Simulation Of Multilayer Extrusion-based 3D Printing Using Level Set And Moving Mesh Methods

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Abstract

Numerical simulation of 3D printing processes is complex because it requires tracking the free surface of the ink while considering the (relative) horizontal and vertical movements of the system. By coupling the Navier-Stokes equations with the level set method (i.e., Two-phase flow multiphysics in COMSOL), it is possible to simulate the deposition of a single strand and analyze the effects of the printing settings on its shape. However, these two components are not enough to simulate multilayer printing because the relative motion of the system cannot be directly included in the boundary conditions. In this work, we propose the use of a moving mesh to add the vertical motion of the printer and enable multilayer printing simulations. To the best of our knowledge, this is the first time that the level set method and moving mesh methods have been combined to simulate multilayer printing in COMSOL. The process is represented with one subdomain for the nozzle and another for the print bed, but the prescribed mesh motion is only applied to the bottom wall of the bed. Furthermore, only half of the domain is considered to reduce the computational cost. The fluid dynamics is modeled with a creeping flow physics and includes symmetry, open, and wall boundary conditions. The horizontal motion of the bed is imposed with a translational velocity in the x direction. In the level set method, we adjusted the reinitialization and interface thickness parameters by making sure that the mass is conserved in the first layer printed. We simulate the printing of two layers of concrete to evaluate the proposed approach. All the dimensions and settings are based on the work in [1], and for simplicity, the constitutive model only considers the viscoplastic effects with the Bingham-Papanastasiou model. Despite the variations in the constitutive model considered in this work, the results are consistent with the reference study. Finally, the methodology proposed in this work opens up the possibility of simulating more complex scenarios, not only for extrusion-based printing but also for two-phase simulations in general.

Reference

[1] Spangenberg, Jon, et al. “Numerical Simulation of Multi-Layer 3D Concrete Printing.” RILEM Technical Letters, vol. 6, Oct. 2021, pp. 119–123. DOI.org (Crossref), https://doi.org/10.21809/rilemtechlett.2021.142.

Figures used in the abstract

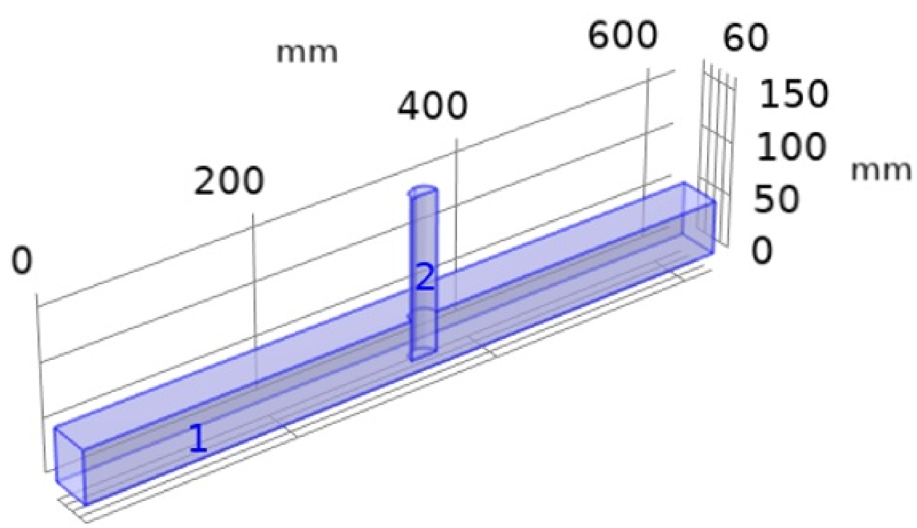

Figure 1: Geometry considered for the simulation

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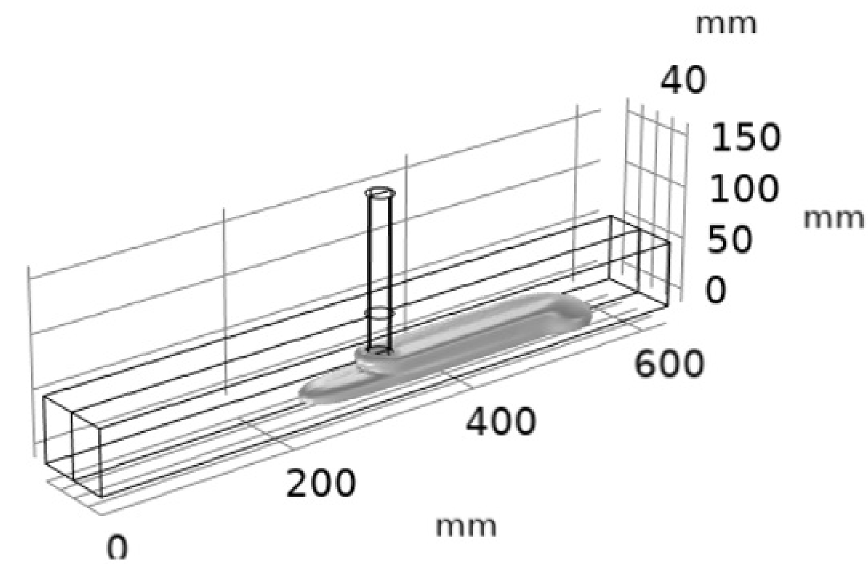

Figure 2: Volume fraction of fluid for level set = 0.5 (Ink)

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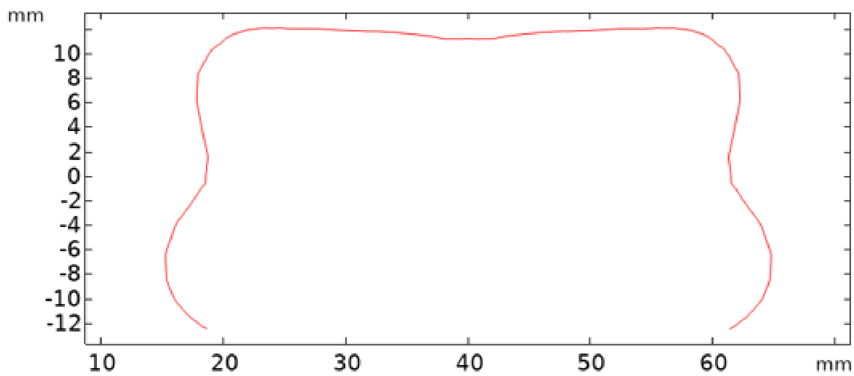

Figure 3: Cross-section of the 2 layers printed

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