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Analysis of crack growth in 3D printed plastic wrench

P. Dlhý [a,b], L. Náhlík [a], F. Arbeiter [c], A. Gosch [c], P. Hutař [a]

[a] *Institute of Physics of Materials, Academy of Sciences of Czech Republic, Žižkova 22, 616 62 Brno, Czech Republic*
[b] *European Institute of Technology, Brno University of Technology, Technická 10, 616 00 Brno, Czech Republic*
[c] *Material Science and Testing of Polymers, Montanuniversitaet Leoben, Otto Gloeckel-Straße 2, 8700 Leoben, Austria*

Fused filament fabrication (FFF) is a type of extrusion-based additive manufacturing technique also known as fused deposition modeling (FDM) or 3D-printing. It is possible to use the process of additive manufacturing for manufacturing of prototypes and also the final products [2]. It is widely believed that parts produced by this method have the disadvantage of slightly worse mechanical properties because of consisting of many weld-lines in layers [4]. However, newer studies confirm that this negative effect can be significantly reduced by appropriate choice of welding conditions of the printing process [3]. Mechanical properties like ultimate tensile strength, modulus, etc. of printed parts can then be similar to properties of injection molded [2] or compressed parts [3].

Fracture properties and crack growth kinetics of the 3D-printing material (polylactic acid, PLA) were determined in a series of measurements on CT and SENB specimens (manufactured by FFF) carried out by Arbeiter [1]. Material constants A and m determining the crack kinetics in the Paris-Erdogan region were established: $A = 10^{-3.78}$ and $m = 2.87$. These parameters are necessary for estimating lifetime of the part. In order to verify the validity of the obtained material constants, a study of crack growth in a real mechanical part made of PLA is now in progress. This contribution deals with a simulation of crack growth in a mechanical part (a wrench) manufactured by FFF, as a part of this study. The results of the simulation are compared to an actual experiment and the numerical model is modified to match the behavior of the real part.

The wrench was modelled by FEM. The model is schematically pictured in Fig. 1. The wrench was fitted on a fixed nut via contact elements and a force load was applied by a small cylinder near the free end of the wrench (also via contact elements).

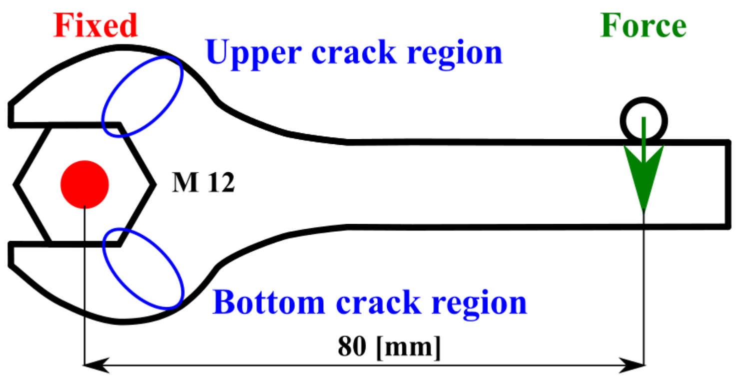

Fig. 1. Schematic figure of simulated wrench model

A 2D contact analysis using plane elements in plane strain condition was carried out. The material model used for the wrench as well as for nut and small cylinder was linear elastic and isotropic. Young's modulus of 3.4 GPa and Poisson's ratio of 0.37 were used for the wrench. Young's modulus of 210 GPa and Poisson's ratio of 0.33 were considered for the nut and the loading cylinder.

First results showed that crack should appear in the area marked as bottom crack region in Fig. 1. However, first experiments showed crack in the upper crack region. It was concluded that this might be happening due to friction between the wrench and the nut. Therefore, study of coefficient of friction between the wrench and the nut was done (the basic Coulomb friction model has been used in the model). It was found that there is a strong dependence of the SIF on the coefficient of friction, as showed in Fig. 2. SIF has been monitored over simulations with different coefficient of friction. SIF at bottom crack tip decreases with raising of coefficient of friction. On the other hand, SIF at upper crack tip has almost the same value over the whole range of studied coefficients of friction. There is only a small decrease between coefficients 0 and 0.2.

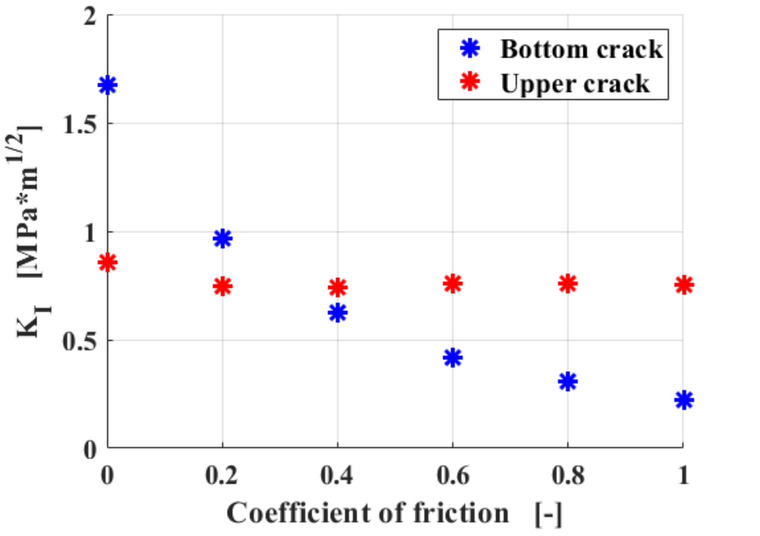

Fig. 2. Stress intensity factor dependence on coefficient of friction, crack length 0.1 [mm], force 7 [N]

This contribution deals with modelling of crack propagation in a wrench manufactured by FFF. First results from simulation and experiments was different. Therefore, there was a study of coefficient of friction to determine the cause of the difference. Results showed strong dependency of SIF on coefficient of friction. In order to validate material constants obtained from test specimens and obtain lifetime for real component, further work is needed to achieve equivalence of the numerical and experimental results.

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