Borehole Inspection on Aircraft Structures using Multifrequency EC-Technique

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Abstract. The eddy current inspection of boreholes using rotating probes is a commonly used method for the inspection of aircraft structures. Typically a single frequency method is applied. Earlier investigations using a multifrequency system have shown better results in determination of the crack length from the eddy current signals.

The latest developments resulted in a custom designed application for borehole inspections. It uses the four frequency technique with a standard rotating probe and a position encoder to allow the recording of the signals including depth information. To improve reliability, several helpful functions have been implemented. A data structure adapted to the inspection task allows easy archiving of the data. One of the main aims is the reduction of the human factor. Therefore, the application is equipped with an automatic adjustment procedure, as well as an automatic analysis algorithm.

The analysis algorithm detects cracks and results in the determination of crack lengths based on the correlation obtained from several test series in the laboratory and on a A340-600 structure test. Furthermore, a schematic representation of detected cracks provides additional information to the user. The recorded signal scans can be analysed directly or for detailed investigations later in the office.

Currently the system is put into practice for the A380 structure test, which takes place in Dresden.

1 Introduction

Dynamic eddy current inspection of boreholes using rotating probes is a well established inspection method for aircraft structures [2, 9]. Previous studies carried out by Airbus and TMT have shown that the use of four frequencies as opposed to single frequency EC-technique improves the reliability of inspections [5, 6, 7, 8]. First of all the detection rate is higher, as for example cracks that are closed at the surface can be detected with the additional lower frequencies. Furthermore the false alarm rate is reduced as additional information to distinguish between cracks and disturbances is available. Finally it is possible to deduce crack lengths from signals, resulting in more detailed repair plans and eventually reduced repair costs.

Unfortunately despite its obvious benefits, multifrequency EC-technique has not been widely adopted. We traced this fact back to the additional complexities, and have set out to develop a system that helps to alleviate these obstacles.

2 Inspection Task

Rivet joints are a widely used feature of aluminium structures in aircraft. The riveted structures can be manufactured of a single layer or multiple layers with or without stiffening layers made of titanium or steel. Boreholes in certain areas of an aircraft structure are exposed to higher load and have to be inspected in the course of in service inspections. The inspection task is to detect incipient vibration cracks in hidden layers. A well established method for this task is the dynamic borehole inspection method using rotating Eddy Current probes.

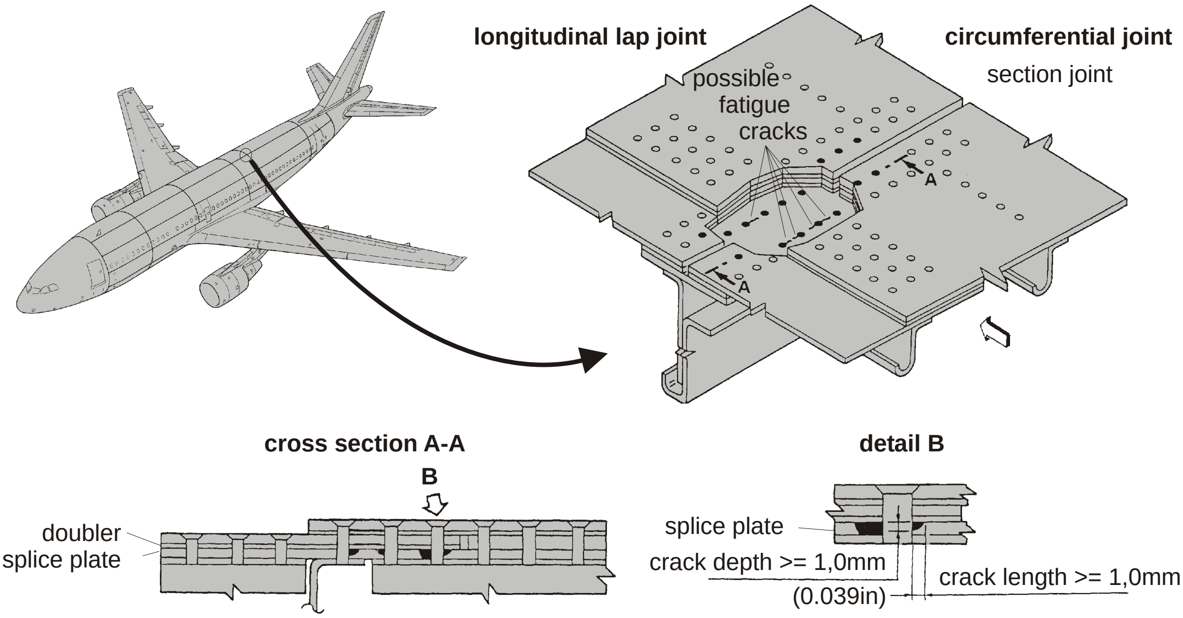

Figure 1 illustrates as example an inspection at the intersection of a longitudinal lap joint and a circumferential joint.

3 Equipment

3.1 Requirements for the New System

Earlier investigations have provided evidence of the benefits of using multifrequency eddy current methods to inspect boreholes. However, not only the adjustment of a system with four frequencies is more complex and laborious than the adjustment of a conventional system but also the manual analysis of crack length and depth is more complex than the monitoring of a simple threshold.

To improve the ease of use, reduce the human factor and eventually to increase reliability, a project was initiated to develop a system that provides automatic and easy adjustment, automatic analysis of crack depth and length, consistent storage and archive of inspection data and results as well as automatic report generation.

3.2 Hardware

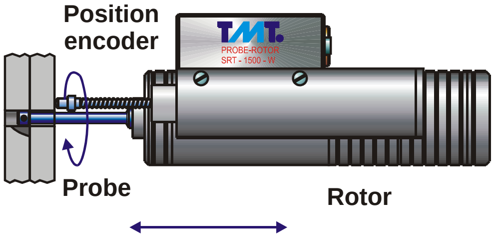

Figure 1

The basis of the system builds a portable eddyMax® 4U instrument with eddyMax® plug-in board. To enable the analysis of crack depths, a manual rotor with flexible integrated position encoder as shown in Figure 2 is used. For multifrequency EC-technique no special probes are necessary, hence standard rotating probes can be used.

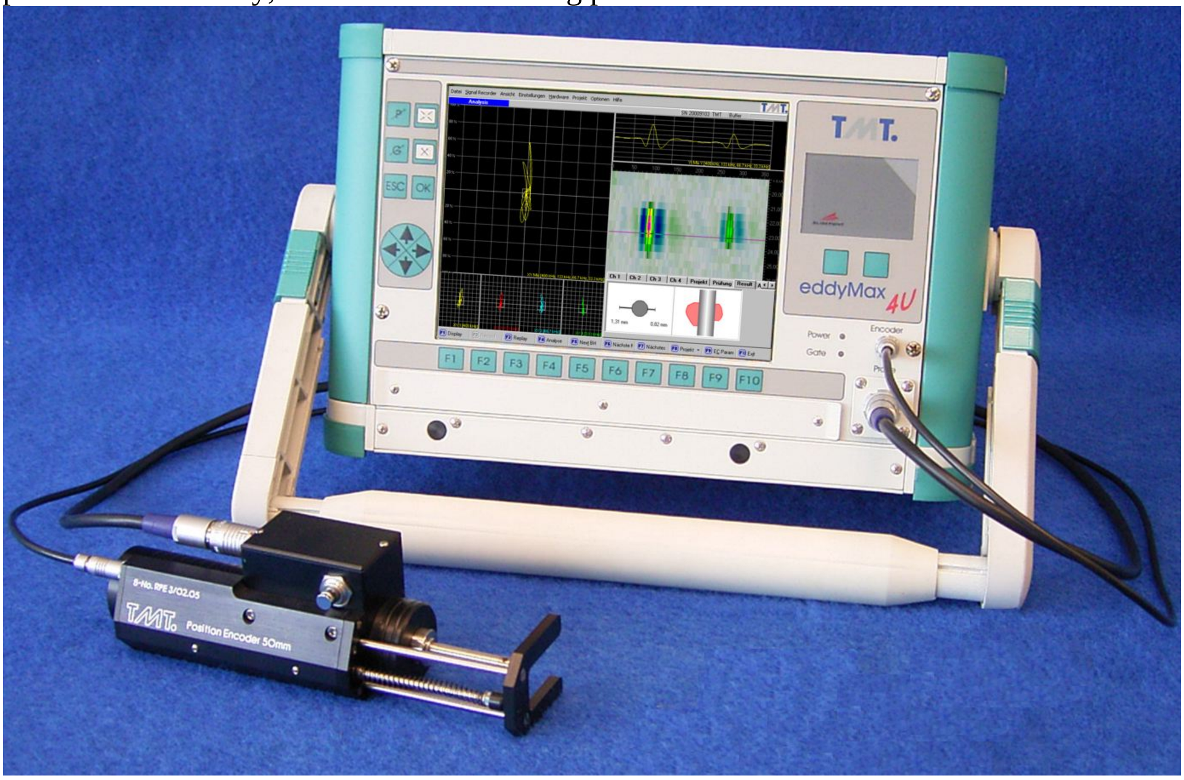

Figure 3 shows the full setup including the running software.

3.3 Signal Flow

The software of the system has been developed as a part of the eddyMax® product line and therefore proven software architecture and well tried software components provide the foundation of the software [3]. The software provides four independent frequency channels, which are preset to 400 kHz, 133 kHz, 66 kHz and 33 kHz. The signals of the four channels are combined by the use of an algorithm that has been developed on the basis of results obtained from A330/340 structure tests. Each of the four channels can be displayed in its own impedance plane, while the mixed signal is displayed in an impedance plane, a circumferential (y-t) and a scan representation.

The signal stream consists of eddy current and position encoder signals. The scan representation evaluates the position encoder information and aligns the signal data accordingly. In case more than one sample has to be assigned to the same position, one of three merge algorithms can be selected: either the first sample, the sample with the maximum y-amplitude or the last sample is chosen. A colour palette is used to transform the y-amplitude of the signal to colour information.

3.4 Adjustment

The careful adjustment of an EC system is decisive for the reliability of the inspection, the more so when four instead of a single channel have to be adjusted. To ensure a proper adjustment an automatic adjustment procedure has been developed. The user enters the rotating probe into a test specimen with a defined artificial reference defect. Now the user can start the procedure and the software automatically adjusts gain and phase for each channel simultaneously, in order to align the maximum peak of the signal to a predefined angle and amplitude. The whole adjustment procedure can be done within seconds.

3.5 Analysis

The required result of a borehole inspection is the length and depth of potential cracks. In earlier systems, it was possible to deduce the length of a crack by manually measuring the maximum y-amplitude of a signal [5].

The new system provides automatic analysis algorithms that can find and trace crack indications. A calibration curve is used to calculate the crack length while the position encoder information is used to calculate the depth of the crack. The software allows users to enter the layers of the composite structure in a tabular form. This information can be used to assign crack indications to layers, providing valuable information for detailed repair plans.

3.6 Representation of Results

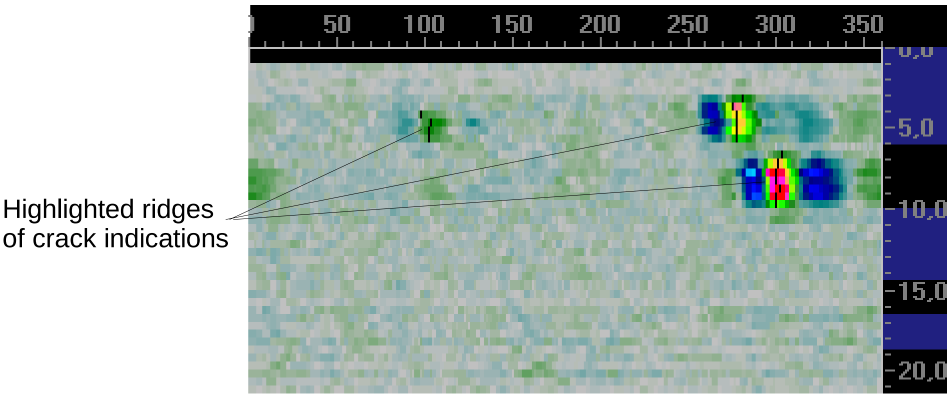

Figure 2

The representation of results is divided into three parts. First, the ridges of crack indications are directly highlighted in the scan display (see Figure 4). Second, a schematic top-view of the borehole is provided that shows the lengths of the longest cracks (see Figure 5, left side). Third, a schematic cross section depicts the layers of the composite structure as well as depth and length of individual cracks (see Figure 5, right side).

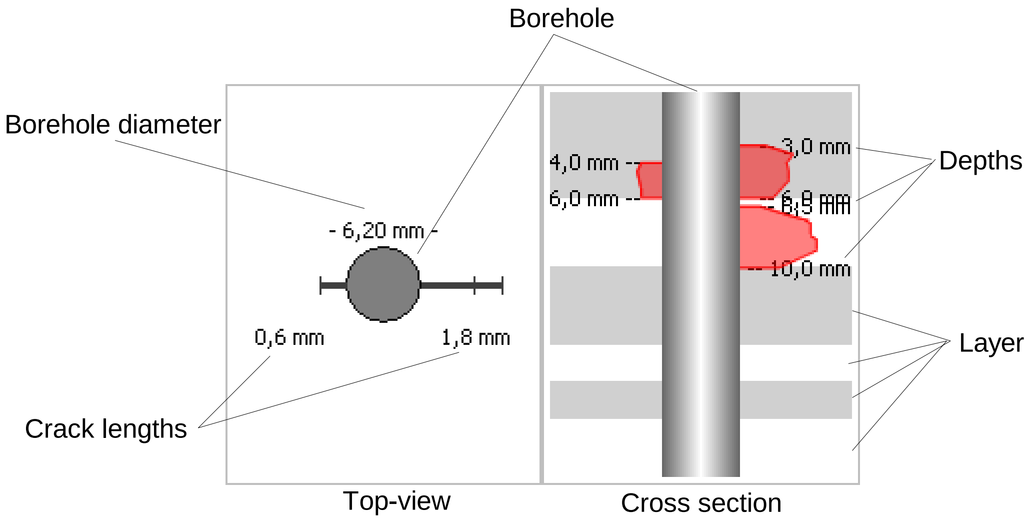

Figure 3

4 Test Results

The system has been evaluated in several test series in the laboratory. For these tests sample sheets with fatigue cracks as illustrated in Figure 6 were used. The results from the laboratory test series were compared to results gained from microscopic inspection and figure 7 shows the correlation between the results.

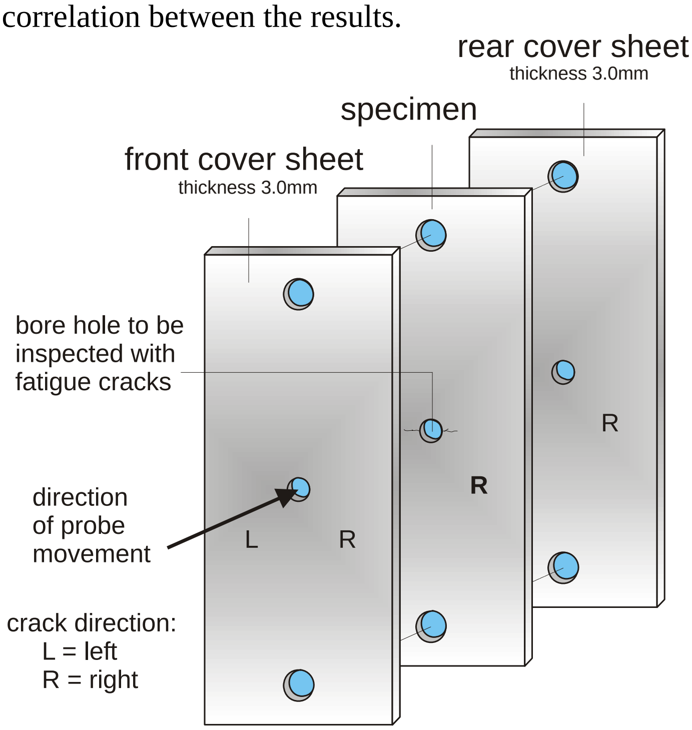

Figure 4

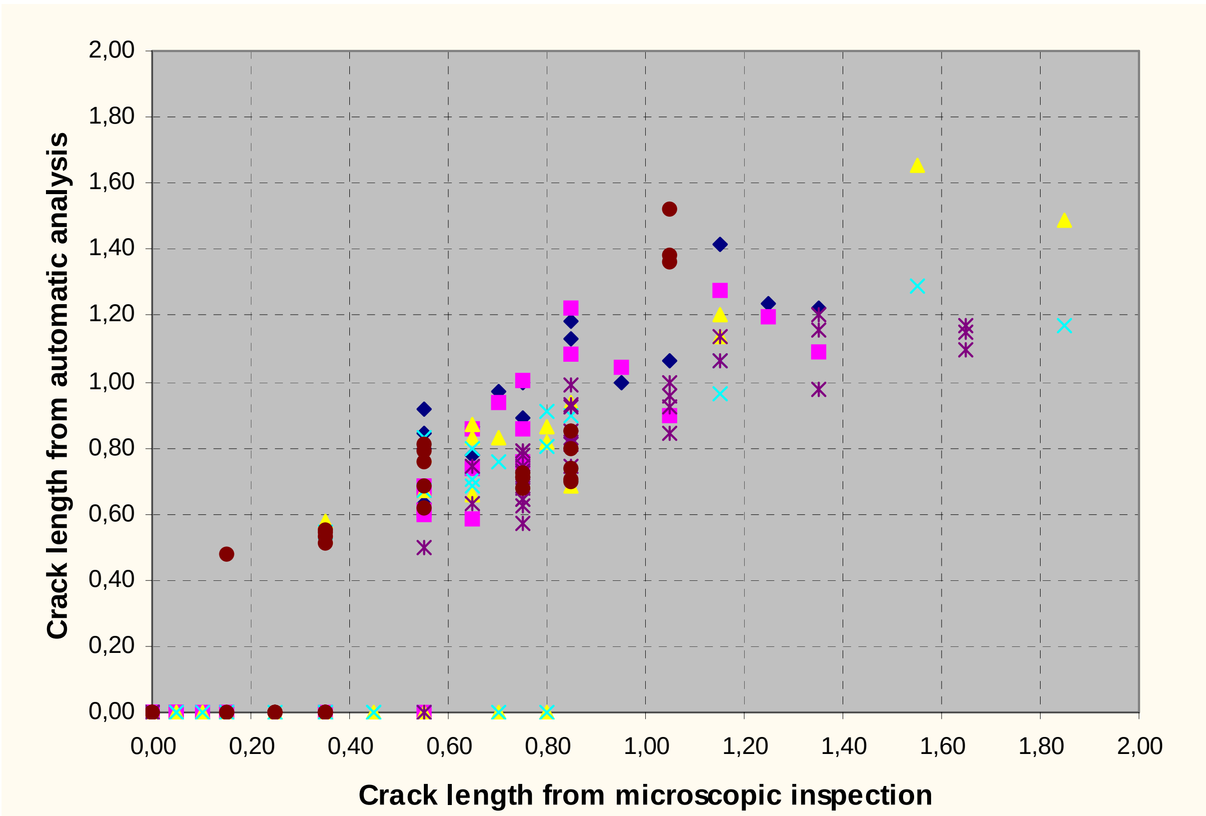

Figure 5

Practical experience could be gained from inspections of parts of the Megaliner Barrel test structure and the A380 test structure in Dresden, Germany. Especially the automatic adjustment and analysis features were well received by practitioners.

5 Conclusion

We have developed an EC system for the inspection of borehole that aims to provide all the benefits of the multifrequency EC-technique without the additional complexities. By automating the most complex parts, adjustment and signal analysis, we were able to improve the ease of use and to decrease the human factor. This led to more accurate inspection results and finally to a higher reliability of the overall inspection.

As of now only the combined signal of all four frequency channels is analysed. Evaluations of earlier test series have shown that amplitude and phase shift of each single channel give important clues to whether a signal indicates a crack or a disturbance [5, 7]. Further developments focus on ways to include this information into the automatic analysis algorithms and finally to provide a classification of indications into cracks, burrs/ovalities, ferrous particles, smeared cracks and cracks in steel doublers.

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