Modeling approach to evaluating reduction in stress intensity factor in center-cracked plate with piezoelectric actuator patches

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Abstract

Active repairs using piezoelectric actuators can play a significant role in reducing the crack damage propagation in thin plate structures. Mode-I crack opening displacement is the most predominant one in tension, and it is responsible for the failure which in turn affects the load carrying capability of the cracked structure. In addition, there are limited studies that investigated the effect of the piezoelectric actuator over mode-I active repair. In this study, the mode-I stress intensity factor for a plate with a center crack, and a bonded piezoelectric actuator was modeled using the linear elastic fracture mechanics. For this, an analytical closed-form solution is developed using the virtual crack closure technique taking into account mode-I as the only effective mode, coupling effects of the piezoelectric patch, and the singular stress at the crack tip. In addition, the total stress intensity factor was obtained by the superposition of the stress intensity factor obtained from the stresses produced by the piezoelectric actuators on the crack surfaces as the only external loads on the cracked plate and the stress intensity factor due to the far-field tension load. The proposed analytical model for mode-I stress intensity factor was verified by a finite element-based approach using ANSYS finite element software. The results demonstrated a good agreement between the analytical and finite element models with a relative error of less than 4% in all the cases studied. The results illustrated that the piezoelectric patch is efficient in reducing stress intensity factor when an extension mode of the actuator is applied. However, applying a contraction mode of the piezoelectric actuators produced negative strain which increased the stress intensity factor and thus the severity of the cracked structure and could lead to damage propagation.

Keywords

Author Keywords: Energy release rate; mode-I stress intensity factor; piezoelectric actuator; finite element; fracture mechanics

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