# ADAPTIVE FLOW CONTROL OF WIND TURBINE BLADE USING MICRITABS

Nailu Li[1], Mark J. Balas[1]
[1] *Electrical and Computer Engineering, University of Wyoming, Laramie, WY, USA*

*Abstract* Aerodynamic load over the rotating wind turbine blade is modeled by Beddies-Leishman model. The flutter issue of the blade caused by unsteady loads has been addressed by the design of Adaptive Controller. The robustness and effectiveness of designed controller are shown by good performance in suppressing the blade vibration and reaching the desired pitch angle required by wind turbine operation for open-loop and closed-loop simulation tests. The ability of Microtabs in active flow control is revealed by the response of gurney flap within 5% of chord length and reasonable rate. Experiments are implemented to demonstrate the superior ability of Adaptive Controller in flutter suppression for a wide range of aerodynamic loads.

## MODEL DEVELOPMENT

The blade model is an aeroelastic model, which is also a pitch and plunge system, with the actuator, microtab on the trailing edge, shown in Fig.1. The dynamic motion of this aeroelastic system are plunging and pitching, presented by plunge displacement h, down-forward and pitch angle θ, nose-up. The blade is rotating on the vertical plane at rotor speed $w_r$ with constant wind velocity U. The rotation of blade can burden periodic time-varying aerodynamic loads over the blade. The Microtabs installed on the trailing edge can be deployed approximately perpendicular to the airfoil surface to a height on the order of the boundary layer thickness as 5% of chord length. Lift enhancement and mitigation are achieved simply by deploying the tab on the pressure (bottom) and suction (upper) side of the airfoil respectively[1,2]. When extending from pressure side of the airfoil near its trailing edge, it produces increase in lift coefficient while with suction side deployment, the lift coefficient decreases gradiently with the change of gurney-flap height g. Effect of these tabs on lift and moment coefficients of an airfoil has been shown to be as effective as conventional flaps[3] The dynamics of actuator is not included for consideration.

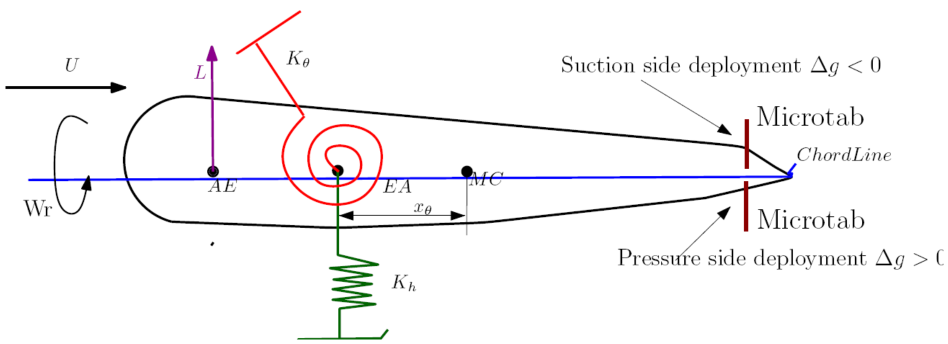


**Figure 1.** Sketch of rotating wind turbine blade section.

## EXPERIMENTAL RESULTS AND DISCUSSION

Since the wind turbine mainly operates in region 2 and region 3, two cases as V=3m/s, 5m/s are chosen in region 2 (1.5 m/s to 8 m/s), with the control goal as stabilizing the system and reaching the desired pitch angle 6 deg with initial value 6 deg when turbine control is to capture maximize wind power with fixed pitch angle. Another two cases as V=9m/s, 15m/s are chosen in region 3 (8m/s to 20m/s), with the control goal as stabilizing the system and reaching the desired pitch angle 10 deg with initial value 15 deg when turbine control is to keep rated wind power with pitch angle control. The simulation results of both open-loop and closed-loop tests are illustrated in Fig. 2. Several conclusions can be made as: 1) for open-loop tests, the system can be marginal stable unless it reaches high wind velocity in region 3. However, the pitch angle can not attain the desired value without any control. And in region 3, the stable h response still needs to be adapted to meet the reasonable range. 2) for closed-loop tests, first, the desired pitch angle can be obtained by Adaptive Controller in both regions with the precise initial value as required in a short settling time;then, both of h response and θ response are stabilized at each wind velocity. The steady state error of h response is due to the fact that the desired pitch angle is no longer 0, which means the system is stabilized at certain non-zero equilibrium. 3) for the response of actuator, in region 2, the gurney flap g can be limited within 5% of chord length, and with higher wind velocity, the Adaptive Controller performs better with a smaller gurney flap as around 2% c. Moreover, the step input disturbance is also rejected at 1 second, as shown in V=3m/s, 4m/s. In region 3, the gurney flap needs to be saturated as 5% c to suppress the blade vibration with a shorter settling time than that in region 2, which furthermore proves the superior of Adaptive Controller in flow control at high wind velocity. It can also be noted that the rate of g is around 16 hz, which is reasonable and applicable. All in all, the device as Microtabs is capable of suppressing the vibration of rotating wind turbine blade within its mechanical limitations in both region 2 and region 3.

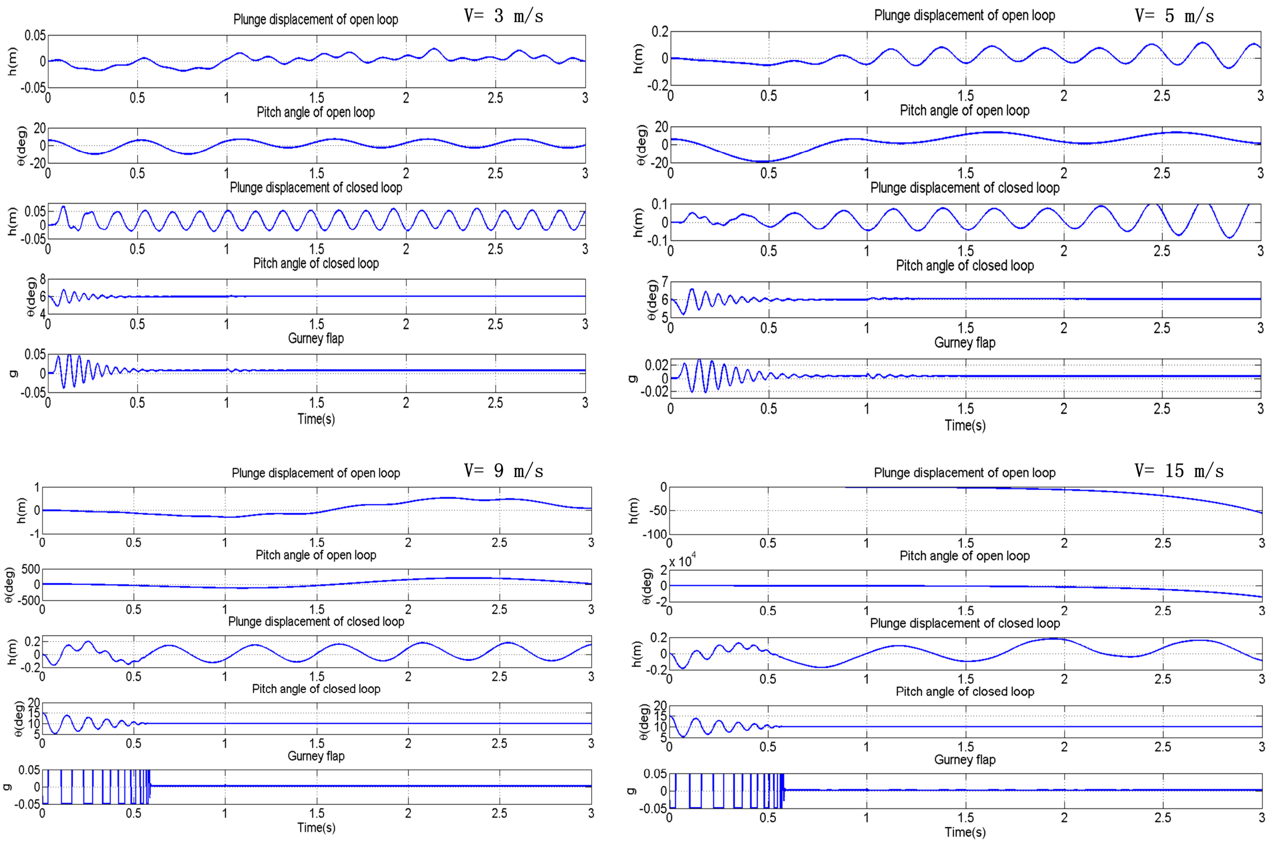


**Figure 2.** Open-loop, closed-loop responses of plunge displacment and pitch angle, and response of gurney flap.

## References


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[3] Kuik, T.K. Barlas and Van G.A.M., “Review of state of the art in smart rotor control research for wind turbines”,1, s.l. : Elsevier, January 2010, Progress in Aerospace Sciences, Vol. 46, pp. 1-27.