OPTICAL TOOL FOR IMPACT DAMAGE CHARACTERIZATION ON AIRCRAFT FUSELAGE

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Abstract: During the manufacturing / assembling process of an aircraft, or in service after delivery, surface damages may occur on external side of the fuselage. Most of those defects are small compared to the size of the aircraft and are generally spread out on the whole surface of the fuselage. In order to characterize properly these kind of anomalies, new means are always wanted in the field of Non Destructive Testing. They need to be reliable, portable, fast and accurate. For this kind of defect, optical techniques offers usually good solutions. Then, new technologies based on optics are developped to meet the requirements of the aircraft manufacturer in terms of damages characterisation. Particularly, a portable device, based on the shadow moiré effect, was developped to characterize the exact geometry of impact damages on aircraft fuselage. The system is easy to use, portable, fast and low cost. It will help the operators in terms of defect classifications and will allow a substancial time saving during the inspection. After a test period, the device should be used in the Final Assembly Lines of aircrafts.

1 – Introduction: In the field of aeronautics, both national and international authorities impose to the manufacturers, airlines and maintenance organisations to strictly comply with the current regulations concerning the safety and security of aircraft. The structures of airplanes are submitted in service to heavy mechanical loads and each part is made for a determined lifetime. Parts have to be regularly controlled in order to check their serviceability, and systematic non-destructive inspections are scheduled all along their lifetime. When damages occur, panels have to be subjected to extra control to insure their integrity for continued use.

The increasing complexity and the new materials used to achieve enhanced mechanical capabilities and weight reduction of structures leads to the continuous development of new means for the control. The tools have to be as efficient as the old ones, faster, more accurate, more automatic and more limitative concerning the human interpretation. This evolution is part of the overall quality strategy followed by all actors in aeronautics.

Among all the damages that may affect the structure integrity, accidental surface dents are one of the most monitored: the impacted areas have to be controlled in order to ensure that no crack initiation, delaminating or disbonding is generated. Prior to any deeper NDT control, operators have to evaluate the criticality of damages in terms of surface and depth. Tolerances are given by the manufacturer's design offices to sort the damages into classes, based on these criterions, which determine the pursuant actions. Then, the precise geometry of the dents have to be recovered by the controllers for two main reasons: to help them to classify the damages and to help the design offices to determine the new mechanical properties of the impacted structure, when the dents geometry is critical enough to run such procedures.

2 - Dent characterisation tool : Moireview©: A new tool was developed to answer the needs in term of dent characterisation. The system is based on optics and allows retrieving of the 3D shape of impacted areas. It was developed to be complementary to the mechanical means currently used (depth gauges, rugosimeter…). The basic specifications imposed to this tool is to be fast, autonomous, portable and easy to use. The operators in charge of the inspection have to walk around the aircraft to detect the damages and may perform measurements from the ground or from platforms or nacelles. Thereafter, they should be able to carry the tool in bad-access areas. Considering the whole surface of an aircraft, compared to the relatively small size of a dents, which may be numerous and spread out over the entire airplane, the system has to be fast, in order to perform the complete inspection in a reasonable time. Finally, considering the tolerances given by the design office, the tool shall be accurate enough.

2.1 – Principle: The system is based on the moiré effect, which is a physical phenomena based on the spatial interference of two repetitive patterns whose frequency is approximately the same (grid, Ronchi ruling, fringe pattern…), and which produces a pattern with low frequency compared to the initial ones (FIG. 1). Many optical techniques are based on the moiré effect, because of its simplicity and good accuracy. It allows one to observe macroscopically deformations occurring at a microscopic scale : the modulation of the moiré fringes (macroscopic scale) is equal to the one of the two basic patterns (due to microscopic deformation). Then, looking at a deformed pattern (test pattern), too thin to be resolved properly with eyes or camera (high frequency), through a pattern whose frequency is approximately the same (reference pattern), it is possible to visually retrieve the micro-deformation at any points of the space of the distorted pattern. The analysis, by any specific software, of the moiré fringes can be then performed automatically to recover the expected results.
The current application uses the moiré effect of shadow type (shadow moiré). The principle is to light a high frequency grating, engraved onto a photographic film (zero transmittance for the black lines), with an angle. The shadow of the grating appears on the surface to inspect (FIG. 2). Observing the shadow grid (test grid) through the physical one (which is defined as the referenced grid), moiré fringes appear.

2.2 – Application: Applied to the characterisation of dents on structure panels, the shadow moiré allows one to easily determine the depth and the contour of damages. FIG. 3 shows the modulation of the test grid (shadow grating), generated by the height difference at the surface of the tested structure. When the surface is flat (no dents), the shadow grid remains undistorted. When a surface irregularity appears (dents), the shadow grid is distorted according to the height of the valley. Moiré fringes are then distorted according to the dent's height and represent isolines of height of the defect. The result is a direct topographic image of the inspected surface. When the angle of illumination and the pitch of the physical grid are known, the altitude difference between two successive isolines is known as well and it is easy to retrieve the exact depth of the dent by only counting the lines.

2.3 - Inspection system: Based on this principle, the Moireview© was developed to quickly determine the height and contour of dents appearing on aircraft structure panel. The Moireview© includes:

- an optical system allowing to obtain the moiré fringes (see FIG. 4)
- a digital still camera for the acquisition of the moiré fringes
- dedicated software (see FIG. 5 and 6) for the processing of the moiré fringes and the display of the corresponding results.

For practical reasons, a specific software was developed for the application. Most of the fringes demodulation software need at least 3 images to perform the processing of fringes with no carrier, using algorithms based on phase shifting. The processing from one image is also possible using classical FFT algorithms, but then it is necessary to introduce a carrier in the fringe pattern, which highly degrades the contrast of shadow moiré fringes. The actual software is capable of processing fringes pattern without carrier from only one single image, which increases considerably the simplicity of the system (no need for the acquisition of several images, no need for a mechanical device to generate a carrier).

2.4 - Procedure of measurement: The procedure to follow to achieve a complete measurement with the Moireview© is quite simple: the operator has to apply the measuring window on the surface to inspect, look at the fringe through the digital still camera screen. It is already possible to count the fringes to have a rough idea of the depth of the dent. The controller can then choose to store the fringe pattern in the memory card of the camera. At the end of the inspection, images are loaded in a processing unit (PC) via USB link or memory card reader and the software analyses the images. The main results are: 2D field of view of the damage, 3D meshing, max depth, diameters, surface, profiles. The results can be stored under any standard file format.
The whole operation for one dent takes less than 2 minutes. The measurement accuracy is estimated, with a grid of 10 lines/mm, at 20 µm. The Field of view is 75 X 55 mm.

3 – Results: A test campaign was lead at the several Airbus manufacturing plants in France, Germany and Great Britain. The goal was to validate the feasibility of the technique and to assess the functionality of the system in the workshops. Results are presented in FIG. 7 and 8.

The test periods confirmed the functionality of the tool and showed it met the basic specifications. It appears that the damages that can be analysed with the Moireview© on structures panels are: dents, rivet pull-in, reamings and any smooth shape deformations. Comparisons with the current measurement tools were performed and the Moireview© was found to be at least as good as the existing means concerning the accuracy of measurement.

3.1 – Benefits: The main advantages of the Moireview©, compared to the tools currently used for the characterisations of dents are:

- Full field result (instead of single point measurement): the exact geometry of the damaged area is measured and stored. The dent can be easily visualized.
- Time saving
- More accurate results
- More reliable results
- Improved traceability

3.2 – Limitations: The limitations of the system are :

- Field of View : it is possible to analyse dents whose surface doesn't exceed the measurement window size.
- Sharp edge defects : when the slopes are too strong, the number of fringes per mm becomes too important and the processing becomes impossible. The maximum slope was found to be 45 °.
- Very small size defects : when the size of the defects is too small, comparatively to the field of view, the processing is not possible. The minimum size defect was found to be 3 mm.
- Surfaces : when the surfaces are dark (dark blue paint) or too shiny (reworked area), the measurement can be more difficult, because of the light coming back to the camera. It is then recommended to spray white powder on the inspected area.

4 – Conclusions: A simple fast reliable tool based on optics has been developed to characterize dents on aircraft structure panels. It allows one to retrieve the 3D shape of smooth local deformations. The Moireview© have successfully passed the test periods in the Airbus workshops. A qualification process is in process to completely validate the tool. It will then be approved by Airbus authorities and used in the manufacturing workshops. The extension of the use for in-service inspection is already under way.

Figures

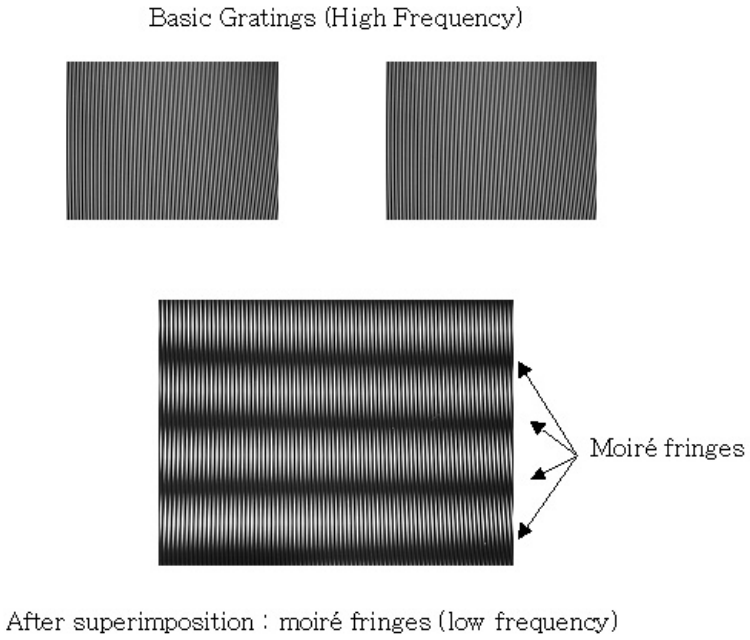

Fig. 1 : the moiré effect

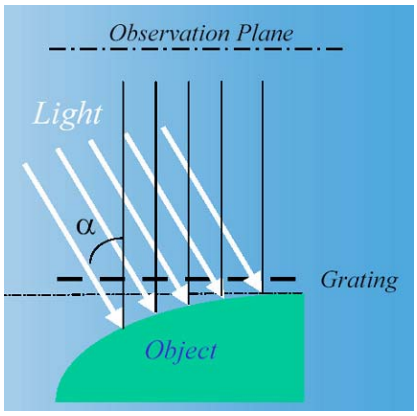

Fig. 2 : the shadow moiré technique

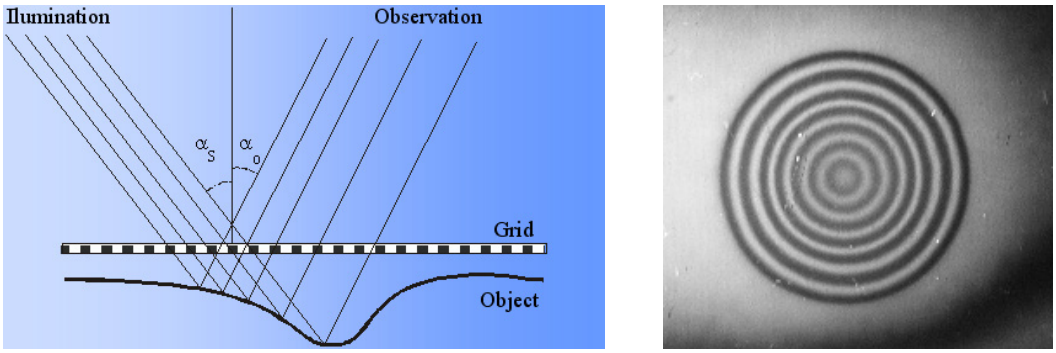

Fig. 3 : the shadow moiré applied to the analysis of dents

Fig. 4 : the Moireview©

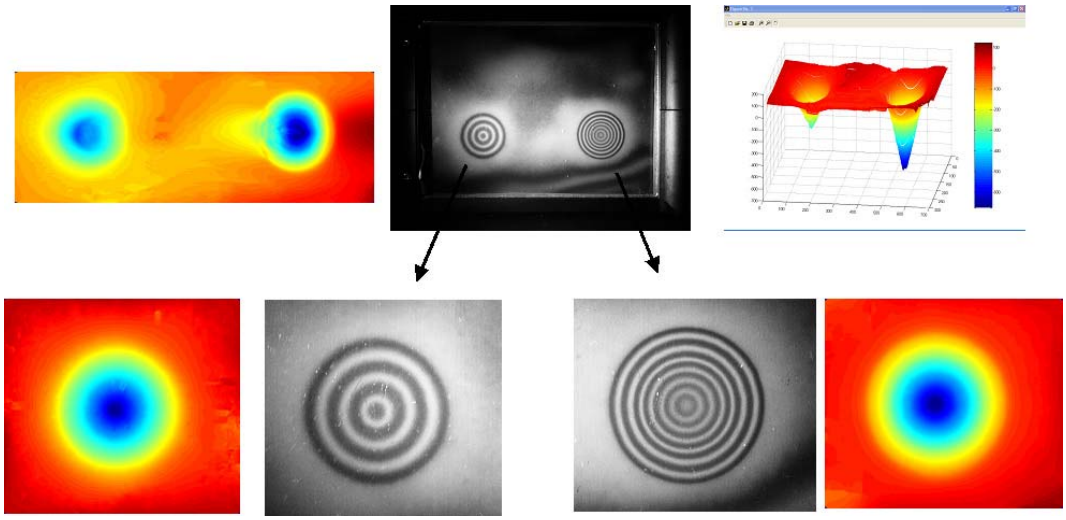

Fig. 5 : moiré fringes and processing

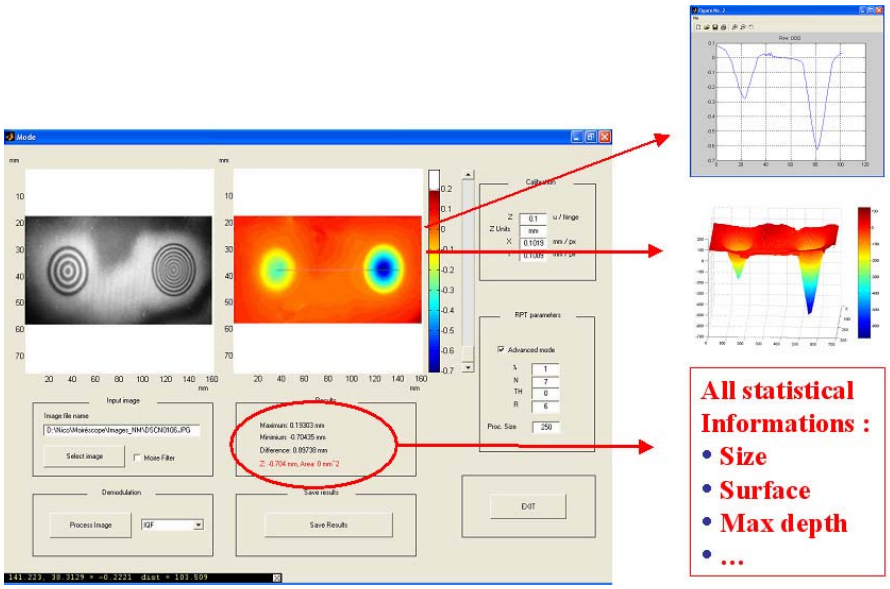

Fig. 6 : the analysis software

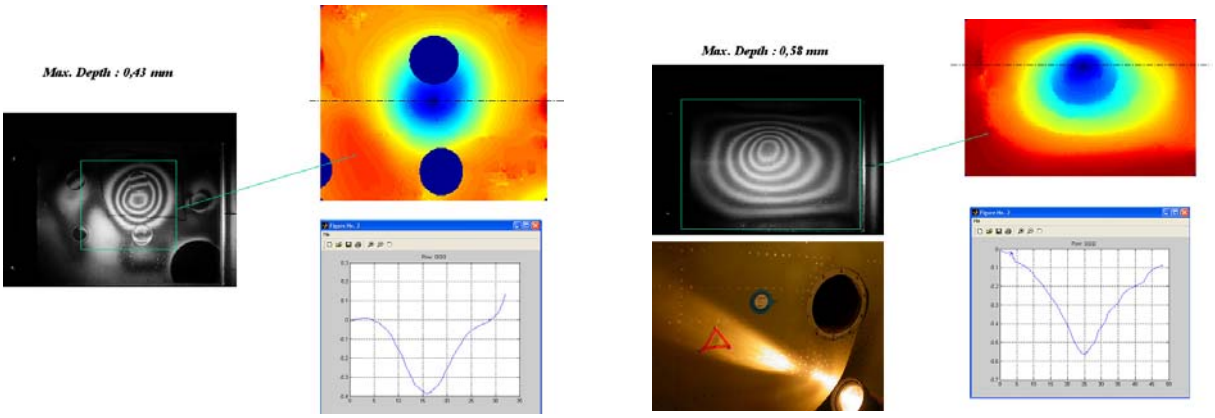

Fig. 7 : Result : dents on aircraft fuselage

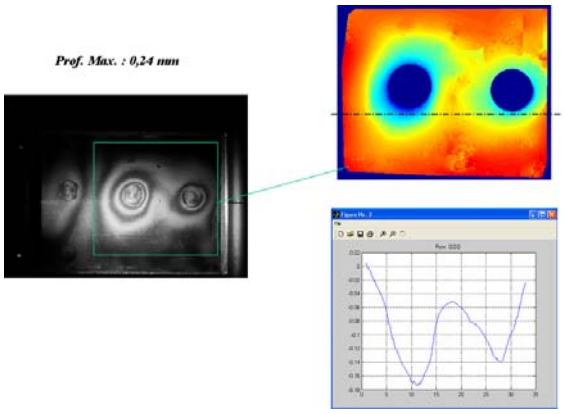

Fig. 8 : Result : rivet pull-in on aircraft fuselage