

Hydrodynamic Interaction Between a Fixed and a Floating Cylinder

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ABSTRACT

Hydrodynamic interaction between a fixed circular cylinder and freely floating cylinders is studied experimentally in the present paper. Six different moving cylinders are used with circular, square and rectangular cross-sectional shapes of various dimensions. Investigation is concentrated on the force acting on the fixed cylinder and motion of the floating cylinder. Comparison of the measured velocity of the moving cylinder shows reasonable agreement with the results of the potential flow model. However, the force on the fixed cylinder is somewhat below the predicted values. Reasons for the over prediction of the theoretical model are attributed to viscous effects and are discussed.

INTRODUCTION

Two solid bodies approaching each other in fluid are not very rare in nature. Such a case can be found in military application when a torpedo is launched toward another ship or submarine in the sea. A very common example which is of grave concern is the flow of an ice mass in an arctic or subarctic region where oil platforms are located. As a large floating ice floe approaches an offshore structure, the water is deflected around the structure. Because the trajectory of the ice floe is not necessarily the same as the pathline especially when the latter is curved, there is no assurance that the ice floe will not impact the structure. Even though the fluid may be deflected around the structure, the ice floe will be influenced by wind, viscous and inertial forces, including the Coriolis force that needs to be taken into account in the case of large-scale motions over great distances. Such ice masses are a direct threat to a platform structure and act as a catalytic motivator to study the two-body interaction problem.

Such a problem was studied theoretically by Yamamoto (1976), Isaacson and Cheung (1988) and later by Landweber, Chwang and Guo (1991). The major feature that appeared different between the first two and the last group of researchers is that the former two predicted an attractive force between two bodies while the latter one predicted a repulsion. Landweber, Chwang and Guo (1991) developed an irrotational-flow model in which time-varying added masses were determined from the solutions of integral equations for source distributions on the surfaces of the two bodies. Forces on the bodies were then obtained from Lagrange's form of the equations of motion in contrast to Yamamoto (1976) and Isaacson and Cheung (1988), who used Bernoulli's equation to obtain pressure distribution on body surfaces. The above procedure can be readily applied to various shapes of bodies to calculate the forces and the resulting velocities of the bodies.

The aim of this investigation is to experimentally verify the theory presented by Landweber, Chwang and Guo (1991). Despite quite a few theoretical works in this area of hydrodynamics, there is virtually no record of experimental works conducted to investi-

gate this phenomenon. This study is restricted to a particular case where one of the bodies is fixed and the other one is carried by free stream current toward the fixed one. A circular cylinder is used as the fixed body and several cylinders of square, circular and rectangular shape are used as the floating bodies.

EXPERIMENTAL SETUP

The experiment is conducted in a water channel. The channel is of the open and recirculating type with a length of 5.8 m. The width and height of the channel are 38.1 and 76.2 cm, respectively. Screens are used in the supply tank at the inlet to the channel to regularize the flow, which is followed by a converging section and the main channel before the collecting tank at the other end. Water from the collecting tank is pumped back to the water channel through the supply tank.

The fixed cylinder is a nylon cylinder of circular cross-section with a diameter of 8.1 cm. The shapes of the floating bodies used for the present study are circular, square and rectangular, each of two different sizes, so that a total of six geometric combinations of the floating cylinders with a single fixed circular cylinder are studied. Every combination with a floating cylinder of a particular geometry is denoted by the initial letter of geometric shape, i.e., *C*, *S* and *R* for circular, square and rectangular cylinders followed by an *L* or *S* to indicate large or small size. The size of the floating rectangular cylinder is denoted by $2a$ and $2b$ where $2b$ is the dimension of the edge facing the fixed cylinder and $2a$ is the size of the remaining face (Fig. 1). The sizes of the floating and fixed circular cylinders are expressed by their radii denoted by r and r_0 respectively. Thus the sizes of the floating cylinders are nondimensionalized by the radius of the fixed cylinder, i.e., by the values of both a/r_0 and b/r_0 for the rectangular cylinder or simply by r/r_0 for the circular cylinder.

Details of the floating cylinders in respect to their shapes and

Experiment code	Geometric shape	Size in cm.	Dimensionless size
SS	Square	4.05x4.05	$a/r_0=1.00$, $b/r_0=1.00$
SL	Square	5x5	$a/r_0=1.24$, $b/r_0=1.24$
CS	Circular	4.15	$r/r_0=1.02$
CL	Circular	5.5	$r/r_0=1.35$
RS	Rectangular	5.05x4.05	$a/r_0=1.25$, $b/r_0=1.00$
RL	Rectangular	4.05x5.05	$a/r_0=1.00$, $b/r_0=1.25$

Table 1 Sizes and shapes of different floating cylinders

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KEY WORDS: Hydrodynamic interaction, two-body interaction, potential flow, floating cylinder.