Explanatory Multiphysics Modelling of Generated Heat in Vat-Polymerization
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ABSTRACT

This research provides an explanatory simulation for the single shot grayscale lithography in a Multiphysics environment. There are a few well-known phenomena such as shrinkage, oxygen inhibition [1] and photo-bleaching/trapping [2] was previously observed in vat-polymerization. However, the intense local heat which is generated during the chemical reaction was not studied well.

Here, by employing a photolysis approach, the generated heat and its potential effects on the reaction rates and material properties will be investigated. The model solves a series of chemical reaction differential equations that model the evolution of chemical species (photoinitiator, monomer, and polymer) concentrations. Additionally, the model incorporates the effects of oxygen inhibition, species diffusion and thermal expansion/contraction.

The simulation result shows that the locally generated heat as a dependent parameter of the polymerization reaction rates can abruptly increase the temperature in the exposed area. It also aggravated by the low thermal conductivity of polymeric material. This temperature increases suddenly when the reaction started and gradually cools down by dissipating heat. A non-contact thermometer (IR-camera) is utilized for experimental measurement of the temperature at exposed area. The experimental result approves the simulation data.

Our simulation reveals a sharp thermal gradient between the exposed and unexposed region in the vat photopolymerization. For single layer analysis, it will cause thermal expansion and contraction along the layer. On the other hand, increased temperature more than polymer glass temperature will reduce the young modules which are desirable for releasing inter-layer tensions in multi-layer processes.

REFERENCES

[1] A. S. Jariwala et al., “Modeling effects of oxygen inhibition in mask-based stereolithography,” Rapid Prototyp. J., vol. 17, no. 3, pp. 168–175, Apr. 2011.

[2] M. M. Emami and D. W. Rosen, “An Improved Vat Photopolymerization Cure Model Demonstrates Photobleaching Effects,” in 29th Annual International Solid Freeform Fabrication Symposium, 2018.