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Fracture saturation and critical thickness in layered materials. (English) Zbl 1193.74133

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Summary: Opening-mode fractures in layered materials are commonly found in a layer with uniform spacing that is nearly proportional to the thickness of the fractured layer. However, when fracture spacing reduces to a certain value, fracture density is saturated and no new fracture forms. If a loading condition is fixed, there exists a critical thickness of the layer, below which no fracture forms. This paper presents a three-layer model, containing a weak layer between two stronger layers, to interpret the fracture saturation and critical thickness of layered materials. Using elastic governing equations and a weak form stress boundary condition, a closed-form solution of elastic fields in the weak layer is derived and the energy release rate for opening-mode fracture is obtained. Interestingly, the normal stress between such fractures undergoes a transition from tensile to compressive with increasing applied tensile loading, which causes fracture saturation. Explicit expressions of critical fracture-spacing-to-layer-thickness ratio and critical thickness are derived for fracture saturation and fracture free conditions, respectively. Comparison with the existing numerical simulation results demonstrates the capability of this model. This explicit, analytical solution is useful to structural design and geosciences.

MSC:

74R10 Brittle fracture

74K35 Thin films

74E30 Composite and mixture properties

Keywords:

opening-mode fracture; energy release rate; layered materials; thin film; fracture saturation; periodic cracks

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