Nonlinear Crack Growth Monitoring

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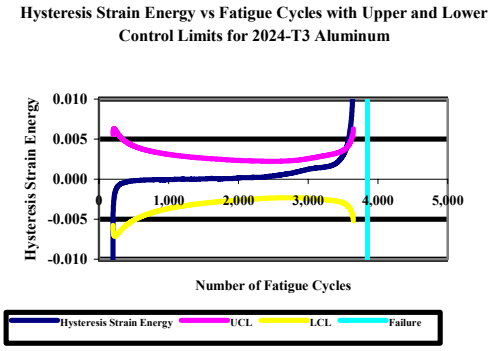
Prediction of fatigue failure in military structures is very difficult by conventional means. This difficulty arises from the fact that the most of the fatigue lifetime (90-95%) is spent in nucleation of very tiny flaws into measurable cracks. Moreover, large variation occurs in the nucleating flaw sizes and the flaw growth rate, even in high quality structures. Thus, the time to failure can vary by a factor of 10 to 20 in a fleet. Allowance for this large variation in fatigue lifetimes leads to conservative statistics, which focus on the weakest members of the fleet while the remainder of the fleet is sound. The result often is premature retirement or overhaul of aircraft or other structures. In addition, conventional prediction uncertainties are based on crack growth rate projections that are only as accurate as the projections of future loading amplitude, frequency, service patterns, and environmental exposure. Finally, uncertainties exist in crack growth rate analysis due to general corrosion and widespread fatigue cracking. Additional conservatism must be incorporated into the allowable structure flaw size to account for these uncertainties, leading to more frequent and costly nondestructive inspection intervals.

Oak Ridge National Laboratory has developed and patented (U.S. Pat. #6,460,012) a technique for forewarning of fatigue failure in structures. The technique uses experimentally acquired data on local strain (e.g., displacement near a crack sensitive area) and a measure of the gross load on the structure. This data is then integrated over time to determine the difference between the local strain energies during the loading and unloading portions of each fatigue cycle. This difference represents net energy into the structure that is available for growing a crack. This technique is based on the Griffith energy absorption method. This net energy absorption per fatigue cycle is then monitored for changes in energy absorption, indicating the approach of fatigue crack failure.



This technique gives forewarning of structural failures, such as critical aircraft structural members, thus allowing repair, replacement, or abandonment of the structure prior to its failure. Concurrently, planned useful life of the asset could be confidently extended with the knowledge that critical members were being monitored. This technique will also allow analysis of the frequency of safety related failures, such as the transition from random failures to wear-out failures. This guidance would facilitate the safety and economic management of the fleet of structures, while avoiding the occurrence of individual safety related failures.