Consequence of the crack tip microcracking statistics on dynamic nominally brittle fracture at the continuum-level

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Linear elastic fracture mechanics correctly models dynamic fracture as long as its application assumptions are verified and a single crack is considered [1, 2]. Locally, the elastic energy release rate must be equal to a material constant, the fracture energy. In contrast, in nominally brittle materials undergoing rapid fracture, the collective dynamics of nucleation, growth and coalescence of numerous microcracks in the near-end region implies a strong dependence of fracture energy on cracking rate, the modelling of which remains a theoretical challenge [3, 4]. Here, microscopic statistics from experimental reconstructions of microcrack dynamics are compared to a refined geometric model.

The experiment were performed on Polymethylmethalcrylate (PMMA), fracture speed, v and stress intensity factor K were determined by potential drop method and finite element analysis. The microcracking processes in the process zone occurs at nanosecond/micrometer scale, *a priori* beyond the reach of standard experimental mechanics methods. However, the microcracks that form near crack tip at high enough fracture speed (for $v > v_{mc} \simeq 0.2c_R$ [5]) have the particularity to leave characteristic conics patterns onto the fracture surfaces [3] which can be analysed post mortem and allow a complete recondstruction of the dynamic [4].

The probability distributions that control the jumps in time and space between microcracks are determined experimentally. Nevertheless all these treatments are very difficult and the range of available parameter is experimentally limited. To overcome this problem, we develop a dynamic random sets model to artificially generate all the damage dynamic. We first check that the model is indeed able to reproduce all the experimental data. Then we extend it to a larger range of parameters and we extract scaling laws between the statistics at the microscopic scale and a control parameter that we choose equal to $d_n \sqrt{\rho}$.

The comparison to experimental data shows that finally these dynamics are entirely determined by two constant, the constant propagation velocity of microcracks and a length scale related to their share in the fracture energy. The areal density of the nucleation centres of the microcracks then controls the dynamic. The upscaling of this geometric microcracking model provides a robust crack growth law at a continuous scale. The three parameters of this model can be fitted to both microscopic and macroscopic data. A clear interpretation of the variation of fracture energy with fracture rate is obtained.

References

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