On the critical Reynolds number of the drag coefficient for a circular cylinder

T. Matsui

Dept. of Mech. Eng., Gifu University,

ABSTRACT

Drag coefficient of a circular cylinder in a uniform flow shows a steep fall when the Reynolds number increases from about 3.0×10^5 to about 3.8×10^5 in our experiments. At about Re = 3.6×10^5, the drag coefficient curve is not continuous , but has a jump, and also a lift force actually acts on the cylinder. This phenomenon results from the sudden and asymmetric appearance of separation bubbles on both sides of the circular cylinder. The asymmetric formation of separation bubbles is the origin of lift. The Reynolds number , Re = 3.6×10^5, is appropriately called the critical Reynolds number for the drag coefficient of a circular cylinder .

Key Words: critical Reynolds number , drag coefficient, lift coefficient, separation bubble

1. Introduction

The steep decrease at large Reynolds numbers in the drag coefficient curve will be described in connection with separation bubbles. A new definition of the critical Reynolds number will be proposed by referring to the experimental results by Ohkura and Okude [(1)] .

2. The discontinuity of the drag coefficient and the generation of lift

The drag coefficient, C_D and the lift coefficient C_L, are shown in Fig. 1 against Reynolds number . We can see a discontinuity or a jump in the C_D curve at about Re = 3.6×10^5 and at about the same Re number , we can see generation of lift, the value of which is not constsnt and it is shown that generation of lift [(2)] [(3)] is a atochastic phenomenon.

3. The pressure distribution on the surface of a cylinder

The pressure distributions on a circular cylinder are shown at different Reynolds numbers , Re = 2.0×10^5 , 3.6×10^5 and 5.0×10^5 and for the frictionless flow, in Fig. 2.

The upward arrows in the figure show the separation of the boundary layer from the cylinder surface., and the downward arrows show the reattachment of the separated shear layer to the cylinder surface. Small steps in the curves show the separation bubbles on the cylinder surface. The pressure distribution at Re = 3.6×10^5 shows that the generation of a separation bubble leads to the delay of the separation of a turbulent boundary layer, which occurs about 130 degrees from the front stagntion point., resulting to the low drag.

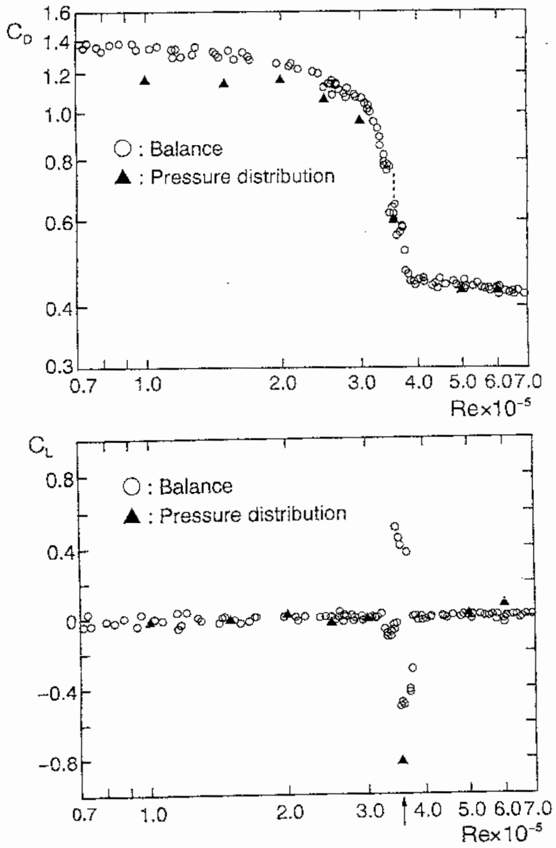

Fig .1 Drag coefficient and lift coefficient

4. Stochastic appearance of separation bubbles

The surface pressure at two points, 90 and 270 degrees from the front stagnation point, was recorded when the uniform velocity was continuously increased from Re = 3.2 × 10^5 to 3.9 × 10^5 during about 100 seconds. The measured results are shown in Fig.3 . This is an example of forming process of a separation bubble.

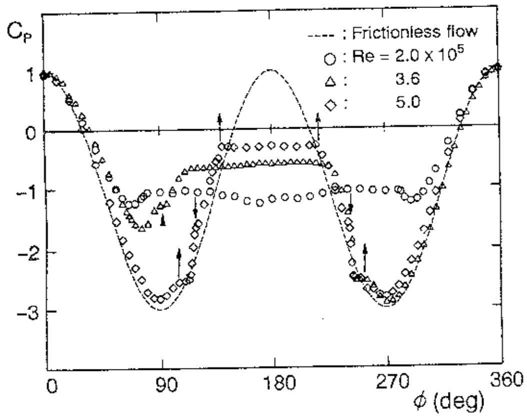

Fig .2 Pressure distribution on the surface of a circular cylinder in a uniform flow

The pressure at 270 deg. suddenly dropped at about Re = 3.6 × 10^5. It shows a jump in the drag coefficient curve and also generation of lift This phenomenon shows the fact that the reattachment of separated shear layer to the cylinder surface, in other words , the generation of a separation bubble is a stochastic process. The duration of the pressure difference or the life time of the asymmetric separation bubbles is short. This fact is seen in Fig. 1, too.

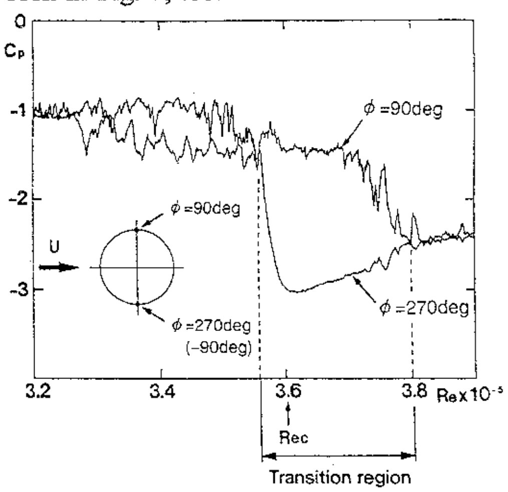

Fig. 3 .Continuous chang of the surface pressure at 90 and 270 degrees from the front stagnation

Therefore, the Reynolds number for the lowest pressure, Re = 3.6 × 10^5, may be taken as the representative value of the transient, critical condition.

5. Summary

At about Re = 3.6 × 10^5, separation bubbles were suddenly formed on a surface of a circular cylinder, as a result, drag was reduced and lift was generated. It is suggested that the Reynolds number is called the critical Reynolds number for drag coefficient of a circular cylinder in uniform flow.

References

1. Ohkura, N.. and Okude, M.: Aero. and Space Sci. Japan **45** (1997),pp. 267-276.

2. Bearman,P.W. : J.F.M.、**37,** (1969),pp.577-585.

3.Kamiya,N. Suzuki,S. Nakamura,M .and Yoshinaga,T. : The 13th Congr. of Internat. Coun. Aero. Sci. (1980), pp. 417-428.