Fatigue life estimation of a 1D aluminum beam under mode-I loading using the electromechanical impedance technique

Abstract

Structures in service are often subjected to fatigue loads. Cracks would develop and lead to failure if left unnoticed after a large number of cyclic loadings. Monitoring the process of fatigue crack propagation as well as estimating the remaining useful life of a structure is thus essential to prevent catastrophe while minimizing earlier-than-required replacement. The advent of smart materials such as piezo-impedance transducers (lead zirconate titanate, PZT) has ushered in a new era of structural health monitoring (SHM) based on non-destructive evaluation (NDE). This paper presents a series of investigative studies to evaluate the feasibility of fatigue crack monitoring and estimation of remaining useful life using the electromechanical impedance (EMI) technique employing a PZT transducer. Experimental tests were conducted to study the ability of the EMI technique in monitoring fatigue crack in 1D lab-sized aluminum beams. The experimental results prove that the EMI technique is very sensitive to fatigue crack propagation. A proof-of-concept semi-analytical damage model for fatigue life estimation has been developed by incorporating the linear elastic fracture mechanics (LEFM) theory into the finite element (FE) model. The prediction of the model matches closely with the experiment, suggesting the possibility of replacing costly experiments in future.