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Multiphysics Modelling for Polymer Additive Manufacturing Technologies

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Polymer additive manufacturing (AM) technology is a relatively young and highly versatile manufacturing process which focuses on creating intricate geometries that would be difficult or impossible to achieve with other manufacturing methods. It is a type of AM that involves the layer-by-layer construction of three-dimensional objects using polymers as the raw material. Polymer AM has the potential to revolutionize the manufacturing industry, enabling faster and more cost-effective production of parts and components. This technology offers immense opportunities for innovation and design, making it an exciting area of research and development. The study works on Multiphysics modelling for two leading polymer AM, selective thermoplastic electrophotographic process (STEP) and selective laser sintering (SLS).

STEP utilizes a combination of electrostatic forces, heat, and pressure to deposit and fuse thermoplastic powder into 2D layers, creating a final 3D structure. Notably, STEP is capable of producing parts with complex details using multiple materials, and it is highly efficient, making it ideal for high-volume production. The thermomechanical model was proposed to simulate warpage and dimensional defects of the final products and was further validated by sensor data, measurements, and statistical models. Besides, the work also provided a comprehensive parametric study of the process. SLS employs a laser as a heat source to sinter polymer particles together and creates a 3D object. Compared to conventional manufacturing methods, SLS is easy to set up and can be done quickly. SLS is widely used for rapid prototyping and experimental applications due to its ability to produce high-fidelity, robust, and isotropic products. In SLS, the thermos-fluid dynamic model was used for melt pool morphology prediction, which has a significant impact on the stability of the process and quality of the product, such as surface roughness and stiffness. Similarly, the model was validated by experiments.

The incorporation of a Multiphysics model is a crucial aspect of constructing digital twins, as it provides a comprehensive understanding of processes from a physical standpoint. By analyzing the physics behind the system, the Multiphysics model can simulate the behaviour and performance of the digital twin in different scenarios, enabling better prediction of its real-world behaviour. The development of digital twins for an additive manufacturing process represents a crucial step toward improving the efficiency and effectiveness of manufacturing processes. The potential benefits of using a digital twin for process optimization are significant, including reductions in production costs and improvements in product quality. By simulating the manufacturing process digitally, engineers can identify potential problems before they occur and make adjustments to the process to prevent them.

Primary author: Mr YEH, Hao-Ping (Technical University of Denmark)

Co-authors: ROTARI, Marta (DTU Technical University of Denmark); Mr SHAN, Shuo (Technical University of Denmark); Mr MEINERT, Kenneth (Technical University of Denmark); Prof. HENRI HATTEL, Jesper (Technical University of Denmark); KULAHCI, murat (DTU)

Presenter: Mr MEINERT, Kenneth (Technical University of Denmark)

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