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Editorial

Special issue on fracture and contact mechanics for interface problems

The examination of materials and structures shows that homogeneity is often a simplification of reality. Interfaces exist at different scales and they govern the material properties and the structural response. An ambitious task to be undertaken is the development of accurate criteria for the strength and fatigue life assessment of structures containing interfacial cracks. This aim is very challenging, since coupled contact and fracture mechanics problems are often present and special techniques have to be employed for their solution. In this context, under the assumption of linear elasticity, it has been found that the stress field diverges at the tip of interface cracks, multi-material wedges and junctions. These singular fields are important to be quantified for an accurate stress analysis. Asymptotic methods based on series expansions have been found to be very efficient. At the beginning, most of the studies focused on the characterization of the power of the stress-singularities depending on the material parameters and geometrical configuration of the joints. Later on, the research has been extended to the computation of the generalized stress-intensity factors and to their use in new strength criteria. Higher order terms in the series expansion can also be relevant, depending on the geometry of the problem being considered. In presence of cyclic or dynamic loads, the unilateral contact condition along the crack faces has to be imposed, which adds further complexity to the already complex fracture mechanics problem. Due to the coupling between contact mechanics and fracture mechanics, semi-analytical iterative methods or fully nonlinear numerical techniques are therefore employed.

Research in the field of interface mechanical problems is particularly active, as demonstrated by the rapidly increasing number of papers published every year in scientific journals on this topic (see Fig. 1). This graph, obtained by selecting in the Scopus database the articles having the words "interface" and "mechanics" in their title, abstract or keywords, shows the rapid evolution of the research in this area, with up to 1400 papers published per year on interface mechanical problems.

To provide a forum for researchers to exchange their ideas and be informed by the state-of-the-art development, a symposium on Fracture and Contact Mechanics for Interface Problems was organized as part of the fourth European Conference on Computational Mechanics (ECCM 2010) held in Paris, France, May 16–21, 2010. The 4-day symposium featured more than 40 outstanding speakers with five keynotes and attracted a large audience. The presentations given reflected a wide spectrum of the interesting topics being pursued by different groups on fracture mechanics and contact mechanics of interfaces, with a wide range of applications. In light of the success of the symposium and responses, we organized a special issue on "Fracture and contact mechanics for interface problems" in the Journal of Engineering Fracture Mechanics, with a selection of the best papers discussing advances in mathematical models.

Based on the theme of this special issue, Hills, Paynter and Dini proposed a procedure based on the Williams edge analysis to quantify the fretting fatigue damage arising at the edges of complete contacts subject to oscillatory loading. Complete contacts arise when the contacting face of the components is flat or almost flat, and an abrupt change in profile of one of the components takes place. Singular stress fields occur at the edge tips and their characterization requires the use of analytical methods based on asymptotic expansions. Asymptotic analysis is proven to be useful not only in describing explicitly the form of the stress and displacement fields around bi-material junctions, but also in predicting failure of joints that contain such junctions. In this context, Mintzas and Nowell proposed a failure criterion for butt and double lap joint configurations based on the critical value of the generalized stress-intensity factor.

The effect of higher order asymptotic terms on the competition between crack penetration and debonding at a bi-material interface between aligned orthotropic materials was quantified in the contribution by Ševeček, Kotoul and Profant. In particular, a crack perpendicularly impinging the bi-material interface and a crack arbitrary inclined to the interface were considered for a wide range of elastically mismatched materials. Results indicate that the effect of higher order terms on the crack penetration/debonding at a bi-material interface strongly depends on the elastic mismatch of dissimilar materials and on the crack-specimen configuration.

3D fracture dynamic problems for elastic bi-materials with cracks located at the bonding interface under time-harmonic loading was investigated by Menshykov, Menshykova and Guz. The problem for a penny-shaped interface crack under

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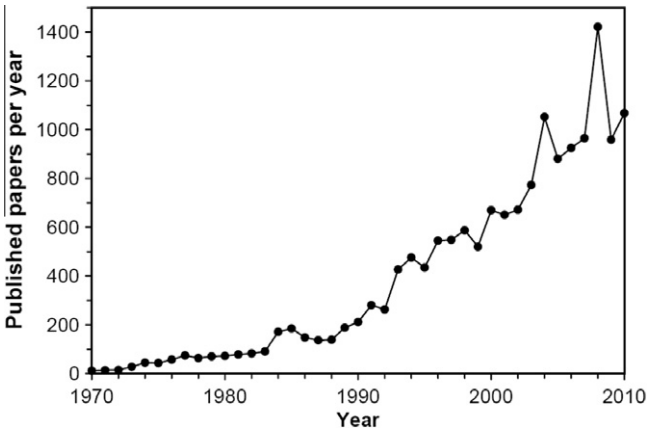

Fig. 1. Statistics of published papers per year with the words "interface" and "mechanics" in their title, abstract or keywords. Source: Scopus.

normally incident tension–compression wave was solved taking the phenomenon of crack closure into account. Interface cracks were also investigated in the study by Piccolroaz, Mishuris and Radi, considering micropolar elasticity for the materials and antiplane deformations for the crack. Again, an asymptotic analysis was employed to investigate the behaviour of the solution near the crack tip depending on the internal characteristic lengths of the couple-stress elastic materials. Dag, Apatay, Guler and Gulgeç proposed an analytical method for fracture analysis of functionally graded coatings bonded on a homogeneous substrate with a surface crack subjected to contact stresses. A two-step solution procedure was put forward to solve the coupled fracture-contact problem for the estimation of the stress-intensity factors at the crack tip. Finally, Greco, Leonetti and Nevone Blasi proposed a numerical method based on finite elements for the analysis of the effects of damage initiation and evolution due to micro-cracking along an a priori unknown path on the homogenized response of fiber-reinforced composite materials. Accurate non-linear macroscopic constitutive laws are obtained for combined axial and shear macro-strain paths by taking into account changes in micro-structural configuration owing to crack growth and crack face contact.

In conclusion, the collection of the seven papers in this special issue represents some of the most significant research directions that are being pursued by the researchers in the fields of mathematical modelling of interface mechanical problems. Much more contributions in this field are however expected in the next years. With the significant advances in computational power and computing algorithms, more accurate interface constitutive laws coupling contact mechanics with fracture mechanics formulations should be pursued. We hope that the publication of this special issue will foster the diffusion of the mathematical models for the study of interface mechanical problems across different disciplines and research fields.

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