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Title

Aeroelastic Demonstrator and Methodology for Experimental Investigation of Propeller Aerodynamic Derivatives

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Abstract

Whirl flutter is a specific type of flutter instability that is driven by motion-induced unsteady aerodynamic propeller forces and moments acting in the propeller plane [1]. The complicated physical principle of the whirl flutter requires the experimental validation of the analytically gained results. One of the key issues is the solution of propeller aerodynamic forces on a vibrating propeller, for which the analytical solution is unreliable. To determine the forces and moments acting at the propeller disc plane using quasi-steady theory, propeller aerodynamic derivatives are used. The complete solution includes 16 derivatives in total (pitch force, pitch moment, yaw force and yaw moment due to pitch angle, pitch velocity, yaw angle and yaw velocity). The number of derivatives may be reduced to six independent derivatives by using the (anti)symmetry and by neglecting of the negligible ones. Four ones may be investigated experimentally.

In the past, VZLU developed a demonstrator for investigation of the whirl flutter characteristics representing a wing with a nacelle, motor, and propeller (W-WING). The demonstrator was used for the measurement of a structure vibrational response. The similar demonstrator for the measurement of aerodynamic derivatives represents a sting-mounted nacelle with a motor and propeller (W-STING). The demonstrator includes two degrees-of-freedom (engine pitch and yaw). The stiffness parameters in both pitch and yaw are modelled by means of cross spring pivots. The spring leaves are changeable, and both stiffness constants are independently adjustable by replacing these spring leaves. Both pivots are independently movable in the direction of the propeller axis to adjust the pivot points of both vibration modes. The gyroscopic effect of the rotating mass is simulated by the mass of the propeller blades representing a scaled-down real 5-blade propeller. The propeller is powered by an electric motor.

For the measurement of aerodynamic derivatives, a single degree-of-freedom model is to be used; therefore, the blocking of either pitch or yaw movement is provided. Pitching moment due to the pitch angle ($c_{m\Theta}$) and vertical force due to the pitch angle ($c_{z\Theta}$) derivatives are measured using pitch-only model arrangement. Pitching moment at the pitch gimbal axis is measured for the variable pitch angles (movement by manipulator). From the slope of measured curves, the reference coefficient is evaluated. Pitching moment due to the yaw angle ($c_{m\Psi}$) and vertical force due to the yaw angle ($c_{z\Psi}$) derivatives are measured using yaw-only model arrangement. Similarly, yawing moment at the yaw gimbal axis is measured for the variable pitch angles. From the slope of measured curves, the reference coefficient is evaluated. In addition to the above-mentioned measurement, the dynamic pressure dependent yaw-to-pitch angle ratio must be also considered here. To separate the contributions of both force and moment to the total moment, the measurement of two configurations varying the distance between the gimbal axis and the propeller plane is used for both of the above-mentioned measurements.

References

[1] Čečrdle, J.: Whirl Flutter of Turboprop Aircraft Structures, 1st ed., Elsevier Science, Oxford, UK, 2015.