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RESISTANCE OF 3D PRINTED POLYMER STRUCTURES AGAINST FATIGUE CRACK GROWTH

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ABSTRACT

The results of this study help to evaluate the sensitiveness of 3D printed polymer structures against fatigue crack growth. Fatigue crack propagation (FCP) experiments are very sensitive in regard to process-induced anisotropy. It reveals the potential of 3D printing with regards to its development from a "rapid prototyping" to a "rapid manufacturing" technique for technical products. The results of the investigations show that the FCP properties of 3D printed components are comparable to injection molded of similar material and geometry.

Keywords: fatigue crack growth, 3D printing, FFF, FDM, APF, additive manufacturing.

INTRODUCTION

Additive manufacturing (AM) technologies enable the production of plastic components with complex geometries that cannot be realized by conventional mold-based processes. Since polymer components are mainly exposed to dynamic loading in daily use, it is utterly necessary to characterize the fatigue properties of additive manufactured polymer structures and to understand how inherently existing material defects affect the durability of the components. However, in contrast to the numerous publications focusing on the quasi-static mechanical properties, just few investigations with regards to the behavior of dynamic loaded 3D-printed polymer parts have been carried out (Blattmeier, 2011; Munguia *et al*., 2014).

In this study, the performance of 3D-printed (Arburg plastic freeforming - APF and fused filament fabrication - FFF) polymer compact tension (CT) samples under dynamic mechanical load is analyzed and compared to injection molded (IM) samples by investigating the fatigue crack propagation (FCP) behavior. The build-up direction of the CT-samples which are based on acrylonitrile butadiene styrene (Terluran® GP-35) is varied to evaluate influences of the process-induced anisotropy.

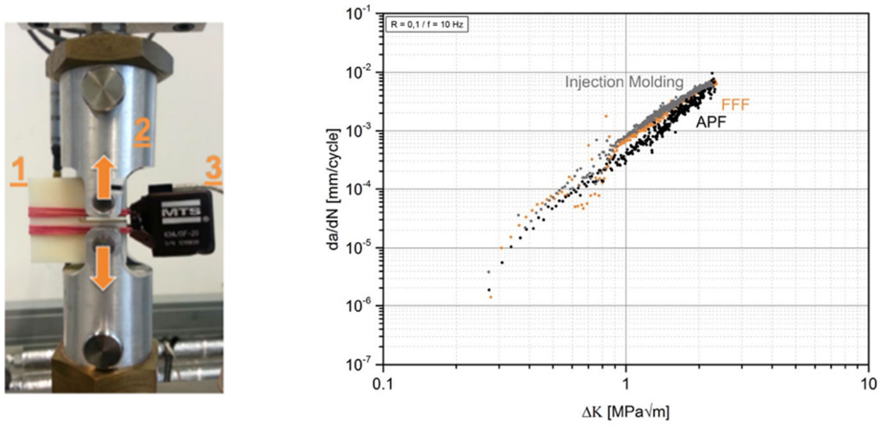
RESULTS AND CONCLUSIONS

It can be concluded that the fatigue crack growth behavior of Fused Filament Fabrication (FFF) samples hardly depends on the build-up direction. The stress intensity factor at which the crack growth is initiated (Kth) is on the same level as for IM samples. Moreover, the crack propagation rate is quite similar for FFF and IM specimens. By contrast, the crack growth resistance of horizontally printed APF samples is partially higher than that of conventional IM components (see Figure 1).

The FFF-specimen analyzed in this study show just a low level of anisotropy with regards to the FCP. Due to the significant anisotropy of the static mechanical properties (tensile strength varies up to 50%) (Ziemian *et al.*, 2012, Ahn *et al.*, 2002) this behavior is unexpected. APF components exhibit an anisotropic behavior (see Table 1). The FCP is significantly decreased by a vertical build-up.

Table 1 - Characteristic FCP values of 3D printed APF-samples

Build-up direction	ΔK_{th} (MPa√m)	ΔK_{crit} (MPa√m)
Horizontal 0° Infill	0.28	2.02
Horizontal 90° Infill	0.27	2.33
Vertical	0.21	1.31
Injection molding	0.27	2.27



(a) (b)

Fig. 1 - (a) Testing set-up for the analysis of the fatigue crack growth behavior. 1: CT-specimen; 2: load application device; 3: transducer. (b) Comparison of FCP properties of in plane printed CT-samples with a 90°-infill. The curve of an injection molded sample is plotted as a benchmark.

The results of the investigations show that not just the static mechanical properties but moreover the FCP properties of 3D printed components are comparable to injection molded ones.

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