STUDY ON THE INFLUENCE OF PROCESS PARAMETERS ON SURFACE PROPERTIES OF ADDITIVELY MANUFACTURED PARTS

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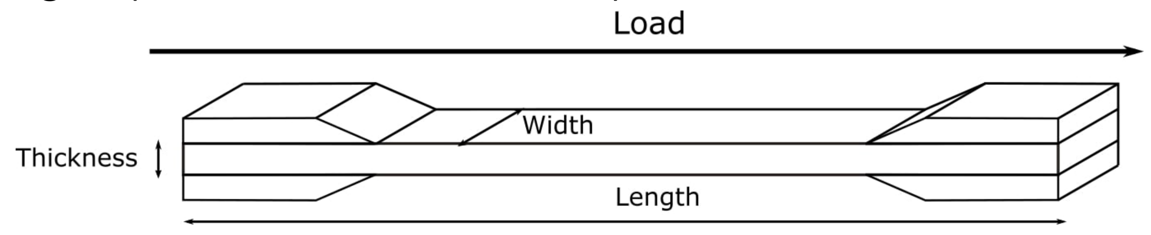
Introduction

- Additive Manufacturing (AM) offer several advantages: *in-situ* production of parts, the ability to make complex structures due to topological optimization, the reduction of waste by depositing material only where it is needed. The most widely used **Fusion Deposition Modeling (FDM).**
- For printing **techno-polymers**, AM machines with special features are used, such as the building chamber heated up to high temperatures and nozzles suitable for high printing temperatures and to resist damage due to carbon fibres in the filament. To use this technology for full scale component manufacturing, it is necessary to control the quality and the properties of components, using simple and repeatable methods.
- In this study, **surface roughness** was chosen as control parameter of the parts printed in C-PEEK. Based on the machine knowledge, this value vary according to the process parameters chosen and are indicative of quality of the printing and of possible problems during manufacturing. This method would allow an **early evaluation** of the process parameters variation and its influence on the printed parts, thus providing good potential for optimization of the process parameters of the machine and for tuning them with the desired material properties.

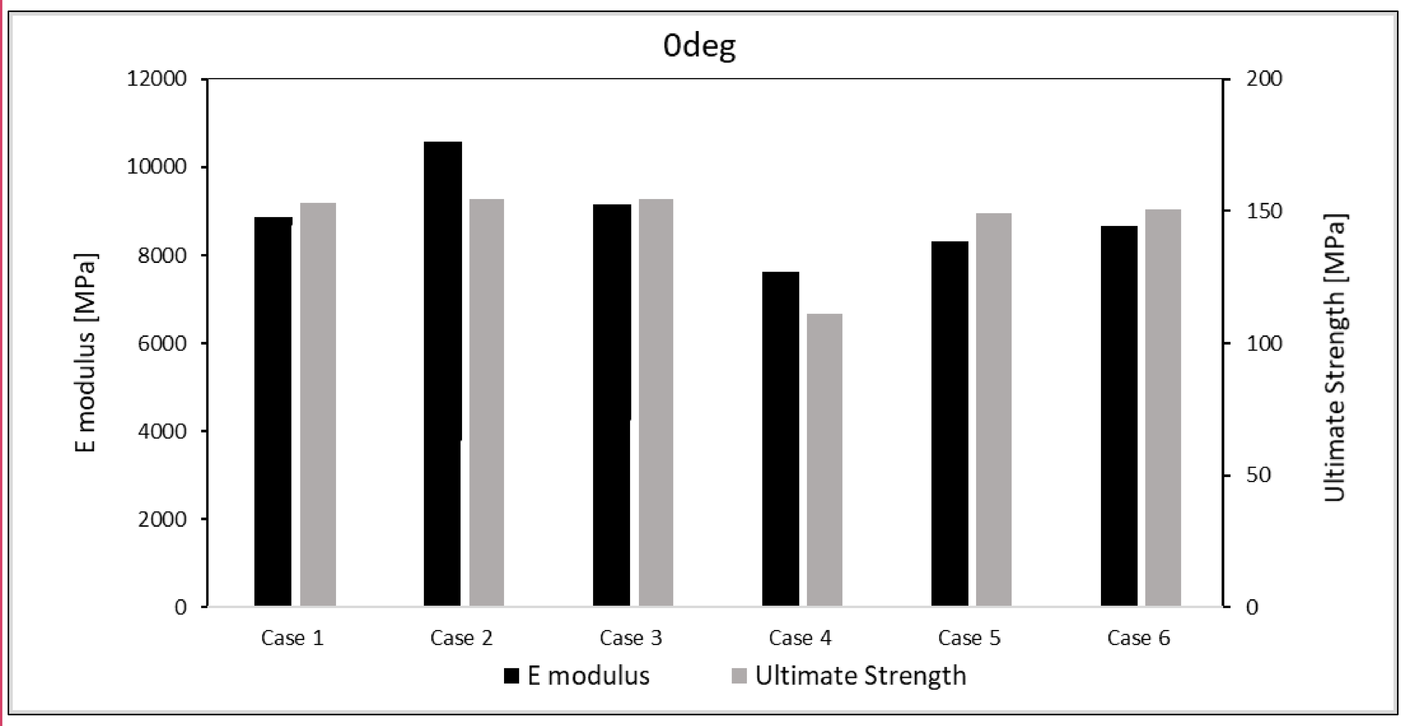
Materials and methods

- **Carbon PEEK** specimens were produced using the **Roboze Argo500 3D printer** and the commercial material Ketaspire® CF10 LS1 AM Filament. The filament is made by PEEK matrix reinforced with 10% of short carbon fibres.
- All specimens were printed with an **infill rate of 100%** and a **printing strategy of 0°**, using two different Argo500 printers and three different batches of filament.
- The roughness of the specimens is measured by a roughness meter, the porosity is evaluated by specimen weight and Optical Microscope (model Hirox RH – 2000) analysis of the cross section.
- **ASTM D3039** was used for specimen preparation and tensile testing and the nominal dimensions of the samples are 4.05mm x 25.4mm x 254mm. The tabs used are Aluminium alloy (EN AW 6082) and were attached to the specimens through a two-component epoxy glue (Araldite 2031-1 Huntsman).

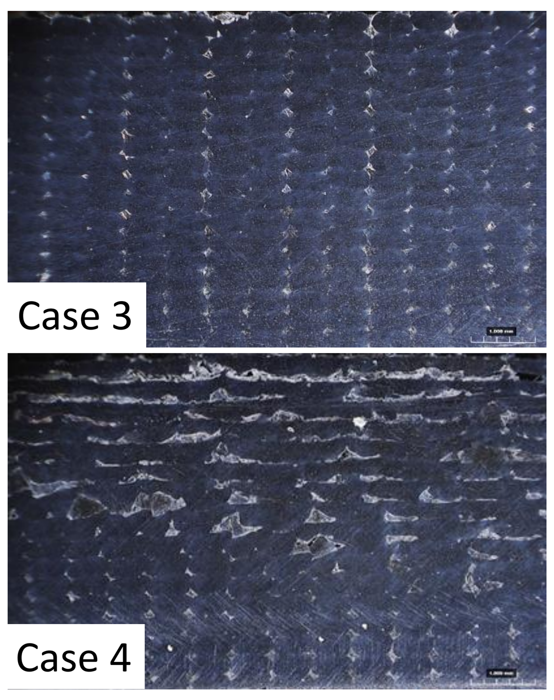


Standard specimens for tensile tests according to ASTM D39.

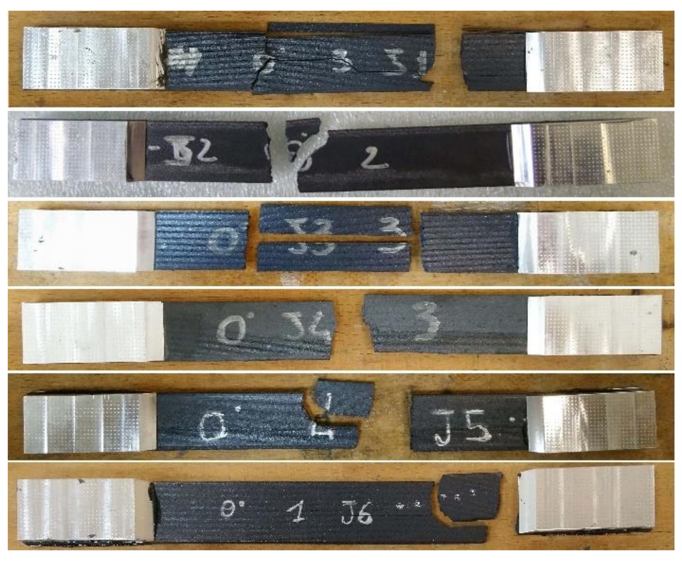
Results and discussion



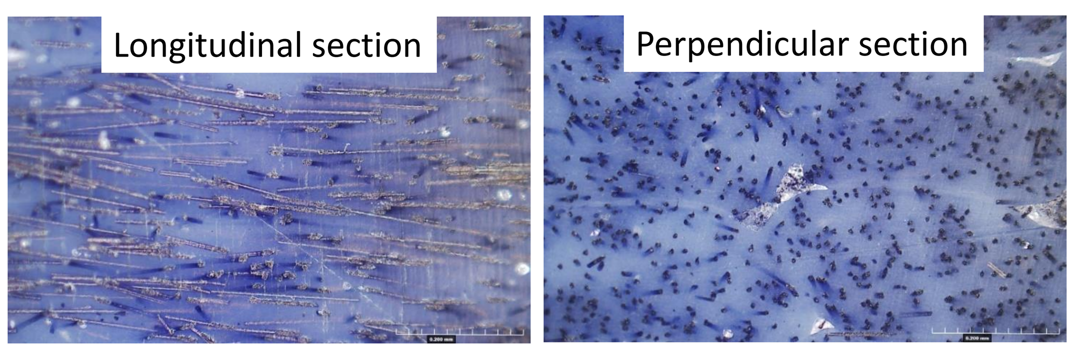
- **Case 1, 2, 3 and 6**: Ultimate Strength and modulus present good values and low standard deviation. For Case 2 testing was performed using different instrumentation (SG for the modulus and INSTRON as test machine).
- **Case 4**: average E modulus is 7630 MPa and the average Ultimate Strength is 111 MPa, lower compared, for example, with Case 3 with an E modulus of 9290 MPa and Ultimate Strength of 156 MPa.
- **Case 5**: one specimen has an Ultimate Strength of 131 MPa, lower than the average. This specimen has the same cross-section as the 0° specimens in Case 4 and the same high surface roughness.



- **Optical Microscope cross-section** images: specimens in Case 4 have a larger amount of pores and these are distributed unevenly in the cross-section. Some pores are very enlarged and prevent adhesion between the layers, lowering the mechanical performance.
- In the table the values of **roughness** of all the specimens tested are reported. Higher is the roughness measured, lower are the mechanical performances.
- Case 4 specimens, which exhibited lower mechanical properties than the other Cases and higher porosity, show higher roughness along both 0° and 90°. The same thing can be observed for specimen number 4 of Case 5.



The contribution of Carbon fibres within the PEEK matrix was evaluated through observations of the sections by OM and SEM. Carbon fibres are all **strongly oriented in the direction of extrusion** of the filament. This contributes to increase the mechanical properties of the 0° specimens, while it does not provide many benefits to the 90° specimens, as the fibres do not contribute to reinforce the adhesion between the filaments.



Specimen ID	Roughness along 0° [Ra] - average	Roughness along 90° [Ra] - average	E [GPa]	σ_{max} [MPa]
Case 1_1	7.19	19.65	8887	150
Case 1_2	7.66	19.38	8679	152
Case 1_3	6.45	19.82	8966	152
Case 1_4	7.46	18.18	9007	157
Case 1_5	9.71	18.13	8751	150
Case 2_1	8.93	17.41	10163	148
Case 2_2	9.45	16.86	9877	147
Case 2_3	6.41	17.78	10492	158
Case 2_4	7.16	16.76	11169	163
Case 2_5	8.96	17.09	11247	157
Case 3_1	7.91	18.16	8980	155
Case 3_2	7.17	18.38	8616	150
Case 3_3	5.50	18.09	8887	158
Case 3_4	6.06	18.18	8995	158
Case 3_5	9.63	17.10	10296	155
Case 4_1	16.12	38.86	7517	110
Case 4_2	15.69	25.72	7400	107
Case 4_3	14.54	25.14	7766	110
Case 4_4	14.74	25.54	7695	118
Case 4_5	13.15	25.02	7772	116
Case 5_1	8.86	19.26	8463	152
Case 5_2	7.63	19.04	8747	156
Case 5_3	8.91	18.61	8632	156
Case 5_4	20.76	26.25	7441	131
Case 5_5	6.88	17.89	8327	150
Case 6_1	5.68	17.77	8909	156
Case 6_2	7.11	19.24	8670	154
Case 6_3	8.92	17.87	8048	141
Case 6_4	6.82	17.55	8690	143
Case 6_5	6.95	16.24	9036	157

Conclusions

- From this preliminary characterization of the Carbon PEEK Ketaspire® CF10 printed with the Roboze Argo500 machine, it was possible to compare two different parameters: the machine and the batch of material.
- The specimens were printed in **six different Cases** by varying three batches of material and two machines of the same type, to observe the influence of these factors on mechanical tests.
- **The greatest influence is given by the machine used**: it seems that the specimens produced with Printer 1 (Cases 1, 2 and 3) have less dispersed and more repeatable results than those of the specimens obtained with Printer 2 (Cases 4, 5 and 6).
- This aspect has been confirmed by the comparison between the roughness measured in the two direction and the mechanical properties.
- This results can be traced back to differences in the extrusion temperature and more generally to the **machine hardware**. Better process control would be required to ensure repeatability of results on all machines.

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