Health Monitoring during Aircraft Vertical Empennage Fatigue Test by Acoustic Emission Method

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Abstract
During aircraft fatigue testing under flight loading conditions, acoustic emission (AE) was used to monitor the health conditions of the inaccessible key components, thus guaranteeing the success of the whole test by the early detection of fatigue cracks. With high noise background due to severe vibration and high sound wave attenuation of the complex components, the AE work especially the data acquiring and processing were confronted with great difficulties. This paper presents health monitoring of aircraft vertical empennage fatigue test using acoustic emission. AE data analysis methods including spatial filtering and AE source linear localization, were used to predict the fatigue damage. According to the acoustic emission signal analysis results, the vertical empennage was disassembled for comprehensive inspection, and two fatigue cracks were found between the girder and the jointing places with the main structures, proving the effectiveness of the AE monitoring of the aircraft vertical empennage fatigue test.

Keywords: Health monitoring, Aircraft fatigue test, Vertical empennage, Acoustic emission

1. Introduction

Aircraft structures are susceptible to fatigue cracks, corrosion damages and impact defects during service in harsh environmental and working conditions, leading to a tendency to catastrophic failures of critical structural components if not detected and repaired. Therefore, there has been an increased emphasis on and non-destructive evaluation (NDE) for aircraft \cite{1}, which play important roles in the entire process from aircraft structural design to the manufacture and subsequent maintenance, till the final structural failure or retire.

Various advanced aircraft NDE techniques have been developed to date in addition to the conventional ultrasonic and eddy current testing methods. These NDE techniques involve many key technologies, among which advanced sensors are necessary to monitor the vibration, ultrasonic wave, magnetic field, temperature, strain, displacement, etc. The sensors used for NDE systems have different working theories, types, sizes, weights, sensitivity, costs, numbers, arrays and locations, which affect the sensitivity, efficiency and safety of the overall systems.

Nowadays, acoustic emission (AE) technique is becoming widely used in the endurance
testing of structures, because this technique makes it possible to continuously control virtually any area of a structure, to automate the measuring process, and to make prompt decisions. Acoustic emission is good way to realize the real-time monitoring of the health conditions of aircraft structures [2-3]. However, to the best of our knowledge, few papers have been published till now on AE monitoring during the aircraft fatigue test under flight loading conditions [4]. The objective of this paper was to perform health monitoring of aircraft vertical empennage fatigue test using acoustic emission method.

2. Experimental procedures

According to the advice by the experts in aircraft fatigue test, the monitoring area was focused on the inaccessible jointing area of the vertical empennage, especially the girder and the jointing places with the main structures. As shown in Fig.1, three sensors were located in the critical area of the vertical empennage.

![Figure 1. Schematic diagram of the structures of aircraft vertical empennage with sensor positions](image1)

The AE apparatus used in this work was the DiSP system with 20 channels by Physical Acoustic Corporation (see Fig.2). The system parameters were set as follows: (a) the threshold value of 40-46 dB depending on the noise level; (b) the gain of preamplifier being 40 dB with the main gain being 20 dB; (c) the pre-triggering time being 32 μs, data length of 1024 points, the PDT, HDT and HLT being 1000, 2000 and 5000 μs, respectively;
(d) the filtering frequency between 100 kHz-400 kHz and the sampling frequency of 1 MHz for the resonance sensors.

3. Results and discussions

Under flight loading conditions, acoustic emission was used to monitor the health conditions of the inaccessible key components, thus guaranteeing the success of the whole test by the early detection of the fatigue cracks. With high noise background due to severe vibration and high sound wave attenuation of the complex components, the AE work especially the data acquiring and processing were confronted with great difficulties and high challenges.

Variations of the AE hits of #1 and #2 sensors with the flight hours were shown in Fig.3 and Fig.4. As seen in the variation trend, the hits increased suddenly for $T_1$ to $T_2$ hours, suggesting certain damage near #1 and #2 sensors.

According to the spatial filtering technique, linear localization of the AE source, damage may occur if the AE events appear suddenly. Fig.5 showed the location graph with AE events of #1 and #2 sensors at different flight hours. Under flight hours of $T_1$, the AE events were low without much disturbing signals. With the increasing of the flight hours to $T_2$, the flight loading led to the emergence of AE events located at about 160-165mm far from #2 sensor.
According the above AE data analysis, the fatigue test was advised to stop at $T_2$ flight hours to inspect if fatigue damage really originated from the monitoring area between #1 and #2 sensors. Through inspection after the disassembly of the cover, two fatigue cracks were found between the girder and the jointing places with the main structures, see Fig.6. The results proved the effectiveness of the AE monitoring of the aircraft vertical empennage fatigue test.

4. Conclusions

Acoustic emission was used to monitor the health conditions of the inaccessible key components, thus guaranteeing the success of the whole test by the early detection of the fatigue cracks. However, the AE work especially the data acquiring and processing were confronted with great difficulties and high challenges, because of the high noise background due to severe vibration and high sound wave attenuation of the complex components. In this paper, health monitoring was conducted for aircraft vertical empennage fatigue test using acoustic emission method by AE data analysis including spatial filtering technique and linear localization of the AE source. Through inspection after the disassembly of the cover, two fatigue cracks were found between the girder and
the jointing places with the main structures, proving the effectiveness of the AE monitoring of the aircraft vertical empennage fatigue test.

References