SYSTEM OF INSPECTION ASSISTED BY MICROPROCESSOR*

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PRESENTATION OF THE STUDY

In spite of significant advances in the field of automatic inspection (robotization, motorization), there are still numerous cases where the cost of such facilities cannot be justified due to the low production rates, or to the fact that they are not easily applicable due to the shape of the parts or to the environment (on-site maintenance inspection or inspection during manufacture in particular areas of composite parts).

In both of these cases, these inspections must be carried out manually by an operator, and many questions arise concerning the traceability of such operations (have all the parts been inspected? Were all the settings correct? Was the operator's interpretation of the results correct?).

The system developed by AEROSPATIALE was so designed as to gather around a microprocessor all the functions required to ensure reliability of the inspection and to relieve as much as possible the operator of all the phases where interpretation or positioning errors could occur.

Thus, in order to demonstrate that with a limited investment, the reliability, rapidity and performance of a manual inspection can be equalled, a SIAM (System of Inspection Assisted by Microprocessor) has been set up to tackle an arduous task: the maintenance inspection of aircraft joints (figure 1) for which very stringent requirements have to be satisfied:

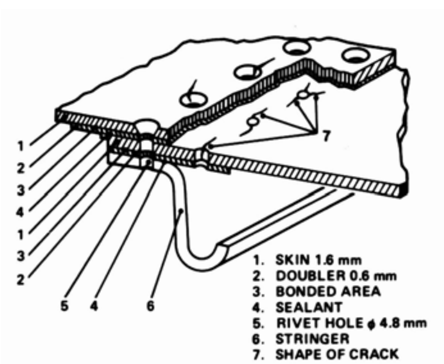

Fig. 1: Location of the cracks searched for on the assemblies.

* This development has been awarded the Golden Medal for Innovation NDT Diploma of the 6th International conference on NDT in STRASBOURG 1986.

- inspection of more than 30,000 rivets in 24 h,

- guarantee that no rivet has been missed on the 500 meters of joints to be inspected,

- length of defect detected with a 95% confidence level: less than 5 mm,

- false alarm rate lower than 1%,

- management of data,

- easy handling for on-site inspection.

All the functions (measurements, positioning, management) required to guarantee the reliability of this kind of manual inspection are presented below.

SELECTION OF THE NDT METHOD

The method selected is not the one which provides the highest detection level, rather it is the method best suited to the problem (search for cracks around rivets, figure 1), which can be easily applied to maintenance. Ease of utilization led us to select the eddy current method.

Two differential probes were used (figure 2); they were specifically designed to provide a solution to this problem. They consist of a central transmitter, two receivers separated by a distance equal to rivet centerline spacing and two lift-off compensation coils.

Such a probe arrangement allows two kinds of deviation to be obtained in the impedance plane; the deviation on the x axis corresponds to resistance variation (rivets), while the deviation on the y axis corresponds to inductance variation (cracks). The value of the latter deviation does not depend on paint thickness and rivet presence (figure 3).

Since the crack may start either on the external sheet (second rivet line) or on the internal sheet (first rivet line), the two probes operate at different frequencies (2.9 kHz and 13.5 kHz, respectively). They are connected to an EC 3000 (HBS) apparatus provided with 4 outputs for each of the two probes.

This type of system allows artificial defects, approximately 2 mm long, to be detected on each inspection line.

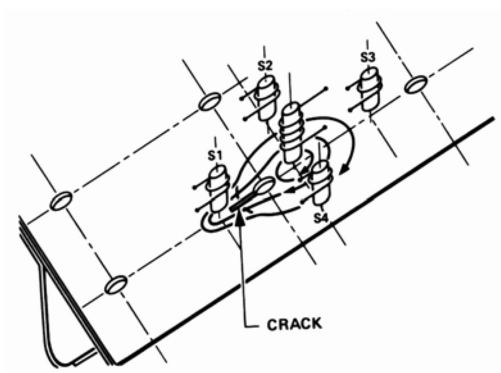

Fig. 2: Design of eddy current probe

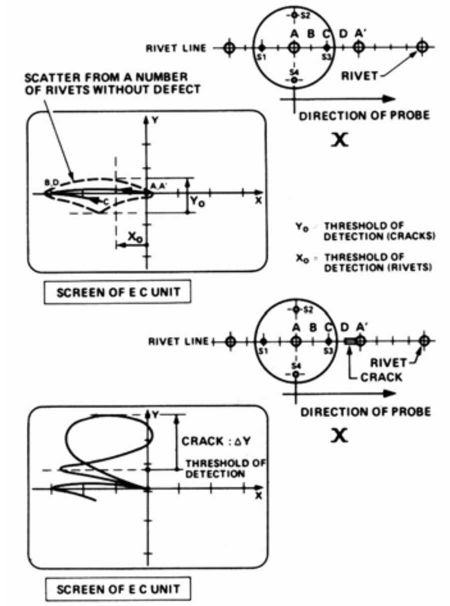

Fig. 3: Display of the impedance plane

The use of a manual method on a large number of rivets may, however, lead to non-detections due to differences between artificial defects and actual cracks (orientation, shape) and, on the other hand, to detection misses due to human errors (fatigue, incorrect signal interpretation, missed inspection sites).

Therefore, even if the performance requirements of the method seem to be satisfied, its reliability for the whole structure remains to be guaranteed.

SCANNING MODE

To make sure that all the rivets have been inspected, it is necessary to set up a scanning system which provides the position of sensors. The conventional solution of an automated system using stepper motors has been rejected, since it results in a large-size fixture lacking operating flexibility where the coupling of the probes cannot be guaranteed for all local shape irregularities. Therefore, a manual scanning system had to be selected; the movements of the system are repeated by a linear position sensor along which the probes are moved.

The position sensor is a standard model and consists of a bar on which slides a magnet where the probe holder is fitted. Whenever an electric pulse is sent into the bar, it is subjected to a twisting torque at the magnet position. This torsion generates an acoustic wave which propagates in the bar. The time lapse between the exciting pulse and the received acoustic wave is used to determine the position of the magnet and thus that of the scanning system (figure 4).

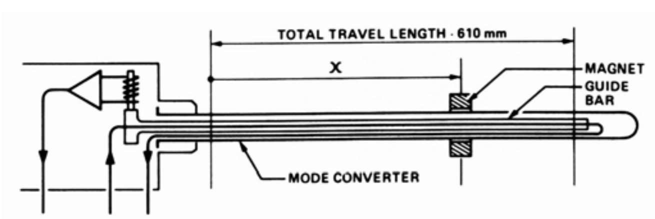

Fig. 4: Schematic of the position probe

This system has many advantages as regards precision (1/20,000 of total travel), transmission speed, ruggedness, light weight. Futhermore, flexible or rigid models up to 30 meters long exist. For adaptation to the fuselage, the overall a length of the system is 1 meter, which corresponds to the spacing between two frames (24 rivets on each line). The scanning system thus defined is very easy to use (figure 5) and it allows the fuselage to be segmented into 500 inspection zones which may be readily identified on a symbolic representation.

THE COMPUTERIZED SYSTEM DEVELOPED

The system (APPLE II) carries out the EC channel acquisition and probe position management functions. It also checks the calibration, displays the 4 EC channels (as a function of position) and stores them on a 10-Mbit disk capable of storing the results for 7 complete fuselages (figures 6 and 7).

Fig. 5: Overall view of the postion probe

Fig. 6: Overall view of the ground SIAM system

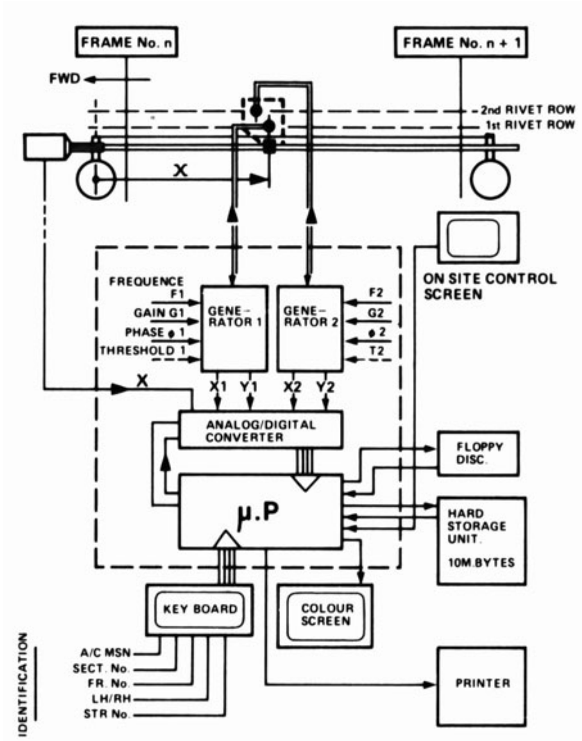

Fig. 7: SIAM block diagram

The study first consisted in structuring the various phases of the inspection and linking them through menus, and then presenting the results in a straightfoward, easy-to-use manner.

As regards the identification of the areas to be inspected, the various fuselage sections are represented symbolically (figure 8). The interframe section subjected to the inspection is identified by blinking of the display and is cleared once inspection is completed. If any anomaly is detected, it is delineated by a thick line of a different color.

The EC data for each interframe section are represented as shown on figure 9. Chanels V1 and V3 represent the responses generated by the rivets, channels V2 and V4 correspond to the response generated by the defects (in this case, standard defects from 2 to 7 mm long). Figure 11 represents the display of a defect-free inspection area (correct inspection of the area can be ascertained by counting the "rivet" indications).

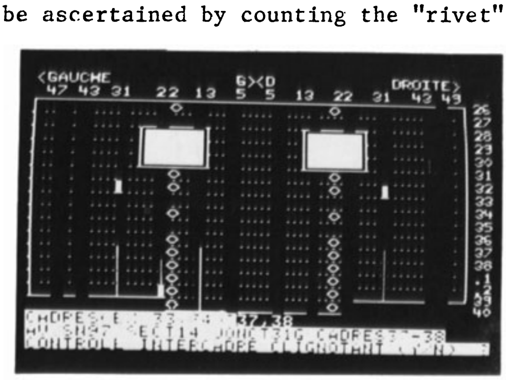

Fig. 8: Symbolic representation of a section during inspection

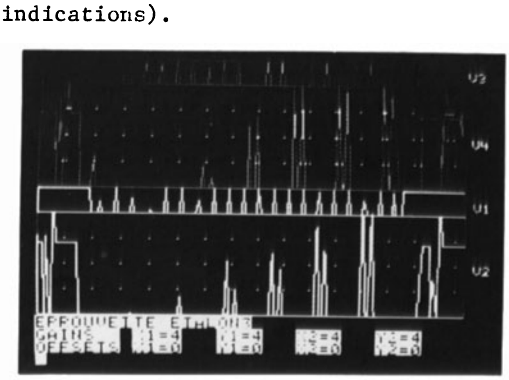

Fig. 9: Display of the EC data on a test specimen

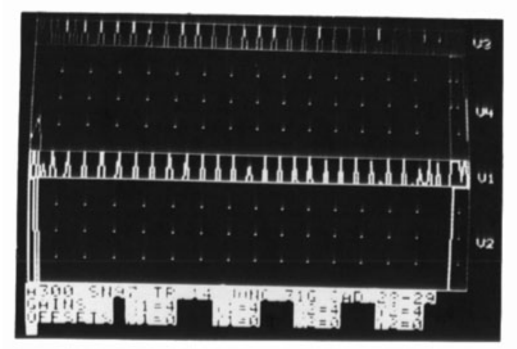

Fig. 10: Display on a defect-free area

VALIDATION OF THE SYSTEM

The SIAM has been mainly designed with a view to rapid detection and inspection management, rather than for assessing the detected defects. Since the probability of cracks is low, the defects detected and identified by the SIAM should be small in number and it should be easy to assess them accurately by a more accurate method which may be slower (i.e. dual-inspection principle: fast detection, then accurate assessment). However, to validate the complete system as regards performance and reliability, it was necesary to know the confidence level of detection of actual defects.

This validation was performed on specimens representative of the actual structure in which 750 fatigue cracks were created on one or the other of the rivet lines. After 3 inspections, the specimens were opened, and this allowed curves for probability of detection by SIAM to be plotted as a function of the actual defect length (figure 11).

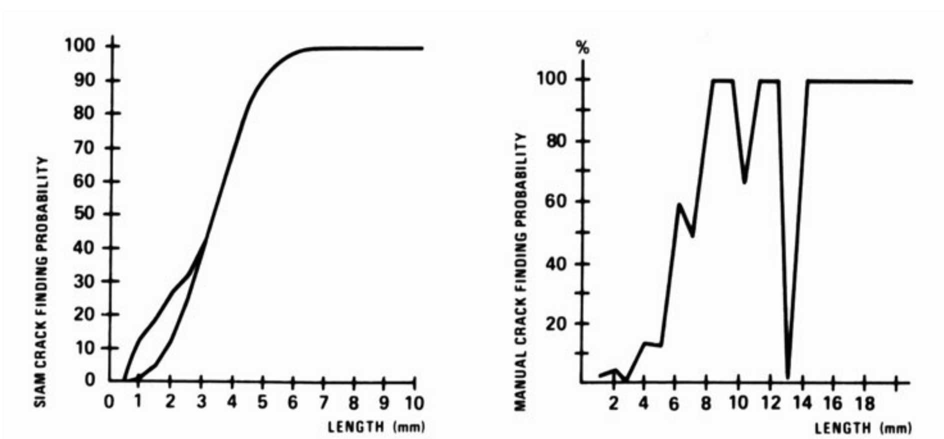

Fig. 11: Probability of detection on real cracks with SIAM

The curve was then fitted using the WEIBULL law, which allows the definition of a 95% confidence level detection length of approximately 4.5 mm for a detection threshold close to 2 mm, and a very high relability level was achieved since all defects longer than 4.5 mm were detected and no false alarm was trigged.

RESULTS OBTAINED ON AN AIRCRAFT

Once the performance and realibility had been established, the feasibility of actual scale inspection on a fuselage had to be demonstrated.

For this purpose, four aircraft were partly inspected, i.e. 65,000 rivets were inspected. The inspection rate increased from 510 rivets/hour to 1400 rivets/hour from the first to the fourth aircraft. The task was conducted by a team of 3 operators.

After a period of time required for running up the system and for team adaptation, the inspection conducted on the fourth aircraft complied with the requirements of the specification which stipulates a total inspection time of 24 hours.

The indications detected during each inspection, which determined the gross false alarm rate, were due to rivets of different materials (aluminium, monel, standard rivets being in titanium) or to doubler edges or local incidents (highly offset rivets).

After a rapid check of these local indications (visual inspection or conductivity measurements), the net false alarm rate becomes zero.

CONCLUSIONS

In a situation where inspection automation would be difficult and costly, the concept of computerized assistance to manual inspection proves straightforward, easy to use, while provising a high level of rapidity, reliability and performance for a moderate investment cost.

AEROSPATIALE has also adapted this concept to the ultrasonic inspection of composite structures in manufacture, since it had been noticed that although 90% of the surfaces (flat sections of composite parts) were inspected by automatic facilities (pools, sprays), the remaining 10% of the surfaces, which correspond to shape irregularities (strengtheners, bent sections), were still inspected manually, which occupied approximately 50% of the entire inspection time, since the inspection raised many reliability problems.

Both in manufacture and maintenance, the SIAM concept allows the inspection cost to be reduced while still guaranteeing high quality and reliability.