Study of an Oscillating Blade from Stable to Stalled Conditions

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The prediction of the dynamic characteristics of turbomachinery blades is still a challenging problem despite the progress in both experimental techniques and numerical simulation tools. In this paper, an effort is presented aiming at understanding the relationship between changes in the incidence of vibrating blades and the corresponding aerodynamic loads.

Wing tunnel measurements of the pressure on the suction side of an oscillating blade (NACA63-006) at an inlet Mach number of 0.5 and Reynolds' number of 850,000 have been performed[1, 2, 3]. Oscillation frequencies varied from 60 to 210Hz while the amplitude of oscillation was kept constant. The mean incidence was also varied between 0° to 10°. The time-dependent pressure measurements show that the aerodynamic loads are not linear for the near stall region. It was found that an increased mean incidence caused a higher excitation of the blade from the aerodynamic forces, while the effects of varying the blade's amplitudes and frequencies were more difficult to determine. At 6° mean incidence, and below, increased blade amplitude for a constant frequency caused the blade suction surface to experience an increased excitation, while for the 7° incidence, and above, the opposite was shown. The fact that the blade amplitude dependence changes when the mean incidence increases above the steady state stall angle is explained by the increased portion of the oscillation cycle spent at stalled conditions[4, 5]. A shift in phase was seen for the highest investigated frequency of 210Hz.

The PMB solver of the University of Glasgow was also employed for calculating the flow at the same conditions [6]. Indicative results are presented in Figure 1 where the pressure signals from three taps are compared against CFD predictions. As can be seen, the overall agreement is fair predicting the variation of the loads both near the leading and trailing edges of blades, as well as, close to the pivot point. This good agreement also indicates that the

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unsteady pressure and the incidence angle are in phase during the oscillation. This can be seen from the stability diagram of Figure 2 where both experimental and CFD results are processed via Fast Fourier Transformation. The same good agreement holds for a frequency of 110Hz while it collapses at the highest frequency (220 Hz) attempted during experiments. For this case experiments indicate that the pressure and incidence are out of phase while CFD indicates the opposite; the phase difference is about 180 degrees as shown in Figure 3. Further CFD investigations have been undertaken in order to resolve this issue and detailed results will be presented in the final paper.

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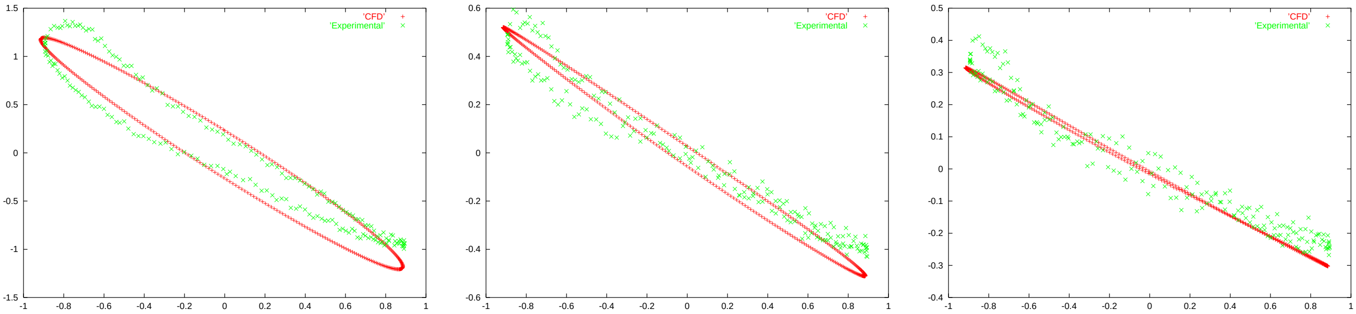

(a) (b) (c)

Figure 1: Comparison between experiments and CFD for the pressure history on the suction side of the blade (f=60Hz, M=0.5, $Re = 850 \times 10^3$, mean incidence 0°, amplitude of oscillation 0.6° RMS) (a) $x/c = 0.15$, (b) $x/c = 0.46$, (c) $x/c = 0.7$.

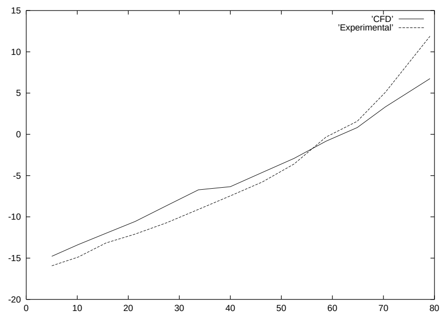

Figure 2: Comparison between experiments and CFD for the phase difference between incidence and pressure (f=60Hz, M=0.5, $Re = 850 \times 10^3$, mean incidence 0°, amplitude of oscillation 0.6° RMS).

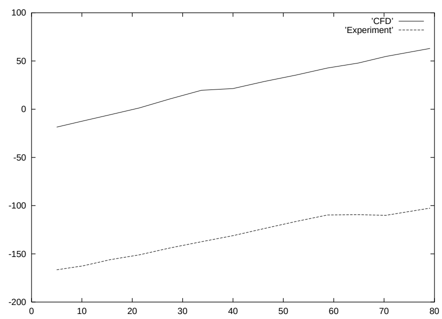

Figure 3: Comparison between experiments and CFD for the phase difference between incidence and pressure (f=210Hz, M=0.5, $Re = 850 \times 10^3$, mean incidence 0°, amplitude of oscillation 0.6° RMS).