Numerical Investigation of Strouhal Frequencies of Two Staggered Bluff Bodies

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Introduction: Unsteady viscous flow around two cylinders is studied by numerical solutions of the unsteady Navier-Stokes equations with a finite element formulation using COMSOL Multi physics. The results of a numerical investigation of the Strouhal frequencies of two identical, stationary, parallel circular cylinders arranged in staggered configurations is presented in this paper.

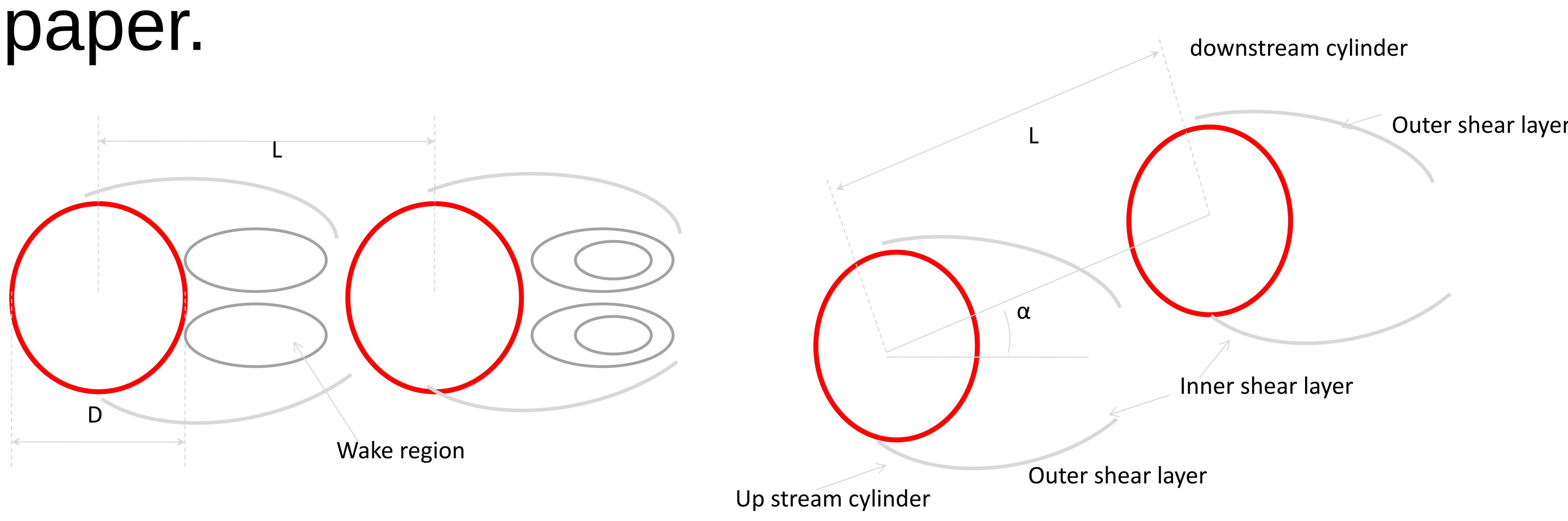

Figure 1. Notation for staggered configuration.

Numerical Approach:
Based on the Navier-stokes time averaged equations and using Bousssinesq approximation for Reynolds stresses, differential equations for governing viscous turbulent flow is solved. The fluid is assumed incompressible.. Two cylinders of equal diameter are placed in a 35*D* x 20*D* rectangular domain, where *D* denotes the cylinder diameter. At the inlet, velocity boundary condition is applied. The pressure boundary is applied on outlet. No slip boundary condition is applied at the boundary of fixed cylinder. The top and bottom boundaries of the computational domain are considered as symmetry boundary. Temporal discretization is performed based on second order implicit method which causes much less damping and is thereby more accurate.

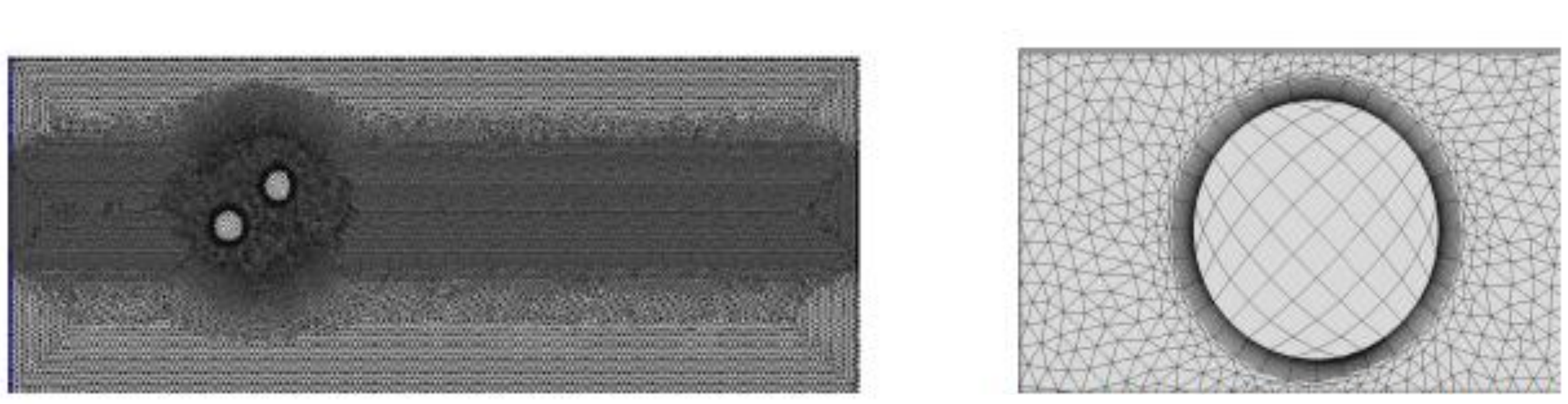

Figure 2. Grid arrangement and boundary layers

Results: In order to better understand the flow characteristics and wake interference between two tandem cylinders, 3 cases were studied. Case 1: Flow past two tandem cylinders at Re =200 and α =0˚.

Case 2: Flow past two tandem cylinders at *Re* =200 and at different staggered angles. And Case 3: Flow past two tandem cylinders at Re =15000.

Table 1. Comparisons of flow two tandem cylinders at Re =200 and α =0˚.

Parametric Results	cylinder	Mean drag coefficient			Strouhal Frequency		
		Present	Slaouti and stansby	Meneghini et al.	Present	Slaouti and Stansby	Meneghini et al.
L/D =2	UC	1.0641	0.89	1.03	0.1401	0.13	0.13
	DC	-0.1628	-0.21	-0.17	0.1401	0.13	0.13
L/D =3	UC	1.0685	0.87	1.0	0.1465	NA	0.125
	DC	-0.1578	-0.16	-0.08	0.1465	NA	0.125
L/D =4	UC	1.1052	1.11	1.18	0.1650	0.19	0.174
	DC	0.7991	0.88	0.38	0.1650	0.19	0.174

UC= Upstream cylinder ; DC = Downstream cylinder.

Table 2. Flow past two tandem cylinders at *Re* =200 and *L/D* =2.

Parametric results	cylinder	Mean drag coefficient C_d	Strouhal frequency *St*
α =10˚	UC	1.169542	0.1625
	DC	0.391452	0.166
α =15˚	UC	1.135565	0.1455
	DC	0.611852	0.1456
α =25˚	UC	1.246236	0.1325
	DC	1.125252	0.132

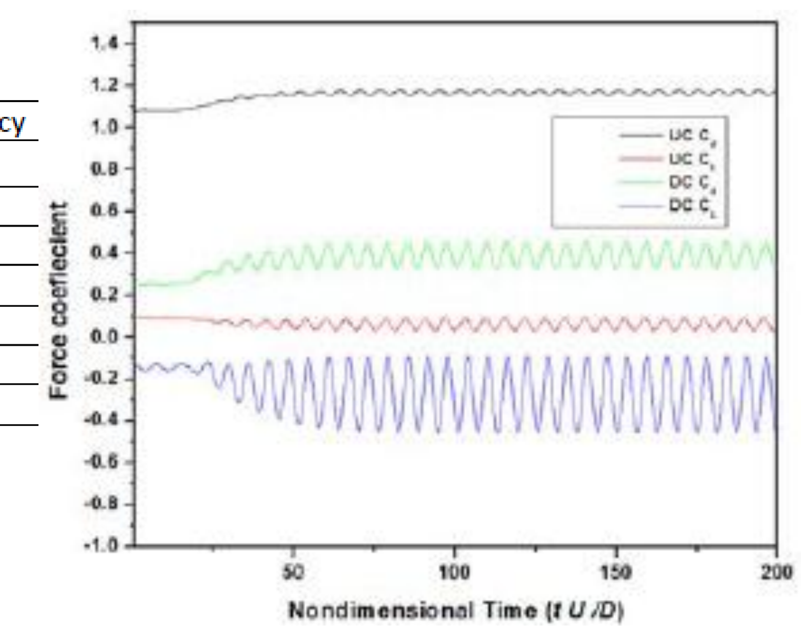

Figure 4. Force coefficient on cylinders of α =10˚, *Re*= 200 and *L/D* =2.0.

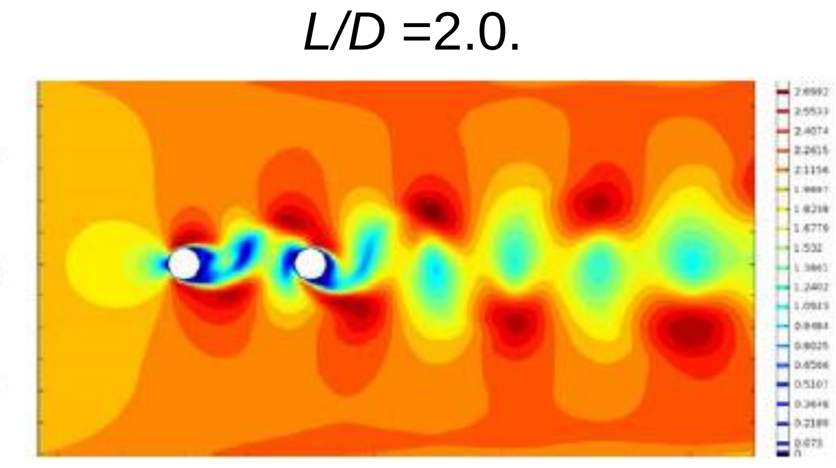

Figure 5 velocity contour plot for tandem cylinder α =0˚ and L/D =4.0

Conclusions: During the low Reynolds number and low gap spacing, the rear cylinder highly disturbed the flow behind this cylinder. Drag values are negative. in the other hand when the gap ratio is more, then vortices are shed counter wise from both cylinders and not synchronized.

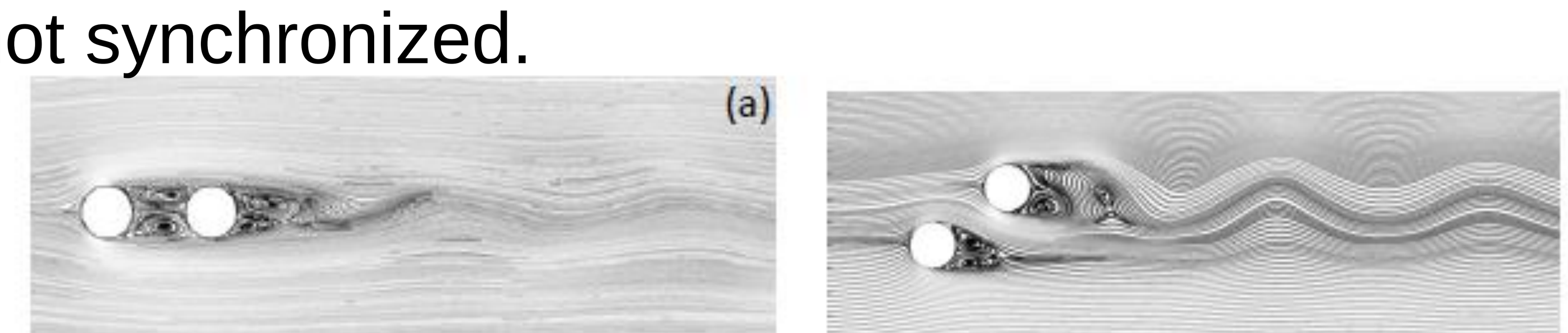

Fig 6. Streamline for Re= 1.5E4 and *L/D* =2.0 at α =0˚ & α =15˚).

In the turbulent region, the lift force time histories for these two groups show nearly smooth and related variations and drag values are negative like laminar cases.

References: [1] Singh and Sinhamahapatra KP, 2010, High resolution numerical simulation of low Reynolds number incompressible flow about two cylinders in tandem, journal of fluids Engineering, ASME, 2010, 132(1): 011101.
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