Crack deflection versus penetration in extrusion-based additively manufactured polymeric materials

Christoph Waly

Increasing advances on the part of science and industry in the field of additive manufacturing (AM) in the last few decades increasingly enable 3D-printed components to be used in areas with increased demands, such as medical technology, where the end user has to be assured of function and durability. Owed to the manufacturing process, components produced via polymeric AM, especially extrusion-based methods, possess many either weak or strong interfaces between strands and layers, depending on the used process parameters. When a crack reaches such an interface, two different scenarios regarding further crack propagation can occur (Fig. 1). Either the crack grows into the interface (crack deflection) or penetrate through the subsequent layer (crack penetration).

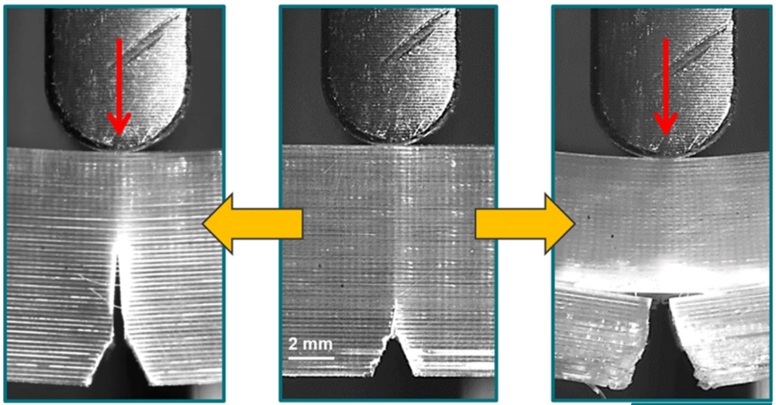

Fig.1

Possibilities of crack propagation during fracture testing (left: crack penetration; right: crack deflection)[1].

[1]C. Waly, S. Petersmann, F. Arbeiter (2023); Theoretical and Applied Fracture Mechanics, doi: https://doi.org/10.1016/j.tafmec.2023.104032

In this study, the applicability of two approaches, a strength (Cook & Gordon)- and an energy-based (He & Hutchinson) approach, to predict the failure mode has been tested on four different polymeric materials. The energy-based approach proved unreliable for failure mode prediction (Fig. 2). The strength-based approach, in contrast, correctly predicted the crack path for all tested materials and seems a promising candidate for failure mode prediction (Fig. 3).

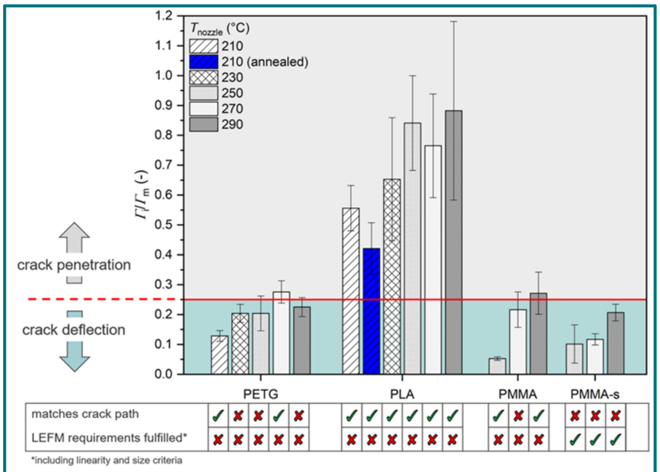

Fig. 2

Results from the energy-based approach, fracture toughness ratio of the interface to matrix (Γ_i/Γ_m) as a function of the nozzle temperature T_{nozzle}[1]. The red line indicates the transition from crack deflection to penetration according to the suggestion given by He & Hutchinson.

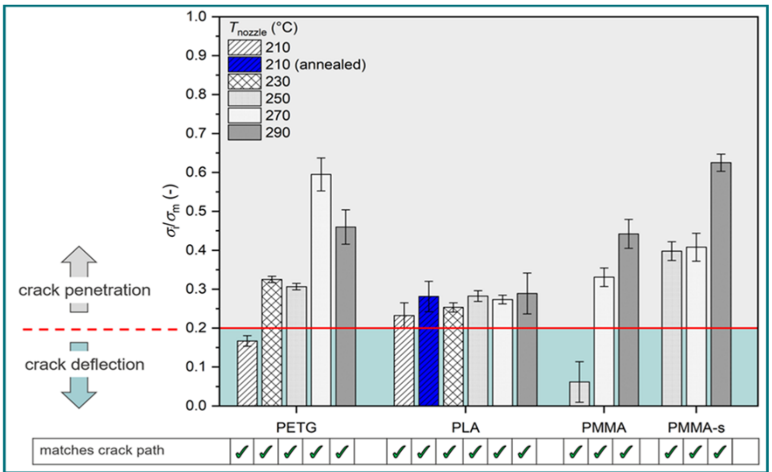

Fig. 3

Final results of the from the strength-based approach. Strength ratio of the interface to matrix (σ_i/σ_m) as a function of the nozzle temperature T_{nozzle}[1]. The red line indicates the transition from crack deflection to penetration according to the suggestion given by Cook & Gordon.

CHRISTOPH WALY
Materials Science and Testing of Polymers
christoph.waly@unileoben.ac.at

RESEARCH FOCUS: additive manufacturing, polymer mechanics and fracture mechanics, multi-layered systems

PROJECT: CrackDePe 4 3D-Print
PROJECT PARTNERS: -
FUNDING: This research was partly carried out as part of the eFAM4Ind project (877409), which is funded by the Austrian Research Promotion Agency (FFG) and the Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology (BMK).