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Published in:
EWEC 2009 Proceedings online

Publication date:
2009

Document Version
Publisher's PDF, also known as Version of record

ID: 284
TRACK: TECHNICAL TOPIC: Aeroelasticity loads and control

AEROSERVOELASTIC STABILITY OF AN AIRFOIL SECTION EQUIPPED WITH TRAILING EDGE FLAP

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The effects of applying a deformable trailing edge (flap) control on an airfoil section are investigated with relevance to the system stability. Namely, the flow speed limits, at which aeroelastic instabilities as flutter and divergence occur, are computed by applying an eigenvalue analysis. The flap, when controlled to alleviate loads, decreases the flutter limit. Nevertheless, only one of the three investigated control strategies returns a flutter limit critically close to the flow speeds encountered by a wind turbine blade during normal operation. The possibility of extending the aeroelastic stability range through a control gain re-scheduling is also investigated.

Recent studies [1] concludes that, by applying a controlled deformable trailing edge (flap) device, is possible to achieve a reduction above 40% in the loads acting on wind turbine blades.

The work investigates how this flap device modifies the stability limits of the aeroelastic system. In fact, dynamic instabilities such as flutter may become problematic if, due to the presence of the controlled flap, the flow speed at which they occur decreases and approaches the normal operation speed range.

The analysis is based on the aerodynamic model developed by Gaunaa [2], coupled with a three dof (heave, pitch, flap) structural model of an airfoil section. The flap is controlled by algorithms based on measurements of heave motion, of angle of attack and of pressure difference between the two sides of the airfoil. Time delay in the control is introduced as a first order filter. The full aeroservoelastic system is then solved in the frequency domain and stability of the modes assessed through eigenvalue analysis.

After validation with literature cases, the section described in [3] is investigated. Results show increased flutter limit for a sufficiently rigid and not controlled flap. Reduced limits are instead reported when controls for load alleviation applies, but, while pressure difference and angle of attack algorithms are still stable well above the normal operative range, the heave controlled section shows a critically low flutter limit. Gain rescheduling can increase the flutter speed and limits even above the non-controlled case are reported with angle of attack and pressure controls. The effects of a control time delay are not straight forward and should be assessed for each particular case.

To conclude, in most of the investigated cases, stability does not seem to be a limiting issue in the application of trailing edge flap. On the other hand, the results are depending on the proprieties of the investigated structure and different conclusions may be reached with other sections, the usefulness of a stability tool is thus significant.

[1] Andersen, P.B.; Henriksen, L.C.; Gaunaa, M.; Bak, C.; Buhl, T., Integrating deformable trailing edge geometry in modern Mega-Watt wind turbine controllers. In: EWECProceedings, (2008) Brussels.

[2] Gaunaa, M., Unsteady 2D potential-flow forces on a thin variable geometry airfoil undergoing arbitrary motion. RisøR1478EN (2006)

[3] Buhl, T.; Gaunaa, M.; Bak, C., Potential load reduction using airfoils with variable trailing edge geometry. J. Solar Energy Eng. (2005) 127