Journal of KONES Powertrain and Transport, Vol. 21, No. 4 2014

ISSN: 1231-4005
e-ISSN: 2354-0133
ICID: 1130520
DOI: 10.5604/12314005.1130520

STRUCTURE FATIGUE CRACK IN THE EFFECT OF ACOUSTIC LOAD – CASE STUDY

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Abstract

The paper presents a method for detection mechanisms and prevention of the fatigue cracks caused by acoustic loads acting on the aircraft elevator structure. During aircraft inspection, the fatigue cracks in elevator rib caps were discovered. The theory emerged, that cracks were caused by acoustic extortion on elevator sheet covering, caused by jet engine exhaust airstream, engine gas flow expanding in convergent nozzle and acting as the source of the strong acoustic load. To prove this theory, investigations were arranged, in which the strains in the elevator sheet skin, between the ribs area, were determined in harmonic excitation. The results, after frequency analysis, showed strong resonance in 270 Hz area. Mode of this resonance caused drumming of covering, resulting in bending of the ribs caps and causing them to fail from fatigue. Changes in elevator design raised the resonance frequency and lowered strains in modified elevator covering. The changes mainly increased sheet-covering stiffness by increase of thickness and lowering the sheet-metal covering mass in selected places, mainly by technological means - metal bonding (gluing) and metal covering chemical milling.

Keywords: *acoustic loads, resonance tests, fatigue cracks*

1. Introduction

Inside the structure of aircraft elevator, at one of the elevator ribs, the fatigue crack was detected. It was hypothesized that the crack is the result of the action of acoustic loads, extorted by the exhaust gases of aircraft jet engines.

The proof of the concept

Through the resonance tests, the fundamental resonance frequencies and vibration modes of elevator sheet skin covering were determined.

For the aircraft operational conditions the strains in the sheet skin covering between the elevator ribs were determined.

The results of the strain gauge signal harmonic analysis indicated presence of a single resonance frequency (despite broadband extortion force).

Figure 1 shows the results of the harmonic vibration analysis of the strains in the elevator sheet skin covering.

Through the resonance tests, it was found that the frequency of 270 Hz (Fig. 1) corresponds to the resonance vibration mode, presented in Fig. 2.

Thanks to the correlation of structure strains measurement in operational conditions and resonance tests, the mechanism of ribs fatigue crack was detected.

“The rib caps were bent in accordance with the sheet skin covering resonance vibration mode”.

The next research stage of was the realization of the inverse problem. On a laboratory stand resonance was forced with the vibrations mode as shown in Fig. 2 and resonance frequency of 270 Hz. The elevator rib fatigue cracked in test, after a number of cycles similar to the number of cycles occurring in aircraft exploitation [2].

The designers have proposed several new solutions to the elevator structure.

1. Two-hinged elevator structure with 40% chord and more densely spaced ribs, covered with bonded panels made from the two glued together sheets with a thickness of 0.5 mm each. The inner sheet was grooved. After bonding, the total thickness of the covering was 1.2 mm.

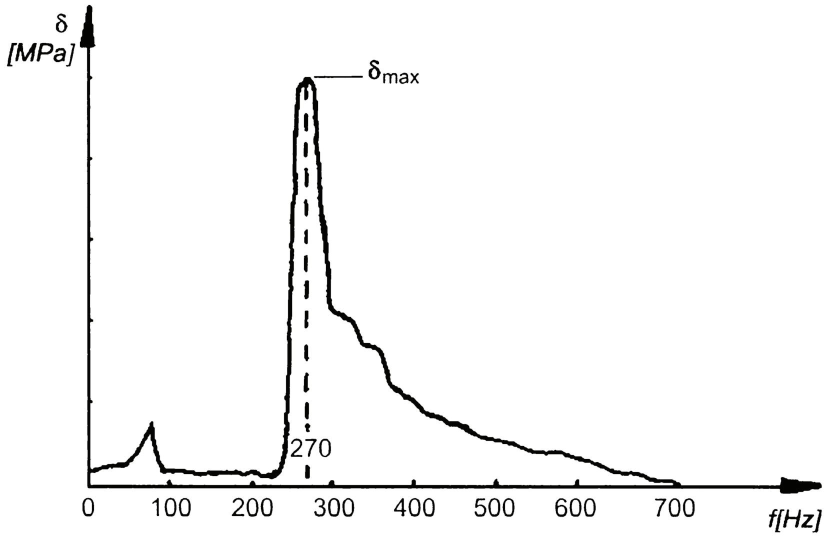

Fig. 1. Harmonic vibration analysis of the strains in the elevator metal sheet covering [3]

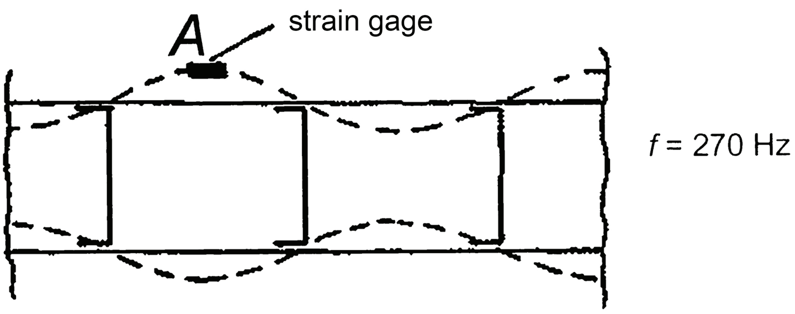

Fig. 2. Presented mode of sheet metal covering resonance vibration - a section along the span [3]

2. Two-hinged elevator structure with 40% chord and more densely spaced ribs, covered with a 1mm thickness sheet metal, chemically milled between the ribs to a thickness of 0.7 mm.
3. Three-hinged elevator structure with 30% chord with honeycomb core trailing edge segments bonded to the 0.6mm sheet metal covering, chemically milled to the thickness of 0.3 mm.
4. Three-hinged elevator structure with 30% chord, covered with the 1.2 mm sheet metal, chemically milled between ribs to the thickness of 0.6 mm.

These elevators versions were then tested on a laboratory stand with resonance method [2] and the simulated acoustic load conditions from TS-11 Iskra aircraft engine.

The investigation results showed that:

– maximum values of total strains on the glued sheet covering of 40% chord elevator with two hinges were 0.45% of the strains on the elevator with classic covering,
– maximum values of harmonic vibration strains on the glued two-sheet covering (40% chord elevator with two hinges), amounted to 0.49% strains of a classic covering,
– maximum values of total strains on the elevator with a honeycomb core (30% chord elevator, with three hinges), amounted to 0.24% of the strains on the classic elevator,
– maximum values of harmonic strains on the elevator with a honeycomb core (30% chord elevator with three hinges), amounted to 0.63% strains of a classic covering.

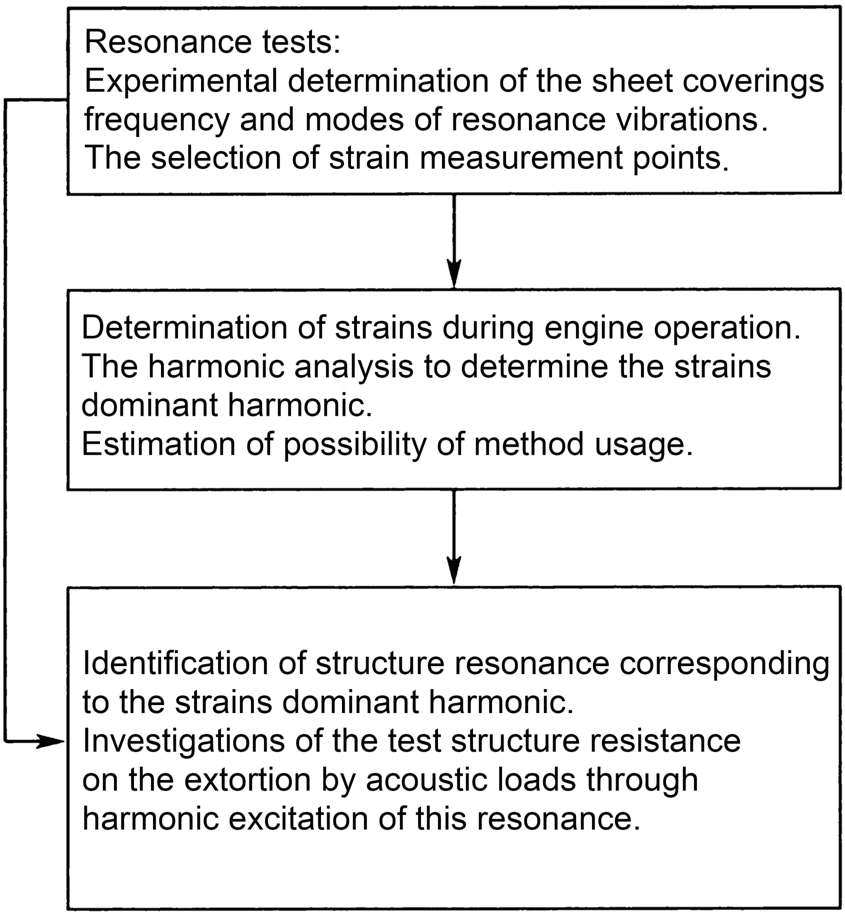

Fig. 3. Schematic of the implementation of harmonic acoustic loads mapping [3]

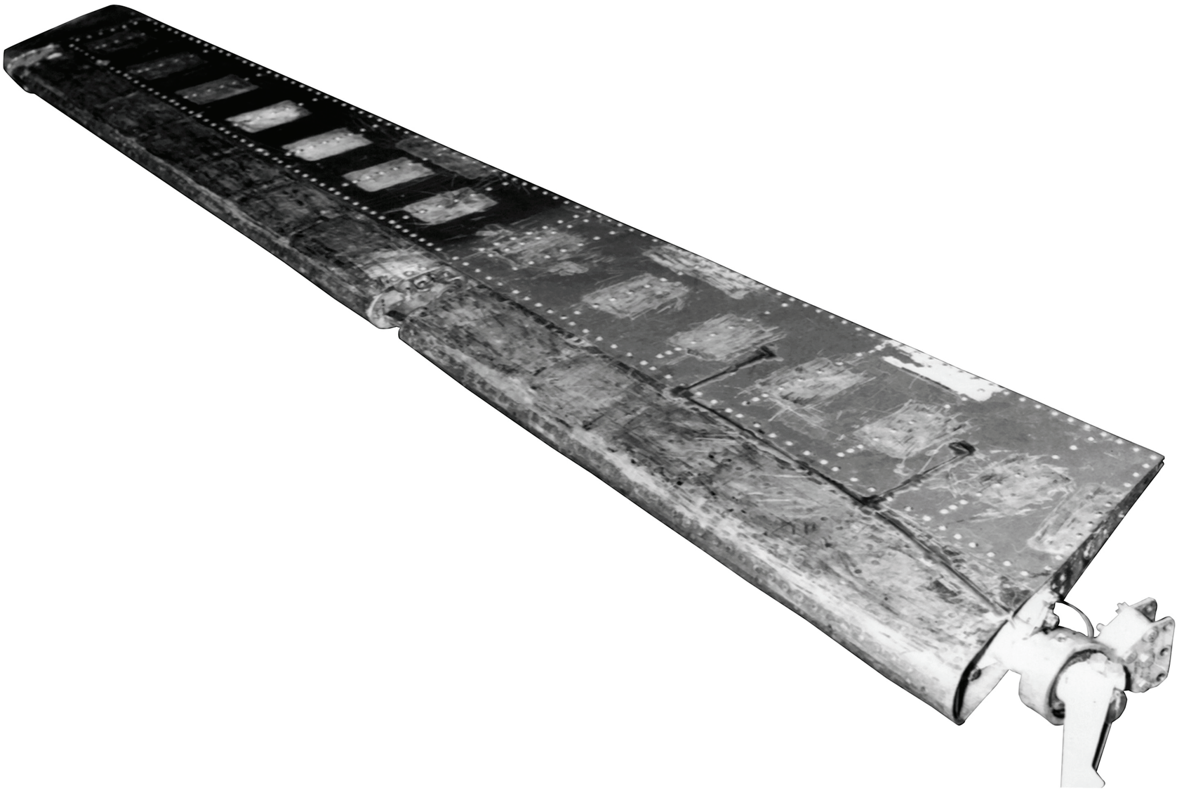

Fig. 4. Three-hinged, 30% chord elevator with more densely spaced ribs [2]

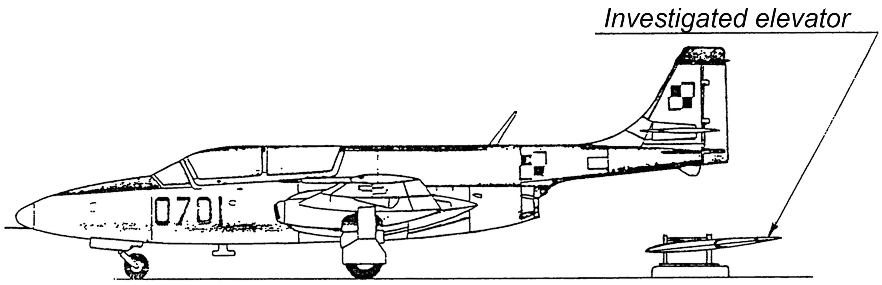

Fig. 5. Schematic of the investigation test stand for measurement of strains in the covering skins of the elevator different variants

Conclusions

The cause of elevator structure ribs fatigue cracks were broadband force extortion, generated by the operating aircraft engine, wherein:

- broadband vibrations extorted the one (single) resonance of the elevator metal sheet covering, wherein the elevator rib caps were bent, leading to fatigue fracture,
- lowering the elevator ribs pitch eliminated dangerous form of the elevator resonance.

References

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