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ОСОБЛИВОСТІ ВИЗНАЧЕННЯ ВІТРОВОГО НАВАНТАЖЕННЯ НА ВЕРТИКАЛЬНІ ЦИЛІНДРИЧНІ РЕЗЕРВУАРИ З МЕМБРАННИМ ПОКРИТТЯМ У СКЛАДІ ГРУПИ

В. П. Мущанов, Г. В. Зубенко
Донбаська національна академія будівництва і архітектури,
2, вул. Державіна, м. Макіївка, Донецькая область, Україна, 86123.
E-mail: zubenkoanna@dr.com

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Анотація. У даній статті розглядається порівняльний аналіз аеродинамічних характеристик для ВЦР об'ємом 10 тис. м^3 та прогнозування на основі отриманих результатів аеродинамічних характеристик для ВЦР з мембранним покриттям у складі групи способом чисельного моделювання в програмному комплексі SolidWorks Flow Simulations, також запропоновано методичний підхід, що забезпечує коректне відображення фізичних процесів обтікання вітровим потоком стінки резервуара. Для груп з 2-х і 4-х резервуарів на основі чисельного моделювання отримані уточнені значення аеродинамічних коефіцієнтів вітрового тиску для кожного з резервуарів, які забезпечують надалі уточнену оцінку напружено-деформованого стану конструкції стінки і покриття в порівнянні з нормованим зараз підходом за ДБН і Єврокод.

Ключові слова: вертикальний циліндричний резервуар, чисельне моделювання, вітровий тиск, аеродинамічний коефіцієнт.

ОСОБЕННОСТИ ОПРЕДЕЛЕНИЯ ВЕТРОВОЙ НАГРУЗКИ НА ВЕРТИКАЛЬНЫЕ ЦИЛИНДРИЧЕСКИЕ РЕЗЕРВУАРЫ С МЕМБРАННЫМИ ПОКРЫТИЯМИ В СОСТАВЕ ГРУППЫ

В. Ф. Мущанов, А. В. Зубенко
Донбасская национальная академия строительства и архитектуры,
2, ул. Державина, г. Макеевка, Донецкая область, Украина, 86123.
E-mail: zubenkoanna@dr.com

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Аннотация. В данной статье рассматривается сопоставительный анализ аэродинамических характеристик для ВЦР объемом 10 тыс. м^3 и прогнозирование на основе полученных результатов аэродинамических характеристик для ВЦР с мембранным покрытием в составе группы способом численного моделирования в программном комплексе SolidWorks Flow Simulations, также предложен методический подход, обеспечивающий корректное отображение физических процессов обтекания ветровым потоком стенки резервуара. Для групп из 2-х и 4-х резервуаров на основе численного моделирования получены уточненные значения аэродинамических коэффициентов ветрового давления для каждого из резервуаров, которые обеспечивают в дальнейшем уточненную оценку напряженно-деформированного состояния конструкции стенки и покрытия по сравнению с нормируемым в настоящий момент подходом по ДБН и Еврокод.

Ключевые слова: вертикальный цилиндрический резервуар, численное моделирование, ветровое давление, аэродинамический коэффициент.

WIND LOAD DEFINITION ON VERTICAL CYLINDRICAL TANK WITH MEMBRANE ROOF IN THE GROUP

Volodymyr Mushchanov, Hanna Zubenko
Donbas National Academy of Civil Engineering and Architecture,
2, Derzhavina Str., Makiyivka, Donetsk Region, Ukraine, 86123.
E-mail:zubenkoanna@dr.com

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Abstract. This article describes a comparative analysis of the aerodynamic characteristics for VTDR of 10 thousand m^3, and forecasting on the basis of the results of aerodynamic characteristics for vertical cylindrical tanks (VCT) with membrane roof in a group of numerical simulation method in the software package SolidWorks Flow Simulations, also a methodical approach, ensuring the correct display of physical process flow wind flow tank wall, has been suggested. For groups of 2 and 4 tanks on the basis of numerical simulations, improved values of the aerodynamic wind pressure coefficients for each of the tanks have been found out, these values provide further refine the assessment of the stress-strain state of the wall structure and the coating compared with normalized currently on approach DBN (State Building Norms) and Euro Cods.

Keywords: vertical cylindrical tank, numerical simulation, wind pressure, aerodynamic coefficient.

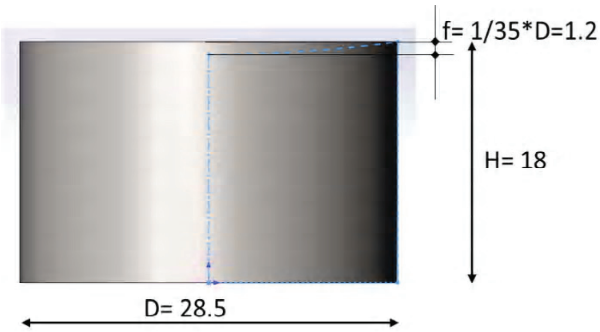
Raising of task

With the increase of capacity of tank the cost of storage of oil products goes down considerably, the real-estate of petroleum bases increases. But proportionally the overall grow it, sizes of construction (her «windage» increases) at the very insignificant increase of thickness of wall, that causes the danger of loss of stability of shell of corps of empty reservoir at the action of the wind loading.

A research object is a vertical cylindrical tank (VCT) by volume of 10 thousands м³. Geometrical sizes: diameter a 28,5 m, a height of wall is a 18 m.

Analysis of the recent research and publications

General scientific principles of planning, building and operating reliability of reservoir are set forth in works of V. G. Shuhov, G. V. Raevskiy, V. S. Kornienko, M. M. Safaryan, B. V. Popovskiy, B. P. Berezin, E. M. Yasin, V. E. Shutov, F. F. Abuzova, V. B. Galeev, V. A. Burenin, A. A. Tarasenko, E. A. Egorov, V. F. Mushchanov, Yu. V. Fedoryaka etc. Research groups engaged in these issues VNIImontazhspetsstroy, TsNIIproektstalkonstruktsiya, VNIPIneft, UGNTU, Tyum. GNU, DonNASEA and other [2–7, 12–14].



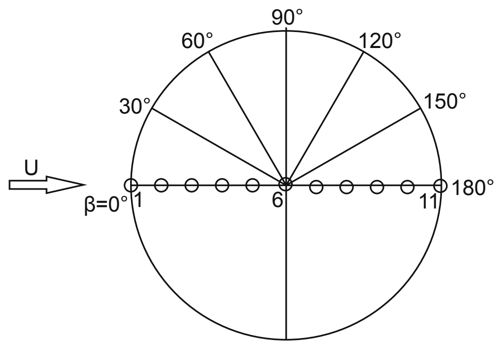


Figure 1. Geometrical parameters of VCT.

To present tense questions are decided as evaluated by durability and stability, both separate knots and tank on the whole, the methods of calculation of remaining resource are worked out.

In spite of numerous works in the areas of planning, building and exploitations of tanks, row of questions, related to the estimation and increase of capacity of tanks with membrane roofs, remain open. Among them it should be noted following:

- loading and influences is studied not enough on VCT for the new types of roofs, including with sagging membrane roofs;
- loading and influences is studied not enough on VCT including with sagging membrane roofs in composition a group.

For the calculation of building on the wind loading there are a few methods of determination of aerodynamic descriptions with the use of analytical, and experimental data. Exact analytical decisions in building aerodynamics embrace the very limited circle of tasks, as a clear mathematical model for aerodynamic processes, getting is difficult and in most cases for new and difficult building researches in a wind-tunnel, that are the reliable means of study of process of flowing around by the current of air of building, building and their complexes, are executed. Specialists lately all more often call to the numeral design of aerodynamic processes.

When designing according to the normative requirements [7, 8] the wind load is determined with the use of the diagram of dependence of the aerodynamic coefficients on the position of the angle between the element of the cylindrical surface and the wind flow direction (Fig. 2). The quantity of these values therewith depends on

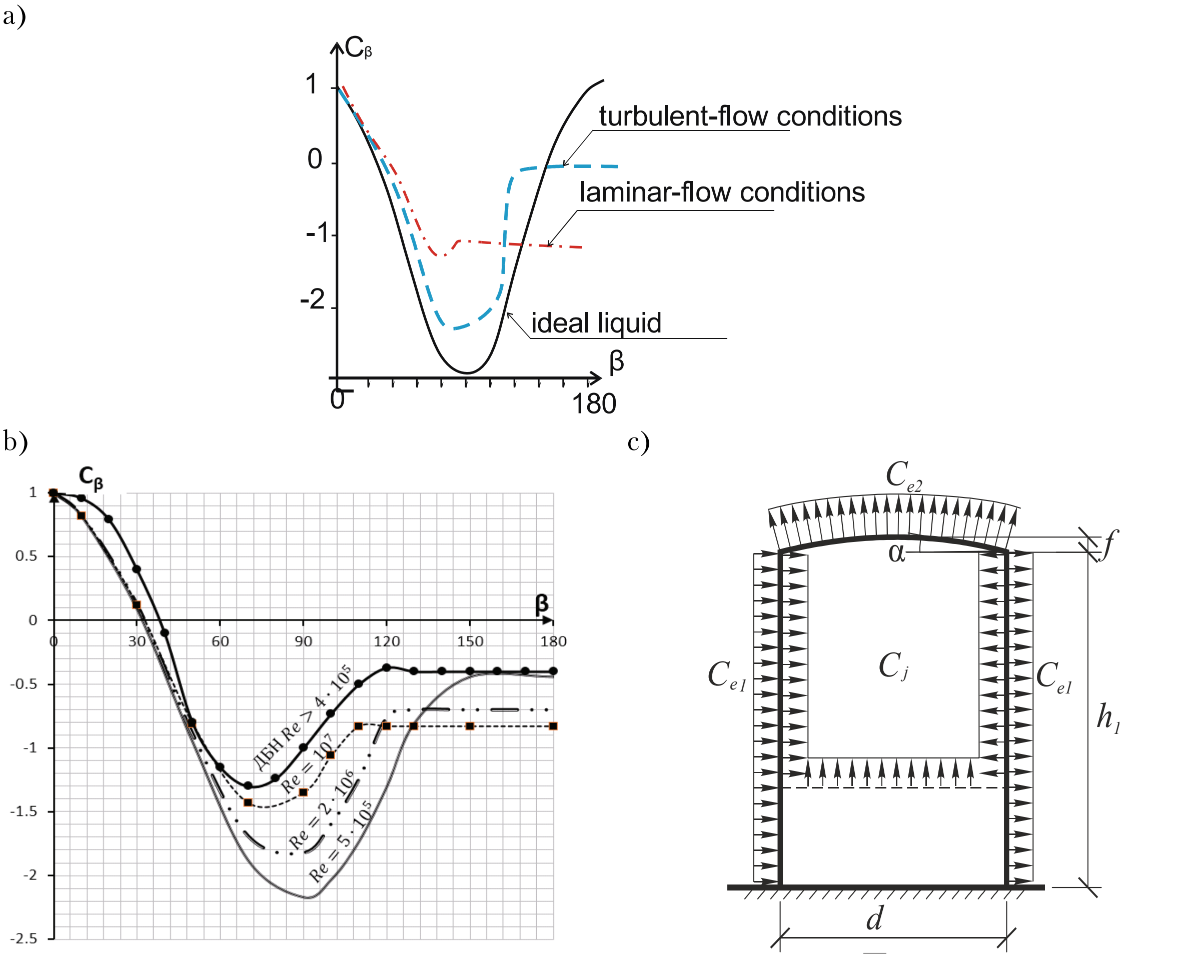


Figure 2. The valuation aerodynamic coefficients of C_β: a) diagram of distribution of coefficients [9]; b) aerodynamic coefficients of C_β for the wall of VCT determined in accordance with normative documents [7, 8]; c) diagram of distribution of coefficients, at the account of wind influence in accordance with normative documents.

Reynolds' number. For the home norms, the coefficients are determined at Re > 4·10^5, and for the European norms the coefficients are determined from three values of Reynolds' number, namely, Re= 2·10^6, Re= 10^7, Re= 5·10^5.

For the decision of the tasks formed below a verification calculation is executed for the model of VCT in a programmatic complex SolidWorks Flow Simulations, results over of that are brought in the article [10].

Raising of task of numeral experiment:

- to get the values of aerodynamic coefficients for a separately standing vertical cylindrical reservoir presented as a circular cylinder with initial geometrical and thermodynamics preset parameter and to compare to the operating normative documents;
- on the basis of the got results as coefficients of wind pressure on the roof of vertical cylindrical reservoir to compare to experimental data driven to [6];
- at providing of possible convergence within the limits of 10–15 % to execute a calculation for a group from 4th vertical cylindrical reservoirs.

Basic researches

On the surface of tank a frontier layer the thickness of that is determined on a formula was generated [1]:

$$\delta = 0.035 \cdot L \cdot \mathrm{Re}_L^{-\frac{1}{7}}. \qquad (1)$$

At the initial data of the characteristics of the velocity wind flow, the value of Reynolds' number is determined from the formulae:

$$\mathrm{Re} = \frac{L \cdot \mathrm{U}(z_e)}{\nu}, \qquad (2)$$

where L is a diameter;

ν it is kinematics viscidity of air, $\nu = 1{,}5 \cdot 10^{-5}$ m²/c;

U(ze) – is the peak value of wind velocity, $U(z_e)$=30 m/sec.

Re =5,7·10^7, that corresponds to the values of coefficients determined for an Euro Cods 1 at Re = 10^7 [8].

Within the framework of decision of the first task on a fig. 3 values over of aerodynamic coefficients are brought for a single reservoir. Values are certain on a mark at 10 and 17 m, their accordance with normative values.

Analysing, got results, it should be noted satisfactory convergence on greater part of diagram (from 0 to 120), at considerable divergences (to 40 % for the values of spades) in the zone of action of vacuum gauge pressure (from 120 to 180). In spite of these distinctions, that diminish on occasion for the values located on other marks, distinction «in a supply» allows to use offered approach for the decision of next task.

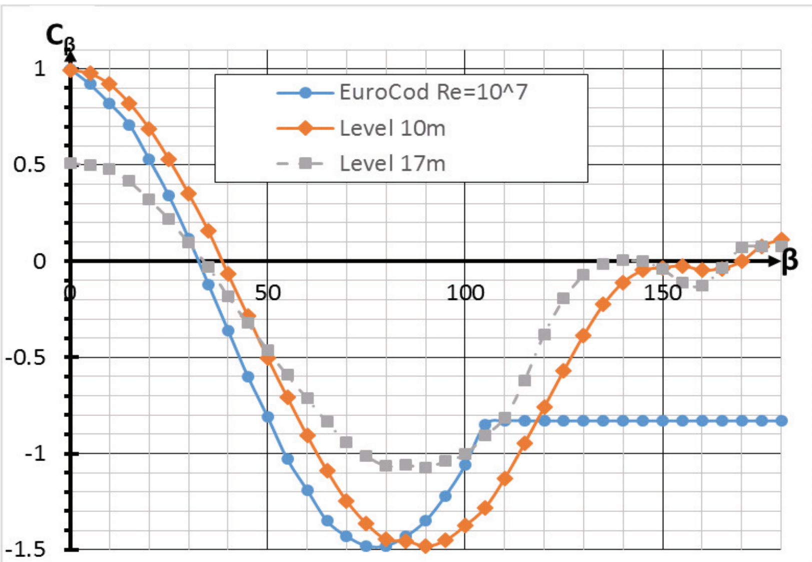


Figure 3. Comparison of aerodynamic coefficients for the wall of separately standing tank.

Passing to the analysis of wind pressure on the wall of reservoir being in a group, it is necessary to mark the following:

– studies are undertaken a for a group from 4th tanks by volume of 10 thousands m^3 with the sizes of diameter of D=28.5 and in H=a 18 m high, distance between reservoirs in a longitudinal and transversal location is equal to 1.5D, that corresponds the requirements of norms [11] for the group of tanks within the limits of building of tank farms;
– basic data of calculation (δ , Re) are accepted like the previous considered case.

The results over, presented on a fig. 4, are brought for the section plane located on a level +10 and a +17 m from a ground.

Analysing the dependences presented on the Figures of 4a, 4b it should be noted that a stream becomes asymmetrical.

For the plane located in the level of membrane roof distribution of coefficients is brought around to a fig. 5.

Conducting the comparable analysis of the obtained data it is possible to draw conclusion also about substantial influence of amount of VCT being in a group. Their arrangement influences on

a)

b)

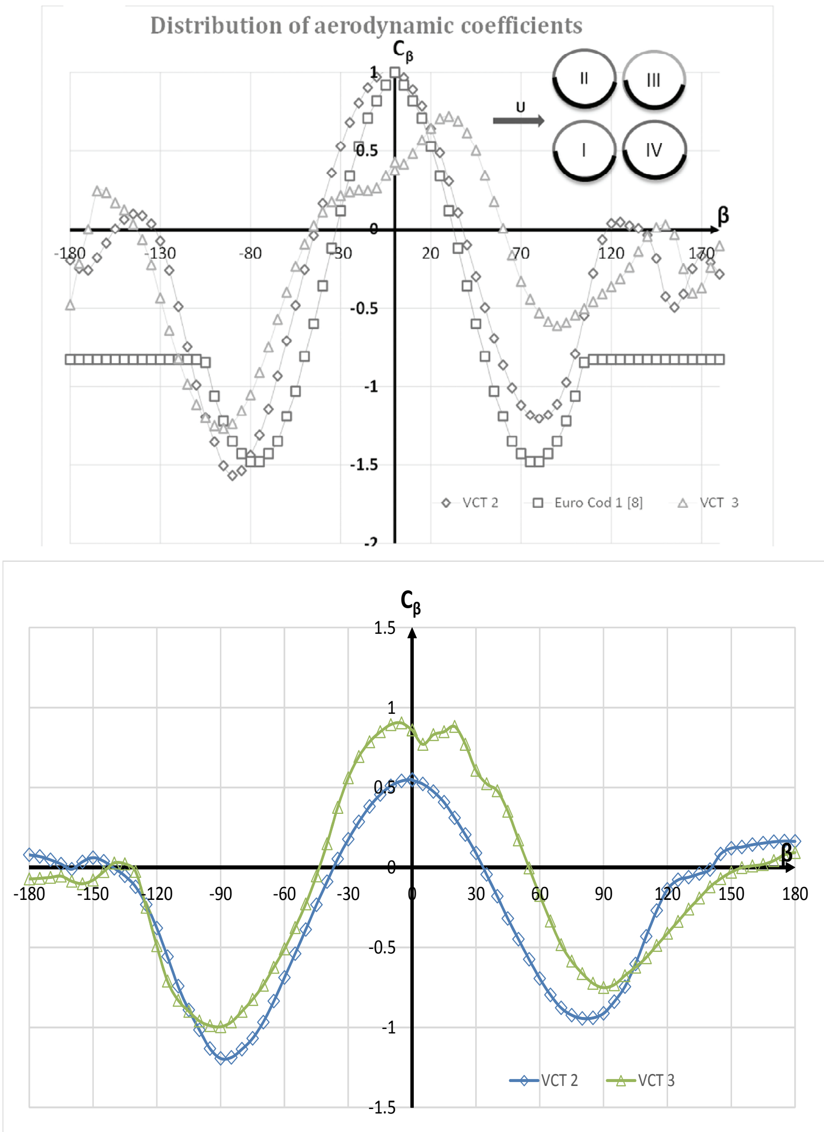


Figure 4. Diagram of distribution of aerodynamic coefficients for the group of tanks: a) maximal value of coefficients (on the level +of 10 m); b) maximal value of coefficients (on the level +of 17 m).

distribution of wind pressure on the surface of constructions of wall of VCT, and it it is necessary to take into account in the calculation of the tensely-deformed state of construction of VCT.

The general view visualization of wind stream is shown on fig. 6.

On a fig. 7 dependences over of distribution of aerodynamic coefficients are brought on the surface of membrane roof.

Conclusions

1) On the basis of the obtained data of comparative analysis of experimental, analytical and normative data a calculation diagram is formed for the calculation of single and group VCT in the environment of SolidWorks Flow Simulation for the numeral design of aerodynamic processes. Determining size of area of computer design became the basic feature of this procedure constituent.

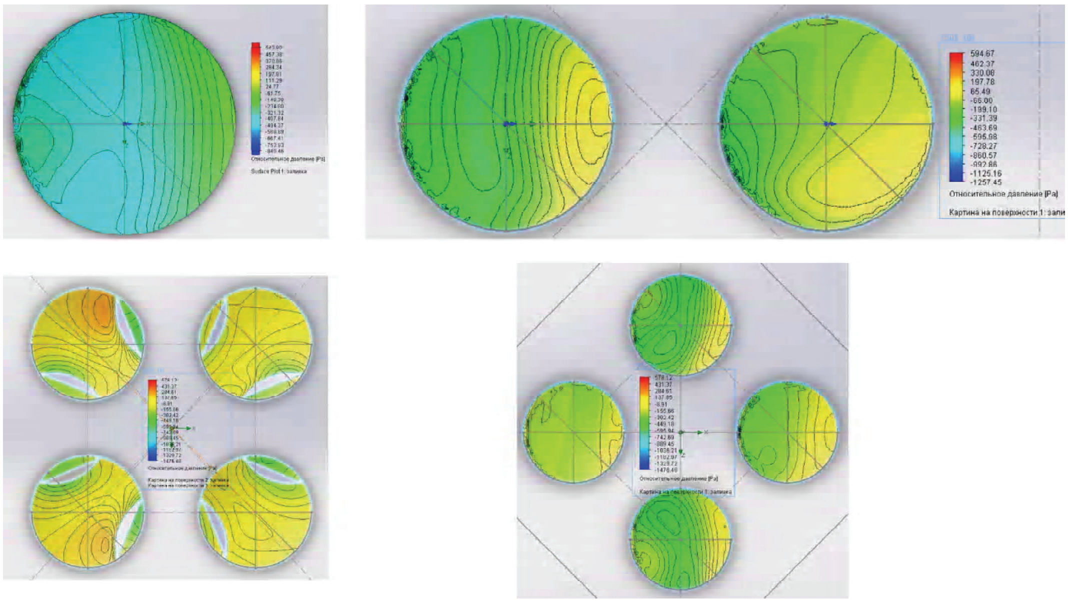


Figure 5. Isolines of distribution of aerodynamic coefficients for membrane roof of tank oil storage consisting of group.

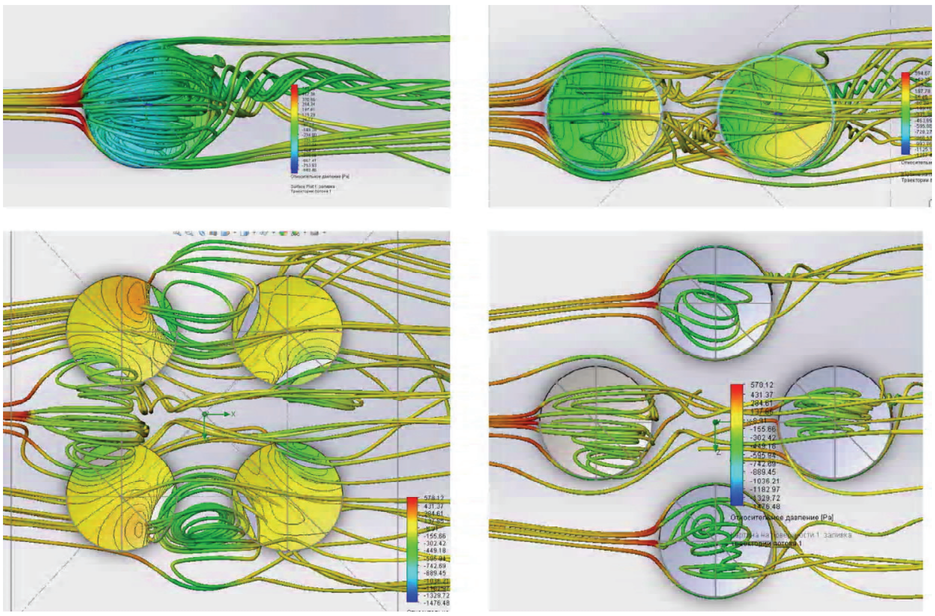


Figure 6. Lines of visualization of distribution of wind stream for membrane roof of reservoir consisting of group.

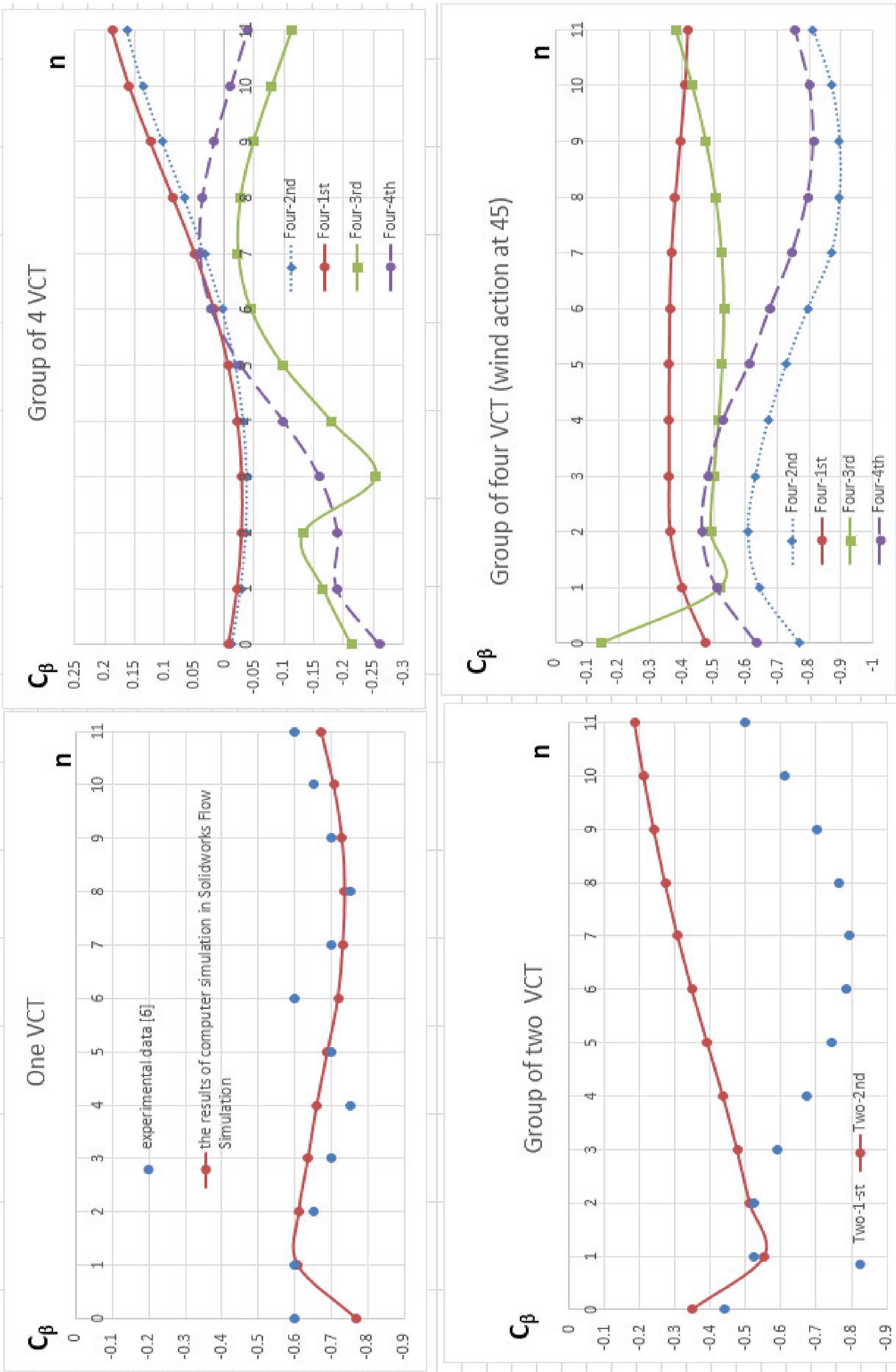


Figure 7. Distribution of aerodynamic coefficients on membrane roof of VCT.

2) There is proposed a technical approach providing a correct representation of the physical processes of the wind flow past a tank wall (the comparison of the experimental and numerical investigation results provides convergence in the range of 15 %).
3) For a group of 4 tanks the numerical simulation resulted in the improved values of the aerodynamic coefficients of wind pressure for each tank of the group which, in their turn, will provide an improved estimation of the mode of deformation of a wall structure as compared with the approach which is currently rated by the DBN (State Building Norms) and Euro Cods.
4) A basic calculation situation for the calculation of group VCT pressure became on a verge (fig. 4a), here the sizes of active pressure made in relation to normative data on 35 % less than.

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Мущанов Володимир Пилипович – д. т. н., професор, завідувач кафедри теоретичної і прикладної механіки, проректор з наукової роботи Донбаської національної академії будівництва і архітектури. Академік Української академії наук, академік Академії будівництва і архітектури, член-кореспондент Академії архітектури України, дійсний член Міжнародного інституту інженерів будівельників и член Міжнародної асоціації «Просторові конструкції». Наукові інтереси: теорія надійності, розрахунок, проектування та технічна діагностика просторових металевих конструкцій.

Зубенко Ганна Василівна – асистент кафедри теоретичної і прикладної механіки Донбаської національної академії будівництва і архітектури. Наукові інтереси: динаміка споруд, розрахунок і проектування просторових конструкцій.

Мущанов Владимир Филиппович – д. т. н., профессор, заведующий кафедрой теоретической и прикладной механики, проректор по научной работе Донбасской национальной академии строительства и архитектуры. Академик Украинской академии наук, академик Академии строительства и архитектуры, член-корреспондент Академии архитектуры Украины, действительный член Международного института инженеров строителей и член Международной ассоциации «Пространственные конструкции». Научные интересы: теория надежности, расчет, проектирование и техническая диагностика пространственных металлических конструкций.

Зубенко Анна Васильевна – ассистент кафедры теоретической и прикладной механики Донбасской национальной академии строительства и архитектуры. Научные интересы: динамика сооружений, расчет и проектирование пространственных конструкций.

Mushchanov Volodymyr – DSc (Eng.), Professor; Head of the Theoretical and Applied Mechanics Department, vice-rector on the scientific activity of the Donbas National Academy of Civil Engineering and Architecture. He is a member of Ukrainian Academy of Science, a member of Ukrainian Academy of Civil Engineering and Architecture, a corresponding member of Ukrainian Academy of Architecture, a real member of International Institute of Civil Engineering, a member of International Association of Spatial Structures. Research interests: theory of reliability, analysis, design and technical diagnosis of spatial metal construction.

Zubenko Hanna – Assistant; Theoretical and Applied Mechanics Department, Donbas National Academy of Civil Engineering and Architecture. Research interests: the dynamics of structures, calculation and design of spatial structures.