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Closed-loop model validation techniques for health monitoring of aeroservoelastic systems

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To ensure flight safety, extensive flight-testing and active structural servo control strategies are required to explore and expand the boundary of a flight envelope. Aeroservoelastic (ASE) models can provide online flight monitoring of dynamic instabilities to reduce flight time testing and increase flight safety. The reliability of an ASE model for the flight envelope prediction and flight safety monitoring is determined by several factors. These factor show that it is beneficial to use models that are developed on the basis of experimental data in order to improve reliability and that an accurate nominal model is crucial to describe the relevant nominal flight behavior. It has also been shown that the parameterization and characterization of the model perturbation is necessary to predict/monitor allowable perturbations in the nominal flight behavior.

In general, a model can be formulated by considering a nominal model along with a model uncertainty (or allowable model perturbation). The nominal model captures the dynamic coupling between mechanical flexibilities and dynamic effects caused by actuator bandwidth limitations, mechanical flexibilities, and sensor locations. The model perturbation is used to take into account model variations and modeling errors at different test conditions. The model perturbation may contain structural uncertainty such as variation of dynamic pressure and possible variations of structural elastic models and unstructured uncertainty such as high frequency elastic modes and actuator saturation.

Closed-loop identification and model validation techniques are used to robustly characterize the dynamic performance of an ASE system. These techniques are based on a fractional representation approach and have two main benefits. Firstly, it will address the problem of correlation between the input and output signals that are observed in feedback controlled systems. Secondly, the fractional representation allows the formulation of a unified approach to estimate models via the estimation of stable coprime factorizations based on closed-loop data. The model validation problem for coprime factorizations can be considered for closed-loop frequency domain data where both noise-free and noisy measurements can be handled. In the latter case of noisy measurements, the model validation test implements the μ-method and the validation results simplify considerably when the controller used to parameterize the models is also used to create the feedback control. The proposed method will be evaluated on flight data from the F18 Aeroservoelastic program being developed at NASA Dryden.

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