Multifrequency Eddy Current Inspection of Rivetrows on Aircraft Structures

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Abstract. Riveted connections are present on aircraft structures in various realisations. Most of the riveted joints have to be inspected in frequent intervals. To detect cracks, a low frequency eddy current inspection using sliding probes is a commonly used method. Typically a single frequency method is applied.

Investigations using a multifrequency system have shown better results in detection of small cracks. For this reason a custom designed system for rivetrow inspections is being applied to the full-scale structure test of the Airbus A380. It uses the four frequency technique with a standard sliding probe. The automatic online analysis counts the signals from the rivets and marks signals exceeding a threshold as defect. One frequency is used to fulfil the requirements of the Nondestructive Testing Manuals (NTM). Additionally the analysis algorithm uses information from the other frequency channels to identify small cracks, whose signals are below the threshold. A specially designed data structure allows easy archive and identification of the data. An automatic adjustment procedure helps to setup the system. For detailed investigations the recorded signal traces can be analysed later in the office.

1. Introduction

Riveted joints are present on aircraft structures in different realisations. The joints are longitudinal along the aircraft parallel to the stringers and circumferential at frame locations. The joints are realised either as lap joints or as butt joints. Figure 1 shows the typical joints. In the riveted connections fatigue cracks may occur from the applied forces. For this reason many of the riveted connections have to be inspected in certain intervals. The eddy current inspection of the riveted joints using a sliding probe following the inspection procedures written in the Nondestructive Testing Manuals (NTM) is a commonly used method. Earlier studies [2] have shown that, by simple means, the evaluation and documentation of the inspection results could be improved.

As described in other publications [4, 5], the multifrequency eddy current technique provides more information from the inspected structure. Therefore we have set out to develop a new system that not only applies multifrequency EC-technique to the inspection of rivet rows, but also aims to set new standards on analysis and documentation.

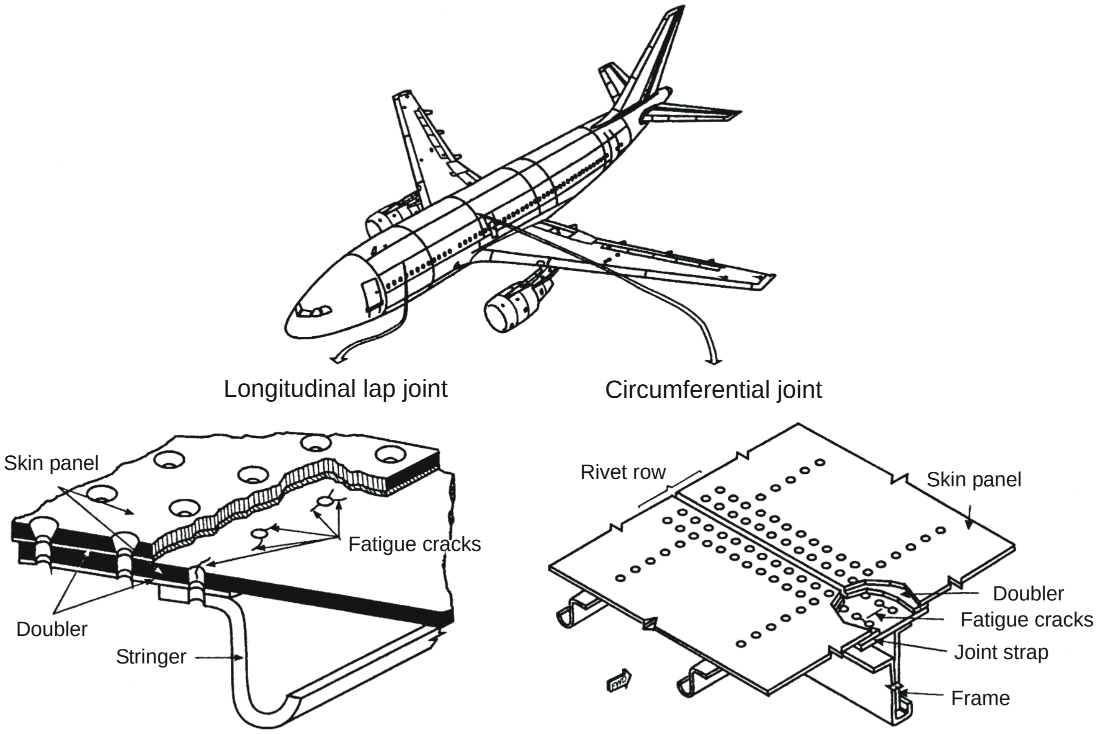

Figure 1

2. Equipment

2.1. Requirements for the New System

The aim of the new system is to improve the inspection of rivet rows in a way that incipient cracks can be detected earlier. For this reason, apart from conventional threshold based evaluation procedure following the NTM, new algorithms based on further evaluation of the signal data are to be developed. For the comparison of repeated inspections previously recorded data have to be available. Therefore it shall be possible to reliably attribute inspection data to rivet rows and to use this information to store the data. The eddyMax 4U eddy current instrument is used as a host for the application

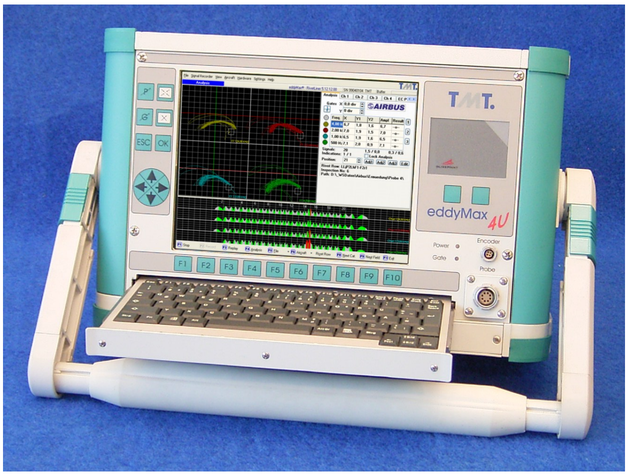

Figure 2

2.2. Identification of the Rivet Rows

One of the aims of the system is the reliable identification of the inspected rivet rows. The identification consists of the kind of the joint (Longitudinal or Circumferential, Lap joint or

Butt joint) the position on the aircraft (Right hand or Left hand, Frame and stringer (P) position, AFT or FWD, Upper or Lower) and the number of the row starting from the joint. The assignment is made using a dialog window (figure 3) from a choice of possible combinations. For each rivet row an entry in a database is created to collect the results from the inspection. Additionally settings and other relevant data for further documentation are stored. Once entered rivet rows can easily be selected for repeated inspections. From the entries a unique filename is generated as an abbreviation allowing the identification of the related signal data files independent from the database.

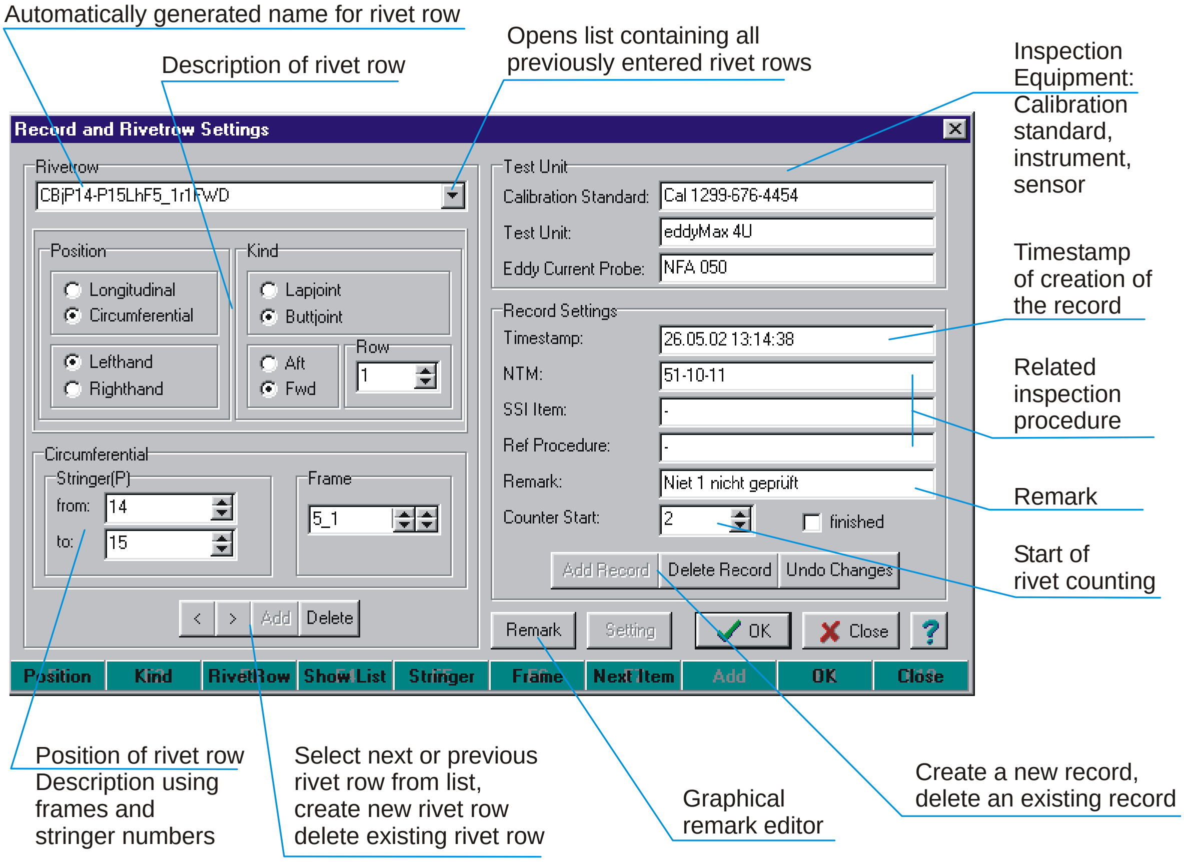

Figure 3

2.3. Recording of the Signals

After selecting a rivet row all further actions are performed related to the selection. By sliding over the rivets with the EC probe the signals are recorded and pre-evaluated for threshold passes. So each signal passing the counter line is counted as a rivet and signals exceeding the threshold line are marked as defect signals according to the NTM. Figure 4 demonstrates recordings from a riveted joint with a growing crack. The first recording shows the signals before the crack starts. A difference can be seen in the second recording, the threshold was passed in the third.

2.4. Signal Analysis

After recording the signals are analysed by newly developed analysis algorithms. The aim is to calculate representing values to identify growing cracks before the threshold is exceeded. The first step is to extract significant values from the signals of all the 4 frequency channels. These are mainly the highest amplitudes and the highest vertical signal values for each rivet signal. These values are collected in the database related to the rivet positions. Based on these values three different analysis algorithms have been evaluated.

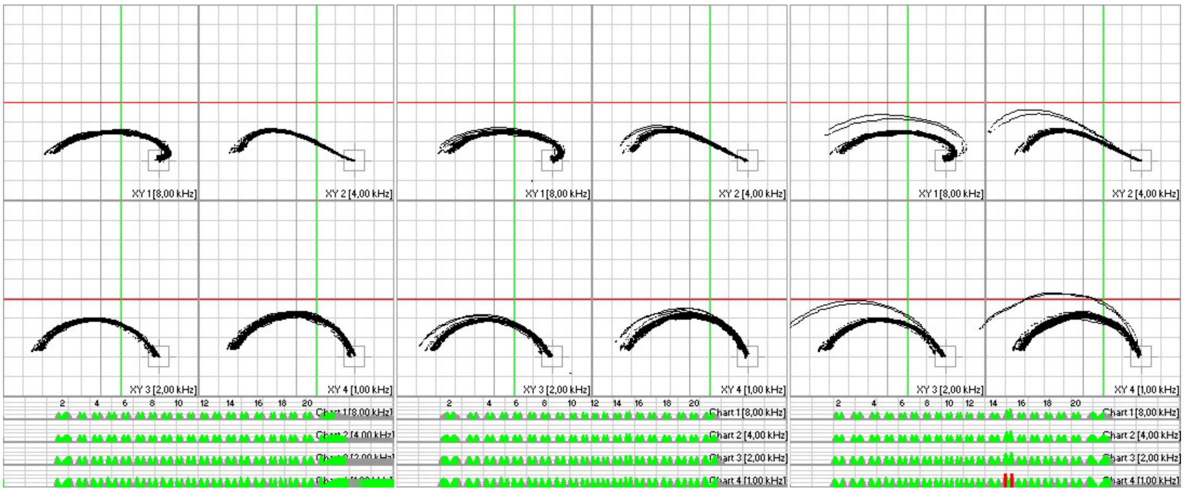

Figure 4

2.4.1. Comparison of two Inspections

One possibility is the comparison of the current results to the stored results of an earlier inspection. When a crack starts at a certain rivet position, the change in the signal values relative to the previous results will give an indication.

2.4.2. Statistical Analysis of one Row (All Channels)

This method presumes that if at the position of one rivet in a row a crack develops, the eddy current signal deviates significantly from the average of the signals of the whole rivet row.

2.4.3. Statistical Analysis relative to the highest Frequency Channel

Another approach is to compare the signals of the lower three frequency channels with the signal of the highest frequency. As the highest frequency has a lower depth of penetration, the influence of a crack in the hidden layer will be less and the signals of the other channels will differ perceptibly.

3. Test Results

In a dynamic tensile test rig samples with a riveted joint were exposed to cyclic loads. During the tests the eddy current signals from the riveted connections were frequently recorded, as shown in figure 5. These signal data were analysed using all of the above methods.

Exemplary the analysed values as well as the EC-signal itself at a rivet postion with a growing crack were calculated. Figure 6 shows the results relative to a given threshold. It shows that the analysed values pass the threshold earlier than the signal value. After the 9th inspection the signal threshold for the EC-signal was passed. A following fractographic analysis of the sample showed a crack length of 3 mm. The statistical analysis has passed its threshold much earlier at the 8th inspection. A fractographic analysis of another sample showed that a crack of 1.7 mm length was detected by the statistical analysis algorithm.

Figure 5

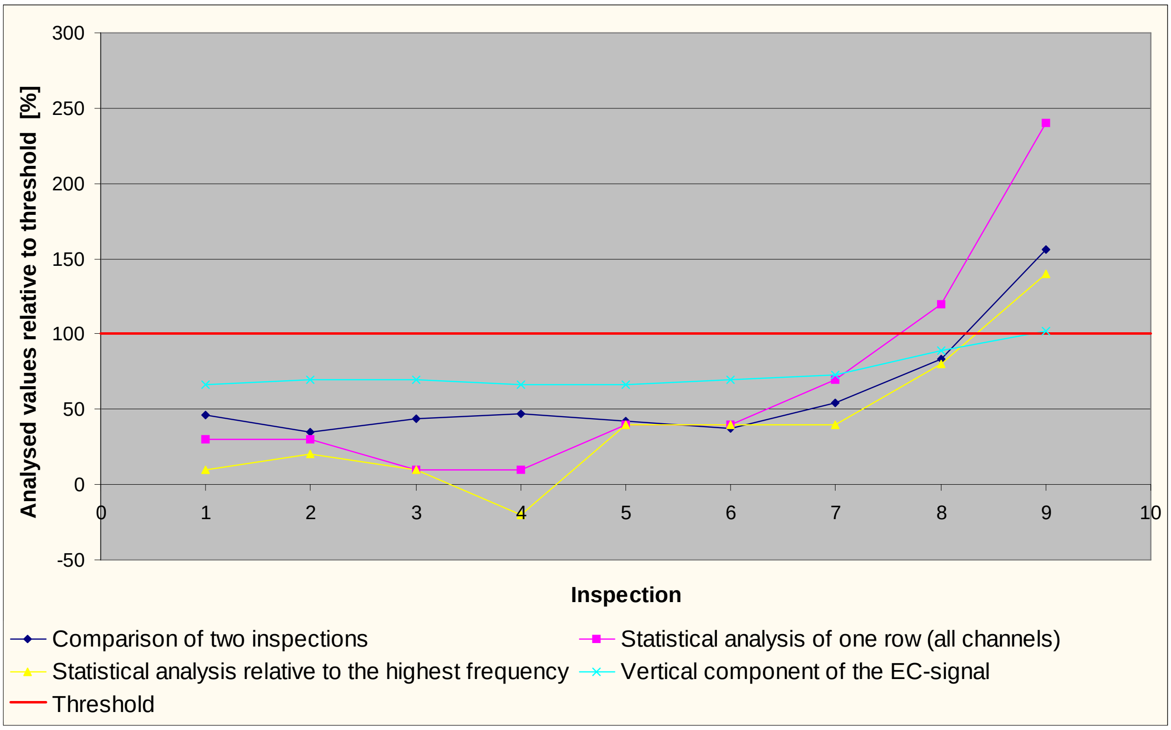

Figure 6

Another test was made on a set of samples with cracks of known sizes. The larger cracks were detected by the threshold analysis, additionally several smaller cracks were detected using the statistical analysis methods.

At first glance the comparison to an earlier inspection seems to be a suitable approach. Unfortunately apart from applications under ideal laboratory conditions, it showed some disadvantages in field trials. The settings for the inspections have to be very accurate. Small differences in balancing the probe and signal adjustment as well as the alignment of the probe to the rivet row during the recording have negative influence on the signal analysis. In addition there is a need for previous results to make a comparison, rendering it impossible if no results from earlier inspections are available.

The concept of the statistical analysis does not have these disadvantages. The statistical analysis of one row is more robust against variations in setting, balance and probe alignment. Additionally the comparison to the highest frequency channel shows better results with thick skin layers.

4. Conclusion

We have developed RivetLiner, a multifrequency eddy current system for the inspection of rivet rows of aircraft structures. Apart from simple threshold evaluation it provides more sophisticated analysis methods that enable to detect emerging cracks at an earlier stage. Additionally it allows for collecting inspection data in a database resulting in a more reliable documentation and archive.

Inspections at the A380 full scale fatigue test structure that currently takes place in Dresden, Germany, take advantage of the systems innovative new capabilities.

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