

Optimisation of nonlinear elastic wave spectroscopy for diagnostic nondestructive testing and imaging

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Wave Propagation and Signal Processing



The author

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Aim of the study

Material damage is known to introduce nonlinear wave distortion. This behaviour introduces spectral changes such as harmonics generation and wave modulation, both macroscopic footprints that reveal the presence of defects. Nonlinear Elastic Wave Spectroscopy (NEWS) deals with these effects in order to quantify and localise cracks [1]. Three NEWS methods are tested and compared on a steel bracket of an airplane landing gear. Two samples contain a crack that is located on the surface and whose sides are perpendicular to it. This kind of damage is called a surface breaking crack.

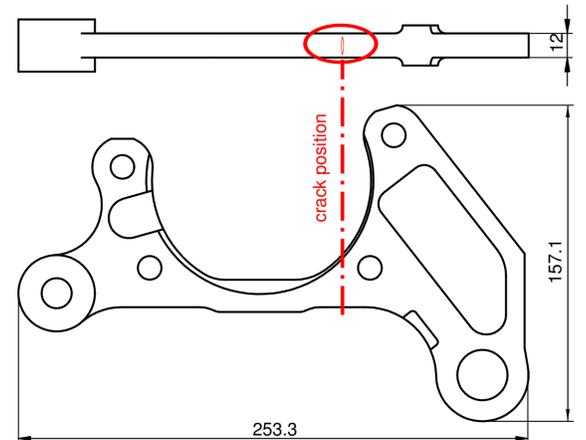


Figure 1: Front and top view of the sample, showing dimensions (in mm) and crack position.

Reverberation Spectroscopy

The elastic constant of a material determines its eigenfrequencies. Resonance peaks of a nonlinear material measured for varying excitation amplitudes reveal a frequency shift proportional to the material nonlinearity.

Nonlinear Reverberation Spectroscopy (NRS) uses the amplitude variation in a damped signal (reverberation) after applying a high amplitude audible sound source on a sample [2].

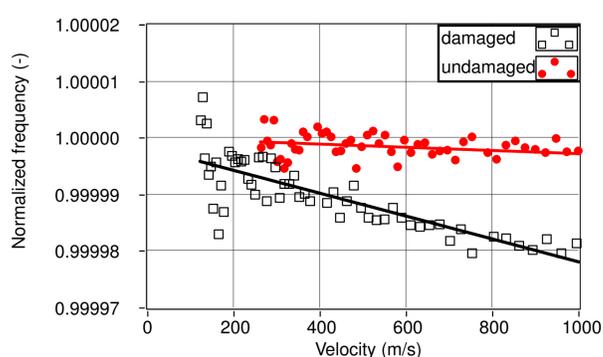


Figure 2: NRS results. The frequency shift is much larger in the case of a damaged bracket.

Investigated NEWS methods

Impact Modulation

Two independent waves with different frequencies f_0 and f_1 ($f_1 \ll f_0$) propagating through a nonlinear medium will interact, resulting in modulation frequencies $f_0 \pm n f_1$, in which n is a natural number. The Impact Modulation (IM) technique uses the transient signal generated by a short impact as low frequency signal. The high frequency signal is provided by a PZT transducer [3].

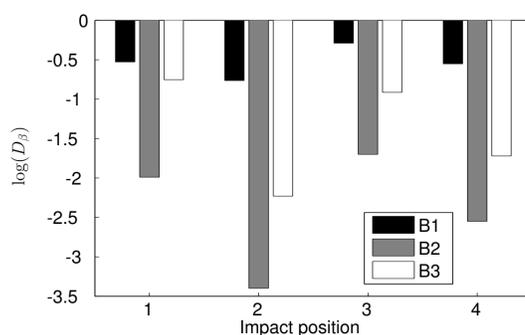


Figure 3: Quantification of the sideband energies for a damaged (B1), undamaged (B2) and slightly damaged bracket (B3).

Vibration dipole

Time reversed acoustics (TRA) is a well known technique to focus energy on any point in a material, using a limited amount of source transducers and a laser vibrometer as a receiver [4].

To trigger the nonlinear behaviour of a crack, two opposite pulses (a so called vibration dipole) are generated left and right of the crack. Generating dipoles in a zone around the crack will result in high nonlinear responses if the peaks are left and right of the crack (situation (b)), and low nonlinear response if both peaks are at the same side of the crack (situation (a)).

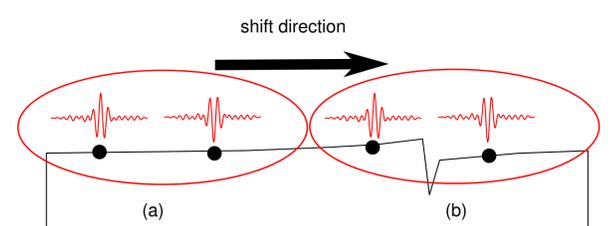


Figure 4: Schematic overview of the TRA vibration dipole experiment.

References

- [1] Van Den Abeele, K., Sutin, A., Carmeliet, J., and Johnson, P. *NDT and E International* **34**(4), 239–248 (2001).
- [2] Van Den Abeele, K., Le Bas, P., Van Damme, B., and Katkowsky, T. *The Journal of the Acoustical Society of America* **126**, 963 (2009).
- [3] Van Damme, B. and Van Den Abeele, K. In *Emerging Technologies in Non Destructive Testing 5* (ETNDT, Ioannina, Greece, 2011).
- [4] Van Damme, B., Van Den Abeele, K., Li, Y., and Bou Matar, O. *Journal of Applied Physics* **109**, 104910–1–104910–10 (2011).

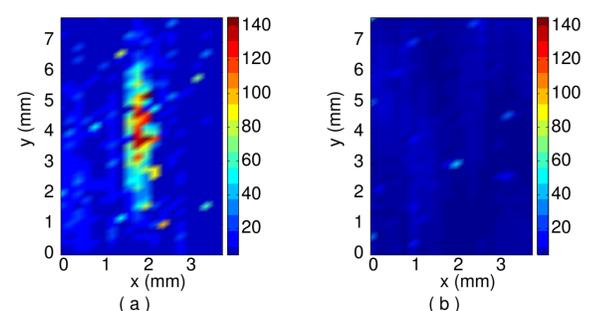


Figure 5: Results of the vibration dipole TRA experiment for the damaged (a) and undamaged (b) bracket.