

SIZE EFFECT AND THE NOTCHED EFFECT IN 3D PRINTED COMPONENTS

Doctoral Thesis – Summary

for the attainment of the scientific title of Doctor at

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in the doctoral field of Mechanical Engineering

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The doctoral thesis entitled “Size effect and the notched effect in 3D printed components”, carried out within the Doctoral School of IOSUD – Politehnica University Timișoara, under the supervision of PhD supervisor Prof. Dr. Eng. Liviu MARȘAVINA, presents the results of the author’s research in the field of additive manufacturing.

Chapter 1: Evolution and Current State of the Art Regarding the Mechanical Properties of Specimens Manufactured Using Photopolymerization-Based Additive Manufacturing

Additive Manufacturing (AM), most commonly known as 3D printing, has developed rapidly over the past decades, becoming an important technology for producing prototypes used in various industries and customized specimens for testing new materials. 3D printing technologies based on vat photopolymerization, stereolithography (SLA), and masked stereolithography (mSLA) are increasingly used to manufacture various components from photopolymerizable resins, offering high accuracy and fine details that are difficult to reproduce using other methods.

Chapter 2: Mechanical Characterization of 3D-Printed Components Manufactured by mSLA

Masked stereolithography (mSLA) is a 3D printing technology used to rapidly manufacture polymeric components through photopolymerization. It belongs to the family of additive manufacturing technologies known as vat photopolymerization. A light source, such as a laser beam, LCD screen, or projector, is used to cure a liquid resin into a solid material through polymerization.

Chapter 3: Evaluation of the Size Effect in Photopolymerized Materials

The size effect is experimentally demonstrated in this work for the two investigated resins. The results are in agreement with the size-effect law proposed by Bažant Z.P. (2005). The main conclusion is that the presence of defects and the principles of Linear Elastic Fracture Mechanics (LEFM) must be considered when designing structures manufactured by photopolymerization.

Chapter 4: Results Regarding the Notch Effect

The Theory of Critical Distances (TCD) was adopted to evaluate fracture in components made of brittle materials containing stress concentrators. TCD represents an engineering approach for evaluating and predicting the behavior of materials containing defects, supporting the design and maintenance of structures in order to prevent catastrophic failure. Notches create localized regions of stress concentration, which can lead to premature failure.

Chapter 5: Evaluation of Mixed-Mode Fracture

This chapter investigates mixed-mode fracture in specimens manufactured by mSLA and compares the results with classical fracture criteria. Previous studies on different materials have shown that this specimen configuration can produce different ranges of mixed-mode loading, from pure Mode I to pure Mode II, simply by changing the position of one support.

Chapter 6: Characterization of Lattice Structures

Lattice structures, consisting of repeated unit cells arranged in a specific pattern, provide a high strength-to-weight ratio. Biological structures have inspired engineers to apply natural principles to innovation in materials science and engineering. In recent years, bio-inspired approaches have expanded to improve technology in various fields, including biomedical applications, robotics, and sustainable design. Typical examples include cellular structures such as foams and honeycomb structures, inspired by natural materials such as wood, cork, bone, cuttlebone, and bamboo.

Chapter 7: Conclusions and Original Contributions

The thesis addresses SLA, DLP, mSLA, and other techniques derived from these technologies. It discusses methods for increasing 3D printing speed, enabling the transition from prototype 3D printers to industrial-scale systems.

The thesis then examines materials used in 3D printing, including biocompatible, biodegradable, flexible resins, materials with high mechanical and thermal resistance, and nanocomposites containing metallic and oxide nanoparticles.

The importance of polymerized layer thickness, printing orientation, post-curing treatments, and other manufacturing parameters on the tensile, flexural, impact, and compressive behavior of printed materials is highlighted. The results clearly demonstrate the mechanical anisotropy of 3D-printed specimens.

The main original contributions of the doctoral research include an extensive literature review of photopolymerization-based additive manufacturing, the influence of manufacturing parameters on the mechanical properties of components produced by photopolymerization, and the influence of fracture parameters on the mechanical properties of components manufactured using the mSLA printing method.

Future studies will investigate additional parameters affecting the behavior of 3D-printed materials.