DEVELOPMENT OF AN X-RAYING HIGH DEFINITION SYSTEM ABLE TO BE DEPLOYED IN PRODUCTION AND IN-SERVICE ENVIRONMENTS

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Abstract: The present work describes the development of XHINIA, a novel X-ray detection system able to be deployed both in production and in-service aeronautical environments. The system is based on a portable high-resolution X-ray detection system coupled to an automatic displacement tool. The evaluation of the detection system performances as well as the detection system detectability performances are here described. Finally the displacement tool is presented and some results of in-service capabilities of the complete system (detector and displacement tool) are presented. The XHINIA system proved to be a unique and very useful tool for in-service recurrent X-ray inspections (circumferential assemblies) and also for expertises in the aeronautical field.

Introduction: The use of classical X-ray based inspection systems in an aircraft maintenance environment is never an easy job. This is mainly due to the need for dark rooms nearby for the X-ray film development, no quick access to the recorded data and the restricted access to the aircraft for long periods of time for people not involved in the X-ray inspection. This last point makes this type of inspection to be executed mainly during nightshifts.

Last years developments in the field of X-ray detection systems were made in the direction of portability, high resolution and high quantum efficiency solutions. Nowadays digital X-ray detection systems become a real alternative to the classical X-ray films in the field of the aerospace Non Destructive Testing.

The present work describes a novel X-ray inspection system (XHINIA) based on a digital high-resolution portable X-ray detector coupled to an automatic displacement tool enabling both aeronautical in-service and in-production inspections. XHINIA stands for *X-ray system with High resolution Numerical Imaging and Automatic displacement*.

A view of the main component of the XHINIA system, the detector, and of NDT Expert X-ray bunker installation is shown in figure 1.

The detector is a customized ImageStar camera model from Photonics Science with a fibre optic taper to couple the information from the scintilator to a high-resolution CCD camera. This customisation focused in large active window (at least 3 rivet lines should be able to be inspected at the same time) and high quantum efficiency (by a correct definition of the scintilator material and thickness). These points were the guarantee for an effective detection of aeronautical flaws (fatigue cracks, gas holes, metal inclusions…). The chosen detector had a 70mm X 70mm rectangular window and a gadolinium oxysulphide scintillator with an entrance resolution of 34 μm.

Figure 1 – XHINIA at NDT Expert facilities and detailed view of the ImageStar detection camera.

Results:

2.1: Detector Characterization

The characterisation of the ImageStar detector was necessary to determine the parameters that will be used to compare the intrinsic performances of the detector with the ones of the classical film. In literature one can see that the accurate measurement of a digital X-ray detector image quality is based on the Detective Quantum Efficiency (DQE). This parameter measures the combined effect of the noise and contrast performance of an imaging system, expressed as a function of the object detail. The determination of the DQE relies on the determination of the Modulation Transfer Function (MTF) and the Noise Power Spectrum (NPS). This measurement is based on the line pair phantom profile. Figure 2 shows the line pair phantom obtained by the Imagestar detection system.

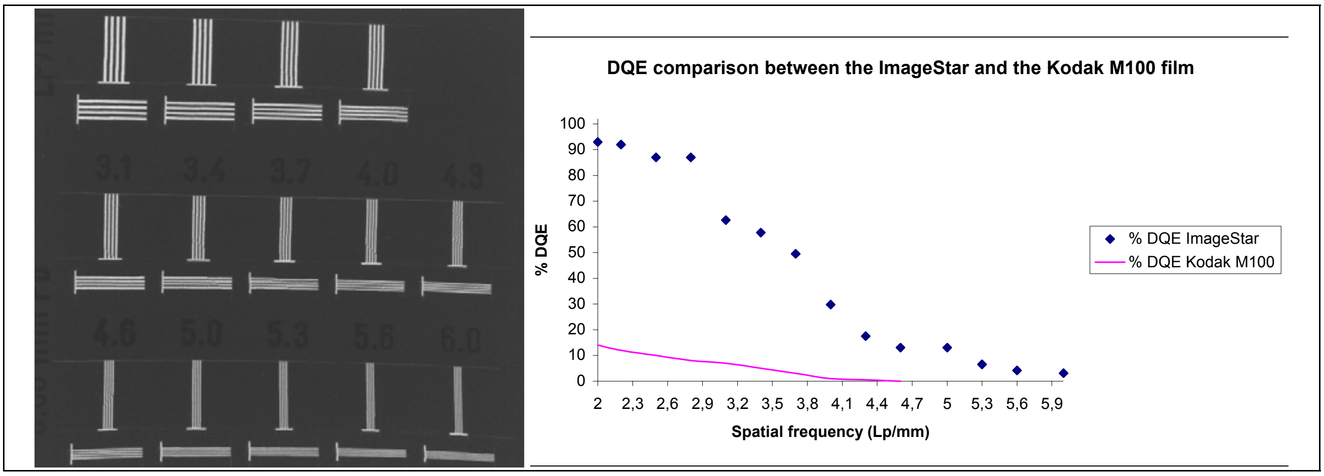


Figure 2 – Line pair phantom image for detector characterization and comparison of DQE detector performances (ImageStar VS Kodak M100 film @ 80 kV).

The very high DQE values of the ImageStar detector confer to the system a combination of very low noise and superior contrast performance. A high DQE especially affects the ability to view small low-contrast objects.

2.2: Evaluation of in-service flaws detectability

Tests with representative samples have been carried out to evaluate the detection system performances in terms of flaw detectability. Several representative parts were chosen keeping in mind the in-service applications of the XHINIA system. A specimen representative of a lap joint was used for the tests. This part allows us to validate the system for the circumferential assembly X-ray inspection. The specimen had artificially and real defects (two electro-eroded cracks and three fatigue cracks). The part was constituted of three layers with a total thickness of 9.5 mm. Figure 3 represents the type of part to be inspected in a circumferential assembly and an X-ray inspection result of the sample. A zoomed image allows us to clearer identify a fatigue crack.

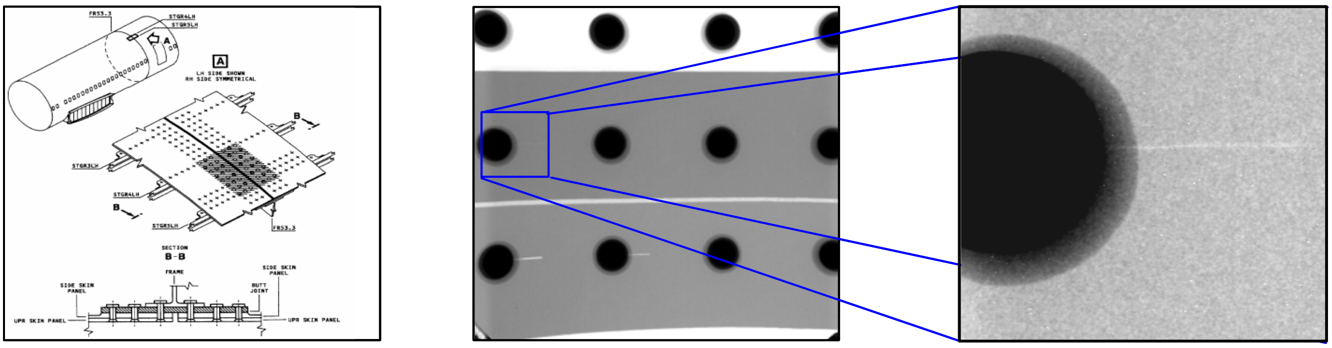


Figure 3 - Lap joint with electro-eroded and fatigue cracks: zoomed image - fatigue crack of 0.1mm opening.

The crack opening in the depicted case has around 90 µm. Smaller apertures were detected with this system, around 60 µm, but with a lower reliability on the inspection.

2.3: In-service application with automated displacement tool

The main goal of this development was the usage of XHINIA for in-service inspections being the focal point the circumferential assemblies. Figure 4 presents the foreseen application and how the XHINIA system will be used to perform the inspection. The use of a panoramic X-ray generator will allow the inspection to be made with only the displacement of the detector head. The detector is coupled to the automatic displacement tool fixed to the structure by means of vacuum pumps, only possible due to the portability of the detection system (low volume and low weight). One should note that existing in-service inspection systems are all based on magnetic fixtures and are used on the petrochemical industry.

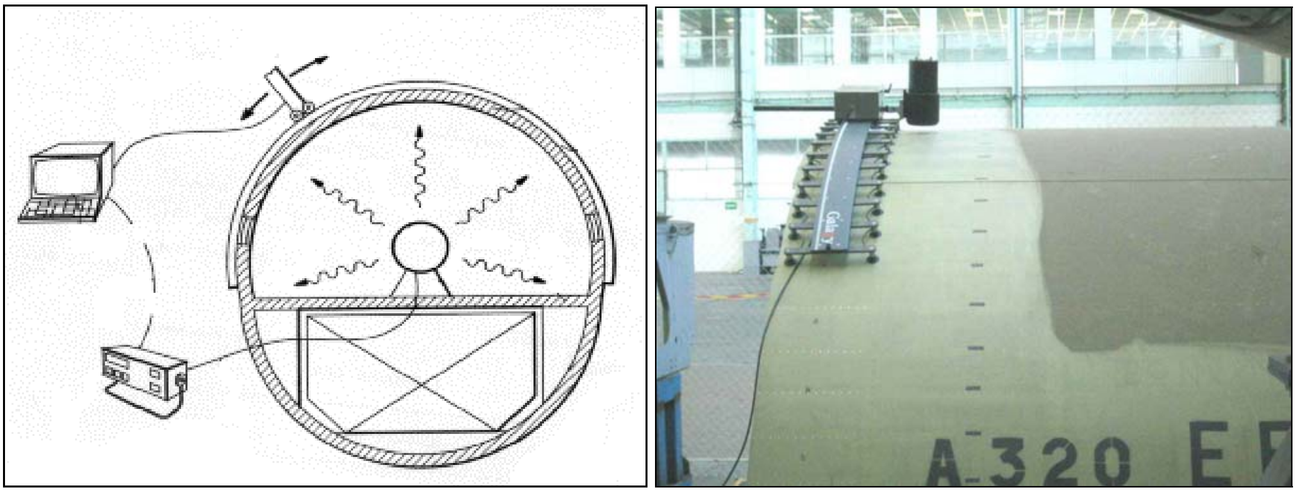


Figure 4 – Foreseen application for the XHINIA system: in service circumferential assembly inspection.

Another inspection situation XHINIA will probably be requested to be applied includes the longitudinal assemblies. In figure 5 this situation is described. Again, with the vacuum pumps the detection system is mounted on the structure to be inspected and the X-ray generator is placed inside the aircraft.

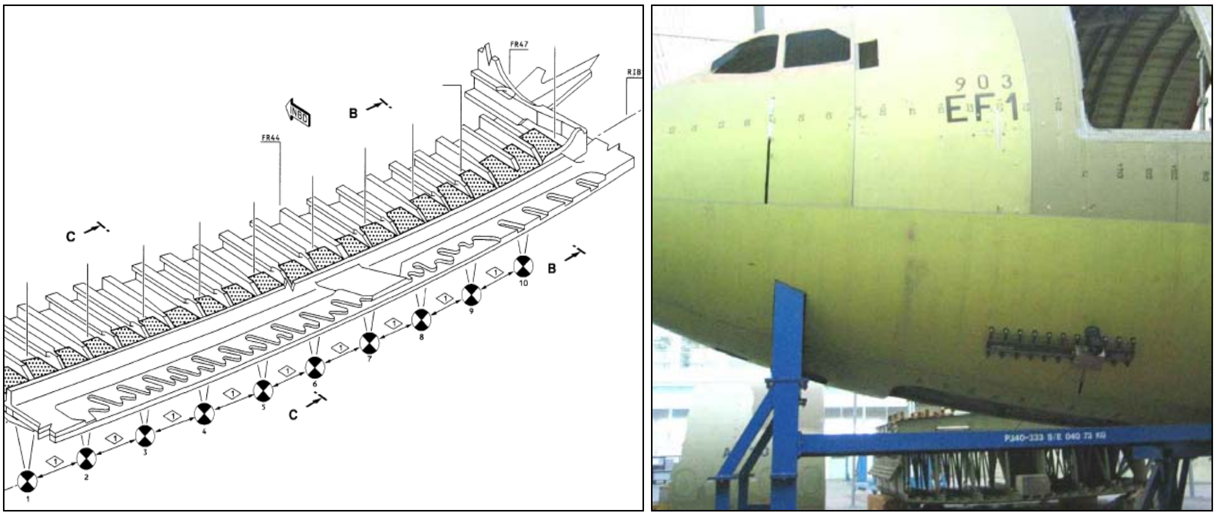


Figure 5 – Foreseen application for the XHINIA system: in service expertise on longitudinal assembly.

Discussion: The objective of the development described above was the realization of an X-ray inspection tool able to simplify the restrictions undergo during in-service inspections while performing classical X-ray inspections. When comparing this new X-ray approach to the classical approach with films, one sees that the latter has a better spatial resolution (~1μm instead of 34 μm for the digital camera). However, this disadvantage can be compensated for by the higher dynamic range and sensitivity of the solid state matrix based approach, see figure 6a). Another important advantage of the new approach is reduction of required dose without image quality loss. For example the exposure time for the images in figure 6a) is 10 sec (at 70 kV) instead of 90 sec (at 100kV) with a film.
A productivity increase may arise from the fact that non-interpretable films will be eliminated and the access to image databases will be easier cheaper and faster. Also, not to be ignored is the cost in developing chemical solutions and in films acquisition. The reduction on film acquisition, and possible elimination, depends mainly on changing of established methods and, from a technical point of view, on the visualisation screen

performance. The on-screen interpretation of digitised images needs high resolution screens so that the inspector can take maximum advantage of the inspection system. Also better traceability and faster inspections are possible due to the fact that any parameters adjustment can be made on-site. Moreover the user friendly software is able to quickly generate flaw sizing and location, see figure 6b)

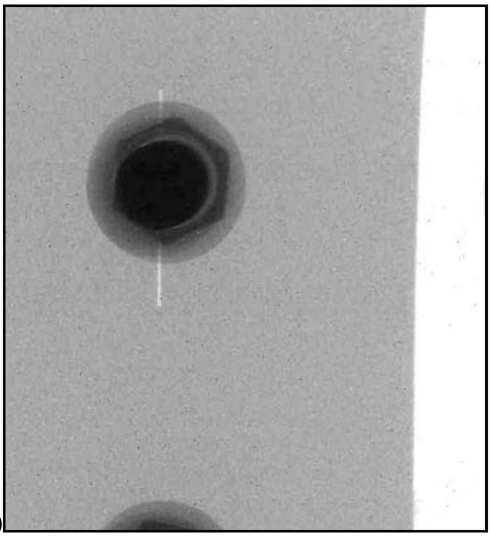
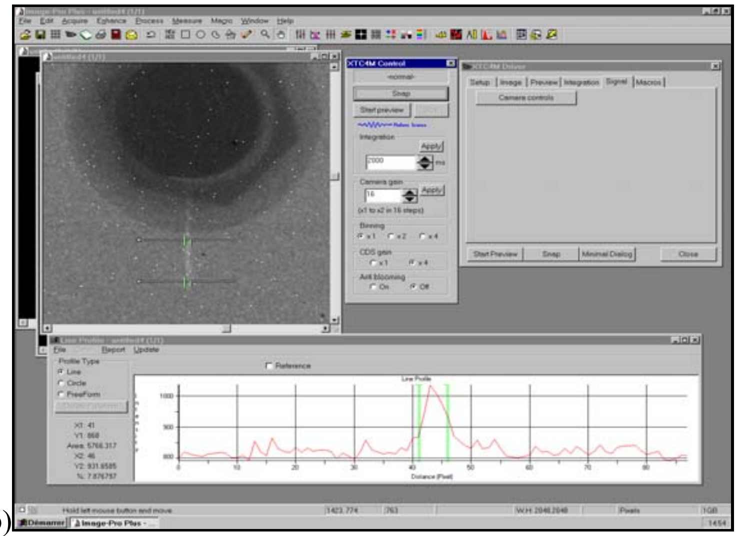
a)

b)


Figure 6 – a) X-ray image of crack under rivet. B) User interface with measuring tool.

In terms of flaws detectability the results were very satisfying. Fatigue cracks from representative samples of aluminium circumferential assemblies, gas holes from engine spar titanium parts, see figure 7, all where seen with a high contrast.

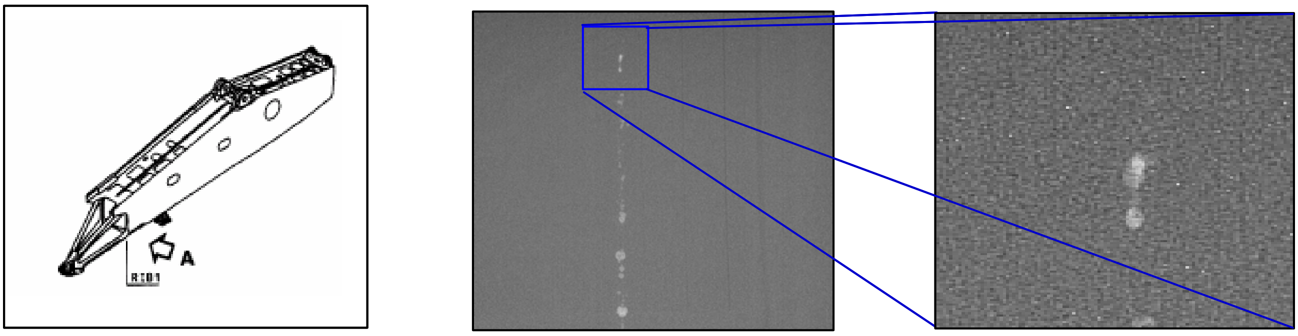


Figure 7 – Engine spar 25mm titanium weld with flaws: zoomed image – gas holes of 0.8mm diameter.

Concerning the automatic displacement tool it is easy to install on aircraft fuselage, either on single aisle either on wide-body. All the geometrical and mechanical constraints as fuselage radius or system weight didn't were complied within the specifications of the automated displacement tool.

Conclusions: The XHINIA system proved to be a good tool for X-ray inspection in aeronautical environments. The advantages regarding film based inspections are the decreasing of immobilisation time of the part to inspect (automation of the inspection by the use of a common interface displacement/acquisition of X-ray images), the X-ray inspection cost reduction by elimination of films and development products, the possibility of real-time adjustment of X-ray parameters, the easier evaluation on doubtful indications and the improving of traceability.

This corresponds to an important decreasing of costs associated with a conventional X-ray inspection.

Moreover, the automated displacement tool can be also coupled to UT/ET probes.

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