

Effect of Turbulence on the Flow Past Dual Step Cylinders

Shreenivas Rangarajan¹, Serhiy Yarusevych² & Chris Morton¹

¹ Department of Mechanical Engineering, McMaster University, Hamilton, Ontario, Canada

² Department of Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, Ontario, Canada

Introduction and Objectives

Cylindrical structures in cross-flow commonly experience vortex-induced fluctuating loads, making them susceptible to fatigue failure. Passive flow control using dual step cylinders has demonstrated up to 70% fluctuating load reduction for low Reynolds numbers[1]. However, their effectiveness in turbulent flow remains unexplored. This work investigates the aerodynamic load reduction capabilities of dual step cylinders under varying turbulent inflows at a moderately high Reynolds number, $Re_d = 2 \times 10^4$.

Methodology and Results

Experiments were performed in the closed loop wind tunnel at the University of Waterloo at $Re_d = 2 \times 10^4$. The dual step geometry consists of a finite span cylinder (having length, L , and diameter, D) attached coaxially to a uniform cylinder of diameter, d . Dual step cylinders with diameter ratios (D/d) of 1.3 and 2, and aspect ratios (L/D) 1 and 3, were evaluated. Aerodynamic forces were acquired through a load cell. The flow physics driving the aerodynamic force changes were investigated through planar Particle Image Velocimetry (PIV) measurements at the mid-span of the larger diameter cylinder. An Active Grid was used to generate freestream turbulence with intensities (TI) ranging from 2.3% to 11.8%, and integral length scales (L_x/d) ranging from 2 to 23, effectively covering a broad range of turbulence parameters relevant to practical engineering applications.

The most significant drag reduction was achieved by $D/d = 1.3$, $L/D = 1$, which exhibited a consistent 5% reduction across all turbulence levels. All dual step geometries yielded substantial RMS lift reductions, with the most pronounced reduction of 60% at $D/d = 2$, $L/D = 3$. The instantaneous vorticity fields representative of the wake for uniform, $D/d = 1.3$, $L/D = 1$ and $D/d = 2$, $L/D = 3$ are illustrated in Fig. 1. Based on the similarity of the fields with those reported by Morton and Yarusevych [2], the dual step cylinders were established to be in the No Shedding (NS) and Irregular Shedding (IS) flow regime, respectively. The observed drag and RMS lift force reductions are directly linked to the flow regimes induced by the dual step, which will be presented in detail at the meeting.

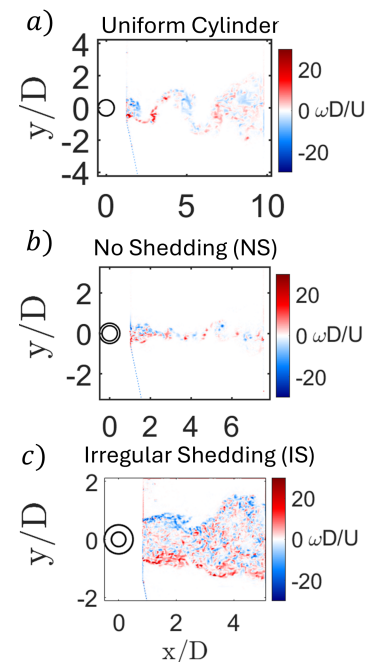


Figure 1: Instantaneous vorticity fields for (a) uniform cylinder, (b) $D/d = 1.3$, $L/D = 1$, (c) $D/d = 2$, $L/D = 3$.

References

- (1) McClure, J.; Morton, C.; Yarusevych, S. Flow Development and Structural Loading on Dual Step Cylinders in Laminar Shedding Regime. *Physics of Fluids* **2015**, *27*, 063602.
- (2) Morton, C.; Yarusevych, S. Vortex Shedding from Cylinders with Two Step Discontinuities in Diameter. *Journal of Fluid Mechanics* **2020**, *902*, A29.