

EXPERIMENTAL INVESTIGATION OF WHIRL FLUTTER STABILITY AND 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. This paper discusses the recent accomplishments in the testing of the W-WING demonstrator. The demonstrator represents the wing, nacelle and the powered propeller. The tests included the dynamic measurements of aeroelastic response (whirl flutter stability) using wing-mounted nacelle and propeller and the static measurements of a propeller aerodynamic derivatives using sting-mounted nacelle and propeller. The paper includes brief outline on the theoretical background on the whirl flutter phenomenon and the demonstrator concept and preparatory experiments. The main focus is then paid on the wind tunnel measurements at the low-speed wind tunnel. The paper presents the tests arrangements, methodologies, configurations and the examples of results. The measured quantities for the static measurement aimed at evaluation of a propeller aerodynamic derivatives included pivot moment (pitch or yaw) and pitch and yaw deformation angles. Moment at the active gimbal axis was measured for the variable pitch angles provided by the movement of the manipulator within ± 20 deg. From the slope of the measured curves, the reference moment coefficient was evaluated. To separate the contributions of both force and moment to the total moment and to evaluate the final derivatives, two configurations varying the distance between the gimbal axis and the propeller plane were measured. The results for various secondary parameters include pitch force due to pitch angle, pitch moment due to pitch angle, pitch force due to yaw angle and pitch moment due to yaw angle derivatives. The dynamic measurement of the whirl flutter stability (dynamic response) included various configurations considering pitch and yaw hinge station, balance weight station, choice of propeller (duralumin or steel), and finally, by the propeller blade angle of attack. Propeller was operated mostly at the thrust mode. In addition, the windmilling mode was also used. Excitation was realized by the flow turbulence or by the aileron harmonic sweep flapping. Vibration records were processed using FFT. A detailed assessment in the frequency domain was focused on the frequency range up to 20 Hz. Further, the averaged Cross Power and Auto Power spectra of vibrations were evaluated. The data of the runs with the turbulence excitation were assessed by the operational modal analysis (OMA). The results included modal parameters (frequency, mode shape, damping ratio) of the evaluated modes at the airflow velocities ranging from 10 to 40 m/s. The identified modes include both backward and forward whirl modes as well as the wing modes, especially 1st bending mode. The dynamic measurements were split into two campaigns. During the 1st campaign, the fixed-RPM and variable airflow velocity scenario was used. Then, during the 2nd campaign, the scenario was changed to the fixed-thrust and variable airflow velocity as the significant influence of thrust on the stability was found. Finally, several flutter states were reached during the 2nd campaign. The aerodynamic flow-field measurements including the steady measurement using five-hole pressure probe and the unsteady measurement using hot-wire anemometer probe were also realised. The steady results include the velocity magnitudes and pitch and yaw angles. The unsteady results include the phase averaged velocities and turbulence intensities over the propeller azimuth angle.