# Wake behind a step cylinder from laminar to turbulent

C. Tian,[*] J. Zhu[*] and L. E. Holmedal[*]

Cylindrical structures with abrupt changes in diameter, namely step cylinders, are widely used in various industrial applications, for example, risers with buoyancy elements and the hull of spar-offshore platforms. The abrupt cross-section change of a step cylinder causes more complex wakes than a uniform straight cylinder. By conducting direct numerical simulations (DNS) of flow around a single step cylinder with a diameter ratio $D/d$=2 (where $d$ and $D$ are the diameters of the small and large cylinder, respectively), we explore how the step cylinder wakes to transform from laminar to turbulent within the Reynolds number region 150$\leq$ $Re$ $\leq$3900 (based on $D$) and the corresponding variation of the structural loads.

An overview of the vortex structures in the step cylinder wakes at $Re$= 150, 200, 300, and 3900 are shown in figures 1(a), (b), (c), and (d), respectively. Overall, consistent with the publications[1] [2], mainly three spanwise vortices occur in the step cylinder wake. As $Re$ increases, more and more streamwise vortices form in the wake until the wake becomes fully turbulent. Results from an in-depth exploration of the wake dynamics and the correspondingly varying structural load utilizing fast Fourier transform, proper orthogonal decomposition, and wavelet analysis will be presented.

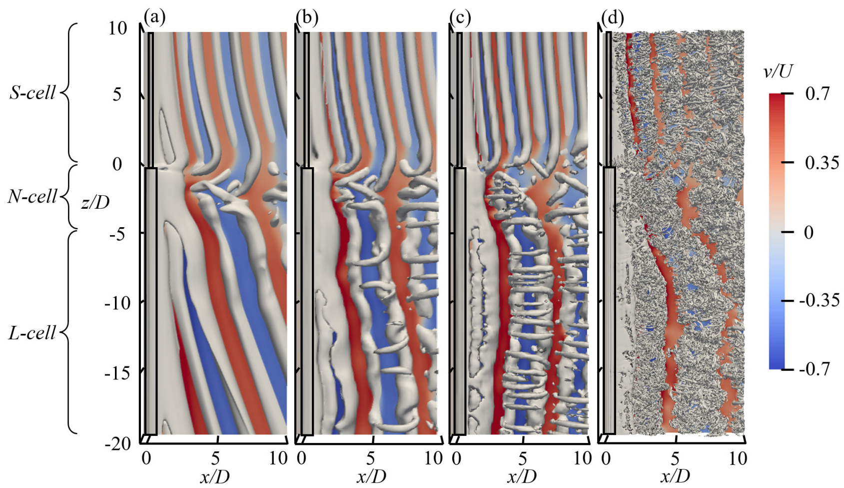


Figure 1: Vortex structures in the step cylinder wake visualized by the iso-surface of $\lambda_2$: (a) $\lambda_2$=-0.05 at $Re$=150; (b) $\lambda_2$=-0.1 at $Re$=200; (c) $\lambda_2$=-0.2 at $Re$=300; (d) $\lambda_2$=-0.5 at $Re$=3900. The instantaneous cross-stream velocity $v$ at the symmetry ($x$, $z$)-plane ($y/D$=0) is included to highlight the alternating pattern of the main vortices. The approximate extensions of the three vortex cells (S-, N-, and L-cell vortices) are indicated.

[*]Department of Marine Technology, Norwegian University of Science and Technology (NTNU), NO-7491 Trondheim, Norway

[1]Dunn and Tavoularis, *J. Fluid Mech.* **555**, 409-437 (2006).

[2]Tian et al., *Phys. Fluids* **33**,4 (2021).