Flow control for vortex shedding of a circular cylinder based on a steady suction method

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Abstract: In this study, a suction flow control method was employed to suppress the vortex shedding of a circular cylinder based on a multi-point suction type. A digital particle image velocimetry (PIV) system was used to conduct detailed flow field measurements under different suction flow control conditions; and a digital pressure measurement system based on the model DSA3217 pressure scanner (Scanivalve Corporation) was simultaneously used to measure the pressure distribution on the test models. Five steady suction flow rates of 20, 40, 60, 80 and 95 L/min were employed to in the testing. The suction control effects were first investigated under four angles (90.0, 112.5, 135.0 and 157.5 degree) of the suction holes; then two test models with different suction hole space arrangements with the suction hole angle of 90.0 degree were studied; at last, the effects of the suction flow control along the axial direction of the test model were investigated. The mean and fluctuating pressure coefficients, the lift and drag coefficients, the mean velocity fields of the circular cylinder and the mean velocity profiles in the wake under the suction flow control were then analyzed. The results indicated that the steady suctions exhibited excellent control effects and could dramatically reduce the fluctuations of lift coefficients and the averages of the drag coefficients and distinctly suppress the alternating vortex shedding (changing into symmetric mode) at the suction hole angle of 90.0 degree. At other three angles of suction holes, the suction flow control behaves little effect. The model 2 with a smaller space arrangement of suction holes behaves a more efficient control effect than that of model 1 with a sparse space arrangement of suction holes. The control effects of the suction along the axial direction of the model are not uniform and the control effects are improved from the section without suction to the suction section.

Keywords: Circular cylinder, vortex shedding, flow control, steady suction, PIV, pressure distribution

Experimental Setup and PIV System

The experimental study was conducted in a closed-circuit low-speed wind tunnel located in the Aerospace Engineering Department of Iowa State University. The tunnel has a test section with a 1.0×1.0 ft cross section and the walls of the test section are optically transparent. The tunnel has a contraction section upstream of the test section with honeycombs, screen structures and a cooling system installed ahead of the contraction section to provide uniform low turbulent incoming flow into the test section. The standard deviation of velocity fluctuations at the test section entrance was found to be about 0.8% of the free-stream velocity, measured by using a hotwire anemometer. The test model used in the present study was a circular cylinder. The circular cylinder had a diameter d=0.0508 m and a width equal to the test section width. Its roots were mounted on two sides of the wind tunnel wall. During the experiments, the wind-tunnel speed was adjusted to 8.0m/, which corresponds to a Reynolds number $\mathrm{Re} = 2.8\times10^4$.

Figure 1 shows the schematic of the experimental setup used in the present study for the two-dimensional PIV measurements. The flow was seeded with 1~5 μm oil droplets.

Illumination was provided by a double-pulsed Nd:YAG laser (New Wave Gemini PIV 120-15) adjusted on the second harmonic and emitting two pulses of 120 mJ at the wavelength of 532 nm with a repetition rate of 8 Hz. The laser beam was shaped to a sheet by a set of mirrors, spherical and cylindrical lenses. The thickness of the laser sheet in the measurement region is about 1.0 mm. The high-resolution 12-bit (1376 x 1040 pixel) CCD camera (SensiCam, CookeCorp) were used to perform two-dimensional PIV image recording. In the present study, the distance between the laser sheet and image recording plane of the CCD camera is about 1000 mm. The CCD camera and double-pulsed Nd:YAG lasers were connected to a workstation (host computer) via a Digital Delay Generator (Berkeley Nucleonics, Model 565), which controlled the timing of the laser illumination and image acquisition.

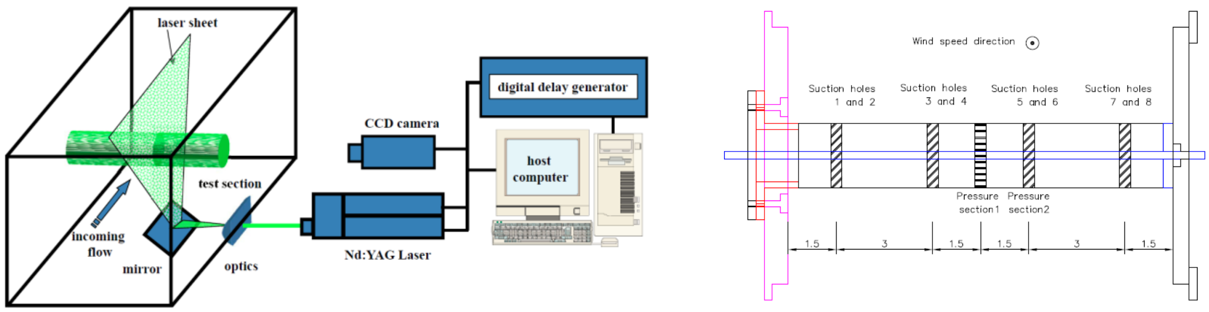

Figure 1: Schematic of the experimental setup

Experimental Results and Discussions

Figure 2 shows the instantaneous vorticities at different suction flow rates with a suction angle of 90 degree, respectively. The results indicate that the suction flow rate lager than 20L/min behaves good control effect, but when the suction flow rate exceeds 40 L/min the control effect tends to be steady. Extensive discussions about the measurement results to elucidate underlying physics will be given in the full version of the paper.

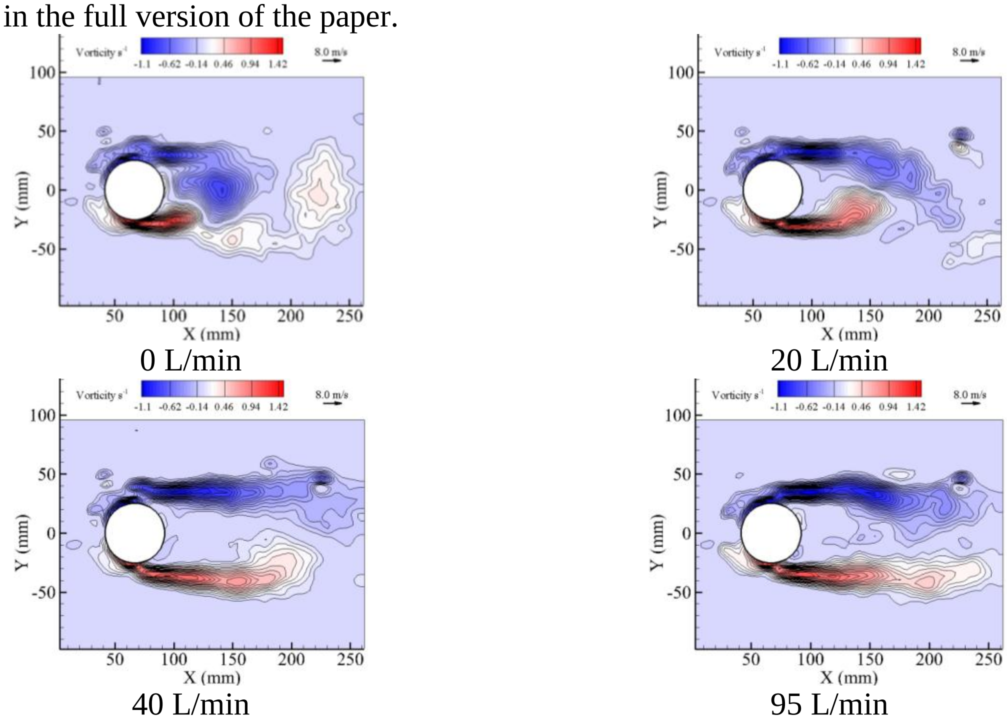

Figure 2: Instantaneous vorticity at different suction flow rates with a suction angle of 90 degree