DIGITAL MATERIALS: A HYBRID 3D-PRINTING SYSTEM

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INTRODUCTION

Additive manufacturing (AM) has developed into a promising technology for various applications and provides advantages over conventional manufacturing methods like casting or milling. Drawback of most commercially available systems, however, are the insufficient mechanical properties and the limited resolution of the printed parts. With industry calling for tougher and stronger materials, especially for engineering applications, we developed a stereolithography (SL) process based on the principal of digital light processing (DLP), combined with direct inkjet printing. With this, we are able to print highly viscous photocureable resins with high resolution and excellent surface quality and mimic the thermo-mechanical properties of natural structures like nacre by jetting thin layers of soft material into a hard matrix. Those so-formed "digital materials" show promising results regarding enhancement of the thermo-mechanical properties, as first experiments indicate an increase of the strain at break and impact strength by over 50% and 40%, respectively – compared to the plain matrix material.

FUNDAMENTALS OF THE PROBLEM AND EXPERIMENTS

In nature, many biological materials are known to be both stiff and tough, such as biosilica or nacre[1]. The combination of tough protein and stiff mineral results in extraordinary mechanical properties exceeding those of the single components by far. The structure of those materials has a determining influence on the toughening of the materials, possibly resulting from crack deflection at weak interfaces in layered structures[2] or shielding effects by local variation of material properties[3]. Replication of such materials is difficult and is best done by manufacturing delicate laminates. Therefore, the layerwise buildup of 3D-printed structures has potential to reconstruct nacre-like materials, even exceeding lab scale. Advantages of stereolithography as AM technology are the high resolution and surface quality of the printed parts as well as the possibility to process high viscous materials. However, conventional SL machines allow the processing of only one material at once. We therefore developed a DLP-based SL process and combined it with a direct inkjet system. In the first step of the process, a material vat is coated with an acrylate-based resin. A digital micromirror device (DMD) projects blue light (light emitting diodes with a wavelength of 460 nm) onto the resin and cures it layer by layer, forming the matrix of the printed part. In a second step, the building platform rotates and a high-resolution print head selectively places elastomer droplets onto this previous layer, which then are cured during the next stereolithographic step. In order to evaluate the influence of the inkjet-layers, specimens with different elastomer content – without ink ('Reference'), every 2nd layer ('50%'), and each layer ('100%') – were printed. DMA measurements, tensile and impact tests were performed to measure the thermo-mechanical properties and their modification.

RESULTS AND DISCUSSION

DMA measurements showed a slight decrease of the storage modulus at room temperature, resulting from an overall softening of the material by adding elastomers. However, the glas transition temperature T_g was constant for all specimens. Decreasing tensile strength of 15% (‘100%’ compared to ‘Reference’) could be observed during tensile test, but a significantly higher elongation at break (+55%) is a promising result (see Chart 1).

(a) (b)

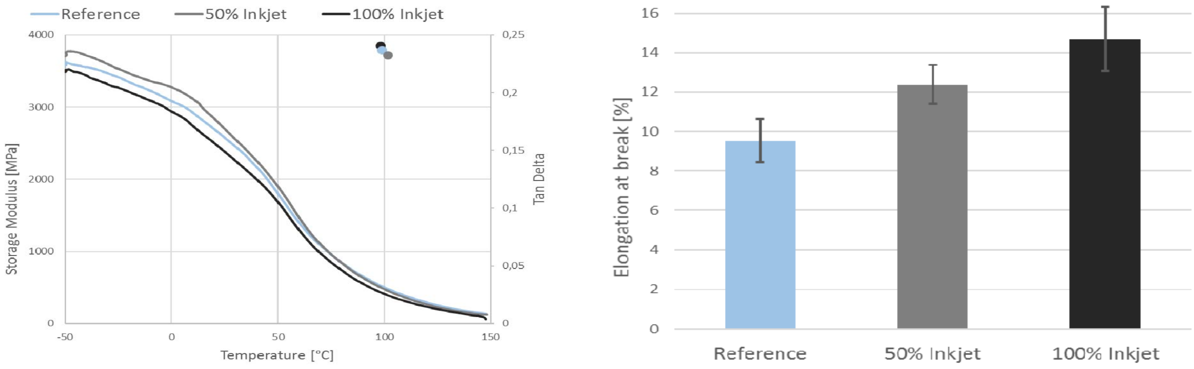

Chart 1 DMA measurements (a), but results in significantly higher elongation at break (b)

Dynstat impact tests of samples with three different ink-layer orientations showed an increasing toughness for all building directions by 25 – 45% (see Chart 2). In addition, creep behaviour was not influenced by jetting ink-layers into the part.

(a) (b)

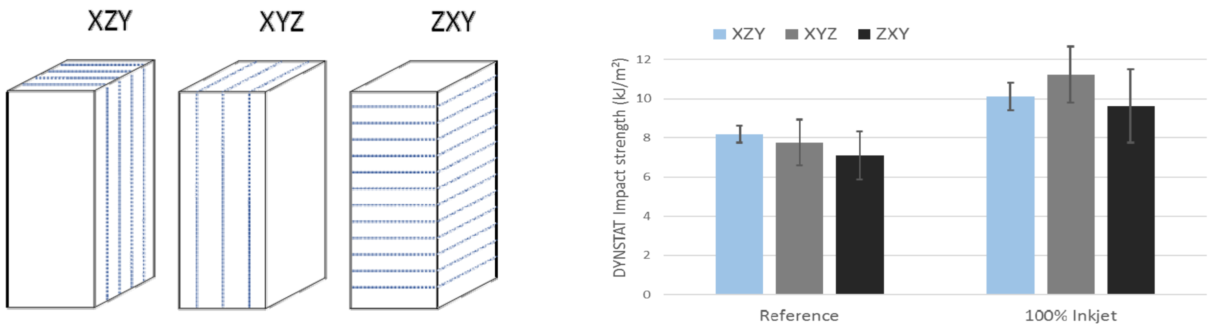

Chart 2 Different jetting directions, correlating the building direction of the printed part (a). In each direction, a significant increase of the impact strength was observed (b)

CONCLUSION

The first feasibility analysis shows promising results, as elongation at break and impact strength could be increased without significantly weaken the material. Apart from toughness modification, this novel technology allows further modifications of the printed parts in a way, which has not been feasible up to now: conducting tracks inside complex shaped parts, surface modification with inorganic materials, customized coloring and other multimaterial approaches can be established.

REFERENCES

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