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FLOW INDUCED VIBRATION OF SINGLE AND MULTIPLE CYLINDERS

Vinod Kumar **Sanjay Mittal**
Department of Aerospace Engineering, IIT Kanpur, Kanpur 208 016, India.

ABSTRACT Flow induced vibration of single and two cylinders, in tandem arrangement, is investigated using the stabilized space-time finite element method. The cylinders, mounted on lighly damped springs, are allowed to vibrate in both in-line and cross-flow directions. The flow is governed by the incompressible Navier-Stokes equations while the motion of cylinders follows the Newtons laws of motion for rigid bodies. For the single cylinder case, *lock-in* is observed and the cylinder motion resembles the figure of *8*. In the case of two cylinder arrangement, the upstream cylinder oscillates in the same manner as a single cylinder while for the downstream cylinder one observes the phenomenon of wake induced flutter. Compared to the upstream cylinder, the downstream one undergoes larger amplitude oscillations, especially in the in-line direction.

1. Introduction

Flow induced vibration of cylinders is an important phenomenon in engineering flows; for example, it occurs in flows that involve off-shore structures, transmission cables with twin conductors, twin chimney stacks, heat exchanger tubes [1,2]. A fairly comprehensive study of cross-flow vibrations of a single cylinder in a uniform flow is reported in [3]. Here, results are reported for flow induced vibration of single and two cylinders, mounted on lightly damped springs, that are allowed to vibrate in both in-line and cross-flow directions.

2. Formulation

Stabilized space-time finite-element method [3] is employed to solve the incompressible Navier-Stokes equations in the primitive variables formulation. The space-time method enables one to handle flows that involve moving boundaries and interfaces. In this method the variational formulation of the equations is written over the space-time domain and the finite element interpolation functions depend on both space and time. The GLS (Galerkin's Least Squares) stabilization technique is employed to stabilize the computations against spurious numerical oscillations and to enable one to use equal-order-interpolation velocity-pressure elements. The equation systems, resulting from the finite element discretization, are solved iteratively by using the preconditioned GMRES technique.

3. Results & Discussion

The cylinders reside in a rectangular computational domain whose upstream boundary is located at 5 cylinder diameters from the center of the upstream cylinder. The downstream boundary is located 25 cylinder diameters away from the center of the downstream cylinder.

The upper and lower boundaries are placed at 5 diameters from the center of the two cylinder. The no-slip condition is specified for the velocity on the cylinder wall and free-stream values are assigned for the velocity at the upstream boundary. At the downstream boundary the viscous stress vector is set to zero. On the upper and lower boundaries, the component of velocity normal to and the component of stress vector along these boundaries is prescribed zero value. Reynolds number, based on the diameter of the cylinder, free-stream velocity and the viscosity of the fluid, is 324 for the single cylinder case and 100 for the case of two cylinders.

Figure 1 shows the time histories of the drag and lift coefficients and the displacements (normalized by cylinder-radius) for the single cylinder case when the natural frequency of the spring-mass system (=0.27) is higher than the vortex shedding frequency of the stationary cylinder (=0.21). Figure 2 shows the vorticity and pressure fields at the minimum, zero and maximum vertical displacement of the cylinder during one cycle of motion. Figure 3 shows the vorticity and pressure fields for the two cylinder case that are initially arranged in tandem and with the natural frequency of the spring-mass system of each cylinder equal to the vortex shedding frequency of the stationary cylinders in the same arrangement (=0.168). Figure 4 shows the time histories of the drag and lift coefficients and the displacements of the two cylinders. The upstream cylinder oscillates in the same manner as a single cylinder. For the downstream cylinder one observes the phenomenon of wake induced flutter. Compared to the upstream cylinder, the downstream cylinder goes through larger amplitude oscillations, specially in the in-line direction.

References
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[2]Chen, SS, Flow-Induced Vibrations of Circular Cylindrical Structures, (1987).
[3]Mittal, S & Tezduyar, TE, Int. J. Num. Meth. in Fluid Mech., 15, 1073-1118, (1992).

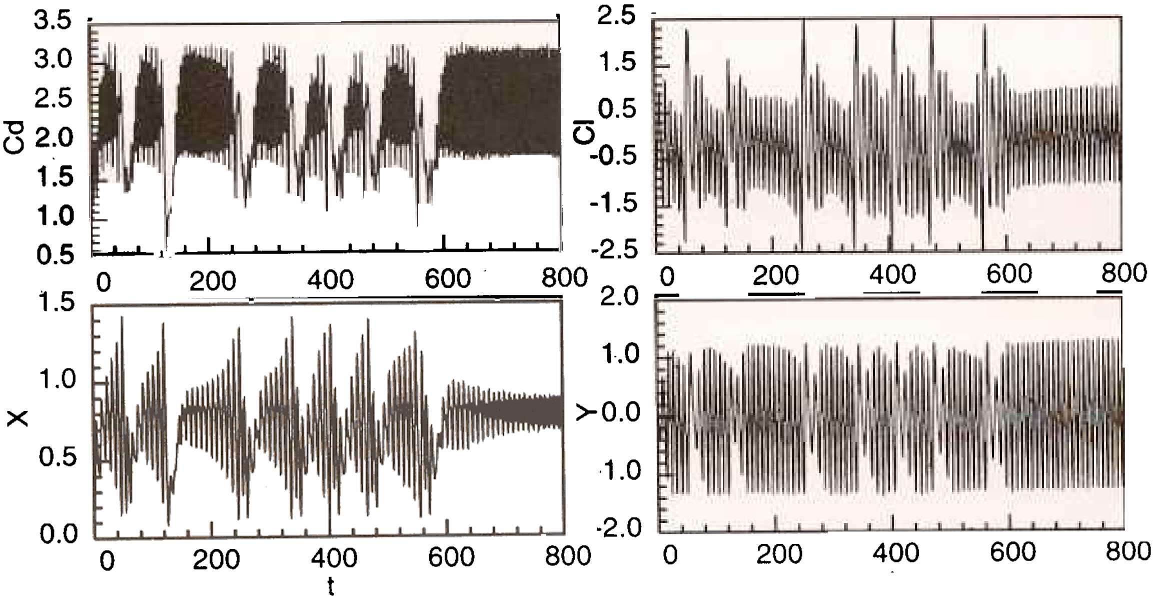

Fig. 1. *Re* = 324 flow past an oscillating cylinder: time histories of the drag and lift coefficients and the displacements (normalized by cylinder-radius).

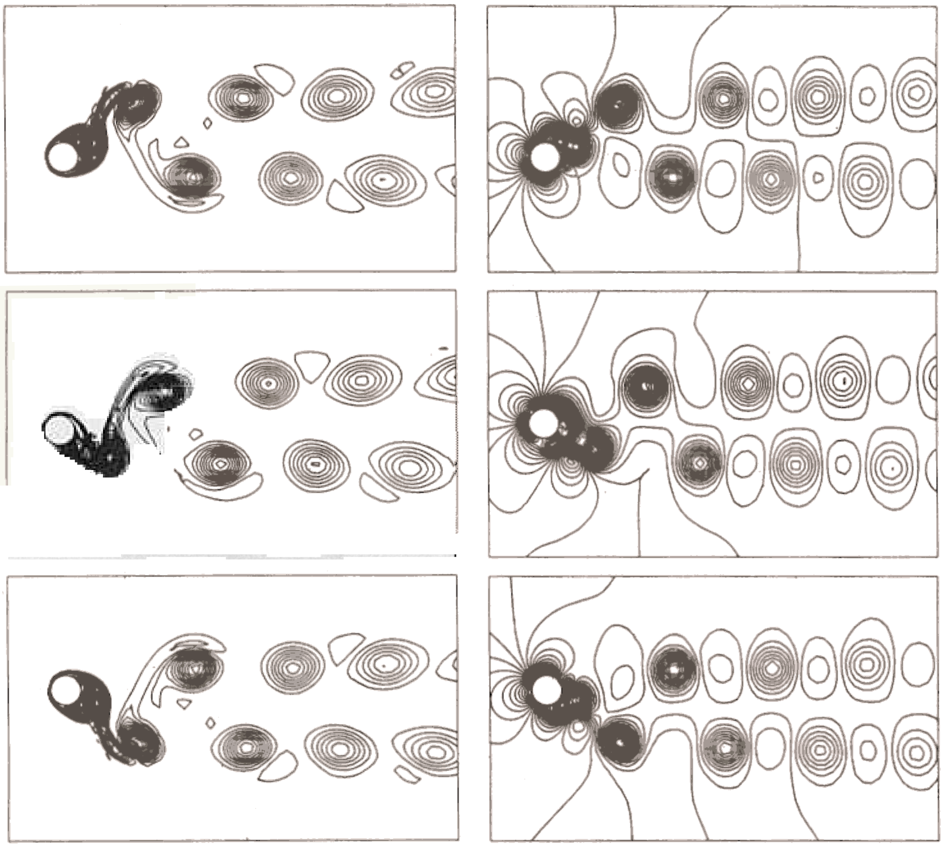

Fig. 2. *Re* = 324 flow past an oscillating cylinder: vorticity and pressure fields at the minimum, zero and maximum vertical displacement of the cylinder during one cycle of motion.

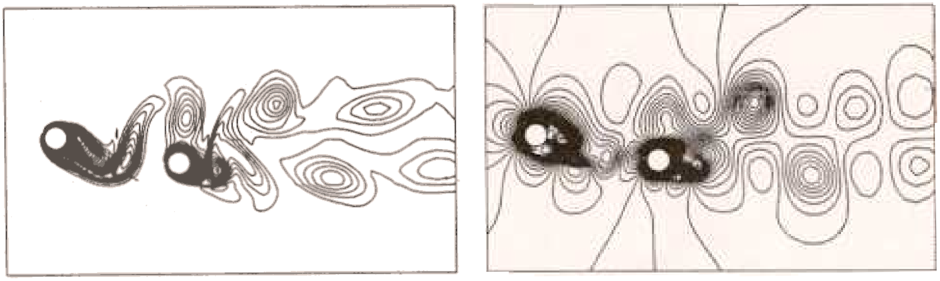

Fig. 3. *Re* = 100 flow past two oscillating cylinders: vorticity and pressure fields.

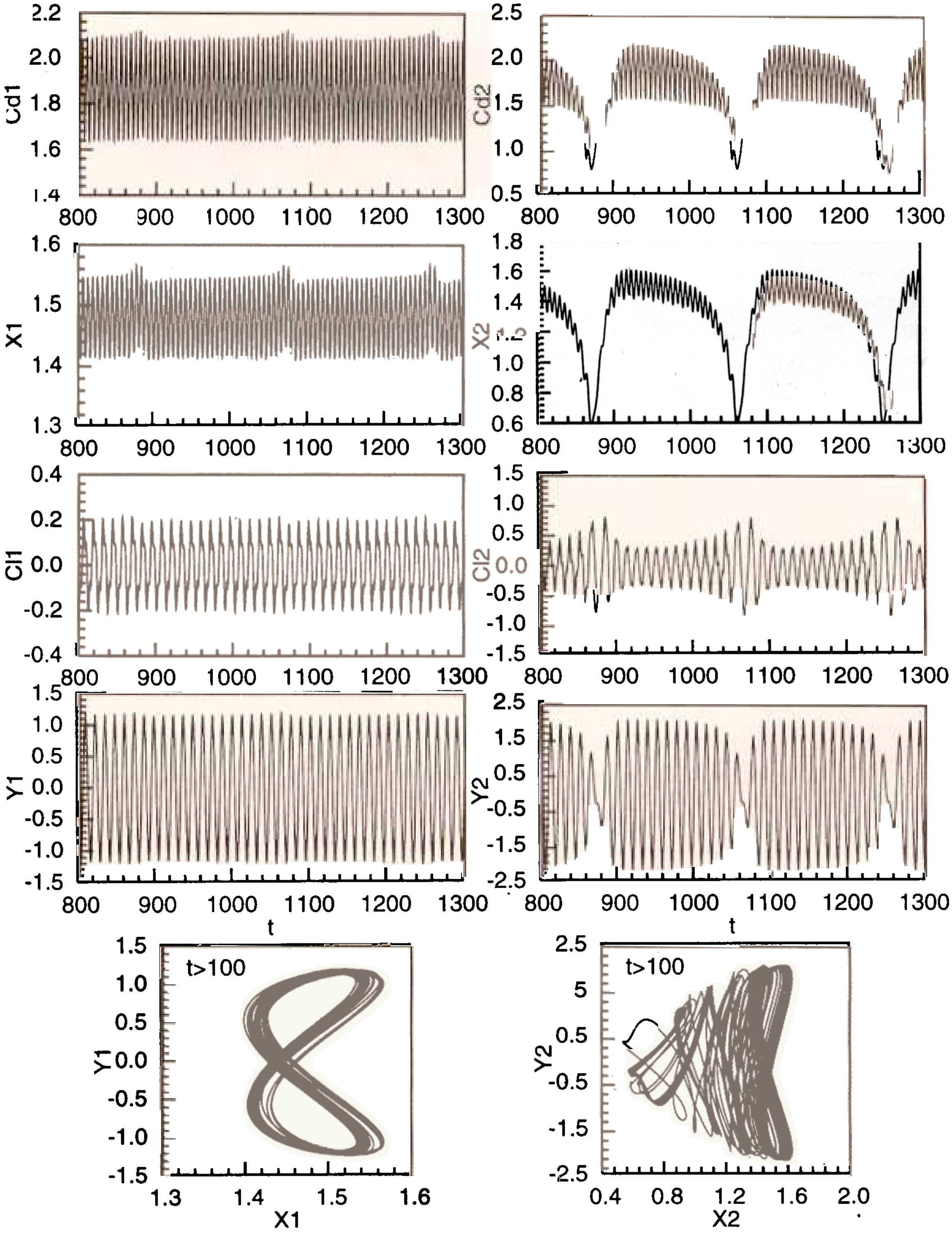

Fig. 4. *Re* = 100 flow past two oscillating cylinders: time histories of the drag and lift coefficients and the displacements (normalized by cylinder-radius).