ADAPTIVE CONTROL LAW FOR ACTIVE FLUTTER SUPPRESSION IN PRESENCE OF ACTUATION FAILURE

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ABSTRACT

To meet the sustainability requirements, research and industry agree that future aircrafts will be equipped with high aspect ratio wings. Among the challenges posed by the increase in aspect ratio, higher structural flexibility is involved, and adverse aeroelastic phenomena become more likely to occur.

Active Flutter Suppression (AFS) systems are currently ignored for flying aircrafts, due to lack of reliability on real operational conditions (see [1]). Nontheless, they have been research topic for many years, and even if certification rules do not explicitly comply with the presence of such systems, there are literature precedents where similar concepts have been implemented on commercial aircrafts (see [2]).

To make a step towards the safety increase of AFS, the kinematic chain that goes from the control signal to the actual control surface rotation must be studied and understood carefully, addressing the worst case scenarios. An adaptive active controller for flutter suppression, capable to detect actuation failure and re-allocate the workload on the functioning control surfaces by means of adaptive methodology will be studied in this work. The control strategy will be applied to an already available wing model equipped with two ailerons to be used for flutter suppression. The aeroelastic plant consists of a Linear Time Invariant (LTI) State Space (SS) system, representative of a hybrid-electric regional aircraft wing, available in Simulink. The adaptive control methodology will be therefore implemented in the same environment.

After having introduced the problem statement and the methodology to address it, the design of adaptive control law for flutter suppression in presence of actuation failure will be explained in details. Aeroservoelastic Simulink plant will be introduced along with numerical results showing the capability of adaptive allocation, ensuring fault tolerant flutter suppression, when sufficient redundancy is present in the control surfaces. Analyses of robustness to uncertainties will be considered in the adopted adaptive methodology.

Model

The authors are involved in two European projects (HERWINGT and HERA), explained in detail in a dedicated abstract submitted to the conference. Although the projects are different, they share the same wing concept. In particular, in the context of HERWINGT, Politecnico di Milano (POLIMI) will address wind tunnel flutter testing. Starting from the external shape of the wing, which was a project requirement, POLIMI has generated and sized the numerical stick model (Fig. 1) using NeoCASS, an in-house tool developed for aerostructural sizing. The model is equipped with two ailerons, highlighted in the figure. To build the wind tunnel model, a scaling isofrequency procedure has been applied starting from the structural properties obtained from sizing. A detailed FEM has been realized and the correspondent physical model is currently under manufacturing. Once the physical model will be received and assembled, GVT will be computed to correlate the numerical model with the experimental one.

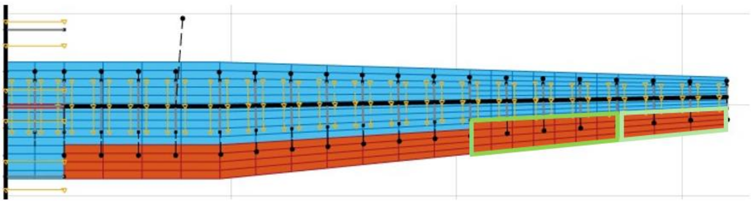

Figure 1. HERWINGT NeoCASS wing model

Figure 2 shows the CAD detailed half-wing model. Tip winglet will be removed and substituted by a pod, containing a ballast mass that will be activated by a pneumatic safety system in case the adaptive AFS control law fails during wind tunnel tests. Even though the purpose of the present work is to assess numerical simulations of the controller capabilities, the tip pod is included inside the numerical model, since its presence affects the aeroelastic response of the plant.

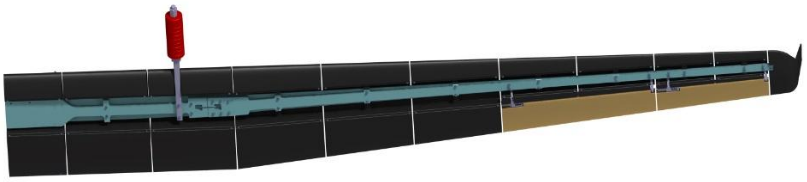

Figure 2. HERWINGT CAD wing model

Linear flutter analyses have been computed on the current model, showing V_{fl} = 35 m/s (see Fig. 3) at f_{fl} = 3.2 Hz. The phenomenon will be suppressed by the active controller even in presence of actuation failure.

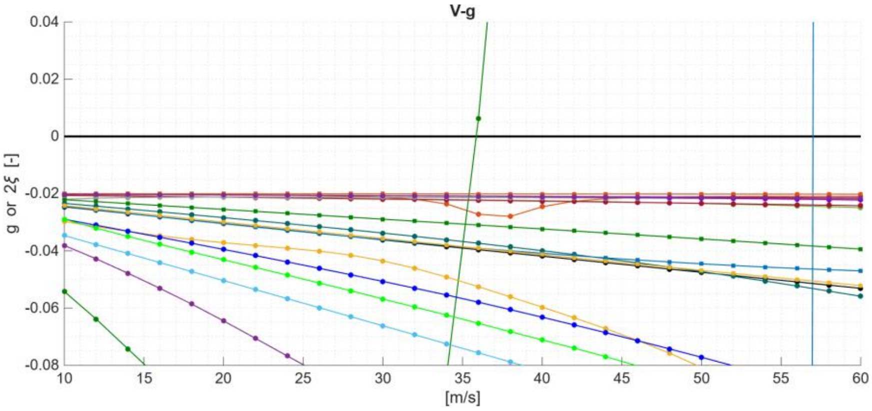

Figure 3. V-g plot (zoom) for HERWINGT wing model.

Control law strategy

Given the correlated FEM model, it is possible to design the AFS control law in Simulink. In particular, to account for the presence of actuation failure, adaptive control allocation methodology will be implemented. With adaptive allocation, depending on how the actuators are behaving, the work load is split between the two control surfaces in a way that depends on two adaptive coefficients. Ideally, if neither of the actuators are exhibiting problematic behaviors, the AFS action is equally divided between the two ailerons, such that the two control surfaces are behaving as a whole. On the opposite, if one of the two ailerons is stuck, flutter suppression must be completely exercised by the safe one. These are the two limit cases for the adaptive control law design for flutter suppression with multiple control surfaces.

Innovation

Adaptive control for flutter suppression has been already studied in literature, but to the author's knowledge there is lack of information on how to deal with AFS in presence of actuation failure, exploiting the presence of multiple control surfaces. Additionally, the involvement in wind tunnel tests opens the possibility to experimentally test the feasibility of the proposed design in future activities.

Bibliography

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