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Finite-element analysis of velocity mode transition of crack propagation in rubber materials

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Crack propagation in rubber materials has been intensively investigated because it is one of fundamental processes of failure in rubber materials and is strongly related to the lifetime of rubber products. Some experiments have observed dynamic crack propagation in stretched rubber sheets and reported an interesting phenomenon called the "velocity mode transition". The mode transition is an abrupt change of tendency in the relationship between the crack propagation velocity and the tearing energy (or the loaded strain), as schematically shown in Fig. 1. There are two regions below and above a certain transition point, which are referred to as the "slow mode" and the "fast mode", respectively. According to the experiments, the crack velocity exhibits a nearly discontinuous change by more than two orders of magnitude at the transition point. While the behavior of a propagating crack at the fast mode can be explained theoretically, the mechanism of the mode transition phenomenon has been still unclear despite its importance. Furthermore, no numerical simulation has been established to reproduce the transition phenomenon thus far. In this talk, we present a series of analyses based on the finite element method (FEM) for purpose of revealing the mechanism of the mode transition phenomenon. We carried out FEM simulations of the pure-shear test to mimic a precedent experiment and obtained the relationship between the loaded strain and the crack propagation velocity. The material model consists of the hyper elasticity and viscosity, which were determined to reproduce the mechanical properties of a filled elastomer. As a result, the mode transition phenomenon was reproduced by the present FEM analyses, which revealed that the mode transition correlates to the viscoelastic behavior with a wide range of time scale. The mechanism of the transition phenomenon was well explained through a characteristic mechanical behavior at the crack tip.

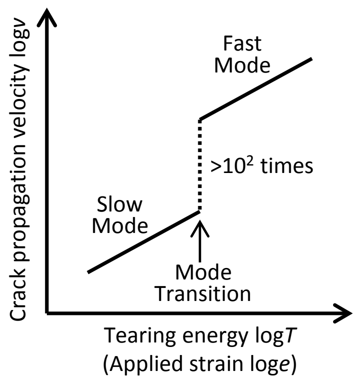

Figure 1: Schematic illustration of crack propagation velocity as a function of tearing energy (applied strain) in logarithmic scales, where the mode transition occurs.

Biography

Atsushi Kubo received his Doctorate degree in Mechanical Engineering from the University of Tokyo in 2015. His research interest is in a wide range of the computational simulation and modeling (mainly at the atomistic level) for the structural and functional materials, including semiconducting materials, ferroelectric materials, polymers, etc. In his current work at the Institute of Industrial Science, The University of Tokyo, he is investigating the mechanical properties of the structural polymers based on the atomistic- and macroscopic-level approaches.

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