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# EXAMINATION OF POSSIBILITIES OF THE STRENGTH MODIFICATION IN THE CASE OF FDM/FFF MANUFACTURING TECHNOLOGY

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**Abstract:** In many situations the result of the topology optimization or generative design can be manufactured only by additive manufacturing technologies. It is also important to know how the optimised shape behaves from the mechanical stiffness, the manufacturing technology and beneficial point of view. These two different goals can be combined and just the infill properties can be changed and optimised within the main body of 3D printed part.

***Keywords:*** *Hybrid infill, FDM, Additive Manufacturing, Generative Design*

## 1. INTRODUCTION

Additive manufacturing technologies has become increasingly widespread in many fields. Nowadays 3D printed products can be found in many different environments like health care service, where the individual orthoses and prostheses can be 3D printed. One of the new fields of application is jewellery where AM technologies are also a widely used [1], [2], [3]. In numerous cases the 3D printed products must be loadbearing. For this reason, the application of simulations is inevitable, where a proper 3D geometry, the environment and structural constraints, the loads and material characteristics must be well known [4], [5], [6]. In the light of these circumstances the weak and overdesigned points of structure can be found by using numerical simulations, then the 3D model can be modified based on the results. This step can be automatised by CAD and FEM software and topology optimisation also can be performed [7]. Engineering design software like Fusion 360 by Autodesk or Solid Edge by Siemens use artificial intelligence (AI) for generative design which can provide lighter and stronger parts. *Figure 1* shows an axle stub designed with generative design.

In this figure the complex geometry can be seen. It is easily observable that the geometry is inproducible by conventional technologies and an AM technology must be applied. The complexity of geometry requires support structures to achieve precise dimensions and it can highly raise the production time and material cost [8]. Besides increased costs the remove of supports can also be a difficulty therefore the small details can increase price directly and make the production more difficult. The small parts can easily brake during the support removal process. For this reason, the customisation of infill features for more sufficient mechanical properties can be easier and cheaper.

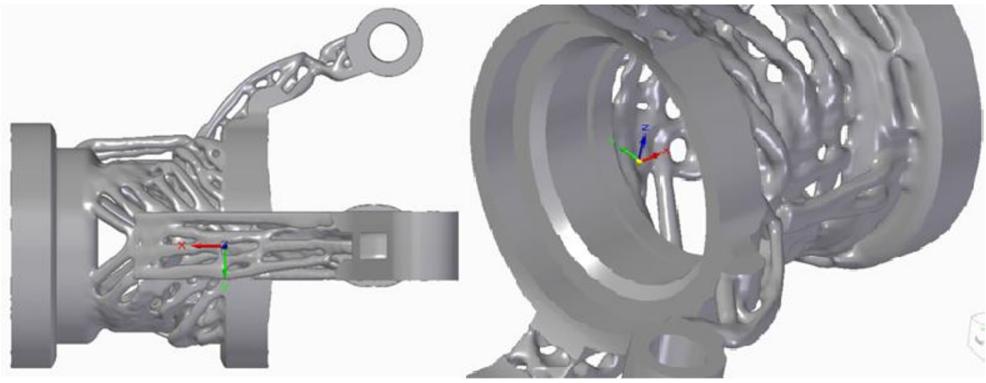

***Figure 1***
*Axle stub produced by the help of generative design*

## 2. METHOD

In case of a simple bending specimen it is easily visible that the stress is much higher in the sides of the specimen, while the neutral axis is exactly in the middle of the specimen where the stress is nearly zero *(Figure 2).*

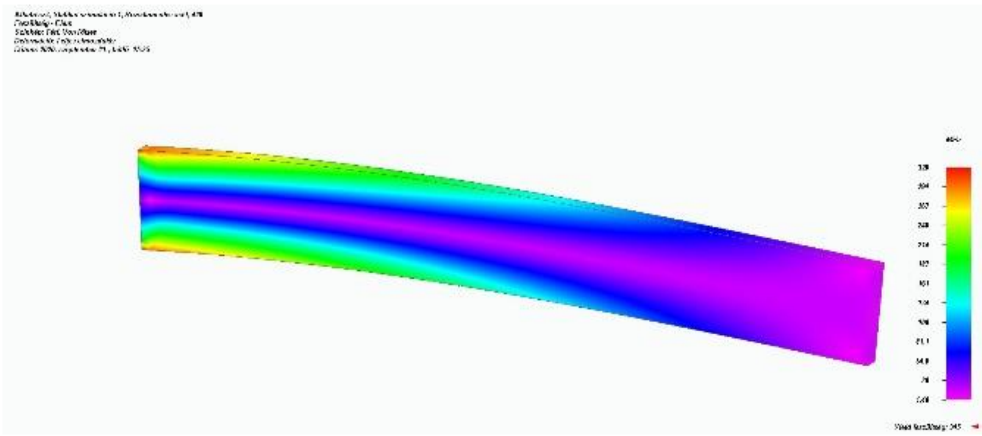

***Figure 2***
*Stress distribution in a bent beam*

For this reason, it is logical if the unladen parts are hollowed and the loaded parts are filled with material, but infill properties can be optimised as well.

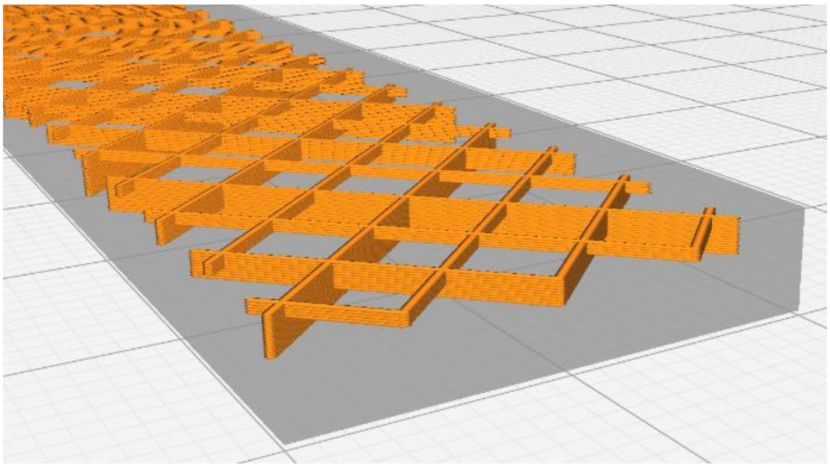

***Figure 3***
*Gradual infill*

Furthermore, there are many options to change infill pattern, direction and dense.

Important to notice that these parameters can be modified just in the production simulation software – slicer software – like Cura, Simplify, etc. For this reason, mecha-nical strength can be just estimated.

For the proper simulations the infill must be generated by a CAD software than the validation could be done by numerical simulations.

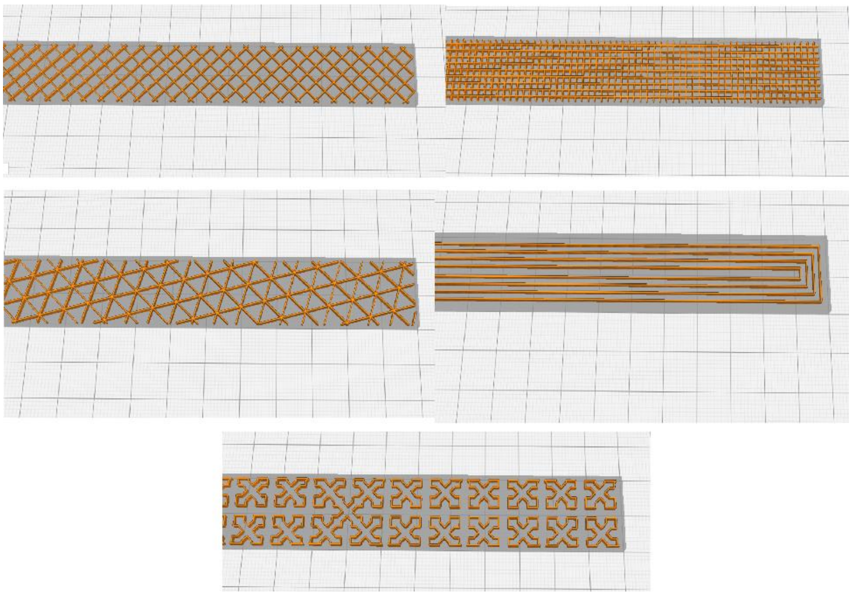

***Figure 4***
*Infill types with same density but with different line directions*

In light of mechanical properties of infill patterns there is a possibility to use a special gradual infill to provide an optimised filling. For optimised mechanical properties a Finite Element Method needed wherefrom the results (iso surfaces) can define the exact infill borders.

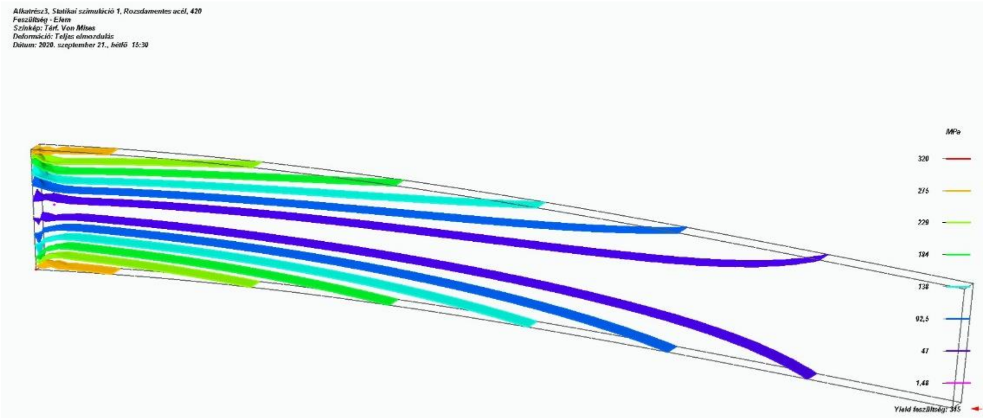


***Figure 5***
*Iso surfaces within a test specimen*

An advantage of mechanical strength optimisation by infill variation can be highlighted such as the small details can be avoided therefore the support extraction can be much easier and material costs can be lower [9]. Another way to increase the strength of composite-based manufacturing, but it is much more expensive and requires more consideration [10]

## 3. RESULTS

The shape of the specimen made by generative design can be seen in *Figure 6*.

***Figure 6***
*Geometry produced by generative design*

In *Figure 6* it is easily observable that the geometry is more sufficient from mechanical perspective, but it is relatively hard to produce even with 3D printing. The small

details require more support structures which can make the production expensive (more time and material) and the removal of support structure is also can be difficult, the small details can easily brake during the process.
In *Figure 7* some infill variations can be seen.

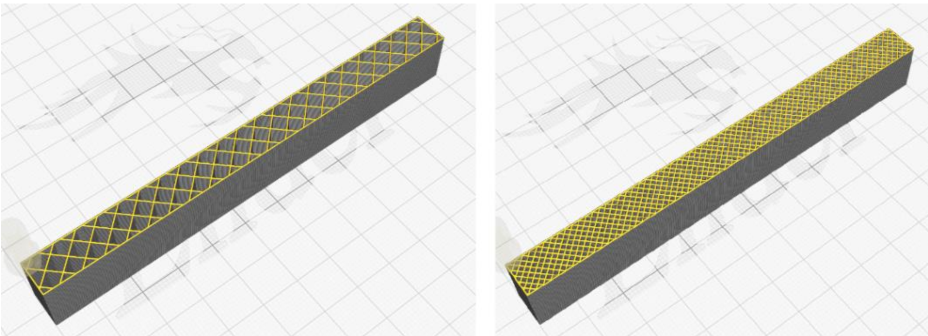

***Figure 7***
*Different infill densities*

Based on *Figure 2* it is easy to notice the consistent infill is unnecessary since the middle of the specimen is not loaded. For this reason, a hybrid solution can be applied where the infill is changed based on the stress volume.

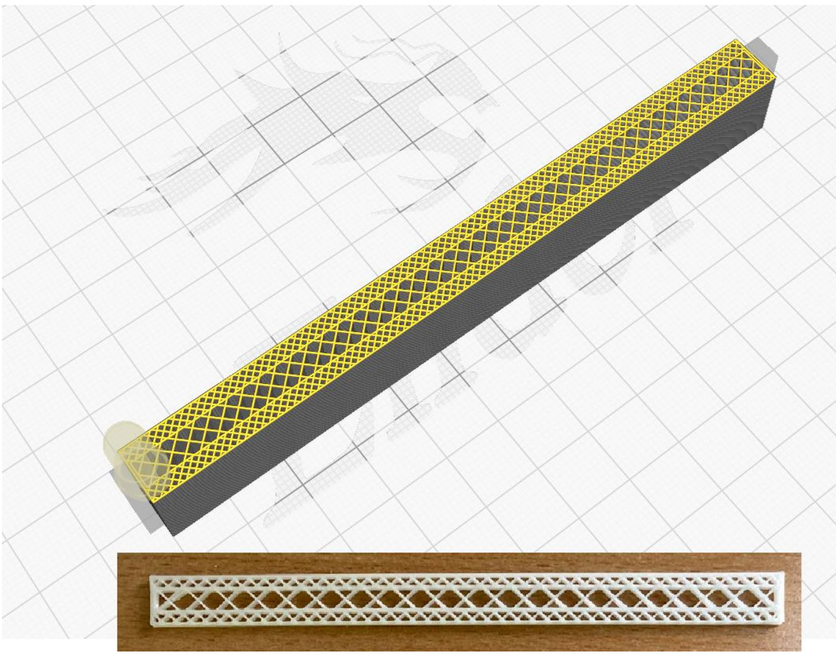

***Figure 8***
*Hybrid infills*

Infill is dense in the sides of the specimen while near to the neutral axis it is more diffuse. This easy solution provides lighter and stronger 3D printed parts *(Figure 8)*. Based on *Figure 5* – where the result of bending test is – an infill modifier body can be used in slicer software which can provide optimised infill modifications. This solution can be seen in *Figure 9*.

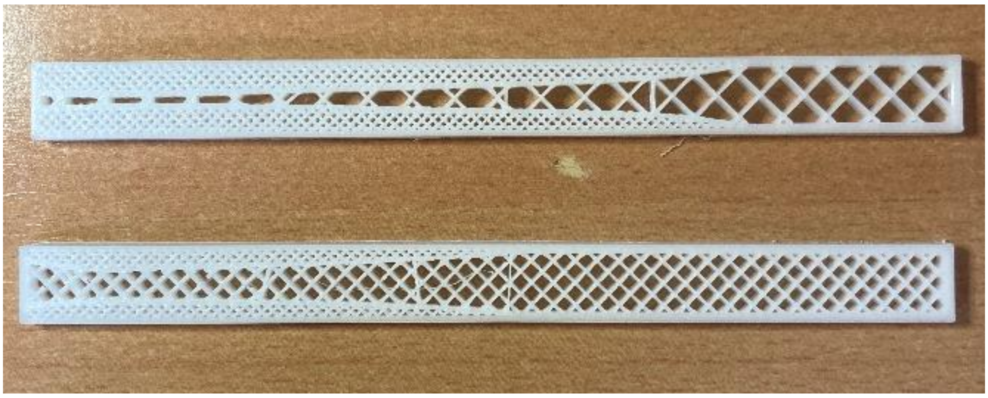

***Figure 9***
*Modified specimens based on iso surfaces*

## 4. Analysis

Based on the results it is easy to notice the infill properties can be changed properly which has a huge effect on mechanical properties. Therefore, this feature can be optimised and the production can be cheaper and faster. The removal of supports can also be easier. For this reason, the exact effects of infill properties on mechanical strength must be well known.

Furthermore, some important source of errors can appear, for example if there are not walls between the different infills. *Figure 10* shows a pair of specimens with and without walls between infill transitions.

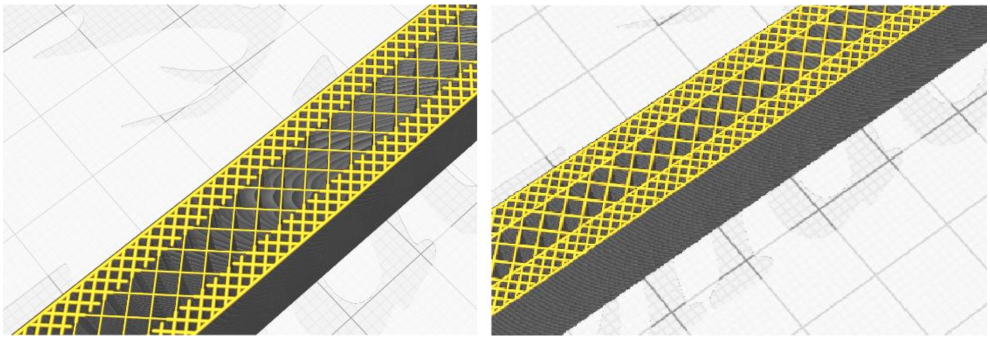

***Figure 10***
*Infill connections without and with walls*

It is worth highlighting that if there is not wall between infills the lines of different infills cannot connect to each other which can cause the 3D printed parts to lose strength. This phenomenon can be the issue of a new investigation.

## 5. CONCLUSION

Due to the popularity of 3D printing the technology has a good progression therefore new features are available for users. Nowadays the individual or low volume production require advanced solutions and AM technologies are good options. The goal is the best and the strongest product on the cheapest and faster way as possible. For this reason, the affect of the different infill parameters has been investigated. There are a huge number of different infill settings which can help the production of better products. For the proper use numerical simulations and experimental validation are required. Furthermore, the application and education of new thinking method are needed.

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