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

NUMERICAL MODELING OF THE EXTRUSION PROCESS IN FUSED FILAMENT FABRICATION

Mehul Lukhi*, Christoph Mittermeier, Josef Kiendl
Institute of Engineering Mechanics and Structural Analysis, Bundeswehr University Munich
mehul.lukhi@unibw.de

Key Words: *Fused Filament Fabrication, Arbitary Langrangian-Eulerian Method (ALE), Viscoelastic model, Residual Stresses*

Fused Filament Fabrication (FFF) is the most widely used extrusion-based additive manufacturing process. To understand and improve the FFF process, it is necessary to perform experimental and numerical investigations. The mechanical behavior of polymer is viscoelastic one but for simplicity, polymer flow is often considered as a generalized Newtonian flow for the numerical modeling of the FFF process [1]. For the realistic modeling of the FFF process, it is necessary to consider polymeric flow as a viscoelastic one. Comminal et al. [2] have considered a viscoelastic constitutive model for FFF modeling but their work is limited to the 2D planar case. An integrated model is developed which aims to include solid polymer filament melting inside the liquefier, flow inside the nozzle and flow through the nozzle orifice, and polymer deposition on the printing bed in a single model. In this study, 3D viscoelastic FFF simulations for polylactic acid (PLA) are performed. The conservation of mass, linear momentum, and energy equations (Navier-Stokes equations for incompressible fluid) are solved using the Finite Element Method and the free surface is resolved using Arbitrary Lagrangian-Eulerian (ALE) method for the deforming mesh. For this purpose, the commercial Finite Element software Ansys Polyflow is used. Most researchers have used analytical models and thermomechanical analysis to numerical investigate warpage and residual stresses [3]. There are also numerical studies, e.g., Cattenone et al. [4] where residual stresses and distortions are calculated on the basis of thermal simulations, no extrusion. In this study, residual stresses are extracted from the FFF process simulation. Residual stresses from the simulation can be used for the 4D effect investigations. Along with this, various parametric studies regarding the effect of layer height, extrusion rate, and printing speed on the printing process are studied.

REFERENCES

[1] Bellini, A. (2002). Fused deposition of ceramics: a comprehensive experimental, analytical and computational study of material behavior, fabrication process and equipment design. Drexel University.
[2] Comminal, R., Hattel, J. H., & Spangenberg, J. (2017). Numerical simulations of planar extrusion and fused filament fabrication of non-Newtonian fluids. Nord. Rheol. Soc. Annu. Trans, 25, 263-270.
[3] Armillotta, A., Bellotti, M., & Cavallaro, M. (2018). Warpage of FDM parts: Experimental tests and analytic model. Robotics and Computer-Integrated Manufacturing, 50, 140-152.
[4] Cattenone, A., Morganti, S., Alaimo, G., & Auricchio, F. (2019). Finite element analysis of additive manufacturing based on fused deposition modeling: distortions prediction and comparison with experimental data. Journal of Manufacturing Science and Engineering, 141(1), 011010.