INSPECTION OF BONDED ASSEMBLIES USING ROLLER-TYPE ULTRASONIC PROBES WITHOUT COUPLING FLUID

D. Lecru

Aerospatiale, Central Laboratory
12 rue Pasteur, 92150 Suresnes, France

PRESENTATION OF THE STUDY

For several years now, the use of bonded assemblies in aircraft construction has been more and more widespread. These structures have a number of advantages, such as more even stress distribution, longer fatigue life and significant weight gains.

On the other hand, one of the main limits to the use of adhesives is related to the difficulty of finding a fast and straightforward method for inspecting the metal-on-metal bonded joints.

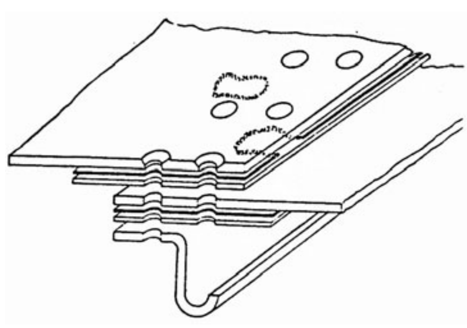
Today, most of the inspection performed at the end of the manufacturing line or during maintenance operations make use of the Fokker Bond Tester (FBT) which allows correct detection of bonding defects, at the cost of a number of drawbacks (only small surface areas can be checked at a time, interpretation of the results is complex and a coupling medium must be applied).

Any replacement method shall thus enable the same degree of detection and resolve all these problems, while meeting reliability and rapidity requirements and offering a possibility of automation with a view to adaptation to the SIAM (System of Inspection Assisted by Microprocessor) principle.

SELECTION OF THE METHOD

In order to test and compare different methods, the study was first conducted on bonded/riveted metal structures where delamination was searched for between the external skin and the doubler, as shown on figure 1.

Fig. 1: Location of bonding defects searched for in the assemblies.



In addition to FBT, various examination methods were tested to determine which gave the most satisfactory results while meeting the requirements for a rapid inspection method applicable both on the manufacturing line and in maintenance.

In particular, the influence of the adhesive film thickness, roughness surface condition and differences in paint film thickness were studied.

The following methods were thus rejected :

- high-frequency ultrasonic techniques based on the measurements of echo amplitude or attenuation,
- the ultrasonic techniques requiring signal processing (ALN),
- the amplitude/phase measurements such as BONDASCOPE,
- the mechanical impedance measurements (MIA 3000).

A low-frequency ultrasonic method with selective filtering in the receiver was finally selected. This technique allows the use of special probes, whose coupling is ensured by a soft rubber end-piece (no need for a coupling fluid). A first study was conducted with straight probes (figure 2), it enabled the inspection method to be validated.

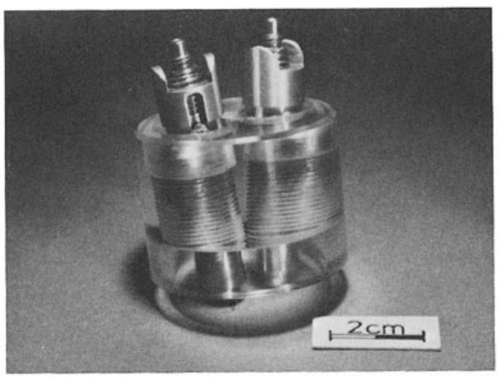


Fig. 2: Dry coupled straight probe

However, to further increase the rapidity of the method, studies were conducted in the AEROSPATIALE Central Laboratory in order to define a reliable, high-performance roller-type probe capable of giving the same results as those obtained with straight probes.

OPERATING PRINCIPLE OF THE METHOD

The probe is composed of the piezoelectric ceramic (PZT) vibrating at 1.5 MHz in thickness mode. Due to the small size of the probe (diameter 5 mm), there is also a radial vibration mode around 440 kHz. The ceramic is mounted, without a back-damper, in a special housing, in order not to attenuate the radial mode. A perspex rim fitted with a rubber "tire" rotates around this assembly (figure 3). Particular attention has been paid to the design in order to obtain maximum transmission toward the tire and to attenuate stray signals in the probe.

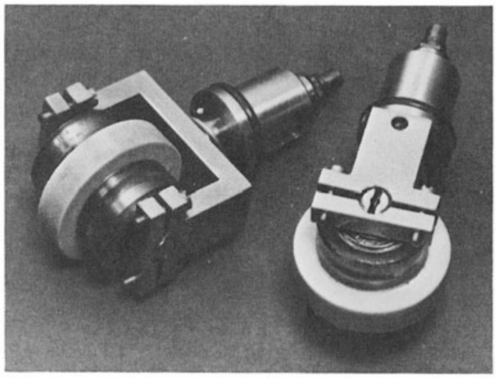


Fig. 3: Roller-type probes

Owing to the long duration of the signal (non-damped ceramic), this method still requires the use of a separate transmitter and receiver.

The received signal is fed to an AF filter, whose center frequency equals the radial vibration frequency. This filtering is equivalent to monitoring the variation of the 1.5 MHz signal modulation (thickness mode) by the 440 kHz signal (radial mode).

Results interpretation merely consists in measuring the amplitude of the signal downstream the filter (figure 4). Correct bonding corresponds to a low amplitude (the waves propagate in the adhesive and the lower sheet). Delamination corresponds to high amplitude (the waves remain in the outer sheet). In order not to be disturbed by edge effects, it may be desirable to analyze only the beginning of the signal (figure 5).

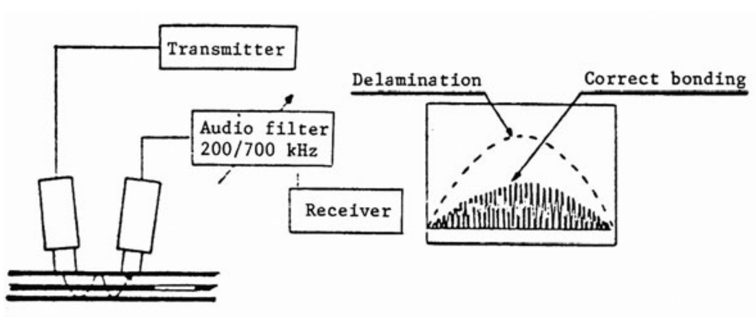


Fig. 4: Examination method principle

This type of examination may be performed with almost any kind of ultrasonic equipment, provided that an AF filter is available and connected in the reception circuit. It is also possible to use excitation by tune burst (around for 440 kHz) while keeping the filtering function in the reception circuit. This technique allows the SNR to be improved.

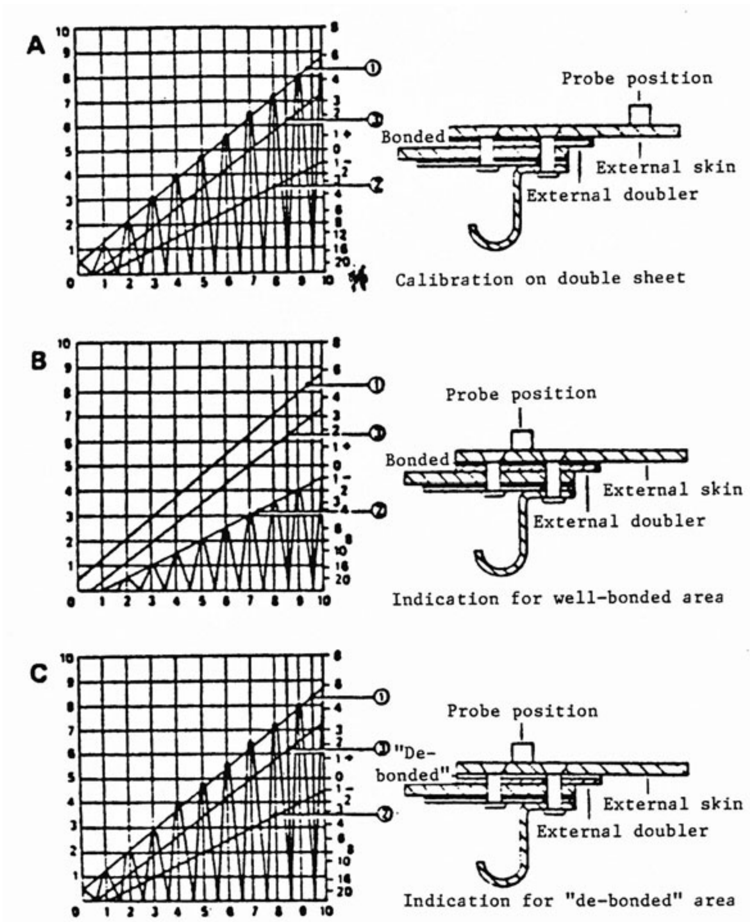


Fig. 5: Inspection procedure

Since the use of the signal is straightforward (measurements of an amplitude in a gate), the measurements principle can easily be connected to a C-scan screening or to a System of Inspection Assisted by Microprocessor (SIAM). This system is detailed in another lecture of this symposium.

Just let us recall that the SIAM provides the operator with assistance during manual inspection; this consists in recording and processing the measurements and the probe position by a computerized system which also takes charge of all the inspection process.

For the joints, a special program has been designed to enable the display on a screen of the joint with its 22 rivets per line on the one hand and the signal amplitude in the analysis gate as a function of probe position on the other.

RESULTS OF TESTS CONDUCTED WITH ROLLER-TYPE PROBES

Since the roller-type probe design closely resembles that of the straight probes, the inspection procedure and the results obtained are very similar to those of figure 5.

Figure 7 represents, from top to bottom, the actual position of defects (such as non-removal of the adhesive separating film, figure 6), the FBT results (the "de-bonded" areas detected are represented by dots) and the results obtained with roller-type probes processed by SIAM, along various inspection lines with and without defects.

Other tests performed on other types of bonding defects (with water or stripping agent spray) show a very good correlation between FBT and this new inspection method. However, it can be said that the two methods only reveal significant bonding defects (presence of an air layer between the sheet and the adhesive). This method dot not allow the quality of bonding to be assessed.

On figure 8, the roller-type probes have been installed on a C-scan in order to scan the defects (the white line in the middle of the defects corresponds to the rivet line). These tests made it possible to determine that the inspection method is not affected by the sheet thickness (same setting for 0.6 to 2.5 mm) and the paint film thickness from 0 to 200 microns, which is a major advantage for inspection carried out during aircraft maintenance.

Other tests on C-scan have also been carried out on metal/nomex structures where bonding defects have also been correctly detected (diameter 10 mm).

On the other hand, tests on composites must be continued, since it has been shown that detection of delamination is strongly dependent on the orientation of the probes with respect to the fiber direction in the surface layer.

CONCLUSIONS

The development of high performance roller-type probes has allowed the advantages of this technique for delamination detection to be demonstrated: simplified adjustments and signal analysis, low sensitivity to sheet and paint film thickness. AEROSPATIALE's experience in this field shows that this technique provides a solution for a number of bonding inspection problems which cannot be tackled by conventional methods, be it on the manufacturing line or in maintenance.

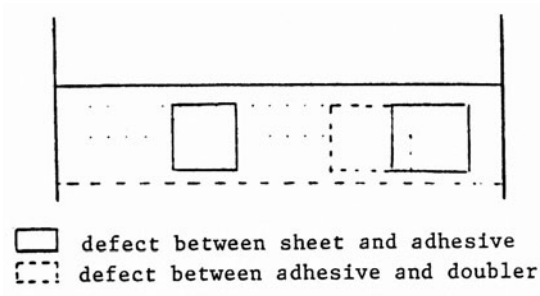


Fig. 6: Test specimen with bonding defect

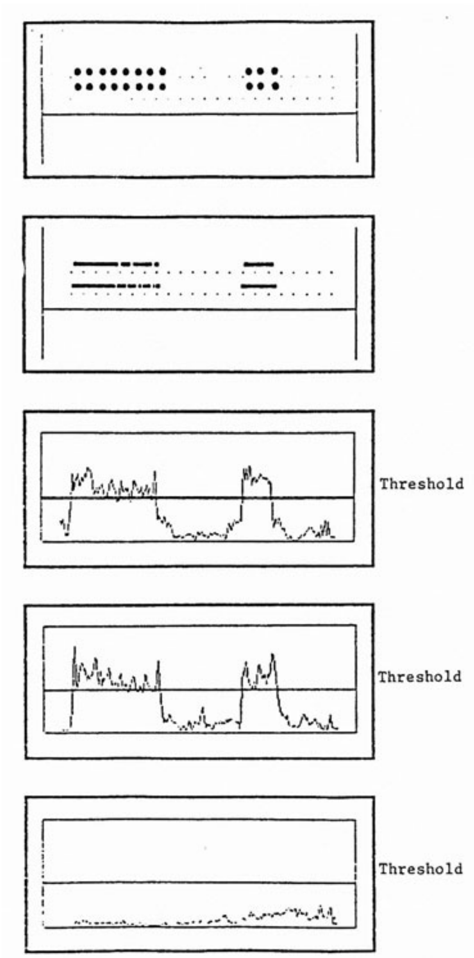


Fig. 7: Comparison with the FBT results

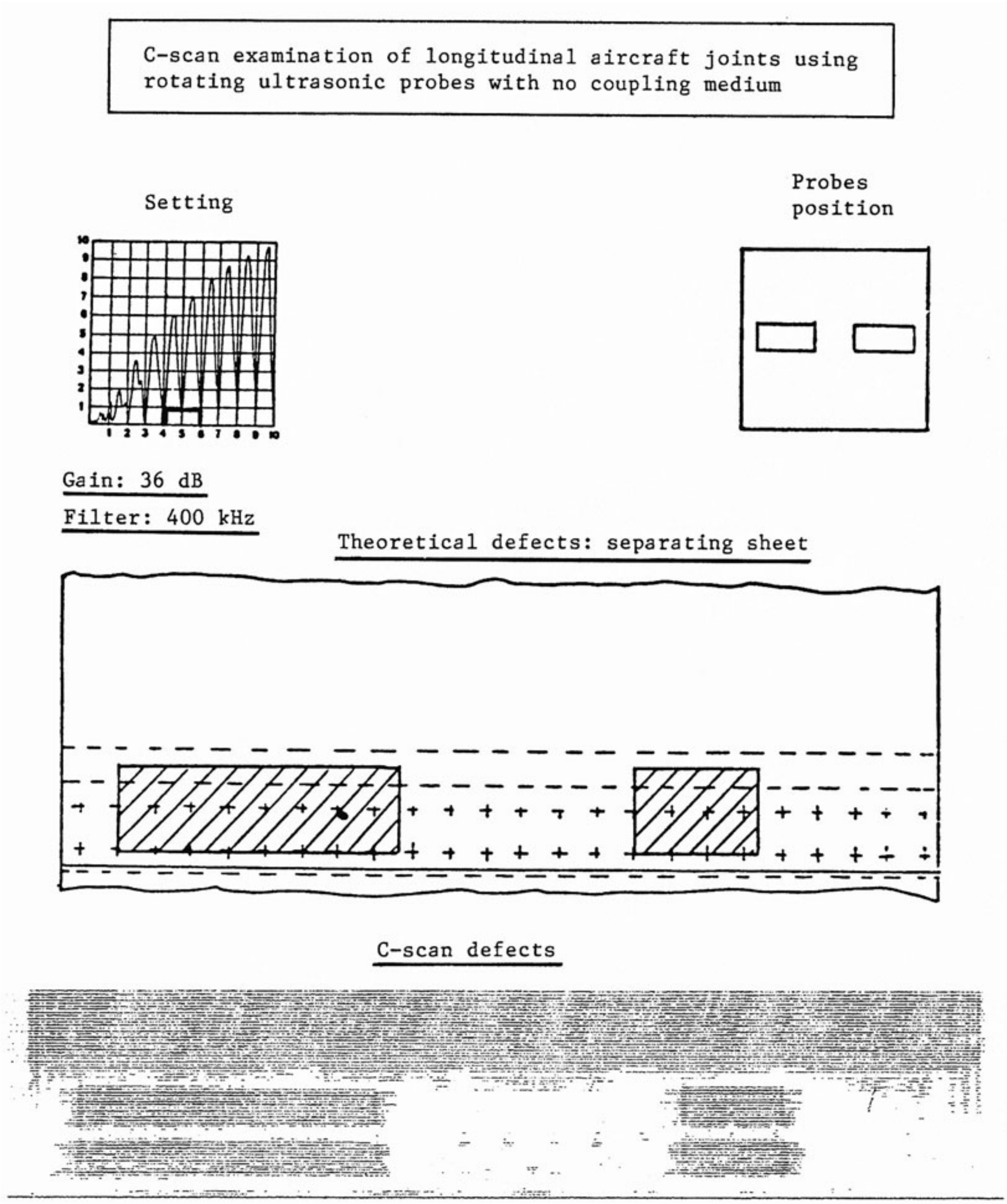


Fig. 8: C-scan inspection on the same test-specimen with roller-type probes