aerospace industry, the automotive industry, the production of household parts and other uses [16, 17]. Likewise, by using 3D printers, different product prototypes can be produced quickly and easily, with which it is possible to perform different controls, comparisons or use subtypes for marketing purposes [17].

In this paper, first of all, the working principles of 3D scanners are presented and the working principles of various 3D printers that are most often used today are analyzed. At the same time, a comparative analysis of the software used to write the generic code with which the printers work was performed, for two different models of printers that differ according to the principle of operation.

2. 3D SCANNERS

3D scanners are devices that turn a physical model into a virtual model. 3D scanners make it possible to make a virtual model from a physical model with the aim of remaking or making certain corrections on an existing product. There are different types of scanners, and they are basically divided into stationary and portable [18]. They allow scanning from the smallest products to some very large products. Figure 1 shows the basic components of a 3D scanner. Through the scanner, which consists of a laser projector and a camera, the model is scanned and processed into a virtual model using a computer [19].

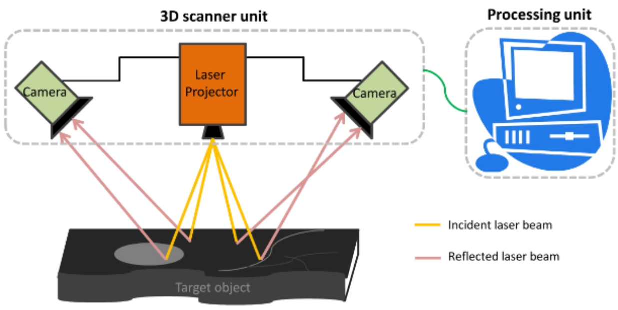


Fig. 1 *3D scanner components [20]*

The principle of operation of the scanner is based on the collection of data that is scanned, which is done using a laser and a camera. The principle is shown in Figure 2. Scanning is possible if specific points of the object to be scanned are collected together or from different projections. The signals sent to the computer are processed, and all the projections are combined with each other to form the surface of the virtual object [21]. With the calculated coordination and arrangement of all projections and points of the model, a complete and accurate 3D digital model of the target object is generated [20].

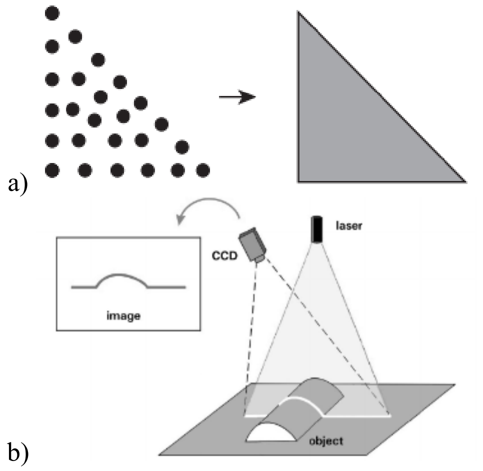


Fig. 2 *Process The process of 3D model generation, a) collection of specific points and model projection, b) role of elements in model scanning [21, 22]*

3. 3D PRINTERS

Today, various 3D printers are used, that is, there is a greater selection of different technologies for printing products. The most popular printer technologies are Fused deposition modeling (FDM), Stereolithography (SLA) and Selective Laser Sintering (SLS) [23]. Figure 3 shows the principles of all three types of printers.

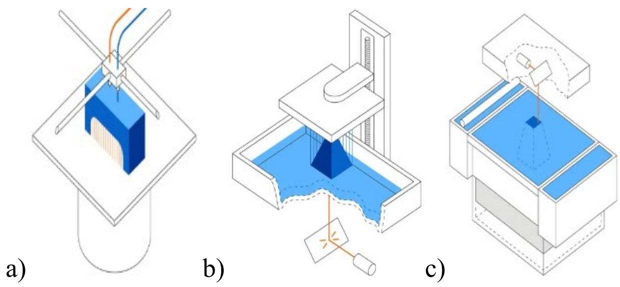


Fig. 3 *Different 3D printer technologies, a) Fused deposition modeling (FDM), b) Stereolithography (SLA), c) Selective Laser Sintering (SLS) [23]*

In principle, FDM differs the most from the other two technologies. FDM uses string-shaped filament as a material. If the material is made of plastic, the filament is drawn into the extruder, where it melts and is printed on the plate to be printed [24]. SLA uses a liquid resin, which where the resin hardens into a hard layer that represents the model layer [25]. SLS technology uses polymer powder as a material, which is incorporated and becomes a physical model layer by layer [26]. FDM is perhaps the simplest printing method, but SLS is the most favorable technology for final products. SLS technology enables the production of cheap and fully functional products. However, FDM and SLA technology are the easiest to use. SLA printing technology provides models with the highest resolution and surface finish.

The entire process of printing the model is shown in Figure 4. In order for the model to be printed and for the printer itself to work, it is necessary to generate G-code first. G code is a programming language that is used to write the printing rules, that is, it is written how the printer should work. The G code includes all the parameters on the base that the printer works on. G code is the only file understandable to the printer and written in a programming language that it can read. Then the code is transferred to the printer and the model is printed based on the code [27, 28].

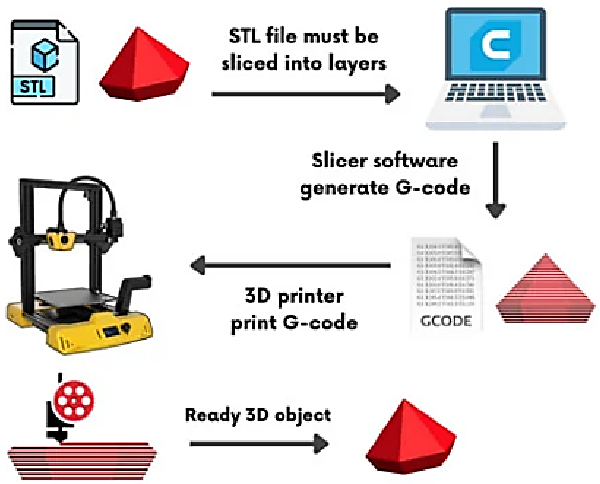


Fig. 4 *Model printing process [27]*

As 3D printers are mechatronic devices, they consist of different control units as well as electric motors that regulate the operation and printing process. They also consist of sensors that regulate the temperatures or the height of the plates on which the models are printed. As all three printing principles shown are different, they also have different components. The components for all three printer technologies are shown in Figure 5. Figure 5 illustrates the 3D printer components: a) Fused Deposition Modeling (FDM), b) Stereolithography (SLA), and c) Selective Laser Sintering (SLS).

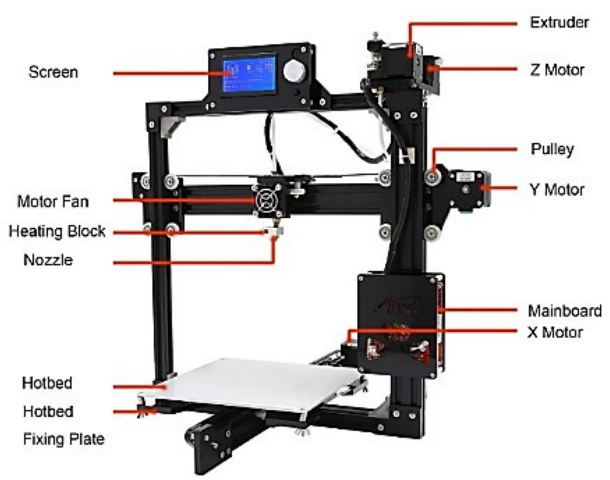


Fig. 5a *3D printer components: Fused deposition modeling (FDM) [29 – 31]*

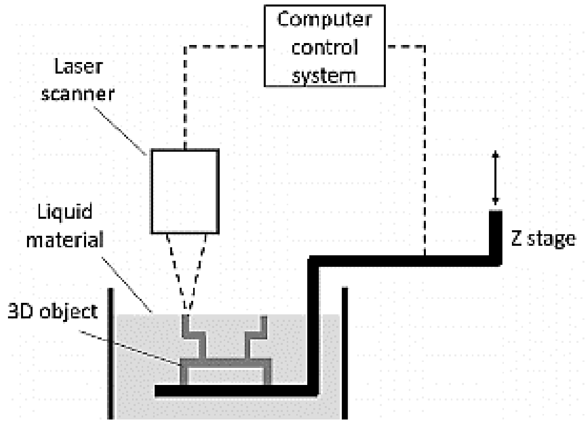


Fig. 5b *3D printer components: Stereolithography (SLA) [29 – 31]*

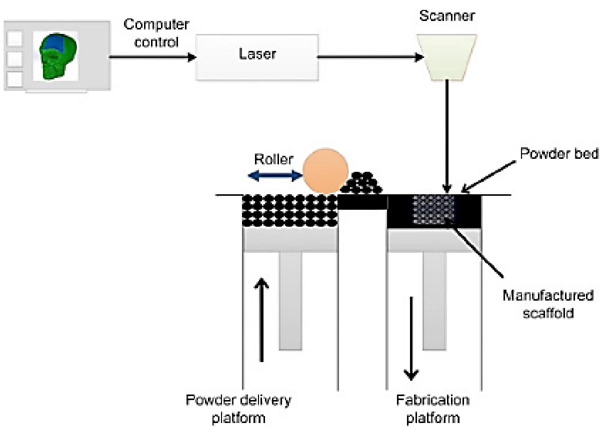


Fig. 5c *3D printer components: Selective Laser Sintering (SLS) [29 – 31]*

3.1 Application of supports when printing models

As emphasized, the printing of the model is done layer by layer. Quite often, the models are such that some parts of the model can slip during the printing of the model, that is, on the model itself, so it is not possible to print them beautifully [32], as shown in Figure 6. During printing, the extruder releases the filament, but due to gravity and slower drying, those parts are not printed correctly as shown on the figure.

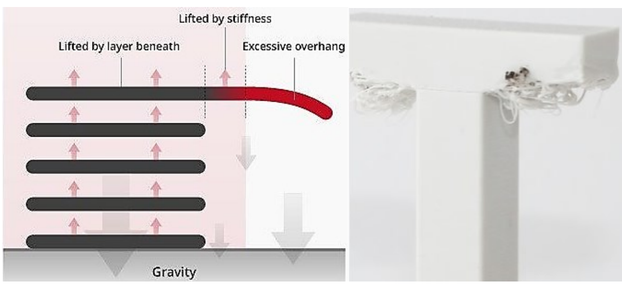


Fig. 6 *Printing models without supports [33,34]*

In order to prevent this from happening when adjusting the printing, it is possible to place supports, which would also be printed. However, when printing critical parts, it would happen that the layer that would fall due to gravity would rest on that support, as shown in Figure 7. As can be seen in the picture, in this case supports were placed and there is no irregularity of the printing file or the fall of the print layer. So this is an important and even mandatory element that needs to be added when making champagne. At the conclusion of the printing process, the supports are taken out and the model that was correctly printed remains.

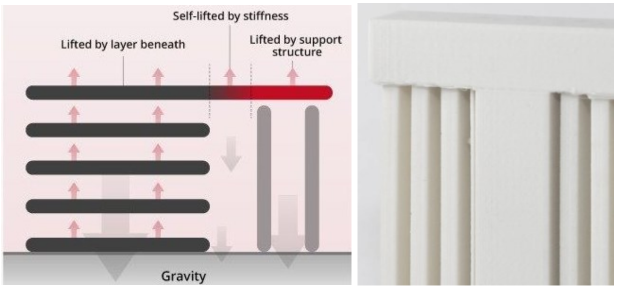


Fig. 7 *Printing models with supports [33,34]*

Figure 8 shows the rule related to the placement of the supports. Thus, it is necessary to place supports on the model if the angle of some part of the model is greater than 45 degrees in relation to the vertical plane of the model, then it is necessary to place supports on that part of the model in order to print the model correctly. This rule is known as the 45 degree rule [34, 35]. It is necessary to take into account the fact that some parts can be printed without supports, but this depends on the printing speed and the shape of the model itself. Of course, it is always necessary to take into account the very appearance of the model, but also the parameters of printing the model, such as printing speed and layer thickness, cooling of the material used for printing. Using supports is always recommended.

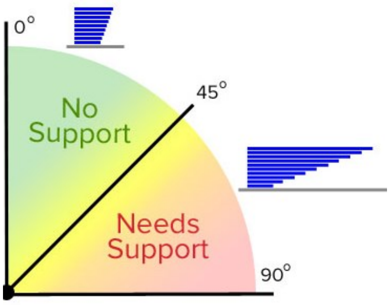


Fig. 8 *Placing supports according to the 45-degree rule [36]*

4. RESEARCH METHODOLOGY

In this paper, an analysis of the preparation of printing was performed on two different models of printers, which differ according to the printing method, that is, according to the printing methodology. In this case, the software used to generate the G code for stamping was used for comparative analysis. The software used in this case is shown in Figure 9. Figure 9a shows the interface of the Flash Print software, which is used, among other things, to write G code for the Flashforge Creator Pro printer. Figure 9b shows the Halot Box software used for writing the code for the Creality Halot Max 3D printer. As mentioned, these two softwares generate codes for two different types of printers. Flashforge Creator Pro is a printer that uses filament to print models. Creality Halot Max is a printer that employs resin as its printing material.

a)

b)

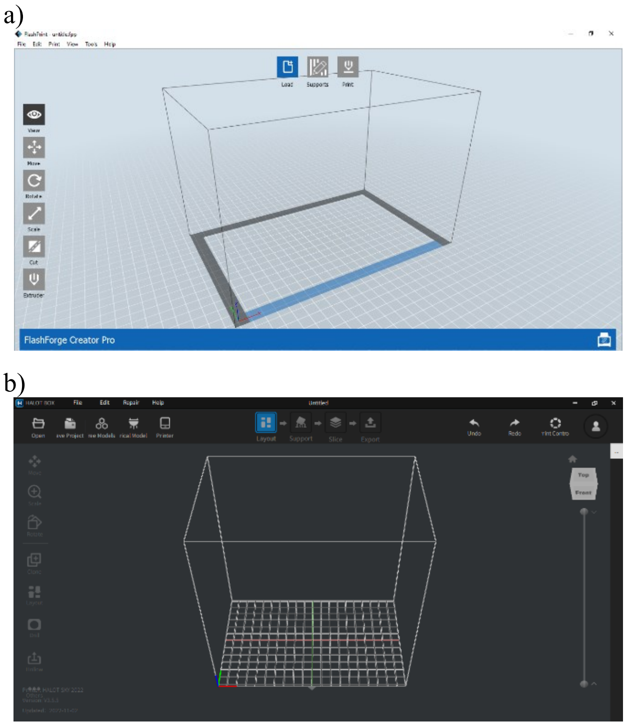


Fig. 9 *Applied software in research, a) Flash Print, b) Halot Box*

To perform a mutual analysis of the software used in the research, it is necessary to enter a specific 3D model into the software. The model depicted in Figure 10 was selected in this instance. The model has relatively small dimensions, formed so that it is possible to print the model quickly and easily.

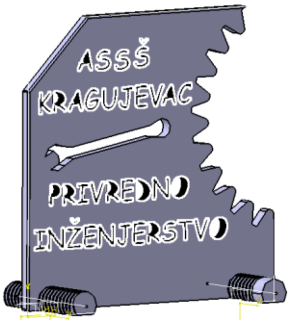


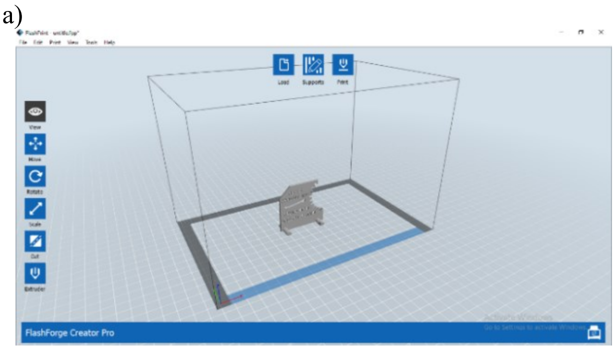
Fig. 10 *3D model that was applied for a comparative analysis of printer software*

By comparing the software, the difference can be seen primarily in the printing capabilities. Thus, this kind of analysis of two software programs for writing code for two different printing principles makes it possible to see the differences from this aspect as well. In this way, it is possible to select the optimal printer based on the code writing aspect and the possibilities offered by the printer.

5. RESEARCH RESULTS

Entering the 3D model is the first step when opening both software. The only way to input is either by dragging the model onto the surface or by using the options to open the model. In both cases it is possible to import models that are in multiple formats, this model was .stl. The display of the entered model is given in Figure 11. The size of the working surface is similar for both printer models. Certain changes can be made by entering the model in both software. Both software allow for positioning the model on the printing plate, rotating it, reducing or enlarging it, duplicating it, etc.

a)



b)

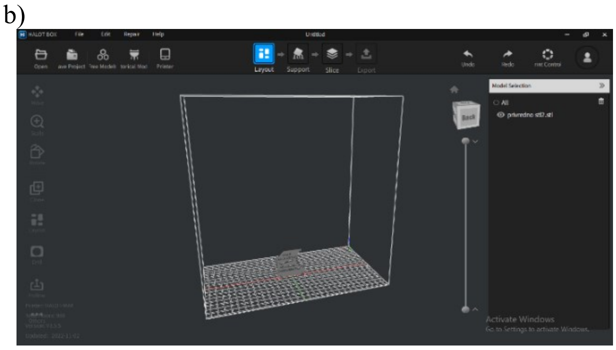


Fig. 11 *3D in software to write code to the printer, a) Flash Print, b) Halot Box*

The options offered by model processing software can be easily compared. However, some of the options are slightly different or more advanced. Thus, the Halot Box software offers an option that other software also offers, which is to cut the model, with this software offering the option of measuring the model and the exact measure at which the cut is made, as well as adding text on the model that can be printed, as shown on Figure 12.

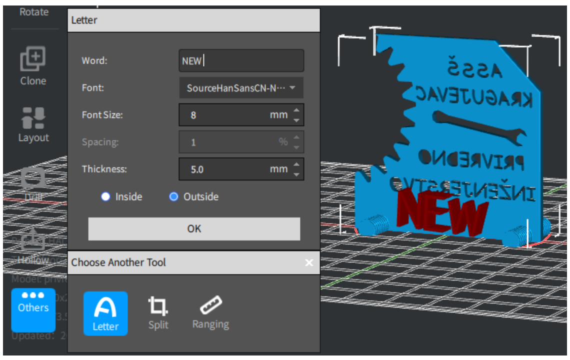
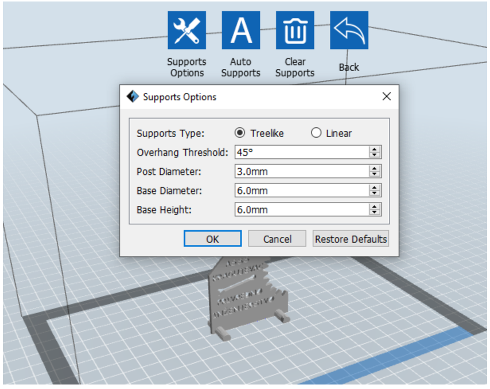


Fig. 12 *Option to add text on the model*

The placement of supports on the model is one of the most significant options offered by the software. All the model's elements can be printed correctly without any material falling off or warping due to their ability. Figure 13 shows an example of these options, i.e. the options they offer and are related to the way of placing supports on the model.

a)



b)

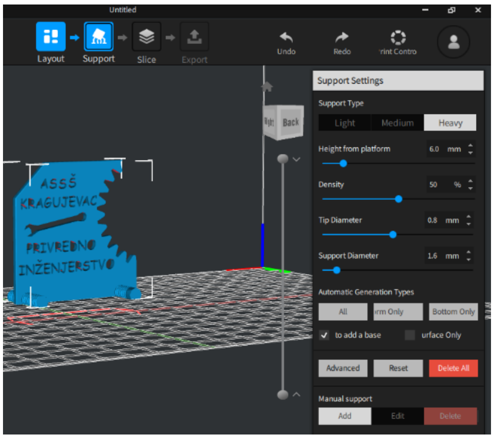


Fig. 13 *Setting up supports for the printer to help when printing the model, a) Flash Print, b) Halot Box*

Both softwares allow for self-calculation of critical parts of the model that cannot be printed properly, so it is necessary to place supports that would help during printing. Figure 14 displays the supports automatically placed by the software based on its own calculations. The figure includes two examples: a) Flash Print and b) Halot Box.Both software allow different settings. With the fact that in the case of Flash Print it is possible to adjust the supports in more detail and there are several different types. Both software also offer manual placement of supports.

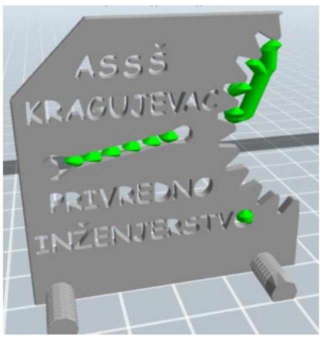


Fig. 14 a *Automatically placed supports: Flash Print,*

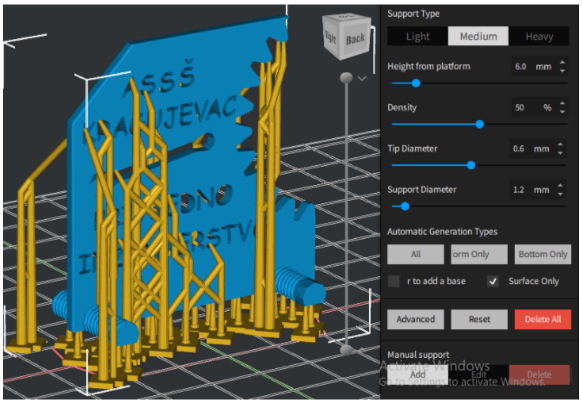


Fig. 14 b *Automatically placed supports, a) Flash Print, b) Halot Box*

The next important step before generating the G code for printing the model is to set the print parameters and set the operating parameters of the printer. A view of the window inside the printer and print setup software is shown in Figure 15, for both software. Relying on different printing technologies, there are significant differences here. Flash Print, which is a software used to write the code of a filament printer, allows a number of options related to printing, so there are different options such as the speed of printing or discharging the filament, the speed of the extruder, filling the model with filament, temperatures that depend on the material that is applied, ... Halot Box offers a smaller number of options, but it must be noted that some options are not applicable and have no significance for that printing technology. Print quality generally depends on the thickness of the layers being printed, the thinner the layer, the higher the quality, but the thinner the layer, the longer the printing time. The choice of layer thickness depends on the desired quality. Flash Print enables adjustment of the thickness of the print layer from 0.05 mm to 0.40 mm, while Halot Box offers the possibility of 0.005 mm to 0.20 mm. This difference is precisely due to the technology used to print the model.

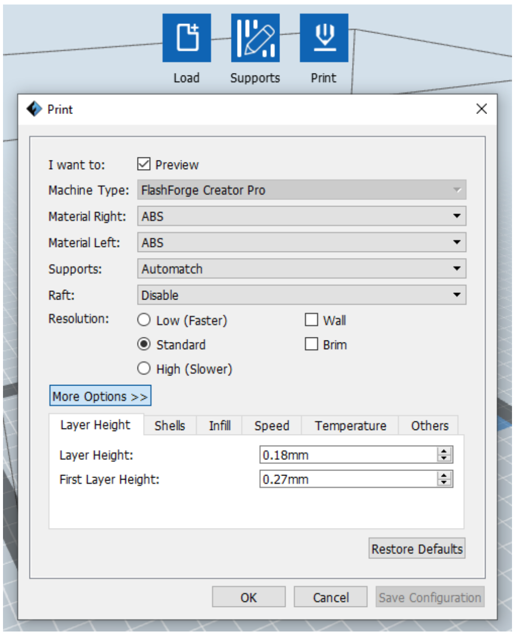


Fig. 15 a *Setting the model print parameters: Flash Print*

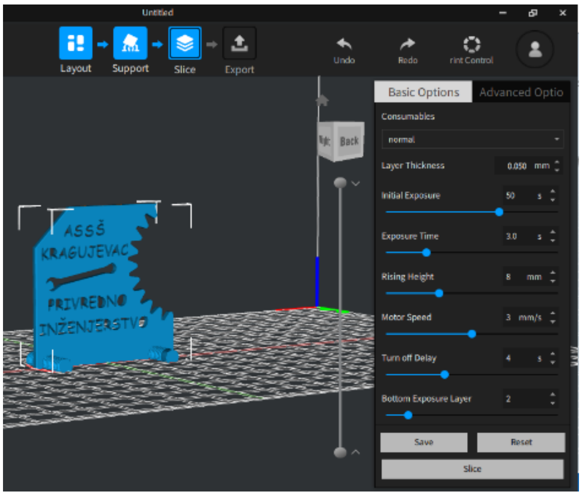
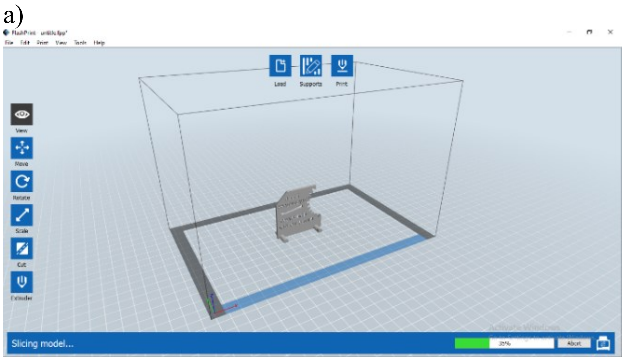


Fig. 15 b *Setting the model print parameters: Halot Box*

After setting the parameters of the printing and operation of the printer, the code that is readable by the printer and according to which it prints is generated. Figure 16 shows the process of code generation, calculation of printing time and necessary printing material.

a)



b)

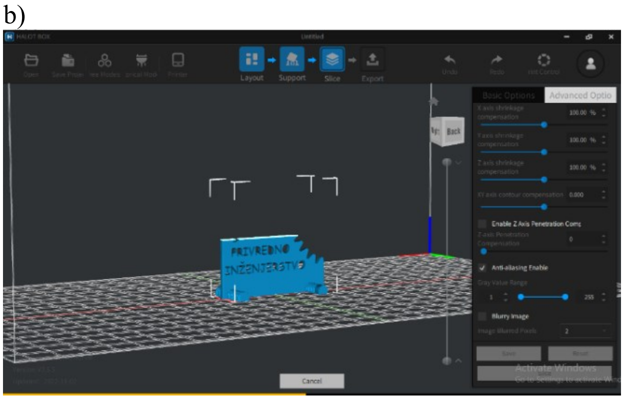


Fig. 16 *The process of generating code for printing, a) Flash Print, b) Halot Box*

Figure 17 shows the obtained values related to the printing process. It is noticeable that both softwares provide information about the printing time as well as the required printing material. Model mass data is also obtained or obtainable. Considering the printing technology, Flash Print shows the required length of filament to print the model while Halot Box shows the amount of resin.

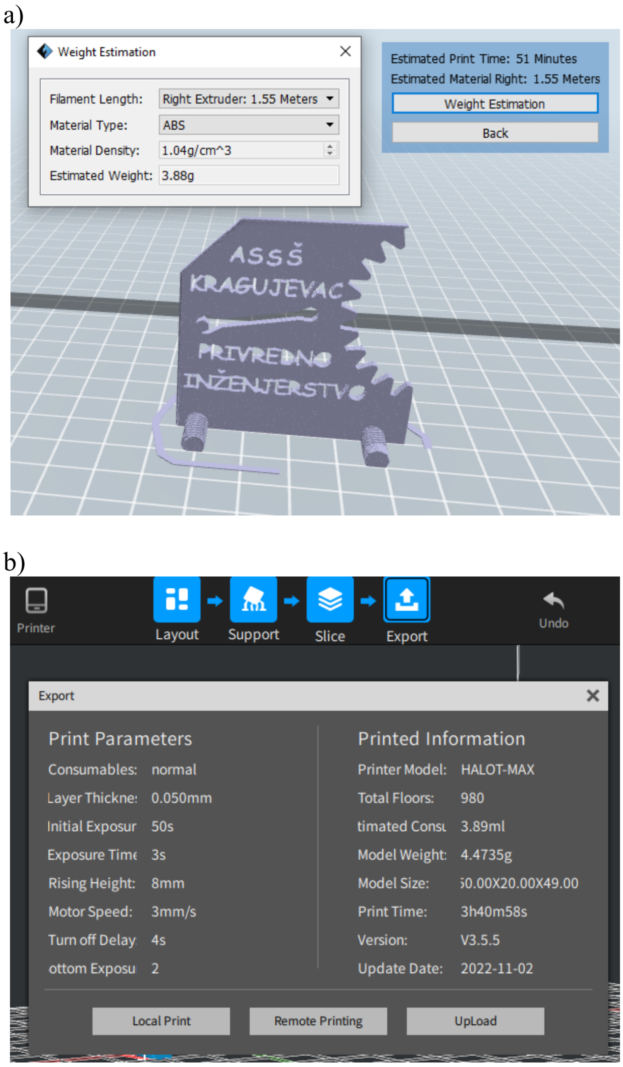


Fig. 17 *Information about generated code and model printing: a) Flash Print, b) Halot Box.*

Application of different printing parameters can lead to reduction of printing time, required amount of printing material. Also, changing the printing parameters leads to a decrease or increase in the quality of the model's printing. Generally, if the printing time is longer, the model is of better quality.

Figure 18a shows an example of a print group. In the event that using Flash Print, the layer thickness is set to 0.05 mm and the printing time is 2 hours and 59 minutes, while using the same parameters for a layer thickness of 0.40 mm, the printing length would be 24 minutes. By the same change of other parameters, e.g. occupancy of the printed model could decrease or increase the amount of material needed.

Figure 18b shows the results of the Halot Box software, where only the layer thickness parameter has also been changed, while the other parameters are the same. Thus, with a minimum thickness of 0.05, the required printing time would be 36 hours 28 minutes and 19 seconds, while with a thickness of 0.20 mm, the printing time would be 57 minutes and 1 second. In the case of default parameters and with a layer thickness of 0.20 mm, Flash Print showed that it could print the model in 46 minutes.

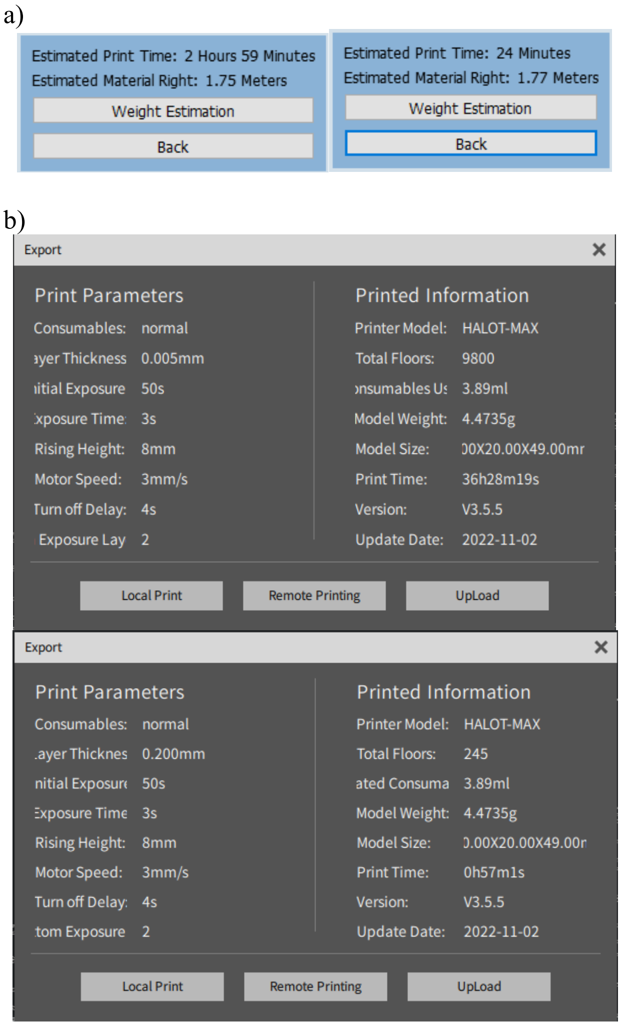


Fig. 18 *Time length of model printing i basic characteristics at different values of printing parameters, a) Flash Print, b) Halot Box*

6. CONCLUSIONS

Today, modern mechatronic systems are being greatly developed and improved with the aim of product development but also speeding up the production process. Two very important mechatronic systems are 3D printers and 3D scanners. These two systems in the process of production and product development have completely complementary functions. The process of speeding up production and product development can be achieved using 3D printers. They are widely used due to their flexibility and ease of creating physical product models from a virtual model. Today, they are used for different purposes, but at the same time, different technologies are applied, which differ according to their working principle. Sometimes, in order to print the model correctly, it is necessary to add supports to the model so that there are no irregularities during printing.

In this case, in addition to the analyzed models that are used today, the code generation software used to set the rules for the printer to print the model was analyzed. In this case, two software were analyzed that are used to generate code for two types of printers that differ according to the technology of stamping models. It can be concluded that the softwares have similar options that the user can use when it comes to arranging or modifying the model. The options related to the parameters of printing and operation of the printer differ according to the technology used. Therefore, the options related to setting the parameters of printing and the operation of the printer differ in accordance with the possibilities that the printer can perform in accordance with its working method. Also, both softwares have shown that they can provide the user with information about the required amount of material needed to print the model, the time needed to print the model, as well as basic information about the physically printed model (its mass). A comparative analysis of the displayed time of the printing length according to the calculation of the software and the printing of the model on the printer showed that the calculated and the real time are approximately the same, about which there will be more data in the following research.

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