Development of a single mode nonlinear acoustic resonance method for the detection of delamination due to low velocity impact.

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Abstract:

Modern aerospace structures make increasing use of fibre reinforced plastic composites, due to their high specific mechanical properties. However, due to their brittleness, low velocity impact can cause delaminations beneath the surface, while the surface may appear to be undamaged upon visual inspection. Such a damage is called barely visible impact damage (BVID). Such internal damages lead to significant reduction in local strengths. These initial delaminations can slowly grow under alternating or fluctuating stress leading to a loss in stiffness and ultimately could lead to catastrophic failures. It is therefore important to detect and monitor damages in high loaded composite components to receive an early warning for a well timed maintenance of the aircraft.
The non-linear acoustic spectroscopy methods are promising damage detection and material characterization tools. Detailed studies of dynamic non-linearities and hysteresis in inhomogeneous media[1,2] have shown that the occurrence of mesoscopic elements in the material structure gives rise to strongly nonlinear dynamic phenomena accompanying the elastic wave propagation [3]. These non-linear effects are observed in the course of the degradation process much sooner than any degradation-induced variations of linear parameters (propagation velocity, attenuation, elastic moduli, rigidity etc.). Non-linear parameters have proved to be very sensitive to the presence of any inhomogeneities and progressive degradation of the material structure.
In this paper, single mode nonlinear resonance acoustic spectroscopy (SIMONRAS) technique was applied to detect delamination damage due to low velocity impact on a composite. A nonlinear resonant acoustic spectroscopy is a resonance-based technique exploiting the significant nonlinear behaviour of damaged materials. The resonant frequency of an object was studied as a function of the excitation level. As the excitation level increased, the elastic nonlinearity was manifest by a shift in the resonance frequency, as showed in Fig. 1.

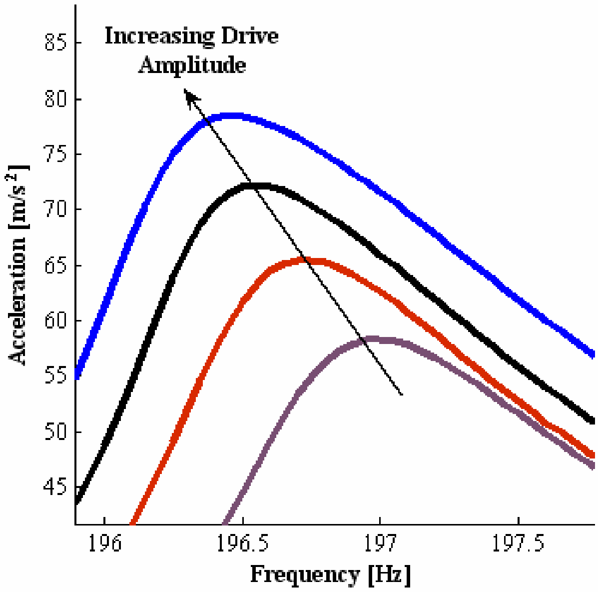

Fig. 1. Shifting of resonance frequency due to the load increasing.

The frequency shift was a manifestation of nonlinearity due to the presence of the cracks, in this case back-plate delamination. As the damage increased the NRAS test revealed a corresponding increase in the nonlinear response (see Fig. 2). The measured change in nonlinear response was much more sensitive than the change in linear modulus. The results showed that the proposed methodology appear to be highly sensitive to the presence of damage with very promising future applications.

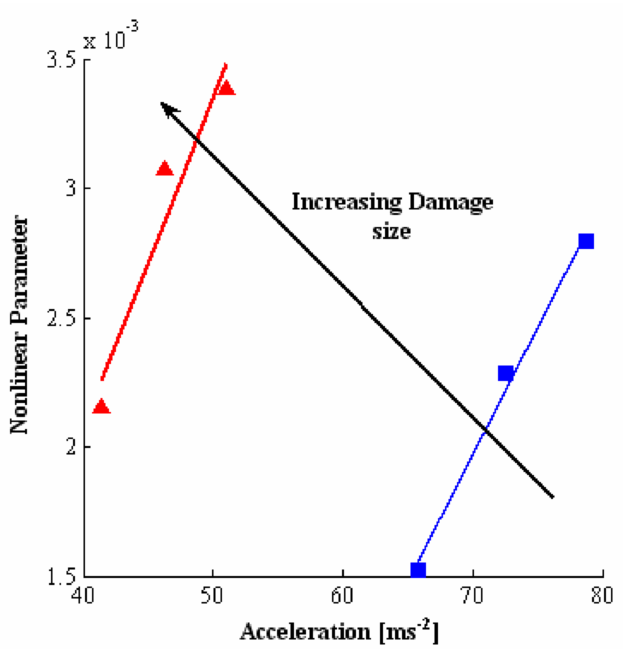

Fig. 2. Non linear response for two damage stages.

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