On the effect of Reynolds number for flow past three staggered rows of square cylinders

Abstract: To understand the flows around complex and large structures, one needs to study fluid flow across simple bluff bodies and its vorticity dynamics. In this study, interesting flow patterns have been observed of the flow across a three rows of identical staggered square cylinders. These interesting flow patterns depend on the incoming flow and the gap spacing between the cylinders. These cylinders not only shed vortices individually but, also ensues wakes interaction. The importance of current study to engineering applications includes turning of vanes in duct elbows; multi-slotted airfoils; flow around large building blocks; screens and filters. A two-dimensional computational study of flow across a three rows of identical square cylinders in staggered fashion is carried out to systematically investigate the complex flow physics depending upon the Reynolds number (Re) and separation ratio (g) between the cylinders. The combined effects of Re and g on the flow physics across three rows of staggered cylinders are numerically studied for $30 \leq Re \leq 140$ and $1 \leq g \leq 6$. Numerical investigations are performed by a lattice Boltzmann method. It is observed that for the onset of vortex shedding the critical Reynolds number increases as the gap ratio increases. At a gap ratio, especially, $g = 3$ and $4$, a strong effect of Reynolds number on the flow across the cylinders is noted. Secondary cylinder interaction frequency significantly contribute to the forces experience by the cylinders. It is found that the primary vortex shedding frequency control the flow for larger Reynolds number and at $g = 3$ and $4$, whereas the secondary frequency vanishes. In other words, an increase in the Reynolds number at these gap ratios ($g = 3$ and $4$), the interaction of the wakes behind the cylinders weakens. It is proposed that the jets in the gap region have strong influenced upon the wake interaction. The nature of the wakes can be changed by changing the spacing and Reynolds number, and the change wake size behind the cylinders confirms it. This provide us the base for proposing two critical spacing ratios, $g = 2$ and $4$ for the considered range of Reynolds number. These spacing ratios depending on the Reynolds number are used to split the flow regimes into chaotic, synchronous, quasi-periodic-I and quasi-periodic-II flow regimes. To find out such critical spacing ratios the mechanism of wake interaction has been studied. The important physical parameters such as mean drag coefficients, Strouhal numbers, root-mean-square values of the drag and lift coefficients are also analyzed and discussed in detail.