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Parametric snow generator for closed circuit wind tunnel

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SUMMARY:
Due to the complexity of multiphase flows, time and resource consuming of its numerical modeling the use of a snow generator as a validation tool as well as the main research tool in cases of complex geometric shapes of structures is relevant for various fields. There are many examples like special turbulent, temperature and humidity conditions of wind flow, such as research and development in the automotive and aviation industries, clarification of snow loads on buildings and engineering facilities, preservation and restoration of cultural heritage. Within the framework of the presented paper the authors describe the principle of operation of the designed snow generator for a wind tunnel. The first preliminary experiments on the accretion of snow particles around and on the surfaces of buildings and historical heritage architectural objects were made.

Keywords: artificial snow, snow engineering, ice nucleation

1. EXPERIMENTAL SETUP

Climatic Wind Tunnel(CWT) of Institute if Theoretical and Applied Mechanics of the Czech Academy of Sciences (ITAM), see Fig. 1, has been designed as a closed circuit type with controlled wind velocity and temperature. It consists of regular aerodynamic part with removable ABL hardware and climatic part aimed for investigation of influences of climatic parameters like wind, temperature, rain and heat radiation. In this section, the wind speed ranges from 0.8 to 18 m/s. The rain intensity together with the size of droplets is regulated to simulate the effects from drizzle to heavy rain by 16 sprinklers. Using the heat exchanger the temperature of the airflow is available in the whole tunnel is changed within the range of -5 to 30° C.

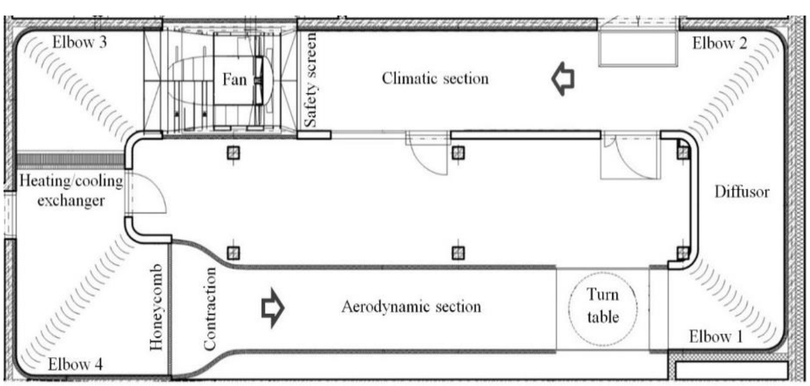

Figure 1. CWT of ITAM in Telč.

In large climatic tunnels, as RTA Vienna (Rail Tec Arsenal Fahrzeugversuchsanlage GmbH), and CSTB (Thiis et al., 2007) or the snow-wind combined experiment facility at the HIT (Liu et al., 2018; Jin et al., 2022) is used method based on the gradual freezing of a water spray in a moving air stream and long-term accumulation of snow (ice) particles in the wind tunnel space to achieve the required concentration for testing. Due to the smaller size and the high density of the radiator plates in our tunnel, this method is inapplicable: most of the water drops do not have enough time to freeze and (or) settle on the radiator plates and fan blades. To solve the above problems it was decided to create a snow generator which produces snow particles of the required quality on the exhaust and which can be placed in an existing wind tunnel.

2. CYCLONE-BASED SNOW GENERATOR

The principle of the designed snow generator is based on the creation and subsequent cooling of the water aerosol in the active zone of the generator until the crystallization of water droplets id shown on Fig. 2. The prepared water aerosol is injected into the cyclonic wind flow with the spiral rotation inside the generator core. To accelerate the crystallization process the special nucleating additive, precooling of the water and also deep cooling of the inlet air into the generator core are used.

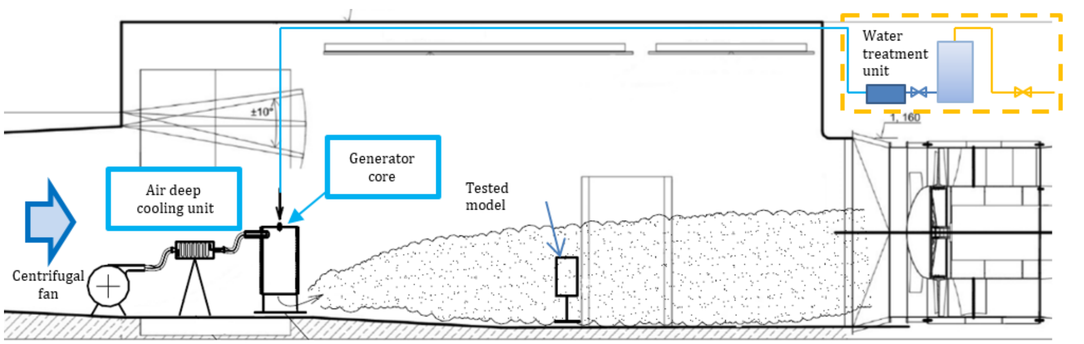

Figure 2. Schematic layout of snow generator.

1.1. Water treatment unit

Tap water is mixed in the tank (1) with nucleation agent to prepare suspension, then by the pump (2) and expansion vessel (3 – used to reduce water pressure pulsations from the pump in the system) water under the required pressure is supplied to cooling unit (4 - temperature slightly above the freezing point) and then through a thermally insulated pipeline into the core of the generator. The water treatment unit is permanently installed outside the wind tunnel, see Fig. 3. The other technological blocks are movable and located in the climatic part of the tunnel.

2.1. Air deep cooling unit

The system of deep cooling of the air at the inlet significantly reducing the time required for the crystallization of water droplets in the core of the generator. Air from the climatic section of the wind tunnel is blown into the cooling box using an industrial centrifugal fan. The cooling box consists of a with heat exchanger through which air passes and heat-insulated container. Container space is filled with dry ice pellets(coolant) and technical ethanol for more efficient heat transfer between the exchanger and coolant.

Figure 3. Water treatment unit

2.1. Generator core with cyclonic flow

The cyclone has an upper inlet of cooled air and a lower cylindrical outlet, see Fig. 4, and consists of a larger diameter plastic pipe (1), tangentially connected air supply pipe (2), rotating top cover (3) with a block of nozzles (4). The movable nozzle block allows to change the injection angle and the distance between the nozzles and the air inlet. The block consists two nozzles in aluminium housings: one nozzle is placed vertically down and supplies cold water solution, the other nozzle is placed at an angle to the first and supplies compressed air.

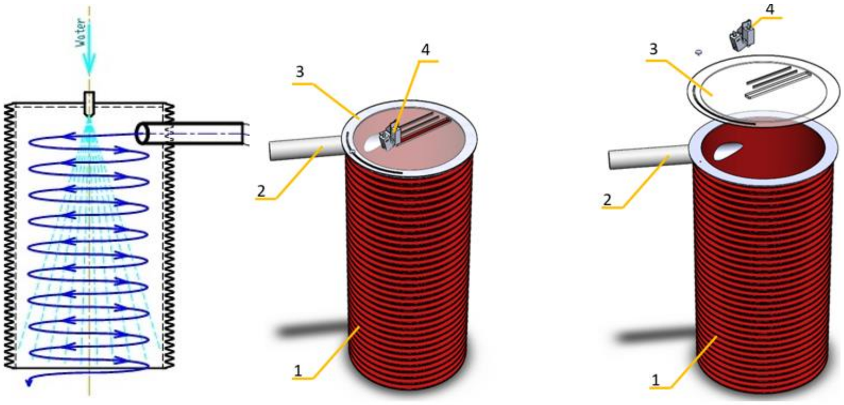

Figure 4. Generator core with cyclonic flow

3. RESULTS

In the Fig. 5 the exemplary results of experiments on snow accumulation between the urban buildings models (left) and objects of historical heritage (right) are presented. In the first case experiments were carried out at a temperature of minus 8° C and an air speed of 2 m/s for 2 hours on small scale models of low-rise buildings with flat and saddle roofs with a slope of 45°. In the second case snow accumulation was tested on model of the Plaque column of the Holy Trinity in Olomouc made on a 3D printer from PLA plastic in a scale of 1:75 at a temperature of minus 8° C to minus 9° C and the wind speed of 2.5 m/s for 1 hour.

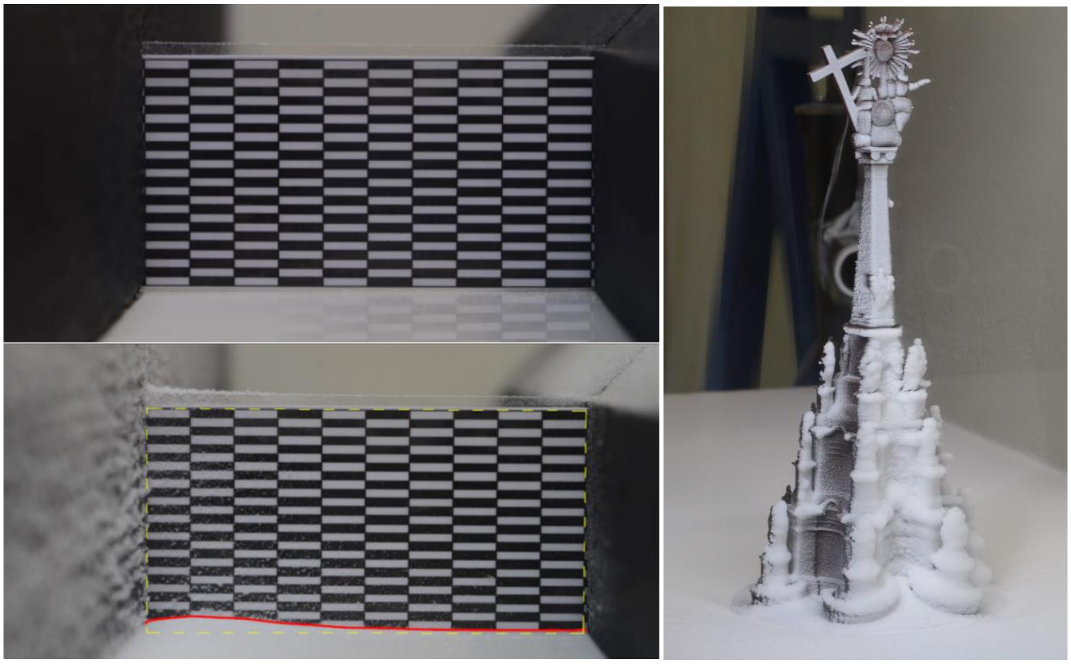

Figure 5. Results of generated snow particles accumulation on models.

4. CONCLUSIONS

Designed and manufactured snow generator is a special equipment suitable for using in a smaller wind tunnels for the production of snow similar to the natural one. Thus equipment creates very close experimental conditions to the real winter climate. The equipment can be scaled to meet the needs of greater amount of snow particles as well as different wind tunnel dimensions. The obtained results are the basis for further study on the methodology of snow loads modeling on buildings, engineering structures and cultural heritage objects.

ACKNOWLEDGEMENTS

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