Crack facet initiation in pure Mode III fracture

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Mode III, or anti-plane shear cracking, is a peculiar phenomenon. Initially, when Irwin introduced his mode decoupling theory, he assumed a horizontal crack propagation. Since then, many experiments have shown that in brittle materials, when deformed in an anti-plane manner, the original mother crack fragments into many daughter cracks with an angle different from horizontal [1]. These small facets then coalesce and continue propagating in the original direction with an increasing rugosity.

The talk focuses on the detailed analysis of the daughter crack initiation using the phase-field technique [2, 3] and the coupled criterion [4]. After our recent study on tensile and in-plane shear fracture [5], we present a comparison between the two techniques focusing on the characteristic initiation distance in pure Mode III loading conditions.

To induce instability, in the phase-field method, the critical energy release rate was varied based on a gaussian random field. We show that without any significant defect, our implementation is capable of localizing the cracks. Furthermore, we present a meticulous study of both numerical and material parameters to investigate their effect on the initiation distances.

The model was found to be very robust, and we show that only the characteristic regularization length of the phase-field model and Poisson's ratio changes the initial distance between the automatically formed daughter facets.

We extended our previous analysis [5] using finite fracture mechanics to understand the phenomenon observed in our numerical experiments. We found that the reinitiating cracks are initiated in an unstable manner but propagate stably after. This is in good correspondence with the results observed in phase-fields. Furthermore, we observed that the maximum tensile stress criterion dominates the initiation. The energy release rate in facet formation mode was significantly lower than in horizontal advancement. This results in stronger resistance. This was also found to agree with our phase-field simulations.

Interestingly, we saw that Griffith's original theory is unable to predict facet formations in pure Mode III because the existence of a finite length scale is essential. This confirms our reasoning that the addition of the regularization length scale in the phase-field fracture is crucial to capture relevant physical phenomena in crack initiation.

References

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