Numerical Investigation of Strouhal Frequencies of Two Staggered Bluff Bodies

Eswaran M[1], P. Goyal[2], Anu Dutta[2], G.R. Reddy[2], R. K. Singh [2], K.K. Vaze[1]

[1]Bhabha Atomic Research Centre, Mumbai, India
[2]Bhabha Atomic Research Centre, Mumbai, India.

Abstract

A 2-D unsteady viscous flow around two cylinders is studied by numerical solutions of the unsteady Navier-Stokes equations with a finite element formulation using COMSOL Multiphysics®. 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. A simple two cylinder tandem arrangement is validated for a certain range of values of spacing ratio (L/D) with few previously published results. Results of measurements of the Strouhal frequencies of circular cylinders arranged in tandem and in some selected staggered configurations are also presented. In the present case of two circular cylinders, the numerical analysis is carried out at different staggered angles , and lift and drag forces are calculated.

The simplest arrangement of multiple slender structures is two cylinders in either tandem or side-by-side arrangement. Though the staggered arrangement is perhaps the configuration most commonly found in engineering applications, numerous investigations on the flows past two circular cylinders in side-by- side and tandem arrangements have been performed, but investigations pertaining to two staggered cylinders are relatively few, particularly investigation of the vortex-shedding processes in terms of the Strouhal frequencies of two staggered cylinders. As has been revealed in the previous studies, for a small value of L/D (see Figure 1 for definitions of symbols), i.e., when the downstream cylinder is fully or partially submerged into the upstream cylinder wake, the two cylinders behave like a single body and the frequencies of vortex shedding behind the two cylinders are the same. For an intermediate value of L/D, at which narrower and wider wakes are formed behind the upstream and downstream cylinders, respectively, the frequencies of vortex shedding behind the upstream and downstream cylinders are of a higher and lower magnitude, respectively. For a higher value of L/D, i.e. when each cylinder sheds vortices independently, the frequency of vortex shedding behind each cylinder is the same as that in the case of a single, isolated cylinder. Downstream cylinder is submerged into the upstream cylinder wake for the lower L/D ratio. The negative drag will disappear, while increasing the staggered angle α. Here the Figure 2 and 3 show the tandem arrangement with $\alpha = 0°$ and L/D =3.0 drag and $\alpha = 15°$ and L/D =2.0 drag respectively.

Table 1 shows comparisons of flow two tandem cylinders at Re =200 and $\alpha = 0°$. It can be seen from Table 1 that the negative drag has completely eliminated in the co-shedding regime while increasing the T/D ratio. The reattachment of upstream shear layer onto the second cylinder is observed. Due to this, negative drag is found on the downstream cylinder which results from the pressure difference between front and back sides of this cylinder.

Reference

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Figures used in the abstract

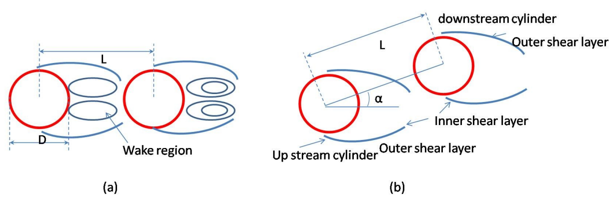

Figure 1: Notation for staggered configuration.

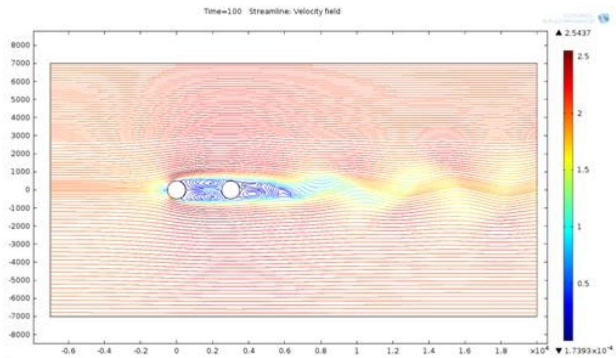

Figure 2: Streamline plot for tandem arrangement with α =0° and L/D =3.0.

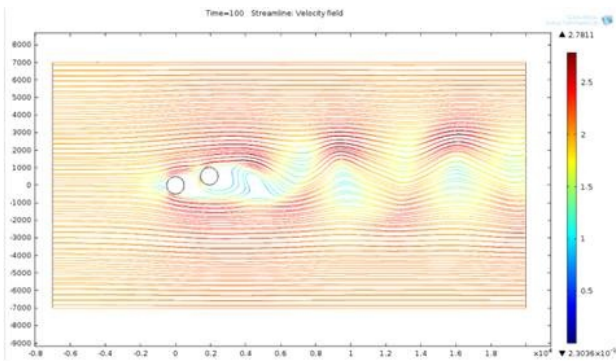

Figure 3: Streamline plot for tandem arrangement with α =15° and L/D =2.0.

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.
T/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
T/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
T/D =4	UC	1.0821	1.11	1.18	0.1920	0.19	0.174
	DC	0.7991	0.88	0.38	0.1920	0.19	0.174

UC= Upstream cylinder ; DC = Downstream cylinder.

Figure 4: Table 1. Comparisons of flow two tandem cylinders at Re =200 and α =0°.