EXPERIMENTAL RESEARCH INTO WHIRL FLUTTER AEROELASTIC PHENOMENON

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ABSTRACT
This paper is focused on experimental research into the whirl flutter aeroelastic phenomenon. First, theoretical background on the whirl flutter and on its occurrence in the aerospace practice is outlined. Next, summary of the past main developments in the field is provided. The main part deals with the new aeroelastic demonstrator designed and developed at the VZLU. The paper includes information on demonstrator design, development, and preparatory experiments.

Keywords: aeroelasticity, whirl flutter, wind tunnel test, W-WING.

INTRODUCTION
Whirl flutter [1] is a specific type of aeroelastic flutter instability, which may appear on turboprop aircraft because of rotating parts, such as a propeller or a gas turbine engine rotor. Rotating mass generates additional forces and moments and increases the number of degrees-of-freedom. Rotating propellers also cause an aerodynamic interference effect between a nacelle and a wing. Whirl flutter instability is driven by motion-induced unsteady aerodynamic propeller forces and moments acting at the propeller plane. It may cause unstable vibration, which can lead to failure of an engine installation or an entire wing.

The propeller whirl flutter phenomenon was analytically discovered by Taylor and Browne in 1938 [2]. The next pioneering work was performed by Ribner, who set the basic formulae for the aerodynamic derivatives of propeller forces and moments due to the motion and velocities in pitch and yaw in 1945 [3, 4]. After the accidents of two Lockheed L-188 C Electra II airliners in 1959 and 1960, the importance of the whirl flutter phenomenon on practical applications was recognized. The complicated physical principle of whirl flutter requires experimental validation of the analytically results obtained, especially due to the unreliable analytical solution of the propeller aerodynamic forces. Further, structural damping is a key parameter, to which whirl flutter is extremely sensitive and which needs to be validated. Therefore, aeroelastic models are used. The important experiments were carried out in 1960s, especially in NASA Langley by Reed, Bennett, Kvaternik and many others, e.g. [5, 6].

The whirl flutter aeroelastic demonstrator developed by VZLU has a character of a half-wing with a span of 2.56 m with the nacelle, engine, and propeller. The total mass is approximately 55.5 kg. The demonstrator is capable of simulating changes of the main parameters influencing the whirl flutter. The nacelle model includes the engine pitch and yaw vibration modes. The stiffness parameters are modeled by means of cross spring pivots. The changeable leaf springs are used, and the stiffness parameters can be adjusted independently. Both pivots are independently movable in the direction of the propeller axis. The inertia of the engine is modeled by the replaceable and movable weight. The gyroscopic effect of the rotating mass is simulated by the mass of the propeller blades. The demonstrator, combined with the splitter plate which prevents the induced effects at the wing root region, is fixed to the attachment arm.
inside the 3-m diameter low-speed wind tunnel test section (see Figure 1). The model is instrumented by accelerometers, strain gauges and by other sensors.

Two measurement campaigns have been accomplished so far. The first was focused mainly on the variation of the engine pitch and yaw stiffness. The second was focused on the variation of the secondary parameters. The measurement variant of the model was defined by pitch and yaw attachment stiffness, pitch and yaw hinge station, balance weight station, choice of propeller (duralumin or steel blades), and finally, by the propeller blade 75% section angle of attack. In the first phase, the excitation was realized by the airflow turbulence only. The propeller rotated in the windmilling mode at the several levels of airflow velocity. Provided that the flutter state was not reached, the measurement was repeated with the aerodynamic excitation by the aileron flapping using frequency harmonic sweep. The structural response was measured by the in-house system based on LabVIEW and by the LMS TestLab system. Vibration records were processed using FFT. The typical vibration spectra showing the growth of the response as the flutter is approached and finally reached is shown in Figure 2. The flutter state was defined by the amplitude criterion that was set to avoid a damage of the model or the test equipment.

During the tests, the usage of the thrusting propeller was found to be problematic due to the insufficient power of the motor. Future planned activities include redesigning the power system and installation of more powerful motor capable of working in a wide range of airflow velocities and propeller revolutions.

REFERENCES