Detecting microscale material degradation using waveform evolution of broad-band Rayleigh waves

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ABSTRACT

Early detection of material degradation can provide sufficient warning to avoid failure of engineering components. Micro-scale degradation enhance nonlinearity in materials. Therefore, assessing the evolution of nonlinearity can provide information about micro-scale degradation. In case of harsh environments, or limited accessibility, noncontact wave generation can be a priority, where lasers can be used. We studied the applicability of broad-band Rayleigh waves in nondestructive evaluation of engineering components. Unlike narrow-band surface acoustic waves where the acoustic nonlinearity parameter (β) is widely being used to assess material degradation, broad-band surface acoustic waves evaluate degradation and material nonlinearity using waveform evolution. Laser-generated surface acoustic waveforms are amplitude and propagation distance dependent. Characterization of waveform evolution, while challenging, is measurable. We proposed a robust method to measure the evolution of changing waveforms and used waveform evolution to detect micro-scale degradation in thermal-aged samples. In this regard, two IN718 samples, one baseplate and one made by directed energy deposition additive manufacturing (DED-AM), were artificially aged. The aging process causes precipitation of the δ-phase at grain boundaries, which are a source of nonlinearity. Q-switched Nd:YAG laser pulses were formed into a narrow beam to generate planar surface acoustic waves (SAWs). Steepness, the slope of the fitted straight line on the right-hand side of the V-shaped waveforms, ignoring 25% of the points close to the peak and valley, was measured to have a quantitative assessment of waveform evolution. The study considered both absolute and normalized values of waveform evolution (steepness). More severe waveform evolution was observed in aged samples compared to the pristine one, concluding that the normalized value of waveform evolution can be used for early detection of material degradation. The aged AM IN718 sample shows more severe steepness evolution compared to the pristine AM sample indicating that AM IN718 samples are more prone to precipitation of δ-phase compared to the base plate. These novel results reveal that waveform evolution has considerable promise to characterize micro-scale degradation based on the waveform evolution of SAWs using noncontact laser-based methods.