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Discussion

Separation Points on a Cylinder in Oscillatory Flow[1]

M. M. ZDRAVKOVICH.[2] Professor Sarpkaya has carried out enormous fundamental and applied research of oscillatory flows over more than two decades. This time he and his co-author focused attention on the elusive separation point which travels around the cylinder perimeter during the acceleration, deceleration and reversal of the flow. The meticulous measurements revealed a surprisingly regular and repeatable displacement of the separation point from cycle to cycle, despite the fact that during acceleration the vortices are being formed and becoming stronger, while during the deceleration the vortices rapidly diffuse and dissipate in a rather haphazard manner.

My first question concerns the initiation of the separation (point). At which K number is the separation first observed and at what time during the oscillatory cycle?

The second question is related to a symmetric separation on two sides of the cylinder at $K = 5$. The authors attributed this symmetry to a high Reynolds number. However, in 1976, Sarpkaya measured a considerable lift coefficient at $K = 5$ for $\beta = 3123$, which is comparable to $\beta = 3233$ in the present paper.

Sarpkaya and Isaacson (1981) wrote:

> "At $K = 4$, there is only a 5 percent chance that the asymmetry will appear for very short periods of time. Experiments by Sarpkaya (1976) have shown that there is a 90 percent chance that the asymmetry will appear at $K = 5$."

Surface flow visualization has confirmed wake asymmetry in progressive waves, Zdravkovich and Namork (1977). Hence, the question is, what has happened with the asymmetry of separation points at $K = 5$?

The third and penultimate question may be taken as a comment. The authors amply emphasized that there is no relation between the measured drag coefficient and separation point travel. This finding seems to be analogous to the constant separation angle at about 80 deg in the range $2000 < \text{Re} < 20000$, while the drag coefficient in the uniform flow increases from 0.8 to 1.2. The rise in drag coefficient is accompanied by a drastic reduction in the length of the formation region; see Zdravkovich (1989). If there is an analogy between the uniform and oscillatory flow, it may be hypothesized that the reduction of drag coefficient $C_D = 0.86$, 0.72, and 0.66 for $K = 20$, 30, and 40, respectively, could be caused by the change in location of the forming vortex behind the cylinder. The latter is seen in Fig. 9 to be very close to the cylinder, but it is not given for $K = 20$, 30, and 40 in the paper.

The last question concerns the puzzling K-independence of the separation travel for roughened surface cylinders—whether in that case the boundary layer becomes turbulent during some stage of the oscillatory cycle?

Finally, the authors should be congratulated for an excellent paper dealing with unsteady separation, still the least explored area of fluid mechanics. All the readers are looking forward to the second installment on spanwise variation of separation.

References

Sarpkaya, T., and Isaacson, M., 1981, *Mechanics of Wave Forces on Offshore Structures*, Van Nostrand Reinhold Co., New York, p. 105.

Zdravkovich, M. M., and Namork, J. E., 1977, "Formation and Reversal of Vortices Around Circular Cylinders Subjected to Water Waves," ASCE, WW3, *Journal of Waterways, Harbours and Coast Engineering*, Vol. 103, pp. 378–383; Discussion by S. K. Chakrabarti, 1978, Vol. 5, ASCE, WW2, pp. 259–260.

Zdravkovich, M. M., 1990, *Bluff Body Aerodynamics and its Applications*, eds., M. Ito et al., Elsevier, Amsterdam, pp. 53–62.

Author's Closure[3]

The smallest K at which separation occurs cannot be determined experimentally. It was generally assumed, on the basis of Blasius' well-known solution of the impulsively started flow about a circular cylinder, that separation might not occur in oscillating flows below a finite K. Our current view, supported by numerical analyses (Justesen, 1991; Sarpkaya and Dalton, 1992, just to name two) is that separation *does not occur at all* K *values*. Additional numerical work with smaller grids and time steps might shed further light on the time of incipient separation. It must be noted that even for simpler flows, such as an impulsively started steady flow, there are a number of unresolved questions regarding the existence of a direct relationship between the loss of convergence of the numerical schemes and the onset of separation in the form of a spontaneous *breaking away of unsteady flow from the surface*; see, e.g., Sarpkaya (1990a). Additional work and ingenuity are needed.

The apparent symmetry of the separation points near $K = 5$ is a fact deduced from direct measurements (within ± 3 deg), not inferred from the lift force or the wake asymmetry. The lift is neither very sensitive to nor a direct measure of the separation-point excursions and asymmetries. If, in steady flow, one were to consider only the separation-point excursions (± 3 deg), one would have inferred very little or no lift force. Similarly, if one were to consider only the measured life, one would have inferred large separation-point excursions. It is an experimental as well as numerical fact (see, e.g., Sarpkaya and Shoaff (1979)) that there is no simple relationship between the

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