"ShapeView" - A Portable Shape Measurement System

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Abstract. During aircraft manufacture, assembly and maintenance, checking the external aspect of structure panels is usually the first step in a more complete non-destructive testing process. Because of the large surfaces involved when checking an aircraft, the systematic inspection of the inside of structures using standard NDT methods is generally not possible. Inspectors carry out a visual inspection of the aircraft surface to detect all shape irregularities on the panels. Once any affected areas have been identified, the damage must be mapped prior to any non-destructive testing. In this domain, optical techniques can offer many advantages compared to mechanical methods such as depth gauges.
For the analysis of structural damage such as dents or buckling, or any shape irregularity on the surface of an aircraft panel, design office requirements are usually very stringent and appropriate tools have to be used. In addition, the environmental conditions may be severe. The main capabilities required of any device used to assess damage in a "real environment" are usually: portability, robustness, ease of use, accuracy, quick results and easy interpretation. All these parameters make the replacement of depth-gauge type instruments difficult.
A new optical tool called ShapeView has been designed to replace or complement usual techniques. The system is rapid, portable and simple to use. ShapeView can analyse a 1m² area in less than 2 minutes, with a very high accuracy. It is a hand-held tool and results are immediately available through the processing unit embedded in the system. This paper describes the technique used by the tool and typical applications.

1 - Introduction

In the field of aeronautics, the economic market is more and more challenging for aircraft manufacturers, who have to meet increasingly stringent technical requirements to satisfy the customers. To reduce the total cost of an aircraft, including in-service and maintenance costs, the manufacturers have to associate embedded high technology with weight reduction. New systems and structures are constantly being developed in order to meet the "further for cheaper" challenge and reduce aircraft fuel consumption.

Concerning the structures, the main tendency at the moment is to implement lighter panels. New materials are used and the thickness of traditional materials is optimized to be as light as possible, which raises the issue of the robustness of materials and structures. Manufacturers and national authorities are focussing more on this aspect as panels are increasingly optimized. New inspection methods are constantly required.

Another service proposed by the aircraft manufacturers to their customers to decrease maintenance costs is an enhanced technical documentation and the efficiency of the information exchange between stress offices and the airline maintenance teams. A major effort is currently being made to make damage reporting easier and reduce the number of technical discussions between the two parties, by exchanging the right information the first time. This involves new work organisations on both sides as well as new reporting resources. What is at stake here is the aircraft "down time" which needs to be reduced as much as possible.

Concerning accidental structural damage such as dents and buckling in particular, new tools are required to satisfy the needs described above. They will replace or complement the tools already in use and will bring new features such as flexibility, easy interpretation and better reporting. A tool, based on optical technology, has been developed to meet these requirements: - ShapeView. The system was developed to respond specifically to the needs of aircraft manufacturing and in-service activities. Its basic features are: ease of use, accuracy, speed of measurement, wide field of view, portability, autonomy and automatic reporting. ShapeView is intended for use by operators performing external damage assessment. This paper presents the system and its applications.

2 – Principle of measurement

ShapeView is based on an optical technology called image stereo-correlation. The principle is to analyse two images of a speckle pattern, recorded under two different view angles, to retrieve the geometric information included in the combination of both pictures. The speckle pattern is projected onto the surface to be analysed by a slide projector. The two images, from the two cameras, are recorded synchronously to the projection. Analysis of the projected speckle pattern by a dedicated software enables a 3D reconstruction of the tested surface (see FIG.1). The 3D information is used to analyse the shape imperfections of the surface, such as dents, buckling or any irregularities.

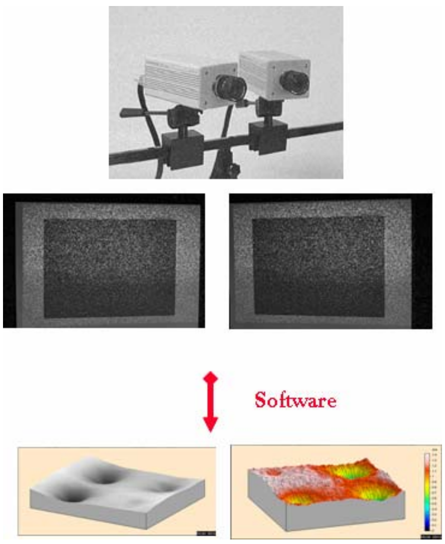


FIG.1 : principle of the image stereo-correlation technique

The image stereo-correlation technique was chosen due to the basic requirements expressed by the aircraft manufacturers. Out of a large number of optical techniques including fringe projection, laser tracking, fringe reflection and laser triangulation, the image stereo-correlation technique was the only one to fulfil most of the needs for a proper in-service inspection. As the measurement is taken within 1/1000 s, the system can be hand-held by the operator when recording, which is generally not the case with other techniques (need to take several pictures, measurement time of a few seconds, etc.). This avoids having a tripod or any holding device to fix the tool during measurement, which is essential for portability. Another advantage of image stereo-correlation is the small number of components required: basically two cameras, one projector and one computer.

The image stereo-correlation technique is widely used in the field of structural deformation measurement (mechanical testing). The technical background of this domain issues from the shape measurement application, even if some hardware and software modifications have been carried out. Particularly, the easy calibration algorithms and speed of processing came directly from the initial application. It has considerably reduced overall development time, while retaining very high measurement accuracy.

3 – The ShapeView system

3.1 – Hardware

The initial specifications required the system to be autonomous and portable. Inspectors move around the aircraft to detect and analyse any dents or bumps on the panels and need to use the measuring equipment in-situ, where an electrical supply is often not available. So ShapeView was developed to be able to take measurements and analyse results at the place where the inspection is performed. All the components are embedded in the equipment: cameras, projector, touch-screen, computer, hard drive, battery pack… supported by an aluminium structure and encapsulated into two composite hoods. Most of the components were specially designed for this application and to fit in the system. (see FIG.2).

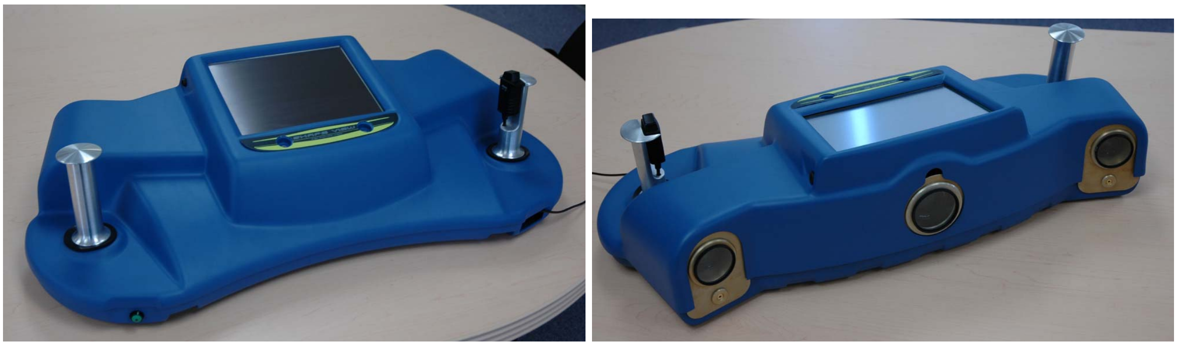


FIG.2: the ShapeView system

3.2 – Measurement procedure

ShapeView is designed for use by aircraft inspectors and is very easy to use. Only a few operations are necessary to perform a complete measurement and analysis:

1 – Calibration of the orientation: this stage is necessary to be sure to perform measurements with sufficient accuracy. It consists of recording a measurement on a white diffusing screen

2 – Test on a reference standard sample: to check the measurement is valid and the equipment operates correctly

3 – Measurement on the real structure (see FIG.3): the operator holds the equipment and positions himself so that the distance between the equipment and the tested panel is roughly 1 m. He is guided in this step by 2 diodes targeting the centre of the field.

4 – Analysis of the result: the computer and the touch-screen embedded in the system allow the operator to analyse the recordings and save the results immediately.

Measurements are therefore very simple to perform and no qualifications are required for the operators to use the equipment properly.

FIG.3: on-site measurement

3.3 – Technical Specifications

- Size of the inspection area: 900 mm X 700 mm
- Accuracy: 50 µm
- Spatial resolution: 5 mm
- Working Distance: 1m
- Measurement Time: 1/1000 s
- Calculation Time :< 1 mn
- Portable and autonomous; power supply: batteries
- No need for any holder or tripod: the measurements are taken by the operator holding the equipment by hand
- Possibility to achieve measurements on bright surfaces with an average sunlight (50 KLux)

4 – Results and applications

ShapeView may be used to map any type of surface damage or irregularities within its technical specification. It can be used in the aircraft manufacturing plants or for in-service application. Numerous tests have been performed to demonstrate the ability of the system to make rapid measurements in-situ, and many applications have been identified.

4.1 – Applications in manufacturing plants

During the manufacturing process, many irregularities can occur when milling, forming or assembling the panels. ShapeView was tested to analyse some shape deviations which are very long and difficult to map with standard means.

4.1.1 – Deformation of a leading edge

An analysis was carried out on a leading edge where a shape deviation was detected on the part after painting. The deformation was very small and could not be properly analysed, or even seen, with standard methods (see FIG.4).

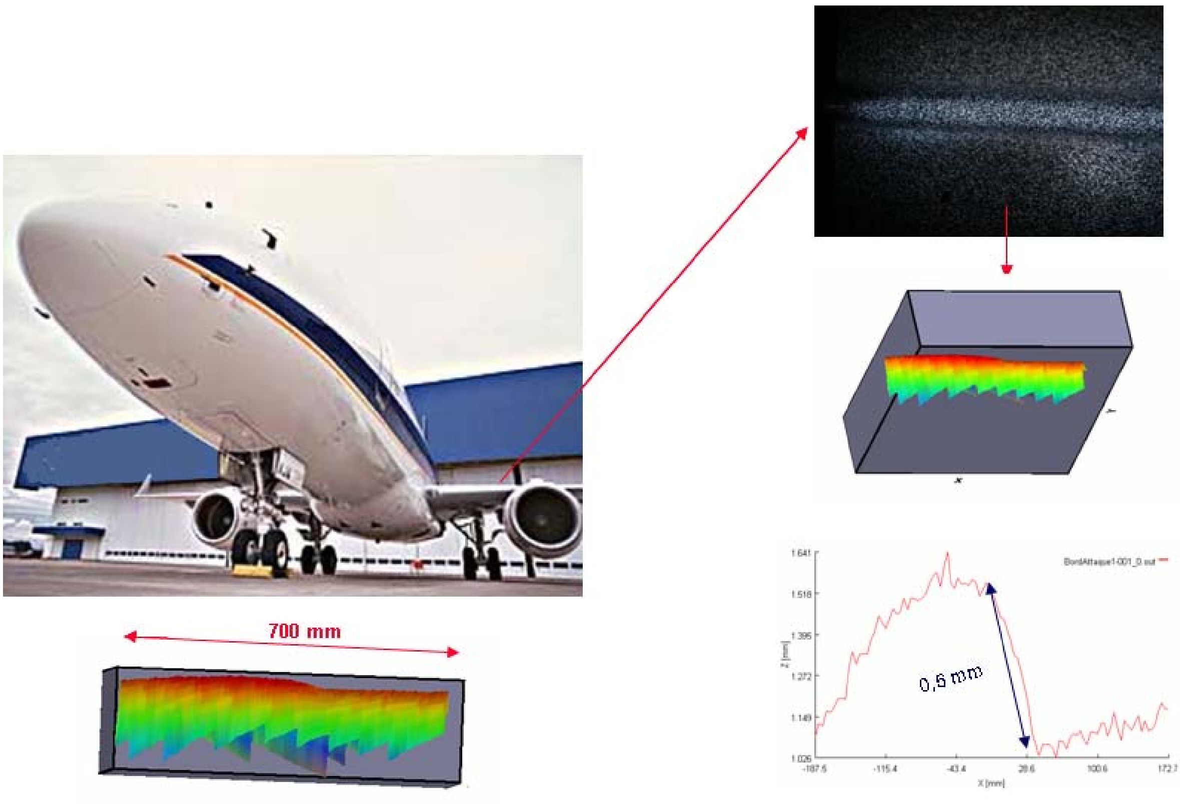


FIG.4: analysis of a leading edge

The height difference along the edge of the part was 0.5 mm over 700 mm, and was easily mapped by the system.

4.1.2 – Bird Strike analysis on a shield

For material resistance calculation purposes, the finite element calculation and the real shape of a panel after impact need to be compared after a bird strike-type test. The shape of the impacted panel was measured, and the digital results retrieved to be implemented in the mechanical processing software. The results of the measurement are presented below (see FIG.5).

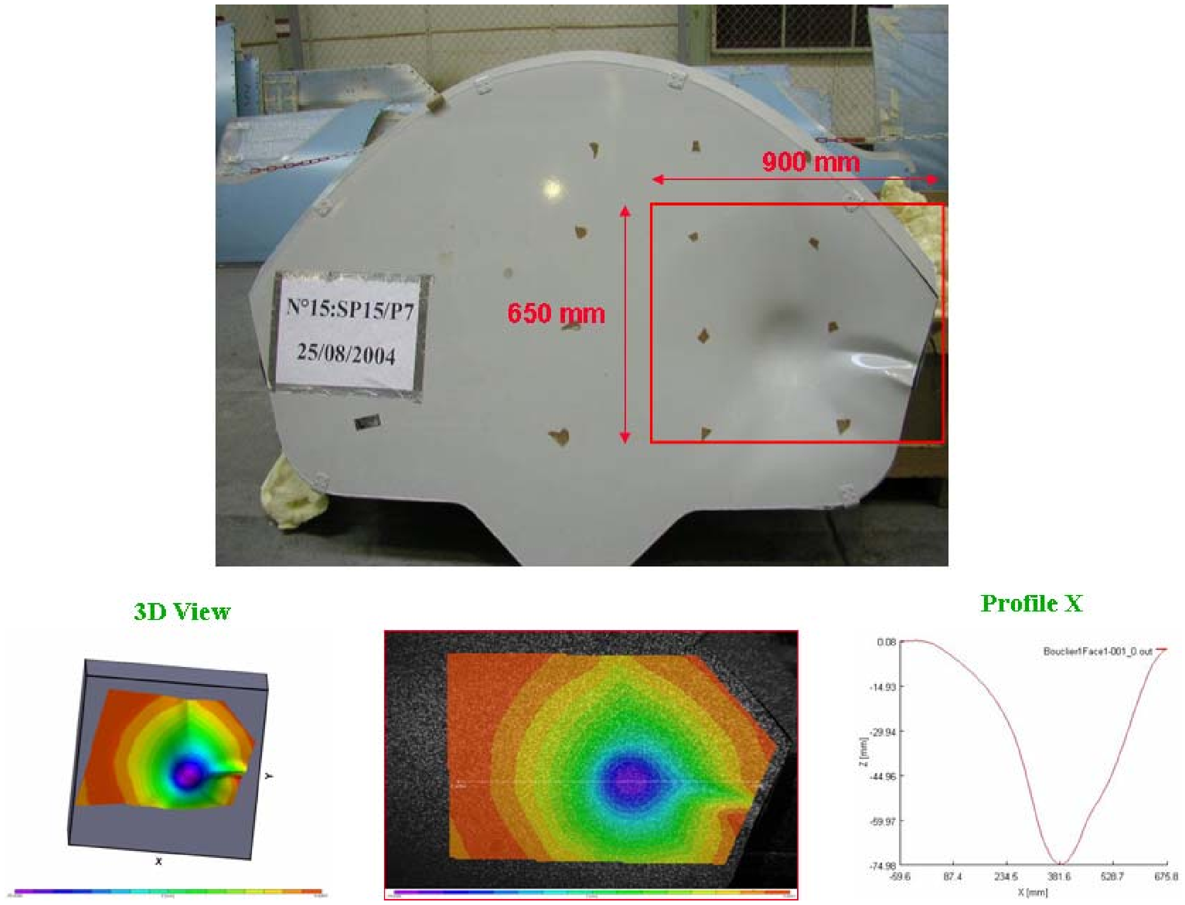


FIG.5: analysis of a shield

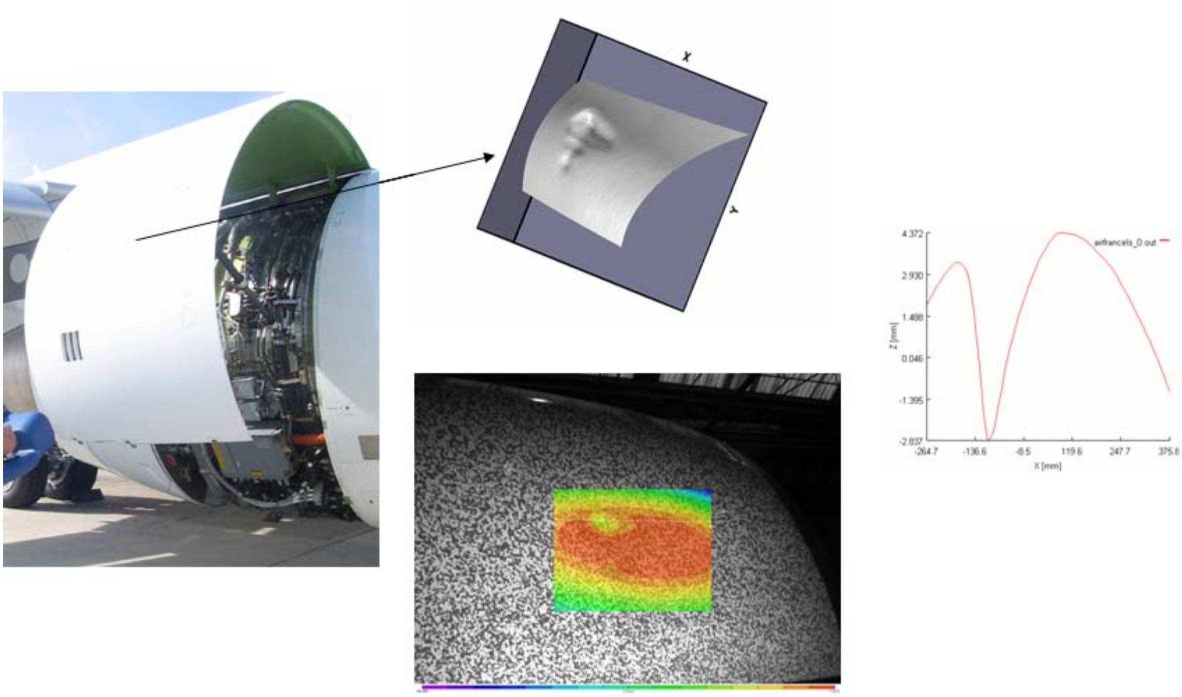
The measurement time was approximately 5 minutes. The maximum depth was around 90 mm.

4.2 – In-service applications

ShapeView is intended for use by the airlines in service, to rapidly map accidental damage occurring on the ground or in flight. The aim of the measurement is to have a complete report, including all the information from the operators, ready to be sent to the manufacturer’s stress office. Tests were performed with the system directly on aircraft. Some results are presented below.

Impact damage on an engine cowl

Damage occurred on an engine cowl and needed to be analysed before more in-depth NDT inspection. The exact mapping of the damage was available in less than 3 minutes with ShapeView. The results are presented below.



Max Depth = 6 mm ; Max Length : 25 mm

FIG.6: damage on an engine cowl

5 – Conclusion

ShapeView is a system based on optical technology, developed for rapid analysis of structural damage such as dents or buckling, or any shape irregularity on the surface of an aircraft panel. The system is portable, battery-powered and accurate and provides geometrical data for immediate reporting. It is intended for use in aircraft manufacturing plants and in service. The user interface has been developed to have easy access to all the information required in the manufacturer's Structure Repair Manual (SRM).