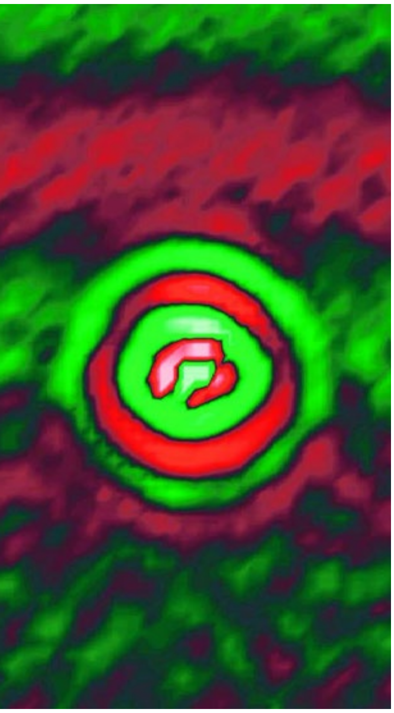


Aircraft Health Monitoring
Laser Vibrometry for Damage Detection Using Lamb Waves
Application Note

Lamb Wave Inspection Uses Guided Ultrasonic Waves to Detect Damage in Structures. Scanning Laser Vibrometry Clearly Identifies Structural Damage in a Non-contact Way.

Commercial exploitation of lamb wave inspection has been limited by drawbacks in current detection techniques. Using the non-contact method of 3D Scanning Laser Vibrometry, structural damage is clearly identified by locally increased in-plane and out-of-plane vibrations. The method is simple, fast and reliable, avoiding complex Lamb wave propagation studies, baseline measurements and signal post-processing.

Introduction

Aircraft designers, manufacturers and operators face many test and measurement challenges. New, large capacity civil airframes that make greater use of composite materials are being developed and will be more widely used. At the same time, new military structures exhibit improved performance by relying on greater structural complexity.

End-users of these new aerospace structures demand reduced life-cycle costs and high operational availability. These goals can be achieved with the application of new materials and wider use of damage-tolerant design concepts that result in lighter structures and better performance.

While these new aircraft are being developed, the existing fleet is ageing and must be maintained. A number of life extension programs have been considered and performed; civil structures are being converted from passenger aircraft to freighters and military aircraft are redesigned to add new weapon capabilities. These developments are a major challenge to existing aircraft structure inspection and maintenance methods. Ageing aircraft structures require a significant maintenance effort. The application of new materials and damage-tolerant concepts in next-generation aircraft also require enhanced and reliable structural health monitoring, with regular periodic inspections, to assure a safe and an extended operational life.

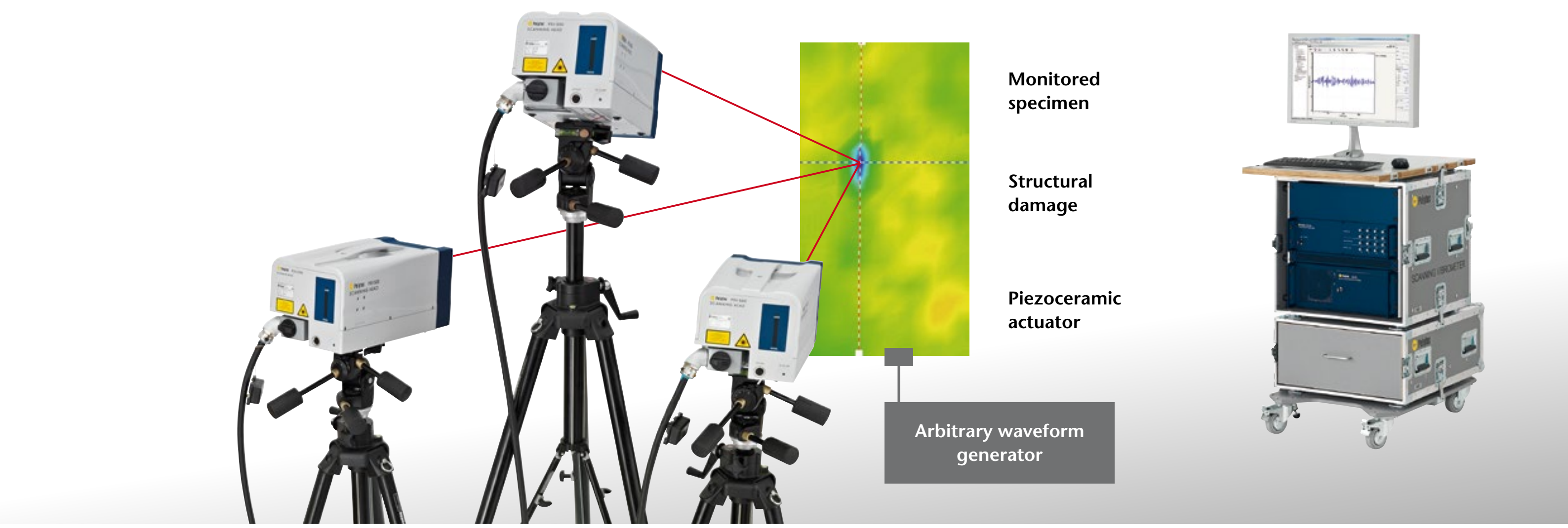
Damage Detection with Lamb waves

There is a number of technologies for automatic damage detection in aerospace structures. Lamb wave inspection is a widely used technique based on guided ultrasonic waves, i.e. ultrasonic wave packets propagating in bounded media. There are three major drawbacks associated with conventional Lamb wave damage detection techniques:

1. A significant number of actuator/sensor transducers are required for monitoring large structures. This is labor intensive, slow and costly. From the logistic point of view, it is not practical to cover an aircraft with many thousands of bonded or embedded transducers.

2. Lamb wave monitoring strategies, often associated with complex data interpretation, require highly qualified NDT technicians for point-by-point field measurements. Consequently, broad deployment is restricted by higher costs and lack of properly trained technicians.

3. Current signal processing and interpretation techniques used for damage detection utilize signal parameters that reference baseline data representing the “no damage” condition. These parameters can be affected by effects other than structural damage such as changes in temperature or bad coupling between the transducer and the structure.

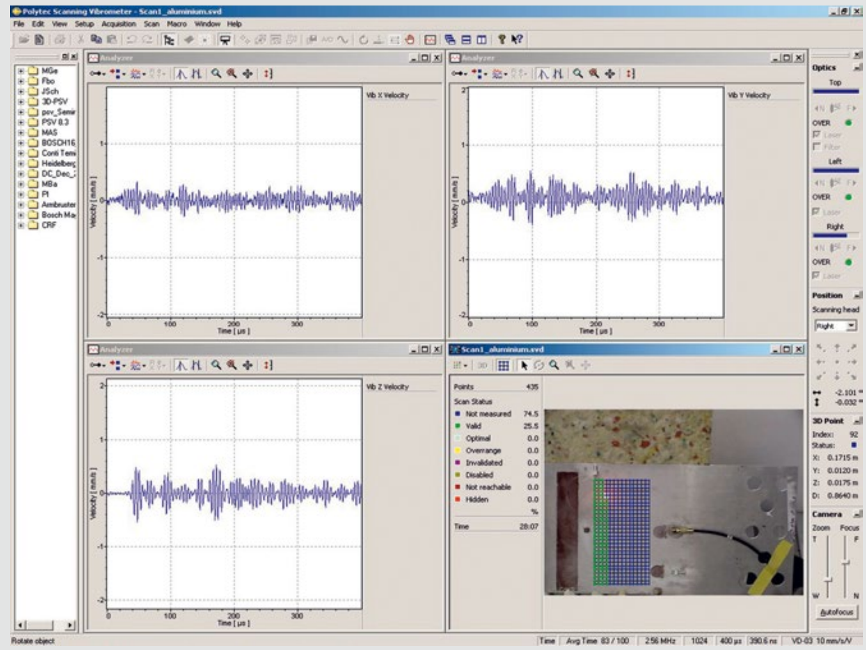


3D Scanning Laser Vibrometry

Laser vibrometers can overcome many difficulties associated with Lamb wave damage detection techniques. In figure 1, the application of a non-contact, PSV Scanning Laser Vibrometer to structural damage detection is illustrated.

Lamb waves from a piezoceramic transducer are sensed using the PSV-3D Scanning Vibrometer from Polytec (figure 2).

The 3D Scanning Vibrometer covers the complete optically-accessible surface with a high density of sample points. At each sample point, the vibration vector is measured including both in-plane and out-of-plane components. These measurements are assembled into an intuitive 3D animated deflection shape.



2
In-plane and out-of-plane Lamb wave responses plotted using Polytec's PSV Software

1
Experimental setup for Lamb wave damage detection using 3D Laser Scanning Vibrometry as receiver

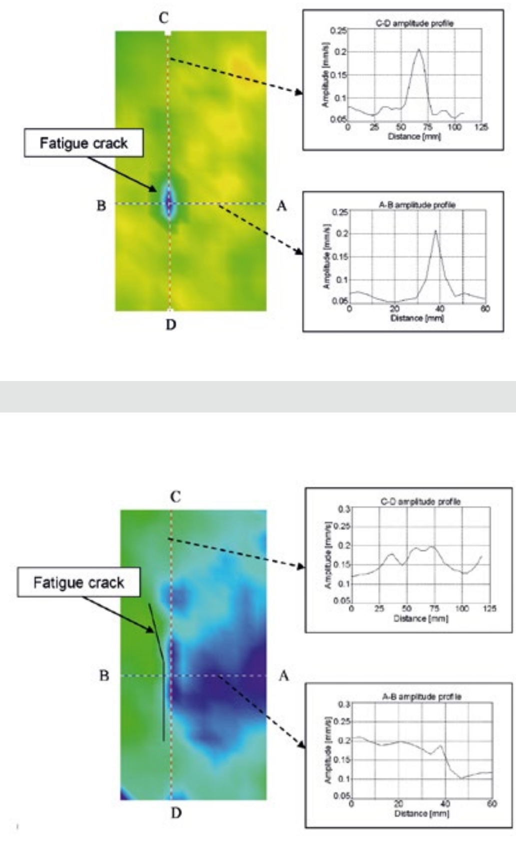
Examples of damage detected in aerospace specimens using Lamb wave monitoring are shown in figures 3 and 4. These results show that structural damage can be identified clearly by locally increased in-plane vibration amplitude (e.g. fatigue crack in figure 3, above, and delamination in figure 4) and by attenuation of out-of-plane vibration amplitude (e.g. fatigue crack in figure 3, below).

Conclusions

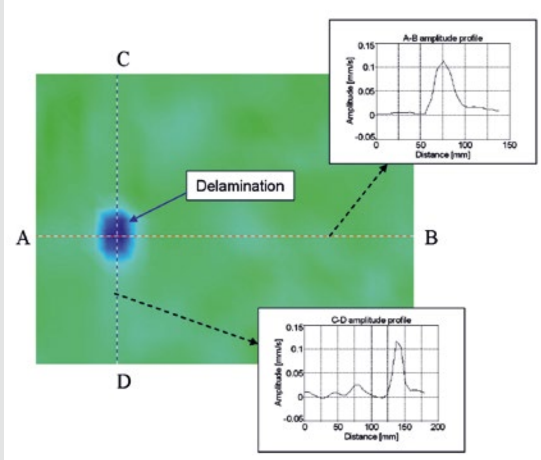
Laser vibrometer scans can reveal structural damage and its severity such as crack length and delamination area. Simple contour maps and profiles of Lamb wave amplitude across the structure are sufficient to see the damaged areas and do not involve studies of complex Lamb wave propagation in the structures, baseline reference measurements in undamaged structures, or signal post-processing to extract damage-related features. The method is straightforward, fast, reliable and immune to environmental effects.

We thank Professor Wieslaw Staszewski of Sheffield University for his work in this area.

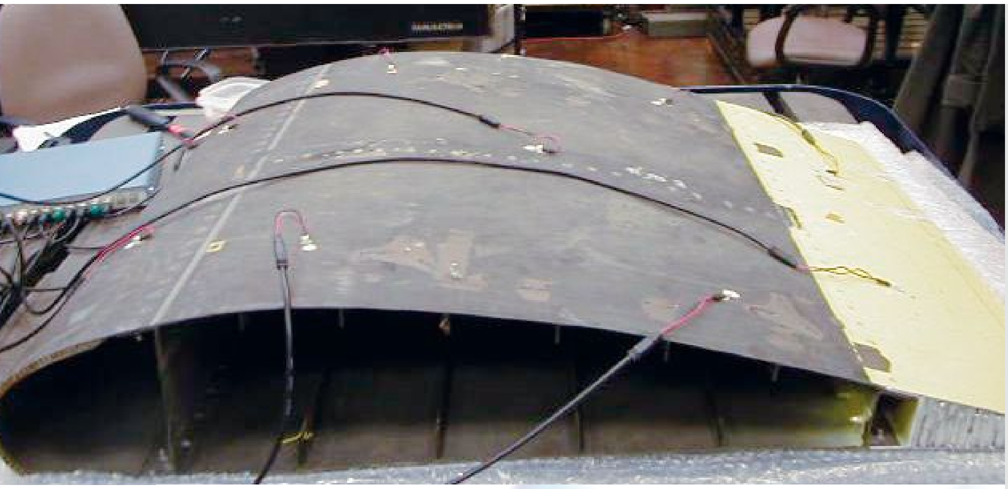
3
Fatigue crack detection in metallic structures with Lamb waves – RMS amplitude contour maps with amplitude profiles across fatigue cracks for: 75 kHz in-plane vibration (above) and 325 kHz out-of-plane vibration (below)

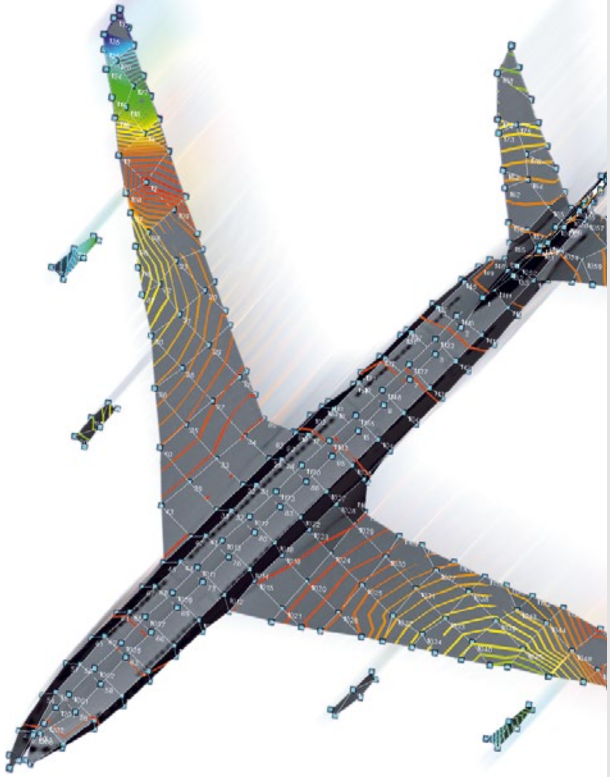


4
Impact damage detection in composite structures with Lamb waves – amplitude contour map with amplitude profiles across delamination for 100 kHz in-plane vibration



Laser Vibrometer Scans can Reveal Structural Damage and its Severity such as Crack Length and Delamination Area.





5
Measurement Setup: Piezoactors for local excitation of Lamb waves on a carbon fiber wing section

6
Full-field measurement with high spatial resolution on large components or complete aerospace structures

Authors

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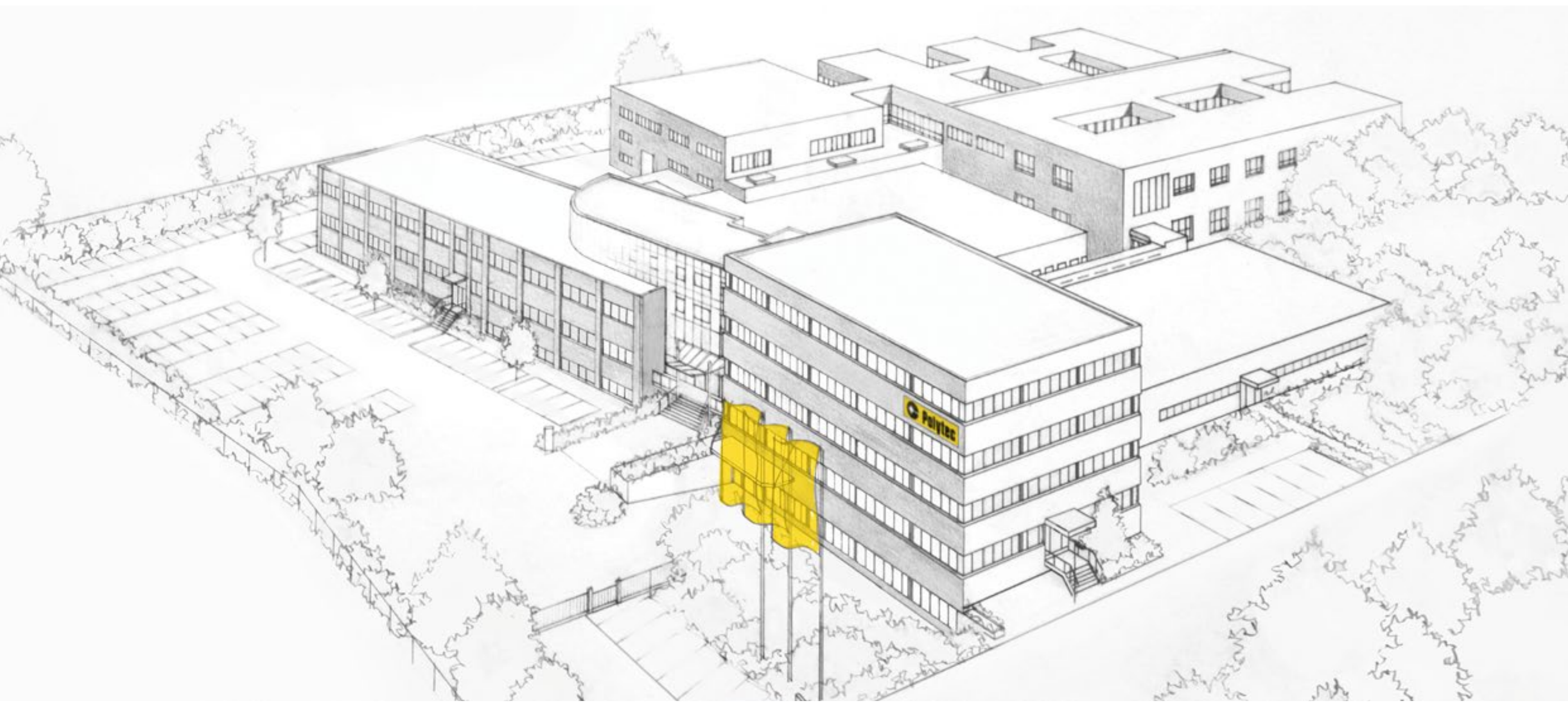

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