Computational Fluid Dynamics Modelling of Material Extrusion Additive Manufacturing

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Computational Fluid Dynamics Modelling of Material Extrusion Additive Manufacturing

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Introduction: In Material Extrusion Additive Manufacturing (MEX-AM), a component or structure is fabricated in a layer-by-layer manner on a substrate/support. MEX-AM covers several techniques such as “Fused Deposition Modelling (FDM) or Fused Filament Fabrication (FFF)”, “Robocasting”, and “Contour Crafting (CC) or 3D Concrete Printing (3DCP)”. A wide range of materials has been used in MEX-AM such as thermoplastics, thermosets, reinforced polymers, ceramics, hydrogels, and concrete. The processing conditions applied for the material varies, but is hereinafter subdivided into two categories: thermoplastic printing and wet-on-X printing, where X could be wet, semisolid, or solid, cf. [1-6].

Wet-on-X printing:

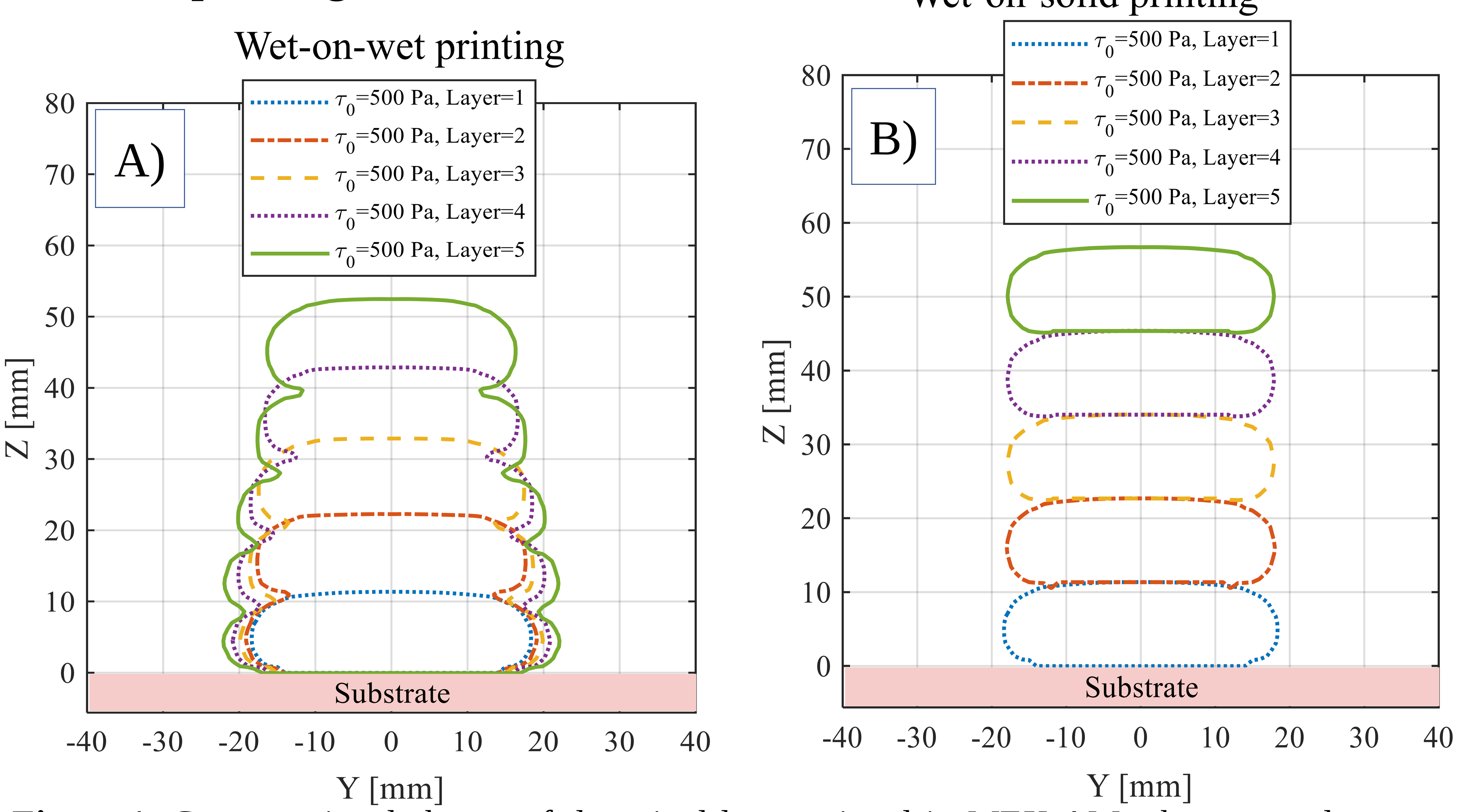

Figure 1: Cross-sectional shapes of deposited layer printed in MEX-AM when a wet layer was printed onto the substrate for the first layer and later on the wet (A) and solid (B) printed layer.

Computational Fluid Dynamics (CFD) models were developed to predict the 3-dimentional extrusion-deposition flow of materials during the wet-on-X printing in MEX-AM. The model explained the morphology of the deposited strands and captured the deformation of the strands in printed layers during printing the next layer on top. Strands printed wet-on-wet got deformed and found non-trivial to stabilize (no deformation) by changing different material and processing conditions, cf. Fig. 1A [1]. In contrast, the wet-on-solid printing showed stable printing but it was found detrimental to the interlayer bond, cf. Fig. 1B [1]. A novel CFD model was developed to predict the wet-on-semisolid printing that found a certain solidity (yield stress buildup) of the printed strand is able to withstand the printing layer without being deformed, cf. Fig. 2C (wet-on-wet) and 2D (wet-on-semisolid) [2, 3].

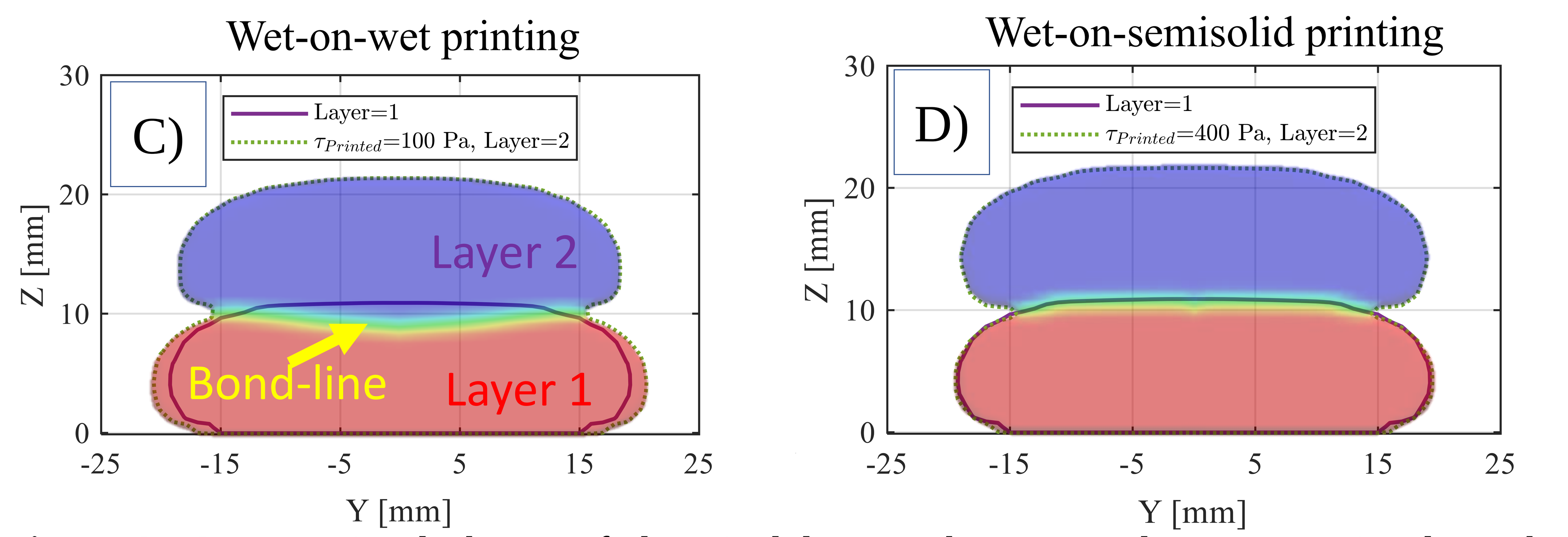

Figure 2: Cross-sectional shapes of deposited layers when a wet layer was printed on the previously printed wet (C), and semisolid (D) layers.

Wet-on-wet printing of reinforcement bar (rebar) integration in 3DCP: CFD model was developed to investigate the in-process rebar integration in 3DCP. The simulated model captured micro-level air void formation during the process and defined how to remove them, cf. Fig. 3 [4].

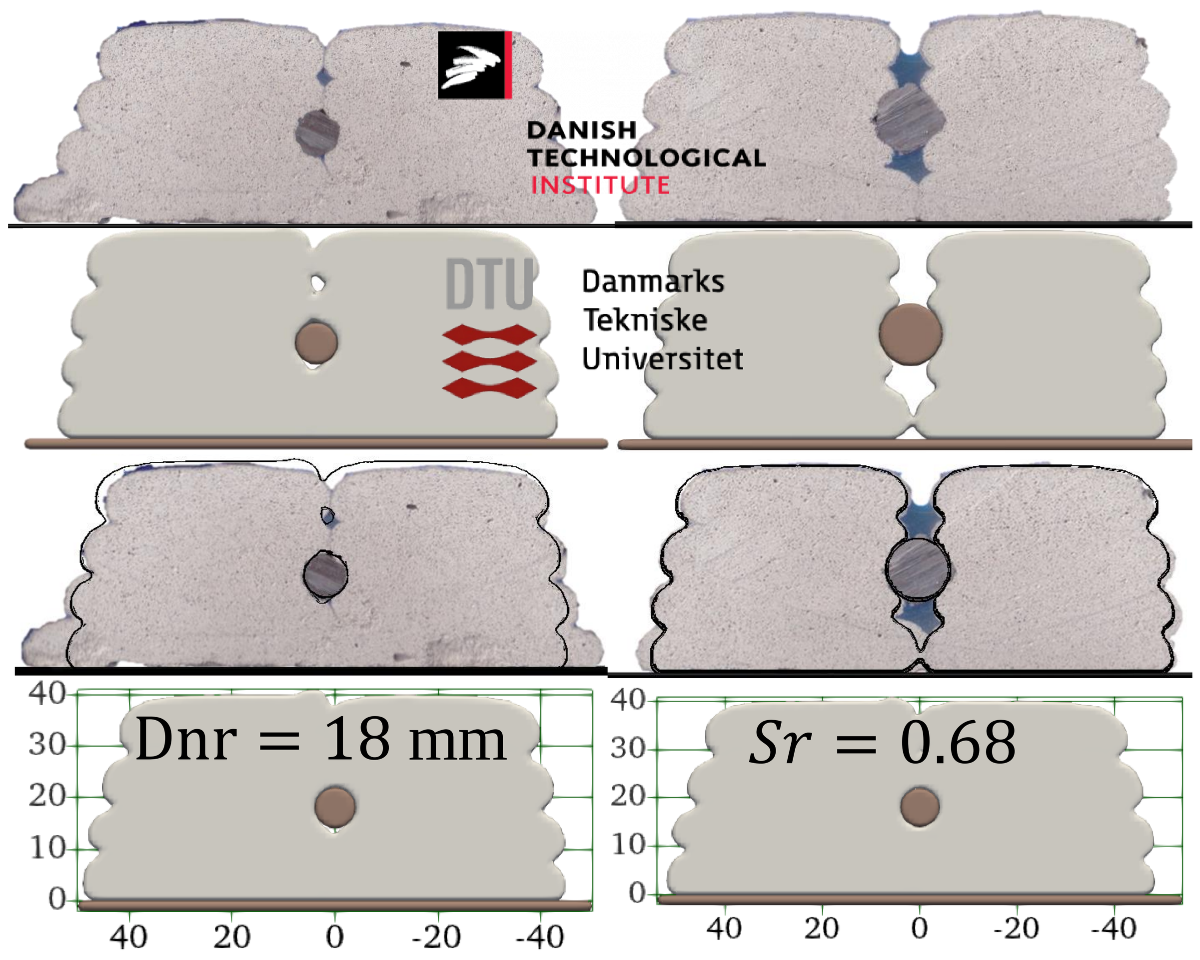

Figure 3: In-process rebar integration and air void.

Thermoplastic printing: CFD model was developed to predict the corner formation in thermoplastic printing. During printing a corner, defects such as corner rounding, corner swelling, and corner ringing are often observed. The model could predict those defects from different angles, as seen in Fig. 4 [5]. Finding an optimal condition to avoid such defects is the ongoing study's goal. Furthermore, a few studies were performed to predict thermoplastic printing through the hot end to optimize its geometry [6, 7].

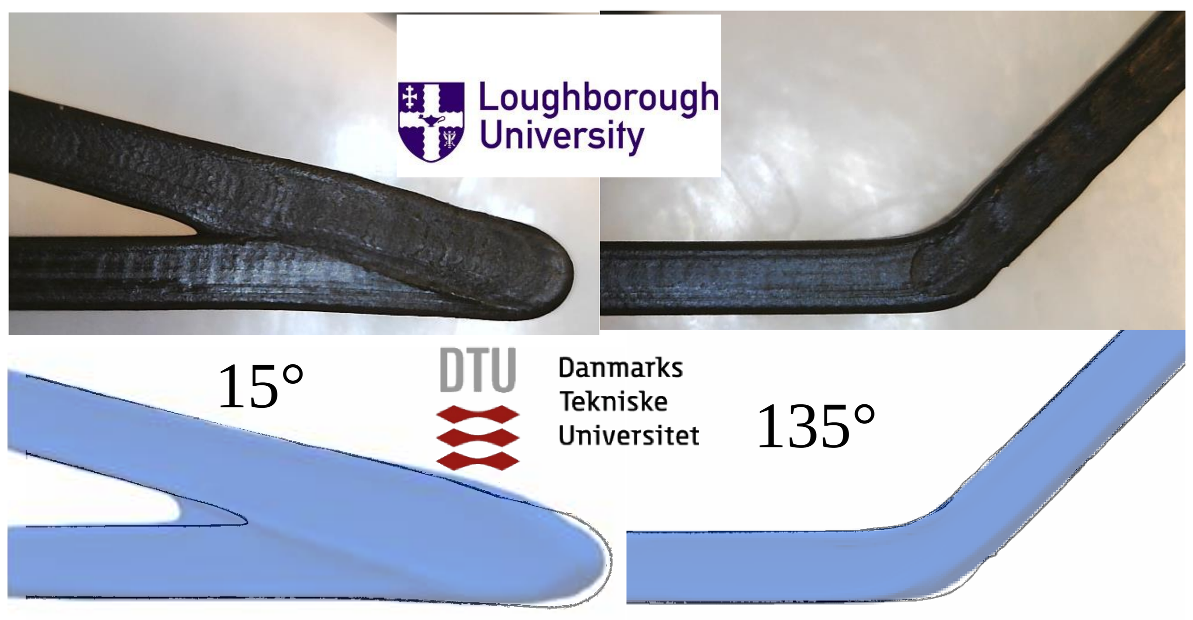

Figure 4: Corner printing in thermoplastic MEX-AM.

Conclusions: Several CFD models were developed to understand the morphology of strands deposited in different MEX-AM technologies. Finally, the models gave a framework to avoid problems like deformations at printed layers, air void formation, and corner defects.

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