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EXPERIMENTAL STUDY IN THE CROSS SECTION OF THE NEW BOUNDARY LAYER WIND TUNNEL TASL1-M

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Abstract: *The aim of this paper is to determine the velocity profile and turbulent structure in the cross section of the new upgraded boundary layer wind tunnel TASL1_M at the Aerodynamics and Wind Engineering Laboratory "Constantin Iamandi", in order to compare the data series obtained for different sections, or for different inlet velocities. Our investigations were made in order to test the internal similitude properties of flowing and to be aware of the capabilities of TASL1-M.*

Key words: *wind tunnel, cross section, axial velocity distribution, turbulence intensity distribution, inlet velocity.*

1. Introduction

Since ancient times, human society was concerned with the study of the ecosystem vital elements, in their attempt to understand it, and use the knowledge to fight against its destructive effects. Currently, due to rapid development in the last centuries, and the sharp rise in global population, it is more often raised the problem of the climate change effects, and the capabilities of our society to adapt it.

In order to adapt to the new climate change challenges, in the Wind Engineering Laboratory "Constantin Iamandi" the aerodynamic tunnel TASL1-M was refurbished due to a POS CCE grant - "Extending the TASL Boundary Layer Wind Tunnel Capabilities in order to cope the Climate Change Challenges".

Some of the wind engineering problems that can be investigated in the new upgraded wind tunnel TASL1-M are static and dynamic wind effects on high raised buildings, suspended bridges, water towers, dams, wind turbines, combined wind and snow action, or combined wind and rain action, urban aerodynamics and pedestrian comforts.

The aim of this study is to determine the axial velocity distribution and turbulent structure in the cross section of the experimental vein for different values of inlet velocities in the new refurbished TASL1-M, equipped with a Laser Doppler Anemometry LDA equipment for measurements.

The practical part of the paper consists in describing and interpretation of the experiments conducted in the cross section of wind tunnel TASL1-M for different inlet velocities in order to measure axial velocity profile and turbulent intensity. Measurements were performed for different frequencies of the fan. After acquiring and

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recording data series in all proposed cases, the data were examined and the velocity was divided by the maximum velocity obtained for each data series in order to obtain dimensionless values.

2. The New Refurbished Boundary Layer Wind Tunnel TASL1-M

The old aerodynamic wind tunnel TASL1-M which is in the Aerodynamics and Wind Engineering Laboratory from the Technical University of Civil Engineering of Bucharest, have undergone an ample modernization modifying completely operational parameters, and its capabilities of developing boundary layers for velocities up to 30 m/s. It has been modified the axial fan, and also the variable roughness system - which is now actioned electrical.

The refurbished boundary layer wind tunnel it's an open circuit wind tunnel, the fan is placed downstream the experimental vein. The airflow is controlled by an axial fan with a 200 kW electric motor equipped with frequency convertor. The total length of the wind tunnel is about 27 m, and the active section is 18.9 m. The dimensions of the cross-section are 1.75 x 1.75 m.

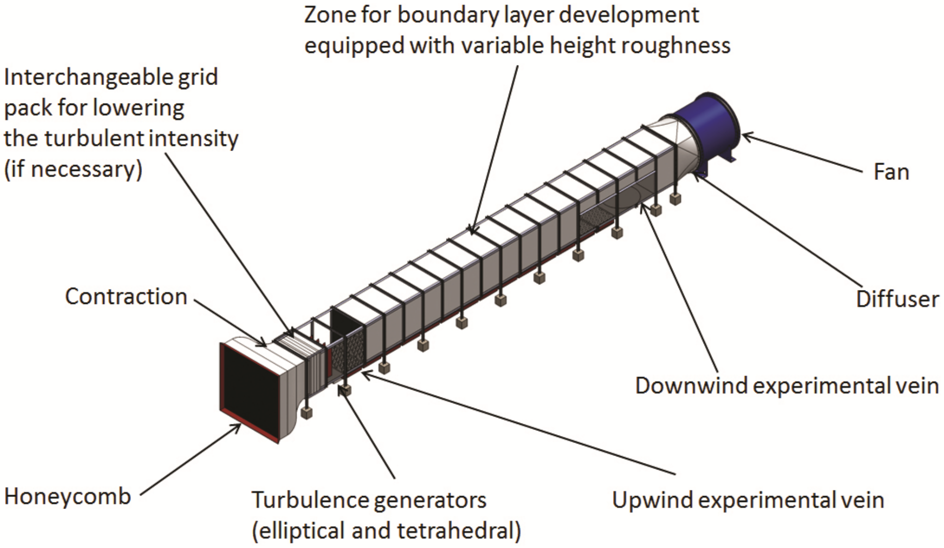

Fig. 1. *The TASL-1M wind tunnel* [10]

The upwind experimental vein ensures a constant velocity profile. The downwind experimental vein, where a well-developed boundary layer velocity profile is required, is placed near the fan. The boundary layer development section is situated between the two experimental veins. This area is equipped with a variable roughness system which is able to automatically modify the roughness on the bottom of tunnel by adjusting the height of 560 bricks between 0 and 200 mm. The bricks can be adjusted by groups of 40 on 14 independent sections of the zone. For these measurements, the variable roughness height was setup to the value of 100 mm (Figure 2).

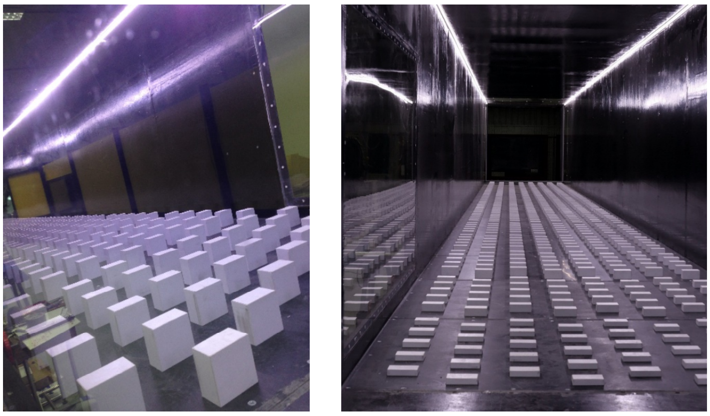

Fig. 2. *Variable roughness in the TASL1-M wind tunnel* [10]

3. Laser Doppler Anemometry LDA Measurement Equipment

Laser Doppler Anemometry LDA is a non-contact optical measuring instrument used to measure the local velocity and turbulence intensity in gases and liquids. The method of measuring with a laser anemometer offers unique advantages compared to other local speed measuring instruments, namely:

- No calibration required;
- Velocity range from 0 to supersonic;
- Non-intrusive measurement technique;
- Measurements of one, two, or three velocity components simultaneously;
- Measurements of flow reversal;
- High spatial and temporal accuracy.

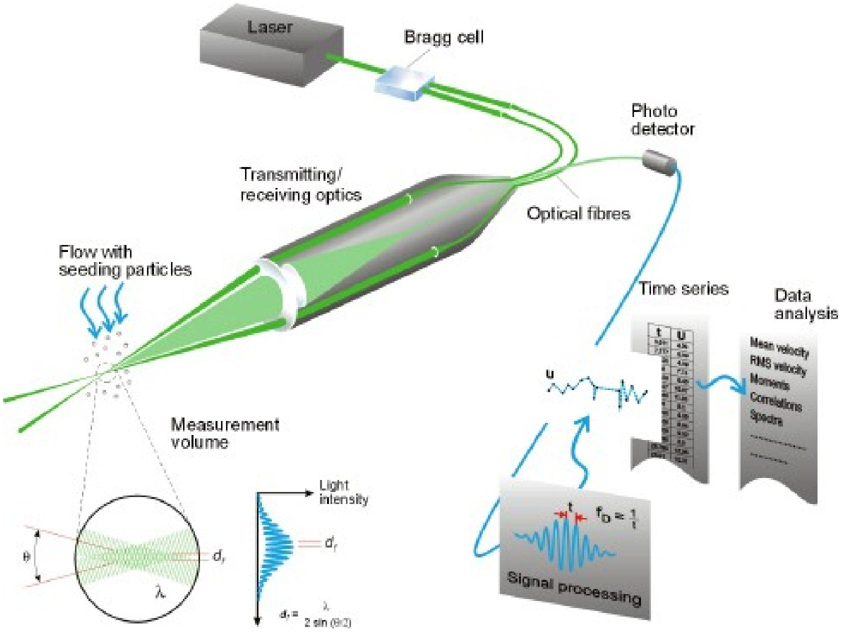

Fig. 3. *LDA measurements principle* [3]

The basic configuration of LDA (Figure 3) consist in a continuous wave laser that is splitted through a beam splitter called Bragg cell, and directed through the focusing lens from the transmitting optics to the measurements volume. The output of the Bragg cell is two beams of equal intensity.

There, the flow with seeding particles send back to the receiving optics a light signals up to the photodetector. From there, the signal is processed through the signal conditioner, and finally to the signal processor.

4. Experimental Setup in the Cross Section of the Wind Tunnel TASL1-M

As it has been described previously, in the section 1 of this paper, the measurement was done by changing the value of inlet velocity, through the variable frequency converter of the fan, from values of 10 Hz, 20 Hz, and 30 Hz. As we previously mentioned, he value of variable roughness was set up for 100 mm.

Measurements were made in the cross section of the experimental vein, for 5 different axes, as is illustrated in Figure 4.

Before setting up the frequency converter, it is important to know the axes of the LDA equipment, and the axes of the traverse system which is changing the position if the LDA probe, and of course - the axis that are measured in the cross section.

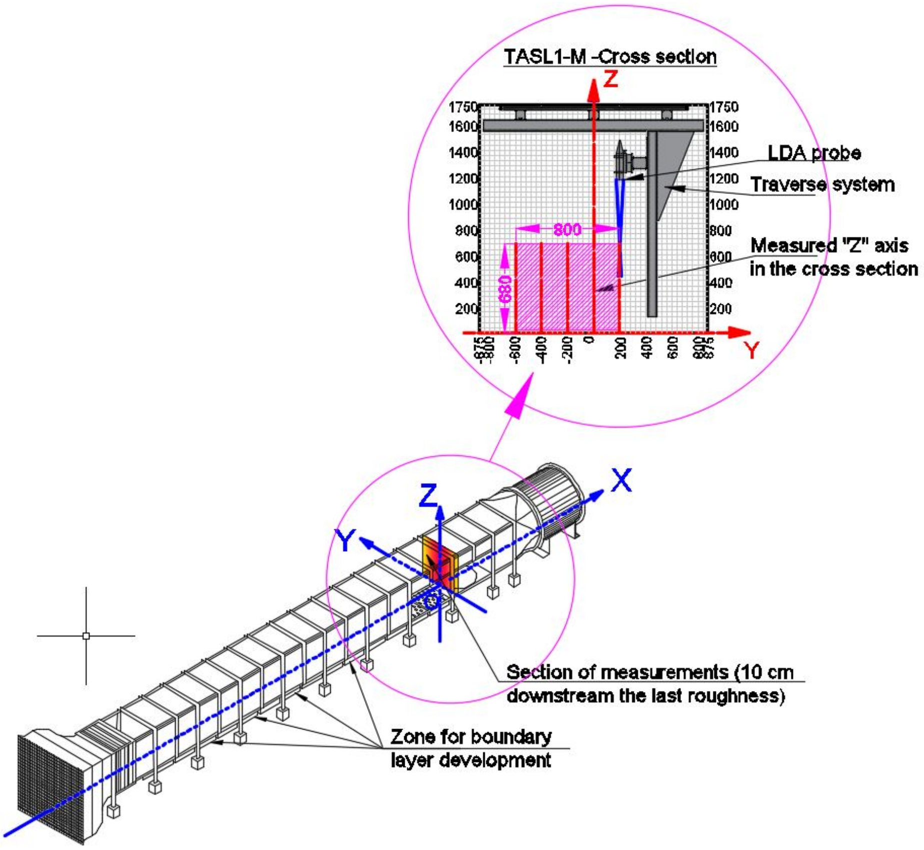

Fig. 4. *Measurement axis in the wind tunnel TASL1-M*

According with Figure 4, the measurements were done for the cross section 10 cm downstream the last roughness block, for 5 Y axis (Y = -600 mm, Y = -400 mm, Y = -200 mm, Y = 0 mm, Y = +200 mm), starting from Z = 0 mm, up to the Z = 680 mm, with a step of 2 cm, resulting a number of 15 data sets for velocity distributions and turbulence intensity in the experimental boundary layer of TASL1-M

The measurements of local axial velocity, and turbulence intensity were done by mediation of about 10.000 velocity signals, for a period of 30 seconds. The number of velocity signals that are received by the photodetector is a function of the quality of seeding's. For these measurements, we used paraffin oil, that is sprayed from an atomizer in the inlet section. This kind of seeding offer a quality seeding, reaching in 99% of the situation to the value of 10.000 signals in less than 10 seconds.

In order to observe if there is a similitude in the axial velocity distributions measured, regardless the value of inlet velocity and also - regardless the axis Y measured inside the cross section - it has been divided the value of local axial velocity measured by the maxim measured velocity for each measured data sets (u/u_{max}).

The values for u_{max} are:

Maximum axial velocities u_{max} *measured in TASL1-M* Table 1

f (Hz)	10	20	30
Velocity *u* (m/s)	7.18	14.44	21.26

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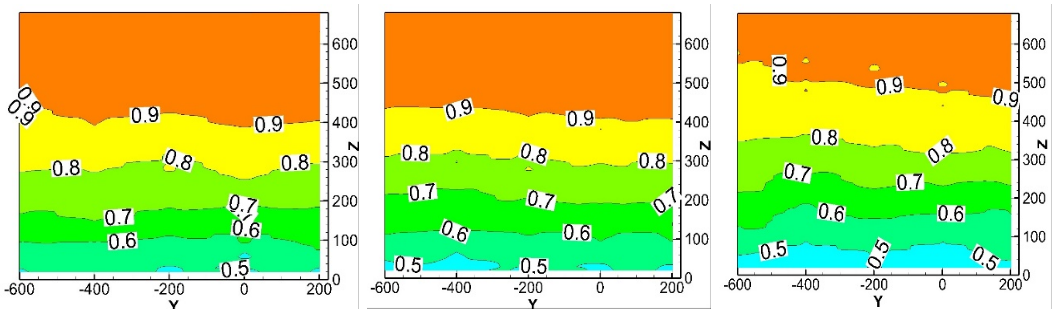
The local dimensionless velocity obtained was extrapolated in order to have a general view of the velocity distributions obtained in the cross section for different values of inlet velocities. The results are presented in the Figure 5 below.

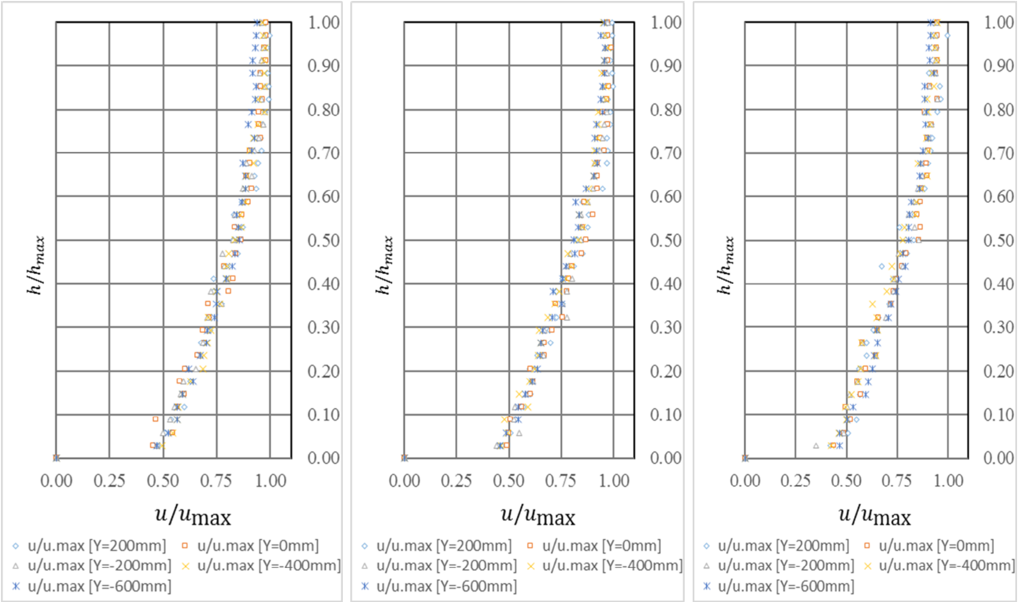
As one may observe, the extrapolated view of the dimensionless velocities for different inlet velocities looks very similar, which means that the velocity distribution in the boundary layer is similar, regardless the value of inlet velocity in the experimental vein of the wind tunnel TASL1-M. Also, the velocity distribution profile in the cross section is pretty similar, regardless the measured Y axis.



a) b) c)

Fig. 5. *Dimensionless velocity distribution in the cross section experimental vein of the wind tunnel:* a) *f =10 Hz;* b) *f = 20 Hz;* c) *f = 30 Hz*

In order to have a better view of the velocity distribution profiles regardless the Y axes that was measured inside of the cross section, the dimensionless data series for measured Y axis was overlaid, as we can see in Figure 6 below.



a) b) c)

Fig. 6. *Dimensionless velocity distribution with Y axis measured overlaid*: a) *f = 10 Hz*; b) *f = 20 Hz*; c) *f = 30 Hz*

Having e better view of the dimensionless velocity profiles, it can be seen - regardless the axis Y measured inside the cross section of the experimental vein, the points are agglomerates around a very well-defined zone, suggesting the fact that the velocity profiles are similar in the entire cross section of experimental vein, concluding that the aerodynamic wind tunnel is developing uniform velocity distributions in the entire cross section.

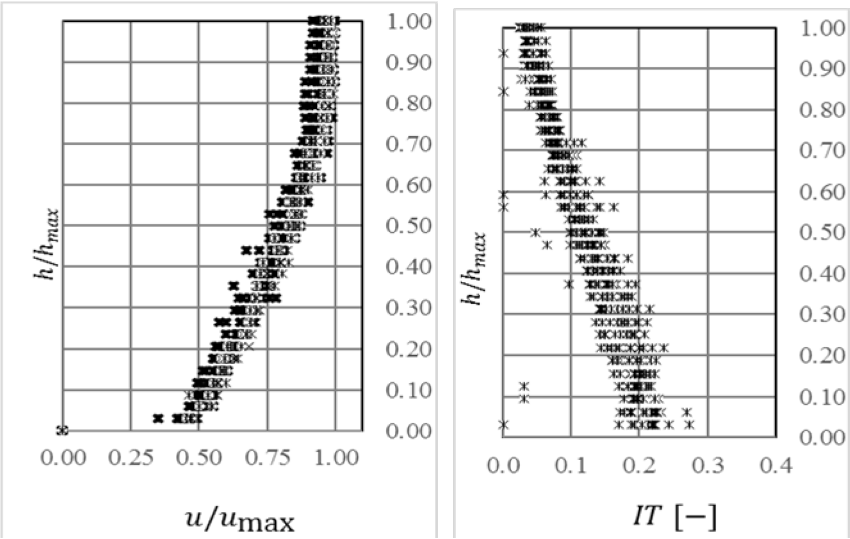
Also, as it can be seen in the Figure 7, when the velocity distributions profile regarding the inlet velocity are overlaid, we obtain a really good view that the velocity distributions developed in the aerodynamic tunnel TASL1-M are similar, regardless the inlet velocity, which conducts to the idea that there are a very good internal similitude property in the air flowing inside the experimental vein of the wind tunnel TASL1-M.

Also, in order to have a view of the turbulence intensity measured inside the cross section, and to conclude if there are the same internal similitude properties, and the same uniform developing profiles in the entire cross section for the intensity turbulence profiles (based on the conclusion obtained that velocity distributions are similar, regardless the measured Y axis), all values of local turbulence intensity obtained for all 15 data series was overlaid. The turbulence intensity is defined as:

$$IT = \frac{u'}{u}, \tag{1}$$

where *u'* is the root-mean-square of turbulent velocity fluctuations, and *u* is the measured mean velocity.

The results are presented in Figure 7.



a) b)

Fig. 7. *Dimensionless velocity distribution (u/u_{max}) and turbulence intensity (IT) regardless the axis Y measured, and also the inlet velocity in the wind tunnel: a) u/u_{max} ; b) IT*

The intensity turbulence profile is higher in the bottom part of the cross section - due to the roughness from the floor (the value of variable roughness was set up at 100 mm, and is lowering - increasing the measured height in the experimental vein. From the chart above (Figure 7b), we can get the same conclusion for the intensity distribution as it has been concluded for the velocity profiles. The turbulence intensity distribution profiles are similar, regardless the inlet velocity in the wind tunnel, and also - regardless the axis Y measured inside the cross section of the experimental vein. This also induces the idea of the uniform turbulence intensity fields in the entire cross section of the experimental vein, and also strong internal similitude property of the aerodynamic wind tunnel TASL1-M.

5. Conclusions

The new refurbished aerodynamic tunnel from the Aerodynamics and Wind Engineering Laboratory “Constantin Iamandi” of the Hydraulic and Environmental Protection Department from the Technical University of Civil Engineering Bucharest is operational, and it can simulate boundary layers for different values of roughness (from 0 to 200 mm), and for different values of inlet velocities (from 0 to 30 m/s). Measurements performed in order to see the performances of the TASL 1-M confirm the fact that the velocity and turbulence intensity profiles obtained in the tunnel vein are reproducing the atmospheric boundary layer structure.

The measurements that was done with a new, non-intrusive equipment, that requires no calibration - Laser Doppler Anemometry LDA was processed in order to observe if there is a similitude in the axial velocity distributions measured, regardless the value of inlet velocity. As anyone can observe, from the Figures 5, 6 and 7, there is a uniform field for the entire cross section of the experimental vein, with a strong constant similitude in the dimensionless axial velocity distribution, the velocity distributions and turbulence intensities for the section measured are very similar - and develop the same distribution profile. From the idea that the there are similar velocity distribution profile regardless the axis Y measured in the cross section (Figures 5 and 6), the conclusion is that the aerodynamic tunnel is developing uniform velocity fields in the entire experimental vein. From the idea resulted from the Figure 7a - that the velocity profiles are similar regardless also the inlet velocity, we conclude that there is a strong internal similitude properties of the air flow inside the experimental vein of the aerodynamic wind tunnel.

As for the turbulence intensity *IT* (Figure 7b), as we expected, a higher turbulence intensity is observed at the bottom part of the cross section - due to the roughness from the floor, and is lowering - increasing the measured height in the experimental vein. Also, it was concluded that there are unifom fields inside the cross section of the wind tunnel, and also similitudes for turbulence intensity profile, regardless the inlet velocity or the Y axis measured in the cross section of TASL1-M.

References

1. Coșoiu, C.I.: *Extending the TASL1 Boundary Layer Wind Tunnel Capabilities in Order to Cope the Climate Change Challenges.* In: EENVIRO 2014 - Sustainable Solutions for Energy and Environment, 2014.
2. Coșoiu, C.I., Georgescu, A.-M., Degeratu, M., Hlevca, D.: *Numerical Predictions of the Flow around a Profiled Casing Equipped with Passive Flow Control Devices.* In: Journal of Wind Engineering and Industrial Aerodynamics (2013), p. 48-61.
3. Dantec Dynamics: *Laser Doppler Anemometry. Introduction to Principles and Applications.* User Manual, 2013.
4. Degeratu, M., Georgescu, A.-M., Alboiu, N.I., Bandoc, G., Coșoiu, C.I., Golumbeanu, M.: *Turbulent Structure of the Wind Flow and Wind Tunnel Tests Achieved for Atmospheric Contamination Modelling.* In: Journal of Environmental Protection and Ecology (2013) p. 405-413.
5. Degeratu, M., Georgescu, A.M., Bandoc, G., Alboiu, N. I., Coșoiu, C.I., Golumbeanu, M.: *Atmospheric Boundary Layer Modelling as Mean Velocity Profile Used for Wind Tunnel Tests on Containment Dispersion in the Atmosphere.* In: Journal of Environmental Protection and Ecology (2013), p. 22-28.
6. Degeratu, M., Georgescu, A., Haşegan, L., Coşoiu, C.I., Stefan, R.S., Sandu, L.: *Some Aspects About a Vortex Generating Building Model Placed Upwind an Aeroelastic Model in the Boundary Layer Wind Tunnel.* In: Scientific Bulletin of the Politehnica University of Timişoara, Transactions on Mechanics **52**(**66**) (2007), p. 55-61.
7. Degeratu, M., Georgescu, A.-M., Haşegan, L., Coşoiu, C.I., Pascu, R., Sandu, L.: *Dynamic Wind Tunnel Tests for the Bucharest Tower Center.* In: Scientific Bulletin “Politehnica” University of Timişoara, Transactions on Mechanics **51**(**65**) (2006), p. 83-88.
8. Hașegan, L., Degeratu, M., Sandu, L., Georgescu, A., Coșoiu, C.: *Experimental and Numerical Modeling in Wind Engineering* (in Romanian). București. Printech, Ed., 2008.
9. Hlevca, D.: *Numerical and Experimental Research on Flow Control at Aerodynamic Tunnels Used in Wind Engineering.* In: Ph.D. Thesis, Universitatea Tehnică de Construcţii Bucureşti, Bucureşti, 2012.
10. Vlăduț, A.C., Popa, I., Cosoiu, C., Georgescu, M., Degesatu, M., Hasegan, L., Anton, A.: *A New Boundary Layer Wind Tunnel.* In: U.P.B, Sci. Bull., Series D, Vol. 79, Iss. 2, 2017.