Outline of ORNL Crack-Related Research of Interest to Structural Assessment of Aging Aircraft

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I. Structures fail due to a variety of crack-related causes, and the life of an individual structure can only be estimated.
   A. Fatigue
   B. Stress corrosion
   C. Corrosion fatigue
   D. Low temperature creep
   E. High temperature creep

II. Methods have been developed to manage fleets subject to crack-related structural failure, and each has advantages and disadvantages.
   A. Safe flight based on fleet probability of failure
   B. Damage tolerance accepts initial presence of flaws, and determines their effect based on projections of operational and environmental effects

III. Based on patented research in another field, a <u>new</u> method for assisting both the safe flight and the damage tolerance methodology by experimentally detecting the end of life in structures subject to several kinds of crack growth has been discovered.
   A. Basis in previously patented nonlinear mathematical techniques applied to electroencephalographic data to detect the onset of epileptic seizures in patients.
   B. Similar methods applied to structural crack-related failure
   C. Datum selected for analyzing is hysteresis strain energy

IV. By using this method, it possible to improve the advantages and decrease the disadvantages of the current methods for structural integrity management
   A. For structures managed according to safe flight techniques, implementation of this new method will avoid the occurrence of crack-related structural failures, and will utilize each member of a fleet of structures subject to crack-related failure to its fullest potential, thereby significantly increasing the average operational life of a fleet.
   B. For structures managed according to the damage tolerance method, it will have the added benefit of increased reliability of detection of flaw progression in individual aircraft, and the reduction in the cost and frequency of full-scale fleet NDE for flaws.

V. Significant internally funded initial development of some aspects of this method have been conducted, with promising results.
   A. Repeatability established under lab conditions for various materials tested (random chopped mat fiberglass, 2024 aluminum, ASTM A-36 bridge steel)
   B. Works with “simulated” Multiple Site Damage (MSD) samples
   C. Works with pristine or corroded samples
   D. Detects flaw growth due to multiple crack-related mechanisms (fatigue, stress corrosion, etc.)
   E. Potential for working with variable loading pattern established (stair-step loading effect on damping)

    F. Basis of method in fracture mechanics established

VI. There are a number of questions which need to be answered to determine the extent of potential for application in more complicated field situations.

    A. Effects of fatigue frequency and spectrum
    B. Effects of environmental variation
    C. Interactive modes of crack-related failure (corrosion fatigue or fatigue and stress corrosion)
    D. Effects of various modes of loading (tension, flexure, shear/torsion)
    E. Effects of various modes of crack growth (Mode I, II, or III)
    F. How close must deflection sensor be to critical defect?
    G. Applications envisioned
    H. New hardware or instrumentation needed

VII. Based on the considerable laboratory experimentation in simple applications which has been performed to date, there is a potential for some suitable transition to field implementation in Aging Aircraft structures.

    A. Example is KC-135 fuselage longeron stringer-tie fatigue failure (twelve rivet holes per stringer tie, 60 per fuselage circumferential rib, hundreds in aircraft, extensive field and DPM NDE required)
    B. Material is 7075-T6 aluminum, mechanism is fatigue and/or stress corrosion cracking, loading is tension, mode is Mode I cracking at longeron joining rivet holes.
    C. When Mode I rivet hole cracks are detected by NDE, stringer ties are field replaced by field drilling matching holes in stringer tie to match holes in longerons. Potential for misalignment and resulting load distribution problems is great.
    D. Potential near term solution may be installation of thin fiber optic cables along fuselage longerons with embedded Bragg grating displacement sensors for measuring local critical displacements.

VIII. There are significant opportunities within the Air Force to perform, at relatively minor cost, additional investigation of the potential for this method.

    A. Potential for demonstration of technology developed thus far by minor test add-ons to currently planned full scale T-38 fatigue tests.
    B. Potential for demonstration of technology in future planned pressure bulkhead tests in DC-9