1
2023
jntes

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Doi: 10.53412/jntes-2023-1-4

MODELING OF THE DISTRIBUTION OF WIND PRESSURES OF THE BUILDING OF THE NEW SAFE CONFINEMENT OF THE CHERNOBYL NPP

Abstract: *Distribution of wind pressures on the outer surface of the New Safe Confinement (NSC) is necessary to determine the unorganized air exchange from the NSC (outward or inward) with radioactive aerosols to the environment, since it is not hermetically sealed. The results show the discrepancy between the wind pressure distribution on the NSC outer surface in the small-scale 1:300 physical model of the NSC tested in the wind tunnel and the literature data. The computational CFD model of the NSC external air flow was developed to determine the distribution of pressures on the NSC surface at different wind directions and speeds. The adequacy of the calculated model is confirmed by the proximity of calculated and literature data, as well as calculations according to the European standard.*

Keywords: *ChNPP, New Safe Confinement, CFD modeling, external wind flow, surface pressure distribution, wind loads, building aerodynamics*

Introduction

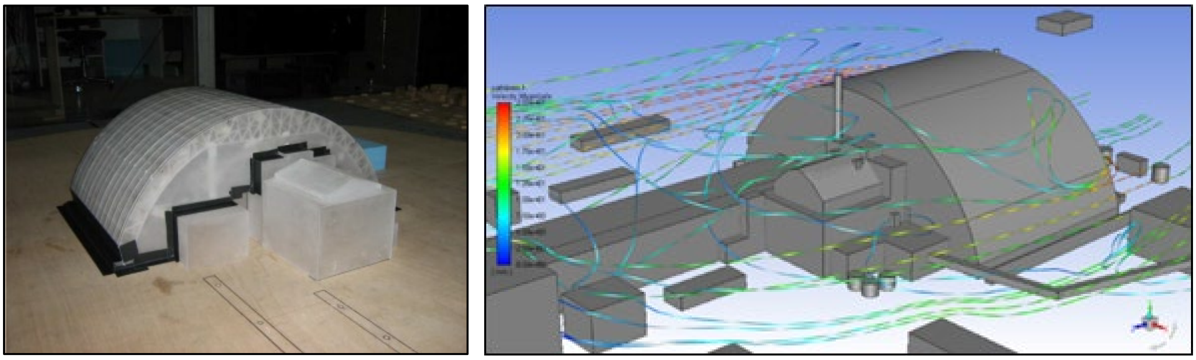
Determination of the distribution of pressure maps in buildings is necessary to determine the resistance of buildings to winds with high air velocity, the mutual influence of buildings in densely built-up areas for the design of the supply ventilation system of premises, for emergency buildings with particularly valuable or hazardous substances inside it, the air exchange of which depends on the pressure distribution maps on the outer surfaces of buildings through a large number of small gaps. Because due to the difference in pressure inside and outside, air from the windward side enters the building, and from the in 2016, the NSC was built over the destroyed ChNPP Unit 4, which was built using modern technologies and design standards, but it could not be completely sealed. There are many small gaps between the NSC walls and the rest of the ChNPP Unit 4 structures through which air can flow both inside and outside the NSC, therefore, to analyze and control the release of unorganized air exchange and radioactive aerosols (RA) from the main volume (MV) of the ChNPP NSC into the environment (EE), information on the distribution of wind pressures on the NSC outer surface and on the Shelter building structures is required. Such maps of pressure distribution on the NSC outer surface can be obtained by means of full-scale or computational experiment.

For this purpose, a small-scale physical model of the NSC at a scale of 1:300 (Fig. 1a) was tested in a wind tunnel during NSC design and maps of wind pressure distribution on the outer surface of the NSC model were obtained for all directions of air blowing from 0° to 360° with a step of 10 degrees [1] in order to determine the stability of NSC arch structures against wind with a wind speed of 23 m/s, both during construction and during NSC operation.

The pressure maps are the values of pressures in 197 separate sections of the western, eastern and cylindrical surfaces of the NSC of the small-scale physical model of the NSC (Fig. 1a), which did not include all structures under the walls and near the NSC. During operation, these wind pressure distributions were used to perform the above task, the results of which showed that these pressure maps qualitatively and quantitatively do not correspond to the literature experimental and calculated data. An alternative way to obtain pressure maps is to build a computer model using CFD (Computational fluid dynamics) technology (Fig. 1b).

Defining the goal and objectives of the study

The purpose of the work is to build a three-dimensional full-scale 1:1 computer CFD model of the NSC external air flow (Fig. 1b) for arbitrary rotation angles and wind speeds and to pre-tune the model according to the literature and experimental data of the ChNPP, which includes all structures under the walls and near the NSC to obtain the pressure distribution on the NSC outer surface and building structures of the Shelter during air flow.



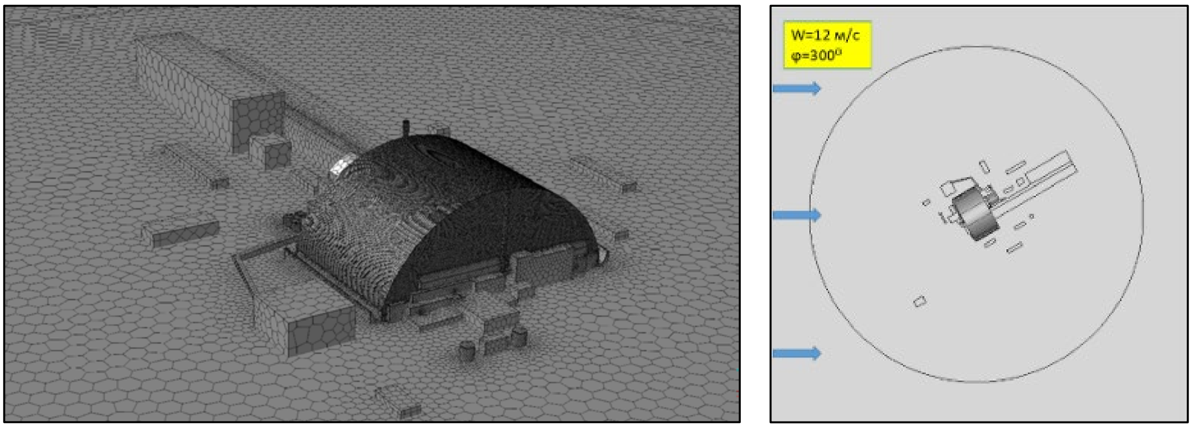
a) b)

Figure 1. *The NSC and the Shelter: a) photo of a small-scale physical model in the wind tunnel channel from the southeast angle; b) full-scale modeling of the external aerodynamic flow of the NSC and adjacent buildings from the northeast angle*

The geometric, physical, and mathematical models

The paper considers a three-dimensional full-scale 1:1 computer model of the NSC external airflow (Fig. 1b) for the same rotation angles and arbitrary velocity range, which was pre-tuned according to the literature and experimental data of the ChNPP, containing all structures under the walls and near the NSC. The geometric model has dimensions of 3.5x3.5 km, up to the upper limit of 800 m. The computational grid of such model consists of about 4 million cells (polyhedral mesh). Thickening of cells (Fig. 2a) was carried out to obtain the result of acceptable in time and stable calculation results in the CFD model of the NSC external flow.

To properly take into account the wind flow, the distance from the NSC to the lateral edge of the computational domain was chosen to be at least 1.0 km, taking into account the NSC height of about 110.0 m, as well as the atmospheric pressure at the remote $P_\infty = 10^5$ Pa and the air temperature T_∞ = 15°C. The wind direction was taken into account by rotating the internal volume of air with the geometry of the NSC with a radius of 1.0 km (Fig. 2b), the dimensions of which are selected in accordance with the literature [2-4] to simulate the external air flow around the buildings. At the input boundary of the computational domain, the wind direction and speed are set, the distribution of which in height corresponds to the power law for the terrain of type III with the power law index m = 0.31.



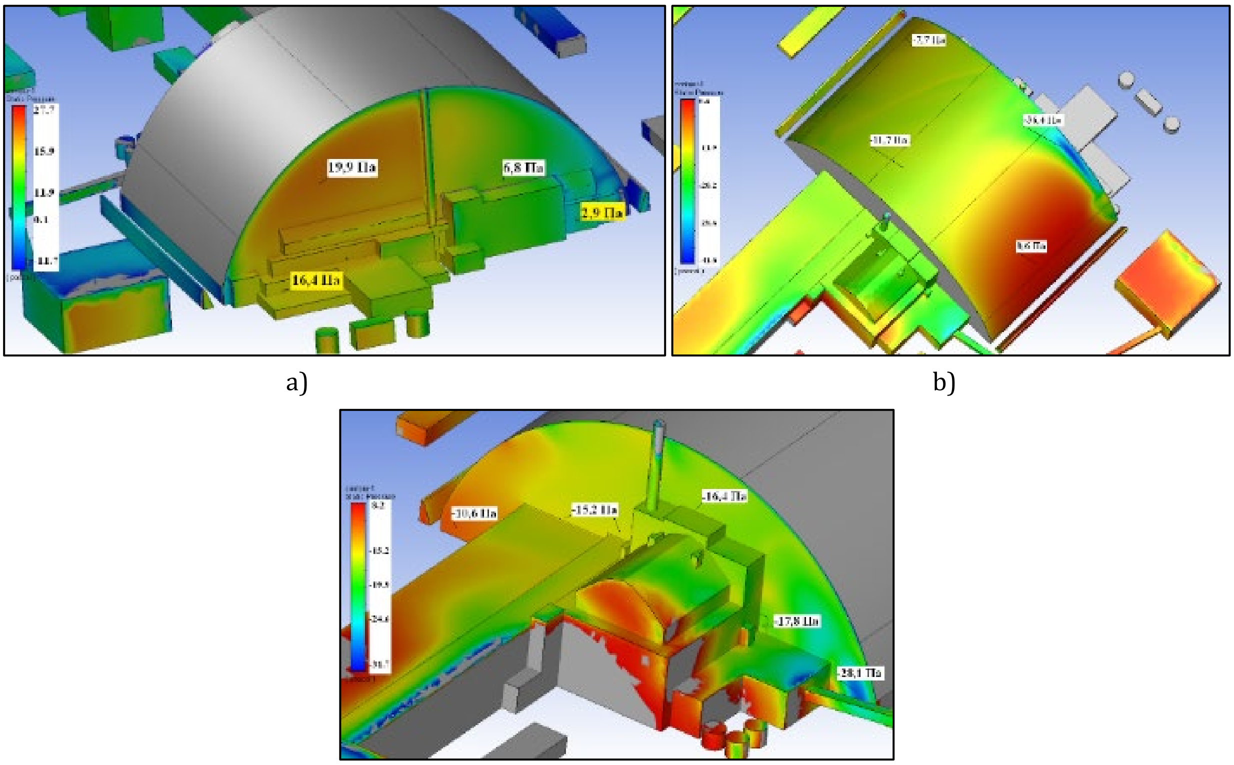
a) b)

FIGURE 2. *Computational grid of the NSC air flow model and the area of the computer model of the NSC and the environment that is rotated relative to the wind direction (direction 300 ° is indicated)*

When setting up the CFD model of the NSC, the variable profile of wind speed in height, surface roughness, intensity and scale of turbulence at the entrance to the computational domain, turbulence model and its parameters, ground temperature, as well as the geometry of buildings at the ChNPP industrial site were adjusted.

Research results

In contrast to the small-scale physical model, the full-scale computer model allows obtaining continuous pressure distributions over the entire NSC surface (Fig. 3), which is 87.6 thousand m^2, as opposed to 197 values in individual sections of the small-scale physical model of the NSC.



a) b)

c)

FIGURE 3. *Distribution of static pressure on NSC surfaces and Shelter structures*

Maps of pressure distribution on the outer surface of the NSC and building structures of the Shelter were obtained for different wind directions, which qualitatively and quantitatively coincide with the literature data [2-4] on the external flow of buildings and greenhouses.

The obtained pressure distributions on NSC surfaces were calculated for all wind directions from 0° to 360° through 10° at wind speed of 3.8 m/s. For other wind speeds, the pressures obtained with the help of physical and computational models are recalculated using dependence (1) [1]:

$$P_c = P_b \cdot \left(\frac{V_c}{V_b} \right)^2 \tag{1}$$

where P_c is the pressure for the current (c) value of wind speed; V_c is the current value of wind speed; P_b is the pressure for the base (b) value at the base wind speed V_b = 3.8 m/s.

As a result, the obtained maps of wind pressure distribution on the NSC outer surface and Shelter building structures can be used during scientific support as information support, monitoring and forecasting of air flow rate Q (m^3/s) of radioactive material outlet to and inside the NSC and control of the NSC ventilation system in order not to exceed the maximum permissible level of radioactive material release from the NSC [5].

Conclusions

The paper presents a three-dimensional full-scale 1:1 computer model of the external air flow around the New Safe Confinement (NSC) for different rotation angles and an arbitrary range of wind speeds. The results of calculations of wind pressure distribution on the NSC outer surface are in good agreement with the literature and ChNPP experimental data. Wind pressure distributions on the NSC outer surface are used to solve an important task of controlling the release of unorganized air exchange with radioactive dust from the NSC into the environment.

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