1.10.10. IMPACT DAMAGE DETECTION IN COMPOSITE MATERIALS OF AIRCRAFTS BY OPTICAL FIBRE SENSORS

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Introduction. The safe use of aircrafts can only be guaranteed when efficient means of damage assessment are in place. In the last years there is an increasing interest in structural health monitoring systems for composite materials of the aircrafts based on optical fibre sensors.

One prominent possibility to detect damage in aircraft materials is nondestructive testing (NDT) using ultrasound. Ultrasonic waves are usually excited and sensed by piezoelectric crystals that offer excellent possibilities in non-destructive testing since many decades. However, these are essentially point sensors, implying a number of disadvantages, such as the vulnerability to interferences. A possible solution is the application of ultrasonic array sensors, but these arrays are usually costly high-tech devices, difficult to wire and integrate.

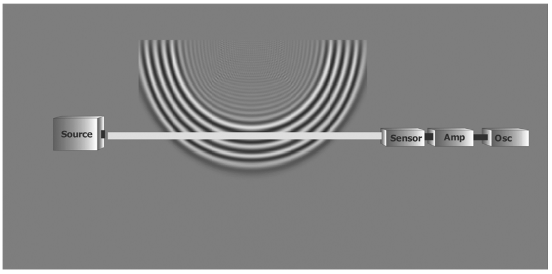

Fig. 1 Single mode optical fibre sensor in a polarimetric setup for the detection of impact damage

An interesting alternative is offered by optical fibres that can work as line-integrating sensors. There are in general many reasons why the application of optical methods for acoustic sensing is more advantageous compared to the widespread use of traditional piezoelectric crystals. The most frequently applied optical fibre technology in structural health monitoring is Fibre Bragg Grating (FBG) for which a big number of applications are already existing e.g. civil infrastructure monitoring. For many other technologies, such as the Fabry-Perot Interferometer, or micro-bend sensors, the single-mode fibre in a polarimetric set-up is the most promising method. However, the studies performed so far are quite limited, and this is in contrast to the high potential that emerges from this technology.

Basic results and discussion. In this paper, ultrasonic Lamb wave technology is used as the basic physical damage detection principle for developing an aircraft damage monitoring system. Lamb waves are essentially ultrasonic waves, but they differ from classic bulk ultrasonic waves in their propagation properties:

– Lamb waves propagate in plate-like structures;

– Lamb waves can propagate over long ranges (up to tens or even hundreds of metres) and they are therefore well-suited for global and long range inspections.

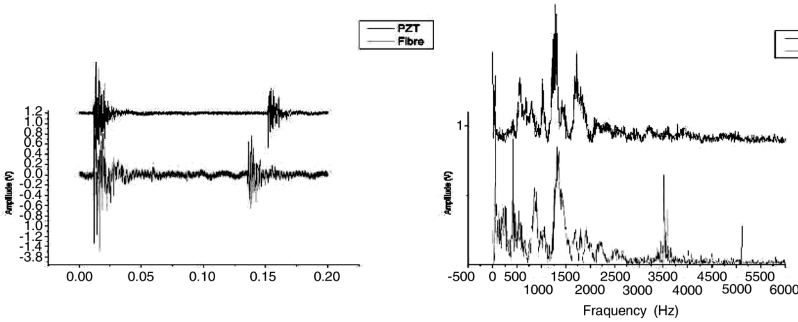

Fig. 2. Acoustic emission waveforms (2nd burst is an echo) and frequency distribution recorded by piezoelectric crystals (PZT) and by optical fibres, obtained from impact in monolithic carbon fibre reinforced plastics (CFRP)

Composite plate structures as well a helicopter tail-boom has been used for the tests presented. The impact signals are directly detected by the optical fibre sensors as well as by piezoelectric sensors (acoustic emission, fig. 2). The optical signal is created by altering the intensity of light due to a change in ultrasonic pressure. This change in the light intensity is an integrated response of all the phase dependent changes along the length of the active fibre sensor.

When the sensing area of the optical fibre is clearly larger than some wavelengths, the signal obtained by fibre sensor shows thus peculiarities with respect to a point sensor. This phenomenon can be understood if one considers the optical fibre as a kind of acoustic interferometer. Signals arriving from the acoustic source arrive at the fibre at different times (time-of-flight), according to their increasing distance from the source. The detector itself measures all incoming signals at one instance, thus adding-up all the incoming waves. Depending on the respective amplitude and phase shift, a resulting waveform will be measured. Furthermore, the sensitivity for the detection of the Lamb modes, S_0 and A_0 depends on the polarisation of the light propagating in the sensing fibre. Lamb mode selection will be achieved by corresponding polariser settings. Line-integrating sensors can thus show improved performance, and it is one of the main tasks of this paper to give an answer to that question: Why this is the case, and how this can be explored toward practical application in a systematic way?

Beside acoustic emission also the results from active ultrasonic testing will be presented. Those tests require an ultrasonic point source (piezoelectric excitation).

Summary. The influence of different degradation mechanisms upon the signal from the optical fibre sensing the Lamb wave in a composite plate-like structure is investigated. Quantitative correlations between the monitored transient signals of the optical fibre and the type and extent of the damage are established. We can show that damage detection by single-mode optical fibres is an appropriate tool for structural health monitoring.

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