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Heat Transfer Augmentation in a Straight Channel via Two Oscillating Circular Cylinders

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We consider flow-through systems in which the characteristic length is limited such that turbulent flow is not reached even at high fluid velocities, i.e., the flow remains laminar. In these flow regimes, inducing circulation or vortices in the flow enhances mixing and heat transfer [1]. These can be created by placing obstacles in the flow path, for example.

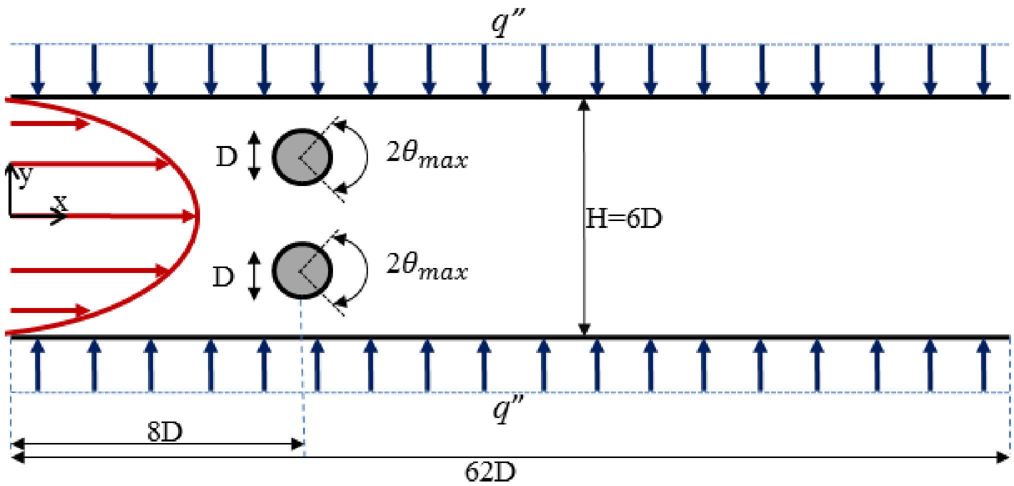

Figure 1. Geometry of the simulation: Parameters D, θ_{max} q" are cylinder diameter, rotational oscillation amplitude and heat flux, respectively.

Heat transfer enhancement in a channel via a single stationary and oscillating cylinder was considered previously [2, 3]. Here, heat transfer augmentation by using two oscillating cylinders is investigated systematically and the results compared with the results for a single cylinder. As shown in Figure 1, fully developed fluid flow with a parabolic velocity profile enters the channel in which two oscillating cylinders (blocking ratio of three) are placed a distance of 8D from the inlet. In the simulation, the Reynolds number was fixed at 900 (based on the channel hydraulic diameter) and the Prandtl number at 1. The cylinders oscillated with a frequency of $f_e$and maximum amplitude of $\theta_{\max} = \pi/$. Define $\emptyset_1$ and $\emptyset_2$ as the oscillation phases of lower and upper cylinders, respectively. Simulations were performed for three conditions: I) $\emptyset_1 = \emptyset_2$(synchronized oscillation), II) $|\emptyset_1 - \emptyset_2| = \pi/2$, III) $|\emptyset_1 - \emptyset_2| = \pi$ (converging and diverging oscillations). For each case, the vorticity structure and temperature field along the channel were computed for different non-dimensional frequencies ($F = f_e/f_{0d}$), defined as the ratio of cylinder oscillation frequency to the frequency of vortex shedding for a motionless cylinder. The optimal frequency for each condition was identified by measurement of the average Nusselt number curve over a period of oscillation.

In comparison with a straight channel, using this mechanism improves heat transfer considerably, but placing a single cylinder with diameter of $2D$ at the middle of channel is more efficient. Because the cylinders are offset, the results showed that the generated vortices are suppressed as a result of interaction with the walls. On the other hand, the vortices generated at the channel center are restricted to the middle of the channel and cannot move toward the walls in order to agitate the thermal boundary layer and increase heat transfer. Therefore, the generated vortices are not as effective in enhancing heat transfer as placing one cylinder with diameter of $2D$ along the channel centerline, as considered previously [2, 3].

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