PROTOTYPE FOR FIT INVESTIGATIONS

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Abstract: Nowadays, additive manufacturing is a powerful tool and promising technology both for manufacturing and educational purposes. This work aims to present a case study of using 3 dimensional (3D) printing technology for fit investigations. It describes the creation of a physical model (prototype) by using the Fused Deposition Modeling (FDM) method. The prototype of two plates was made to perform an inspection how the prototype fits with other components.

Keywords: *additive manufacturing, Fused Deposition Modeling, fit investigations, rapid prototyping*

1. INTRODUCTION

Additive manufacturing (AM) is defined as the process of joining material to make parts from 3D model data. The real part is built layer by layer. This process is the opposite of the substractive manufacturing and formative manufacturing methodologies. The 3D-Printing technology is the "fabrication of objects through material deposition using a print head, nozzle, or another printer technology" [1]. The history of AM [2], [3] begins at 1980 when Hideo Kodama made the first 3D printing patent application. He invented a prototyping system based on the hardening of photopolymer material with ultraviolet (UV) light. Three years later, an American engineer Charles Hull, co-founder of the 3D Systems company, invented the first commercial rapid prototyping technology based on the stereolithography (SLA). This machine uses the .stl file format as basic data source for the printing process. The patent dates of 1986. Carl Deckard, in 1987, invented another printing process that uses the laser as the power source for sintering the material powder, known as the selective laser sintering (SLS) process. In 1988, 3D Systems put on the market the first 3D printer for rapid prototyping called SLA-1. In 1989, the "Fused Deposition Modeling" (FDM) process was presented, discovered by Scott and Lisa Crump. In this process, a spool of thermoplastic rope, called filament is pressed in a heated printer head. The movement of this head is controlled by a computer to create the desired geometry of an object layer by layer. In the same year, two well known companies were founded: Stratasys Inc. by Crump in the USA, and "Electro-Optical System" (EOS) GmbH, by Hans Langer in Germany. The process known as "Laser Additive Manufacturing"

(LAM) was developed in 1997 by the Aero Met company, which is a part of MTS Systems Corp. The LAM process uses a high-powered laser for fusing powdered titanium. In 1999, the Institution of Wake Forest for Regenerative Medicine, realized successfully the first 3D printed organ transplantation in a patient body. In 2005, Dr. Adrian Bowyer started an open design project called "RepRap" an abbreviation for Replicating Rapid prototype. RepRap project aimed to develop a 3D printer that can produce most of its own components. Based on this concept, the "Darwin" 3D printer became available in 2008 at a commercial level. The price of an FDM 3D printer fell below 1,000$ since the patent expiration in 2009. In the same year, 3D printers using materials like "Poly-lactic Acid" (PLA) and "Acrylonitrile Butadiene Styrene" (ABS) were available for consumers, as well as an online library of model files that can be used by 3D printers. In 2011, a complete aircraft and a car body prototype were built using 3D-printing technology.

The "Digital Light Processing" (DLP) printing process was presented in 2012. This process uses a projector for curing a photopolymer resin. In 2015, a 3D bio-printer technology was introduced to the market using a specific type of bio-ink. *Figure 1* illustrates the general classification of AM processes based on the state of the raw material used in this technology. Nowadays there are more than 170 3D-printer manufacturers, including a wide range of applications of this technology in a large variety of sectors like the medical field, engineering industrial application, or educational purposes [4], [5]. In this paper, a detailed case study using FDM printing technology is presented. A 3D-CAD model will be printed, in order to check how the part will fit together with other parts before the manufacturing of the real part in metal.
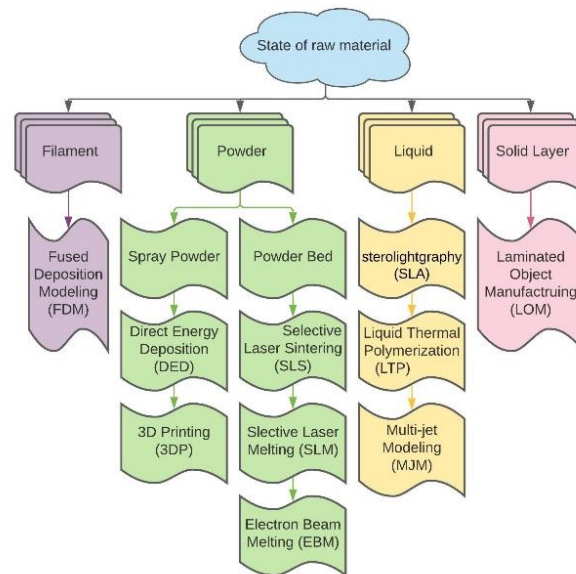

Figure 1
Classifications of AM processes based on the state of used raw materials [6]

2. PROCEDURE

Many road accidents occur due to wheel bolt loosening [7]. *Figure 2* shows a 3D CAD model of a test rig for experimental research on bolted link self-loosening due to vibration.
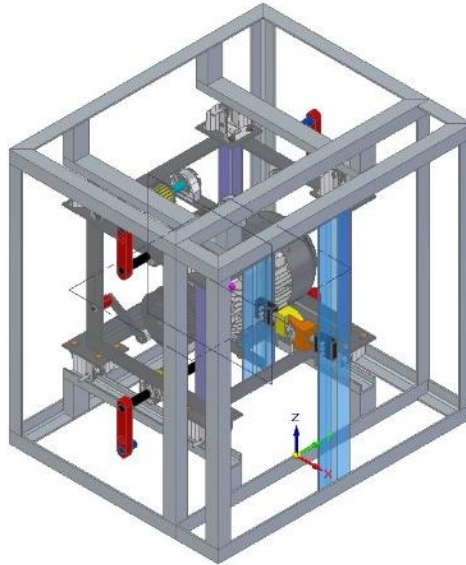

Figure 2. *Bolted link test rig*

The object of the measurement is a bolted link that compresses two stainless-steel plates together, as shown in *Figure 3*. In the experimental study, different measuring sensors will be mounted on the two plates for data collection. It comes in handy to use 3D-printing technology to facilitate the investigation of the prototype and to study fitting of the parts at low-cost. The flowchart in *Figure 4* outlines the main process steps.
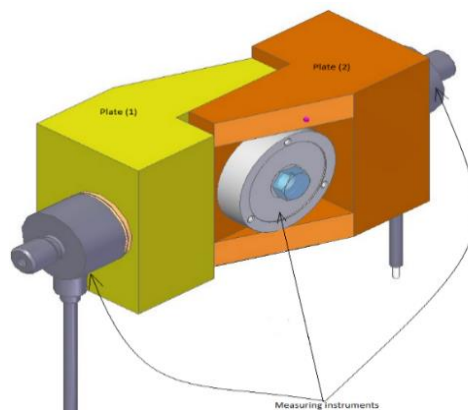

Figure 3. *Bolted link*

A 3D-printer available at our department is used for printing the two plates. The printer is a Zortrax M200 3D-printer using ABS material. The standard printing parameters of the machine were applied: the ABS material was extruded at 250 °C at a speed of 50 mm/sec with a heated bed surface of 60 °C. The following sections will present further details related to the printing process.
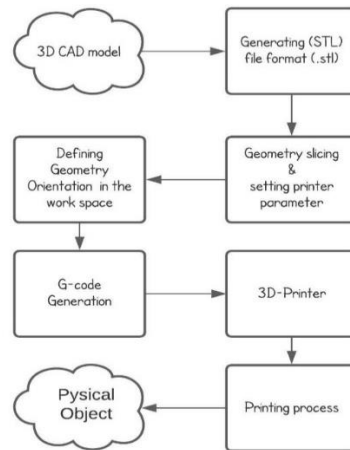

Figure 4. *3D-Printing steps*

2.1. Prototype for fit investigations

3D printing or other rapid prototyping processes have been used for a long time to produce object prototypes. Although CAD models are excellent in geometry representation, it is not always clear how efficiently a model fits and satisfies the prescribed functions until you have a real part based upon a CAD model.

The investigated 3D model consists of two plates. One of these plates shown in *Figure 5*. The geometry was built in a commercial CAD environment. The software exported the model in the required .stl format, and another program performed the slicing of the geometry for the printing process.
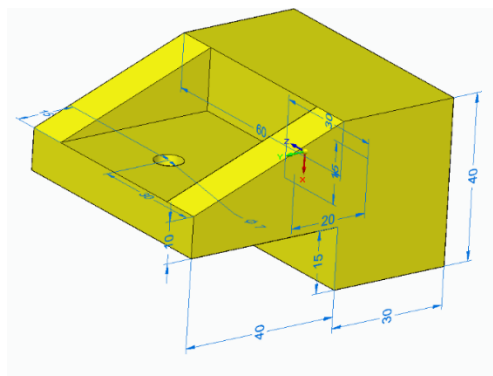

Figure 5. *3D-CAD model of the plate*

2.2. STL file conversion

The data describing a 3D-CAD model is packed in a file that contains the desired geometry surface information. To perform the printing process by the 3D printer, a specific file format is needed. This file type is known as "Surface Tessellation Language" or "Standard Triangular Language" or simply STL file. 3D Systems company introduced this file format in 1987. Our CAD environment, the Solid Edge software generates the STL file format using a built-in function, after setting the parameters as shown in *Figure 6*. An STL file consists essentially of a long list of triangles that together cover the surface of the object as shown in *Figure 7*. It is relatively simple to generate an STL file format for both ASCII and binary file versions [8].
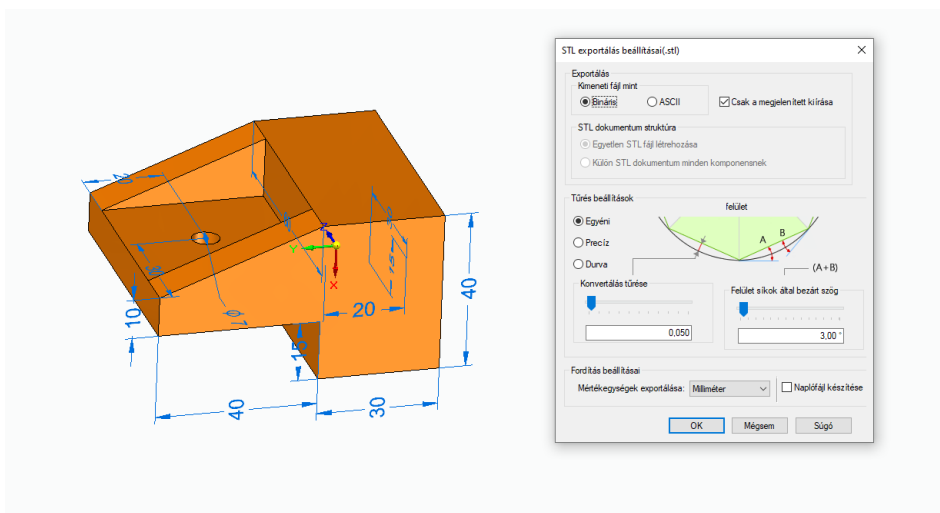

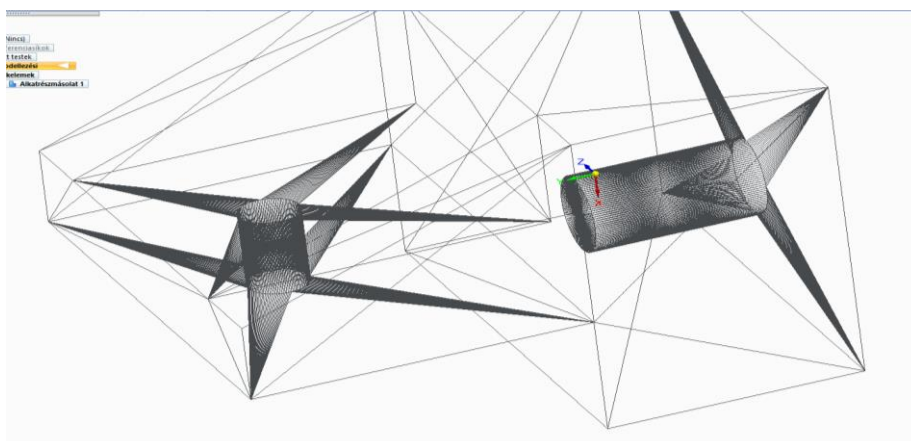***Figure 6.*** *Parameters for generating .stl file format*

Figure 7. *Model representation using (.stl) file format*

2.3. Orientation

In this step, the main task is to figure out the best orientation of the model on the 3D printer platform during the printing process. We have to select which face of the geometry is the base, giving the orientation of the layers. It is good practice to choose such geometry orientation that minimizes the need for support material. If there are hollow features in the shape, then there are two options. Either the hollow features are laid down perpendicularly to the base surface, or the 3D printer will print them in any position by bridging across geometrical gaps. In our prototype case, the hollow cylinder feature is an example of that, where the 3D-printer bridged the cylindrical gaps. *Figure 8* shows the selected orientation for the plates during the printing process.
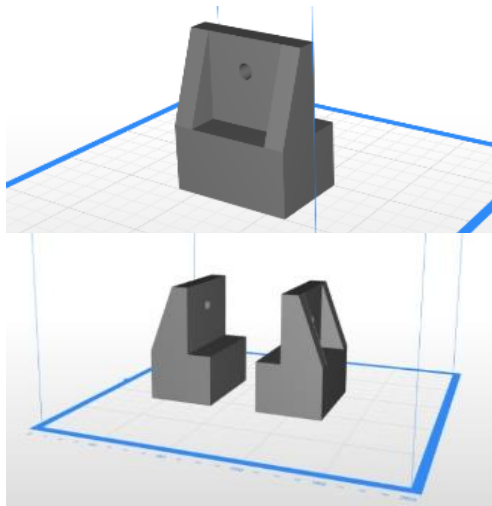

Figure 8. *Model orientation on the platform*

A 3D-printer can not use a direct 3D-CAD model file format. A conversion into another file format is needed that the 3D printer can understand. 3D printers build the part layer by layer, thus, the division of the model into printable layers is required. The first conversion results a 3D model in an easy to handle .stl format. Then, the separation into layers named slicing is realized, based on the selected geometry dimensions and the capability of the 3D printer itself [8].

2.4. Printing parameter setup

The parameters governing the printing process were as follows. The 3D-printer was a Zortrax type M200, the printing material an ABS filament material, and the standard default parameters of the 3D printer were used, with automatic support creation. The ABS material was extruded at 250 ℃ with honeycomb pattern, with 20% filling option at a speed of 50 mm/sec and with heated bed surface at 60 ℃. *Table 1* summarizes the 3D printer parameter settings, and *Figure 9* shows the set of printing parameters.
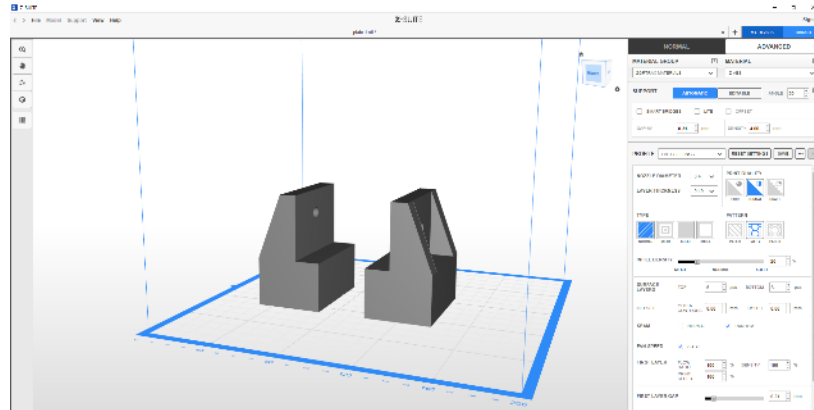
Figure 9. *3D-Printer parameter set up*

Table 1
Printing parameters

	Parameter	Setting
1	Nozzle diameter	0.4 mm
2	Layer thickness	0.19 mm
3	Infill pattern	honeycomb
4	Infill density	20%
5	Speed	50 mm/sec
6	Platform surface temperature	60 ℃

After setting the 3D-printer parameters, there is an option for visualizing the printing process versus time as a print preview. Using that, the time estimation at a different level of process completions can be determined with a 3D preview based on the defined parameters, as shown in *Figures 10–13*.
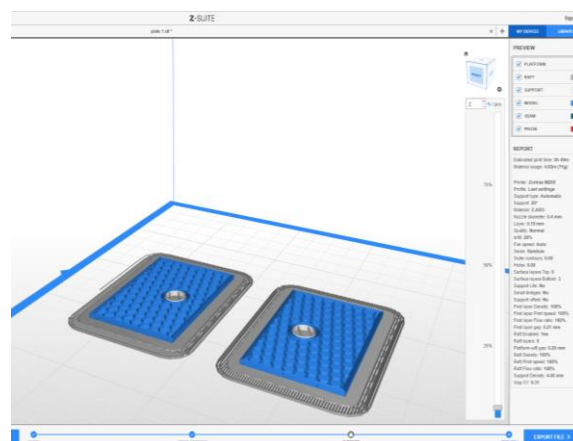

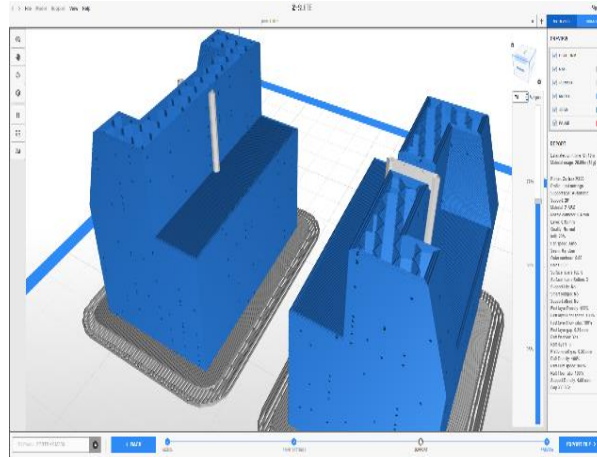***Figure 10.*** *Printing process preview at 2% readiness*

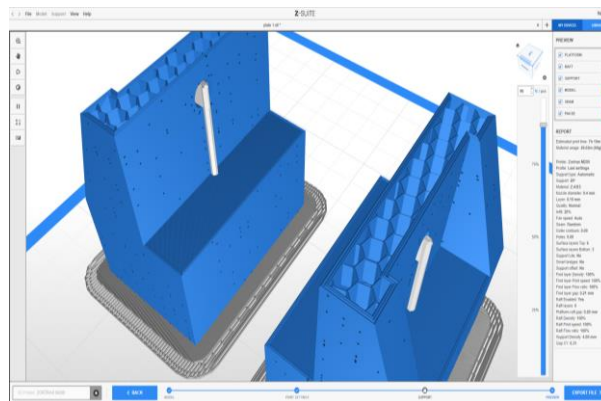**Figure 11.** *Printing process preview at 70% readiness*

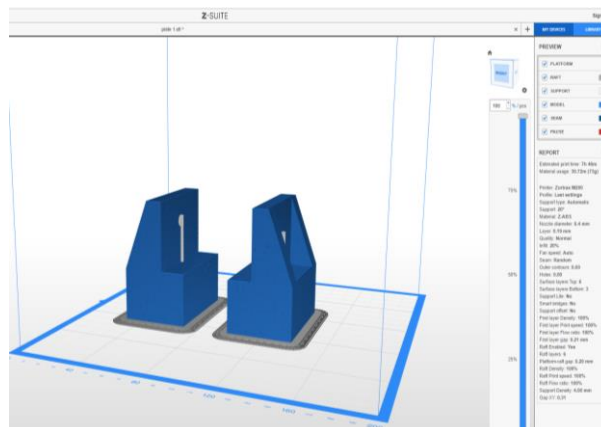**Figure 12.** *Printing process preview at 90% readiness*

Figure 13. *Printing process preview at 100% readiness*

2.5. G-code to the printer

The G-code is a simple programming language used to control the printing process and describe the nozzle path in the 3D printer. The code for the printing of the part is created automatically after the generation of the slices. In our case, the generated code is uploaded to the 3D printer using an SD card interface. The printer microcontroller follows the G-code during the printing execution process. Typical G-code functions include commanding an extruder to heat to a specific temperature, instructing the printer to pause until the extruder reaches the desired temperature, moving the extruder to given (x, y, z) position, and carrying out other related tasks.

3. CONCLUSION

Before manufacturing a new part, it is often required to check the geometric fitness of a designed geometry. To reach this goal, 3D printing technology was selected due to the advantages of the technology: speed, low cost, and flexibility.

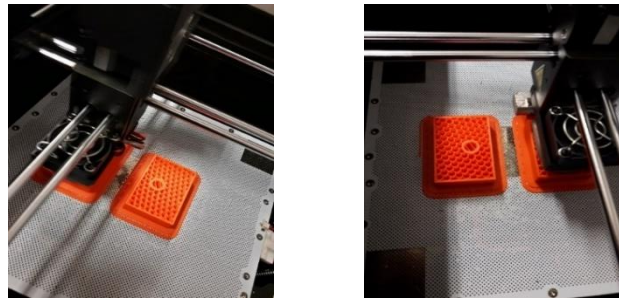*Figures 14–15* show the printing process at different time steps.
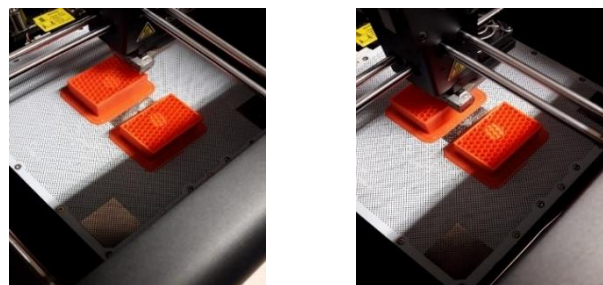

Figure 14. *Printing progress*

Figure 15. *Printing progress*

A Zortrax M200 3D printer was used for printing the 3D model of our part, using ABS material. We followed the steps of the manufacturing procedure from CAD model to the ready pieces with the previously defined parameters. *Figure 16* shows the final printed model. The time needed for printing both plates was 7 hours and 46

minutes, while using 37 g of ABS material. In this approach, the model's physical properties were not a point of interest. _Figure 17_ shows the final assembly of the geometry after the 3D-printing process. The manufactured geometry shows good agreement with the expected target, and no modifications are needed to enhance the structure compatibility with other parts.
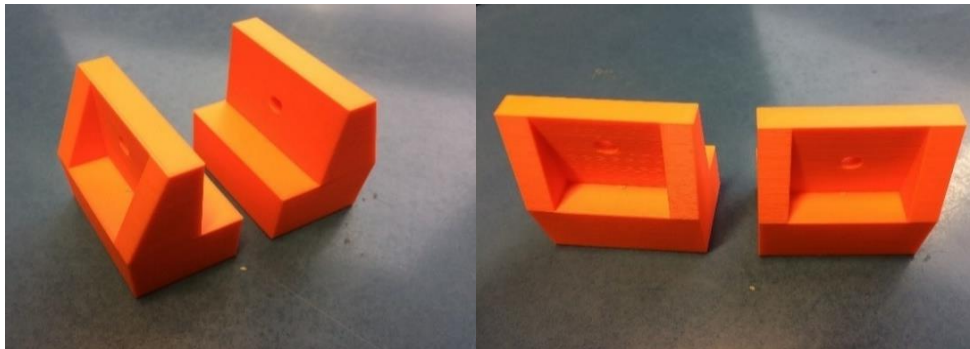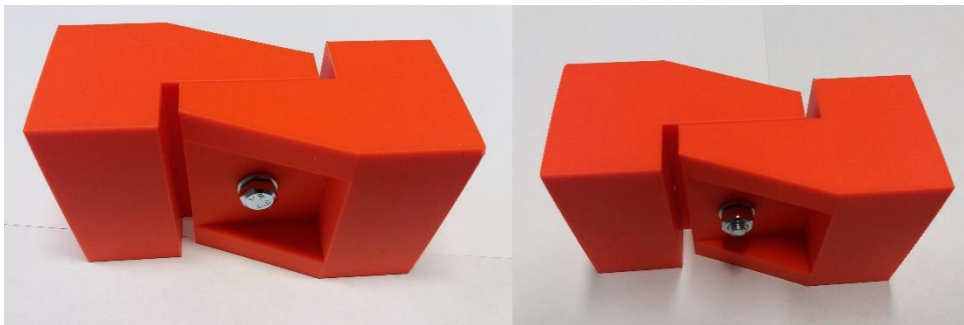

Figure 16. _The printed model_

Figure 17. _Assembled joint_

REFERENCES

[1]   ISO-ASTM: _ISO-ASTM 52900:2015(en), Additive manufacturing – General principles – Terminology._ 2015, https://www.iso.org/obp/ui/#iso:std:iso-astm : 52900:ed-1:v1:en (accessed Dec. 12, 2020).

[2]   González, C. M.: _Infographics: The History of 3D Printing, ASME._ 2020, https://www.asme.org/topics-resources/content/infographic-the-history-of-3d-printing (accessed Dec. 24, 2020).

[3]   Wohlers, T. – Gornet, T.: _History of additive manufacturing_. Wohlers Report, 2014.

[4]   Ford, S. – Minshall, T.: Invited review article: Where and how 3D printing is used in teaching and education. _Additive Manufacturing_, Vol. 25, January 2019, pp. 131–150, 2019, DOI: 10.1016/j.addma.2018.10.028.

[5] Ficzere, P. – Horváth, Á. M. – Sipos, T.: Elalvásos balesetek csökkentési lehetősége additív gyártási eljátrással fejlesztett kapszulák segítségével. *Közlekedéstudományi szemle*, Vol. 70, Nr. 1, 2020, pp. 77–85, DOI:10.24228/KTSZ.2020.1.3.

[6] Korner, M. E. H. – Lambán, M. P. – Albajez, J. A. – Santolaria, J. Ng Corrales, L. C. – Royo, J.: Systematic Literature Review : Integration of Additive Manufacturing and Industry 4.0. *Metals*, Vol. 10, Nr. 8, pp. 4–7, 2020, DOI: 10.3390/met10081061.

[7] Sipos, T.: Coherence between Horizontal and Vertical Curves and the Number of the Accidents. *Periodica Polytechnica Transportation Engineering*, Vol. 42, Nr. 2, 2014, pp. 167–172., DOI: 10.3311/PPtr.7403.

[8] Horvath, J.: *Mastering 3D printing: modeling, printing, and prototyping with reprap-style 3D printers*. Apress Media LLC, California, 2014.