



APPLICATION OF 3D PRINTED FIXTURES FOR WELDING

Received: 21 December 2018 / Accepted: 25 March 2019

Abstract: 3D printing is also known as additive manufacturing (AM). Additive Manufacturing is the manufacturing of products by the addition of layers of material. Additive Manufacturing, in comparison with conventional production processes where the material is taken from workpiece, enables the manufacturing of parts with a minimum quantity of material. 3D printing is often used for rapid prototyping. This paper presents the application of 3D printing for the manufacturing of fixture for welding, in case of welding two parts that form a spatial angle whose accuracy affects the quality of the product's work. The fixture is used for welding the disc support on the agricultural machine, stubble cultivator. This paper presents the procedure of 3D modeling of fixture, preparing for 3D printing and setting the printing parameters. The fixture is printed using the 3D printer Makerbot Replicator 2X from ABS plastic. ABS plastic was selected due to better mechanical properties at higher temperature in relation to PLA material.

Key words: 3D printing, fixtures, welding, ABS plastic.

Primena 3D štampe u izradi pribora za zavarivanje. 3D štampa je poznata kao tehnologija aditivne proizvodnje (AM), koja se zasniva na izradi proizvoda dodavanjem slojeva materijala. Aditivna proizvodnja, u poređenju sa konvencionalnim proizvodnim procesima kod kojih se vrši skidanje materijala sa pripremkama, omogućuje izradu delova sa minimalnom količinom materijala. 3D štampa se često koristi za brzu izradu prototipova. U ovom radu je prikazana primena 3D štampe u izradi pribora za zavarivanja delova koji zaklapaju prostorni ugao čija tačnost utiče na kvalitet rada proizvoda. Posmatrani pribor se koristi za zavarivanje nosača diska na poljoprivrednoj mašini - razrivač. U radu je prikazan postupak 3D modeliranja pribora, priprema za 3D štampu i podešavanje parametara štampanja. Pribor je štampan pomoću 3D štampača Makerbot Replicator 2X od ABS plastike. ABS plastika je odabrana zbog boljih mehaničkih karakteristika na povišenoj temperaturi u odnosu na PLA materijal.

Ključne reči: 3D štampa, pribor, zavarivanje, ABS plastika

1. INTRODUCTION

The process of rational production requires the connection of the process of designing products with the technological processes necessary for its production. In practice, a number of DfX methods are used that help the successful cooperation between constructors and technologists. In the literature there are two interpretations of the meaning of "X" within the term DfX. First, the design for "X", where "X" represents a variable that can relate to: M-manufacturing, A-assembling, C-cost, etc. Second, design for excellence where "X" represents the application of all "Design for" methods, in order to achieve "excellence" of the product [1].

Design for Manufacturing (DfM) represents the connection between design and technology, as a measure of the benefits of the product for manufacturing. During product design, if consideration is not given to the construction of a product from the aspect of the convenience of its manufacture and assembly, we can get a product that is difficult to manufacture, or too expensive. Production costs affect the price of the final product, and thus to the size of the profit, and on the sustainability of products on the market. For this reason, when designing a product, it is trying to create a product that fulfills the project tasks, while having low production costs. By applying the

DfM method, a reduction in product manufacturing costs is achieved, productivity increases are achieved by increasing the number of produced products in a unit of time.

At the design stage we strive to, designed parts are being manufactured on computer numerically controlled machines (CNC), which are easily accessible today and financially acceptable. By manufacturing parts on CNC machines the possibility of employee error is minimal. Parts made in this way are ready to be fitted into assemblies so that the worker's job in the production is assembling and/or welding. In this way, the manufacturing time of the product is significantly reduced.

Using fixtures for the positioning of parts in the assembly process, the possibility of error is further reduced as well as the time of assembling. Fixtures can be made using conventional or non-conventional methods, such as 3D printing. This paper presents the application of 3D printing for the production of fixture for the positioning of parts when welding the sub-assembly of the disc support of the agricultural machine stubble cultivator. In this example, the successful application of the DfM method is shown, where designers and technologists work on the development of product that meets the conditions defined by the project task, while being constructive and technologically feasible, as well as financially justified.

2. STATE OF THE ART

Additive Manufacturing (AM) is a technology that has been developing intensively for more than 30 years, and the basic principle of working is the addition of layers of materials in the manufacturing process. According to [2] the contribution of Additive Manufacturing has grown significantly over the past 30 years. At first, AM technology was used primarily for prototyping Rapid Prototyping/RP. With the development of technology, the scope of AM application development is being expanded at tool production, Rapid Tooling/RT. Today it is possible to manufacture products that are ready to be used, and that technology has name Rapid Manufacturing /RM [3].

3D printing is often used as the name for Additive Manufacturing and it is widely used in all areas of human activity such as industry, medicine, education, art, and others. Like any technology in development and 3D printing, it has disadvantages such as low precision, low speed of production and in some cases high price. Stereo-Lithography (SLA), Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM) and Laminated Object Manufacturing (LOM) are the most advanced technologies [4]. Among them, the most common is FDM, a technology used by the 3D printer Makerbot Replicator 2X of the American manufacturer Makerbot, which was used to manufacture the fixture analyzed in this paper. Fixtures made with 3D printing technology are easy to manufacture and use, the cost of manufacturing is not high, and the accuracy of the geometry of the parts is sufficient and they have a low mass. Changes to the fixtures are carried out by additional printing of new fixtures or if it is modular, printing only those modules that are being changed. A wide range of materials that are used today in Additive Manufacturing has led to it finding a place in almost all industries and areas of human society. Standard ISO 17296 provides basic terminology, materials, test methods and data format in the field of Additive Manufacturing.

The tools and fixtures made by FDM technology take a significant place in large systems. Paper [5] gives an overview of the most frequently applied materials in FDM technology and their applications with basic characteristics. Because of its good mechanical properties, acrylonitrile butadiene styrene (ABS) material is the most used in the field automotive, aerospace and medical-device. According to [6], tools and fixtures made by FDM technology make significant savings in money and time. In the case of BMW, manufacturing fixture from ABS plastic, a reduction in the weight of fixture by 1.3 kg was achieved, compared to the same fixture made by conventional methods. Mass reduction significantly affects the efficiency of the workers who use the fixtures many times in the shift. Significant savings in the manufacturing of fixture are also realized in the fact that it is not necessary to produce technical documentation, but the 3D model can be directly converted into a file suitable for making on a 3D printer [7] gives an overview of the results of the effect of setting the parameters of the 3D printing on the

mechanical characteristics of the part printed from ABS plastic, while [8] shows the influence of layering and wire laying on the mechanical characteristics of the ABS plastic specimen.

3. DESIGN AND PRINTING OF FIXTURE

3.1 Description of the problem of construction and technology of fixture manufacturing

Disc support with discs of the stubble cultivator, which is analyzed in this paper, is given in Figure 1. The role of discs is that the soil is smashed and prevents the outflow of the soil outside from the workplace.

Figure 2 shows a subassembly of the disk support which is obtained by welding certain parts. The subassembly consists of a vertical plate (1) for which the plates for disc hub (2) are welded. The main problem with welding plates for disc hub is their placement into the correct position at a certain spatial angle, which is difficult to achieve without use of fixture. If it is known that the position of the discs affects the quality of the operation of the machine, it was necessary to construct and manufacture the fixture for placement and welding, as shown below.

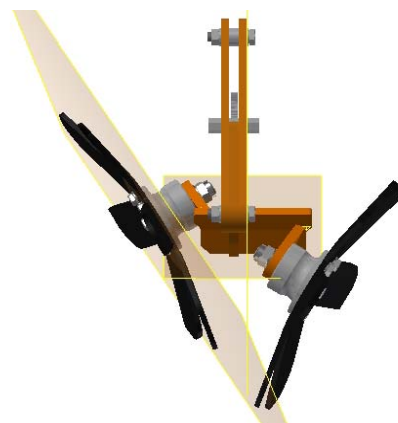


Fig. 1. Disc support with discs

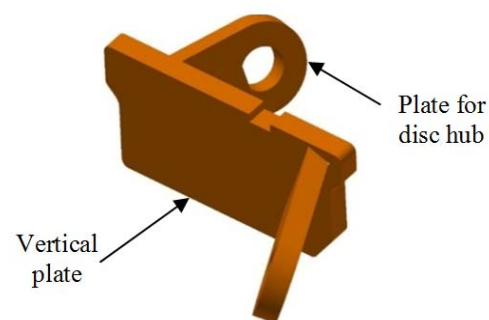


Fig. 2. Subassembly of disc support 1- (vertical plate), 2- (plate for disk hub)

3.2 3D modelling and setting of 3D printing of fixture

The basic construction condition is to satisfy the required angles of 20° that the plane of the disc builds with the horizontal and vertical plane, Figure 1. The components of the disc support are made of steel sheet. The shape of these parts is made so that it is suitable for assembling, and the requirements for quality and accuracy of parts manufacture are not large and it can be realized on a laser plasma or cutting machine. In this

way, the manufactured parts can be mounted without finishing, thus reducing the time and cost of production.

In order for the manufacture fixture by 3D printing, it is necessary to create its 3D model. The development of the 3D model of fixture starts with subtracting the subassembly of the disk support from the initial shape of the square and in this way remains a negative, Figure 3. After that, the excess material is removed and gets the final shape of the fixture. During 3D printing there is a slight shrinkage of the material, so it is necessary to increase the dimensions of the holes and grooves in order to get the desired dimensions after printing. The fixture consists of two parts that are assembled using a groove and provided with a shaft through the tool holes, Figure 4.

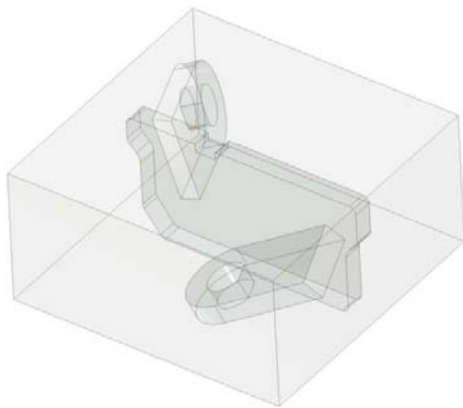


Fig. 3. Initial shape of fixture

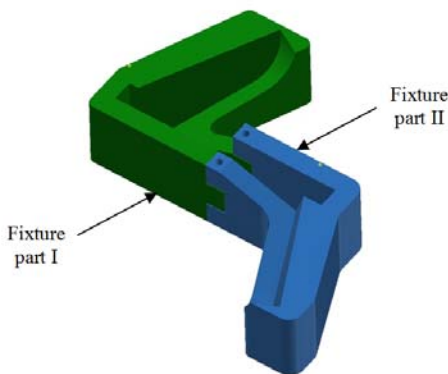


Fig. 4. Fixtures for welding of disc support

In order to obtain a quality product, it is necessary to make good preparation and adjustment of parameters of the 3D printing process. The originally 3D model is converted into STL (Stereo-lithographic) format in order to be suitable for further processing in the appropriate software. The model in the STL format consists of a mesh of triangular planes and represents an approximation of the 3D model. Correctly adjusted mesh density allow satisfactory print quality. The STL file that is being prepared for printing is imported into the Makerbot Desktop software. There are a number of settings that affect the result of the printed fixture, which are displayed on Figure 5. and 6.

First, the layer height is set, that is, how the model will be sliced in the Z axis. For the part that should be done precisely, the height of the layer is from 0.1 to 0.2 mm. In our case, high precision is not required, so the height of the layer is 0.4 mm. By reducing the height of

the layers it significantly affects the increase in the printing time and vice versa.

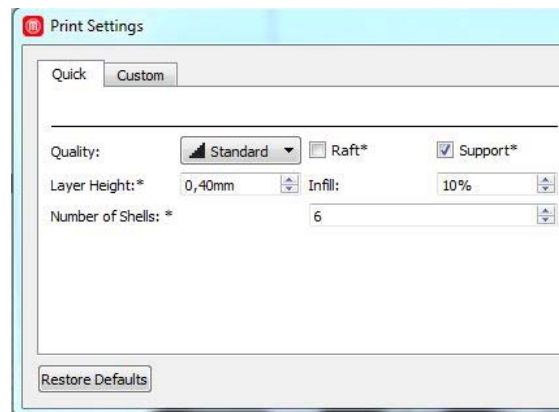


Fig. 5. Print settings part I

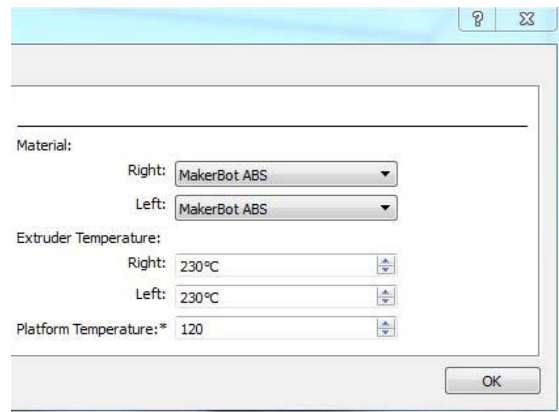


Fig. 6. Print settings part II

The next setting to be implemented is the infill. If the infill is 100%, the part will be made entirely of plastic. If the percentage of infill is lower, then the software will, depending on the settings, define the way to infill of part volume, e.g. hexagonal, linear, etc. In this case, a percentage of infill of 10% is sufficient and a hexagonal fill is selected, which significantly affects the reduction in the amount of material used and the time of the printing. In addition, the number of shells must be set. The most common in use are 2, 3 or 4 number of shells. In this case 6 shells are adopted in order to improve the rigidity and durability of the fixture. By increasing the number of shells, a larger thickness of the outer shell of the fixture is obtained, and in this way the surfaces in contact with the parts are more durable and the fixture is able to withstand a higher number of use cycles.

By adjusting the parameters of the 3D printing in this way the fast manufacturing fixture is obtained. Amount of used material is minimal, and the surfaces in contact with the parts are robust and durable. The hexagonal infill allows a significant reduction in the weight of the fixtures, while providing sufficient rigidity and dimensional stability of the fixture. A cross section of the fixture is given in Figure 7. The fixture analyzed in this paper is printed from ABS plastic because it has better mechanical properties, especially at higher temperature, compared to PLA plastic. Figure 8 shows the fixture and parts of the disc support in the welding position.

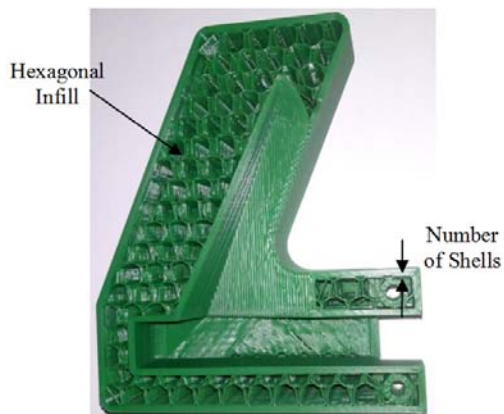


Fig. 7. Cross section of fuxture

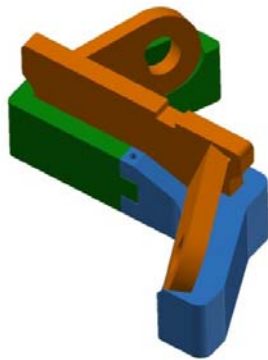


Fig. 8. Fixture and parts before welding

4. RESULTS

The result of the work is simultaneously designed and printed fixture (Figure 9) which can be immediately exploited. Changes that may be necessary may be done by changing the 3D model and then printing a new fixture or part of it. Technical documentation is not necessary, which affects the reduction of the cost of manufacturing the fixture. The material for manufacturing is very cheap today, and the entire fixture has a weight of only 300 g, which significantly reduces the costs in individual and small-sized production. The only drawback of this method of production is the printing time that is about 9 hours for these two-component fixture.



Fig. 9. Printed fuxture

5. CONCLUSION

Today, tools and fixtures can be made with different manufacturing methods, among which AM technologies are increasingly in use. This way of manufacturing opens the possibility of creating new shapes and

purposes of tools and fixtures that were not possible or difficult to produce by conventional manufacturing processes, and in addition they have high production costs. Further research directions may be aimed at analyzing other structural and techno-economic characteristics of fixtures, such as the accuracy of assembling assemblies, determining the durability of fixtures, etc.

6. REFERENCES

- [1] Tarr, M., The DFX concept, URL: http://www.ami.ac.uk/courses/topics/0248_dfx/index.html.
- [2] Eyers D., Potter A.: Industrial Additive Manufacturing: A manufacturing systems perspective, *Computers in Industry*, 92-93, pp. 208-218, 2017.
- [3] Levy G., Schindel R., Kruth P.: Rapid Manufacturing and Rapid Tooling with Layer Manufacturing (LM) Technologies, State of the Art and Future Perspectives, *CIRP Annals Manufacturing Technology*, 52, pp 483-695, 2003.
- [4] Mitrovic R., Miskovic Z.: Investigation on Influence of 3D Printing Direction on Mechanical Properties of ABS Plastic Prototypes, *COMETA 3rd International Scientific Conference: Conference on Mechanical Engineering Technologies and Applications*, pp. 293-300, Jahorina, B&H, Faculty of Mechanical Engineering in East Sarajevo, Jahorina, Dec. 7 – 9. 2016.
- [5] Jian-Yuan L., Jia A., and Chee Kai C.: Fundamentals and applications of 3D printing for novel materials, *Applied Materials Today*, 7, pp. 121-132, 2017.
- [6] Stratasys, Direct Digital Manufacturing at BMW, Manufacturing Jigs and Fixtures with FDM, http://www.stratasys.com/~media/CaseStudies/Automotive/CS_FDM_AU_BMW_EN_0916.pdf?la=en, (accessed on March 2018)
- [7] Cantrell J., Rohde S., Damiani D.: Experimental characterization of the mechanical properties of 3D-printed ABS and polycarbonate parts, *Rapid Prototyping Journal*, 23, pp. 811-824, 2017.
- [8] Cole D., Riddick J., Jaim I. Strawhecker K., Zander E.: Interfacial mechanical behavior of 3D printed ABS, *Applied Polymer Science*, 133, 2016.

ACKNOWLEDGMENTS

This paper is a result of the TR35036 project. The project is titled “Application of information technologies in the ports of Serbia - from the monitoring of machines to the networked system with the EU environment”.

Authors: M.Sc. Ivan Knezevic, Assoc. Prof. Savo Bojic, Assoc. Prof. Dejan Lukic, Assist. Prof. Milan Rackov, Assist. Prof. Maja Cavic, M.Sc. Marko Pencic, M.Sc. Sabolc Cako, University of Novi Sad, Faculty of Technical Sciences, Trg Dositeja Obradovica 6, 21000 Novi Sad, Serbia.

E-mail: ivanknezevic@uns.ac.rs; bojicsavo@uns.ac.rs; lukicd@uns.ac.rs; racmil@uns.ac.rs; scomaja@uns.ac.rs; mpencic@uns.ac.rs; szabolcsako@uns.ac.rs