Flow around a Circular Cylinder in a Converging or Diverging Rectangular Working Section

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NOTE

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As is well known, the laminar twin vortices with a finite length are formed behind a circular cylinder at low Reynolds numbers, when the cylinder is placed in a parallel and uniform basic flow[1]. For the case connected with non-parallel basic flows, however, it seems clear that there yet remains many unsettled questions. This short report presents the result of a preliminary experimental investigation of the effect of convergence or divergence of the basic flow on the steady flow pattern of a circular cylinder.

The experiment was carried out using a 40 cm × 38 cm × 200 cm water tank. Photo. 1 shows the front view of the experimental apparatus. A specially made rectangular working section (channel system) equipped with a test circular cylinder was attached to a carrier as shown in Photo. 1, and made to move with constant velocity in the water tank. Two plane side walls (30 cm in flow direction length, and 27 cm in vertical width) of the working section consisted of a transparent plastic sheet whose leading edge was sharpened. The side walls were held vertically between an upper and a lower horizontal 30 cm × 30 cm end plates using small junction bolts; an upper and a lower points of the middle of the side walls were connected with the horizontal end plates by keeping a transverse width of 27 cm. As illustrated in Fig. 1, an angle θ made between the direction of motion of the channel system and that of each side wall (thus meaning the angle of attack) could be varied about a vertical axis within $\theta=\pm 15°$, where + sign indicates a converging working section, and − sign a diverging one as also shown in Fig. 1.

The test cylinder was an ebonite rod of 1.00 cm in diameter and 30.0 cm long. It was placed vertically near the center of the working section by fixing its both ends to the horizontal end plates. By the use of the set-up described above in somewhat detail it was possible to establish the diverging, parallel, or converging basic flow in which the test cylinder was immersed automatically. The flow velocity varied along the flow direction necessarily when $\theta \neq 0$. The precise measurement of the channel-flow velocity distribution was not made in the present work.

The fluid motion was visualized by using the aluminum dust method. A 1 kw

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slide projecter was used for illumination of a horizontal sheet of water containing a number of aluminum dusts. Many photographs of vortices behind the test cylinder were obtained at various values of θ and low Reynolds numbers.

Photo. 2 (a-f) shows the flow patterns at the Reynolds number of about 24 when θ is varied. It should be remarked that the Reynolds number R is here defined as U_0d/ν, where U_0, d, and ν are the cylinder speed, the cylinder diameter, and the kinematic viscosity respectively; namely, U_0 is not the precise basic flow velocity in the vicinity of the test cylinder. The photographs show clearly that the vortex length is reduced in the converging flow, and on the contrary increased in the diverging one. In the diverging flow for large $|\theta|$, two vortices forming a pair are fairly elongated and the vortex region extends far downstream as will be seen from Photos. 2 (e) and (f). In these flow patterns the center of the vortices can no longer be settled definitely.

To show the effect of convergence or divergence of the basic flow on the cylinder wake at somewhat larger values of R, two examples of the flow pattern are presented in Photos. 3 (a) and (b). The former indicates that the wake region is reduced considerably in the converging flow, although R is more than twice that for the latter showing the wake in the diverging one. Photos. 4 (a), (b) and (c) show the top view of the whole flow pattern.

The measured vortex length of the test cylinder is plotted against the Reynolds number in Fig. 1. The flow direction length S of vortices is non-dimensionalized based on the cylinder diameter. For comparison the $S/d-R$ relationship for the case

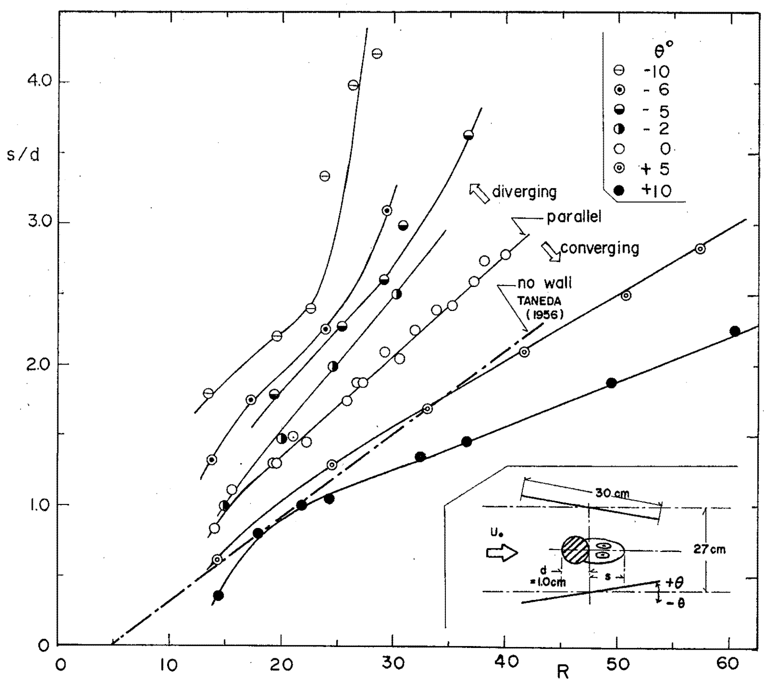

Fig. 1. The vortex length plotted against the Reynolds number.

of no channel walls is also reproduced from the experimental result obtained previously by Taneda[1]. As is evident from this figure, the measured value of S/d for the case of parallel flow lies considerably above Taneda's curve for the case of no channel walls. This may be interpreted as due to the effect of the walls on the length of the vortices. As stated before, there is the general tendency that S/d is decreased in the converging flow, and on the contrary increased in the diverging flow. The value of S/d is also increased with R for each θ. In the extreme case, the length of the vortex region increases rapidly and indefinitely as R increases. The curve for $\theta=-10°$ is a good example of such a case.

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Reference

1) S. Taneda: J. Phys. Soc. Japan 11 (1956) 302.

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