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SONIC FATIGUE CERTIFICATION OF AIRBUS AIRCRAFT

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1. INTRODUCTION

Acoustically induced fatigue failures in aircraft have been a design consideration for over thirty years. The problem was introduced with the advent of the turbojet engines and the resulting high intensity acoustics pressure levels experienced on the surfaces of aircraft. The acoustic fatigue failures can substantially increase the maintenance burden and life cycle cost of the aircraft.

Design methods to predict the acoustic fatigue life of conventional metallic riveted structures and CFRP structures exposed to broad band random sound of high intensity generated by propulsion and flow induced dynamic excitations have been developed although the techniques usually lead to conservative designs. With the advancement of the composite materials, improved structural efficiency and weight saving potential can be achieved by fine-tuning and optimising the structures for specific loading situations. On the Airbus type aircraft, composite materials now account for fifteen percent of the total aircraft weight, including their use on the primary structures, see Figure 1. Consequently composite structures comprise many of the components likely to be affected by noise excitation. Acoustic fatigue certification clearance of these new materials are usually carried out by ground and laboratory tests.

Since the establishment of Airbus Industrie in 1970's the Airbus products continue to grow. Recent products include the four engined long range A340, the medium and short range twin engined A330 and the A321 aircraft. The certification of the aircraft includes the acoustic fatigue justification of aircraft components most likely to be affected by acoustic excitation. The aircraft components should also meet the normal structural damage tolerance requirements (threshold and damage growth) for the whole aircraft design life. The justification includes prediction, flight, ground and laboratory tests. The following sections describe the sonic fatigue certification work carried out for these Airbus aircraft.

2. ACOUSTIC FATIGUE CERTIFICATION REQUIREMENTS

The complete aircraft structure has been considered for its susceptibility to acoustic fatigue. The structural components which are most likely to be affected by acoustic excitation are agreed with the Joint Airworthiness Authorities (JAA). The components typically selected for an Airbus aircraft configuration are:

Rear Fuselage and auxiliary power unit (inlet region);
Main wing box, fixed leading edge, slats, inboard and outboard landing flaps, inboard and outboard ailerons and spoilers;
Fin, rudder, horizontal tailplane and elevators.

The Joint Airworthiness Requirements (JAR) to be met in order to cover acoustic fatigue strength is JAR 25.571 (d). The requirement states that it must be shown by analysis, supported by test evidence or by the history of aeroplanes of similar structural design and sonic excitation environment, that:

(a) sonic fatigue cracks are not probable in any part of the flight structure to sonic excitation; or

(b) catastrophic failure caused by sonic cracks is not probable.

One or more of the following Means of compliance (MC) have been used to clear each component against the JAR 25.571 (d). They are

Description: For a component which is covered by analysis based on calculations. Established methods and data such as those presented in Engineering Sciences Data Unit (ESDU) Data sheets have been used.

Laboratory Tests: Certain components require the demonstration of structural response (to support calculations) or of acoustic fatigue endurance by the use of ground test facilities such as a high intensity noise siren. In order to demonstrate the acoustic fatigue endurance in a reasonable timescale recourse will frequently be made to 'accelerated' testing. In this case the component is subjected to acoustic loading at levels high than the expected 'real life' levels and an estimate made to the change in fatigue endurance by means of established S-N data.

Flight Tests: Flight test measurements are usually carried out on the basic aircraft to be certificated to obtain sound pressure levels and structural response measurements (strain and acceleration) to validate the levels used for calculation and test demonstration.

Relevant flight test data from other aircraft may also be used for this purpose.

Ground Tests: Ground test measurements are normally conducted on aircraft with different engine variants to obtain sound pressure levels and structural response measurements for comparison with those obtained for basic certified aircraft.

The primary structures of an aircraft refer to fuselage pressure shell, wing, fin and tailplane boxes and associated attachment structure. Other components usually referred to as secondary structure and removable items. A removable item may be designed to accept, at low probability, replacement or repair at a stage where it is considered more economical than designing to the full life requirement. All the components should meet the normal structural damage tolerance requirements (threshold and damage growth). However, due to the difficulty of demonstrating damage growth under acoustic loading, the primary structure should be able to accept a complete local failure unless a damage free life is shown.

3. ACOUSTIC LOADING

The high by-pass turbofan engines used to power Airbus aircraft are relatively quiet and the noise levels (far field) have fallen some 20 dB since the early days of the pure jet and low by-pass powerplants. The maximum overall sound pressure level recorded during the flight test is less than 150 dB for the empennage, and rarely higher than 155 dB for the landing flaps.

The exposure times are based on the flight plan for the fatigue mission. The levels given for each mission stage are the maximum levels assumed to occur and are taken to hold throughout the quoted exposure time. Flight test measurements have shown that the acoustic level may vary during a mission stage and this variation is most noticeable during the take off and landing stages. Hence the acoustic loading chosen to represent take off and landing phases is usually estimated conservatively.

The acoustic loading data for the A321, A330 and A340 aircraft certification items are based on information from (i) model scale test data of previous certified Airbus aircraft such as A320 using the jet/wing/flap noise rig; (ii) flight test data of the A300, A310 and A320 aircraft; (iii) engine noise predictions based on the engine performance information of each aircraft type; (iv) a jet noise prediction method.

A typical flight test installation comprising microphones, accelermeters and strain gauges is given in Figures 2 and 3. Measurements are made during a typical flight mission although for most components the maximum noise loading will occur during the take off and climb out phase and also during the landing phase covering the use of engine reverse thrust operation.

4. AIRBUS AIRCRAFT SONIC FATIGUE CERTIFICATION

The introduction in 1986 of the then new A320 model with new engines and with many new composite components had resulted in many tests being carried out. The test data together with the new A321 engine data have been used to define the acoustic loading for A321 aircraft sonic fatigue strength calculation and analysis. For certification purposes the twin-engined A321 aircraft was considered as a development of the A320 model rather than as a new type. The changes compared to the A320 were a stretched fuselage and more powerful engines. Full flight and ground tests have been carried out and the results are similar to those of A320 and agreed with predictions.

The acoustic fatigue certification procedures of the four engined A340 aircraft were similar to those of A321 aircraft. As usual, conservative acoustic loading levels have been used for calculation and analysis. Full flight tests have been carried out and the results obtained are lower than predictions. Other noise tests also drawn similar conclusions.

The twin engined A330 aircraft is of the same size as the A340 aircraft (see Figure 4). However, the maximum take off thrust of the engines are the highest on the Airbus aircraft. As a result, acoustic loading on the surfaces of the aircraft is expected to be higher than those on all other Airbus aircraft models. Full flight and ground test results have confirmed this and are in agreement with predictions.

5. CONCLUSIONS

This paper has outlined the sonic fatigue certification requirements and procedures laid down by the Joint Airworthiness Authorities for the certification of the Airbus aircraft. The sonic fatigue certification of the four engined A340 and twin engined A330, A321 aircraft are also discussed.

FIGURE 1 A340 AIRCRAFT STRUCTURES

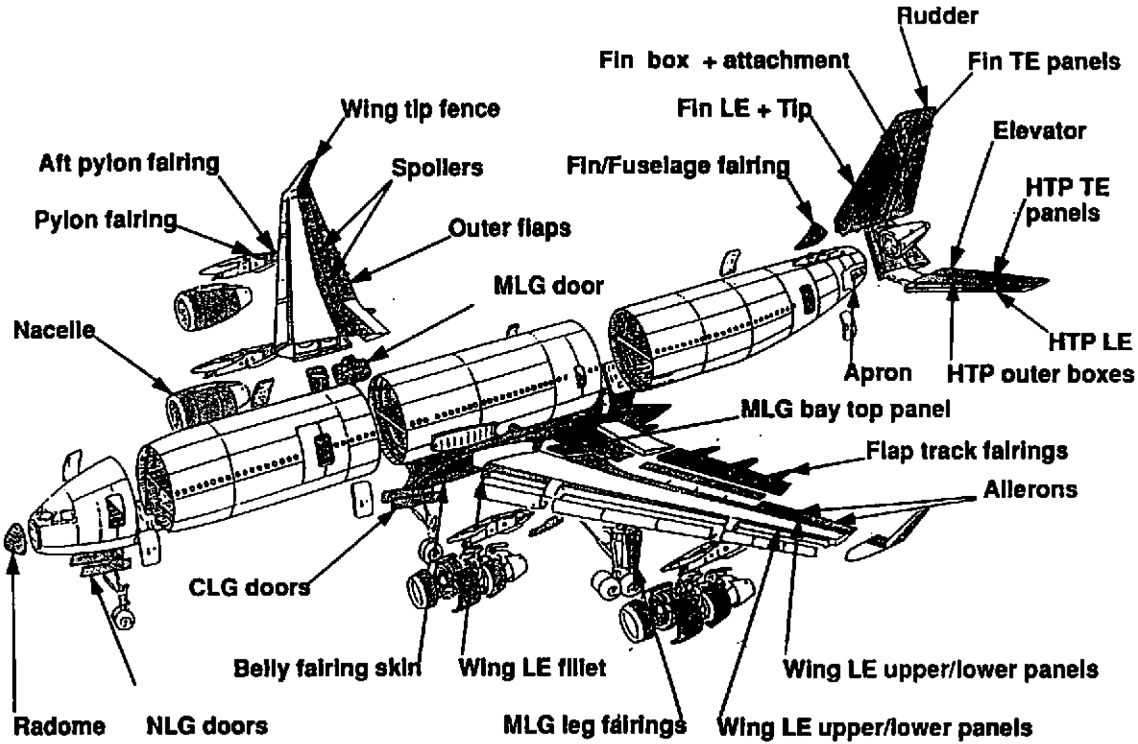
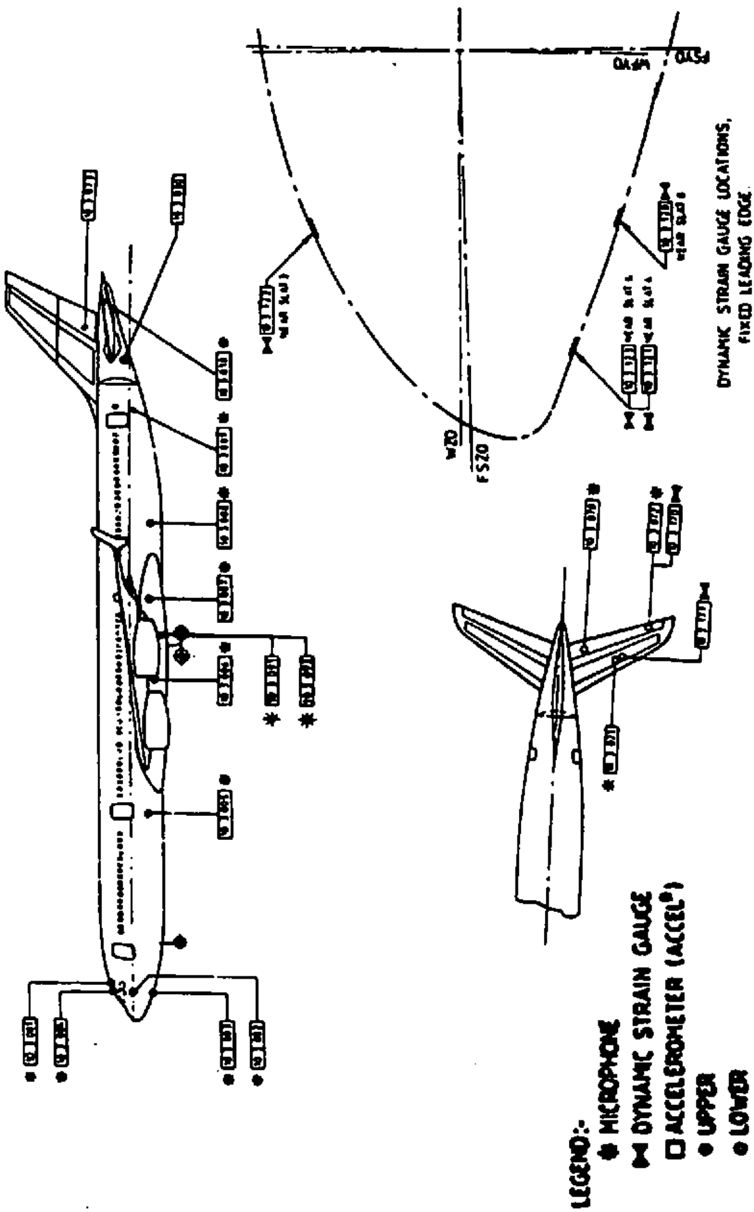


FIGURE 2 A340 TRANSDUCERS LOCATION



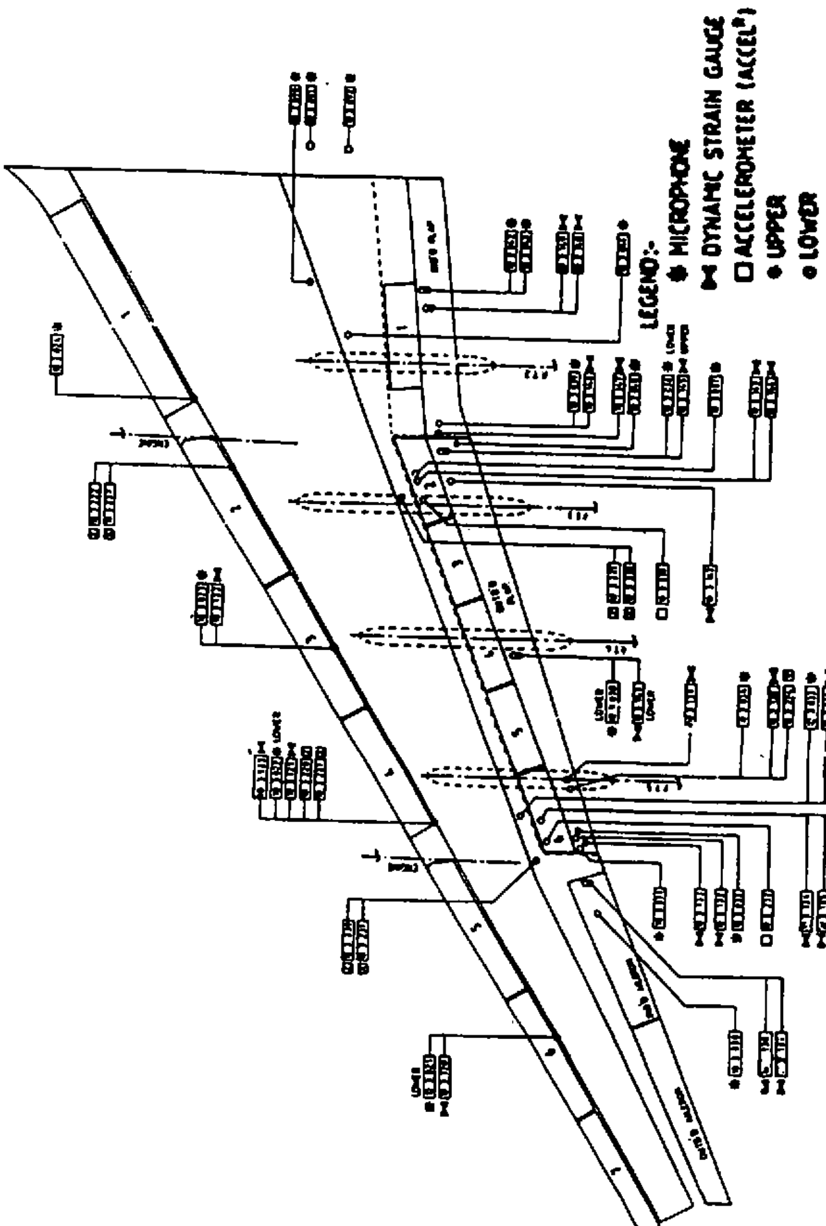


FIGURE 3 A340 TRANSDUCERS LOCATION

FIGURE 4 A330 AIRCRAFT STRUCTURES