VIBRATION TESTS FROM A TURBOPROP ENGINE AND AIRSCREW OF A SMALL TRANSPORT AIRCRAFT

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ABSTRACT

During the initial operation of the prototype of the airliner, an increased level of vibration was observed, which originated from the turboprop engine and propeller and was transferred to the engine-mounting frame and the airframe. These vibrations caused an increased noise level and increased force level in the mounting frame and the airframe, as well as reduced the comfort of passengers and crew during the flight.

Tests on the vibration level of the aircraft structure were performed in various operating conditions and engine loads. Vibration tests of the engine-mounting frame were carried out in the engine operating conditions on the ground, in flight at different heights and during the landing of the aircraft for different flap deflection values. The analysis of the results was done using Fast Fourier Transformation (FFT). The results of the analysis are illustrated graphically. The paper presents only the elements of the flight, in which the amplitude of the force was observed. An analysis of the results obtained was performed to determine the actual dynamics of forces in the frame fastening the engine to the airframe during all elements of the flight.

Keywords: aircraft, turboprop engine, airscrew, vibration test, Fast Fourier Transformation.

INTRODUCTION

The article concerns the small communication aircraft had a PWD-10B/PZL-10S turboprop engine with a five-blade HC-B5 propeller from Hartzell. Test tests consisted, inter alia, of checking the dynamics of the axial force of the frame fixing the engine in the frequency band from 200-400 Hz. The second goal was to determine the effect of changing flight conditions on the vibration of the engine and its mounting frame in the airframe. Strain gauges were used to measure the force. The longitudinal force in the frame and the bending moment in the vertical and horizontal planes were recorded. Two sensors were installed in the engine to measure the vibration of the propeller planetary reducer in the vertical and transverse directions. The tests were carried out during take-off, climb, horizontal flight on the characteristic operating ranges, engine starting, in flight, stalling smooth and landing.

The research concerned flight parameters at different altitudes. It was found that in order to maintain a constant indicated speed at a given flight altitude it is necessary to change the angle of the engine control lever. The purpose of these tests was to determine the effect of flight altitude and speed on the values of achieved turbocharger and propulsion turbine parameters at a specified angle of engine control level (αDSS). Engine parameters were recorded during each measurement. Flight and engine operation parameters were recorded on two S2-3A Air Force Institute of Technology recorders. Engine operating parameters were recorded during the flight.
Measurements of actual fuel consumption were also carried out as a function of tilting the DSS engine control lever at individual flight altitudes and during typical manoeuvres, such as take-off, taxiing, climb, lap and landing.

During qualification tests prior to introducing aviation equipment to the inventory of the Air Forces of the Republic of Poland, the following, among others, are tested: equal types of fastening nodes for wings, vertical and horizontal tail, propulsion units of an aircraft and others [1, 3, 4].

Often - additionally – quite unusual tests are carried out, of which the basis are, e.g., previously stated damage, incapacity, crack, etc. Usually, these are tests, which are not a standard part of the binding scope of the qualification tests. However, their principal purpose is to detect the potential cause and develop preventive measures, which eliminate similar events in the future.

A similar case took place during qualification tests of the Bryza-1R aircraft, with an installed propulsion unit, consisting of a PWD-10B/PZL-10S engine, in the configuration with a HC-B5 propeller by Hartzell [2, 5]. During the test flights, the frame for mounting the engine to the airframe was tested (additionally) [6, 7, 8, 9].

The reason was that during the tests, largest stretching forces were found in that tube of the engine frame. Besides, it is fastened to the lug, on which a crack appeared. The aim of these tests was additionally check the dynamics of the axial force in the engine-mounting frame’s tube, after broadening the frequency band from 200 to 400 Hz. The second objective was to determine the influence of variable flight conditions on the engine vibrations and its mounting frame in the airframe [6, 10].

Force measuring, tensometers were used for recording, which were placed in the middle of the tube. Connected were instruments for recording longitudinal forces in the R1R8 tube of the frame (by the upper, right fastening lug - looking from the propeller side) and bending moment in the vertical and horizontal plane.

Whereas, the engine had two sensors connected, to measure vibrations on the propeller's planetary reducer in the vertical and transverse direction.

TESTS RESULTS

A measurement of force dynamics when carrying out some flight elements was repeated, in order to increase the reliability of the obtained results. During each measurement, the operating parameters of the propulsion unit were also recorded.

Table 1 presents the results of the achieved aircraft indicated speed during flight at a given altitude and resulting values of the propulsion unit's operating parameters.

Whereas, Figure 1 presents the dependence of the aircraft indicated speed during level flight $V_p$, in the function of the engine control level angle $\alpha_{DSS}$, on the flight altitude for the right engine (the course for the left one was similar).

It was stated that, in order to maintain constant indicated airspeed at a given flight altitude, the engine control lever angle changes.

It is visible mainly at high speeds, where, together with the flight altitude, to maintain a given indicated airspeed, it is necessary to increase the engine control lever's swing angle. At small flight speeds (up to 250 km/h), these changes are much smaller, and their minor differences (of the order of 1%) result from the accuracy of indicator and a “subjective” readout by the crew.
Table 1 - Operating parameters of the propulsion units of the Bryza-1R aircraft, in function of altitude and indicated airspeed: H - flight altitude; \( V_p \) - indicated airspeed; \( \alpha_{DSS} \) - engine control lever angle; \( n_{TS} \) - turbocharger rotational speed; \( n_{TN} \) - propulsion turbine rotational speed; TWG - exhaust gases stream temperature

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Functional tests of the power unit were carried out on the BRYZA-1R aircraft with built-in TWD-10B / PZL-10S engines and five-blade propellers from Hartzell.

Fuel installation fuelled with JET 1A fuel in accordance with the variant of the flight to be performed, full oil (16 litres) oil installation with engine oil, ATM flight data logger - connected. Fire protection - completed. Checking the operation and readability of the emergency signalling and recording in the flight parameters recorder was done by registering...
the flight parameters and operation of the propulsion unit simultaneously on two recorders. The standard equipment of the Bryza-1R aircraft is the ITWL type S2-3A recorder, while the ATM's on-board recorder has been additionally installed for qualifying tests. The comparison of entries on both recorders allowed for an unambiguous determination of the operation and readability of the S2-3A recorder constituting the standard equipment of this aircraft. The results obtained are convergent, the readability of the good.

Inspection of the work parameters of drive unit for WT compliance was carried out during each flight. All parameters were within the limits defined by WT.

The control of the actual fuel consumption at individual flight heights and during typical manoeuvres such as launching, taxiing, take-off, ascent, circle, landing, run-out, and cooling was also carried out. Figure 2 graphically illustrates the character of the hourly fuel consumption \( Q \) (in l/h) as a function of the swing angle of the control DSS engine control lever. There is a drop in hourly fuel consumption with increasing altitude.

In addition, the apparatus for recording longitudinal forces in the R1R8 frame was connected (at the upper right ear of the fastening - viewed from the propeller side) and the bending moments in the vertical and horizontal plane. On the engine, on the other hand, two sensors are installed to measure vibrations on the planetary reducer of the propeller in the vertical direction and in the transverse direction.

![Fig. 2 - Fuel consumption of the TWD-10B / PZL-10S engine with altitude change](image)

Another stage was the analysis of obtained results and the determination of the actual dynamics of forces in the tube of the frame for mounting the engine to the airframe, during all a/m flight elements.

**ANALYSIS OF TEST RESULTS**

The study was based on Fourier’s analysis, with the use of the Excel software for graphic presentation. It is a useful tool for effectively present a variable signal over time, in the frequency scale. Each analogue signal can be presented in the form of sinusoidal components with an appropriate amplitude, phase, and frequency. It allows the determination of the influence of a particular element of an aircraft, propulsion unit on the presence of excess axial force amplitude in an engine-mounting frame’s tube of an aircraft. Commonly available Microsoft Excel software is a tool sufficient for that type of analysis, which requires only proper
scaling of the amplitude axis and the frequency axis. It is used for transforming registered data with the method of fast Fourier transform (FFT), with the input range being the multiplication of the number 2. Only these flight elements were selected for graphic presentation, in which the force amplitude was visible and showed an impact character of propulsion units. In Figures 3 to 10, each graph is described with the type of the carried out flight elements and the operating range of the engine’s turbocharger.

Fig. 3 - Flight 4, nominal operating range

Fig. 4 - Flight 4, maximum engine operating range

Fig. 5 - Flight 4, landing – LMP engine operating range
Fig. 6 - Lot 8, stall, flaps $0^\circ$, 0.6 of the nominal engine operating range

Fig. 7 - Lot 8, stall, flaps $0^\circ$, 0.75 of the nominal engine operating range

Fig. 8 - Lot 8, stall, flaps $0^\circ$, 0.9 of the nominal engine operating range

Fig. 9 - Lot 8, stall, flaps $15^\circ$, 0.6 of the nominal engine operating range
CONCLUSIONS

The conducted analysis showed a quite small dynamics of axial forces in the R1R8 tube of the TWD-10B/PZL-10S engine-mounting frame, which was confirmed by the initial study. Broadening the band from 200 to 400 Hz showed just a minor (order of several daN) influence for the dynamics of the forces in the frame’s pipe coming from the propeller and the turbine. However, we need to remember that the applied band might not have shown the influence of the turbocharger, since its frequency band appears in the range of 350 to 526 Hz.

Anyway, it was concluded that the decisive influence on the dynamics of forces in that tube was by the low-frequency vibrations coming from the airframe (own vibrations of the plane) and the rotations of the propeller shaft. In a lesser extent, from subsequent harmonics of propeller shaft rotations (i.e., 3, 4 and 6), from the fast-running reducer and the drive turbine.

The biggest force growth in the tube, coming from the airframe vibrations, reaches 42 daN, which results in an increase of stress of the order of 22 daN/cm$^2$. While from the rotations of the propeller shaft, the force increase reaches around 16 daN, which result in a stress increase of about 8÷9 daN/cm$^2$.

The obtained results determine the dynamics of forces transferred through the R1R8 tube of the engine frame, however, they do not give a clear answer to the stress level in fastening nodes (meaning, e.g., in the upper, right lug - looking from the propeller side, on which a crack appeared during initial testing).

At the same time, it was shown that the tested modified propulsion unit has met all the required criteria of a Bryza-1R user and does not influence significant changes of stress on force elements of the airframe.

REFERENCES


