Flow around a Circular Cylinder at the Critical Reynolds Number Regime

TATSUNO, Masakazu
Research Institute for Applied Mechanics Kyushu University

MAEKAWA, Satoru
Kawasaki Heavy Industries, Ltd.

ISHI-I, Koji
Research Institute for Applied Mechanics Kyushu University

KARASUDANI, Takashi
Research Institute for Applied Mechanics Kyushu University

他

https://doi.org/10.15017/6768591

出版情報：九州大学応用力学研究所所報. 122, pp.73-75, 2002-02. Research Institute for Applied Mechanics, Kyushu University
バージョン：

Flow around a Circular Cylinder at the Critical Reynolds Number Regime

Masakazu TATSUNO*1, Satoru MAEKAWA*2, Koji ISHI-I*1 ,
Takashi KARASUDANI*1 and Hajime AMAMOTO*1
E-mail of corresponding author: *tatsuno@riam.kyushu-u.ac.jp*
(Received December 27, 2001)

Abstract

Flow around a circular cylinder has been examined over the Reynolds number range 10^5 to 5×10^5.
The static pressure distributions around the circumference of the cylinder were measured, and the flow patterns were visualized by means of smoke injection method.

Key words : *A circular cylinder. Critical Reynolds number, Laminar separation bubble, Flow visualization*

1. Introduction

The flow around a circular cylinder at Reynolds numbers larger than 10^5 can be classified into four different regimes : subcritical, critical, supercritical and transcritical [1]. In the critical regime, in general, the boundary layer separates in a laminar state and is followed by turbulent reattachment and eventual turbulent separation. Bearman[2], however, reported that a laminar separation bubble was formed on one side only of the cylinder and the cylinder experienced a lift force over a narrow range of Reynolds number before twin laminar bubbles appeared symmetrically on both sides. The appearance of a one sided laminar separation bubble was confirmed by Kamiya[3], Uzuki[4], Farell & Blessmann[5] and Schewe[6] et al.

The purpose of this investigation is to examine closely the flow around a circular cylinder in the critical Reynolds number regime.

2. Experimental apparatus and method

The experiments were carried out in a closed-circuit wind tunnel with a test section 4m wide, 2m high and 6m long. A circular cylinder was hollow vinyl chloride tubes of 42.0cm external diameter, and spanned the vertical 2.0m dimension of the tunnel.

End plates were situated at both sides of the cylinder. The blockage ratio of the test cylinder to the tunnel breadth was 0.105, and the measured values of velocities, drag and lift forces were corrected according to the method by Allen & Vincenti shown in the reference[1].

The surface of the cylinder was coated with several layers of lacquer and finally polished.

The static pressure around the circumference of each cylinder was measured by forty-eight pressure-tapping holes of diameter 0.5mm at 7.5° intervals at middle span of each cylinder. The pressure-tapping holes and inductance type pressure transducers were connected with flexible tubes. The resulting pressure distributions were integrated to determine the drag and lift forces for each cylinder.

The smoke injection method was used in order to visualize the flow patterns around the cylinder.

3. Results

Fig. 1 shows representative mean pressure coefficients, $C_p=(p-p_0)/0.5\rho U^2$, as functions of θ at several Reynolds numbers, where p is the mean pressure at angular location θ on the cylinder surface from the stagnation point($\theta=0°$), p_0 is the undisturbed stream pressure, ρ is the mean density of the flow and U_0 is the uniform flow velocity.

In the subcritical regime, the boundary layer separates in a laminar state, and the mean pressure distributions around a cylinder are symmetric, as will be seen from the pressure distributions at $Re=2.21\times10^5$ and 3.48×10^5 in Fig.1.

*1 Research Institute for Applied Mechanics, Kyushu University
*2 Kawasaki Heavy Industries Co. Ltd.

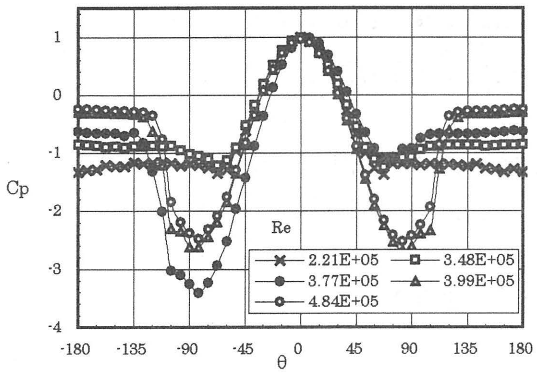


Fig.1 Pressure distributions

The pressure distribution at $Re=3.77\times10^5$ is asymmetric. In this case, a laminar separation bubble is formed on the side $\theta<0$ only, and the cylinder experiences a lift force directed to the side where the bubble is formed.

A single laminar separation bubble is formed on one side or the other side of the cylinder without preference and, in some cases the side where the bubble is formed changes intermittently.

When a bubble is formed on one side only of the cylinder, the forward stagnation point, where the value of Cp is equal 1.0, moves about 5 degrees along the side opposite to that where the bubble is formed.

The pressure distributions at $Re=3.99\times10^5$ and 4.84×10^5 are symmetric. In these cases, laminar separation bubbles are formed symmetrically on both sides.

Figure 2 shows the relationship between the drag and lift coefficients and Reynolds numbers. As mentioned above, when a bubble is formed on one side only of the cylinder, the cylinder experiences a lift force.

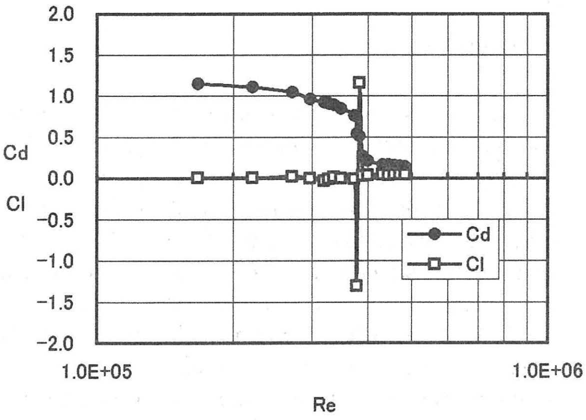
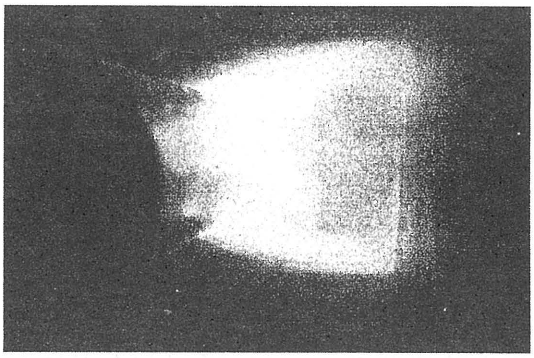
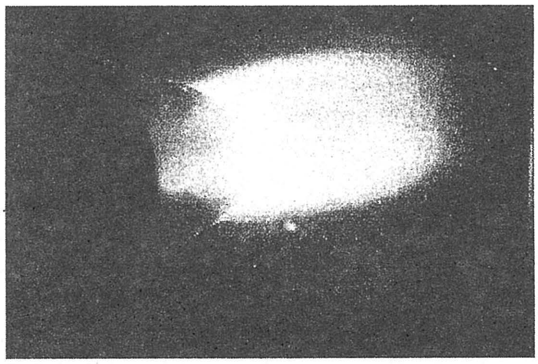


Fig.2 Variations of the drag and lift coefficients with Reynolds numbers

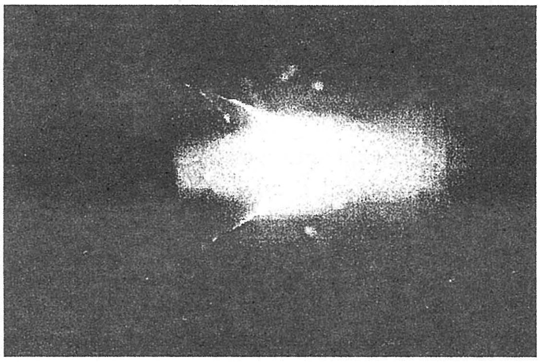
Figure 3 shows three representative flow patterns visualized by means of the smoke injection method. In all cases, the direction of the uniform flow is from left to right. Fig.3(a) shows the flow pattern at $Re=3.53\times10^5$ and the boundary layer of the cylinder separates in a laminar state. Fig.3(b) shows the flow pattern when a laminar separation bubble is formed on one side only of the cylinder at $Re=3.67\times10^5$. In this picture, a bubble is formed on the right-hand side of the cylinder as viewed from the front. It will be seen that the wake inclines transversely. Fig.3(c) shows the flow pattern when laminar separation bubbles are formed on both sides of the cylinder at $Re=4.89\times10^5$.



(a) $Re=3.53\times10^5$



(b) $Re=3.67\times10^5$



(c) $Re=4.89\times10^5$

Fig.3 Flow patterns around a cylinder.

4. Conclusion

The flow around a circular cylinder has been examined in the critical Reynolds number range.

The static pressure distributions around the circumference of the cylinder were measured, and the flow patterns were visualized by means of smoke injection method.

References

1) Roshko, A. : Experiments on the flow past a circular cylinder at very high Reynolds number, J. Fluid Mech. Vol.10, (1961) 345-356.

2) Bearman, P. W. : On vortex shedding from a circular cylinder in the critical Reynolds number regime, J. Fluid Mech. Vol.37, part 3(1969) 577-585.

3) Kamiya, N., S. Suzuki and R. Nishi : On the aerodynamic force acting on circular cylinder in the critical range of the Reynolds numbers, AIAA Paper, 79-1495, Williamsburg (1979) .

4) Uzuki, H. : on lift-coefficient of circular cylinder in two-dimensional flows, Trans. Japan Soc. Aero. Space Sci. Vol.25, No.67 (1982) 53-64.

5) Farell, C. and J. Blessmann : On critical flow around smooth circular cylinders, J. Fluid Mech. Vol.136 (1983) 375-391.

6) Schewe, G : On the force fluctuations acting on a circular cylinder in crossflow from subcritical up to transcritical Reynolds numbers, J. Fluid Mech. Vol.133 (19839 265-285.