A micromechanical approach for the wear prediction of fiber-reinforced composites

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1. Introduction

For the last several decades, micromechanics has been extensively developed to predict the macroscopic properties of inhomogeneous materials in terms of relevant microscopic properties and microstructure. A great number of results of theoretical and practical interest have been obtained for a variety of mechanical and physical phenomena. However, micromechanics seems not to have been developed to model the wear of materials, in spite of the fact any material surface appearing to be homogeneous at the macroscale is in reality heterogeneous at the microscale. The main objective of the present work is to propose a micromechanical approach so as to get a better qualitative understanding and a better quantitative estimation of the wear of two materials sliding one against other.

Considering a fiber-reinforced composite (FRC) which is statistically homogeneous at the macroscale, we first introduce the notion of a representative surface element (RSE), as shown in Fig.1. This notion can be viewed as the surface counterpart of the concept of a representative volume element (RVE) in micromechanics. The local wear behavior of the material forming the RSE is assumed to be described by Archard's law [1], and the macroscopic wear behavior of FRC can be shown to comply with the same law. The key to determining the effective wear property of FRC is the ratio of the load sustained by the fibers to the one of the matrix. Modelling the microstructure of FRC as a composite cylinder assemblage (CCA) [2], we can exactly determine the fibers-to-matrix load ratio under uniform stress and strain boundary conditions. With this result, the effective wear compliances of FRC are analytically expressed in terms of the elastic moduli, Poisson's ratios, wear compliances and volume fractions of the constituents, which serves for optimizing the wear performance of the composite.

Our theoretical results are compared with the previous studies and turn out to be consistent with available experimental results for different fiber-reinforced composites (Fig. 2).

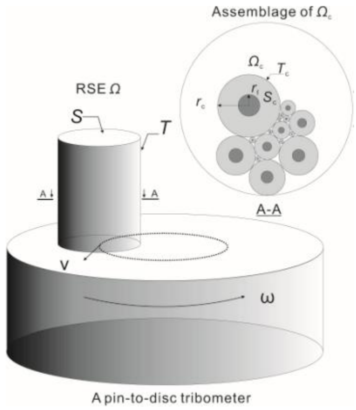

Fig. 1 The pin (RSE) of a tribological system illustrated as a cylinder element assemblage (CCA)

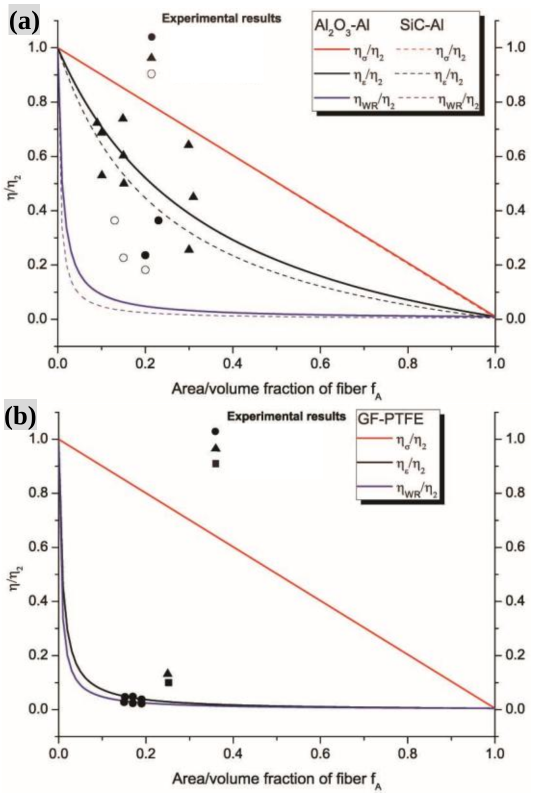

Fig. 2 The ratios of the effective wear compliances of composites to that of matrix under uniform stress (η_σ/η_2), strain (η_ε/η_2) or equal linear wear rate (η_{WR}/η_2) and the experimental wear rates of the corresponding composites: (a) aluminum-based composites (b) glass fiber-reinforced PTFE

2. References

[1] Archard, J. F., "Contact and rubbing of flat surfaces," J. Appl. Phys., 24, 8, 1953, 981-988.

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