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W-WING: Aeroelastic Demonstrator for Experimental Investigation into Whirl Flutter

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Abstract : This paper describes the concept of the W-WING whirl flutter aeroelastic demonstrator. Whirl flutter is the specific case of flutter that accounts for the additional dynamic and aerodynamic influences of the engine rotating parts. The instability is driven by motion-induced unsteady aerodynamic propeller forces and moments acting in the propeller plane. Whirl flutter instability is a serious problem that may cause the unstable vibration of a propeller mounting, leading to the failure of an engine installation or an entire wing. The complicated physical principle of whirl flutter required the experimental validation of the analytically gained results. W-WING aeroelastic demonstrator has been designed and developed at Czech Aerospace Research Centre (VZLU) Prague, Czechia. The demonstrator represents the wing and engine of the twin turboprop commuter aircraft. Contrary to the most of past demonstrators, it includes a powered motor and thrusting propeller. It allows the changes of the main structural parameters influencing the whirl flutter stability characteristics. Propeller blades are adjustable at standstill. The demonstrator is instrumented by strain gauges, accelerometers, revolution-counting impulse sensor, sensor of airflow velocity, and the thrust measurement unit. Measurement is supported by the in house program providing the data storage and real-time depiction in the time domain as well as pre-processing into the form of the power spectral densities. The engine is linked with a servo-drive unit, which enables maintaining of the propeller revolutions (constant or controlled rate ramp) and monitoring of immediate revolutions and power. Furthermore, the program manages the aerodynamic excitation of the demonstrator by the aileron flapping (constant, sweep, impulse). Finally, it provides the safety guard to prevent any structural failure of the demonstrator hardware. In addition, LMS TestLab system is used for the measurement of the structure response and for the data assessment by means of the FFT- and OMA-based methods. The demonstrator is intended for the experimental investigations in the VZLU 3m-diameter low-speed wind tunnel. The measurement variant of the model is defined by the structural parameters: pitch and yaw attachment stiffness, pitch and yaw hinge stations, balance weight station, propeller type (duralumin or steel blades), and finally, angle of attack of the propeller blade 75% section (□). The excitation is provided either by the airflow turbulence or by means of the aerodynamic excitation by the aileron flapping using a frequency harmonic sweep. The experimental results are planned to be utilized for validation of analytical methods and software tools in the frame of development of the new complex multi-blade twin-rotor propulsion system for the new generation regional aircraft. Experimental campaigns will include measurements of aerodynamic derivatives and measurements of stability boundaries for various configurations of the demonstrator.

Keywords : aeroelasticity, flutter, whirl flutter, W WING demonstrator
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