Numerical Simulation of Flow Characteristics of a Circular Cylinder in an Airfoil Wake

Renjing Cao
Department of Mechanical Engineering
The Hong Kong Polytechnic University
Hung Hom, Kowloon, Hong Kong
Tel: ++852 2766 7813, Fax: ++852 2365 4703
E-mail: Renjing.Cao@polyu.edu.hk

Abstract
Interference between airfoil and circular cylinder in staggered arrangement is a practical problem for electronic cooling devices and electric appliances in aerodynamic performance and noise radiation. For the purpose of compact design, most electronic cooling fans usually use cylinder-type structure as the support component in very close proximity of the blade trailing edge, as a result, both the viscous wakes and the potential flows interaction becomes equally dominant (Kemp & Sears 1955). Therefore, the topic of airfoil-cylinder in staggered arrangement can be typically modeled as a circular cylinder behind an impinging wake. In this sense, the frontiers on this closest topic available in the literature concerns the interaction of two or more cylinders (Kiya & Arie 1980, Arie & Kiya 1983, Igarashi 1981, Zdravkovich 1977), the rotor-stator interactions (Leitch 2000, Rao et al. 2001 and Swirydczuk 2002) or wakes impinging on downstream bodies (Simonich et al. 1993 and Jeon et al. 2001) in experimental and numerical manners.

In this study, a two-dimensional flow is governed by the Navier-Stokes equations for a laminar, viscous, unsteady and incompressible solution. Second-order implicit unsteady formulation is employed and the SIMPLE scheme is used. The Reynolds number in calculation is 200 in terms of the cylinder diameter. A NACA 4412 airfoil with a chord $c=89\ mm$ is adopted and the circular cylinder with diameter of *12.7 mm* is employed in this study. The axial spacing is fixed at 1.5 times of the diameter of cylinder, i.e. $L/D=1.5$, where L is the axial distance between the airfoil trailing edge and the center of circular cylinder and D denotes the circular cylinder diameter. The location of the cylinder center in lateral direction is defined by H/D, as

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shown in Fig. 1, where *H* is the distance between the cylinder center and the line extended from the airfoil leading edge to trailing edge. In this study, *H/D* is varied from –2 to 5.

The calculated flow pattern and its comparison with the visualization results by LIF technique are conducted, as shown in Fig.1. It is found that the vorticity cancellation occurs if the lateral spacing *H/D* is sufficient small that allows the rear cylinder is immersed into the impinging airfoil wake generating a slender body. The interference. A bias flow inside the gap not only alters the symmetric vortex pattern shed from the cylinder, but enhances the adjacent vorticity thus tends to delay the vorticity cancellation effect and vortices entrainment as well as changes the base pressure more or less in the near-wake of cylinder.

It is determined through the power spectra that three regimes can be defined in terms of *H/D*. When $-2<H/D<2$, shear layer instability is dominant to *St*, and when $H/D>2$ or $H/D<-2$, the vortex shedding from cylinder and its interference with impinging airfoil wake is dominant to *St*. When *H/D* is larger than 5, only vortex shedding from the cylinder is dominant which is similar to the case of single cylinder where the interference does not exists any more.

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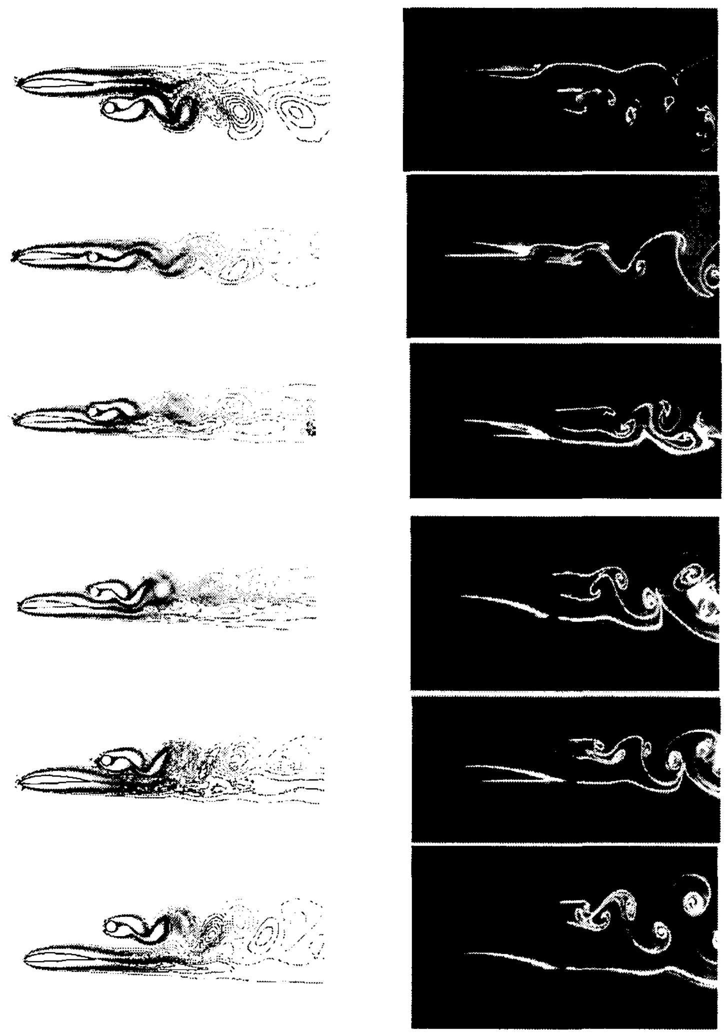

a. H/D=-2

b. H/D=0

c. H/D=1

d. H/D=1.5

e. H/D=2

f. H/D=3

Figure 1 Flow pattern comparison between calculation represented by vorticity contour and LIF visualization for airfoil and cylinder in stagger arrangement at H/D=-2, 0, 1, 1.5, 2 and 3, L/D=1.5 and Re=200.