August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering

Wind tunnel tests of blockage ratio effect on pressure distribution for cylinder at different experimental arrangements

Łukasz Flaga [1], Renata Kłaput [2], Andrzej Flaga [3]

[1] *Researcher, Cracow University of Technology, Poland, lukasz.flaga@pk.edu.pl*
[2] *Researcher, Cracow University of Technology, Poland, rklaput@pk.edu.pl*
[3] *Full Professor, Cracow University of Technology, Poland, aflaga@pk.edu.pl*

SUMMARY:
The paper concerns an evaluation of blockage ratio (BR) effect reduction by slotted side walls of wind tunnel pressure surface distributions for prismatic bars of circular cross-sections. The tests were performed in the boundary layer wind tunnel of the Wind Engineering Laboratory at the Cracow University of Technology. Tests were conducted with the use of prismatic bar models and pressure scanners. Case study focuses on different arrangement i.e. configuration of prismatic bar of BR=15% with respect to both along axis and side walls of the wind tunnel working section. The results obtained on side walls of prismatic bar are similar for both cases i.e. solid side walls and side walls with slots. Results obtained for case with slotted side walls for the blockage ratio of 15% located in the centre core of wind tunnel working section are in good correspondence with results for blockage ratio of 5% known from literature.

Keywords: wind actions, blockage ratio, pressure distributions, 2D case study, circular cross-section

1. INTRODUCTION

Due to the limited working sections of wind tunnels and the aim to reduce of research costs, it is required to scale the research objects. The adopted model scale results from the available dimensions of the wind tunnel working section and its dependence on the blockage ratio phenomenon (BR). In practice, most often it does not exceed 5%, which is confirmed by many published research papers (i.e. Simiu and Scanlan, 1996; Buresti, 1981; Antoine and Olivari, 2009). This ratio results mainly from flow pattern around probe and fluid parameters and are adopted on the level of 5% for solid walls, ceiling and floor of the wind tunnel working section. However, it is not deeply investigated what is the maximum possible BR for wind tunnel with a dedicated stabilization chambers, which are separated from the main working section by slotted walls (see WEL CUT parameters description at Flaga, 2008). Another issue is an arrangement of probe across wind tunnel and the impact of boundary layer of the side walls of the tunnel caused by a proximity of the probe.

The aim of the wind tunnel tests was to determine the evaluation of BR effect reduction by slotted side walls of wind tunnel on pressure distributions on the surfaces of prismatic bars of circular cross-section. The tests were performed in the boundary layer wind tunnel of the Wind Engineering Laboratory at the Cracow University of Technology with the use of pressure scanners.

Case study focuses on different arrangements of prismatic bar of BR = 15% in across wind direction with respect to different perforation of side walls of the wind tunnel working section (see

Fig.1).

a)

b)

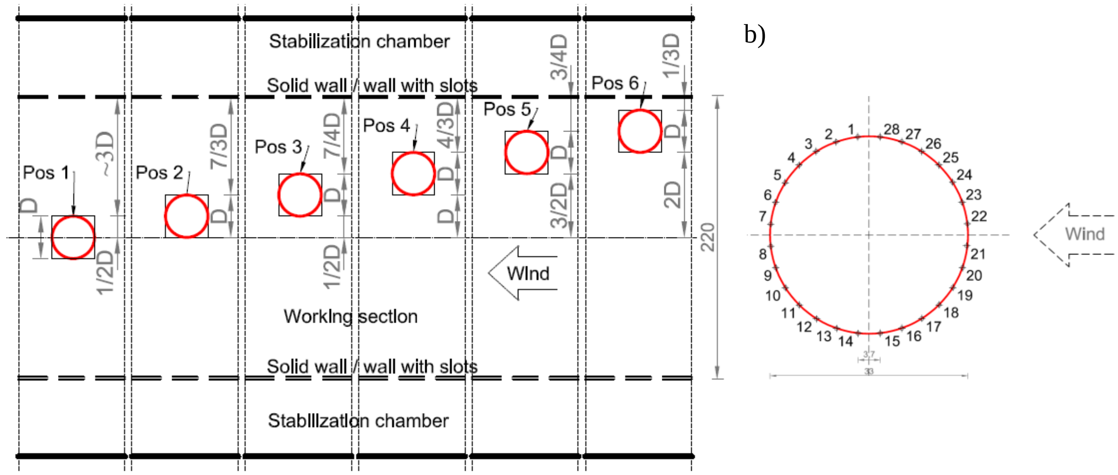

Figure 1. Plan view of each case configuration of prismatic bar with respect to both along axis and side walls of the wind tunnel working section (a); arrangement/numbering of pressure points along perimeter of the probe with indication of onflowing wind direction (b).

2. EXPERIMENTAL SETUP

Experimental setup of the wind tunnel working section is presented in Fig. 1. This experiment included: 1 characteristic dimension of prismatic bar D = 0,33m i.e. diameter of cylinder; BR = 15%; 6 different configurations related to the longitudinal axis of the wind tunnel; 2 different types of sidewalls (solid and slotted with 2.5 cm slots and 11 cm panels, see Fig. 2.); 2 levels of onflow turbulence (approx. 2% and 10% with special turbulence grate mounted at the inlet of working section); mean wind inflow velocity of 8 m/s.

a)

b)

Figure 2. View of the circular prismatic bar (D=0,33m; BR=15%) within the working section of the wind tunnel, case 1: position 1, slotted walls with 2,5 cm slots (a) and solid side walls (b)

Tested model was crafted as a prismatic bar of circular cross section. It was made with the use of steel sheet as a coat and furniture boards as ribs. The bar was mounted to floor and ceiling and contained 28 pressure points along the perimeter (see Fig. 1.b). Pressure scanners were placed inside the bar. Surface roughness for probe was adopted as for steel i.e. k/D=0,001 (see Fig. 3.3). Reynolds number for adopted parameters is $1{,}76 \cdot 10^5$.

3. EXPERIMENTAL TESTS RESULTS

Results were obtained as values of pressure time series for each pressure point along the perimeter. Signals were recorded with 250Hz frequency of sampling and for 20s sampling time, providing a total of 5000 samples. During the tests, three different values of pressure coefficient are determined at each measuring point: mean pressure coefficient, maximal pressure coefficient and minimal pressure coefficient.

Curves of pressure coefficient C_p for each pressure point (PP) distributed on the prismatic bar surface for case of solid walls and side walls with 2,5cm slots, turbulence intensity Iv=2% and for each configuration (pos. 1 – pos. 6) of prismatic bar across wind tunnel are shown in Fig. 3. For better readability windward wall was indicated in blue.

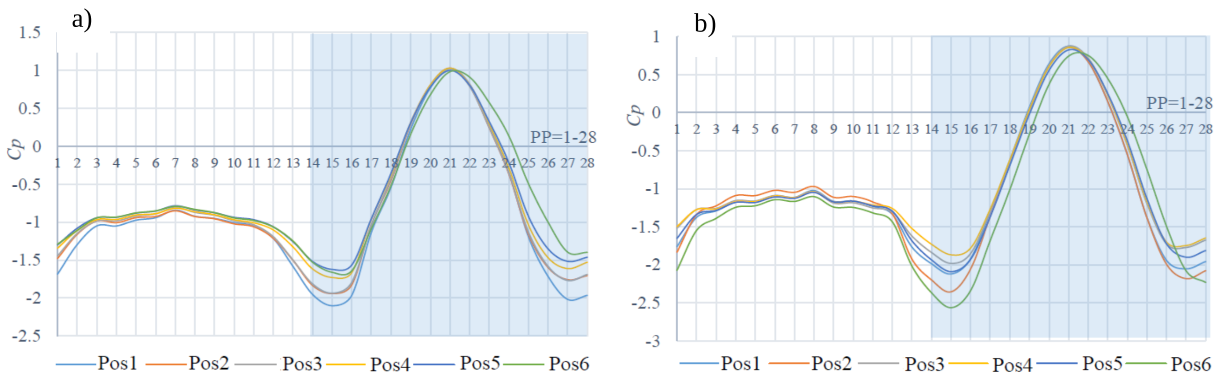

Figure 3. Curves of pressure coefficient C_p for each pressure point (PP) distributed on the prismatic bar surface for case of side walls with 2,5cm slots (a) and solid walls (b), turbulence intensity Iv=2% and for each configuration (pos. 1 – pos. 6) of prismatic bar across wind tunnel

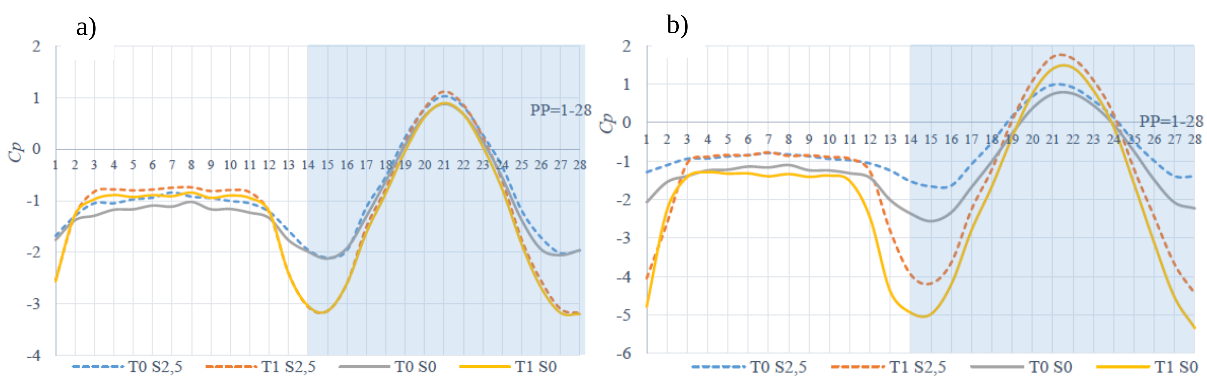

Figure 4. Curves of pressure coefficient C_p comparison of 4 selected cases (description in the text) for each pressure point (PP) distributed on the prismatic bar surface, for configuration pos. 1 (a) & pos. 6 (b) of prismatic bar across wind tunnel

Curves of pressure coefficient C_p for each pressure point (PP) distributed on the prismatic bar surface, for configuration pos. 1 (a) & pos. 6 (b) of prismatic bar across wind tunnel, are shown in Fig. 4. These curves present 4 cases: 1. “T0 S2,5” - side walls with 2,5cm slots & Iv=2%,
2. “T1 S2,5” - side walls with 2,5cm slots & Iv=10%, 3. “T0 S0” - solid side walls & Iv=2%; 4. “T1 S0” - solid side walls & Iv=10%. For better readability windward wall was indicated in blue.
In order to identify how turbulence affects the BR phenomenon, tests were conducted for 2 levels of onflow turbulence (approx. 2% and 10% with special turbulence grate mounted at the inlet of working section). On the basis of the obtained measurement results, the 4 values of the aerodynamic drag coefficients C_x for individual cases were developed.

Methodology of Reynolds number problem solving for a cylinder was elaborated in (Flaga, 1996). Basing on this considerations one can clearly notice transition region. It was proved that turbulence in the approaching flow has a strong effect on the variation of C_x with Re in the transition region as illustrated in Fig. 5.

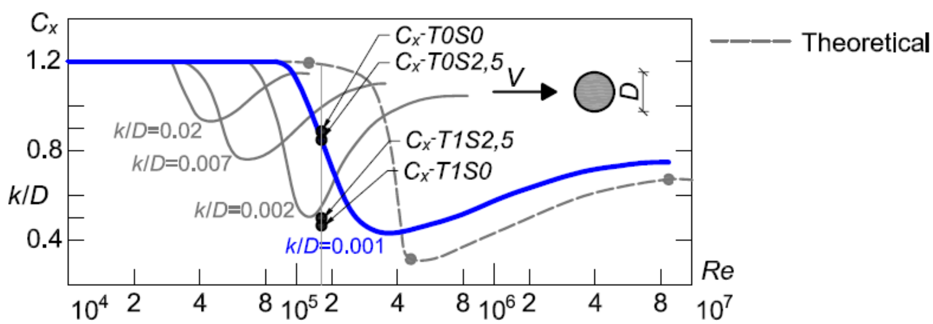

Figure 5. Influence of turbulence on aerodynamic drag coefficients C_x for configuration Pos. 1 of circular prismatic bar for 4 tested cases; k – mean roughness height

5. CONCLUSIONS

The values of pressure coefficient C_p are a bit lower on windward side of circular prismatic bar surface for solid side walls case than for slotted side walls case. Results of pressure coefficient C_p known from literature (see e.g. West and Apelt, 1982, Roshko, 1961) for circular cross section investigations of BR=5% present values equal to 1 in stagnation point. Therefore results obtained for BR=15% with slotted side walls are in good correspondence with results for BR=5% known from literature. Good correspondence of results obtained for Pos.1-Pos.3 confirm a beneficial impact of side walls with slots. Also a beneficial impact to the flow structure can be observed for this case of side walls as the absolute values of negative pressure coefficient C_p (suction) for the leeward wall are lower than for solid walls case. The case of low turbulence and solid side walls differs from other cases. It also differs from results known from literature (see Roshko, 1961; Noda, Utsunomiya and Nagao, 1995) for which $C_p \cong -1{,}0$ for $Re = 1{,}1 \cdot 10^5$.

REFERENCES

Antoine J., Olivari D., 2009 Wind tunnel blockage effect on drag coefficient of circular cylinders, Wind and Structures an International Journal 12(6).

Buresti G. 1981. The effect of surface roughness on the flow regime around circular cylinders Journal of Wind Engineering and Industrial Aerodynamics., 8: 105-114

Flaga A, 2008. Wind Engineering. Fundamentals and Applications, Arkady, Warsaw 2008 [in Polish].

Flaga A.1996: Wind vortex-induced excitation and vibration of slender structures. Single structure of circular cross-section normal to flow. Monograph 202, Cracow University of Technology, 1996.

Noda M., Utsunomiya H., Nagao F. 1995. Basic study on blockage effects in turbulent boundary layer flows. Journal of Wind Engineering and Industrial Aerodynamics 54/55 (1995) 645-656.

Roshko A. 1961 Experiments on the flow past a circular cylinder at very high Reynolds number Journal of Fluid Mechanics., 10 (Pt 3): 345-356.

Simiu E., Scanlan R.H. 1996. Wind effects on structures. Fundamentals and applications to design. John Wiley & Sons, USA, 1996.

West G.S., Apelt C.J. 1982. The effects of tunnel blockage and aspect ratio on the mean flow past a circular cylinder with Reynolds numbers between 10^4 and 10^5 Journal of Fluid Mechanics, 1982