The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

Experimental and numerical investigation on development of 4D printed actuators with integrated temperature-controlled triggering system.

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Key Words: *4D printing, FEM, thermal-electrical-mechanical simulation*

3D printing is becoming a widely used technology for designing complex geometries [1]. The 3D printing process can be implemented in numerous ways [2]. A common technique is Fused Deposition Modelling (FDM), which uses filaments made from different kinds of materials, such as thermoplastic, metal, wood or composite. [3]. Combining different materials in a 3D printed device will allow us to program a particular area and activate it with heat, water, chemical reaction, pressure, and many other external influences. The self-bending actuator is formed by a conductive dual polymer in which one component remains elastic and the other presents variable stiffness depending on the applied temperature, resulting in a reversible switch [4]. Due to the fact that the actuator is warmed by an external source, the main disadvantage of this approach is the difficulty of controlling the temperature along large structures. The response will also vary with the ambient temperature. The emergence of conductive filaments made of carbon particles reinforced thermoplastic allows to print integrated electrical circuits on 3D parts. Conductive filaments allow us to heat a specific area of the actuator from the inside, thus reducing the main drawback.

In this investigation we have developed a 4D printed actuator with an integrated temperature controlled triggering system. The actuation is possible thanks to the following programming steps: (a) Self-heat the actuator above the glass transition temperature (Tg). (b) Stretch the actuator while above Tg. (c) Cool the actuator below Tg while holding the displacement & (d) release the displacement. We have studied the influence of the programming steps parameters on the actuation and compare the results with a thermal-electrical-mechanical simulation on Abaqus. After the programming steps, the 4D printed actuator is bending and recovering to return to its initial position. Results of the FEM model are in good agreement with the experimental results (figure 1) and the numerical model can predict accurately the behavior of the actuator during the programming and the actuation steps.

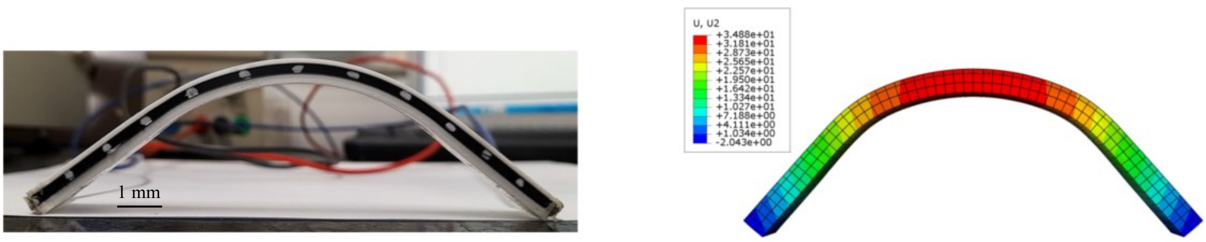

Figure 1: Comparison between the experimental and numerical results after 235s of heating in the actuation step subsequent to programming steps

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