Experimental study of the velocity field characteristics of jet flow in the work zone of small aerodynamic tunnel

Martin Ivanov, Detelin Markov

Експериментално изследване на характеристиките на скоростно поле на струйно течение в работния участък на малък аеродинамичен тунел: *Представената публикация разглежда част от резултатите на проведено експериментално изследване на характеристиките на струйно течение в работна зона на аеродинамичния тунел (АДТ) на Технически университет София. По своята същност, АДТ представляват сложни експериментални съоръжения, намиращи широко приложение като средства за охарактеризиране на комплексни аеродинамични явления. С тяхна помощ стават възможни прецизни изследвания на параметрите на течения, както и на тяхното влияние върху обтечните обекти. В представеното проучване е изследвано експериментално разпределението на скоростното поле на входа на работния участък, и е направен анализ на констатирания пад на скоростта наблюдаван при различните изследвани режими. Резултатите от проведеното изследване охарактеризират адекватно параметрите на струйното течение в работната област и дават важна информация относно хомогенността на полето на скоростта в работна област на съоръжението.*

Key words: *Aerodynamic Tunnels, Velocity Distribution Measurements, Velocity Drop Analyses*

INTRODUCTION

Aerodynamic Tunnels (ADT, or also Wind Tunnels) can be defined as complex tools, used most often in the applied aerodynamics, to study the effect of air movement over solid immersed objects. The small wind tunnels are mainly composed of closed tubular channel where, somewhere in the middle it is mounted a studied object, to which air is supplied by a powerful fan. Some ADT have systems for injection of smoke or other trace substances, with which the flow streamlines around the object, can be visualized. Depending on the velocity of the generated airflow, the ADT essentially are classified as: supersonic, ultrasonic, high-speed and low-speed wind tunnels. ADTs can also be classified by their application, for example: aviation ADT, automotive ADT, etc.

Nowadays, the following small ADTs exist in Bulgaria: “Tunnel UT-1”, situated in aerodynamic facility “ULAK-1” at TU-Sofia - Branch Plovdiv; Wind Tunnel "MINIAT", situated in the Institute of Hydroaerodynamics in Varna; Subsonic wind tunnel of aerodynamic laboratory at NVU "V. Levski "; Wind tunnel of the University of Rousse "Angel Kunchev"; and the Aerodynamic Tunnel at Technical University – Sofia.

AERODYNAMIC TUNNEL OF TECHNICAL UNIVERSITY – SOFIA

The ADT at TU – Sofia Itself, is from the closed type and it is with open working area. The overall dimensions of the tunnel are approximately 6.5 m long and 3.5 m wide. The work area, where the test object is situated, has the size: 1.5 m long and 0.85 m wide. The airflow is created by axial fan which is driven by an AC electric motor with adjustable rpm, "MEZ KB 92-6", mounted in 1968. The electric motor is powered by transformer "MEZ, BB 66-2". The speed of the motor shaft can be varied smoothly from 300 min^{-1} (output 13.6 kW) to 1550 min^{-1} (output 71.2 kW). The cross section of the jet is approximately rectangular with a height of 0.5 m and width 0.75 m. The length of the work area is 1.5 m. The airflow velocity in the work zone may be smoothly changed (via remote control of the speed of the motor) in the range between 6 m/s to 60 m/s.

Up to date, the ADT of the Technical University – Sofia is situated in "Hydroaerodynamics and Hydraulic Machines" department at the Faculty of Power Engineering and Power Machines. It is used as a demonstration tool during the laboratory classes on the "Basic Fluid Mechanics" course. The overall condition can be defined as good, although the neglected appearance, both on the device itself and the room in which it is located. In the past years it has been lost all construction drawings of this ADT. It is missing any other information about the distribution of the main flow parameters at the jet outlet in the working zone, as well as any facts for the performance of this device as a whole. This clearly shows the demand for preparation of usage, support and maintenance documentation (a database) including modern accurate three-dimensional description of the ADT at TU-Sofia. In addition to this information about flow pattern in the work zone is required, which could be obtained only experimentally. All this will help any future preparation of fundamental and applied researches, which might be carried out on this ADT.

Figure 1. Aerodynamic Tunnel at Technical University – Sofia

AIM OF THE PRESENTED STUDY

The aim of the presented study is to investigate experimentally the operating parameters of the ADT at TU-Sofia and to create an accurate graphical description of the facility. To achieve this objective, the following tasks are defined:

1. Descriptive characterization of the current situation of ADT at TU-Sofia and accurate measurement of the geometrical dimensions of the device;
2. Development of three-dimensional graphical model of ADT at TU Sofia, using a commercial software package;
3. Experimental study of the velocity field in the work zone of ADT at TU Sofia, under different regimes;
4. Analysis of the results and development of practical engineering characteristics for various test modes;
5. Development of a flexible and easily accessible database with the achieved results from the performance of the above tasks.

The presented paper focuses on the results achieved from task 3.

METHODS OF THE PRESENTED STUDY

The main method, used to perform task 3, is the physical measurement of the key parameters of the airflow in the ADT work zone. Characterization is performed by measuring in real-time operation of total and static pressure at different points from the airflow. Parallel with the pressure, it is measured also the temperature and the atmospheric pressure. These parameters are sufficient enough to determine the flow velocity at a given point.

The measurements are performed in 176 points from the work zone, in one and the same plane, for one and the same flow velocity, namely 30 m/s.

After measuring the velocity distribution, additional measurements are performed, in order to establish whether this tunnel maintains an even distribution of the flow velocity during its operation. In that case, three flat objects are positioned in the work zone center one by one, and again the velocity distribution is measured in the same points and for the same flow velocity. The three flat objects have rectangular form and are occupying (shading) 40, 60 and 80% from the working area of the ADT. They are made of gypsum board and have the following dimensions: Object 1 („*Тяло 1*") – 350 x 195 mm, Object 2 („*Тяло 2*") – 440 x 230 mm and Object 3 („*Тяло 3*") – 500 x 265 mm.

The objects are mounted on the suction grille, and as mentioned above, the measurements are repeated at the same flow velocity at which it is characterized the free stream. After conducting all experimental regimes, a comparison of the results from the different modes is made. This analysis is of great interest for the engineering practice and has direct engineering application for this particular ADT.

RESULTS

The experimental data show relatively high degree of homogeneity in the velocity distribution in the work area as shown on Figure 2. The dotted white line represents the work zone area („*Работна зона*") and with the colored dots is shown the different objects with the corresponding velocity fields.

The standard deviation in the achieved values at 30 m/s without placed body is 0.21 m/s. The minimum measured value is 3.54 m/s, and the maximum is 31.51 m/s. For the case with Object 1, the standard deviation is 0.20 m/s, minimum measured value is 2.63 m/s, and the maximum is 25.50 m/s. With Object 2, the standard deviation is 0.16 m/s, minimum measured value is 20.58 m/s, and the maximum is 2.67 m/s. And for the case with Object 3 – the standard deviation at 30 m/s is 0.10 m/s, the minimum measured value is 16.46 m/s, and the maximum is 2.31 m/s respectively.

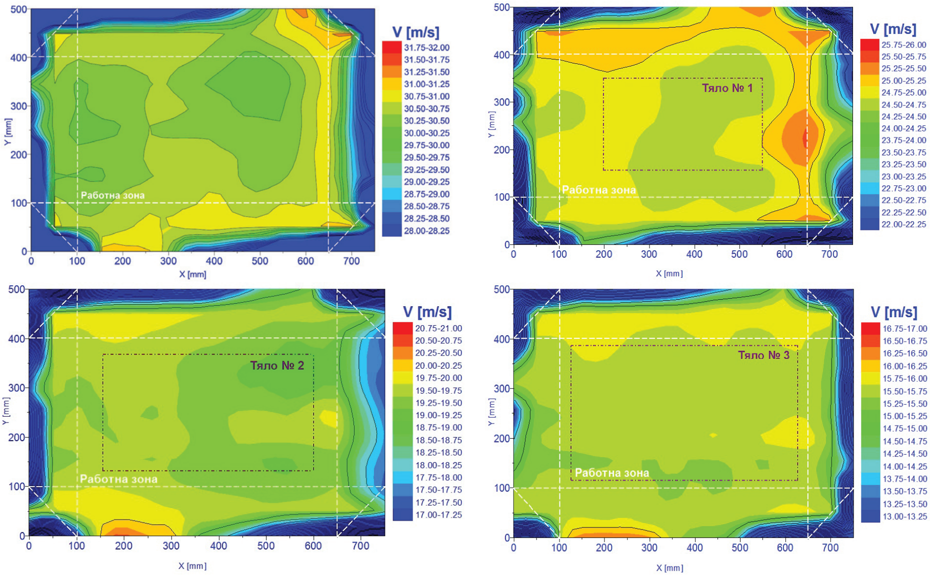

Figure 2. Velocity profiles with measured values for the different studied cases

The relatively low values of the standard deviation give reason to assume that the velocity field in all cases is homogeneous enough and could be represented by an average value. This allows comparing the degree of shading in percentage with the velocity drop also expressed in percentage for the different regimes. The maximum measured velocity of 30 m/s represents 100% of the velocity in the developed flow. Relative to this value, it is calculated the velocity drop in percentage for all other cases. The next step is to compare these velocity rates to the shading percentage of the different objects in the working area of the ADT. The 0% shading mode is considered the regime without a body placed in the work area. This analysis is presented in Figure 3.

The X-axis of the graph in Figure 3 represents the degree of shading in percentage and the ordinate - the resulting velocity drop also expressed in percentage. Red dots on the graph correspond to the measured results from the different experiments, and the trend line was built automatically by the functions of MS Excel.

The graph shows that when small objects that obscure 10-20% of the work zone are immersed, the velocity drop ΔV is approximately 10%. In some cases, this value can be considered as small enough to state that the study of the immersed object is most effective.

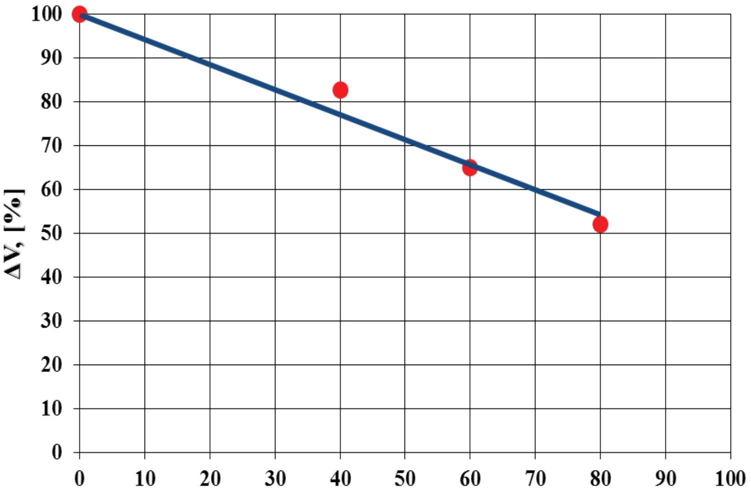

Figure 3. Velocity drop at different shading percentage

The presented graph is considered to have important engineering application, especially in the design stage of applied research studies at ADT of TU - Sofia. However, it should be mentioned that this dependence is only applicable to this particular ADT.

CONCLUSION

An experimental study of the velocity field in the work zone of the ADT in TU-Sofia is performed for various operating modes. Measurement of the air flow velocity is made for 176 points from the ADT work zone. Velocity profiles are conducted and analysed.

The analyses of the results show relatively high degree of homogeneity of velocity field for the different regimes.

A velocity drop in all investigated cases is observed. This velocity drop is analysed practical engineering dependence is conducted, which is valid for this particular tunnel and is important part from the device characteristics

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