International Journal of Modern Manufacturing Technologies
ISSN 2067–3604, Vol. XIV, No. 3 / 2022
https://doi.org/ 10.54684/ijmmt.2022.14.3.265

CUSTOMISED INFILL PATERNS FOR STREGHTENED 3D PARTS

Virgil Gabriel Teodor[1], Razvan Sebastian Craciun[1], Georgiana-Alexandra Morosanu[2]

[1]"Dunarea de Jos" University of Galati, Department of Manufacturing, str. Domneasca, No. 111, 800201, Galati, Romania

Corresponding author: Razvan Craciun, razvan.craciun@ugal.ro

Abstract: The development of rapid prototyping technologies generates a strong concern for saving all types of materials while maintaining, or even increasing, the strength of 3d printed parts. One way to partially meet this requirement is to make models with a low degree of filling. However, the types of predefined filling structures, defined in the slicing programs, are relatively small in number, being based on repetitive patterns. In this paper it is proposed to make a specimen with a filling structure adapted to the expected stress that appear during operation. Model design can be done in any computer-aided design environment. The deformations of the modified specimen were compared with the deformations of some models with predefined filling structures, under the conditions of maintaining the same loads. This comparison allows to verify the strength of the specimen, under the conditions of using the same volume of material, compared to the models with predefined structure. In addition, conclusions can be drawn regarding the strength of various filling patterns and the time required to print the specimen. The favorable results create the premises of developing an algorithm that can allow the generation of some filling models optimized for different types of loads and eventually the possibility of applying the same concept of custom filling structure for other rapid prototyping technologies.
Key words: infill, rapid prototyping technology, algorithm.

1. INTRODUCTION

The growing demand for custom elements and the development of rapid prototyping technologies create the preconditions of a wider use of parts made by such technologies. At the same time, there is a strong concern for saving all types of materials in terms of maintaining, or even increasing, the strength of 3D printed parts. One way of partially meet this requirement is to make models with a low degree of filling, [1–3]. For this purpose, slicing programs allow the choice of structure and the degree of filling, [1]. However, the types of filling structures are relatively small in number, being based on repetitive patterns (rectangles, triangles, circles, sinusoidal patterns, etc.), [3, 4]. In this paper it is proposed to 3D print a specimen with a filling structure adapted to the expected loads that will appear during operation. The adaptation of the filling structure aims to increase the strength of the specimen while maintaining the conditions of using the same volume of material. Starting from the estimated loads that appear during operation, a Finite Element Analysis (FEA) of the deformations that appear in the part was performed, [5]. Subsequently, the part is redesigned, the filling structure being modified so as to ensure an increased resistance in operation. The design of the specimen can be done in any computer-aided design environment (AutoCAD, CATIA, Solid Works, Inventor etc.) considering the fact that any of these programs allow to obtain rib type elements, with shapes and dimensions established by the user [6]. Deformations of the specimen obtained by modifying the filling structure are then compared with the deformations of some models having predefined filling structures, under the conditions of maintaining the same loads. This comparison allows the verification of the fact that the improved specimen can ensure an increased resistance, under the conditions of using the same volume of material, compared to the models with predefined structure. In addition, conclusions can be drawn regarding the assured resistance of various filling patterns and the time required to print the part. The favorable results create the premises of developing an algorithm that can allow the generation of some filling models optimized for different types of loads and eventually the possibility of applying the same concept of custom filling structure for other rapid prototyping technologies. It is intended to experimentally validate the results by printing the specimens, using FFF technology, on an Ultimaker 3 Extended 3D printer.

2. MATERIALS AND METHODS

In order to make the comparisons between the specimens with modified filling structure and the models with predefined filling structure, a parallelepiped model with a square section was made. The comparison of the resistance was made by simulating the compression of the specimens, using as an indicator for the resistance the maximum deformation occurred.

In order to be able to build models with a predefined structure, it started from a solid model, designed in the CATIA program and exported in "stl" format.
Subsequently, this model was inserted in the Cura slicing program, version 4.12.1, where a partial filling of 10% and grid-type filling were applied (figure 1).
The thickness of all the walls was 2 mm, and the thickness of the deposited layer was 0.2 mm.

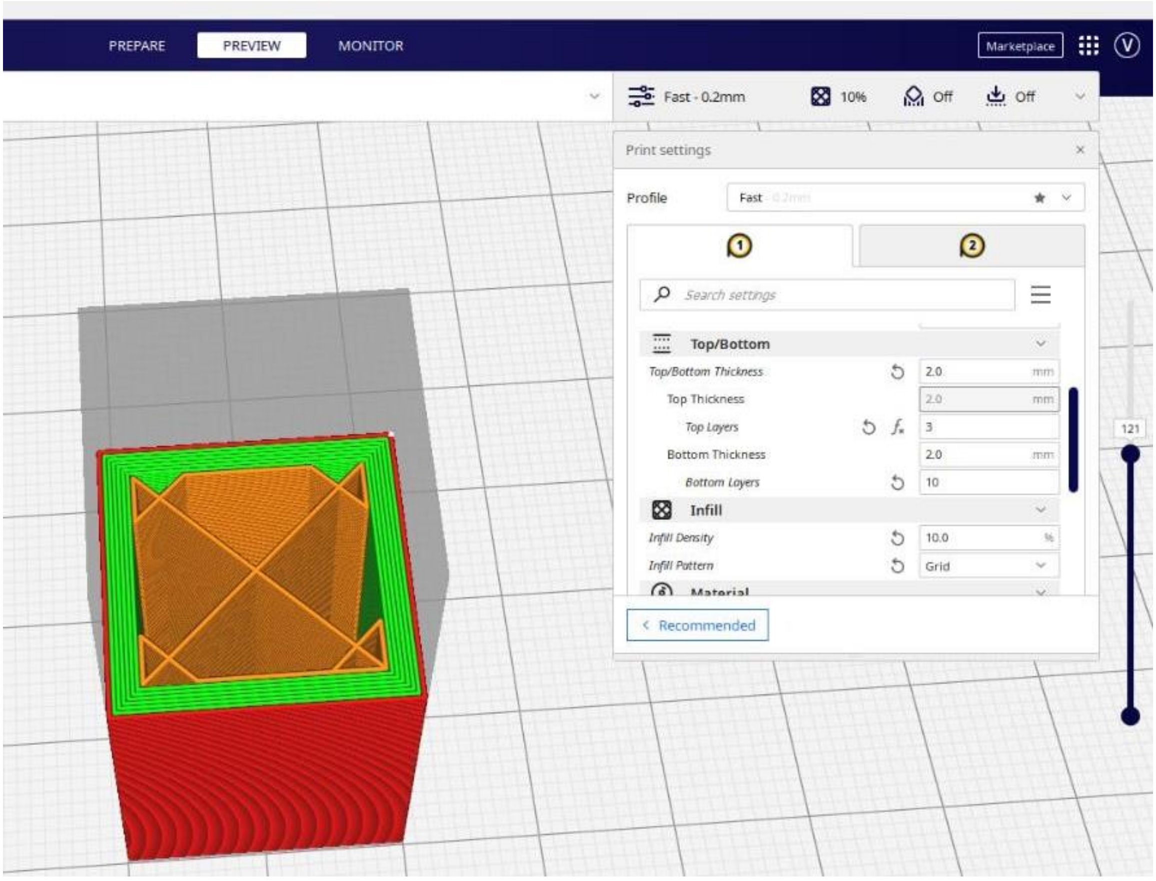

Fig. 1. Model with „grid" filling structure.

A similar model was made in CATIA, having ribs with the same dimensions as the model in the Cura program (figure 2).
The shape and dimensions of the numerical model made in CATIA are shown in figures 3 and 5.

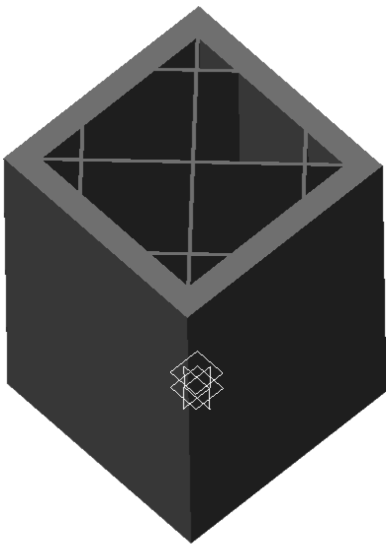

Fig. 2. Model with predefined filling structure, made in CATIA.

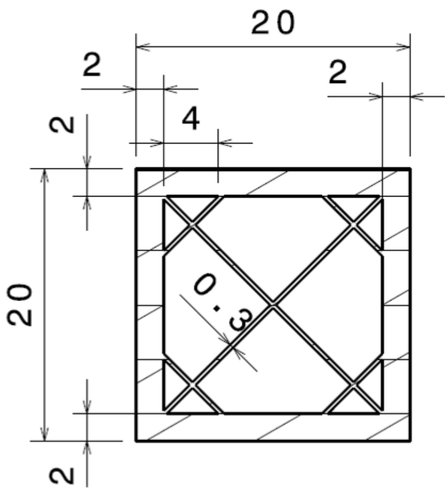

Fig. 3. Model dimensions.

This model has been associated with the "Plastic" material from the material library of the design program. Corresponding to this material the volume and weight of the model was calculated, afterwards the specimen with improved structure to be constrained to have identical values in terms of these characteristics.

3. RESULTS AND DISCUSSION

3.1. Improved specimen

In order to increase the strength of the part, an improved specimen was designed, having the ribs adapted to the loads to which the part is to be subjected. An ogive shape for the ribs is proposed, as shown in figure 4.

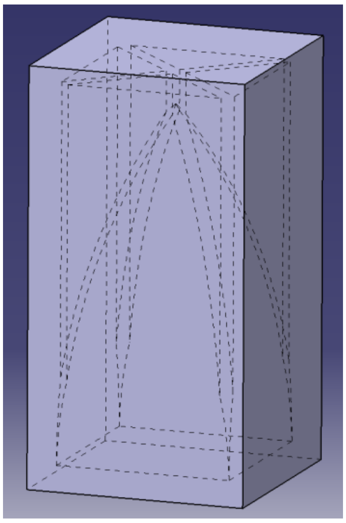

Fig. 4. Specimen with optimized structure.

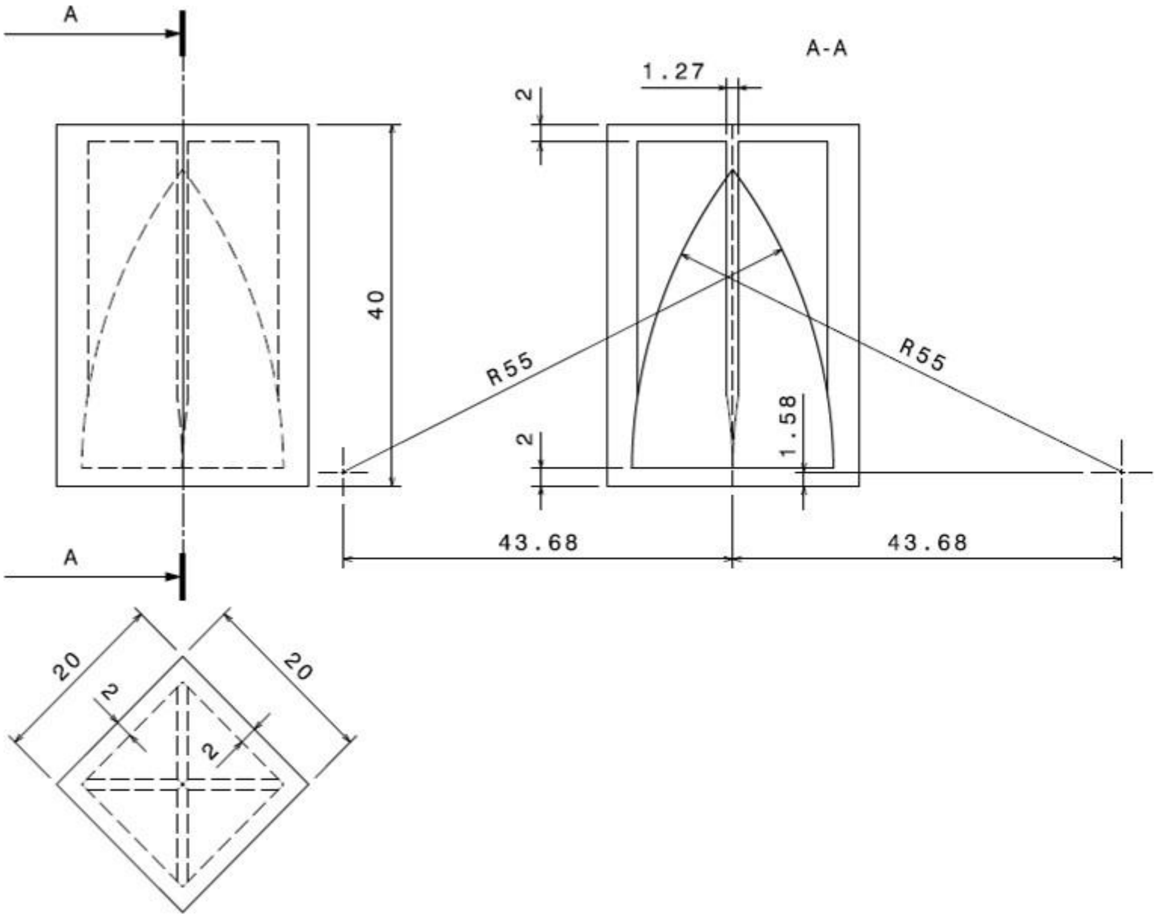

Fig. 5. Optimized specimen dimensions.

The dimensions of the ribs, shown in figure 5, were determined so that the volume and weight of the specimen were comparable to those of the original model. The volume and weight for these two situations are shown in table 1.

Table 1. The volume and weight of the specimens

Predefined structure		Optimized structure	
Volume [mm^3]	Weight [g]	Volume [mm^3]	Weight [g]
7510.648	9.013	7509.665	9.012

3.2. Simulation of loads

Using the program CATIA, the compression load simulation was performed for the two analyzed models.

A uniformly distributed force of 100 Newton's [N] was considered to be applied in the Z-axis direction, the force was applied to the upper face of the specimen.

Holding the specimen in place was done by applying a recessed type constraint to the underside of the specimen.

The characteristics of the network used for the calculation with finite element were: tetrahedron, element type "linear", size 0.5 mm, absolute sag 0.402 mm.

By simulating, the model with predefined filling a maximum deformation of 0.0188 mm was obtained and the specimen with an improved filling structure, a maximum deformation of 0.0152 mm were obtained, see figures 6 and 7.

A decrease can be observed in deformations from 0.0188 mm to 0.0152 mm, which is approximately 20%.

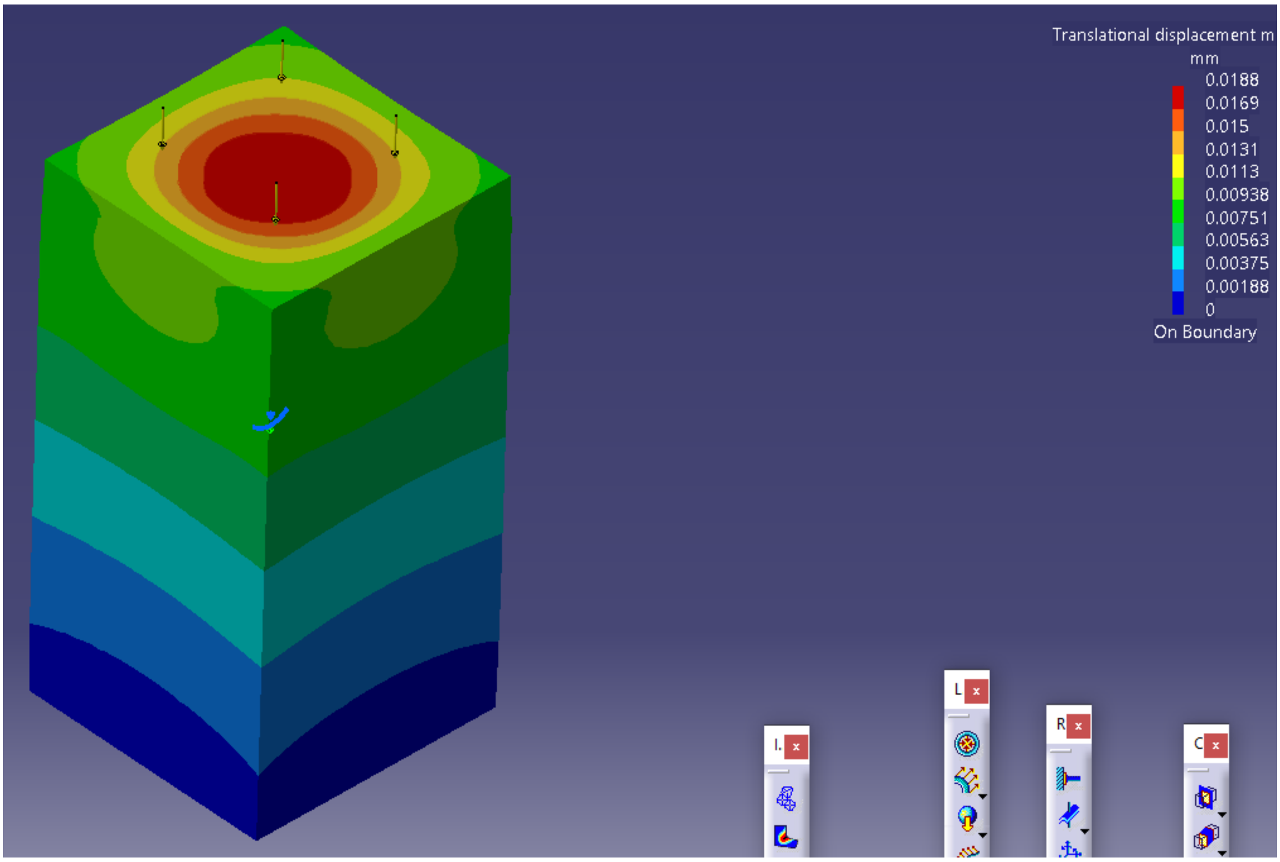

Fig. 6. FEA load simulation for non-optimized model.

4. CONCLUSIONS

By changing the filling structure for parts made by rapid prototyping, their strength can be increased, depending on the type of stress expected to occur during operation.

This increase in strength allows the shape and external dimensions of the part to be preserved, as well as the weight and volume of material used.

The possibility of modifying the filling structure is a feature of additive manufacturing technology and paves the way for material savings, while maintaining the functional characteristics of the parts made. The proposed optimization resulted in a 20% reduction in deformation while maintaining the same material volume of the part.

Subsequent tries have demonstrated that with a higher filling level the decrease of the deformations is reduced, even under the conditions of using optimized filling structures. This was to be expected and explained by the fact that the strength of the part is closer to the strength of a solid part.

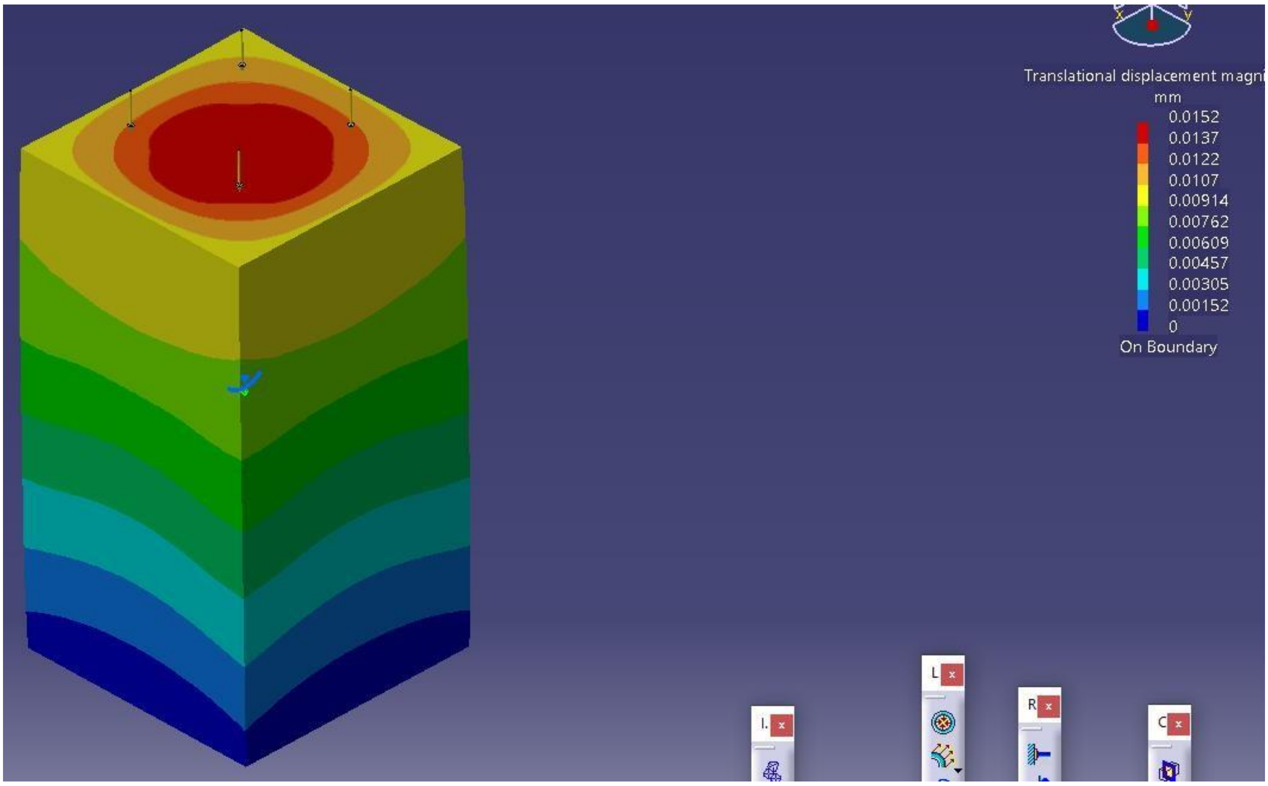

Fig. 7. FEA load simulation for the optimized model.

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Received: April 11, 2022 / Accepted: December 15, 2022 / Paper available online: December 20, 2022 © International Journal of Modern Manufacturing Technologies