Ground Vibration Test of a Small Unmanned Aerial Vehicle

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Extended Abstract

Problem Statement: Modern aircraft designers have started to adopt lightweight, flexible wings as a result of the need for improved performance. A challenge related to this adoption is the adverse interactions between aerodynamic and structural forces (i.e. aeroelastic flutter). These interactions can provoke large in-flight deformations of the wings and can lead to severe structural damages. Hence, a good characterization of the structural dynamics of an aircraft is required. This research delves into the study of such characterization using a small Unmanned Aerial Vehicle (UAV). The results will then be reintroduced in an aeroelastic model to analyze the flutter interaction.

Theoretical Framework: Structural dynamics parameters of any structure can be calculated through an experimental modal analysis. This modal identification encompasses analyzing the system responses in the frequency domain, using frequency response functions (FRFs). The advantage from using this method of computation is the increased accuracy from the results as residual terms are added to the computation. A ground vibration test was done to perform the modal identification of the UAV.

Methodology: Here, the aircraft was suspended using a highly flexible spring to emulate free flight conditions. A vibration exciter shaker, which remained on the ground but was attached to the wing by a stinger, induced a known excitation to the structure. The response from the induced excitation was measured using accelerometers located at different points of the aircraft. In addition, a force sensor was mounted between the stinger and the structure to measure the excitation force. The aircraft was excited with a sine sweep signal from 2 to 40 Hz at the wing root chord. A software developed in MATLAB generated the excitation signal and acquired the acceleration signal.

Results: From the experiments, the first bending and torsional modes of the main wing were identified. The acceleration responses were collected at the wing tip and trailing edge at a sampling frequency of 2048 Hz. The experimental data show the identification of three main frequencies: the first symmetric bending mode, corresponding to 8.47 Hz, the first symmetric torsional mode, corresponding to 26.20 Hz, and the second symmetric bending mode, corresponding to 31.71 Hz.

Impact of Work: Having a deeper understanding of the underlying characteristics behind the adverse interactions between aerodynamic and structural forces can lead to solving the technical challenges behind the implementation of lightweight, flexible wings. These important parameters will be used to study aeroelastic flutter, a phenomenon that if not dealt with can lead to catastrophic structural damage. Preliminary results show a promising trajectory for further research to be done in the validation of models. Likewise, this research will have provided insight in the development of design methodologies to safely exploit the benefits of lightweight flexible aircraft.