Material modelling of UV curing polymers for additive manufacturing processes

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ABSTRACT

Additive manufacturing is an innovative technology to create three-dimensional objects with complex geometry. Although the technology has been used in industrial applications like rapid prototyping and rapid manufacturing for several decades, reliable and experimentally validated models for the design of printed components are still missing. Especially the constitutive modelling and finite element analysis of UV curing polymers for additive manufacturing processes are challenging tasks.

This contribution presents a general framework to model the curing behaviour of UV curing polymers which are used commonly in stereolithography (SLA) and digital light processing (DLP) [1]. A three dimensional model of thermoviscoelasticity is developed with respect to mechanical, thermal and chemical effects. The mechanical part consists of an arrangement of springs and dashpots to cover viscoelastic behaviour. Generally, both springs and dashpots can be linear or nonlinear and depend as well on temperature as on the degree of cure. Time-temperature and time-cure superposition principles are applied in order to capture the long term behaviour of the printed components.

The degree of cure is modelled by a nonlinear evolution equation in terms of time, UV light intensity and temperature. Moreover, further parameters could be exposure time, wavelength and photo initiator concentration. A first proposal for the description of UV cure kinetics was given by da Silva Bartolo, see [2, eq. (10)]. If the curing temperature goes below the glass transition temperature of the curing polymer, the curing reaction is strongly decelerated or even stopped. This behaviour is taken into account by an empirical diffusion factor. Depending on the nonlinearity, the constitutive equations are processed for implementation.

Chemical shrinkage and thermal expansion are initially assumed to be isotropic. The subsequent measurements will show whether the assumption is justified. Since the accompanying research project is in an early stage, planned experiments will be presented. These include differential scanning calorimetry and rheometer measurements of UV curing polymers depending on light intensity, exposure time and wavelength. Additionally, the implementation into a commercial finite element program and the simulation of the layerwise application and curing of the material is presented. Also, the strategy for parameter identification based on experiments will be discussed.

REFERENCES

[1] Bennett, J. Measuring UV curing parameters of commerical photopolymers used in additive manufacturing. *Additive Manufacturing* (2017) **18**:203–212

[2] da Silva Bartolo, P.J. Photo-curing modelling: direct irradiation. *Int. J. Adv. Manuf. Technol.* (2007) **32**:480–491