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Fatigue Damage Monitoring and Remaning Life Assessment using Nonlinear Vibro-Modulation Technique

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Assessment of structural deterioration due to in-service and environmental loads is an essential element in ensuring safety, operability and long life of various structures and structural components. We applied vibro-acoustic modulation technique to monitor material degradation at the micro/meso scale before the onset of the macro-scale fracture. The technique explores nonlinear acoustic interaction of high frequency ultrasound and low frequency structural vibration at the site of the incipient damage. It is shown that micro/meso scale degradation increases the material nonlinearity leading to modulation of the high frequency ultrasonic signal by low frequency vibration, quantified by the nonlinear acoustic Damage Index (DI). Numerous tests with hundreds of test coupons proved high sensitivity of the developed technique to micro/meso scale fatigue damage accumulation. The study further demonstrated that the remaining life of the fatigued material can be predicted using phenomenological damage accumulation rule expressed through measured Damage Index. Work supported by NAVAIR.