A Discrete Element approach for Modeling the Thermal-induced Damage in continuous media

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ABSTRACT

This work is treated in the framework of CUBISM project funded by INTERREG V program. The purpose of the project is to develop a pressure and humidity SAW sensor, in order to follow the drying of refractory materials under high temperature and pressure conditions. More precisely, we aim to describe and predict the thermo-mechanical behavior of the piezoelectric SAW substrate under such conditions for a full set of geometrical configurations and materials. Besides, we expect to take into account the micro-cracks resulting from thermal expansion mismatch between the substrate and its environment. However, at the microscopic scale, the finite element method is less suitable to describe discontinuities induced by micro-cracks. For that reason, we propose to study the thermo-mechanical behavior using the Discrete Element Method (DEM). This choice is also motivated by the advantage of DEM to describe the crack propagation. This contribution presents significant improvement for DEM to model the 3D thermal-induced damage due to thermal expansion. Furthermore, this study allows to follow the damage level of the material during its lifetime. Thanks to the MULTICOR3D++ code developed in our laboratory, a hybrid particulate-lattice model [1] based on the equivalence between a granular system and a network of cohesive beam elements, is investigated. Our contribution is to introduce the linear thermal expansion at the scale of the contact by modifying the initial free length of each link using the model introduced in 2D by Leclerc et al. [2].

Our objectives are twofold. First, we aim to investigate the suitability of the cohesive beam model, in the context of a thermo-mechanical behavior of heterogeneous continuous media. Consequently, some comparisons are done with finite element calculations in terms of effective coefficient of thermal expansion, and stress and strain fields. In this study, the equivalent stress and strain of each particle are determined using Zhou formulation [3]. Second, we are interested in studying the ability of a DEM to simulate the thermal-induced damage in composite materials. For that purpose, damage effects and interfacial debonding are taken into account, and we distinguish between two cases, according to the temperature variation. In the first case, a rise in temperature leads to cracks initiation and propagation which are modeled by the Removed Discrete Element Failure criterion [2]. In the present contribution, we consider the brittle fracture of fragile materials such as silica and alumina. Due to their strong ability to resist in compression, the failure of fragile materials occurs when submitted to tensile solicitations. In fact, we consider that the fracture occurs when the hydrostatic stress for local tensile solicitations is greater than a given tensile strength limit. In the second case, a drop in temperature generates interfacial debonding which is modeled by the Discrete Damage Zone Model [2]. The idea is to replace the cohesive links connecting two particles belonging to two different phases by spring elements, which has a normal stiffness that tends to zero for high displacements. The results obtained in both cases are in good agreement with theoretical expectations.

REFERENCES

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