Wake of an Oscillating Airfoil

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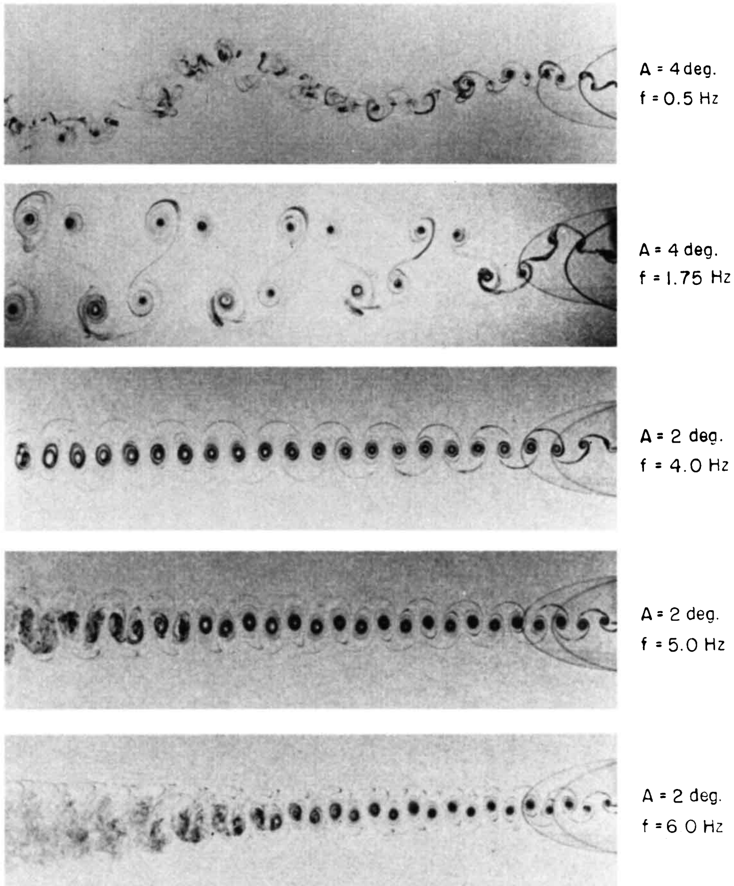

Figure 1

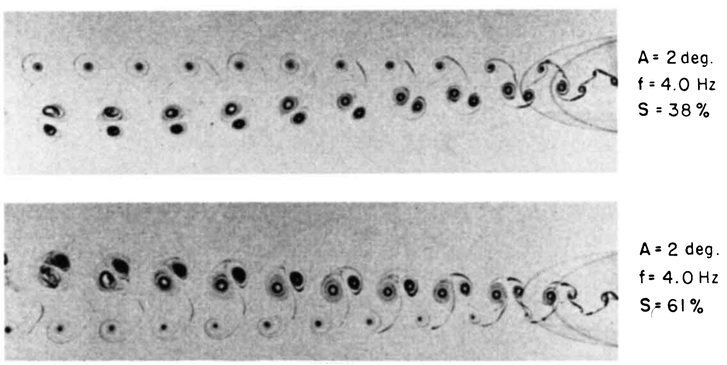

Figure 2

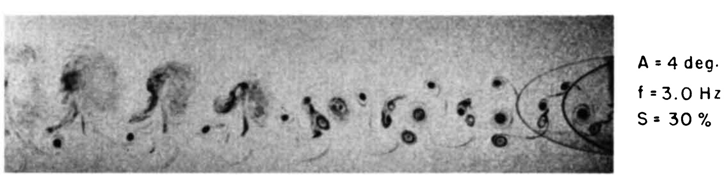

Figure 3

WAKE OF AN OSCILLATING AIRFOIL

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These pictures show the vortical flow patterns in the wake of a NACA 0012 airfoil performing small-amplitude pitching oscillations around the quarter-chord point in a low-speed water channel.[9] The mean angle of attack, the amplitude A, the frequency f, and the shape of the oscillation waveform are independently controlled. In the cases shown here, the airfoil chord is $C = 8$ cm and the freestream velocity is $U_\infty = 15$ cm/sec resulting in a chord Reynolds number of 12 000 and a reduced frequency of $k = 2\pi f C/2U_\infty = 1.67\ (f/\text{Hz})$. The flow is from right to left and the downstream distance visible on the photographs corresponds to approximately 5.5 chord lengths. The mean angle of attack has been set to zero so that the angle of attack of the airfoil varies between $-A$ and A. The effect of the nonsinusoidal oscillation waveform is demonstrated here in terms of a parameter, S, which is the percentage of a period (in one cycle) required to reach the maximum amplitude starting from the minimum amplitude. When $S = 50\%$ the waveform is sinusoidal, whereas a value of S larger (smaller) than 50% corresponds to a slower (faster) rate of pitch-up than pitch-down.

The sequence of pictures in Fig. 1 shows the dependence of the wake structure on the oscillation frequency for a sinusoidal ($S = 50\%$) pitch waveform. The shape of the pitch waveform has a strong effect on the vortical patterns in the wake (see Fig. 2). A variety of complex vortex–vortex interactions can be generated when the waveform is nonsinusoidal. For example, in Fig. 3 note how the single vortex on top goes through the wake and ends up on the bottom unscathed.