Mode-I Crack Control by SMA Fiber with a Special Configuration

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Abstract Crack propagation in solid members is an important reason for structure failure. In recent years, many research interests are focused on intelligent control of crack propagation. With the rise in temperature, contraction of prestrained shape memory alloy (SMA) fiber embedded in matrix makes retardation of crack propagation possible. However, with the rise in temperature, separation of SMA fiber from matrix is inevitable. This kind of separation weakens effect of SMA fiber on crack tip. To overcome de-bonding of shape memory alloy (SMA) fiber from matrix, a knot is made on the fiber in this paper. By shape memory effect with the rise in temperature, the knotted SMA fiber generates a couple of recovery forces acting on the matrix at the two knots. This couple of recovery forces may restrain opening of the mode-I crack. Based on Tanaka constitutive law on SMA fiber and complex stress function near an elliptic hole under a point load, a theoretical model on mode-I control is proposed. An analytical expression of relation between stress intensity factor (SIF) of mode-I crack closure and temperature is got. Simulation results show that stress intensity factor of mode-I crack closure decreases obviously with the rise in temperature higher than the austenite start temperature of SMA fiber, and that there is an optimal position for SMA fiber to restrain crack opening, which is behind the crack tip. Therefore the theoretical model supports that prestrained SMA fiber with knots in martensite can be used to control mode-I crack opening effectively because de-bonding between fiber and matrix is eliminated. Specimen of epoxy resin embedded with knotted SMA fiber can be made in experiment and is useful to an analytical study. However, in practical point of view, SMA fiber should be embedded in engineering structure material such as steel, aluminum, etc. The embedding process in these matrix materials should be studied systematically in the future.