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Entitled

FLUTTER SUPPRESSION BY ACTIVE CONTROLLER OF A TWO-DIMENSIONAL WING WITH A FLAP

by

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Abstract

Flutter is a divergent oscillation of the aeroelastic structure that results from the interaction of elastic and inertial forces of the structure with the surrounding aerodynamic forces. Where at a certain airspeed called the flutter speed, the structural damping changes from positive to negative due to the existence of aerodynamic forces. Flutter is considered as one of the most important instability phenomena in aeroelasticity filed. This is because of its catastrophic effect on the long-term durability and operational safety of the aircrafts structure. Traditionally passive solutions have been presented and used for many years, but they are not favourable due to the weight adding penalty which reduces the aircraft performance.

Active control methods allow for less weight and higher maneuvering capabilities. Although many active control methods have been studied and shown success in the past few decades, none of them has achieved operational status on any aircraft this is due to the fact that aircraft designers and operators are risk averse. But the recent developments of the control systems hardware and software seem to have made the implementation of Active Flutter Suppression technology closer than ever before.

The main objective of this study is to contribute to the efforts of finding the most capable and reliable active control strategy to suppress wing's flutter by investigating the potential effectiveness of Model Predictive Control MPC using Laguerre functions.

Lagrange's energy method and Theodorsen's unsteady aerodynamic theory were employed to derive the equations of motion of Theodorsen's wing model, which is a two-dimensional wing section with three degree-of-freedom in a free-stream. Using MATLAB®, the air speed at which the flutter occurs for a specific wing's parameters were found to be 23.96 m/s, at a frequency of 6.12Hz. A Linear Quadratic Gaussian compensator LQG was designed and simulated. LQG is an active optimal controller that consists of a linear quadratic controller LQR, with an optimal state observer (Kalman filter). MATLAB® was also used to design and simulate a discrete Model predictive controller MPC using Laguerre orthonormal Functions. The simulated results for states regulation and reference tracking tasks, at 10% higher than the flutter critical speed from both controllers were compared and discussed in terms of quantitative performance measures and indices.

The results showed that both LQG and MPC controllers are capable to successfully suppress the flutter and stabilize the system in addition to tracking a reference input value at any air speed accurately with zero steady state error. The superiority for the constrained MPC is manifested by results comparison. MPC were able to save more than 40% of the needed settling time for states regulation task. Furthermore, it performed the job with much less control energy indicated by the ISE and ISU indices. On top of that, the key advantage of MPC, which is the ability to perform real-time optimization with hard constraints on input variables has been confirmed.

Keywords: Flutter, Active control, AFS, Optimal control, Regulator, LQR, State observer, Kalman Filter, LQG, MPC