NON-DESTRUCTIVE TESTING IN THE AERONAUTICAL INDUSTRY

The aeronautical industry makes wide use of non-destructive testing at two stages in the life of its product:

- during and at the end of manufacture, to guarantee the quality of the products delivered,
- during service, to check and maintain the safety of its products.

In both these quality assurance situations, inspection techniques must be developed which are both efficient (i.e. offer a guarantee of detecting any faults in any area of the part) and traceable (i.e. the inspection settings and results must be recorded and stored).

Although, during manufacture, non-destructive testing of metal structures is handled satisfactorily, the same cannot be said for composite structures for the two following reasons:

- the automatic tools in our factories (pools, jets) are capable of efficiently inspecting 90% of the surface of composite parts, i.e. all flat areas. On the other hand, the remaining 10% of the surfaces, which contain irregularities (stiffeners, curved areas, etc.) are still inspected manually and take nearly half the total inspection time.

No self-propelled equipment, which can be easily adapted to the inspection of large surface areas, exists for maintenance purposes. All inspections are carried out manually.

EXAMPLE OF A MANUFACTURING INSPECTION PROBLEM

The composite flaps of an aircraft (Figure 1) are a typical example of the problems which necessitate manual inspection.
These surfaces consist of two carbon fiber composite skins assembled by bonded composite (Figure 2). The skins themselves can be ultrasonically inspected by immersion (C-Scan) but the number of plies and the shape of the part after assembly mean that the bonding can only be inspected manually. The inspection principle used is to ultrasonically measure the thickness: if the rib is not bonded, the thickness measured will again be that of the skin. This inspection requires a highly-skilled operator since he has to move his sensor and interpret the echoes displayed on his screen simultaneously. He must, therefore, discriminate between a lack of bonding, excessively thick bond films and changes in the number of plies (Figure 3).
Bearing in mind the rate at which these parts are produced, the operator would inspect roughly a kilometer of bonded joint per month and there would be no credible trace of his inspection.

Figure 3. Test procedure

ANALYSIS OF POSSIBLE SOLUTION

There are two ways of reducing the adverse effects of manual inspection on reliability, time required and performance:

- existing systems could be made more sophisticated to enable them to scan complex forms. This would require heavy investment and the returns would be minimal due to the low production rates pertaining in the aeronautical industry. In addition, the systems would be difficult to use and, thus, waste time,

- the development of a machine specific to each area with a complex form, based on the SIAM concept (System of Inspection Assisted by Microprocessor). This machine consists of a formed sensing head which carries several sensors and which the operator moves following a guide to allow the position to be accurately detected. The physical phenomena generated by the sensing head are recorded and processed by the microprocessor. The machine also prints out an inspection report and manages the inspection results.

DEFINITION OF THE SIAM CONCEPT

The complete SIAM concept is designed to control the three aspects of the problem of manual inspection reliability.
Position identification

To resolve this problem implies a system capable of both identifying the position of the sensor and being used as a guide for the inspection. The system adopted is simple, accurate (1/20000 of the total length displacement), very easily handled by one person only and capable of computerized processing. It allows real-time identification either of linear position or within a plane.

The system consists of a conductor (which may be flexible or rigid) along which a magnet slides. When an electric pulse is fed through the conductor, the conductor tends to twist (generating an acoustic wave) due to its interaction with the field of the magnet. By measuring the time between the electric pulse and the acoustic wave, it is possible to determine the position of the sensor-holder which is rigidly attached to the magnet. For the flap surface application, a rod is used to identify the rib to be inspected and a second rod to identify the position of the sensor-holder along the rib.

Measurement

Rather than carrying out a manual scan of the bonded zone, we produced an array of 4 ultrasonic sensors (10 MHz, relay) with a partial immersion system (Figure 5). The two end sensors are used as a reference since they are always outside the bonded zone and, therefore, measure the thickness variation of the skin alone (the number of plies can change from 8 to 28).
The set of 4 sensors are connected to a multiplexed thickness measurement unit which can be fully controlled by a microprocessor.

The rapidity with which it can be programmed allows the operator to change the various parameters (gain, measurement on the first, second or third echo) in masked time (16 ms per transducer) and discriminate the data on a computer (lack of coupling, debonding, good bond, excess thickness of the glue, thickness variation).

**Management of the inspection**

The microprocessor fulfills various functions to ensure traceability of the results and to guarantee the overall reliability of the inspection system:

- Calibration of the instrument.

- The possibility of entering a diagram of the part and the areas to be inspected from a graphic table. This possibility allows the results diagrams to be adapted to modifications in the design.

- Recording of the position and measurements taken as described previously. The microprocessor modifies the settings to match the position of the sensor on the skin in relation to the thickness measurement through the two end sensors of the array.

- Real-time display of the position and the ultrasonic results, processed to make it easily understandable by the operator. Figure 6 shows a simplified version of the display on 4 measurement channels (two skin measurements and two measurements in the bonded zone).

  The inspection display represents, from top to bottom, the measured thickness compared to the reference thickness (obtained from the end sensor on the strip), the C-Scan display with different colors (lack of bonding, satisfactory bonding, excess of bond thickness) and a B-Scan section on the sensor position.

- Management of zones still to be inspected and those already inspected (with and without faults) (Figure 7).

- Storage of data on each rib and automatic output of an inspection report.

Figure 6. Display of processed results on the inspection screen
INSPECTION PROCEDURE

The inspection is carried out following a menu displayed by the microprocessor; the replies are input via a mini keyboard. An inspection keyboard is available for skilled operators to make the back-up copies required for a reliable inspection system.

The system operates such that the operator always has a certain degree of freedom and is not controlled by the microprocessor. He is still responsible for his work in the sense that he must trigger each phase in the inspection and always carries final responsibility for the inspection analysis.

Upon completion of an inspection, all the data for each rib, with the appropriate reference, is stored on a hard disk and can subsequently be consulted for check-out or investigation purposes.

CONCLUSIONS

The installation of this system in the AEROSPATIALE factory at NANTES has given practical proof of the advantages of computer assistance in carrying out non-destructive manual tests. The time, compared to a conventional manual inspection, is reduced by a factor of roughly 10 while reliability is still maintained, both from the point of view of efficiency and management of results.

In economic terms, the use of the SIAM concept in manufacture reduces inspection costs while improving efficiency and still maintaining a high degree of flexibility. Moreover, the investment involved is 10 times less than that required for a fully automatic system.