Advances on research on inspection techniques at Amsterdam University of Applied Sciences
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ABSTRACT

With the advent of composite materials being used for commercial airliners, the chain from damage detection to repair needs to be modified. In two recent projects the feasibility of new inspection technologies for composites is investigated. In the first project the applicability of eddy currents for scanning carbon laminates is investigated using the LDC1000EVM. The second project focuses on ultrasonic Lamb waves to assess structural damage of a material, looking at the correlation between a damaged and undamaged reverberated signal.

Keywords: composites, CFRP, eddy current, ultrasound, inspection techniques.

INTRODUCTION

Composite materials are slowly replacing the more traditional construction materials within the aerospace sector. Initially secondary structures were replaced, more recently since the market introduction of the latest generation of aircraft, carbon reinforced plastics have replaced primary structures. In the meantime, other industrial sectors (a.o. wind energy, automotive and civil engineering sector) are surpassing the aerospace sector, using composite materials for primary structures on a larger scale. This inertia in aerospace is mainly caused by the certification requirements. Although the latest generation composite aircraft are now operational, innovation of maintenance inspection and repair techniques is still desired. The Aviation Academy of the Amsterdam University of Applied Sciences (AA) aims to improve on the currently used techniques and procedures within the aviation MRO market to increase efficiency and profitability.

Due to the introduction of composite materials, a shift in mentality is required within all fields surrounding the operation of an aircraft, ranging from ground technicians, supply vehicle drivers to flying staff. Awareness of the new materials is introduced in extensive training programs. Aircraft operators and MRO companies need to invest largely in new equipment and procedures suitable for
the inspection and repairs of these new materials. The suitability of techniques used on metal aircraft for application on composite aircraft can be of importance for acceptance in the industry.

The materials used in aviation are generally carbon and glass fiber reinforced polymers. They show a high specific stiffness and strength due to the low density of the material when compared to aluminum or steel and are almost not susceptible to fatigue and corrosion. This has the advantage that composite structures have larger inspection intervals than metal structures [1]. Although the aircraft OEMs all use a damage tolerant design approach, the disadvantage is the material’s susceptibility to impact damage caused by brittle behavior. This may lead to delamination that cannot be detected by standard visual inspection, as they are hidden under the surface or damage is only visible on the backside of the material, which is usually difficult to access. The inspection techniques used on conventional aircraft may also be used on composite materials, however a lot of training is required before the technician is sufficiently competent, and posing difficulties in out-stations where no proper technicians or equipment may be available. Improvements in non-destructive techniques (NDT) can be made to facilitate inspection but the equipment is generally expensive and scanning of large surfaces is labor-intensive. Examples include: the development of acoustic cameras, phased-array ultrasonics and optical NDT methods. Improved damage detection techniques that can be implemented in a structural health monitoring (SHM) system and tooling that is more affordable may provide a solution to these hurdles and are subject of current research at our faculty.

**EDDY CURRENT INSPECTION ON THIN CARBON LAMINATES**

**Background**

Eddy current inspections rely on the principle of induction. An AC current is fed through a coil, inducing an alternating magnetic field in the surface around it. If an object in the proximity is electrically conductive, eddy currents will start to appear, which in turn generate a second magnetic field counteracting the first magnetic field. By measuring the impedance of a second coil in the sensor, several properties can be derived. Changes in magnetic permeability influence the impedance level of the second coil. These changes can occur due to the presence of cracks, deviating the induced currents (eddies) and so the impedance.

The use of eddy current inspection is not new within the aviation sector and technicians are specifically trained in the use of this NDT technique on metal structures. The technique can be used in order to find cracks and other flaws in surface coatings, tubes and aircraft engines and the use is also
widespread in other sectors such as the oil and gas industry for pipeline monitoring and welding inspections.

**Texas Instruments LDC1000EVM**

In this research the usability of a low cost evaluation module (Texas Instruments LDC1000EVM) is evaluated for the application of Eddy Currents on thin carbon laminates. Recent research showed that the LDC1000 can be used for eddy current measurements on conductive non-metals such as moist wood and cardboard [2], and so it is hypothesized that it will also work for thin carbon laminates. The system consists of three combined units: an LC tank (a resonant circuit consisting of an inductor and capacitor) and coil structure, chip module and a USB interface. All items are located on a perforated circuit board and can be replaced by customized parts, such as different coil sizes and shapes, to allow for variable sensitivity and detection surface. As García e.a. [3] have pointed out, the pancake coil as used on the LDC1000EVM can be used to reveal cracks in plates, however when a horseshoe coil is used, also properties in thickness direction may become visible. In the initial tests the original module will be used, as shown in figure 1. The expectation is that the system is suitable to inspect drill hole edges for internal damage as well as for easy inspection of delaminated areas caused by impact damage on composite structures.

**Future research**

Tests will be conducted making stroke scans of carbon fiber reinforced polymer plates to test the usability of the sensor to find property changes in composite materials. The measurement data can be plotted in density maps for visual presentation, equivalent to the work of Schilder, [2]. First reference measurements will be conducted on virgin specimen, then visible damage will be generated and evaluated. Finally hidden damages, e.g. to the back of specimen or delaminations inside will be inspected. As a next step, the pancake coil will be replaced by the horseshoe coil to see if the system can be used for reverse engineering purposes, revealing the fiber orientations of a composite material. This is particularly useful in e.g. the repair process to visualize the lay-up of a laminate, which is normally done by removing layers one by one.

**ULTRASOUND VERIFICATION USING LAMB WAVES**

**Background**

A lot of NDT methods rely on the propagation of waves through a material. The depth of penetration and size of detectable flaws are dependent on the wavelength of the used signal. The frequencies used
run from audible acoustics (kHz range) to Gamma rays (in the order of $10^{20}$ Hz) each with its own characteristics. In thin plates, Lamb waves can occur [4]. Using these Lamb waves, large surfaces can be investigated using relative low frequencies. This is the basis for Ultrasound Verification which is researched at the Aviation Academy [5].

**Current status**

The aim of this study is to investigate the possibility to develop a fast and efficient method for detection of barely visible impact damage (BVID) on large surfaces. The method works by comparing reverberation signals induced by an ultrasonic pulse (Lamb waves) in-service with the same signal generated in pristine condition. The signals should not change over time unless the specimen is damaged. In this application, instead of focusing on the first arrival of the signal, phase or amplitude shifts, the entire reverberation is considered (see figure 2). Correlation analysis of the reverberated (pristine) reference signal and the in-service signal make it possible to detect changes within composite materials over large surface areas with only a limited amount of sensors. The setup is shown in figure 3 and consists of a PC, function generator, power amplifier, an emitting and receiving piezoelectric transducer, a preamplifier and oscilloscope, which is used as AD converter.

Up to now, this method of ultrasonic verification (USV) has been investigated with bonded PZTs [6] as well as air-coupled transducers [7], both proving the feasibility. Also optical Fiber Bragg grating (FBG) sensors can be used for these measurements as demonstrated in [6]. By changing environmental parameters, changes in signal due to these parameters can be isolated and excluded to prevent false positives.

**Future research**

The USV method will further be developed to examine its operational capabilities and limitations. Once the influence of environmental conditions on measurement results has been established, research is projected with multiple sensor arrays and complex shaped specimens. As such the technique’s feasibility for attaining a position amongst conventional NDT techniques for predictive maintenance and its use as an onboard structural health monitoring tool will be assessed.
REFERENCES


FIGURES

Figure 1: LDC1000EVM, with inductive coil (1), sensor chip module (2) and USB interface (3).

Figure 2. Ultrasonic pulse recording, amplitude as function of time. Several characteristic areas can be recognized. a) trace signal due to background noise, in b) first arrival of the transmitted Gaussian pulse c) reverberated response. Due to multiple reflections, the signal becomes chaotic and is attenuated [5]

Figure 3 Ultrasonic verification experimental setup (left) and schematic description of test setup (right).