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Review

The detection of aeronautical defects in situ on composite structures using Non Destructive Testing

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ABSTRACT

A study of three Non Destructive Testing methods (Ultrasonic Testing, InfraRed Thermography and Speckle Shearing Interferometry, known as Shearography) was carried out on different specific types of composite specimens having a variety of defects. The aim of this study is to evaluate the efficiency of these NDT methods in the detection of in site defects resulting from Barely Visible Impact Damages (BVID) or in-service damages to complex surfaces such as wings or rods. The size and position of all the defects were determined by GVI (General Visual Inspection): GVI being the reference. The evaluation of the three NDT techniques enabled conclusions to be drawn regarding defect detection and size. The first part of the study deals with determining and measuring defects. It appears that only the ultrasonic method enables the depth of a defect to be determined. In the second part of the study, the results obtained by the three NDT methods are compared. Finally, the feasibility and the time taken to set up the experimental protocol are analyzed. The study shows that all the defects were revealed by, at least, one of the three NDT methods. Nevertheless it appears that InfraRed Thermography and Shearography produced results very quickly (in about 10 s) compared to Ultrasonic Testing.

Contents

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1. Introduction

In the aeronautics industry, during manufacture, random porosity or undesirable material may appear in composite structures during the manufacturing process. When structures are in service, impacts may result in delamination or disbonding. These undesirable inclusions or defects affect the structure and its mechanical properties. In order to check the integrity of the composite, these defects have to be revealed.

Several techniques can be used to detect such defects. At the moment, however, the only NDT method leading to certification is Ultrasonic Testing [1]. Ultrasonic Testing is a contact or non-contact method which requires voluminous equipment (pool, etc.). Although it enables many defects such as delamination, disbonding, etc. to be detected easily and accurately [2,3]. It is nevertheless a relatively slow process.

Over the past twenty years, optical methods have gradually appeared and are now being applied to Non Destructive Testing. InfraRed Thermography is commonly used and methods such as Speckle Shearing Interferometry [4] have also recently come into use.

Initial studies on IR thermography were carried out on metallic samples [5], but when used to test composite material, this method cannot detect internal defects. Nowadays, it can reveal many other defects: impact damage, delamination, disbonding, etc. [6–8].

Shearography is a new method. Derived from speckle interferometry, it is used to determine the strain field of a given specimen [9]. Delamination, disbonding or wrinkles can be identified using this method [10]. However, these optical methods are not yet used on an industrial level because the results are relatively hard to analyse and there is also a lack of both standardization and operator training.

The aim of the present study is firstly to check various specific aeronautical specimens in site. Three aeronautical specimens were chosen, each with a distinctive geometric shape making NDT difficult to carry out or problematic (non-detection, deformed shape, imprecise measurements, etc.).

Its aim is secondly to compare and verify the effectiveness of applying various NDT methods to defects visible to the naked eye. These defects can be thoroughly identified and measured. Comparing the visual method and the NDT methods make it possible to evaluate effectiveness (detection and size of defects as well as the speed of the NDT methods studied).

2. Specimens

2.1. Materials

The three specimens studied were manufactured by the aeronautical industry. Their geometric shapes are listed in a later section of the study (Section 4). The first two specimens are carbon/epoxy composites and the third is a sandwich composite specimen (Nomex honeycomb core and Kevlar skins).

They are called Specimen A (cf Fig. 4.1), Specimen B (cf Fig. 4.4) and Specimen C (cf Fig. 4.9), respectively.

Damage analysis on each of the three specimens is extremely difficult because of their distinctive geometry: Specimen A is a hollow cylindrical rod, 100 mm diameter, 10 mm thick and 1 m long. Its specific shape prevents access to the inside of the rod. In addition, it is coated with blue gloss paint to comply with aeronautical service specifications but in order to improve the quality of optical results, the damaged area has to be matt.

Specimen B is a flat plate, 500 mm $\times$ 400 mm $\times$ 2 mm.

Specimen C has geometric discontinuity: an angle (around 135°) with a slope over the entire length of the specimen (700 mm $\times$ 400 mm). NDT methods by contact are not easily applicable when specimens have non-constant geometry, i.e., a shape moving in space [11]. It will therefore be necessary as far as possible to adapt the NDT methods to check these specimens.

2.2. Defects

Each specimen has surface damage. The defect on Specimen A is delamination caused by an in-service impact. During a GVI, the size of the defect can be obtained quite simply using a steel ruler. The GVI defect is 98 mm and 18 mm.

Specimen B damage is the result of a lightning impact which occurred in service. The defect measures 41 mm and 75 mm.

The Specimen C defects are two cases of delamination due to the impact of a falling tool or of hailstones. These were created in the laboratory using a drop weight tester. The defect located above geometrical discontinuity is called no. 1 and the defect located on the geometrical discontinuity is called no. 2 (as defined in Fig. 4.9). Defect no. 1 is 13 mm and 9 mm. Defect no. 2 is 18 mm and 8 mm.

Measurements of all the defects are indexed in Table 1.

Table 1
GVI defect measurements of the three specimens.

	Length (mm)	Width (mm)
Specimen A	98	18
Specimen B	41	75
Specimen C		
No. 1	13	9
No. 2	18	8

3. Non destructive methods

3.1. Ultrasonic Testing

Ultrasonic Testing (UT) is commonly used in Non Destructive Tests. It is based on high frequency wave propagation. The waves are transmitted to the tested object by a transducer. As high frequency waves do not propagate in air, a couplant is required (water, gel coat, etc.). They propagate through the material and are reflected by the rear surface of the specimen. There are two possible ultrasonic techniques: reflection and transmission [12]. In the case of pulse/echo, there are different ways of receiving