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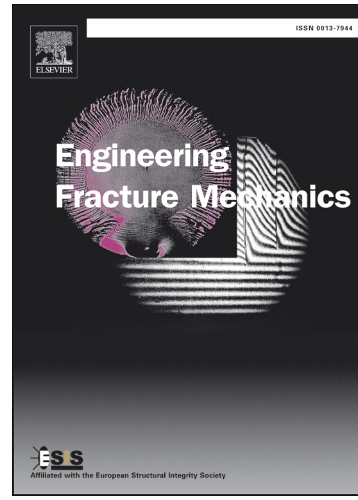

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Numerical simulation of fretting wear in fiber-reinforced composite materials

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Abstract

Computational modeling of fretting wear in fiber-reinforced composite materials is a difficult task due to the fact that contact and wear constitutive laws require considering micromechanical aspects such as the fiber orientation relative to the sliding direction or the fiber volume fraction. In this work, a 3D Boundary Element Method formulation for wear modeling is proposed and applied to simulate fretting-wear in fiber-reinforced composites. New contact constitutive laws for friction and wear modeling in fiber-reinforced composites are incorporated to an augmented Lagrangian resolution scheme and applied to compute and study wear in a carbon FRP film.

Keywords: Fretting wear, Fiber-reinforced Composites, Wear, Boundary Element Analysis.

1. Introduction

Fiber-reinforced composite materials are widely applied in many structural and mechanical systems in Aerospace, Automobile, Biomedical [1] or Building and Civil [2] engineering. In many of these applications, these materials are subjected to contact and interface loads (e.g. mechanical joints between FRP profiles and stainless steel connections or contact pin-loaded holes in FRP composite plates). So nowadays engineers require more sophisticated numerical tools that make it possible to study these materials under contact and wear conditions.

Friction and wear behavior of fiber-reinforced composites has been studied in-depth since the end the second half of the twentieth century in [3, 4, 5, 6, 7, 8, 9, 10, 11]. These experimental works have studied the significant influence of fiber orientation on the wear and frictional behavior of FRP composites. Those works showed that the friction coefficient depends on several factors including the combination of materials, the surface roughness or the fiber orientation (i.e. the largest coefficient of friction is obtained when the sliding is normal to the fiber orientation, while the lowest one is obtained when the fiber orientation is parallel to the direction of sliding) (see Fig.1 (a)). Considering a sliding direction on a plane parallel to the direction of fibers, it was observed in [3] that the friction coefficient sliding in parallel direction was smaller than in the transverse direction ($\mu_L \leq \mu_T \leq \mu_N$). So experiments reveal that contact and wear constitutive laws have to consider not only the micromechanics of the anisotropic bulk but also the fibers orientation (φ) and the sliding direction (θ) (see Fig.1 (b)).

Several semi analytical works [12, 13, 14, 15, 16, 17, 18, 19, 20] have dealt with the problem of contact and interaction modeling of FRP. However, due to their intrinsic mathematical complexity, analytical solutions incorporate several restrictive assumptions (e.g. rigid indenter, half-plane space or the sliding direction presented in Fig.1 (a)).

Numerical solutions based on the Finite Element Method (FEM) [21, 22] started to study some contact problems between composites, but isotropic friction laws were assumed. The indentation problem of fiber reinforced polymer was initially studied in [23]. Subsequently, a FEM formulation involving macro- and micro-contact analysis was presented in [24], and more recently, the fiber–matrix debonding process was studied in [25, 26]. As it can be observed in these works, a very fine mesh must be considered to approximate the contact problem between these composite domains.

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