Component Inspection *with Non-linear*

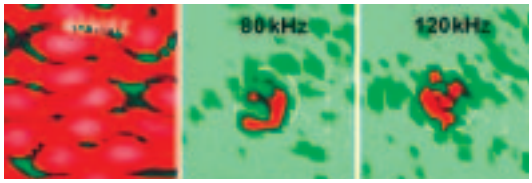
New Method for Non-destructive Testing of Materials and Structures using Non-linear Acoustics

Nonlinear Laser Vibrometry is a new method designed to non-destructively detect defects from higher harmonics produced by a local mechanical rectification of oscillations at the defect. This new method is a reliable quality inspection tool for both production and maintenance applications.

Figure 2: An image of a delamination in a C-C/SiC-Ceramic (Carbon fibre reinforced silicon-carbide) using second harmonic detection (20 kHz excitation).

Introduction

In classical vibrometry a specimen's acoustic response is detected by a transducer like a human ear, a microphone, an accelerometer or a laser interferometer. Defects are found by comparing the specimen's acoustic (resonance) response with a standardized response from a defect-free sample. Resonance frequencies depend on the geometry of the specimen. Variations in specimen size often occur during the production process. These variations in geometry may produce similar spectra to critical localized defects.



Non-linear Scanning Vibrometry

To avoid this ambiguity a defect-sensitive imaging method was developed. Most types of localized defects are correlated with boundaries that can move with respect to each other when acoustically excited. Boundary clapping or rubbing can generate higher harmonics of the exciting frequency (figure 1). This behavior can be seen as a mechanical rectification of an oscillation where, for example, only pressure, not traction, is transferred. This effect is a local non-linearity and is independent of geometry-determined resonances. When a laser interferometer is used as the transducer, the method is known as Non-linear Laser Vibrometry.

Figure 3: Higher harmonics (40 kHz excitation) at a simulated defect: Delamination in carbon fibre reinforced plastics (CFRP).

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Laser Vibrometry

Because a localized defect is marked by higher harmonics, while defect-free areas only show the excitation frequency, defects can be distinguished from defect-free areas by frequency selective imaging systems.

Such an imaging system can be constructed from a mechanically-coupled single-frequency resonant transducer that excites an oscillation in the structure to be analysed. Then a Polytec Scanning Laser-Doppler-Vibrometer (PSV 300-S) images the surface of the structure being inspected. The PSV-300-S was chosen for its high spatial (lateral) resolution, accuracy and measurement speed.

Material delamination and cracking are common defects that can significantly degrade the performance of automotive and aerospace products. Non-linear Laser Vibrometry is used in the following examples (figures 2 to 4) to find localized defects.

In many cases only harmonics of higher order exhibit enough contrast for imaging. By combining 20 kHz excitation with the Polytec Scanning Laser Doppler Vibrometer, defect frequencies up to 1 MHz (fiftieth harmonic) are detectable.

Conclusion

Nonlinear Laser Vibrometry is a new method designed to non-destructively detect defects from higher harmonics produced by a local mechanical rectification of oscillations at the defect. This new method is a reliable quality inspection tool for both production and maintenance applications.

Future Prospects

Given an intense acoustic drive, a localized defect behaves like a highly nonlinear, parametric oscillator. As a result, the resonance effects of the dynamic instability develop in the form of a subharmonic, frequency pair and chaotic oscillations. These effects are localized in the damaged area, making them applicable for locating and imaging of defects.

These effects are currently part of scientific investigations that enhance the understanding and availability of nonlinear effects for defect detection and imaging.

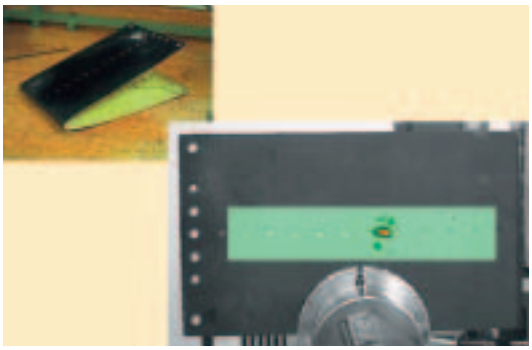

Figure 4: Flaw detection in aluminum: 4th Harmonic (excitation frequency 20 kHz)

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Figure 1: Priciples of non-linear laser vibrometry