# Mechanical performance of a 3D-printed Distributed Fibre Optic Sensor (DFOS)

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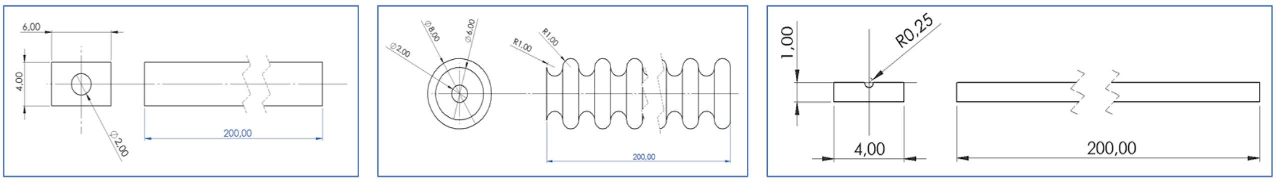
**Abstract.** Additive manufacturing was chosen as an approach to optimise the strain measurement accuracy of Distributed Fibre Optic Sensors (DFOS). The mechanical performance of three polylactide sections was tested, concluding that thinner sections with low rigidity tend to have a ductile behaviour, while higher geometric inertia but insufficient section thickness results in brittle failure. Additionally, strain measurements showed complex deformation modes and clear signs of anisotropic behaviour. Complementary tests are in course; however, geometry and material anisotropy were identified as key factors governing the mechanical behaviour.

## Introduction

In the last decade, DFOS have experienced a rise in demand in numerous fields, replacing the traditional gauge sensors in mechanical strain measurement. Their success is explained by their numerous advantages such as immunity to electromagnetic interference, practicality (light weight and small size), and long operational distances [1]. In addition, DFOS offer high accuracy measurements along the entire length of the optical fibre [2], making them more efficient than other point sensors, especially for large scale monitoring.
When using this sensor, it is expected to obtain high precision values of the strain experimented by the host structure. However, the presence of the protective layer and adhesives, introduce an interference between the sensing fibre and the host material, preventing full strain transfer [3]. Additive manufacturing (AM) offers a promising approach to regulate mechanical and geometrical properties [4], contributing to overcome the limitations in existing DFOS's strain measurements.

## Experimental methodology

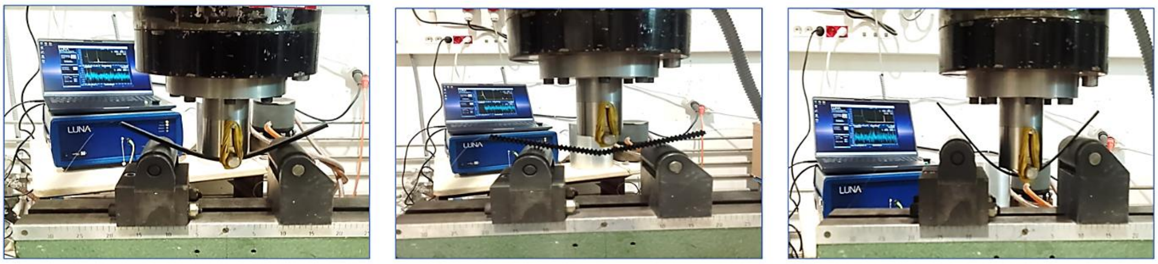
For this study, a fused deposition modelling (FDM) approach was chosen to conceive a fibre optic sensing cable (FOSC) that would allow to compare mechanical behaviour across three sections (Fig. 1) by embedding a polyamide coated fibre optic within a 3D-printed structure. For the aims of this research, the following parameters were adopted based in literature [5]: 0.3 mm layer height, 15% filling percentage, flat build orientation, and 45/90° raster direction.
The 3D printing workflow consisted on three steps. First, a 3D model was designed in SolidWorks. Then, a stereolithography (STL) file was exported into the 3D printer slicing software, followed by the generation of the G-code file to be executed by the 3D printer. All specimens were fabricated with polylactide (PLA), a material known for its versatility, affordability and ease of use [6].




a. Section a    b. Section b    c. Section c

Fig. 1. Sections under study (dimensions in mm)

For models a and b, a solid casing with a circular canal in the middle was printed to insert the fibre in the middle and fill the remaining space with adhesive epoxy. For model c, the process involved printing half of the casing's thickness, positioning the fibre within the canal, applying the adhesive and placing the remaining half of the casing over the fibre.
The mechanical resistance was evaluated using three-point bending tests, applying a constant displacement of 10 mm/min until failure. Simultaneously, the strain was monitored with an Optical Backscatter Reflectometer (OBR) interrogation unit. The experimental setup and its components are presented in Fig. 2. The data acquired by the testing machine (force vs deformation) and the interrogator (distance vs strain) were used to construct fitting curves and establish the relationship between these variables to evaluate their performance.



a. Section a b. Section b c. Section c

Fig. 2. Experimental setup for each tested section

## Results and discussion

From the preliminary mechanical tests performed, it has been observed that the printed FOSC exhibit different responses upon embedment in different shaped 3D-printed casings. Based on Fig. 3, there is an inverse proportional relationship between mechanical resistance and deformation. The specimen with the thinnest section and lowest rigidity (section c) showed the highest deformation under relatively low load, indicating ductile behaviour. In contrast, specimen b, with higher geometric inertia but insufficient section, exhibited brittle failure. Specimen a, illustrates a balanced compromise between the geometric inertia and a thicker section.

From Fig. 4, strain measurements reveal non-uniform behaviour across sections. Peaks do not align consistently, at a certain point one section may be in tension (positive strain) and in another in compression (negative strain), indicating complex deformation modes, such as combined bending and torsion rather than pure axial strain. In addition, strain distribution is not smooth but exhibits rapid sign change over a short distance, suggesting local stiffness variations and discontinuities in load transfer. These features indicate that specimens do not behave as a homogeneous beam but reflect the inherence of anisotropy and structural heterogeneities of additively manufactured elements.

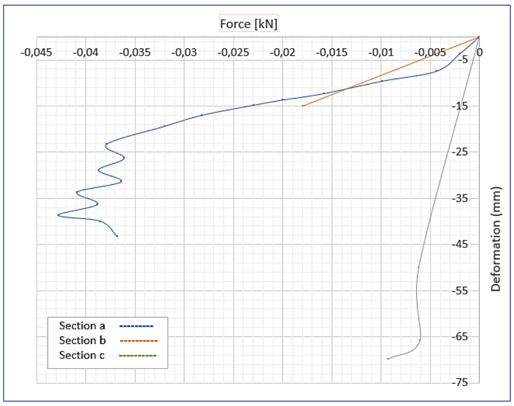



Fig. 3. Force-deformation curve

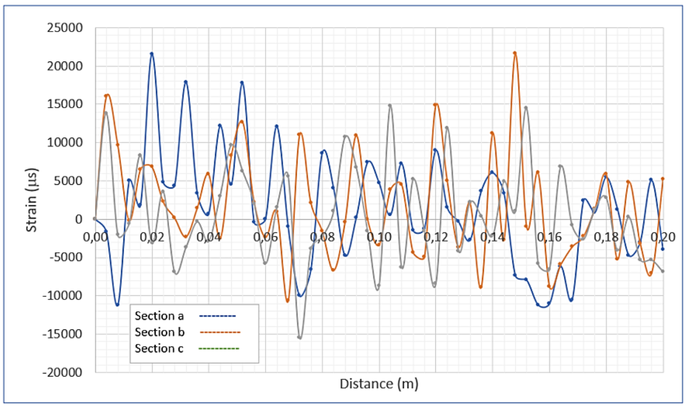



Fig. 4. Strain curve before failure

## Conclusions

Further investigation is required; however, results show that strain measurement precision in FOSCs is significantly affected by mechanical and geometrical properties. Thus, to improve their accuracy and optimise sensor design, a strain transfer analysis needs to be performed taking into account the anisotropic nature of AM components. This would be especially relevant for the development of customised manufactured sensing cables for engineering applications.

## References

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