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A comprehensive database: synchronization sampling of pressure field on rectangular cylinder surface and velocity field around rectangular cylinder

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SUMMARY:
In this study, a comprehensive database of flow past a 2-dimensional rectangular cylinder has been created through wind tunnel testing as Synchronized Particle image velocimetry with Multipoint Pressure Scanners (SPMPS). Three variables as SR, AOA, and turbulence intensity, have been included. The side ratio (SR) ranges within 0.2, 0.4, 0.6, 0.8, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 3.25, 3.5, 3.75, 4.0, 4.25, 4.5, 4.75, 5.0. The angle of attack (AOA) is set within 0-90 with a 5-degree interval. Different turbulence intensities are generated by installing various types of wooden and bamboo grids, which can reach turbulence intensity as the basic 0.4%, and the generated 2.2%, 3.6%, 4.3%, 6.8%, 7.6%, and 12.3%. The high-resolution wind tunnel experiments with SPMPS can capture the instantaneous flow properties around the rectangular cylinder as well as the pressure distributions on the rectangular cylinder surfaces. A total of 2394 cases have been tested, which sets a solid foundation for investigating the flow mechanism of flow past rectangular cylinders under different wind conditions, including flow separation, flow reattachment, and turbulent energy dissipation. It also provides a potential for introducing artificial intelligence techniques into predicting flow field around rectangular cylinders.

Keywords: PIV, rectangular cylinder, turbulence intensity

1. INTRODUCTION

Flow past a rectangular cylinder under different wind conditions have been investigated for decades since the rectangular cylinder is one of the most common geometries in construction, mechanism design, and industrial products(Bearman & Trueman, 1972; Bruno et al., 2010; Okajima, 1990; Schewe, 2013). Wind tunnel testing, including PIV and pressure testing, treated as the reliable approach to obtaining the flow properties, is consistently attracting researchers. While diverse combinations of SR and AOA have posed a burden on experimental feasibility, particularly the synchronized pressure and flow field obtainment(Guissart et al., 2022; Li et al., 2021; Wu et al., 2020). In this paper, a unique method synchronized PIV and Multipoint Pressure Scanners is proposed to simultaneously capture the flow field around and pressure field on the 2-dimensional rectangular cylinder with different SR and AOA as well as turbulent intensity.

2. EXPERIMENT SETUP

The wind tunnel experiments were conducted in a close-loop wind tunnel with a test section of 800mm*500mm*500mm (length*width*height) at Harbin Institute of Technology, Shenzhen, China. The approaching wind velocity of the wind tunnel continuously ranges from 1m/s to 30 m/s. The approaching wind be treated as a uniform flow with 0.4% turbulence intensity. In this study, the approaching wind velocity is set as 10m/s, corresponding to the wind fan generator rotating frequency 14Hz.

2.1. Synchronized PIV and Multipoint Pressure Scanners Setup

The synchronized PIV and Multipoint Pressure Scanners are realized with laser signal processing and synchronization.

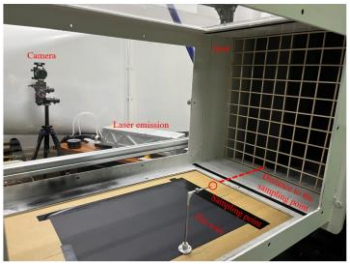
2.1.1. Particle ımage velocimetry (PIV) Setup

The PIV system is a composite of a double-cavity laser (Bernoulli PIV 200-15), a 2.5 m length laser guiding arm (LaVision), more information can be found through Gao et al. (2022). To ensure that the data collected can be adequate for flow mechanism analysis, 1200 snapshots are photographed for each case. The laser triggering frequency is 15Hz, and the time period for data obtainment is 80s, indicating a total of 1200 snapshots are obtained.

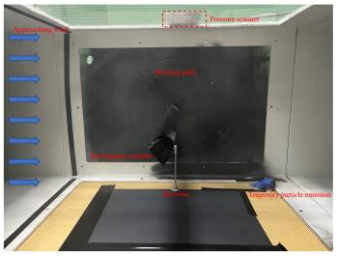
2.1.2. Pressure scanner Setup

The pressure scanners system consists of two pressure scanners (Scanivalve MPS4262) seen Figure 1, a high speed 1Gp/s switch and a high-performance server. The pressure scanners and PIV have been synchronized in this study with the laser L1 signal from PIV system PTU block. The continuous external signal from L1 can be treated as continuous frames to activate the pressure scanners.

Figure 1. Pressure scanner: Scanivalve MPS4262



a) Front view of experiment device



b) Back view of experiment device

Figure 2. Experimental device and grid arrangement

2.2. Testing Models and Turbulence Intensity Generator Grid Setup

The 2-dimensional rectangular cylinder in wind tunnel testing are made of acrylic plate. The pressure scanning tubes are arranged around the middle part of the rectangular cylinders. Two main materials, wood and bamboo, have been used to make grids. Several types of grids have been made and installed to generate different turbulence intensities before the wind tunnel test

section. Table 1 has presented the detailed information with different grids installations and the sampled turbulence intensities. After synchronizing all devices, the experiment can be conducted.

Table 1. Grid details of turbulence generator and turbulence intensity sampled.

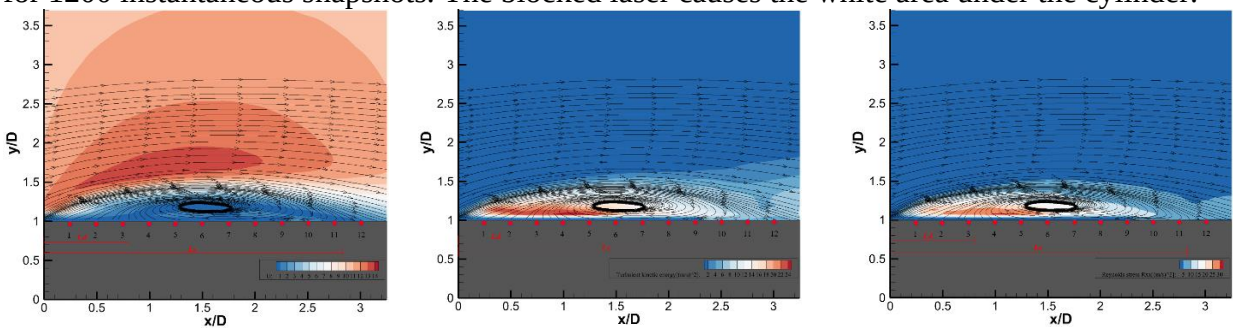
	Material	Material size	Distance from grid to the hot-wire sampling point	Turbulence intensity sampled
Grid 1	Wood & bamboo	Bamboo: 8mm diameter; wood: 6mm square	375mm	2.2%
Grid 2	Wood & bamboo	Bamboo: 8mm diameter; wood: 6mm square	375mm	3.6%
Grid 3	Wood	Wood: 8mm*8mm square	375mm	6.8%
Grid 3	Wood	Wood: 8mm*8mm square	450mm	12.3%
Grid 4	Wood	Wood: 4mm*4mm square	375mm	4.3%
Grid 4	Wood	Wood: 4mm*4mm square	450mm	7.6%

3. RESULTS AND DISCUSSIONS

Before putting recuangular cylindes in the testing section, the empty flow without any turbulence intensity generator past the wind tunnel test section has been performed to check the approaching wind quality. The PIV results suggested the wind speed is around the 10 m/s and the velocity field is nearly uniform with 0.4% fluctuation. Due to the page limit, the calidation process is not presented in this abstract.

3.1 Flow field around a 2-dimensional rectangular cylinder

The following presents the detailed flow field results around various SR and AOA rectangular cylinders. The instantaneous flow properties are obtained through the PIV processing and the averaged flow figures can be calculated with accumulation. Figure 3. presents the averaged flow for 1200 instantaneous snapshots. The blocked laser causes the white area under the cylinder.



Averaged flow | Tuebulent kinetic energy | Reynolds stress(R_{xx})

Figure 3. Averaged flow features for SR 3.25 AOA 0 case

3.2 Pressure distribution on a 2-dimensional rectangular cylinder

The pressure on the rectangular surface is obtained through SPMPS. For lifting coefficient (Cl), the deducted pressure on upper and bottom surfaces has been calculated. Figure 4. and figure 5. have shown Cl-t history diagram of two cases SR 2.0 AOA 0 and SR 2.0 AOA20.

4. CONCLUSIONS

In this study, the flow past a 2-dimensional rectangular cylinder has been comprehensively investigated with three variables: SR, AOA and turbulence intensity. The flow field around the

rectangular cylinder and the pressure distribution on the rectangular cylinder surface have been explored through the unique SPMPS, which succeeds in synchronal processing. The abundant database offers an opportunity for worldwide scholars to dive into flow field analysis and to introduce novel techniques into rectangular cylinder studies.

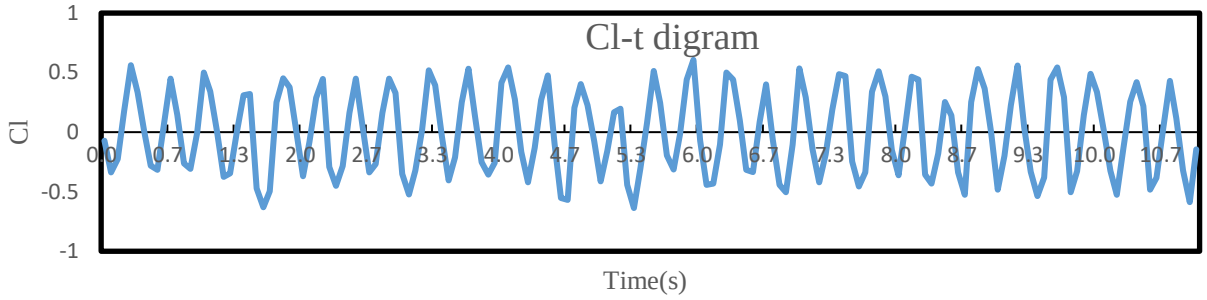


Figure 4. SR 2.0 AOA 0 Cl-t history

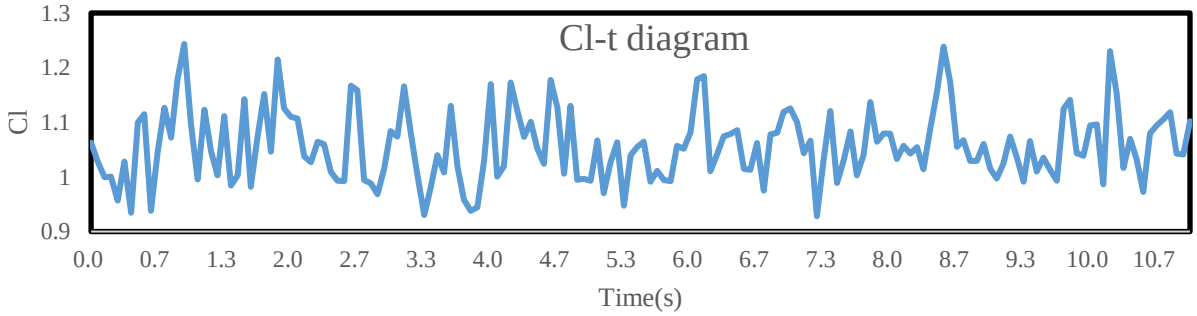


Figure 5. SR 2.0 AOA 20 Cl-t history

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REFERENCES

Bearman, P. W., & Trueman, D. M. (1972). An Investigation of the Flow around Rectangular Cylinders. Aeronautical Quarterly, 23(3), 229–237. https://doi.org/10.1017/S0001925900006119

Bruno, L., Fransos, D., Coste, N., & Bosco, A. (2010). 3D flow around a rectangular cylinder: A computational study. Journal of Wind Engineering and Industrial Aerodynamics, 98(6–7), 263–276. https://doi.org/10.1016/J.JWEIA.2009.10.005

Gao, H., Liu, J., Lin, P., Li, C., Xiao, Y., & Hu, G. (2022). Pedestrian level wind flow field of elevated tall buildings with dense tandem arrangement. Building and Environment, 226, 109745. https://doi.org/10.1016/J.BUILDENV.2022.109745

Guissart, A., Elbæk, E., & Hussong, J. (2022). PIV study of the flow around a 5:1 rectangular cylinder at moderate Reynolds numbers and small incidence angles. Wind and Structures, 34(1), 15–27. https://doi.org/10.12989/WAS.2022.34.1.015

Li, M., Li, Q., & Shi, H. (2021). Effect of sinusoidal vertical gust on the pressure distributions on and flow structures around a rectangular cylinder. Experiments in Fluids, 62(7), 1–18. https://doi.org/10.1007/S00348-021-03192-W/FIGURES/18

Okajima, A. (1990). Numerical simulation of flow around rectangular cylinders. Journal of Wind Engineering and Industrial Aerodynamics, 33(1–2), 171–180. https://doi.org/10.1016/0167-6105(90)90033-9

Schewe, G. (2013). Reynolds-number-effects in flow around a rectangular cylinder with aspect ratio 1:5. Journal of Fluids and Structures, 39, 15–26. https://doi.org/10.1016/J.JFLUIDSTRUCTS.2013.02.013

Wu, B., Li, S., Li, K., & Zhang, L. (2020). Numerical and experimental studies on the aerodynamics of a 5:1 rectangular cylinder at angles of attack. Journal of Wind Engineering and Industrial Aerodynamics, 199, 104097. https://doi.org/10.1016/J.JWEIA.2020.104097