Application of AE Technique onto Landing Gear Controlling Test of an Aircraft

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Abstract. The fatigue test of a full-scale aircraft body aims to understand the initiation and development of fatigue damage and fatigue crack of its critical structures, and hence to determine fatigue life, maintenance and repairing cycles. The work of non-destructive testing and acoustic emission (AE) monitoring during the whole fatigue test plays a key role in guaranteeing the success of the test and achieving the prescribed goal. The controlling test of landing gears is part of this fatigue test. The main structures under considerations are uplocks and lower locks of main landing gears, uplock of nose landing gear, and actuator cylinder flanges of both gears. By using the combination of trend analysis and correlation analysis of AE parameters, real time monitoring of landing gear condition is realized, and the leak in the actuator and the linkage wearing were successfully predicted. The methods used are straightforward and direct, they can supply fast analysis speed and realize real time monitoring. The work provides a useful reference for AE signal processing in the future fatigue test or for AE monitoring technique used in the same environment of high background noise.

Keywords: Aircraft, Fatigue Test, Fatigue Crack, Acoustic Emission, Trend Analysis

1 Introduction

The fatigue test of a full scale aircraft body aims to understand its fatigue damage development and hence to determine its fatigue life and maintenance cycles. The test has significance on this type aircraft group.

Landing gear (LG) controlling test is part of this fatigue test and hence aims to determine fatigue life and fatigue damage development of main components of landing gears. The components include uplock, lower lock, actuator cylinder, etc. There were some reports on AE test of LG during fatigue test, it was however performed on LG independently, that is the gear was tested as a stand-alone part and not mounted with whole aircraft body[1]. Present test is on the landing gear which is part of the full scale aircraft body, and it is expected that more reliable and close to actual condition results can be obtained through this experiment. Due to the nature of dynamic and multi-object monitoring, the AE test is faced with more difficulty.

2 Principle and tactics

The first problem to be solved is the correct selection of locations under supervision from many key structural positions. This selection will relieve future work load. The second is to use proper data processing methods. The fatigue test is carried on continuously and oversized data will be acquired in the process, including much noise. Although waveform analysis can give more useful information on fatigue damage during the test, it will only be used when absolutely necessary because of the requirement for real time monitoring.

The principle to judge the occurrence of damage is based on the assumption that the whole system, which is composed of measuring instrument and loading system, is a stable and stationary system, and that any AE parameter will show no abrupt increment during the test, as long as the structure undergoes no sudden changes[2]. We can therefore use the trend of one or several AE parameters during the course of fatigue test as an indicator of structural conditions. In a period of time, any parameters, such as hit, events, count, energy, rise time and duration etc will certainly undergo large fluctuations, if being properly processed however, they can still show a distinctive trend to vary. One can then relate this trend with the structural condition. It would be impossible to realize the trend analysis without using advanced fully digital AE system for its high stability, high repeatability and very low noise level. If some location is under suspicion for cracks from the AE data, then other NDT means, such as magnetic particle inspection, eddy current and ultrasound inspections may be used to further verify and confirm the results.

3 Experimental set-up

There are altogether 11 locations under supervision, being uplocks (3 locations, left and right main LG, and nose LG, respectively), lower locks of main LG, and flanges connecting actuator cylinder and gear column, actuator and aircraft body, respectively, as shown in figures 1 and 2, respectively.

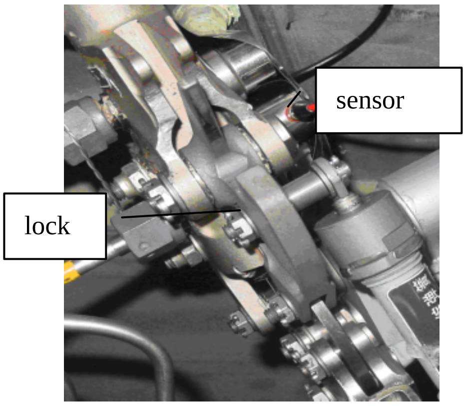


Fig.1. uplock of right main LG

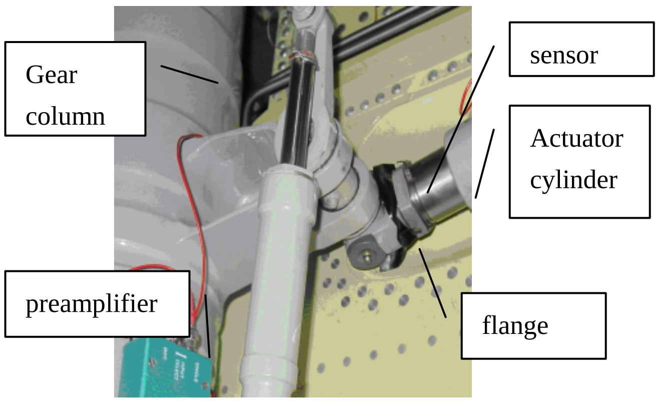


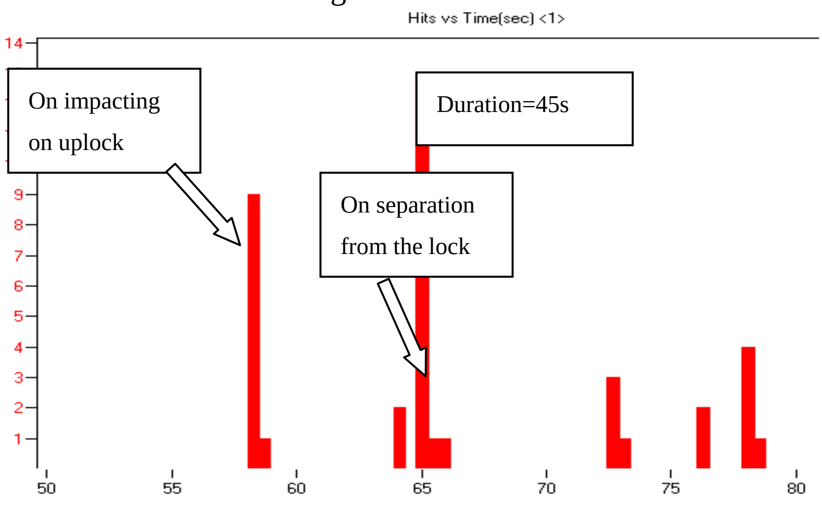
Fig.2 Flange of actuator cylinder of left main LG

A 20 channel DiSP AE instrument of PAC was used to collect the data, with 16 R15 transducers of resonant type, plus 4 WD transducers of wide band type, preamplifier of 1801A of 40dB gain, 1MHz sampling rate, and the threshold value being set to 40 dB.

The mounting of sensors need special precautions. Silicon rubber was selected as the bonding medium to stick the sensors on places as nearer as to the structures under supervision to enhance signal-to-noise ratio. The bond can supply good sound path and sustain strong enough sticking force to combine the sensors and the structure together. On the other hand, it is not very difficult to separate the sensors from the structures without imposing damages to them whenever necessary.

4 Results and discussions

The controlling test on landing gears consists of cyclic pushing up (to the landing gear bay) and pulling down, simulating part of the action of taking off and landing on ground, respectively. The test was lasting for 7500 cycles, with each cycle being around 45 seconds. The impact force was very strong when the gear was locked into the lock in the landing gear bay, and the impact was also strong when it left the lock. Considering following factors: (a), there is a progressive process for any damages to develop to sizable amount and the process shall last for some period; (b), The AE sensor is sensitive enough and will catch signals produced by object condition changes ; and (c), although the data amount is quite large, if there is no abrupt condition change inside the monitoring area of object, it is unnecessary to record data in all controlling cycles. It was therefore decided to acquire data in 10 consecutive cycles for every 30-40 cycles. The data amount was large enough for not missing possible damage information, and was on the other hand appropriate enough for the system to process them. In Fig.3 and 4 are shown results under normal conditions, showing that the received AE signals have good repeatability in consecutive cycles. The variations for different cycles are within reasonable limits and again prove that tendency analysis can be reasonably used for condition monitoring.



X axis time/s Y axis AE hit

Fig.3 AE hit in one cycle for uplock of right main LG

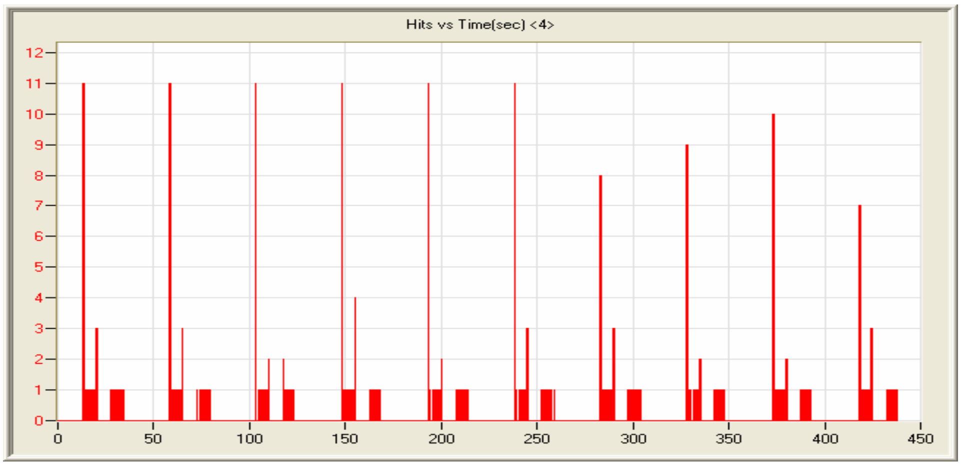


Fig.4 AE hit of left actuator cylinder for 10 consecutive cycles（No. 1257-1266）

X axis:： t/s; Y axis:： AE Hit

In order to make appraisal for LG conditions, one should comply with following steps. The first step was to closely watch the relative change of AE hit from every location under supervision. Although differences in AE hit for different locations (channels) might be quite large, the difference for the same location (the same channel) in consecutive cycle should be within reasonable limit because of the stationary nature of the system. If the changes were over 30% limit, precautious measures should be taken. Following that, the second step was to check the changes of other AE parameters, especially the amplitude distributions and in the case of wide band sensors, the waveform and frequency spectrum were subjected to scrutiny. Other non-destructive means might be used to inspect that area if needed. In figures 5 and 6 are shown AE hit changes during the test of 10 consecutive cycles for each channel. Fig. 5 shows normal condition, whereas fig.6 shows large variations for channel 4 and 6, representing flange of left actuator cylinder. Later analysis proved that leakage was occurred for the cylinder.

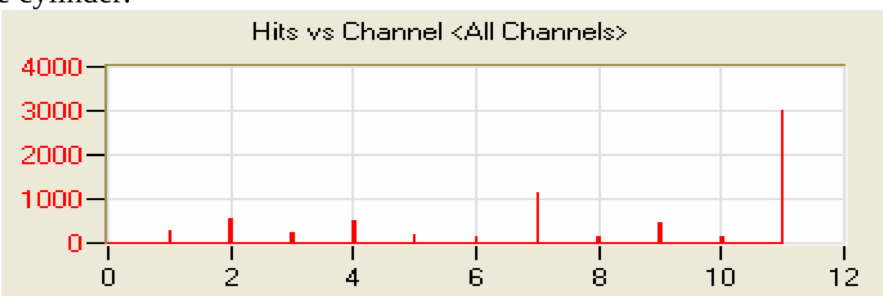


Fig.5 AE hits against channels when without damage

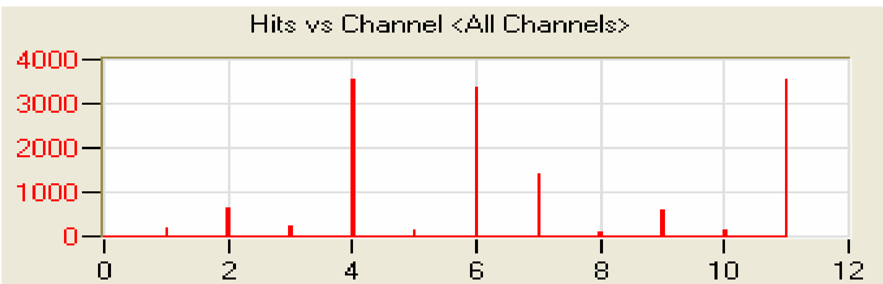


Fig.6 large increment of AE hit for channel 4 and 6 (leakage occurrence)

In figure 7 is shown the AE hit tendency against test cycle till 45 cycles for location near the flange of left LG actuator cylinder. From the figure, it can be seen that AE hits have large fluctuation and distinct increment during cycles 4500 – 5540. Dismounting the cylinder at cycle 5540 showed that the seal was severely damaged, and after replaced by new seal, the hits backed to normal amount, see fig. 7. After cycle 7250, AE hits increased again, meaning that the seal might be damaged again. Fig.8 showed the damaged seal.

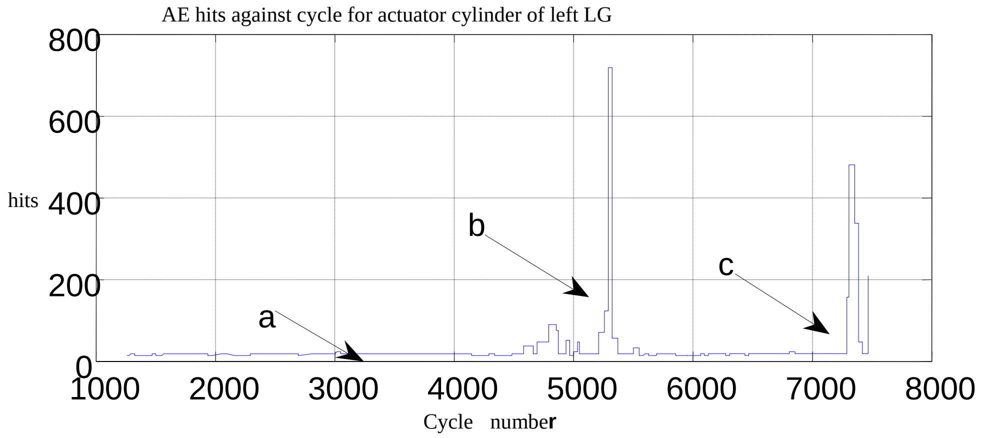


Fig.7 AE hits against cycle number for actuator cylinder of left LG

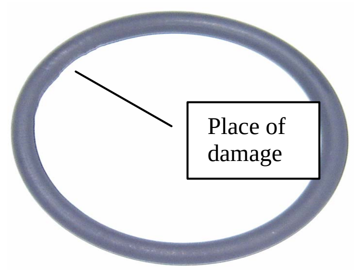


Fig. 8 damaged seal ring

Another example is the actuator cylinder of left LG itself, when test arrived at 3000 cycles, averaged hit number increased from 14 to 19, and more high amplitude events appeared. predicting some abnormal condition being occurring for the cylinder. After dismounting the cylinder the ball joint was found subjected to severe abrasion wear. After proper treatment with lubrication, this faulty phenomenon disappeared and AE hits backed to normal. For the brevity, these figures were not shown here.

5 Conclusions

During the controlling test of landing gears the AE technique is proven an effective means for the monitoring of conditions of main structures and components of landing gears. Although no cracks were detected during the test, it however predicted the abrasion wear fault and leakages, which was also very helpful for the fatigue test. It proves that the combination of trend analysis and correlation analysis of AE parameters is a good approach for real time monitoring of multi- and dynamic objects. The methods used are straightforward and direct, they can supply fast analysis speed and have good prospect in the future fatigue test.

References

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