World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:11, No:05, 2017

On Crack Tip Stress Field in Pseudo-Elastic Shape Memory Alloys

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Abstract : In shape memory alloys, upon loading, stress increases around crack tip and a martensitic phase transformation occurs in early stages. In many studies the stress distribution in the vicinity of the crack tip is represented by using linear elastic fracture mechanics (LEFM) although the pseudo-elastic behavior results in a nonlinear stress-strain relation. In this study, the HRR singularity (Hutchinson, Rice and Rosengren), that uses Rice's path independent J-integral, is tried to formulate the stress distribution around the crack tip. In HRR approach, the Ramberg-Osgood model for the stress-strain relation of power-law hardening materials is used to represent the elastic-plastic behavior. Although it is recoverable, the inelastic portion of the deformation in martensitic transformation (up to the end of transformation) resembles to that of plastic deformation. To determine the constants of the Ramberg-Osgood equation, the material's response is simulated in ABAQUS using a UMAT based on ZM (Zaki-Moumni) thermo-mechanically coupled model, and the stress-strain curve of the material is plotted. An edge cracked shape memory alloy (Nitinol) plate is loaded quasi-statically under mode I and modeled using ABAQUS; the opening stress values ahead of the cracked tip are calculated. The stresses are also evaluated using the asymptotic equations of both LEFM and HRR. The results show that in the transformation zone around the crack tip, the stress values are much better represented when the HRR singularity is used although the J-integral does not show path independent behavior. For the nodes very close to the crack tip, the HRR singularity is not valid due to the non-proportional loading effect and high-stress values that go beyond the transformation finish stress.

Keywords : crack, HRR singularity, shape memory alloys, stress distribution
Conference Title : ICFMPCA 2017 : International Conference on Fracture Mechanics, Polymers, Composites and Adhesives
Conference Location : Paris, France
Conference Dates : May 18-19, 2017