Thesis points of doctoral (PhD) dissertation

Analysis of composite materials in 3D printing technologies

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1. Motivations and goals

My doctoral research was concerned with the analysis of composite materials in 3D printing, with the aim of make the process of 3D printing research more comparable and reliable, mainly set back by the unique quirks of printed structures, with special focus on polyamide filaments with fiber reinforcement.

There are already well established standardized specimen geometries in the plastic industry, like the typical dogbone shape used for tensile testing; however, due to the huge variety of structures that can be built with 3D printing, the differently shaped specimens may not be have the same when different structures or parameters are being examined. Stemming from this fact, the comparability between studies and specimens comes into question. During my doctoral research, I investigated the two main structural types that any 3D printed object has.

My goal is to make the unique inner structure of 3D printed objects part of the research process rather than it being a hindrance to it, and make an overarching printing parameter influence study regarding the behaviours of 3D printed objects and their mechanical properties.

2. Thesis points

I. With the presented evidence and observation, I have demonstrated that the size and shape of a carbon fiber reinforced nylon specimen bear no effect on its strength regardless of the structure and extruded lines that it is made up of when recommended printing parameters are set, thus making the results of differently shaped specimens comparable even in samples with low layer or extruded line count in the range of 2-4.

Furthermore, I have shown that after the material deposition calibration by pressure advance is done, the porosity of specimens may vary slightly; however, it does not influence their strength.

Related publications: 1
Related conferences: 1

II. I have presented the effects analysis of key printing parameters. I have presented the detailed influences of these parameters on different mechanical properties for all three materials used by using Pearson correlation and cross-referencing it with the measured data obtained through tensile testing. It was evident that a new approach was needed for analysing the data, that being the categorisation of samples based on structural parameters, here being the infill orientation and nozzle diameter.

1. I have shown that the extruded line cross section area or ELCSA, does not affect the mechanical properties of 3D printed samples; rather, the two parameters that it consists of do, them being the nozzle diameter and layer height.

Furthermore, the layer height should be given in relative value to the nozzle diameter and not as a stand-alone parameter with its own size value, as it eliminates the dependence of the two parameters when a correlation analysis is carried out and emphasises the meaning behind the layer height influencing the shape of the extruded lines.

2. The only consistent trend among all three materials used was that higher temperature and 0° infill orientation always produced higher strength and Young's modulus values. This trend is mainly due to the fact that with higher temperature within the recommended range the bonding between the individual extruded lines becomes stronger, also with the orientation of said extruded lines being parallel to the tensile testing direction those bonds play a smaller role in the tensile strength of the entire specimen than with a 45° orientation, especially when fibers oriented the same direction are inside the extruded lines.
   Similar conclusions cannot be drawn for the other parameters.

Related publications: 2, 3
Related conferences: 2, 4

III. I have proven that with polynomial Black-Box model fitting the prediction of mechanical properties could be carried out, unlike the Pearson correlation analysis, the model fitting showed much better results when the material groups were not categorized by their structural parameters, mainly due to the fact that by categorization the model that can be fitted is limited to be a linear one

which proved insufficient to predict the behaviours of 3D printed samples.
So, the differentiation by structural parameters is not only not needed in the case of model fitting, but also produces much worse results, meaning that the effects of parameters cannot be predicted by a linear model.

Related publications: 2, 3
Related conferences: 3

3. Application possibilities

In my doctoral research, I established that carbon fiber-reinforced nylon specimens can be compared regardless of their specimen size and geometry. Then, with the inclusion of unreinforced and glass fiber-reinforced nylon materials the effect of the most important printing parameters on their mechanical properties has been presented, with special focus on the differentiation between structural parameters that can alter the parameter influences significantly. Thus, making a clear case for separating specimen groups using structural parameters for better understanding the relation between printing parameters and mechanical properties.

Furthermore, with the fitting of a polynomial model I predicted the mechanical properties based on the printing parameters with excellent model performances. However, the same approach of separating specimen groups using structural parameters made the prediction significantly worse, so for this aim it is not beneficial.

List of publications

Publications which form the basis of the doctoral dissertation

1. Kámán, A., Meszlényi, A., Jakab, M., Kovács, A., & Egedy, A. (2025). Effect of Geometry and Size on Additively Manufactured Short-Fiber Carbon-Nylon Composite Under Tensile Loading. *Polymers*, *17*(3), 401. IF: 5.8 (2025), (Q1)

2. Kámán, A., Balogh, L., Tarcsay, B. L., Jakab, M., Meszlényi, A., Turcsán, T., & Egedy, A. (2024). Glass fibre-reinforced extrusion 3D-Printed composites: experimental and numerical study of mechanical properties. *Polymers*, *16*(2). IF: 5.8 (2025), (Q1)

3. Kaman, A., Balogh, L., Jakab, M., Meszlenyi, A., Tarcsay, B. L., & Egedy, A. (2023). The effect of 3D printing process parameters on nylon based composite filaments: Experimental and modelling study. *Chemical Engineering Transactions*, *100*, 481-486. IF: 0.88 (2025), (Q3)

Conferences which support the basis of the doctoral dissertation

1. Kámán András, Egedy Attila, Jakab Miklós: Próbatest méretének és alakjának hatása az extrúziósan 3D nyomtatott nylon szálakra, 53. Műszaki Kémiai Napok Konferencia Absztrakt kötet 2025, Veszprém: Pannon Egyetemi Kiadó, p. 40. (2025), ISBN: 9789633962992

2. Kámán András, Egedy Attila, Jakab Miklós: Kompozit anyagrendszerek vizsgálata 3D nyomtatási technológiákban, Pannon Egyetem, Mérnöki Kari Tudományos Konferencia 2021. szeptember 15., Veszprém: Pannon Egyetem, p. 22. (2021), ISBN: 9789633962152

3. Kámán András, Egedy Attila, Jakab Miklós: Nylon bázisú extrúziós 3D nyomtatott testek szimulációs vizsgálata, Műszaki Kémiai Napok 2024 Konferencia, Veszprém: Pannon Egyetem, p. 49. (2024), ISBN: 9789633962800

4. Kámán András, Egedy Attila, Jakab Miklós: Nylon bázisú extrúziós 3D nyomtatott testek kísérleti és szimulációs vizsgálata, Műszaki Kémiai Napok 2023 Konferencia, Veszprém: Pannon Egyetem, p. 47. (2023), ISBN: 9789633962565