BENDING AND STATIC FATIGUE BEHAVIOR OF CRACKED PIEZOELECTRIC CERAMICS UNDER ELECTRIC FIELDS

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Lead zirconate titanate (PZT) ceramics are widely used in piezoelectric devices, e.g., sensors and actuators. The high mechanical stresses and intense electric fields in the PZT ceramics may cause microcracks to develop which eventually lead to failure of the devices. The fracture behavior of the PZT ceramics under electromechanical loading has been the subject of recent studies [1-3]. Fatigue crack propagation has also been demonstrated in the PZT ceramics under cyclic electric loading. Literature studies of fatigue in the PZT ceramics under both mechanical and electrical loads are sparse and inconclusive.

In this study, we present experimental and numerical results on the fatigue behavior of piezoelectric ceramics under constant applied mechanical and electric fields. Static fatigue tests were carried out with the single-edge precracked-beam specimens. The crack was created perpendicular to the poling direction. Time-to-failure under different mechanical loads and dc electric fields were obtained from the experiment. Microscopic examination of the fracture surface of the PZT ceramics was performed as well. A finite element analysis was also made, and the applied energy release rate for the permeable crack model was calculated. The effect of applied dc electric fields on the energy release rate versus lifetime curve is examined. The most important conclusion we reach is that the lifetimes for the PZT specimens under positive electric fields are much shorter than the failure times of specimens under negative electric fields for the same mechanical load level.

References

[1] Y. Shindo, H. Murakami, K. Horiguchi and F. Narita, “Evaluation of electric fracture properties of piezoelectric ceramics using the finite element and single-edge precracked-beam methods,” *J. Am. Ceram. Soc.* **85**, 1243-1248, 2002.
[2] Y. Shindo, F. Narita, K. Horiguchi, Y. Magara and M. Yoshida, “Electric fracture and polarization switching properties of piezoelectric cramic PZT studied by the modified small punch test,” *Acta Mater*. **51**, 4773-4782, 2003.
[3] Y. Shindo, F. Narita and M. Mikami, “Double torsion testing and finite element analysis for determining the electric fracture properties of piezoelectric ceramics,” *J. Appl. Phys*. **97**, 114109, 2005.

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