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STUDYING THE DESIGN OF WIND TUNNEL FOR AERODYNAMIC AND AEROACOUSTIC TESTS OF BUILDING STRUCTURES

Statement of the problem. In order to study building aerodynamics, a scientific and industrial laboratory was created at the Moscow State University of Civil Engineering for aerodynamic and aeroacoustic tests of building structures. The main research station in the laboratory was a wind tunnel. This paper describes a design of a wind tunnel to study the aerodynamic and acoustic effects on buildings, structures and their elements.

Results and conclusions. Different variants of principal schemes of wind tunnels were examined and developed. Preliminary calculating characteristics of the setup were obtained. The international experienced of aero setup design was used in elaborating the structure. It was developed using numerical modelling and the method of a series of calculation of gas dynamics of an closed subsonic wind tunnel being designed. It was found that a modified structure with a 7-degree turn of a nozzle and operating area significantly improves gas dynamics in the operating area.

Keywords: building aerodynamics, a wind tunnel, a ventilator setup, wind flow, an aerodynamic experiment.

Introduction

One of the criteria of the building industry today is to define, assess and further account for aerodynamic forces that impact building and structures. Building aerodynamics has been a growing focus of attention due to the increasing trend to construct “one-of-the-kind’ structures that are largely subjected to wind loads. A modelling and experimental study of aerodynamic flows in design helps to improve the reliability of structures, cut down on their cost and enhance the aerodynamic mode of the nearby territory (i. e. to create more comfortable conditions in the vicinity of structures). Currently aerodynamic efforts that arise from flow of solids of different configurations can be defined in two ways: by the methods of mathematical and physical modelling.

The methods of mathematical modelling of aerodynamic processes are developing at a tremendous rate. All the more complex problems get to be addressed using the numerical methods using the computing machines and complexes. However, it is almost always the case that the experimental aerodynamics has the last say in how some problems are to be addressed. A number of practical problems can only be solved by means of physical modelling. This type of modelling is also an absolute testing tool of numerical methods, i. e. their verification. The basic method for the physical modelling of aerodynamic processes is experimenting with aerodynamic tubes. In the world’s practices there are various setups that are presently employed by aerodynamic laboratories but mainly these complexes are designed for engineering aerodynamics research since they originally come from aviation.

The particular feature of construction tubes is a long operating part which is necessary to model the surface boundary layer of the atmosphere. Creating construction aerodynamic setups is part of scientific and practical research and is unique in itself.

In order to study the construction aerodynamics based at the Moscow State Architectural University a studying, scientific and industrial laboratory of aerodynamic and aeroacoustic tests of building structures was set up. The major research complex of the laboratory was a construction aerodynamic tube (CAT).

1. Reasoning behind the choice of the CAT structure

Based on the mathematical modelling of CAT as well as recommendations made by the specialists at the Central Aerohydrodynamic Institute and the Mechanics Institute of the Moscow State University a number of corrections were made to the first variant to the CAT structure (Fig. 1). The modified version is fitted with the improved gas dynamics picture near the operation area.

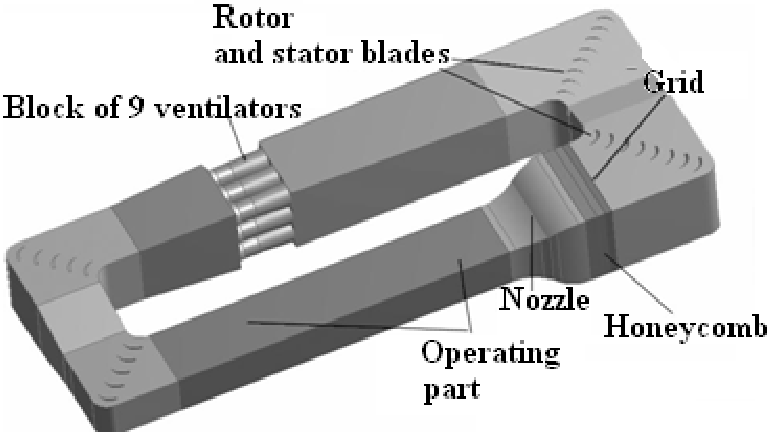

Fig. 1. First variant of the structure of the aerodynamic tube

The final version of the setup is a CAT of small subsonic speeds of the constant action as an isolated channel (Fig. 2) with a ventilator setup inside it that creates an air flow with certain characteristics. The corner parts of the circuit are fitted with blades for the flow to rotate optimally. The air flow exerts on the models of the structures that are positioned inside the operating part of the duct.

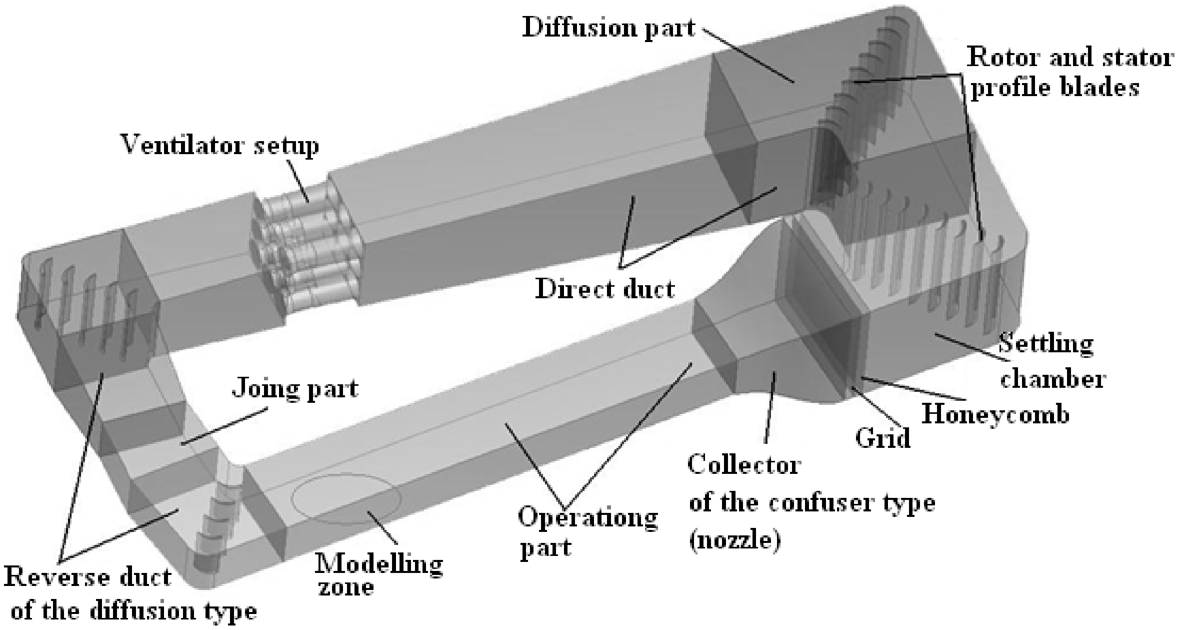

Fig. 2. General schematic diagram of the aerodynamic tube

On the order by the Moscow State Architecture University an aerodynamic setup was constructed by the specialists of the JSC Lada Flekt (Tolyatti). The construction material of the CAT body was metal. The thickness of the sheet is 2 mm. The panels are flanged all around the contour for local rigidity and are joined together with bolt joints. The entire flow part is divided into blocks of about 3 m in length. Each block has the longitudinal rigidity rib that provide spatial rigidity of the entire setup. The aerodynamic tube is positioned in the horizontal plane on 66 props. The maximum length of the setup is 40 m, the width is 20 m, the operating part is 21 min length (Fig. 3). Through the entire perimeter of the flow part of the CAT there are airproof doors for assembly/disassembly and repairs on the contour.

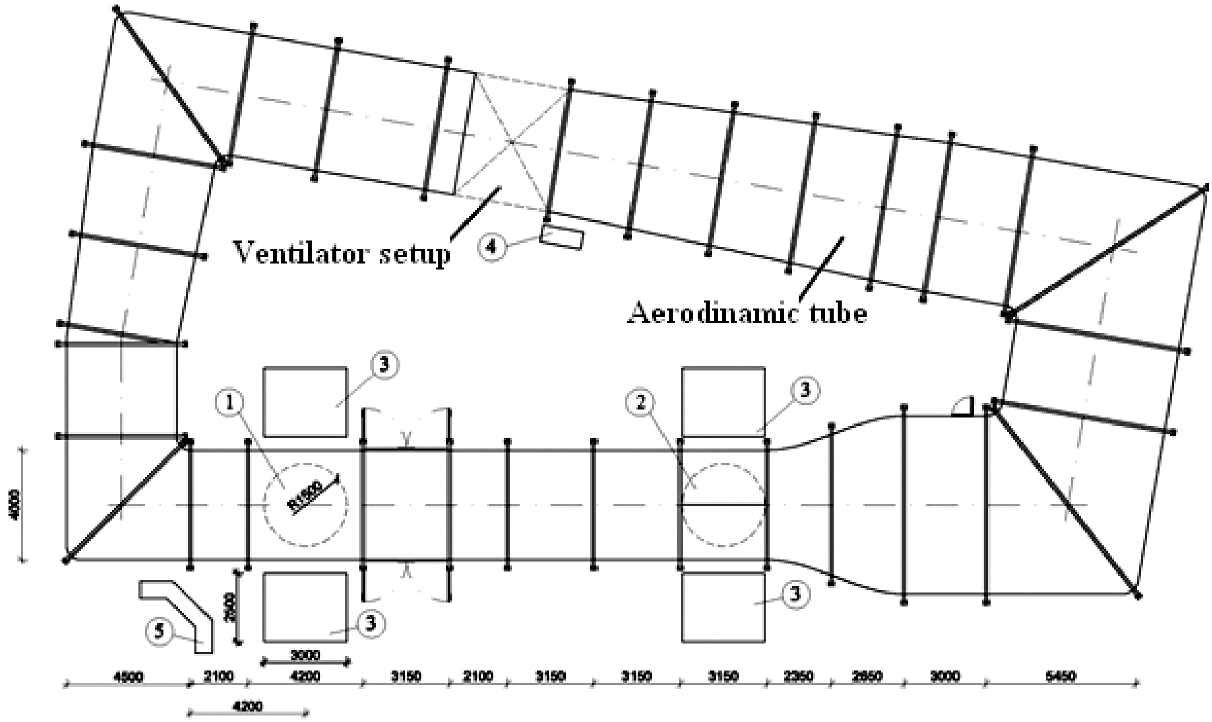

Fig. 3. Aerodynamic setup:
1 — rotary table; 2 — modelling table for even blow on the section; 3 — areas for the control gauges;
4 — frequency transducer; 5 — remote control of the CAT and accessory systems

For the assembly/disassembly as well as repairs in the plan there is a hatch of 3×4 m in size before the ventilator setup. Through this hatch the assembly and disassembly of the parts of the ventilation setup is performed using the ceiling overhead crane beam (Fig. 4).

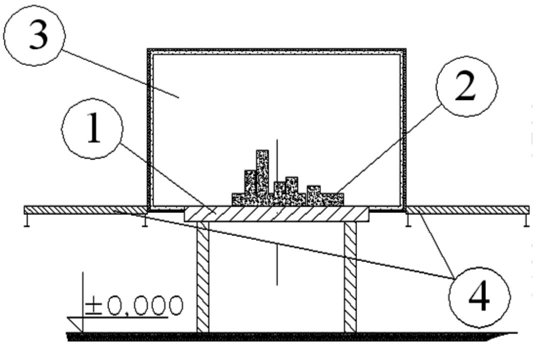

Fig. 4. Modelling area:
1 — rolling table;
2 — models of the construction objects;
3 — operating part of the duct;
4 — areas for the control gauges

2. Description of the ventilator setup and the modelling zone of the CAT

The ventilator setup is an assembly of nine identical axial ventilators Axipal FTDA-125 of series manufacture. This is an integral part of the flow tract of the CAT and is joined with the duct walls by rigid (flexible) bonds to prevent vibrations transmitting to the tube body. The ventilator setup is fastened to the base by vibration damping mounts that are between the frame of the ventilator setup and the base plate.

The modelling zone of the CAT in the longitudinal section is 2.5m high and 4m wide. In the flow part of the tube and on its operating part is a rolling table with the diameter of 3m with the models of the construction objects located on it. The table is 7m away from the end of the operating area of the CAT. The side walls of the modelling zone are made of optical fiber to visualize the observation of the blow of the models. The side walls of the modelling zone are made of optical glass to visualize the observation of blowing of the models. The models on the table are blown by air flow and a specially fitted boundary layer that models a natural surface layer. The table is joined with aerodynamic scales and can rotate 360 degrees around the vertical axis (the rotation step is 1 degree) and is height adjusted.

3. Major characteristics of the CAT flow

The maximum design rate of air flow in the modelling zone is 30 m/sec. The rate of air flow in the modelling zone can be gradually adjusted in the range of 0…30 m/sec due to the frequency control system of all the electric engines of the ventilator setup. The frequency start system helps to reduce the starting current to the nominal operation value. Besides the frequency start allows to generate the rate curve varying in time modelling natural puffs of air.

In order to measure the parameters of flowing of the models by puffs of air different complexes of measuring and registering equipment which is placed on both areas on either sides of the modelling area of the tube tract.

Pressure transducer systems are planned to be used which are highly acclaimed and have a range of applications in physical modelling of aerodynamic processes as well as a modern system based on the particle image velocimetry and a laser non-contact complex *FlowMaster* which is used for the study and quantitative analysis of two- and three-dimensional velocity vector fields of turbulent non-stationary gaseous and liquid flows in a section or experiment of choice with precise timing sequences.

Conclusions

The worldwide experience of creating aerodynamic setups was used in the development of the structure of a construction aerodynamic tube. It was supplemented by the numerical modelling and the well-familiar method of series calculations in gas dynamics of the designed isolated subsonic aerodynamic tube.

A series of the mathematical experiments revealed a number of flaws that have to do with the number, size and position of the blades that turn the flow, the installation of the honeycomb, geometry of the nozzle, properties of the ventilator setup, etc. Specialists with the expertise in the experimental modelling were consulted. The solutions that were obtained following the discussions were numerically modelled. The last iteration revealed compared to the other variants the modified structure with a 7 degree rotation of the nozzle does more to improve the gas dynamics picture in the operating area.

Therefore the use and development of the worldwide experience of creating construction aerodynamic tubes enabled a viable variant of the CAT structure.

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