PhD proposal: Towards advanced modelling of crack propagation in anisotropic materials thanks to Fused Filament Fabrication

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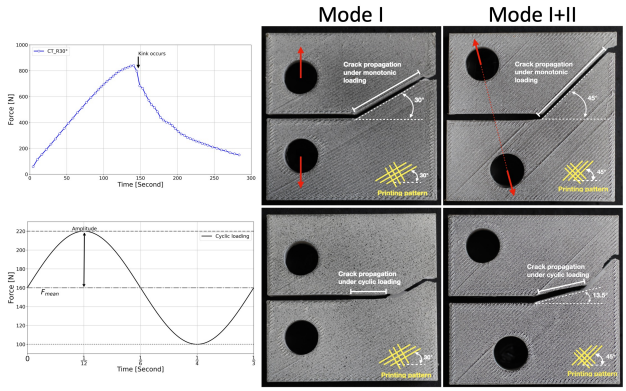

Scientific context: Anisotropic materials gain importance in industry driven by new applications and environmental concerns, from wood construction, single crystals for photovoltaic applications or aerospace turbines, to Additive Manufactured materials. But due to the lack of certified damage tolerance models to guarantee their resistance to failure, their use in sensitive components whose failure must be avoided at all costs is limited.

Several funded projects aiming to fill this gap are currently in progress whithin our multi-disciplinary team. The thrust of these projects is to take advantage of the versatility of fused filament fabrication to design experiments that challenge advanced experimental and numerical approaches to fracture mechanics. Experimentally, advanced measurement techniques from Digital Image Correlation to state-of-the-art Digital Volume Correlation approaches are challenged. Numerically, concepts of linear elastic fracture mechanics, from the classical Griffith variational energy approach to phase-field simulations developed for anisotropic materials, are tested.

Thesis outline: Propagation of cracks in polycarbonate brittle materials printed by Fused Deposit Modeling [1] will be studied in line with a previous PhD thesis [2]. Firstly, an extensive experimental campaign, varying the microstructure and shape of the sample under both monotonic and cyclic loading will be done. Secondly, the experiments will be simulated using classical sharp crack approaches based on the Stress Intensity Factors [3], and phase-field models [4, 5]. Thirdly, comparison between experiments and simulations will aim to improve, calibrate and validate the models. The targeted applications are their use (i) to assess the strength of sensitive components, (ii) to optimise the microstructure or printing strategies towards more resistant and eco-friendly materials.

Candidate profile: Master 2 level student in physics, material or mechanical engineering. Some knowledge in fracture mechanics and a taste for in-depth physical understanding will be appreciated.

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Collaboration: LMPS at ENS Paris Saclay and CIRCS at Northeastern university Boston.

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References

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[2] Xinyuan Zhai. *Crack propagation in elastic media with anisotropic fracture toughness : experiments and numerical modeling.* PhD thesis, Institut Polytechnique de Paris, Dec 7 2023.

[3] X. Zhai, T. Corre, and V. Lazarus. A FDM-based experimental benchmark for evaluating quasistatic crack propagation in anisotropic linear elastic materials. *Engineering Fracture Mechanics*, 324(111175), 2025.

[4] X. Zhai, T. Corre, A. Mesgarnejad, A. Karma, and V. Lazarus. Path differences between quasistatic and fatigue cracks in anisotropic media. *Physical review E*, 110(6), 2024.

[5] Flavien Loiseau and Veronique Lazarus. How to introduce an initial crack in phase field simulations to accurately predict the linear elastic fracture propagation threshold? *Journal of Theoretical, Computational and Applied Mechanics*, Jun 2025.