Nonlinear Crack Growth Monitoring

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Oak Ridge National Laboratory has developed[1] a radically new technique to monitor the growth of cracks in structural members, and to predict at what point failure due to this damage is imminent, requiring structure repair or replacement, in those cases where predictions based on conventional design techniques are difficult. This will allow greater confidence in continued operation of structures with known flaw sites, and will provide a quantifiable means of assessing when structure failure is imminent.

ISSUES

Conventional design codes for structural members, such as piping and pressure vessels, are based on the assumption of constant material geometry and properties, or material geometry and properties which change in a way which is both measurable and feasible to measure. However, during service, temperature, loading changes, and corrosive environments can change the nature of structural materials in such a way as to be very difficult to predict their effect. Also, the presence and growth of inherent or introduced flaws into the structure make assessment of the future response under continued loading using conventional methods very difficult.

Many present structures in service are nearing the end of their useful life, as indicated by the approaching expiration of the design capability. While demonstrably safe when new, the challenge facing many structural engineers today is to demonstrate continued safety in operating structures whose material properties are changing with time as the structure ages.

In actual structures, there are often many possible failure modes, each with its own unique physical mechanism. The key to the application of this technique is that it is based on Griffith critical strain energy consumption, and as such, requires measurement of a variable proportional to global loading and a displacement or strain in the critical area of interest. These signals are mathematically integrated to yield hysteresis strain energy, and nonlinear analysis of this signal versus time, cycles, etc. reveals predictive information about the progress of the damage, and an action level which marks the end of useful structure life.

This technique works best when applied to structures of significant value which would otherwise be replaced or discarded due to the presence of an area of damage or a limited ability to predict the onset of final failure from that damage, leading to a lack of confidence of future survival. Examples of these types of structures are pressure vessels, bridges, railway structures, and aircraft.

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[1] Welch, D. E., Hively, L. M., and Ruggles, M. B., *Nonlinear Crack Growth Monitoring*, ORNL-TM-1999/117, Oak Ridge National Laboratory, Oak Ridge, TN, October, 1999.