Romanian Journal of Civil Engineering, Volume 17 (2026), Number 2

Response of the Boundary Layer Wind Tunnel to small variations of the fan rotational speed

Răspunsul Tunelului Aerodinamic cu strat limită la mici variații ale turației ventilatorului

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DOI: 10.37789/rjce.2026.17.2.9

Abstract. *To be able to induce a controlled transient flow in the Boundary Layer Wind Tunnel by modifying the frequency of the current supplied to the axial fan, the response time of the system to different step functions imposed on the frequency must be determined. Several experiments were performed for different steps of the frequency and different heights of the roughness above the tunnel floor. Measurements were performed for 4 increasing frequency steps for two different heights of the roughness on the wind tunnel floor and consisted in velocity and pressure values at different cross sections along the tunnel.*

Key words: Axial fan; Variable Roughness; Transient flow

1. Introduction

Over time, with the increase of the vertical development and the safety needs the wind engineering field is also developing. In the last years, there are more often wind engineering tests requested, in order to obtain more accurate responses of the new structures and implicitly a better design. [1]

Furthermore, over recent years, due to different types of severe weather events, including potentially damaging wind phenomena like downbursts [2], wind engineering began to dedicate more interest in modelling and simulation such phenomena in order to be able to evaluate their actions on structures.

The article was received on 27.01.2026, accepted on 08.06.2026 and published on 12.06.2026

In this context, the purpose of our research is to investigate the possibility to generate a controlled transient flow in a boundary layer wind tunnel as a consequence of the variations in fan rotational speed. To accomplish this, the response of the entire system, that consist of fan, airflow and wind tunnel, to frequency variations must be evaluated [3].

The methodology to characterize the system's response involved two sets of velocity measurements. The experiment consisted of four frequency steps (1-4 Hz) with two initial frequencies and three different surface roughness conditions along the wind tunnel floor.

2. Methodology

The TASL-1 boundary layer wind tunnel, located at the Constantin Iamandi Aerodynamics and Wind Engineering Laboratory, Technical University of Civil Engineering Bucharest, was used for the experiments.

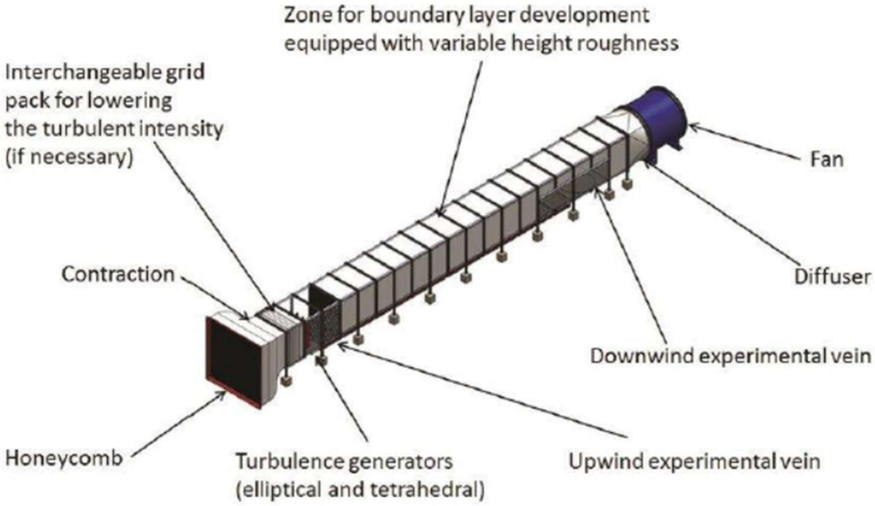


Fig. 1. The Boundary layer wind tunnel 1 [1].

The TASL-1 open-circuit tunnel (Figure 1) is 27 m long with a square cross-section with a side length of 1.75 m. The active test section involves two experimental zones (upwind and downwind), as well as a dedicated boundary-layer development section with a total length of 18.9 m [4].

In order to facilitate the experimental measurements, the wind tunnel was upgraded with a Modbus/TCP option board and dedicated software integrated into the fan’s frequency converter, enabling remote operation via Ethernet [3].

2.1. Experimental data

The present measurements were made using the same configuration as the previous experiments described in [3]. This setup involved four pressure transducers connected to two Pitot-Prandtl tubes, which can be used to read the dynamic pressure value in the wind tunnel and an additional four pressure transducers connected to pressure taps distributed along the wind tunnel.
Thes two Pitot-Prandtl tubes provide the dynamic pressure in the test section, thereby enabling the initial inflow velocity to be determined.

The dynamic pressure pd is determined from Bernoulli's equation as the difference between the total pressure pt and the static pressure ps. For an incompressible fluid, at the stagnation point, Bernoulli's equation can be written as:

$$p_t = p_s + p_d = p_s + \frac{\rho v^2}{2} \quad (1)$$

From the measured pressure difference $p_s - p_t = \Delta p$, the local flow velocity was computed as:

$$v = \sqrt{\frac{2\Delta p}{\rho}} \quad (2)$$

Therefore, velocity profiles were created for each frequency step for the three roughnesses (0 mm, 50 mm and 100 mm), based on measurements obtained from both the downstream Pitot-Prandtl tube and the upstream tube. The aim of this procedure was to assess the influence of surface roughness on the stabilization time.

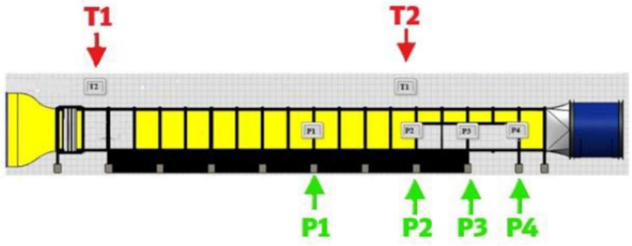


Figure 2: The position of the static pressure taps and Pitot tubes along the wind tunnel [3].

For better visualization, in Figure 2 are presented the position of the Pitot-Prandtl tubes and de pressure taps used in this research. T1 represents the upwind Pitot-Prandtl tube and T2 represents the downwind tube, while the four pressure taps are labeled P1 - P4.
The experiment consisted of eight measurement series, performed for four frequency steps, each initiated at two distinct starting frequencies as summarized in Table 1.

Tabelul 1

Initial frequencies

Frequency step (Hz)	Initial frequency (Hz)	
	I	II
1	5 Hz	10 Hz
2	5 Hz	10 Hz
3	7 Hz	12 Hz
4	6 Hz	11 Hz

Due to manufacturer-imposed limitations, the fan's frequency converter cannot accommodate an instantaneous step signal. The steepest permissible input is a 50 Hz increase over 10 s. For the experimental case, corresponding to 8% of the maximum frequency step (4 Hz), the step duration was 0.4 s as shown in Figure 3.

To achieve an accurate representation of the frequency step slope, the frequencies were normalized to a common origin using the following equation:

$$f_{a,i} = f_i - f_1 \qquad (1)$$

where:
$f_{a,i}$ – frequency translated in the same origin
f_i – frequency obtained from measurements
f_1 – first value of the frequency obtained from measurements

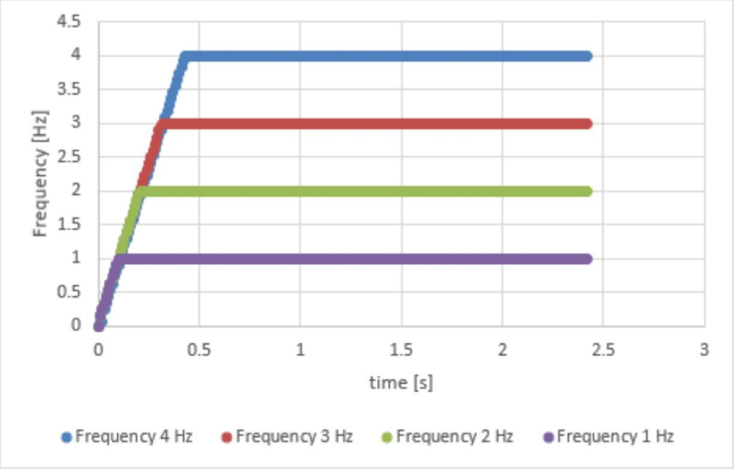


Figure 3: The increasing frequency steps used in the experiments.

2.2. Equations overview

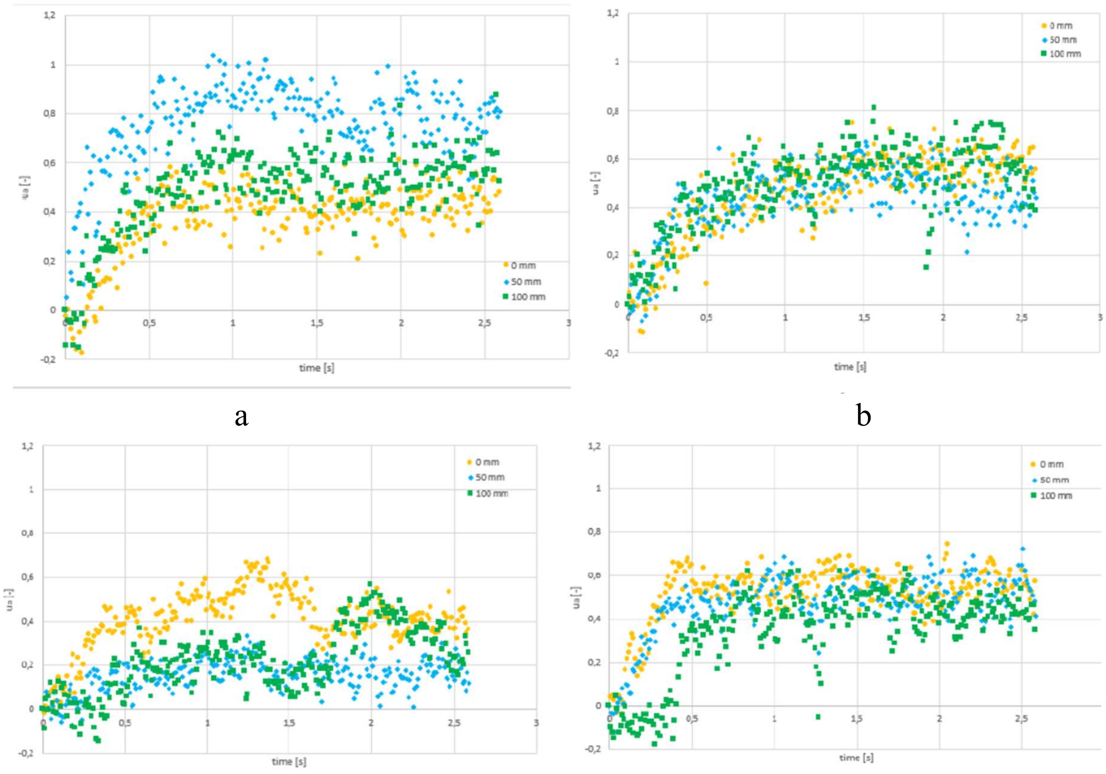
To accurately characterize the variation of velocity as a function of time for the cases described in the preceding section, the results were aligned to a common origin using the following equation:

$$u_{a,i} = u_i - u_1 \qquad (2)$$

where:
$u_{a,i}$ – velocity translated in the same origin
u_i – velocity obtained from measurements
u_1 – first value of the velocity obtained from measurements

3. Results and discusions

The data obtained for a frequency increment of 1 Hz, corresponding to the three different tunnel floor roughness conditions, are presented in Figure 4. The first two plots (a and b) illustrate the results for the frequency range between 5 Hz and 6 Hz, while the last two plots (c and d) present the range between 10 Hz and 11 Hz.

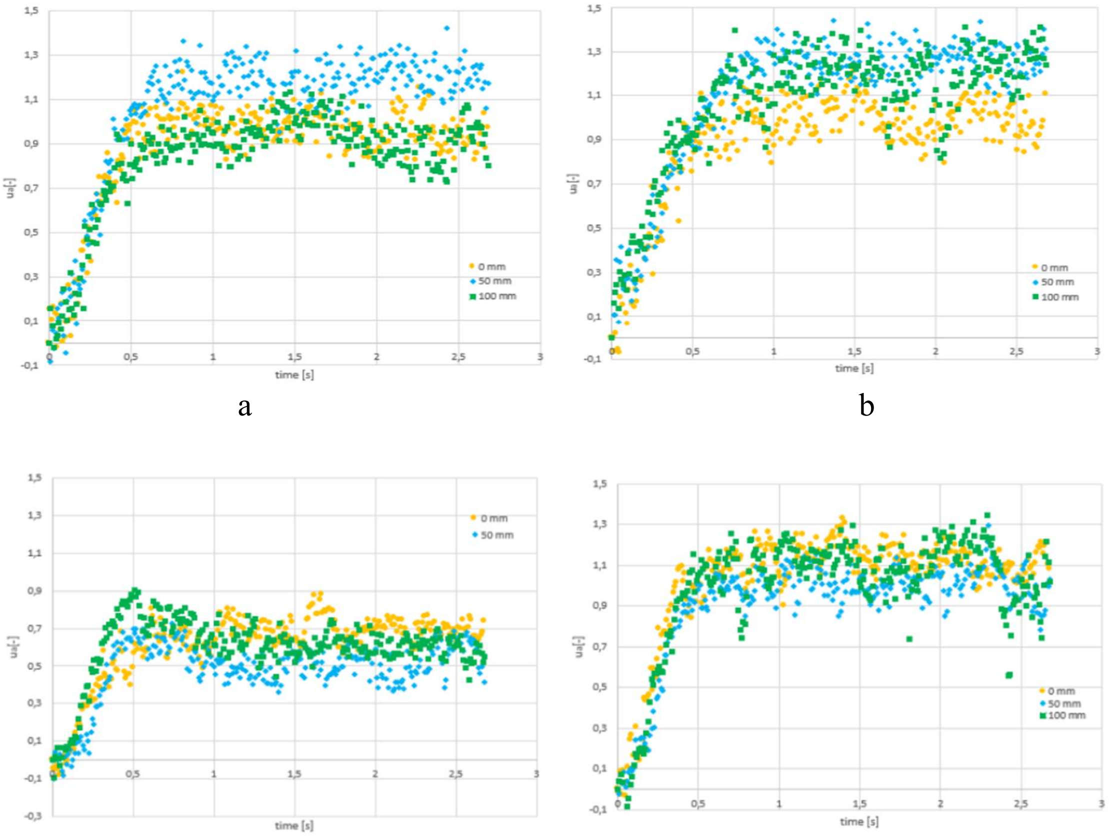


a b

c d

Figure 4. Velocity variation over time for the roughness's of 0 mm, 50mm and 100mm for the frequency step of 1 Hz starting from: a –5 Hz upstream Pitot tube, b – 5 Hz downstream Pitot tube, c – 10 Hz upstream Pitot tube, d – 10 Hz downstream Pitot tube.

Figure 5 the data corresponding to a frequency increment of 2 Hz for the three tunnel floor roughness conditions. The first two plots (a and b) illustrate the results for the frequency range between 5 Hz and 7 Hz, while the last two plots (c and d) present the range between 10 Hz and 12 Hz.

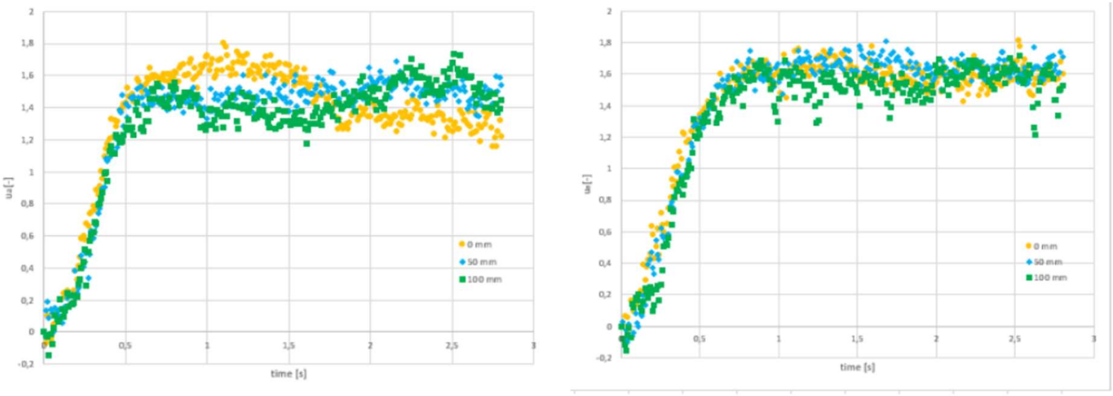


a b

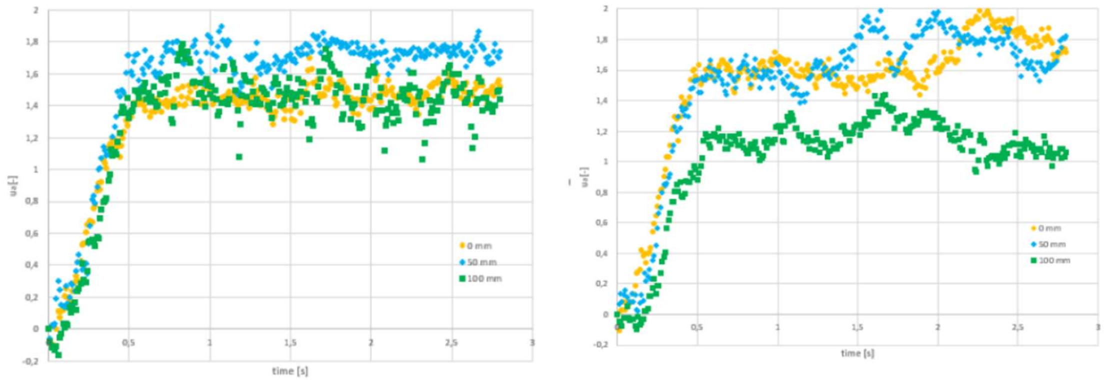
c d

Figure 5. Velocity variation over time for the roughness's of 0 mm, 50mm and 100mm for the frequency step of 2 Hz starting from: a –5 Hz upstream Pitot tube, b – 5 Hz downstream Pitot tube, c – 10 Hz upstream Pitot tube, d – 10 Hz downstream Pitot tube.

Figure 6 presents the data corresponding to a frequency increment of 3 Hz for the three tunnel floor roughness conditions. The first two plots (a and b) illustrate the results for the frequency range between 7 Hz and 10 Hz while the last two plots (c and d) present the range between 12 Hz and 15 Hz



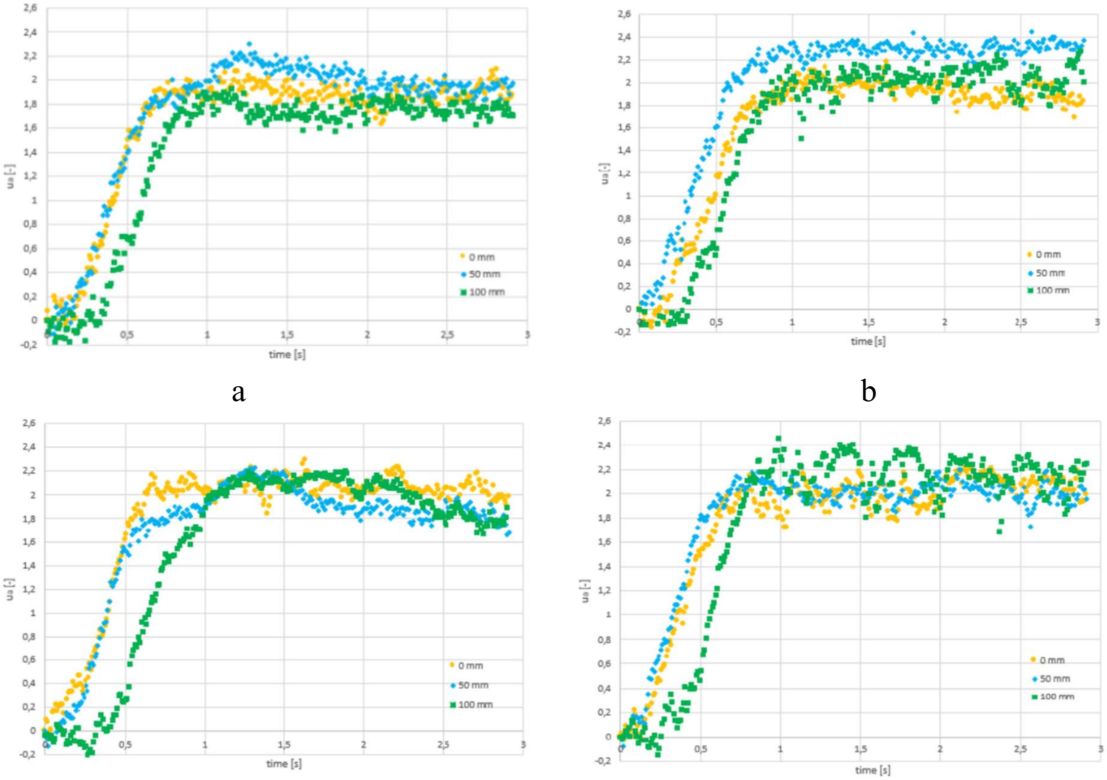
a b



c d

Figure 6. Velocity variation over time for the roughness's of 0 mm, 50mm and 100mm for the frequency step of 3 Hz starting from: a –7 Hz upstream Pitot tube, b – 7 Hz downstream Pitot tube, c – 12 Hz upstream Pitot tube, d – 12 Hz downstream Pitot tube.

And, in the last figure, Figure 7 presents the data corresponding to a frequency increment of 4 Hz for the three tunnel floor roughness conditions. The first two plots (a and b) illustrate the results for the frequency range between 6 Hz and 10 Hz, while the last two plots (c and d) present the range between 11 Hz and 15 Hz.



a b

c d

Figure 7. Velocity variation over time for the roughness's of 0 mm, 50mm and 100mm for the frequency step of 4 Hz starting from: a – 6 Hz upstream Pitot tube, b – 6 Hz downstream Pitot tube, c – 11 Hz upstream Pitot tube, d – 11 Hz downstream Pitot tube.

4. Conclusions

The aim of this research is to evaluate the response of the whole system to different frequency variation steps. Measurements were performed for 4 increasing frequency steps for different heights of the roughness on the wind tunnel floor.

For the 1 Hz frequency step the differences in velocity are hardly noticeable especially at high values of the roughness on the floor of the tunnel due to the increased velocity fluctuations induced by the roughness in the downstream experimental zone.

For the other steps velocity differences are noticeable and a lag of velocity stabilization with respect to the frequency, lag that seems to increase as the frequency step increases was observed. In order to quantitatively estimate this lag, future work will be dedicated to finding a suitable smoothing procedure for the signals obtained in this stage.

References

[1] M. Degeratu, L. Hasegan, R. Pascu, A. Georgescu, C. I. Cosoiu, L. Sandu, Dynamic wind tunnel tests for the Bucharest tower center, Scientific Bulletin of the Politehnica University of Timisoara Transactions on Mechanics Tom 51(65), Fascicola 3, Special issue

[2] Solari G., Mixed Climatology, Non-synoptic Phenomena and Downburst Wind Loading of Structures, XV Conference of the Italian Association for Wind Engineering (IN VENTO), Naples, Italy, 2018, pp. 17-31

[3] Iagar O. A., Vladut A. C., Cosoiu C. I., Georgescu A. M., Popescu O., Response of the "Boundary Layer Wind Tunnel 1" to a 10% variation of the fan rotational speed, 2019 International Conference on ENERGY and ENVIRONMENT (CIEM), Timisoara, Romania, 2019, pp. 274- 278

[4] Vladut A. C., Popa S.I., Cosoiu C. I., Georgescu A. M., Hasegan L., Anton A., A new boundary layer wind tunnel, UPB Scientific Bulletin, Series D, vol. 79, 2017, pp. 159-168

[5] Sandu, L., Degeratu, M., Hasegan, L., Georgescu, A., Stefan, R., Cosoiu, C., “Actual and Perspective Research in Wind Engineering”, Trans. on Mechanics, Sci. Bull. Politehnica University of Timisoara, Romania, Vol. 50 (64), 2005, pp. 23-32.