STRUCTURAL MODIFICATION IMPACT ANALYSIS OF SELECTED COMPONENTS OF SHIELDING EQUIPMENT USING RAPID PROTOTYPING TECHNOLOGY

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The aim of the paper is to analyze the impact of selected components of shielding equipment using Rapid Prototyping technology. Mechanical properties of selected components of shielding equipment will be analyzed using computer simulation in Autodesk Inventor. Based on carried out analysis of the individual alternative will be produced prototypes of shielding components by FDM technology (Fused Deposition Modeling).

KEYWORDS

rapid prototyping, FDM, 3D print, shielding equipment component, mechanical properties

1 INTRODUCTION

Currently, most industries are under constantly increasing pressure and it is necessary to adapt to new trends in the production process. The Rapid Prototyping technology is undoubtedly among the least recent inventions. The greatest benefit of this technology is the speed of prototyping, which it is named after, and almost zero waste and non-toxic materials it uses. For the companies engaged in the development and testing of new products, the use of this technology is almost a necessity. [Marcincin 2011a] Before starting mass production, which requires high investment, it allows for a prototyping in a short period of timein order to verify its shape, dimensions, functionality, and other features.

2 RAPID PROTOTYPING PROPERTIES

This technology serves to create real components from computer data with the highest quality in the shortest possible time. Produced models are usually fully functional and have similar features to those produced conventionally. These technologies belong to the additive manufacturing group. The difference is that the material is not taken off but rather gradually added in individual layers. These layers have a constant thickness. The production of the component is based on a 3D digital model that can be scanned by a 3D scanner or created in CAD software. [Marcincin 2011b]

The Fused Deposition Modeling method is considered a modern and progressive technology of prototyping and manufacture of prototype parts in particular. It can be used to produce a particular component or to produce permanent movable joints. The duration of the print depends on the size and shape complexity of the model, which may be up to several hours. Using this technology can actually save up to 80% of the total costs of prototyping. This is also dependent on the size of the model, as well as the type of the original conventional production. [Pacucar 2008] The principle of AM production is based on a gradual melting of thermoplastic. It is wound on a coil in the form of a wire and the nozzle is fed by the pulley mechanism. The model is produced by using a nozzle, which gradually adds individual layers of the construction material that was heated to a temperature that is 1°C higher than the melting temperature.[Marcincin 2011a] The molten material immediately solidifies upon contact with the pad. When creating more complex models, it may be necessary to use supporting structures that prevent collapsing of the model during production. These supports are removed after completion of the equipment either mechanically or chemically using a suitable solvent. Components produced by the AM technology are used to test functionalities and design properties, but due to their good mechanical properties, they can be used as final products that can cope with real conditions. The main benefit is that it creates a very small amount of waste resulting from the use of support structures. On the other hand, the shrinking of the model during cooling leading to shape inaccuracies is a disadvantage of the technology, however, which can be removed using correction calculation during design phase. Another advantage of the Fused Deposition Modeling is the limited accuracy; this parameter is dependent on the size of the nozzle that extrudes the construction material. The most common material used in the production of models using FDM technology is ABS thermoplastic, PC polycarbonate and derivatives, polyphenyl sulfone PPSU/PPSF and ULTEM 9085 material. ABS thermoplastics: characterized by strength and impact resistance. Other features include its excellent dimensional stability and robustness. It is a suitable solution for conceptual modeling and functional testing of prototypes. One of its derivatives is the ABS+ that has a higher stability under deformation and improved moisture absorption. Derivative ABS-M30 has enhanced properties in terms of mechanical strength by about 25-70% compared to the standard ABS. ABS-M30i bio-compatible thermoplastic is suitable for medical and food purposes. [Sedlak 2005] PC Polycarbonate: Similar to the ABS, it has excellent mechanical properties. The advantage over ABS is its higher impact strength and higher temperature resistance. One of the most widely used thermoplastics in manufacturing is the PC-ABS derivative, which combines a mechanical strength of PC and material elasticity of ABS. PC-ISO derivative along with ABS-M30i is also bio-compatible. PLA: It is a greener and more acceptable solution compared to ABS. It is a polymer made of natural materials, such as corn and potatoes. Compared to ABS it has a lower melting temperature and somewhat inferior mechanical properties. Under standard conditions it transmits light, a variety of colors can be transmitted using dyes. PPSU/PPSF: are thermoplastics with a high chemical and heat resistance and guarantee material guarantees dimensional accuracy. Products made of this material may be preserved using chemical or plasma sterilization if needed. ULTEM 9085: It is characterized by a very high ratio of strength to its own weight. It is mainly used in the automotive industry. These materials differ from each other in composition, material properties, behavior in various conditions, and the like.

Table 1 shows the comparison of general mechanical properties of selected materials. [Piska 2009]

Material	Mechanical properties				
	Tensile strenght (MPa)	Tensile Moduls (MPa)	Elongation (%)	The flexural strenght	The flexural moduls
ABS	22	1627	6	41	1834
ABS+	36	2265	4	52	2198
ABS-M30i	36	2413	4	61	2317
PC	68	2280	4,8	104	2234
PC-ABS	41	1917	6	68	1931
PC ISO	57	998	4,3	90	2140
PPSU/PPSF	55	2068	3	110	2206
ULUTEM 9085	72	2220	5,9	115	2507

Table 1. Comparison of general mechanical properties of selected materials

3 SHIELDING EQUIPMENT COMPONENT DESIGN

We will produce a vertical blind weight. This component performs two basic functions. The first function is to serve as a weight of vertical fabric blinds. It is located at the bottom and strains the fabric and holds it in the correct form. The second function is to serve as a connecting element, which connects the whole system by using brackets located opposite to each other and connecting ropes. By the use of a pulley mechanism it is possible to move the blinds in horizontal direction, as appropriate. The problem of this component is its insufficient mechanical strength of impact at the bracket and consequential risk of damage to the connecting element, which may result in a malfunction of the entire mechanism providing a horizontal movement. Fig. 1 shows the original weight model.

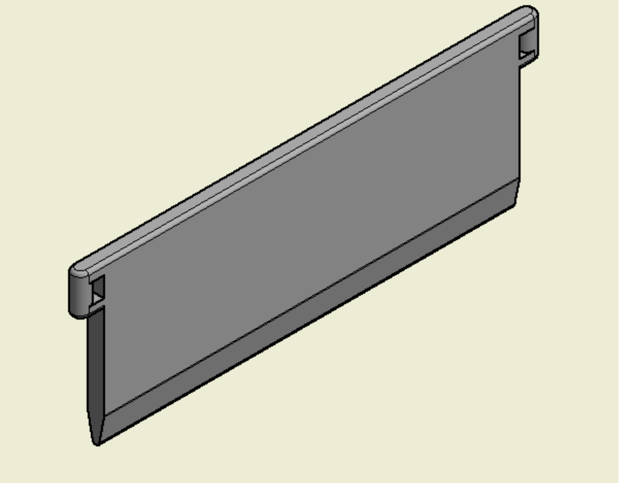


Figure 1. Original model

3.1 Proposed Structural Modifications to the Original Model

The production of the component is based on a model created in the Autodesk Inventor software. General features of future parts were taken into account when designing the model. The basic requirements include the total size of the part, size of the bracket of the connecting mechanism, and axial distance between the opposite brackets. Production using FDM technology provides nearly unlimited shape complexity, however, the more complex the shape is the longer the production takes, resulting in increased costs. Another requirement in terms of strengths is that the component was made in whole and not in part and then assembled. The proposed alternative is different to the original model with regard to the change in the bottom part of the bracket, which was replaced by a rib. This change does not affect the functionality and usability of the component, however, it should provide an increased resistance to mechanical stress - thus longer lifetime. The difference is shown in Fig. 2.

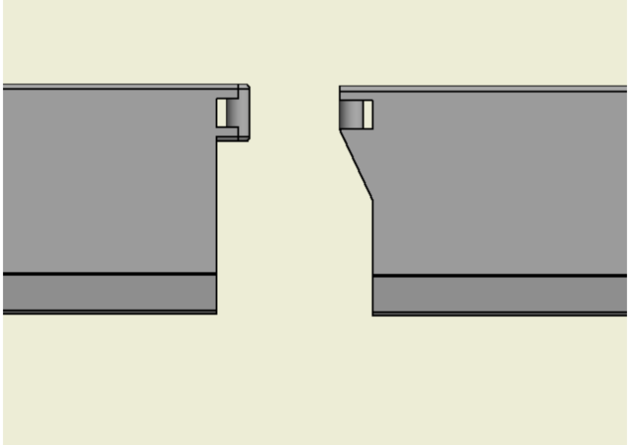


Figure 2. Comparison of the original model and proposed alternatives

3.2 Selection of Material

The selection of the right material depends on the future use of the component, which is an important parameter of the manufacturing process. The designed component that serves as a weight for a shielding device has the most important requirement for its mechanical properties and the impact resistance in particular. The atmosphere of the component, in which it is deployed, does not require any special properties such as a high heat resistance and bio-compatibility. PLA natural polymer was selected to be used in prototyping. Compared to ABS it has better adhesion, which improves the accuracy of the printed model. Other reasons for this decision is its relatively low price and very high availability. The component made of this material is further machined conventionally. For the purposes of 3D printing this material comes mostly in the form of strings with a diameter of1.75-3mm.

3.2 Mechanical Load Simulation

The assessment of structural modifications and their impact on mechanical properties included stress analysis using simulation in Autodesk Inventor. The purpose of this analysis was to check the correctness of the design, detect any gross defects, and verify the viability of the proposed solution. Both models were subject to the same forces. During the simulation, the PLA material with a tensile strength of 41 MPa was subject to 500N force aimed at the place of the gripping. The size of the grind and bond must be set. The simulation used the same settings for all the models. The direction and point of application is shown in Fig. 3.

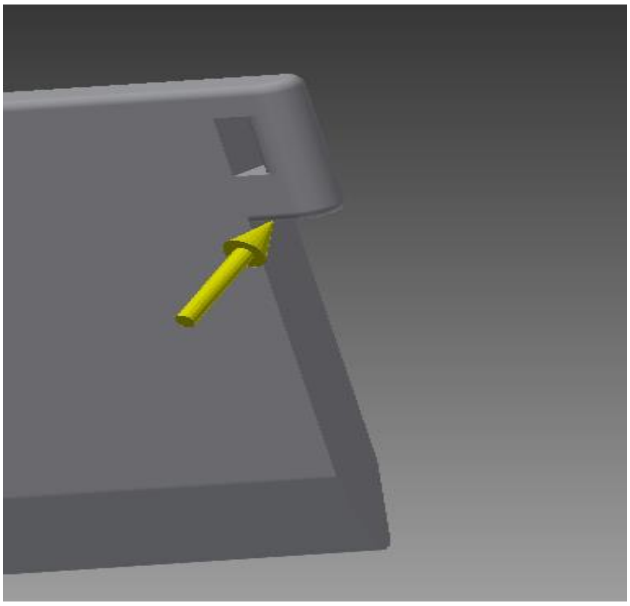


Figure 3. The direction and point of application

Fig. 4 shows the displacement of various parts of the original model under a load of 500N.

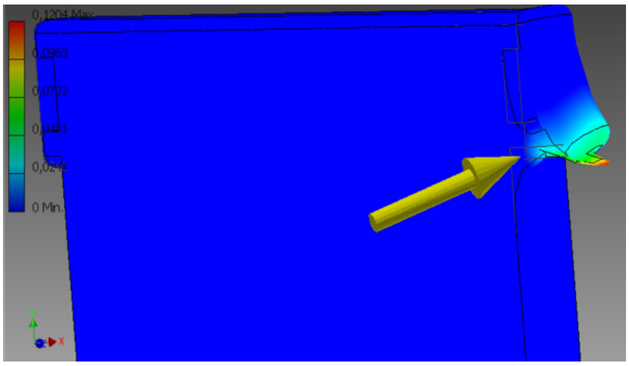


Figure 4. The maximum displacement of the original model

Fig. 5 shows the displacement of various parts of the proposed solution under a load of 500N.

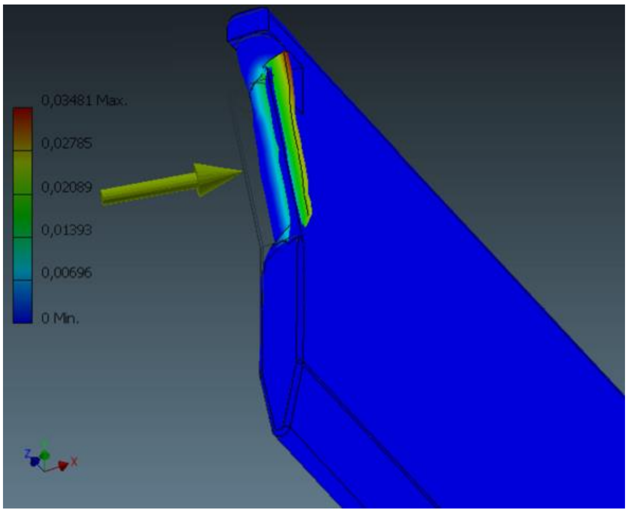


Figure 5. The maximum displacement of the proposed alternatives

Fig. 6 shows a graphical view of the Von Mises stress in MPa of the original model under a load of 500N.

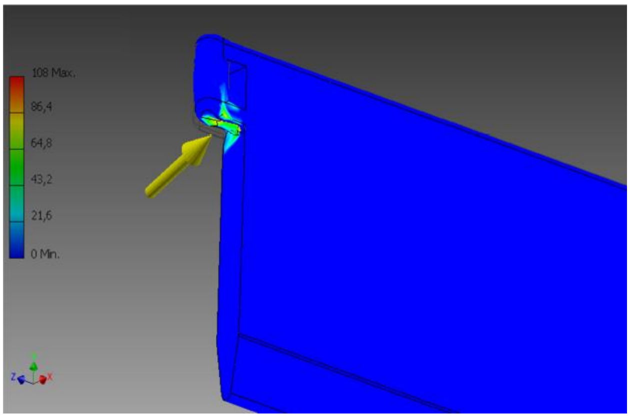


Figure 6. Graphical view of the Von Mises stress of the original model

Fig. 7 shows a graphical view of the Von Mises stress in MPa of the proposed solution under a load of 500N.

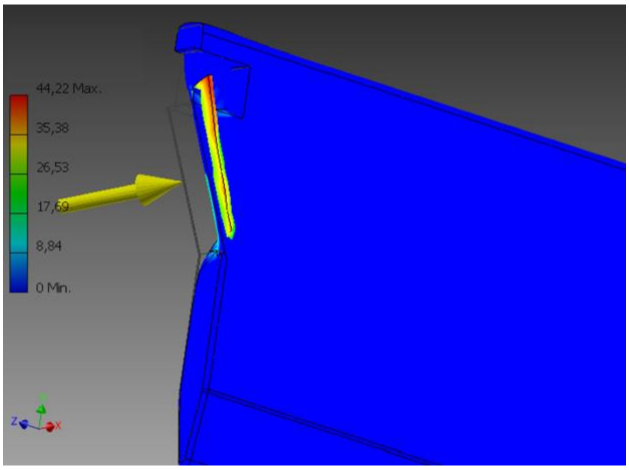


Figure 7. Graphical view of the Von Mises stress of the proposed alternatives

The results of the stress analysis were processed graphically. Fig. 8 and Fig. 9 show the comparison of maximum displacement of the original model and proposed solution and maximum Von Mises stress of the original demo and proposed solution.

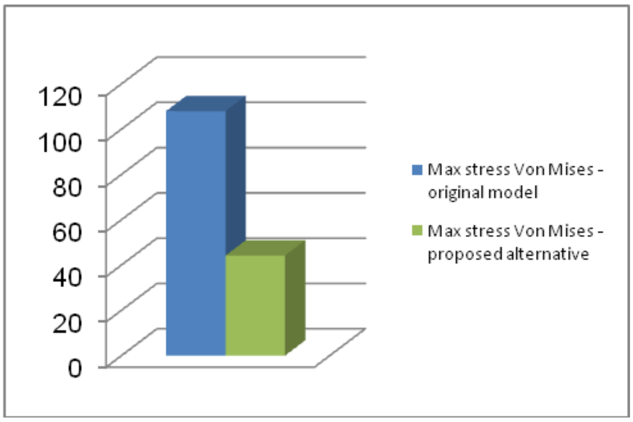


Figure 8. The comparison of maximum displacement of the original model and proposed solution

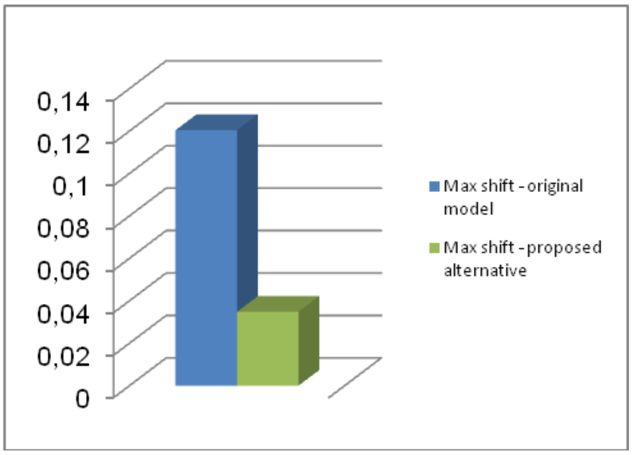
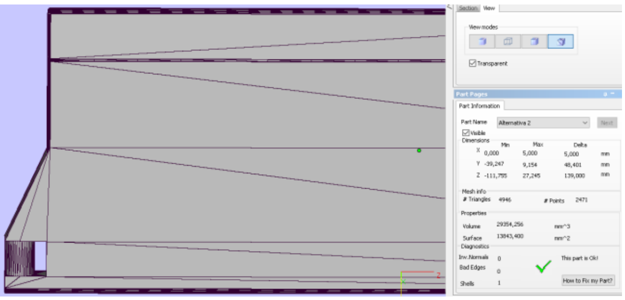


Figure 9. The comparison of maximum Von Mises stress of the original model and proposed solution

4 PRODUCTION OF COMPONENT FOR SHIELDING TECHNOLOGY

Pre-processing - this stage of production includes pre-printing operations. The proposed solution is converted to the required format of ".stl" using Autodesk Inventor CAD Software. The actual conversion offers two output options: "Binary" an "ASCII". Binary format was selected. The next step is to set the resolution, where we decided for "Medium". This is how the model is converted to the required format. The polygon mesh of the model was checked by using Mini-Magics software. The program evaluated the model as OK. The polygon mesh rendering is shown in Fig. 10.



☑ Transparent

Part Name: Alternativa 2

☑ Visible

Dimensions	Min	Max	Delta	
X	0,000	5,000	5,000	mm
Y	-39,247	9,154	48,401	mm
Z	-111,755	27,245	139,000	mm

Mesh info
\# Triangles 4946 # Points 2471

Properties
Volume 29354,256 mm^3
Surface 13843,400 mm^2

Diagnostics
Inv.Normals 0
Bad Edges 0
Shells 1
This part is Ok!

Figure 10. The polygon mesh rendering

Sli3cr is used for printing and changing print settings. This software is open-source and freely redistributable. In the software, the first step is to import the created model to a format ".stl".Fig. 11 shows the model imported to software Sli3cr.

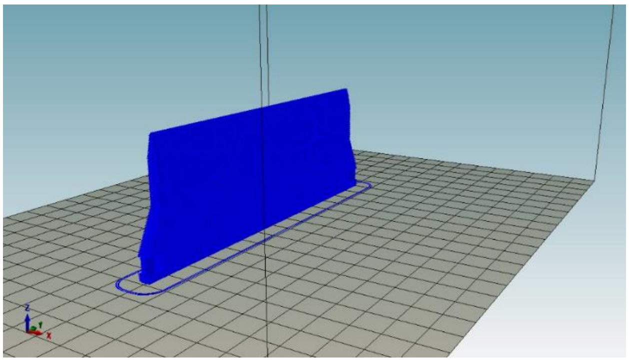


Figure 11. Model imported to software Sli3cr.

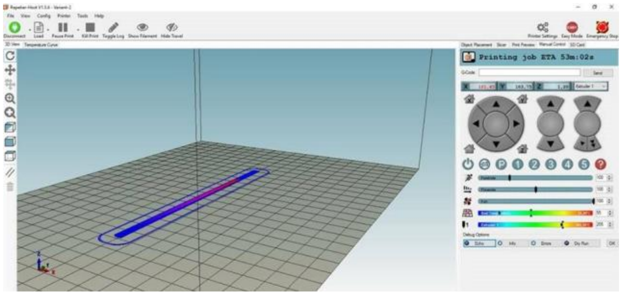
The pre-processing stage ends now and the virtual 3D model is ready for production, we only need to send the virtual data to a 3D printer. The production used RepRad 3D printer shown in Fig. 12, which parameters are given in Table 2.

Figure 12. RepRap 3D printer

Parameters of used 3D printer	
Size of working table (mm)	200x250x160
The diameter of the nozzle (mm)	0.4
Print speed (mm/s)	60
The temperature of the press (°C)	205
Layer thickness (mm)	0.4
The material	PLA, 2mm

Table 2. Parameters of used 3D printer

In this stage of production, the actual 3D printing of virtual data takes place. The entire course of production can be monitored in Sli3cr, showing the animation and data, such as the location of the printhead and remaining time of production. The simulation window is shown in Fig. 13.



Printing job ETA 53m:02s

Figure 13. The simulation window

Upon completion, the component was taken from the 3D printer. No supporting structures were needed for the production, and thus the model was not at risk of damage resulting from the mechanical or chemical removal of the structure.

5 CONCLUSIONS

The aim of the paper was to analyze the impact of structural changes of the selected component used in shielding technology. Autodesk Inventor 3D software and its additional programs were used in the 3D modeling and simulation of mechanical loads. The original model and proposed solution were at the critical point tested under a load of 500N. The results of the stress analysis show that the proposed solution is more resistance against mechanical stress. The following parameters were used as outputs for the comparison of results of the stress analysis: total displacement and Von Mises stress. The proposed solution was made using Fused Deposition Modeling technology that belongs to the group of technologies called Rapid Prototyping.

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