

Experimental investigation and material modelling of the photopolymers for DLP additive manufacturing process

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Digital light processing (DLP)-based additive manufacturing is one of the innovative fabrication methods that builds 3D objects with complex geometry in a layer-by-layer fashion, via simultaneous in-plane photopolymerization [1]. During the UV curing process, the material properties and final product geometries change considerably due to the process parameters. Therefore, reliable and experimentally validated constitutive models are required for the numerical simulations to predict the material behaviour during and after the printing process [2,3].

This work presents experimental investigations as well as material modelling techniques to predict the influence of process parameters on viscoelastic properties. A commercial acrylate-based photosensitive resin PR48 (Colorado Photopolymer Solutions) is used for material characterization. 3D objects are fabricated by curing in a UV chamber (UVP Crosslinker, Analytik Jena) and printing with an Ember DLP 3D printer (Autodesk). Our interest is focused on the effect of the UV light intensity, temperature and frequency on the degree of cure-dependent viscoelastic properties.

Firstly, differential scanning calorimetry (DSC) tests are carried out for the thermal characterization of the PR48 liquid resin. Besides, the specific heat capacity is determined for the almost completely cured and uncured samples with the DSC measurements. Photo-DSC experiments are performed to investigate the curing reaction and modelling of the evolution of the degree of cure depending on the light intensity and temperature. The change in the degree of cure dependent viscoelastic properties is measured with UV rheometry below the gelation point and dynamic mechanical analysis (DMA) beyond the gelation point. Time-temperature and time-cure superposition principles are applied to the experimental results obtained by the DMA. In addition, chemical shrinkage behaviour is captured as a function of the degree of cure by the high-precision balance setup. UV curing properties of the resin are assessed with the thickness measurement by optical tomography. As a result of our experimental studies, model equations are proposed to describe the material behaviour. The model parameters and the constitutive relations for the reaction kinetics are identified to represent the experimental data.

This experimental work has revealed that the viscoelastic properties of the photopolymer have a strong dependency on both the temperature and the degree of cure during and after the photopolymerization reaction. This presentation will highlight that the assumption of linear-elastic material behaviour is insufficient for the numerical simulations.

References

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