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On the wake axisymmetry and secondary structures behind low aspect-ratio wall-mounted prisms

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ABSTRACT

The wake of wall-mounted finite prism is numerically studies and characterized with aspect-ratio (height-to-width) of 1 and varying depth-ratios (length-to-width) between 0.016 and 4, at Reynolds numbers of 50-500. The minimum depth-ratio considered here accounts for the special case of wall-mounted thin flat plate, which is used to establish the mechanism and evolution of wake associated with the free-end effects and shear-layer dynamics in small aspect-ratio prisms. The onset of unsteady wake occurs for the wall-mounted thin flat plate at Reynolds number of 200, characterized by an axisymmetric shedding of hairpin-like structures. Here, an axisymmetric wake is defined by the wake features, such as hairpin-like structures, tip and base vortices, as well as horseshoe vortex, symmetric about a mid-planar axis. A unique non-axisymmetric wake pattern appears at low depth-ratios starting at Reynolds number of 250, which transitions to an axisymmetric wake and steady wake with subsequent increase in depth-ratio. Non-axisymmetric wake features distortions about the mid-planar axis, leading to side-ways (spanwise) tilting of shed structures. The threshold depth-ratio of axisymmetric transition increases with Reynolds number. The non-axisymmetric wake results from alternate shear-layer peel-off from either side of the prism. This itself is attributed to the out-of-phase shedding of tip-vortices at a lower Strouhal number ($St_{sh}/2$) that interact with the detaching side shear layers. Alternate shedding of tip-vortices from secondary vortex structures that are fed by the excess vorticity resulting from shear-layer detachment from either side of the prism. Increasing the depth-ratio leads to simultaneous shedding of tip-vortices, which restores the commonly observed axisymmetric wake patterns. Thus we identify and characterize the formation and interaction mechanism of axisymmetric and non-axisymmetric wakes during the transition process with increasing Reynolds number for different depth-ratio prisms.

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