3D Finite Element Simulation of Polymer Extrudate in FDM 3D Printers

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ABSTRACT

In this work, 3D finite element simulation of the nozzle region of a FDM printer was performed using COMSOL software. The polymer exiting the nozzle of the FDM printer was also included in the simulation in order to capture the dimensional behaviour of the polymer. The domain for the simulation consisted of a nozzle with 0.4 mm diameter, printing table, and the surrounding air. In the simulation, mass and momentum equations were solved to determine the flow characteristics of the polymer along with one transport equation to determine the interface between the polymer and ambient air using level set method.

Simulation was completed for ABS material with a feed rate of 40 mm/s. Based on the feed rate, the average velocity at the entrance of the nozzle region was determined. The average velocity at the entrance was increased from zero to steady state in one second. In order to enforce the relative movement between the nozzle and the printing table, the nozzle was kept stationary, whereas the section of the table where the polymer was located, had a constant relative velocity of 40 mm/s. Non-Newtonian characteristic of ABS polymer was included in the simulation using Cross model. The effect of temperature was not included in the simulation and the temperature of the polymer was kept constant at 220 ºC. The simulation was performed for a period of time taken to print a strip with a length of 90 mm.

One experimental specimen with 30 strips was printed using a 3D printer. In the CAD model of the specimen, each strip had a width of 0.4 mm which was equivalent to the nozzle diameter. While printing, it was ensured that the nozzle had only one continuous vertical movement to print each strip. The printed strips were measured with a caliper at five different locations and the results showed that the average width of the strips changed from 0.41 to 0.46 mm along the printing direction. This behaviour was also observed in the simulations due to the initial movement of the polymer. The numerical results had a good agreement with the experiments and the difference between the numerical and experimental results of strip width were less than 10%. Taking into account the non-isothermal behaviour of polymer in the simulations is expected to decrease the discrepancies between the experimental and numerical results.