Proceedings of the Eighth (2008) ISOPE Pacific/Asia Offshore Mechanics Symposium
Bangkok, Thailand, November 10-14, 2008

ISBN 978-1-880653-52-4

Flow Control behind a Circular Cylinder by Control Rods in Steady Flow

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ABSTRACT

Flow control that attached different sized control rods to the rearward stagnation point of a circular cylinder was carried out in a circulating water channel by PIV technique. Reynolds numbers varied from Re≒5,000, 10,000, 15,000, 20,000 to 25,000 based on the main circular cylinder diameter(D=50mm). Wake velocity distributions were measured with varied control rods and Reynolds numbers. The measured results were compared with each other. The results indicated that the flow control by rods has different effects according to the change of inflow. Strong time mean turbulence intensity appeared within X/D=3.5. The control rod, d/D=0.3 has an outstanding effect to reduce the turbulence intensity around the circular cylinder.

KEY WORDS: Flow control; Circular cylinder; Ocean buoy; PIV; Control rod; Velocity field; Turbulence intensity

INTRODUCTION

The quantity of goods transported at sea has been increasing at the rate of 67% over the last decade due to faster transportation systems and the free trade agreement between countries. There is also a growing potential for marine accidents due to the high density traffic, strong currents and scattered littoral islands. Thus the steady demands on marine buoys also have been increased with the need for improvement of safety at sea. For the sake of safety, the buoy system must be accuracy and have stable performance and position stability. To meet these demands, hydrodynamic research has been conducted in various areas to develop safe and trustworthy systems.

Within the IALA (International Association of Marine Aids to Navigation and Lighthouse Authorities) Buoyage System, there are five types of navigational marks; lateral, cardinal, isolated danger, safe water and special marks, which may be used in different combinations. The system may be composed entirely of a single circular cylinder and a long mooring anchor cable. Its two-dimensional formation under the free surface looks upon a circular cylinder. The flow around the circular cylinder is closely related to many practical applications, such as offshore risers, bridges, piers, and buoys.

The purpose in having a control rod on a buoy system is to control the motion of it. The control rod has one necessary function needed to meet its purpose, which is to develop the control force in consequence of its orientation and movement related to the water. As a result, the control rod makes it possible to control hydrodynamic actions on the buoy. In particular, drag reduction is closely related to the motion of the bodies. So, it is necessary to predict, measure and control the flow around them. Drag force acting on a body might be reduced by changing the near wake. The flow control for drag reduction is very important in practical applications and basic researches.

The buoy system seen in Fig. 2 had a stabilizer that looks like a single rudder and has some brackets to connect the upper floating body to the submerged circular cylinder. The buoy system is supposed to get much of fluid resistance forces caused by the appendages.

The fact that the drag is larger for the oscillatory wake than the symmetric wake is interpreted as a tendency toward an equilibrium state of maximum energy dissipation (Jordan and Fromm (1972). It is noted (Lee and Park, 2004) that the drag coefficient of the main circular cylinder decreases about 29% when a control rod (d/D=0.233) is installed at a pitch ratio close to the critical value of $L_C/D=2.081$. The vortices start to shed from the control cylinder are found to obey the relation $L_C/D=1.5+0.083d$.

To control the flow around a circular cylinder in air-stream, a rod was set upstream of the circular cylinder in raging Re=15,000 to Re=62,000. The optimum conditions of the drag reduction are d/D=0.25, L/D=1.75-2.0. The reduction of the drag including the drag of the rod is 63% compared with that of a single cylinder (Tsutsui and Igarashi, 2002).

To control the flow around a square prism, the flow patterns should be changed at the critical gap(G_C) or critical distance(L_C) between a square prism and a control rod is given as $G_C/d=D/d+4.5$, $L_C/d=1.5(D/d)+5.0$. The added drag of the control rod is less than 10% of the reduced drag of the prism (Igarashi, 1997).

Tsutsui, Igarashi and Kamemoto(1997) investigated the interactive flow around two circular cylinders of different diameters at close proximity by vortex method. The drag coefficient decreases with increasing the location of the small cylinder. The value of C_D is higher than that of the single cylinder because the approaching flow to the