Active control of self-excited roll oscillations of LAR wings

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Extended Abstract

The vortex induced limit-cycle rotary oscillation of wings is often referred to as 'wing rock' [1]. Early studies of wing rock focused on slender delta wings [2,3]. Recent experimental investigations on relatively higher aspect ratio (AR = 2 and 4) rectangular flat plate wings suggested that, even at pre-stall incidences, self-excited roll oscillations occur [4,5]. Previous studies of suppressing the slender wing rock have been conducted by applying both passive [6] and active [7-10] flow control techniques. It has been found that the active techniques, which can often be regarded as steady or periodic addition of momentum that affects the boundary layers and shear layers [11], tend to be more effective [1]. This paper reviews our recent works on the suppression of the self-induced roll oscillations of LAR rectangular wings using active flow control techniques. Both acoustic excitation and synthetic jet blowing were used to attenuate the self-excited roll oscillations. The experiments were conducted in a closed-loop wind tunnel located at the Department of Mechanical Engineering of the University of Bath. Three rectangular wings, of flat plate, NACA0012 and SD7003-085-88 profiles, with an aspect ratio of $AR = 2$ were tested. Quantitative flow measurements were undertaken using two different PIV systems, a TSI 2D-PIV system for time-averaged and phase-averaged velocity measurements and a TSI high frame rate PIV system for the spectral features of the shear layer separated from the leading edge. It was found that roll oscillations can be completely suppressed and the onset of the roll oscillations can be delayed by active flow control approaches (Figs. 1 and 2). PIV measurements indicated that the excitations could restore a symmetric vortex flow over the free-to-roll wings thus stabilizing the self-excited roll oscillations.

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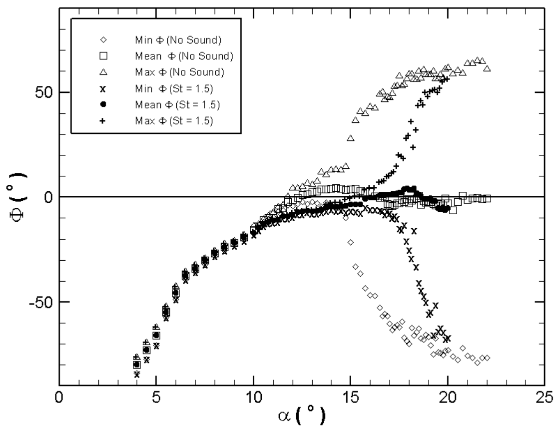

Fig. 1 Variation of roll angle with angle of attack for the flat plate wing with *AR* = 2 without and with acoustic excitation at *St* = 1.5.

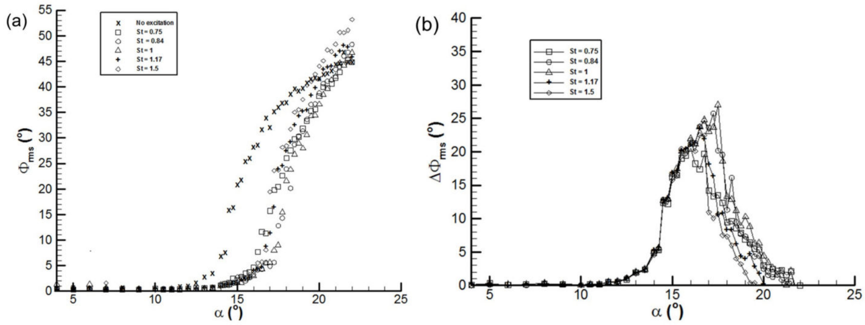

Fig. 2 (a) RMS values of free-to-roll flat plate wing roll angle as a function of angle of attack without and with synthetic jet excitation; (b) Reduction of RMS values of the roll angle as a function of angle of attack.