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Editorial

Editorial for the Special Issue "Advances in Multiscale and Multifield Solid Material Interfaces"

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Interfaces play an essential role in determining the mechanical properties and the structural integrity of a wide variety of technological materials. As new manufacturing methods become available, interface engineering and architecture at multiscale length levels in multi-physics materials open up to applications with high innovation potential. This Special Issue is dedicated to recent advances in fundamental and applications of solid material interfaces. It contains six high-quality articles that were accepted after a careful reviewing process.

Micromechanical models for multiphase composites are fundamental for an accurate design and optimization of engineering materials, in order to predict their effective material properties and give insight into the relation between microstructure and macroscopic mechanical behavior. Three papers of the Special Issue push the boundary to reveal new insights on micromechanical models for composites incorporating interface effects [1–3].

In [1], Nazarenko et al. propose a mathematical model employing the concept of energy-equivalent inhomogeneity to analyze short cylindrical fiber composites with interfaces described by the Steigmann–Ogden material surface model. Closed-form expressions for components of the stiffness tensor of equivalent fiber have been developed and, in the limit, they have shown to compare well with the results available in the literature for infinite fibers with the Steigmann–Ogden interface model.

In [2], Rudoy considers an equilibrium problem of the Kirchhoff–Love plate containing a nonhomogeneous inclusion. The elastic properties of the inclusion rescale as ε^N, with $N < 1$ and ε a small parameter characterizing the width of the inclusion. The passage to the limit as the parameter ε tends to zero is justified, and an asymptotic model of a plate containing a thin inhomogeneous hard inclusion is constructed. It is shown that there exists two types of thin inclusions: rigid inclusion $(N < -1)$ and elastic inclusion $(N = -1)$. The inhomogeneity is shown to disappear in the case of $\mathrm{N} \in (-1, 1)$.

The paper by Sabina et al. [3] implements a two-scale asymptotic homogenization method to calculate the out-of-plane effective complex-value properties of periodic three-phase elastic fiber-reinforced composites with parallelogram unit cells. Matrix and inclusions materials have complex-valued properties. Closed analytical expressions for the local problems and the out-of-plane shear effective coefficients are given. The solution of the homogenized local problems is found using potential theory. Numerical results are reported and comparisons with data in the literature show good agreement.

The mathematical treatment of contact problems for engineering applications is typically very challenging. In [4], Sofonea and Shillor propose the application of the Tykhonov well-posedness concept, which allows a unified and elegant framework for a class of static contact problems. In particular, they present an original unified approach to the analysis of contact problems with various interface laws modeling the contact between a deformable body and a rigid or reactive foundation. A weak formulation of the equilibrium problem is derived, which is in the form of an elliptic variational inequality, and the Tykhonov well-posedness of the problem is established, under appropriate assumptions on the data and parameters, with respect to a special Tykhonov triple. This abstract result leads to different convergence results, which establish the continuous dependence of the weak solution on the data and the parameters. The work enables to elucidate the links among the weak solutions of the different models and their corresponding mechanical interpretations.

In recent decades, adhesive bonded technology has been increasingly used for reduction of structural weight, time, and manufacturing costs, also due to improved mechanical performance and better understanding of failure mechanics. To assess the structural integrity of the joint, an estimate of stress distribution and a suitable failure criterion are necessary. Although for complex geometries and elaborate material models finite element analysis are available, analytical models giving closed-form results are more appropriate. In [5], Raffa et al. present a new analytical model for thin structural adhesives in glued tube-to-tube butt joints. A nonlinear and rate-dependent imperfect interface law is proposed, able to accurately describe brittle and ductile stress-strain behaviors of adhesive layers under combined tensile-torsion loads and explicitly accounting for material and damage properties of the adhesive layer. A first comparison with experimental data available in the literature provides promising results in terms of the reproducibility of the stress–strain behavior for pure tensile and torsional loads.

Structural composite materials are nowadays being engineered employing multiphysics materials to achieve superior functionalized properties. The work by Serpilli et al. [6] proposes new interface conditions between the layers of a three-dimensional composite structure in the framework of coupled thermoelasticity. More precisely, the mechanical behavior of two linear isotropic thermoelastic solids, bonded together by a thin layer, constituted of a linear isotropic thermoelastic material, is studied by means of an asymptotic analysis. After defining a small vanishing parameter ε associated with the thickness and the constitutive coefficients of the intermediate layer, two different limit models and their associated limit problems are characterized, the so-called soft and hard thermoelastic interface models. A numerical example is presented to show the efficiency of the proposed methodology, based on a finite element approach developed previously.

The papers published in this Special Issue constitute only a further step to advance in the field of multiscale and multifield solid material interfaces. However, they extend the frontiers of what researchers are already working on and will continue to investigate.

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