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EVALUATION OPPORTUNITIES OF SEM PICTURES BY CAD SOFTWARE

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Abstract: Nowadays the different 3D printed components are often produced for direct use. In this case the components need to be mechanical designed, therefore the material properties must be well known. It is a fact that the printing parameters have a significant effect on the printing quality. The interference between the printing parameters and the mechanical solidity is well known however the reason for this phenomenon is not. For a deeper investigation a scanning electron microscope is needed. Our study is focused on the potential evaluation of results with the help of the CAD software.

Keywords: *SEM, NURBS, Additive Manufacturing, material investigation, material properties*

1. INTRODUCTION

Due to the popularity of the 3D printing the printed parts can be used as prototypes, tools and in case of small series, even components can be directly produced this way [1], [2]. It is important to note if the 3D printed part is used not only as a prototype (marketing accessory) the part also has to be mechanically resistant [3]. Because of the layer by layer production, most of the 3D printed technologies are characterised by the orthotrop material model, which means that the material properties differ in different directions [4]. It also means that some independent material properties have to be specified exactly, in order to define the behaviour of the material [5]. Furthermore, it is also clear that besides the manufacturing parameters like temperature, layer thickness or printing speed, the position of the part affects the mechanical strength too [6], [7]. The mechanical properties were defined by many research but the reason for these parameters have still not been determined. The researches until now has shown how the possible settings can change the parameters, for example, how the nozzle temperature affects the strength of the whole part [6]. Usually the reason for this effect is not defined because it needs a much deeper analysis. However, by a scanning electron microscope it might be possible to analyse the specimens more precisely. This can help us much more information could be collected about the connection layers what is decisive about the mechanical strength of the parts. The analysis of the SEM pictures is very complicated, it needs experience. There are some patterns that could be easily noticed by a professional but an exact numerical value requires a lot of time. Our study is aimed to demonstrate the possible methods for creating reliable, numerical evaluations required for analysis.

2. Methodology

For our investigations was used the most widespread 3D printing method named FDM (Fused Deposition Modelling). The specimens were created with different specifications which was changed separately. The printing parameters could be changed independently within the limits, and these modifications can highly influence the quality. For this reasons these parameters like printing speed, temperature and layer thickness were separately changed during our investigations.

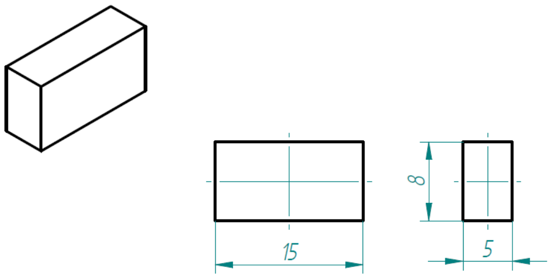

Figure 1. Examined specimen

An important consideration in determining the geometry of the specimen was that it could be quickly and easily produced and that fractions of appropriate size could be pre-set. Another aspect was to reduce the time duration of the production and to save printing material. After producing the specimens and preparing the right fractions, pictures were taken by SEM, which is shown in the *Figure 2*.

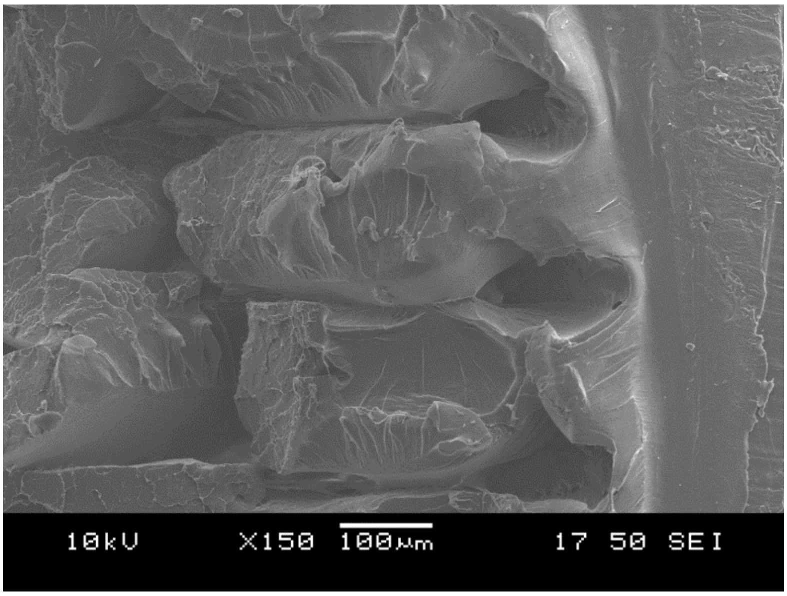

Figure 2. SEM picture (FDM technology, material: PLA)

In the *Figure 2* the layers and gaps can be observed, revealing that the connection between the filaments is not perfect, and the layers are not merged perfectly into each other. The size of the gaps has an effect on the stiffness because this way the cross section decreases as well. Despite of the good visibility this picture is not capable of further investigations because of the direction of the filaments (there are unreal sizes). For the exact numerical evaluation our study needed pictures where the filaments were perpendicular to the fraction.

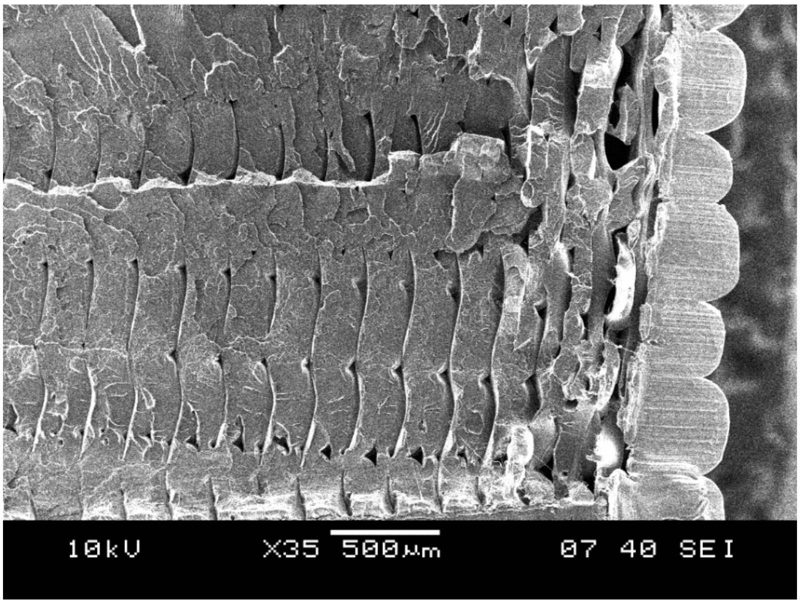

Figure 3. SEM picture, the filaments are perpendicular to the fraction (FDM technology, material: PLA, 220 °C, 0.1 mm, 20 mm/s)

In the *Figure 3* the fractured plane is in the right plane for evaluation. Unfortunately it is less spectacular than the picture in *Figure 2*, but here the inter-layer gaps can be observed on the real size. The purpose of our study is the examination of these triangle-like gaps. The size of the failures is definable with scale on the picture. Theoretically the precise side-size of the gaps is measureable with different photoshop softwares but these gaps have not got an exact shape therefore it would not be the easiest way. In the CAD software there is a function with the size of the closed curves are measureable, furthermore the CAD software are based on the NURBS (Non Uniform Rational Bezier Spline) which means these approximated curves are really well evaluated therefore we can measure the gaps like the curves enclose gaps. The pictures were evaluated with this opportunity.

The steps of the evaluation

- Paste the chosen picture to the CAD software (first a right plane has to be chosen)

- Resize the picture in accordance with scale
- Draft around the gap by NURBS curve (the curve has to be closed)
- Get the size of the gaps
- Recording of measured values, calculate the average

3. RESULTS

With these steps the exact solution can be determined. In the *Figure 4* there is a gap drawn around and its area information. The information was provided by Solid Edge CAD system.

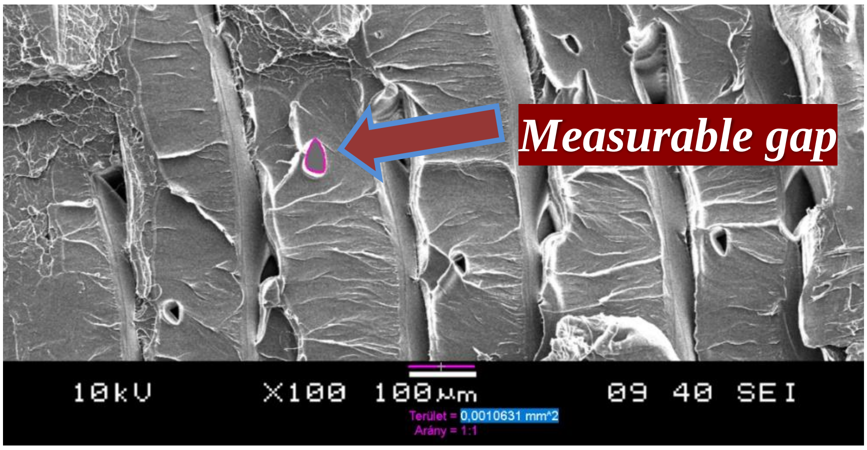

Figure 4. Determination of the gap sizes by CAD software

The average gap sizes were determined by the summarized and statistically evaluated results. The changing of the average gap size, which depends on the changing of the printing parameters, can be analysed. In the *Figure 5* there is a diagram demonstrating the change of the average gap size depending on the nozzle temperature.

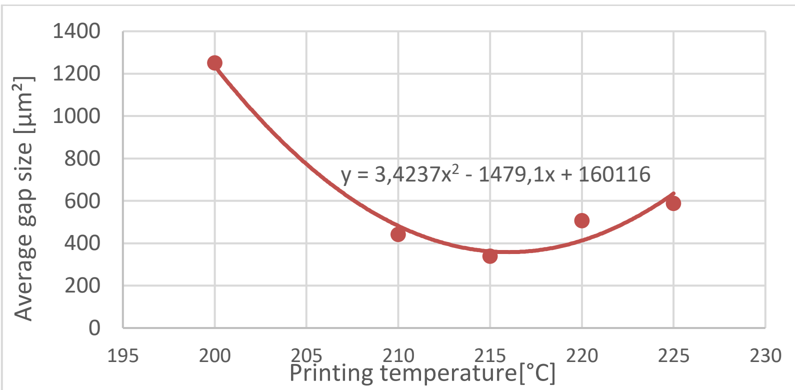

Figure 5. Average gap size depends on the printing temperature

4. Discussion

According to the *Figure 5* the smallest gap size is about 215 °C, but the exact solution can be defined by the equation of the diagram. This point is an optimum too, because this temperature is the recommendation of the material manufacturers. According to the academic literature, the mechanical optimum is about this temperature too [6].

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