Fracture surface topology via Phase field modelling: Statistical aspects

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Fracture, being the most encountered failure mode in design, needs to be prevented. Computational modelling of fracture is an indispensable tool not only to predict the failure of cracked structures; but also, to gain an insight to fracture processes. Linear Elastic Fracture Mechanics (LEFM) has been explained by the pioneer works of Griffith et al [1] and Irwin et al [2]. Still, predictive modelling of fracture patterns in materials and structures poses a significant challenge. Fracture of solids can be numerically modelled using either a discontinuous approach (LEFM, CZM) or a continuous approach (Phase Field Modelling (PFM), Peri-Dynamics). The observation of universal scaling behavior on real fracture surfaces has raised hope for a unified theoretical framework to capture fracture processes in disordered solids. However, such a quantitative understanding of the scaling properties is still missing. Ponson at al [3] showed that most experimental fracture surfaces report persistent fracture profiles with large roughness (Hurst) exponent ($H \geq 0.5$) characterized by failure due to damage coalescence, whereas anti-persistence ($H \leq 0.5$) is predicted by LEFM and characterized as brittle fracture processes. H is also claimed to be universal, irrespective of loading and crack pattern.

The present work attempts verification of the above claim of universality computationally using PFM. A two-dimensional Single Edge Notched Tension (SENT) Steel specimen with an initial notch of size equal to half of the specimen width was considered. The plate was subjected to linearly increasing displacements at the top and bottom edges. A honeycomb grain structure with weaker grain boundaries succeeds the notch. Rate independent variational PFM approach similar to the work of Miehe et al [4] has been adopted. We attempt to compare H values for different cases of constant and random grain boundary fracture toughness.

It is observed that H indeed depends on the typical length scale for roughness measurements. Brittle fracture patterns tend to vary from small scale persistence to large scale anti-persistence, whereas the situation is reversed for fracture patterns due to damage coalescence. To support these results, a thorough study of three real fracture surfaces of different materials has been performed and similar trends have been observed.

References

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