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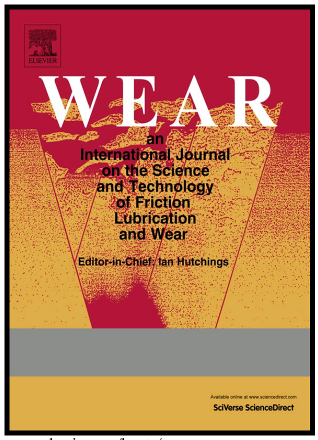

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Finite element modeling and experimental validation of single-asperity sliding friction of diamond against reinforced and non-filled polycarbonate

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Abstract

Polymer composites used as protective coatings are important, tribology-critical applications. In this study, hard or soft particle-filled model systems with a polycarbonate matrix are tested in single asperity sliding friction tests against diamond tips. A numerical approach developed to simulate scratching on unfilled polycarbonate was adapted by computing the effective material parameters for the hard and soft particle filled systems using representative volume elements. Combining this proper constitutive framework with a rate-independent friction model correlated quantitatively with the results of the current scratching experiments.

Keywords: Sliding friction; Contact mechanics; Solid mechanics; Polymer-matrix composite; Scratch testing; Finite element modeling

1. Introduction

Filled polymer systems are important in direct tribological applications, but also in scratch and wear resistant coatings. Scratching surfaces is a challenging subject because of the complex contact conditions involving many variables [1, 2, 3, 4]. Therefore, simplifications are required to arrive at well-defined contact situations and, in this paper, we focus on the single-asperity sliding friction test, often reffered to as 'scratch test'. This test allows studying a wide range of surface mechanical properties in a controlled manner [5, 6]. Generally, friction is understood as the resistance encountered by a body sliding over another. Important for a proper description of friction is the real contact area between the two bodies, in our case the contact area between the indenter-tip and the polymer surface. Usually this contact area is approximated by the projected area resulting from either ideal elastic or ideal plastic deformation, or a combination thereof [1, 6, 7, 8]. For polymers, characterized by their visco-elastic nature, this is a strong assumption. During scratching the polymer already relaxes in the wake of the indenter tip and to determine the real contact area proves challenging. It is either estimated by analyzing the residual scratch geometry [9] or, in the case of transparent samples, in situ monitored with a microscope mounted underneath the sample [10, 11]. The rise of Finite Element Methods (FEM) opened up new possibilities to study nonlinear contact problems and simulations confirm that standard assumptions concerning contact areas are inaccurate for polymeric materials [12]. Therefore, instead, advanced FEM computations are increasingly employed to analyze complex responses in sliding friction [13, 14, 15, 16, 17, 18, 19, 20]. Most studies provide a valuable, but still only qualitative, description of the scratch response, and quantitative predictions based on the polymers' intrinsic mechanical response are challenging.
In our previous study we employed a hybrid experimental–numerical approach to analyze scratching a well characterized model polymer, which was unfilled polycarbonate [21]. The rate-dependent macroscopic friction force proved to be the result of a complex process. It is covered by the subtle

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