Liu, M., Hsia, K., and Shang, J., Driving Forces for Interfacial Fatigue Crack Growth by Piezoelectric Actuator, Journal of Intelligent Material Systems and Structures, 16, 2005, pp. 557-566

Abstract

A new experimental technique for accelerated fatigue testing has recently been developed (Du, T.B., Liu, M., Seghi, S., Hsia, K.J., Economy, J. and Shang, J.K. 2001. "Piezoelectric Actuation of Crack Growth along Polymer–Metal Interfaces in Adhesive Bonds,'' Journal of Material Research, 16(10):2885–2892). Using a piezoelectric actuator, cyclic loading can be applied at frequencies up to 20 kHz, several orders of magnitude higher than that achieved by a conventional mechanical cyclic loading technique. Moreover, the new technique using piezoelectric actuators directly addresses the debonding problem in piezoelectric multilayered smart structures. However, the threshold energy release rate for interfacial crack propagation, evaluated based on plane strain and linear piezoelectricity assumptions in (Du, T.B. 2001. ''Durability of Polymer/Metal Interfaces under Cyclic Loading,'' PhD Thesis, University of Illinois at Urbana-Champaign, Urbana, IL, May), seems to be almost an order of magnitude lower than that measured by the conventional mechanical cyclic loading. In this article, we investigate the origin of such discrepancies, and find that the driving force provided by piezoelectric actuator is intrinsically three-dimensional in nature. To account for this effect, we develop both a plane strain model and a modified plane strain analytical model that takes into account the effects in the third dimension to evaluate the energy release rate. The results show that the plane strain solution underestimates the driving force. We also study the effect of nonlinear piezoelectricity on crack driving forces by performing detailed finite element simulations. The results show that the nonlinear piezoelectric effect is another important factor that contributes to the discrepancy between the results from the piezoelectric loading and that from the conventional mechanical loading.

Keywords

Interfacial crack, Piezoelectric bender, Cyclic fatigue, Finite element analysis, Nonlinear piezoelectricity