Toughening effect analysis in problems of propagating cracks interacting with interfaces.

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Numerous fracture problems display, at the meso or microscale, phenomena involving the propagation of cracks interacting with interfaces. Examples where this mechanism plays a prominent role are: microcracks propagating in laminated composites, intergranular/transgranular fracture in polycrystalline metals, adhesive joints sandwiched between elastic substrates, crack bridging in structural ceramics, fracture mechanisms in biomimetics materials, among others. A notable result of such interactions refers to the possible effective structural toughening due to shielding effects induced by the interface on the propagating crack. Considering the high interest shown by this issue, the study of propagating cracks approaching interfaces has been the topic of intense research in the last few years.

In this work, following [1], we analyze the toughening mechanisms due to a propagating crack interacting with an interface at prescribed angles. The problem consists of a pre-cracked thin film bonded to a substrate, as adopted by [2]. The initial crack propagates toward the interface penetrating the substrate or deflecting toward the interface. In the last case, the film/substrate interface undergoes debonding. This effect inhibits the substrate crack penetration and may induce an effective structural toughness increase. Special attention is paid here to the unstable conditions arising from the shielding effect introduced by the interface.

The penetration/deflection mechanisms which are competing have usually been modeled using either stress-based criteria or energy-based criteria. However, it has been found that both criteria cooperate in the phenomenon. In the present analysis, we use a numerical methodology appealing to two different techniques. We compare the results obtained with: i) a phase field model characterizing the crack propagation across the film and substrate combined with a Cohesive Zone Model (CZM) characterizing the response of the interface (see [3]); and ii) a CZM for describing the crack propagation along the substrate and interface domains (see [4]).

The analysis is performed in the space of parameters defined by the ratio between the substrate and interface toughnesses, Γ_s/Γ_i, and the effective normalized load. The remaining parameters governing the problem, i.e. the characteristic lengths of the interface and phase field model, are also varied accordingly to assess their role in affecting the structural toughness increase.

Conclusions on the capacity of both numerical techniques to assess the apparent toughness and instability response are presented.

References

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