RESEARCH ON TOPOLOGICAL OPTIMIZATION OF FLOATING SUPPORT OBTAINED THROUGH ADDITIVE MANUFACTURING

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ABSTRACT: For the topological optimization of the floating support manufactured using Fused Deposition Modelling technology, a preliminary static study was performed using SOLIDWORKS Simulation, which formed the basis of the topological analysis. The data obtained from the topological study influenced the modeling of the support, resulting in a part with a reduced mass of 34%. Subsequently, a static study was conducted, confirming that this type of part can be achieved through additive manufacturing (AM) technologies.

KEYWORDS: optimization, topology, bioplastic, FDM, milling-centering.

1. Introduction

Fused Deposition Modeling (FDM) is one of the most popular additive manufacturing (AM) technologies for various engineering applications. FDM was commercially introduced in the early 1990s by Stratasys Inc., USA. The quality of FDM processed parts depends mainly on the careful selection of process variables. Since 2009, a variety of kits have been available on the market that have allowed the construction of a low-cost 3D printer in a relatively short time.[1]

Currently, FDM technology is used to produce parts with remarkable quality, increased productivity, safety, low production costs, and reduced delivery times.[2] The flexibility in making products and parts with complex shapes, the variety of techniques for designing the body of the product/part, and the possibility of modifying the shape of the finished product without requiring additional manufacturing preparation are the major advantages of a manufacturing technology that makes the transition from unique production to other types of production, in series or in mass.[3]

In order to reduce costs and time in the production of a floating support, the possibility of manufacturing it using FDM technology from polylactic acid (PLA) was analyzed. PLA is a thermoplastic aliphatic polyester produced from renewable resources such as cornstarch (in the United States) or sugar cane in the rest of the world. It is biodegradable under certain conditions, such as the presence of oxygen, and is difficult to recycle.[4]

The floating support, for which the topological study was performed, is one of the positioning elements of the bar-type semifinished product in the milling-centering device DFC 01.00. It is a part obtained by classical machining technologies, being made of carbon steel C45E SR EN 10083-2: 2007. The semifinished product is used to manufacture the DISTRIBUTOR SHAFT HR01 MH02.11part.[7]

The assembly of the floating support with the support sole is done through a shaft, in a unitary shaft system. For this purpose, three bores are provided (one in the support, D2, and two in the support sole, D1 and D3). The three bores are made with different diameters D1, D2, D3, which is a disadvantage from an economic point of view.[5,pag.14,fig.7.13]

For the topological optimization of the floating support in the milling-centering device DFC 01.00, the topology optimization tool from SOLIDWORKS Simulation was used. Design and production constraints were taken into account, and a simulation of the finished product (FEA) was performed.

Subsequently, the milling-centering device DFC 01.00 can be optimized to reduce the setup time by adding an element that ensures the connection between the two flanges and creates a parallelogram mechanism, making their simultaneous positioning possible. Additionally, the 16 x 10NT - 191 support pin can be replaced with a magnetic pin, reducing the time for positioning and fixing the semifinished product in the device, as well as the force acting on the support.

2. Methods and Materials

2.1. Methods

By using AM costs and production time can be reduced. The 3D modeling software allows for the creation of ergonomic shapes that can be optimized with the topological study tool in SOLIDWORKS Simulation. The initial shape of the support that can be obtained through classical machining methods (milling, drilling,…etc) is shown in figure 1.

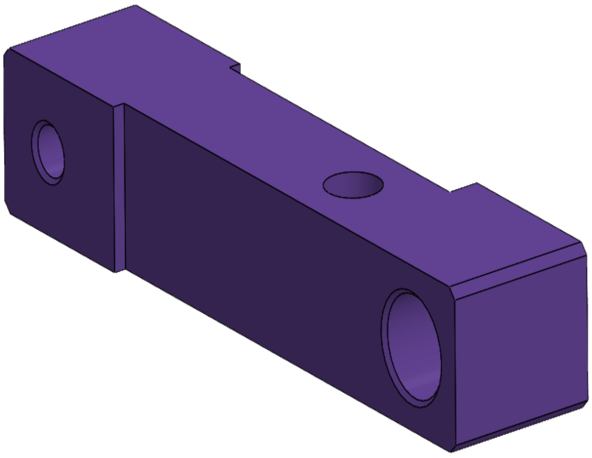


Fig. 1. Floating support - initial shape

The floating support has the role of constraining one degree of freedom (translation on the Z axis) of the workpiece positioned on the two prisms of the milling device - centering DFC 01.00, presented in figure 2.

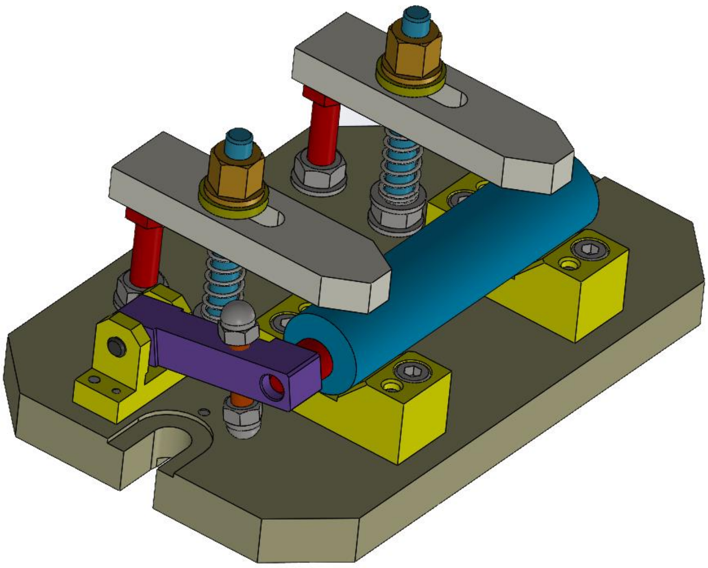


Fig. 2. The milling – centering device DFC 01.00

Computer-aided design techniques play a crucial role in achieving compliant products with material savings while maintaining performance characteristics through optimized modeling. During the topological optimization process, the model's geometry is transformed into three-dimensional finite elements.

The proposed floating support model, shown in figure 3 was created using SOLIDWORKS and saved as an .STL file, which was later imported into Z-SUITE, a slicer software for Zortrax 3D printers. The Zortrax M300 Plus printer was utilized for this project.[6] The ergonomic design of the floating support model eliminates the need for elements that make contact with the base plate, thereby simplifying the device and reducing costs.

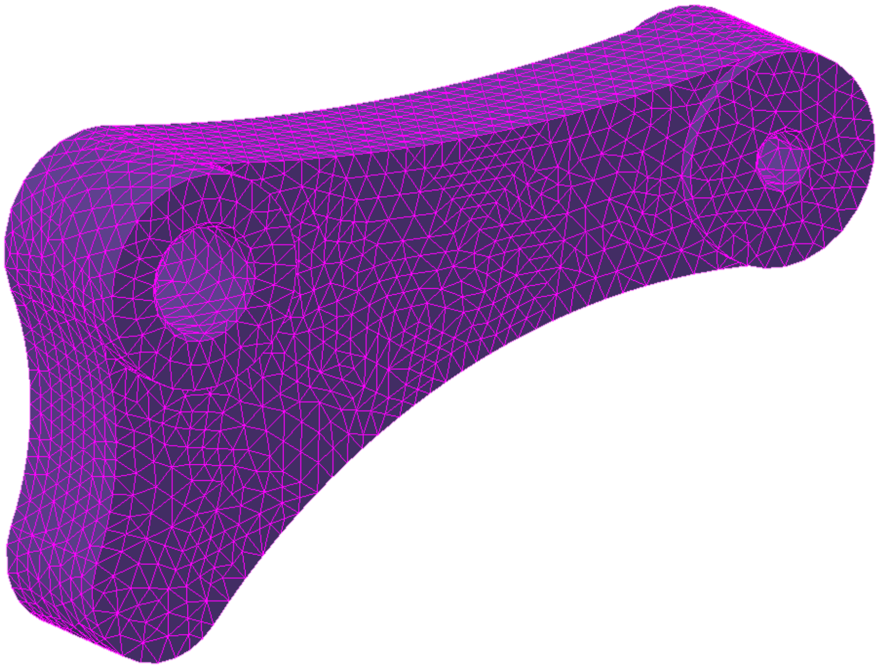


Fig. 3. Floating support model proposed for optimization

2.2. Materials

The floating support model presented in Figure 3 is obtained through FDM technology, using PLA filament. For this purpose, the material properties were defined in SOLIDWORKS Library - Custom Materials - BIOPlastic - PLA.

3. Results

3.1. Topological optimization

The SOLIDWORKS Simulation tool was accessed and a preliminary static study was performed. The Standard Mesh option from the Definition menu, Mesh Parameters section, was used for this purpose. The size of the tetrahedral element edges was set to values between (0.15÷3) mm, with the Automatic Transition option.

In the contact area between the floating support and the 16x10 NT - 191 support pin, a pressure value of 1N was set, according to the measurements. Also, 3 surfaces of the floating support were chosen as fixed zones, when positioning the workpiece, as shown in figure 4.

The preliminary static study confirmed that the shape of the support and the material (PLA) are suitable. The proposed support model for topological optimization fulfills its functional role within the milling-centering device.

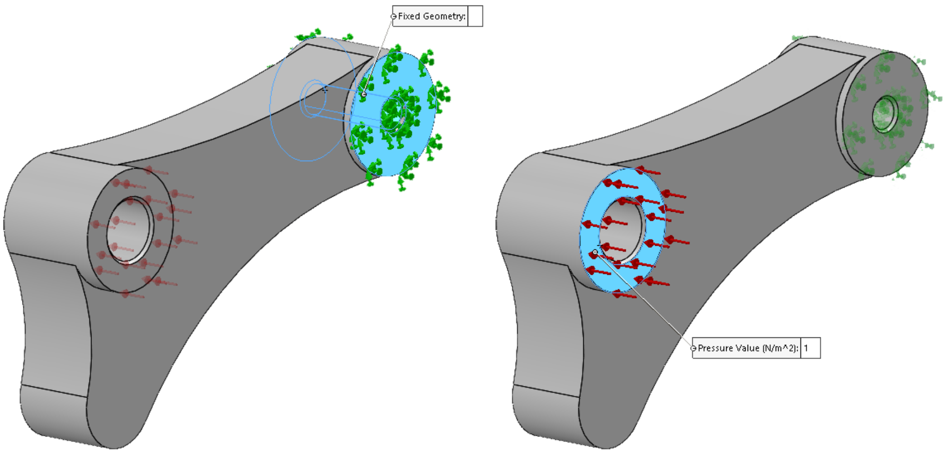


Fig. 4. Applying constraints for static study

The results of the preliminary static study are presented in Figure 5.

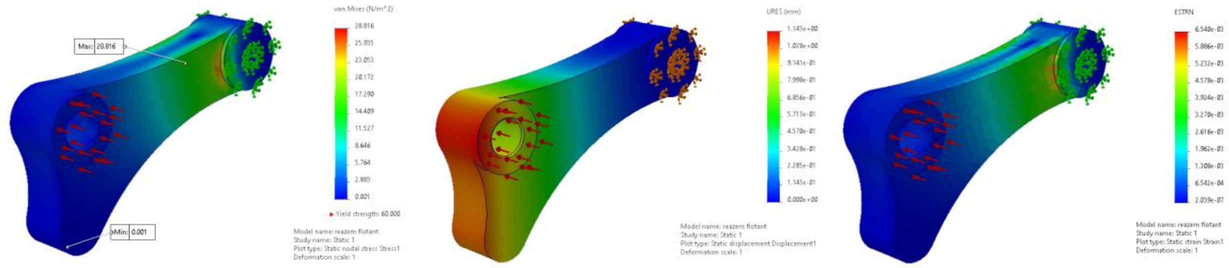
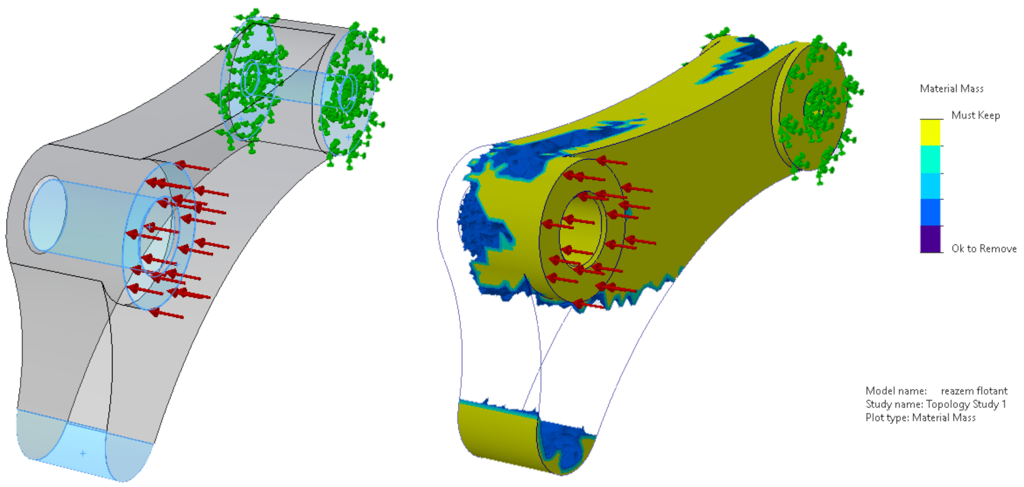


Fig. 5. Preliminary static study

The topology optimization study was created based on the static study 1. The optimization objective was set in the Goals and Constraints menu - Minimize Mass - Mass Constraint and Goals and Constraints - Minimize Mass - Displacement Constraint.

The surfaces that need to be preserved after reducing the mass of the support were selected from the Manufacturing Controls menu - Add Preserved Region, these being contact surfaces with other components in the DFC 01.00 milling-centering device assembly, as shown in Figure 6a.



a) b)

Fig. 6. Floating support: a) Preserved surfaces; b) Reduced volume

After performing the topological study, a three-dimensional map of the volumes that can be hidden was obtained, presented in Figure 6b. Using the information obtained from the topological study, the floating support was modeled and the proposed shape is shown in Figure 7.

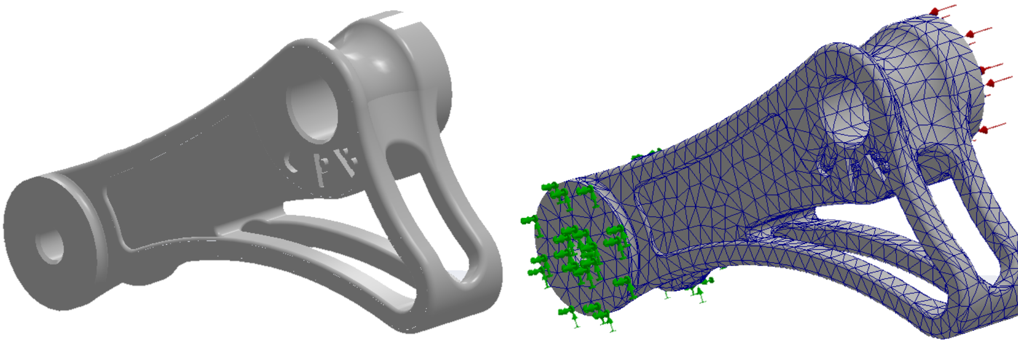


Fig. 7. Optimized floating support

3.2. Final testing

After optimizing the shape of the support, a new static study was performed with the same values as in the preliminary static study. The results are presented in figure 8.

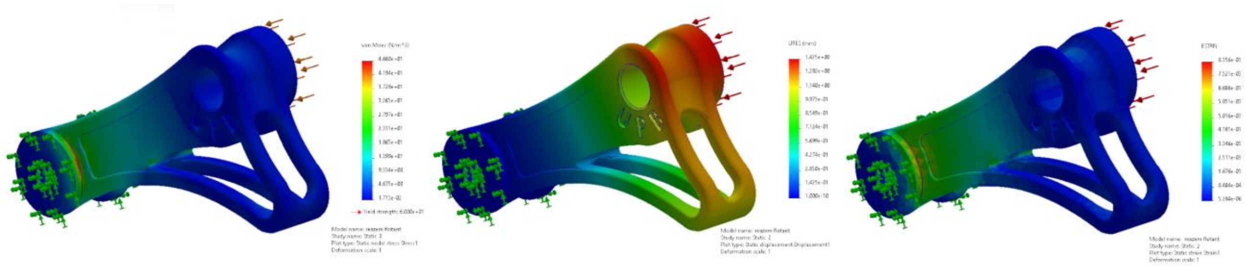


Fig. 8. Results of the final static study

The initial and final data resulting from the topological optimization have been centralized in table 1.

Table 1.

	Support model	Mass [g]	Yield strength [MPa]		Displacement (max.) [mm]	Strain (max.) [mm]
			Yield strength	Simulated values		
1	initial	40,78	60	28,816	1,143	6,540 x 10^{-3}
2	optimized	26,76		46,60	1,425	8,356 x 10^{-3}

After optimizing the floating support, a 34% reduction in mass was achieved compared to the initially machinned model. The recorded values for yield strength indicate that the model can withstand the demands during the positioning of the semi-finished product. The displacement of the contact area with the support pin 16 x 10 NT - 191, for the optimized model, is 282 µm greater than in the case of the initial model. The recorded value for displacement is <1.5 mm (allowance for processing the HR01 MH02.11 DISTRIBUTOR SHAFT reference semi-finished product). The recorded value for deformation is insignificant, being 8 µm.

FDM allows for the creation of such a floating support while adhering to the technical conditions required for milling-centering operations, with reduced material consumption and costs. The time required for the 3D printing of this support is also reduced (2 hours). The ergonomic shape of the model enables the support to be used safely, efficiently, and comfortably.

The recorded value of the displacement (1.425 mm) in the case of the optimized model is close to the maximum allowable limit for the processing allowance (1.5 mm). This distance can be compensated by moving the contact surface between the support and the support pin 16 x 10 NT - 191 by 0.5 mm on the Z axis, by adding material to the construction of the support. Additionally, this distance can be compensated by replacing the 16 x 10 NT - 191 support pin with a 16 x 15 NT - 191 support pin.

4. Conclusions

This study analyzed the possibility of replacing a floating support made by traditional methods with a support manufactured using Fused Deposition Modeling and polylactic acid filament.

In the first phase, it was established that the functional role of the floating support is to orient a shaft-type workpiece along the Z-axis. After topological optimization, a static study was conducted, which validated the use of the new floating support model, achieving a displacement of 1.425 mm (<1.5 mm, the processing margin), a value of 28.816 MPa for yield strength (<60 MPa, the yield limit), and a value of 8.356×10^{-3} for deformation. The topological study highlighted the volume of material that could be eliminated from the model, reducing the mass of the support by 34%.

The study can be continued to reduce the mass of the support by using a magnetic support pin, thus eliminating the need for additional force during positioning and fixing of the workpiece by the operator. To reduce preparation and post-processing durations, the two flanges of the device can be joined, creating a parallelogram mechanism so that they have a simultaneous movement when one of them is activated. This additive manufacturing technology can reduce production time and costs, and the resulting floating support can fulfill its intended functional role.

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