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Thermal fracture analysis of a Griffith crack in a functionally graded material by nonlocal theory

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ABSTRACT

Functionally graded materials (FGMs) are widely used as thermal barrier coatings in high temperature applications. This work is devoted to analyzing the thermal-mechanical response of a FGM containing a completely thermal insulated crack considering the size effect. The nonlocal elasticity is employed to study the thermoelastic fracture behavior in FGMs for the first time, where the moduli of the FGM are assumed to vary exponentially with the spatial coordinate perpendicular to the crack. With the help of Fourier transform, the mixed, boundary-value problems are reduced to two pairs of dual integral equations. The dual integral equations are then solved numerically using the Schmidt method, where the unknown jumps of displacements across crack faces are expressed as a series of Jacobian polynomials. The numerical results show that the thermal stress at the crack tip is finite, and the maximum stress occurs slightly away from the crack tip, which agrees well with the previous experimental findings qualitatively. Nonlocal analysis allows us to eliminate the contradiction in the traditional fracture mechanics where unphysical stress singularities at crack tips occur. It enables us to establish a maximum stress-based fracture criterion for FGMs working in various thermal environments. Besides, the locations of maximum stresses are found to be mainly determined by the nonlocal characteristic length, reflecting a length-scale related feature for materials with heterogeneous microstructure.