APPLICATION OF ADDITIVE TECHNOLOGY FOR MANUFACTURING OF TUNE – O – MATIC BRIDGE ELECTRIC GUITAR SADDLE

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Abstract: Product development includes all activities from the initial idea for the product to the launch of the product on the market. Modern technologies have contributed to the fact that today the construction process is almost inconceivable without the use of a computer. Rapid Prototyping (RP) is a relatively new phenomenon in the industry whose task is to solve problems and limitations of prototyping methods. There are various methods of rapid prototyping, where the common feature is a short production time, the aim is to achieve an effect similar to those in mass production on extremely small series of products, even on personalized products. In order to make newly developed products to be competitive on the market, they must meet many requirements from the aspects of ergonomics, functionality, economy of production (saving materials and reducing production costs). Exploitation conditions can often cause defects in specific components of a particular product, leading to the failure of the production process. Since the goal is to establish the functionality of the system as soon as possible, it is often necessary to repair, repair or purchase a certain component or even the complete system. With the development of additive technologies, the process of rapid prototyping has been further improved through the possibility of using different materials, while the cost of production is very affordable. Once the prototype is perfected, making molds and tools for mass production is risk-free. For small series and personalized products, 3D printing can be a better and more cost-effective solution. The advantage of 3D printing is that at the same time, several products with completely different geometries can be made on one machine. Additive technologies are characterized by a large selection of materials from which parts can be made, such as: plastic, metal, ceramics, composite materials, etc. The combination of CAD software and additive technologies enabled a significant reduction in the total time of product development, especially in the prototyping phase. This paper presents the use of 3D printing, as an additive technology, for the production of the missing part in the saddle for tune-o-matic bridge electric guitar. The prototype of saddle for tune-o-matic bridge made of PLA (Polylactide) material, which is a healthy organic plastic, does not crumble, allows painting and finishing (sanding, milling, polishing, etc.) The accuracy of the element itself is very important, if it is not of adequate shape and dimensions, there is no possibility of precise tuning of the guitar. Due to the operation of the electric guitar, the saddle suffers a significant load from the string, where during the friction of the string and the saddle of the tune-o-matic bridge, a certain amount of heat occurs and, therefore, the deformation of the element occurs. Each saddle has a small groove to match the wire gauge and shape to prevent the tena from slipping off the saddle. Such parts could be used as final products instead as temporary parts or prototypes. In this case, 3D printing technology proved to be the most optimal choice for making the saddle tune - o - matic bridge.
Keywords: 3D printing, CAD model, Additive Manufacturing, Rapid Prototyping, Tune – o – matic bridge.

1. INTRODUCTION

Rapid Prototyping (RP) is a relatively new phenomenon in the industry whose task is to solve problems and limitations of prototyping methods. There are various methods of rapid prototyping, where the common feature is a short production time. The technology of rapid prototyping fundamentally changes the understanding of the product development process, enabling all participants of the development cycle to concretely exchange ideas and optimize the design and technology in time, before entering the expensive processes of tooling, by means of virtual product development. The advantages of virtual product development are to improve the quality itself, and also to increase the number of concepts and variant construction solutions. Three-dimensional (3D) printing, also known as additive

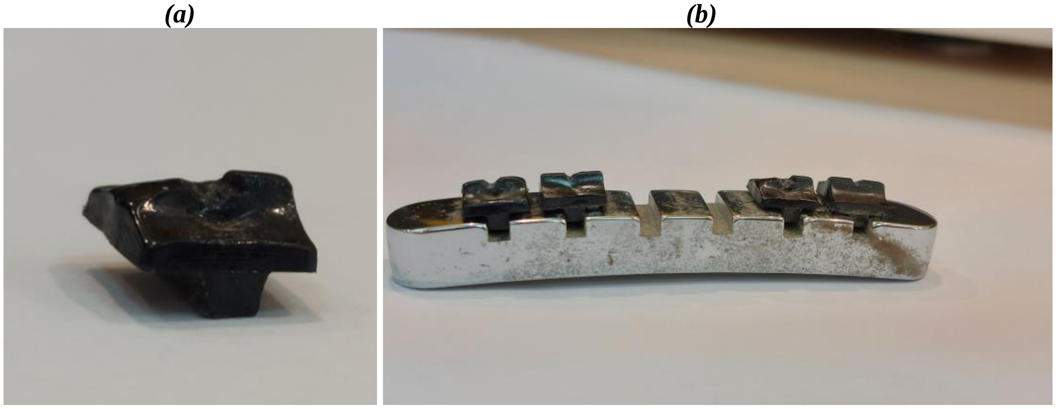
manufacturing or rapid prototyping. With the development of additive technologies, the process of rapid prototyping has been further improved through the possibility of using different materials, while the cost of production is very affordable.
Exploitation conditions can often cause defects in specific components of a particular product, leading to the failure of the production process. Since the goal is to establish the functionality of the system as soon as possible, it is often necessary to repair, repair or purchase a certain component or even the entire system. If it is about components of non-standard dimensions or those specifically designed for that system, the problem of re-modification or replacement often becomes time-consuming and often expensive.
This paper presents the use of 3D printing, as an additive technology, for the production of the missing element in the saddle of tune – o - matic bridge an electric guitar. The accuracy of the manufacturing of the element itself is very important, if it is not of adequate shape and dimensions, there is no possibility of precise tuning of the guitar. In order to make the prototype as accurately as possible, the geometric model was created in the SolidWorks software package, as 3D printing is the most commonly applied additive technology, in the continuation of the work, the process of making the missing element of the tune – o - matic bridge of the electric guitar on the 3D printer will be shown.

2. SADDLE 3D MODEL BUILDING

The tune – o - matic bridge consists of 6 saddles, where the saddle is usually made of bone, plastic, hardwood, metal and graphite, this paper presents a plastic element. Due to the operation of the electric guitar, the insert suffers a significant load from the string, where during the friction of the string and the keel itself, a certain amount of heat occurs and thus the deformation of the element occurs. Each saddle insert has a small groove to match the wire gauge and shape to prevent the tenon from slipping off the saddle insert. When fully assembled, each string rests against the insert and thus marks the end of the vibrating string length. Existing saddle was broken during use, and non-functional (Figure 1 (a)). Due to the temporary impossibility of the supplier to deliver the required element in the shortest possible time, it was decided to make the corresponding element of the tune – o – matic bridge saddle (Figure 1 (b)) according to the existing part.

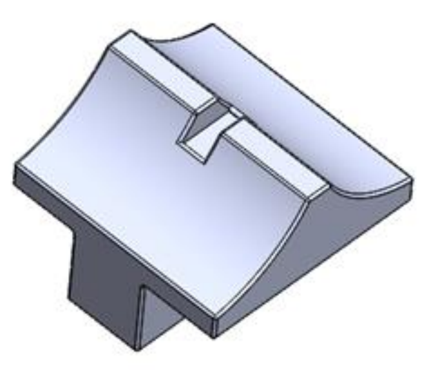
Figure 1. Original saddle (a), tune – o - matic bridge (b)

(a) *(b)*



For the development of a virtual 3D model of the product, it is necessary to obtain data about the product itself, in order to facilitate the process when creating the 3D model in the appropriate software package, the data was obtained by previous measurement and control of the element itself. For the purposes of creating 3D models, the software package SolidWorks was used. This software package enables the creation of the prototype itself without its creation or physical testing, it also enables us to change the dimensions itself, without creating a new model. When creating a 3D model, this software has tools to define the geometry, in addition it includes a parametric design environment for product development at the conceptual level (sketch) and kinematics of parts as well as assemblies. The program, in addition to creating prototypes, also provides the possibility of creating technical documentation. The basis for manufacturing products using rapid manufacturing technologies such as additive technologies is laid by obtaining a CAD model. Figure 2 shows a volumetric 3D model of the saddle.

Figure 2. 3D CAD model of the saddle for tune – o - matic bridge



3. 3D PRINTING OF THE MODEL

3D printing is a rapid prototyping process, where it enables the direct production of objects that are constructed in a digital environment. which is based on the formation of the final product using FDM (Fused Deposition Modeling) or FFF (Fused Filament Fabrication) technology. FDM is an additive manufacturing technology, often used for modeling and making prototypes, and it works on the principle of adding materials. The physical object, i.e., the final product, is created by adding a certain material layer by layer until the completion of the manufacturing process, where there is no need for specific tools. 3D printers offer great potential for the production of various applications, where an idea can easily become a product, the advantage being that at the same time, several products with completely different geometries can be made on one machine. As with other processing processes, the initial step in making a product is the choice of material, in this case PLA (Polylactide) material was used. PLA material has good characteristics, where it withstands temperatures up to 60℃ without deformation, where the melting point is from 120℃ to 170℃, tensile strength from 16 MPa to 117 MPa, density 1.24 g/cm³ [5]. It belongs to healthy organic plastic, does not crumble, allows painting and finishing (sanding, milling, polishing, etc.). This bioplastic is mainly produced from corn flour or sugar beet residues. PLA material allows to print a layer with a thickness of 0.05 mm.

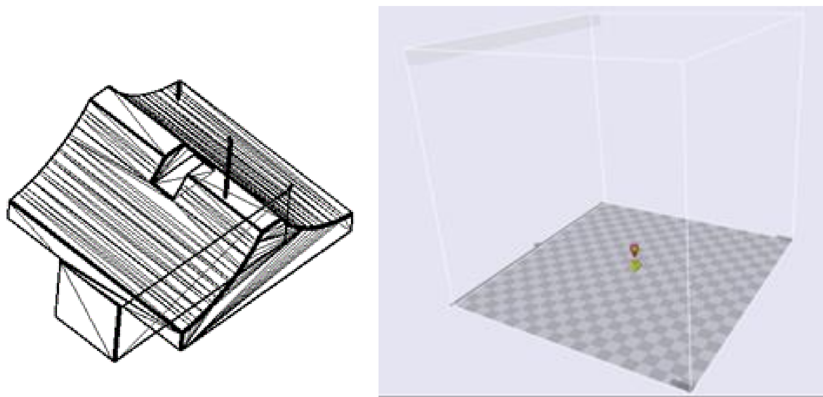
Each of the layers represents a cross-section of the final product in the corresponding plane. The main goal is to speed up production, reduce material waste, as well as increase the quality of the resulting surface, all of this depends on the printer itself and the settings during printing.

The source format obtained in the SolidWorks software package is .SLDPRT, in order to perform 3D printing it is necessary to convert it to .STL format (Figure 3 (a)), which approximates the surface of the model by connecting the three closest non-collinear points of the model into very small triangles. The number of triangles increases significantly if the model itself has curved surfaces in order to define and describe the model as precisely as possible. It happens that STL files are incorrect due to errors in modeling but also due to imperfection of the CAD-STL interface, so geometric errors such as gaps (cracks, openings) can occur i.e., missing polygons, overlapping polygons or degenerate polygons where polygon edges are collinear, as well as ambiguity in topology. These defects are usually removed manually and adjusted by the machine's RP software, which generates a series of cross-sections using a cutting algorithm.

Exported .STL files are imported into specialized software which, based on it, generates G code. G code represents a series of program lines that contain the necessary information about the position of the product, the method of production, etc., in order to make the product correctly.

Figure 3. STL model of saddle (a), Model in 3D Wox software environment (b)

(a) ***(b)***



Before the printer starts with the realization of the G code, it is necessary to calibrate the printer, in order to obtain the most accurate printed part. Calibration consists of a certain number of steps, which must be implemented. Before the key steps in the calibration, it is necessary to perform a construction check. This control involves a visual inspection of the device with an accent on the connections, as well as checking whether there is an empty space or a loose connection between the elements. A very important step during calibration is the leveling of the worktop, the vertical distance between the nozzle and the worktop must be the same in all places in order to print the first layer correctly, which is an important factor for successful 3D printing. After the realization of the previous steps, it is possible to perform the process of 3D printing of the model of the saddle for tune – o – matic bridge. When starting up the printer, it is necessary to set the parameters. However in order to set the parameters, it is necessary to have information about the dimensions of the CAD model. At the end of the manufacturing process, the extruder automatically returns to its initial position, and the manufactured part is manually removed from the substrate after some time, and then, if necessary, the supporting structures are manually removed.

Figure 4 (b) shows the specialized software 3D Wox, where a converted .STL file is imported, the model can be positioned in different positions, user can choose the position and then, based on that, G code is generated. During the generation of the G code, the software automatically slices model and added a supporting structure for a more rigid and accurate construction of the given part (Figure 4 (a)). This structure is only a support during construction, which has a low density of material, in order to be removed mechanically after completion. It is then sent to a 3D printer via a USB connection, in order to obtain a prototype of the saddle for tune – o – matic bridge.

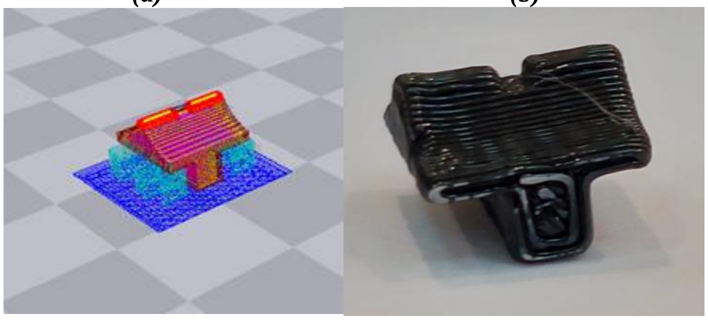
The 3D printer that was used to create the saddle for tune – o – matic bridge is Sindoh DP 200. The basic features of the 3D printer are:

- Printing material: ABS and PLA;
- Dimensions of the working space: 210 x 200 x 195mm;
- Layer thickness: 0.05 – 0.4 mm;
- Base material diameter: 1.75 mm;

3D printed saddle for tune – o – matic bridge is shown in Figure 4 (b), with producing time of approximately 6 minutes, and use of approximately 0.6 grams of PLA material.

Figure 4. Sliced model with support (a), 3D printed saddle of tune – o - matic bridge (b)

(a) *(b)*



Generally, bad characteristic of the 3D printing process is that due to material deposition, the object is deformed during production because the melted base material is extruded through the extruder and cooled during deposition on the substrate, where stresses occur that strain the model during rapid cooling. In order to avoid deformation of the model during printing, it is necessary to set all parameters correctly, where the accuracy of the measurement process of part is very important, Otherwise, if it is not of adequate shape and dimensions, and the groove at the saddle does not meet the exact dimensions, there is no possibility of precise tuning, and therefore significantly affects the sound produced by the electric guitar.

5. CONCLUSIONS

Three-dimensional (3D) printing has wide application prospects in the field of lightweight composite structures due to its superior manufacturing flexibility. Modern software packages provide opportunities to create a virtual product model, while additive technology ensures rapid prototyping. Also, more and more CAD software integrates options to connect to specific 3D printers, so that the user can more easily follow the flow of the creation process.

This paper presents how the saddle of an electric guitar is made using 3D printing technology. Due to the deformation of the mentioned element, the guitar itself cracked and stopped working, so it was decided to make the part on a 3D printer. The process of making the element to the final product took place relatively quickly, where at the beginning it was necessary to measure theexisting part, then create a 3D model using the SolidWorks software package. After that, preparation for 3D printing was carried out by converting the 3D model into STL format file, using the SolidWorks software package, and generating G code, using the 3DWox software, and make part on a 3D printer.

The advantage of making this product is the production time and material usage, where it took approximately 6 minutes with 0.6 grams. More advanced 3D printers,as well as printers that use another technology (SLA, SLS, etc) are able to produce complex parts of exceptional quality, capable of fully satisfying the requirements of the final product. Such parts could be used as final products instead of acting as temporary parts or prototypes. In this case, 3D printing technology proved to be the most optimal choice for making the saddle for tune – o - matic brige. The required manufacturing accuracy, surface quality and strength were within optimal limits.

REFERENCES

Danimir P. J., Robert W., Mirjana V. B., Tanja P., & Dominic E. (2010). Upotreba stereolitografskih podataka za generisanje trodimenzionalnih modela u metodi konačnih elemenata, Acta Stomatologica Naissi 2010.

Excell J. (2013), The rise of additive manufacturing, Book of the Engineer.

Ghadai, S., Jignasau, A., & Krishnamurthy, A. (2021). Direct 3D printing of multi-level voxel models. Additive Manufacturing ScienceDirect 2021.

Jović G., Pavlović, M., & Pešić, M. (2022). Primena 3D skenera prilikom određivanja odstupanja solid modela od odštampanog modela. Zbornik radova Akademije tehničko – vaspitačkih strukovnih studija – Niš 2022, 70 – 74.

Kozomora, M. (2021). Razvoj i konfigurisanje 3D štampača. Zbornik radova Fakultett tehničkih nauka Novi Sad 2018.

Pavlović, M., Jović, G., Ristić, M., & Tjupa, N. (2022). Izrada prototipa hladnjaka za raspberry pi primenom aditivnih tehnologija. Zbornik radova Akademije tehničko – vaspitačkih strukovnih studija – Niš 2022, 44 – 48.

Ristić, M., Pavlović, M., & Pejčić, A. (2016). Izrada plastične spojnice aditivnom tehnologijom. Zbornik radova Visoka tehnička škola strukovnih studija – Niš 2016.

Trajanović, M., Grujović, N., Milovanović, J., & Milivojević, V. (2008). Računarski podržane brze proizvodne tehnologije, Mašinski fakultet u Kragujevcu, Centar za informacione tehnologije.

Valerga, A.P., Batista, M., Salguero, J., & Girot, F. (2018). Influence of PLA Filament Conditions on Characteristics of FDM Parts, Special Issue "Special Issue of the Manufacturing Engineering Society (MES) , International Journals of Materials 2018.

Vučina, A., Obad, M., & Rašović, N. (2015)., Dizajn proizvoda predviđenih za proizvodnju aditivnim tehnologijama, Sveučilište u Mostaru, Mostar.

Yang, L., Hsu, K., Baughman, B., Godfrey, D., Medina, F., Menon, M., & Wiener, S. (2017), Additive Manufacturing of Metals: The Technology, Materials, Design and Production, Springer Series in Advanced Manufacturing, Cham, Switzerland.