Multiphysical modeling of the additive manufacturing process for ceramics

Citation for published version (APA):

Document status and date:
Published: 07/11/2017

Document Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 24. Apr. 2020
Multiphysical modeling of the additive manufacturing process for ceramics

S. Westbeek, J.J.C. Remmers, J.A.W. van Dommelen, M.G.D. Geers

Additive manufacturing (AM) is a potential breakthrough technology. However, before large scale adoption by industry different challenges need to be tackled: increasing the monolithic part density, increasing feasible product size and wall thickness and avoiding the formation of cracks [1]. A better understanding of the AM process for ceramics (as depicted in Fig. 1), is considered key in overcoming these problems [2]. This is pursued here through the development of a (micro-scale) multiphysical numerical finite element framework that focuses on the AM process, as illustrated in the following.

![Figure 1: Overview of the considered additive manufacturing process for ceramics. The project focus is on the highlighted box.](image)

**Light propagation modeling using a wave (electromagnetic) description**

The ceramic slurry, i.e. a suspension with ceramic inclusions in a photo-active monomer solution, is subjected to UV light (400 nm) to initiate a photopolymerization reaction. The propagation and homogeneity of the light through the matter is highly dependent on the inclusions. The figures show the response to a Gaussian shaped, pulsed light source with the intensity normalized by the maximum applied intensity. The considered geometries are $11 \times 11 \mu m^2$ with or without ceramic inclusions ($\varnothing 1 \mu m$).

**Photopolymerization kinetics**

The inclusions clearly induce an inhomogeneous conversion.

**Thermal balance equation**

The combined effect of the exothermic polymerization reaction and the absorption of light cause the temperature in the sample to increase. Temperature is homogeneous in the considered domain.

**Linear elastic thermo-chemical-mechanical modeling**

The project focus lies on relating process conditions and material properties to the build-up of residual stress and deformation. These effects result from the combined effect of solidification, thermal expansion and conversion shrinkage. When the bottom edge is assumed constrained in the vertical direction, the numerical results for stress and deformation (multiplied by a factor 2) are shown. An important conclusion from these simulation results is the more inhomogeneous cure when a ceramic filled polymer is considered, with more significant internal stresses.

References: