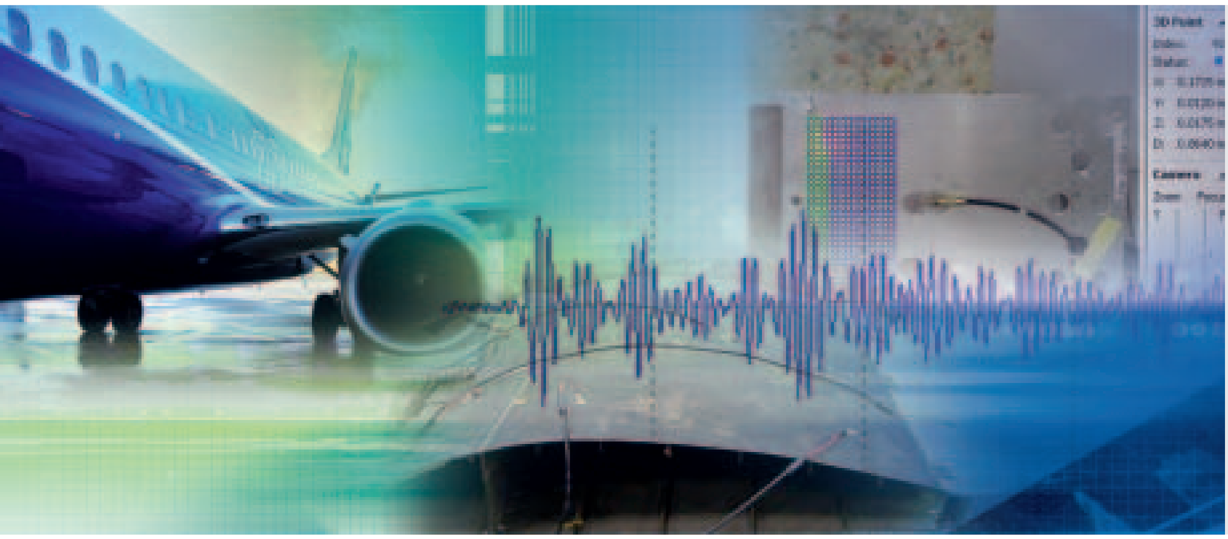
Polytec

Aircraft Health Monitoring



Field of Application

A Aerospace
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S Scientific & Medical
T Structural Testing
U Ultrasonics

Health Monitoring of Aerospace Structures: Laser Vibrometry for Damage Detection Using Lamb Waves

Lamb wave inspection uses guided ultrasonic waves to detect damage in structures. Its commercial exploitation has been limited by drawbacks in current detection techniques. Using a new detection technology known as 3-D 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, eliminating complex Lamb wave propagation studies, baseline measurements and signal post-processing.

Introduction

Aircraft designers, manufacturers and operators face many test and measurement challenges in the near future. 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 in recent years; 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 requires enhanced and reliable structural health monitoring, with regular periodic inspections, to assure a safe and an extended operational life.

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Figure 1: Experimental arrangements for Lamb-wave damage detection using 3-D laser vibrometry as a receiver

Damage Detection with Lamb-waves

A number of new technologies have been developed with the potential for automatic damage detection in aerospace structures. One promising technology is Lamb-wave inspection, the most widely used damage detection technique based on guided ultrasonic waves, i.e. ultra-sonic wave packets propagating in bounded media. While several Lamb-wave applications have been tried over the last 20 years, to date, the practical commercial exploitation of ultrasonic guided waves has been very limited.

There are three major drawbacks associated with current 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.

3-D 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, multi-point scanning laser vibrometer to structural damage detection is illustrated.
Lamb-waves from a piezoceramic transducer are sensed using the Polytec PSV-400-3D Scanning Vibrometer (Figure 2). The 3-D 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 3-D animated deflection shape.

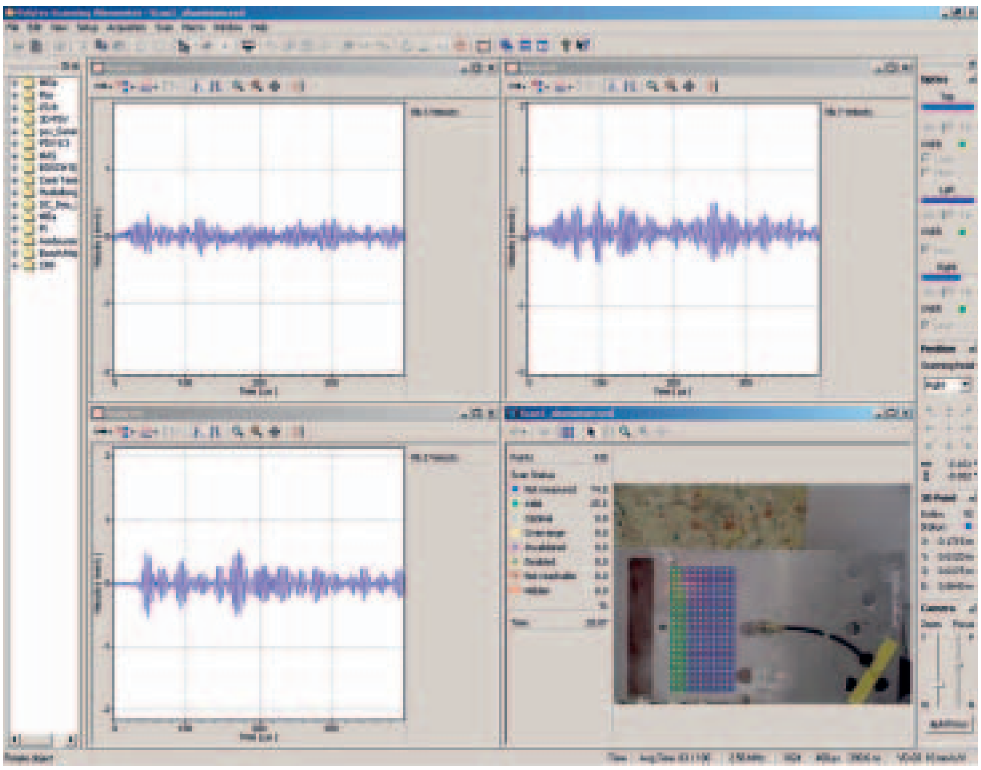

Figure 2: In-plane and out-of-plane Lamb-wave responses plotted using Polytec's PSV Software

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, left, and delamination in Figure 4) and by attenuation of out-of-plane vibration amplitude (e.g. fatigue crack in Figure 3, right).

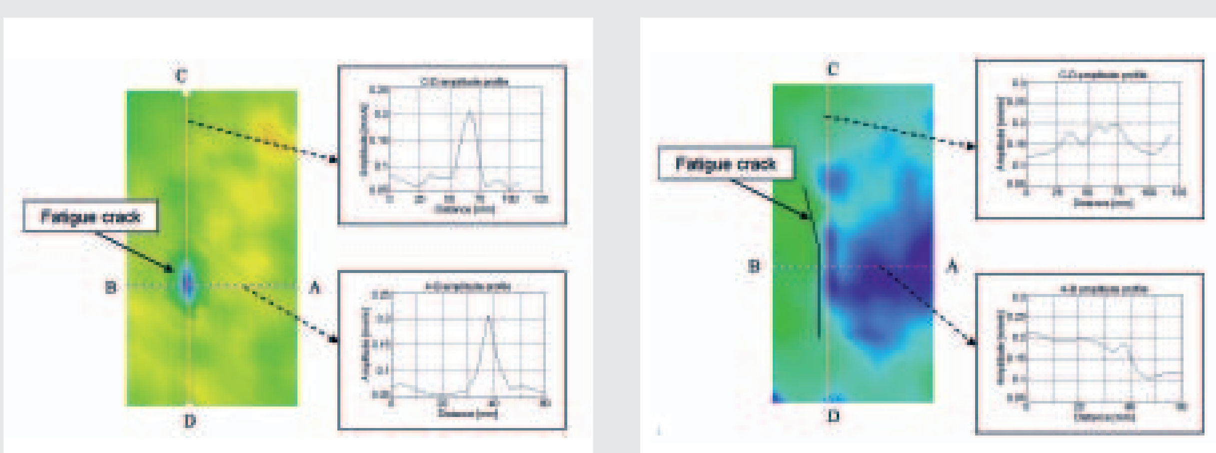

Figure 3: Fatigue crack detection in metallic structures with Lamb-waves – RMS amplitude contour maps with amplitude profiles across fatigue cracks for: 75 kHz in-plane vibration (left) and 325 kHz out-of-plane vibration (right)

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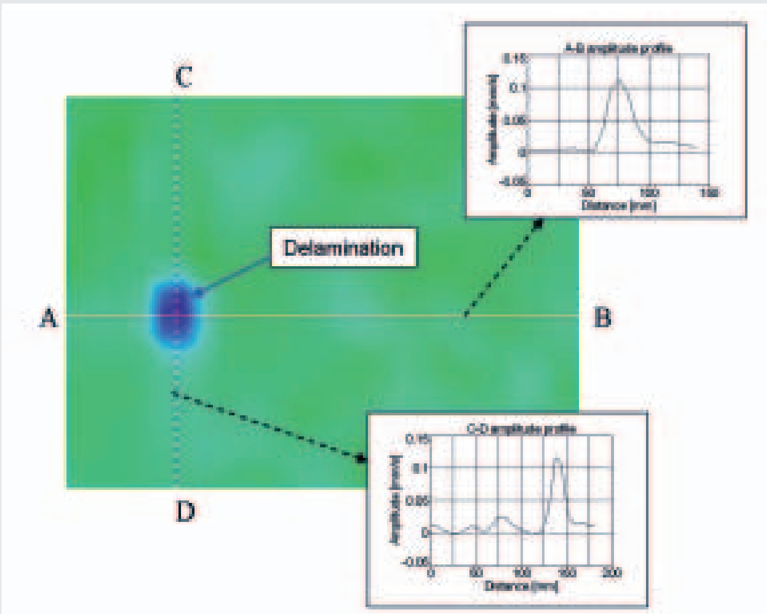

Figure 4: Impact damage detection in composite structures with Lamb-waves – amplitude contour map with amplitude profiles across delamination for 100 kHz in-plane vibration

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 straight forward, fast, reliable and immune to environmental effects.

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

For more information about Polytec Scanning Vibrometers and aerospace applications please contact your local Polytec sales/application engineer or visit our web page **www.polytec.com/aerospace**

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