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ОБҐРУНТУВАННЯ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ ВПЛИВУ ЛОКАЛЬНОЇ ВОГНУТОСТІ НА НДС ОБОЛОНОК МЕТАЛЕВИХ ДИМОВИХ ТРУБ

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Анотація. У статті викладені результати натурних обстежень металевих димарів. Виявлені основні геометричні відхилення оболонок металевих димарів. Виконана систематизація даних геометричних відхилень і визначена частота їх виникнення. Для проведення лабораторних досліджень за визначенням впливу локальної вогнутості на НДС оболонок металевих димарів була визначено і обґрунтовано еквівалентне вітрове навантаження. На підставі чисельних досліджень була розроблена і виготовлена лабораторна установка для дослідження впливу локальної вогнутості на НДС оболонок металевих димарів. Визначена послідовність проведення лабораторного експерименту.

Ключові слова: димова труба, геометричні відхилення, еквівалентне напруження, місцеві напруження, масштабна модель, концентрація напружень.

ОБОСНОВАНИЕ ЭКСПЕРИМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ ВЛИЯНИЯ ЛОКАЛЬНОЙ ВОГНУТОСТИ НА НДС ОБОЛОЧЕК МЕТАЛЛИЧЕСКИХ ДЫМОВЫХ ТРУБ

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Аннотация. В статье изложены результаты натурных обследований металлических дымовых труб. Выявлены основные геометрические отклонения оболочек металлических дымовых труб. Произведена систематизация данных геометрических отклонений и определена частота их возникновения. Для проведения лабораторных исследований по определению влияния локальной вогнутости на НДС оболочек металлических дымовых труб была определена и обоснована эквивалентная ветровая нагрузка. На основании численных исследований была разработана и изготовлена лабораторная установка для исследования влияния локальной вогнутости на НДС оболочек металлических дымовых труб. Определена последовательность проведения лабораторного эксперимента.

Ключевые слова: дымовая труба, геометрические отклонения, эквивалентные напряжения, местные напряжения, масштабная модель, концентрация напряжений.

JUSTIFICATION OF EXPERIMENTAL RESEARCH OF INFLUENCE OF LOCAL DIMPLE ON THE STRESS-STRAIN STATE OF METAL CHIMNEYS SHELLS

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Abstract. The results of field surveys of metal chimneys are presented in the article. The basic geometric imperfections metal chimney's shells are revealed. Systematization of the data of geometric imperfections is performed and their frequency is determined. For the laboratory research on determining effects of the local dimple on the stress-strain state of metal chimney's shells the equivalent wind load was identified and substantiated. A laboratory setting for studying the influence of local dimple on the stress-stain state of shells metal chimneys were designed and manufactured on the basis of numerical studies. The sequence of a laboratory experiment is determined.

Keywords: steel chimney, geometrical imperfections, equivalent, local stresses, scale model, the stress concentration.

Formulation of the problem

Metal chimneys and flue trunks – are high rised cylindrical thin-wall shell structures, intended for the removing exhaust gases into the upper layers of the atmosphere and their subsequent dispersion.

Methodology of calculating these structures on the strength, stability [1, 7, 9, 12, 13], determination of the dynamic response of structures [9, 11] are developed fully enough.

Calculation of sheet structures, which include metal chimneys and flue trunks must be made according to the normative regulations [1, 12], which provide guidance on the need of considering the geometrical deviations.

These instructions are not complete and do not cover all types and sizes of geometric deviations.

The boundary dimensions of these deviations (tolerances) are given in these sources, but in actual structures, the sizes of the deviations occur beyond the limits of these tolerances.

From the sources [3, 4, 5, 11] it is known that in areas with geometric deviations local voltage spikes arise.

Therefore, the actual task is to determine the size of geometrical deviations and their contribution to the overall stress-strain state of the structure.

According to the normative documents [4] and the technical literature [5, 6] the metal chimneys should be calculated as a cantilever beam-curved rods rigidly clamped at the base.

As the works [3, 4] show, it is not always justified, especially during the checking calculations at the operation stage of this kind of structures, when there is a need to consider the different types of the geometric deviations in the form of various dimples, burnouts, docking drawer side with eccentricity, ellipticity of drawer side.

Investigations on studying and determination of the local stress in the areas of metal chimneys initiated in [3, 4, 5].

Tolerances on geometrical deviation in form of local dimple, which depend on the fabrication tolerance quality class, the concavity depth and the length are given in [12]. These limits have insignificant parameter of variation.

According to the [12] the dimple tolerance parameter varies from 0,006 to 0,016 for the different fabrication tolerance quality class.

The aim of the study

Determination the characteristics of stress-strain state of metal chimney's shells with geometric deviations.

The objectives of the study

1. To determine the most common geometric deviations on the basis of surveys of metal chimneys.
2. To substantiate the feasibility of using an equivalent wind load for experimental studies on the basis of numerical studies.
3. To develop and produce a laboratory setting for investigation the impact on stress-stain state of shells of metal chimneys.

The object of the study

Characterization of the changes of stresses in areas with geometric deviations.

The subject of study – the stress-strain state of metal chimneys with geometrical deviations (in the case of the geometric deviation in the form of local dimple).

The basic material

Metal chimneys and flue trunks, which are operated with different kinds of defects and damage, reducing the carrying capacity, and hence the life of the structures, have been identified in the survey.

Some defects or damages that are typical for these structures are shown in Figure 1.

Later, defects and damages associated with changes in geometry of the structure are called as

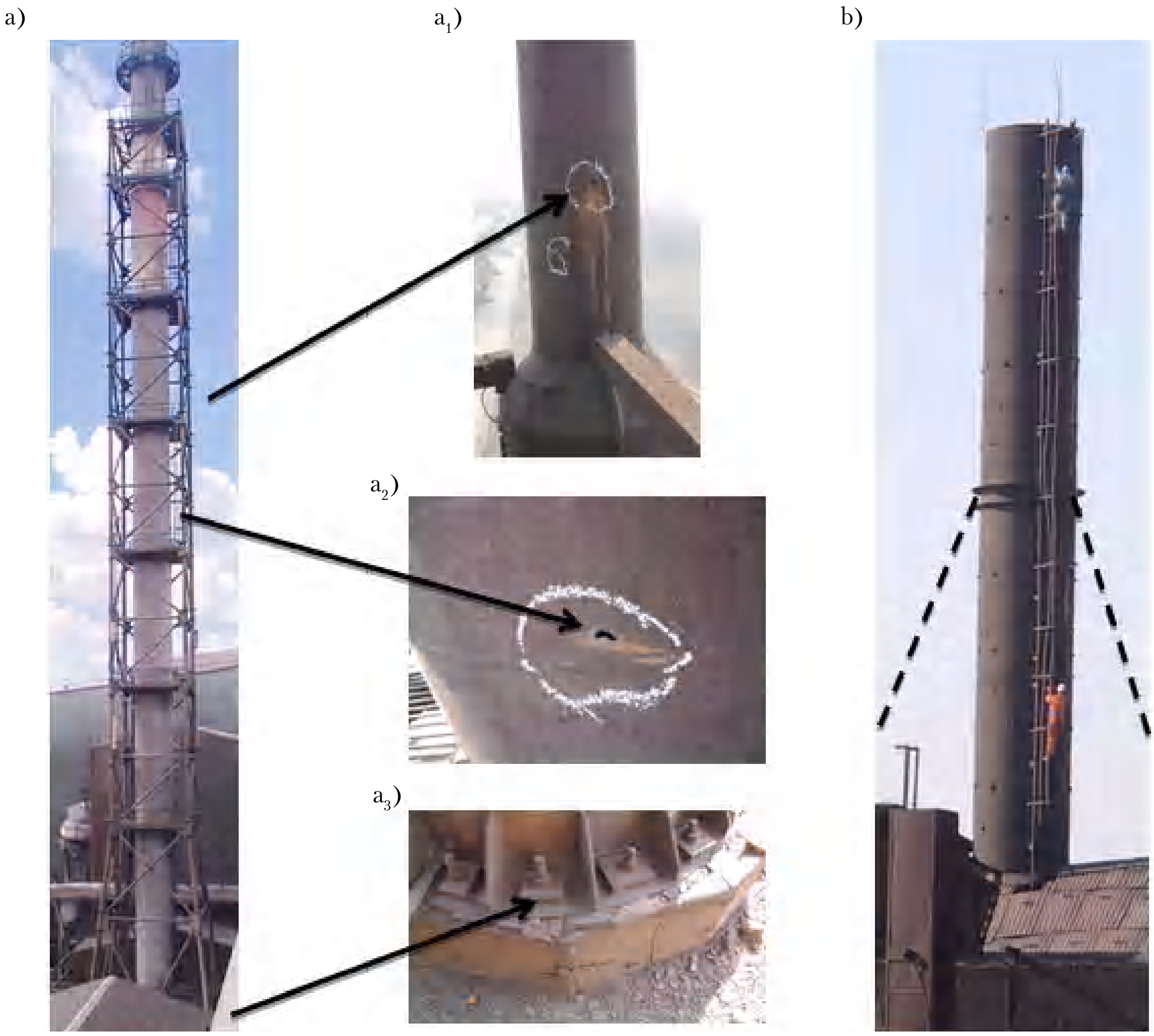

Figure 1. Defects and damages: a) gas exhaust trunks: a_1) burnout in support frame; a_2) burnout in a shell of gas exhaust trunk; a_3) destruction of the supporting basement; b) metal chimneys – backstays, provided by the project, are absent.

«geometrical imperfection». The main types of geometrical deviations for this type of structures are: ellipticity, eccentricities and a local dimple of a shell. The most common of them are presented in Figure 2.

On the basis of surveys of 15 structures in the Donetsk region, 9 of them were chimneys and 6 were gas exhaust trunks in the lattice frame (metal pipes in the frame), the most common geometric deviations were identified. Quantitative characterization of which is shown in Figure 3.

Some causes of geometrical deviations can be distinguished between the following:

– during the design process – the case of abrupt change of thickness of abutting elements;
– during the manufacturing process – depends on admittance of the equipment for the rolling and welding of elements;
– during transportation – low quality fixing of structural elements, leading to changes in geometry, for example to appearance of ellipticity or changing a radius of rolled sheet;
– during mounting – depends on the quality of manufacturing and qualification of employees performing the work;
– during the operation – depending on the power factor, in which structure is operated (e. g., for chimneys with a larger diameter, the local distribution of wind load on the perimeter of the shell can lead to ellipticity).

During the survey of these structures there have been identified a local dimple with the following parameters:

– depth of a dimple Δw varies between 4 to 10 mm.
– length of a dimple l_g varies between 100 to 400 мм.

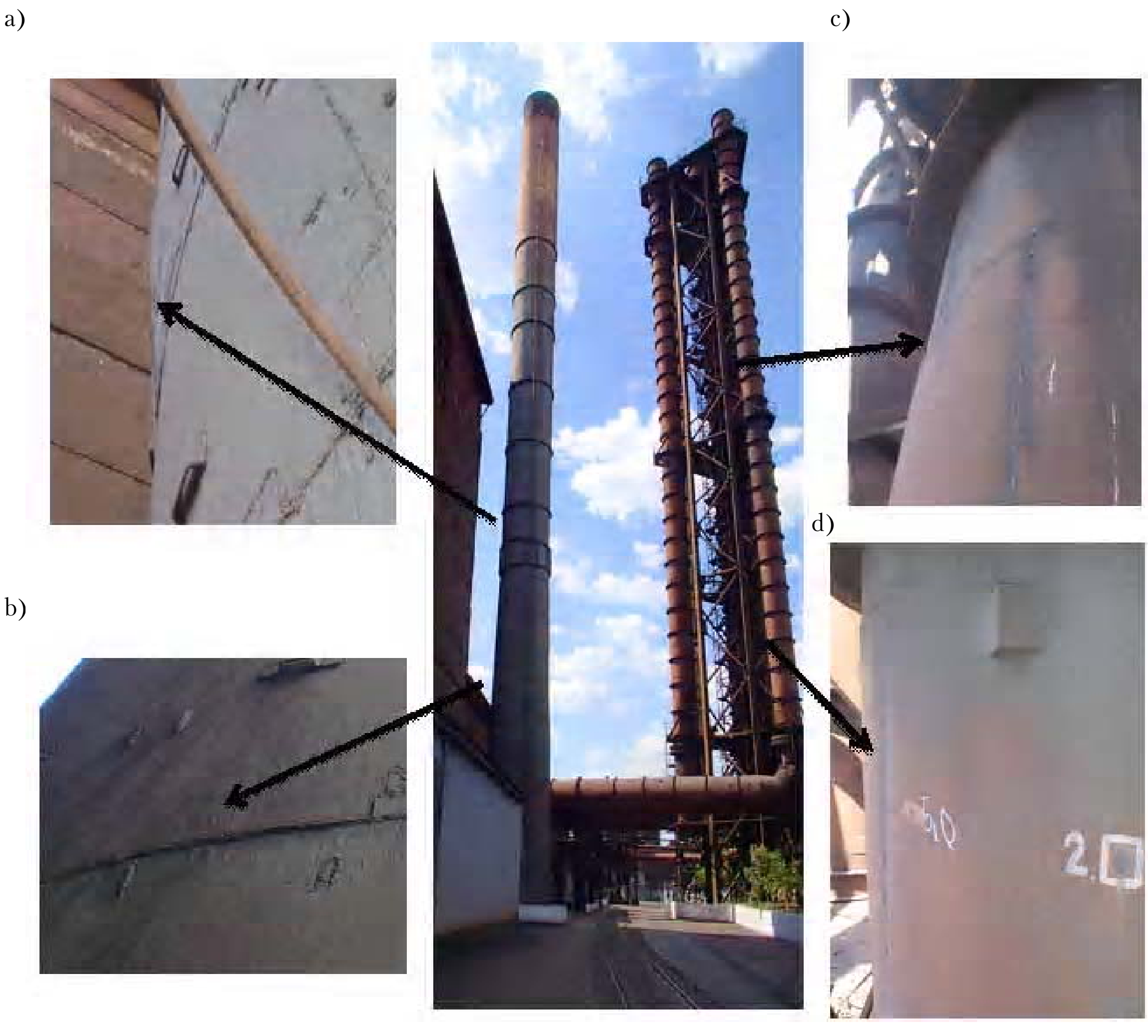

Figure 2. Geometrical deviations: – metal chimneys: a) convexity/dimple on the shell; b) eccentricity; – gas exhaust trunks: c) concavity of a shell; d) withdrawal of edges.

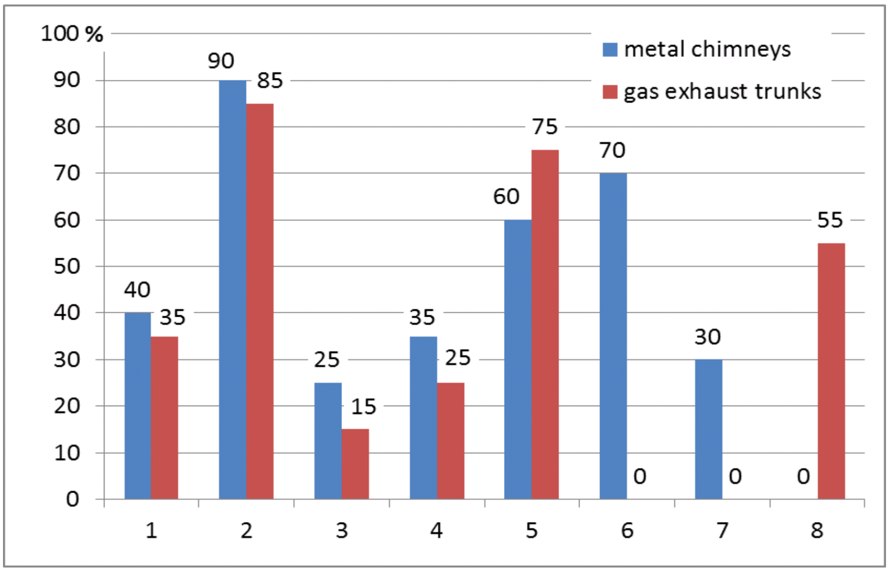

Figure 3. Numerical characterization of geometric deviations, where: 1. Destruction of elements of foundation. 2. Violation of corrosion protection. 3. Concavity of a shell. 4. Eccentricity. 5. A local reduction of a shell thickness. 6. Weakening of a tension of braces. 7. Withdrawal of edges of docking drawer side. 8. Burnout in metal shell.

Therefore, the parameter of tolerance on the local dimple $U_{0,\ max}$ varies between 0,013 to 0,1. From the obtained results it is evident, that a real maximum value of tolerance on the local dimple is что реальное максимальное значение допуска на локальную вогнутость approximately 6.0 times greater than the value given in [12].

Justification of the applicability of the equivalent wind load for experimental researches

To obtain reliable results, concerning new studies, it is necessary to compare numerical and experimental studies.

According to the results obtained in [6], taking into account the influence of geometrical deviations on stress-stain state of metal chimney`s shells, there should be performed a spatial design model. Metal chimney is modeled as a thin-sheet cylindrical shell with transverse stiffeners. Wind load is modeled uneven, both in height and the perimeter of the computational model, according to [1].

For the numerical studies, the wind load is modeled quite simple, but for experimental research on large-scale models, its modeling is almost impossible. It is also possible to carry out researches on the real metal chimneys or on the scale models in a wind tunnel. In the first case, we cannot guarantee the appearance of the wind in the desired direction for us and with the required value of the wind speed, for example, to determine the maximum value of stress concentration in the area with a geometric deviation. Also, we cannot determine the limiting values of the wind speed, at which the design could be destroyed, in order to determine the actual bearing capacity of the construction and the safety factor. Investigations in the wind tunnel exclude the application of strain gages, which are sensitive to extreme temperatures and to the direct influence of the wind. Also, a scale model must have the small thickness (about 0,1 mm) to make the wind speed in the wind tunnel be sufficient to fracture the scale model. The manufacture of such structures in vitro, is virtually impossible.

To solve this problem, a question about replacing a real wind pressure to the equivalent was raised. Using the equivalent wind load, close in value, equivalent stresses and displacements in structural elements will occur.

Studies were conducted on the metal chimney height of $L = 60\ m$ and a diameter $D = 1.2–3.0\ m$ by 0.3 m and a thickness $t = 10\ mm$.

The calculations were performed taking into account the construction of its own weight and wind load, the characteristic value is taken according to [1] *W = 600 Pa.*

Replacement scheme of the wind pressure on the equivalent wind load is shown in Fig. 4.

Order of transition from of the wind pressure (qw0, Pa.) to the equivalent wind load (P1–P4, H) as follows:

1. Dividing the calculation schemes of chimney into 4 equal parts. According to [1], taking into account circuit 12b determines the estimated wind pressure on each calculated site (qw1–qw4, Pa);
2. Moving from the wind pressure (qw1–qw4, Pa) to unevenly distributed load adjustment (q1–q4, N / m)
   where,

$$q_{1\text{-}4} = q_{w1\text{-}4} \cdot D. \quad (1)$$

3. Transitioning from unevenly distributed on the height of the load (q1–q4, N / m) to the horizontal forces (P1–P4, H).
   where P1–P4 are defined by:

$$P_1 = q_1 \cdot l^2 / 3l = q_1 \cdot l / 3, \quad (2)$$

$$P_2 = \left(q_2 \cdot 2l^2 / 3 - P_1 \cdot l\right) / 2l, \quad (3)$$

$$P_3 = \left(q_3 \cdot 3l^2 / 3 - P_1 \cdot l - P_2 \cdot 2l\right) / 3l, \quad (4)$$

$$P_4 = \left(q_4 \cdot 4l^2 / 3 - P_1 \cdot l - P_2 \cdot 2l - P_3 \cdot 3l\right) / 4l. \quad (5)$$

For example, we obtain the values of the equivalent strength to the chimney with parameters: *L = 60 м, D = 3 м.*

According to [1] q_{w1} = 250 Па, q_{w2} = 500 Па, q_{w3} = 750 Па, q_{w4} = 1 000 Па. Using the formula 2 we can determine the values q_1–q_4, where, q_1 = 750 Н/м, q_2 = 1 500 Н/м, q_3 = 2 250 Н/м, q_4 = 3 000 Н/м. Then, using formulas 2–5 we determine equivalent horizontal forces *P1–P4*, where, P_1 = 3 750 Н, P_2 = 13 125 Н, P_3 = 23 750 Н, P_4 = 34 687,5 Н.

Comparing the results of the calculations using real wind pressure and the equivalent wind load is shown in Fig. 5. Because the maximum wind stress occurs at the base of the structure, we present the results for ¼ heights of the building.

Calculation of the models with diameters ranging from 1.2 m to 3 m showed similar results.

Considered plot (¼length of model), conditionally can be divided into three equal areas. Zone 1 is equal to 1/3 of the area (for the model 5 m). The variance under equivalent stresses was about 10 %. In zone 2, the maximum difference for equivalent stresses was 3 %, and the third – 10 %.

From the obtained results, we can conclude, that while creating the test facility and a laboratory model, we must consider that the minimum difference in equivalent voltages from 2 types of load is observed at ½ height of the first

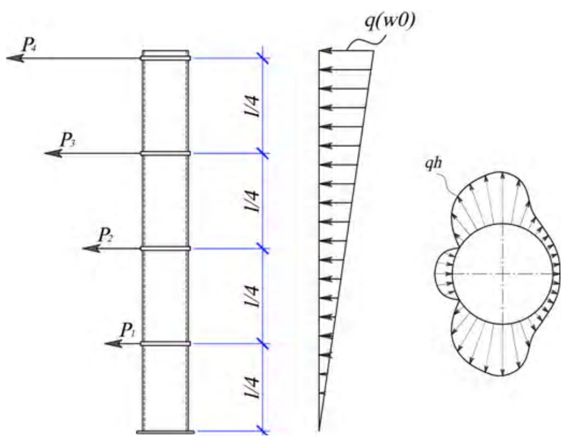

Figure 4. Scheme of replacement the wind pressure by the equivalent one.

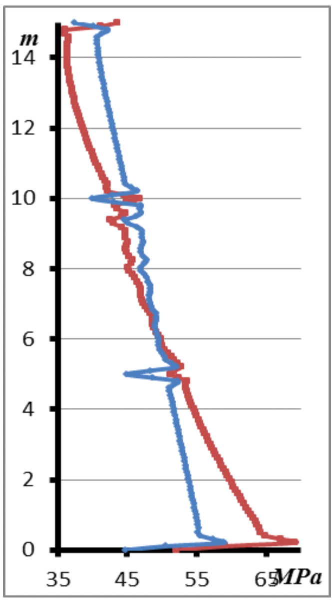

Figure 5. Comparison of the results using wind pressure and wind load equivalent (distribution σeq).

settlement area. Therefore, to obtain reliable data in the laboratory, the concavity need to be modeled precisely at this height.

Development of the laboratory setup for laboratory researches.

A laboratory setup and scheme of application of the load to the studying model developed based on the obtained studies and data. The main geometrical dimensions of the laboratory setup are shown in Fig. 6.

Scale models of chimney with the following parameters will be used in the studies:

– height of the models $L = 1\ 000\ mm$;
– diameter of the models $D = 120\ mm$;
– thikness of the models $t = 0{,}5\ mm$;
– material – 08X18H10.

Basic relations of a scale model $L / r = 16{,}7$, $t / r = 120$, that correspond to the relations of metal chimneys.

General view of the laboratory setup with the main structural elements is shown in Fig. 7.

Using a template, on the particular above / previously height, it is performing a dimple of specified size, after that, it is performing an installation of the model on supporting part, followed by applying the load.

To determine the influence of the local dimple on stress-stain state of shells of metal chimneys, tensoresistance sticker with sensors and a base of 3 mm is produced in an area with a dimple. A pinout of wires to the strain gauges and their subsequent connection to the module of input signals to strain gauges MB110-224.4TД is produced at the test site. This system allows taking 24 load cells in one time.

The order of application and load transfer is following:

– studied model (Fig. 7a) mounted on a support portion (Fig. 7d);
– support portion locked via 5-mm bolts ∅10 to a laboratory setting (Fig. 7a);
– support rings (Fig. 7b) are attached to the studied model;
– cable is attached to the support rings on each mark, which passes through the rollers (Fig. 7) mounted on the support portion;
– a plummet is being hung to the rollers, whose mass is calculated according to the formulas 2–5.

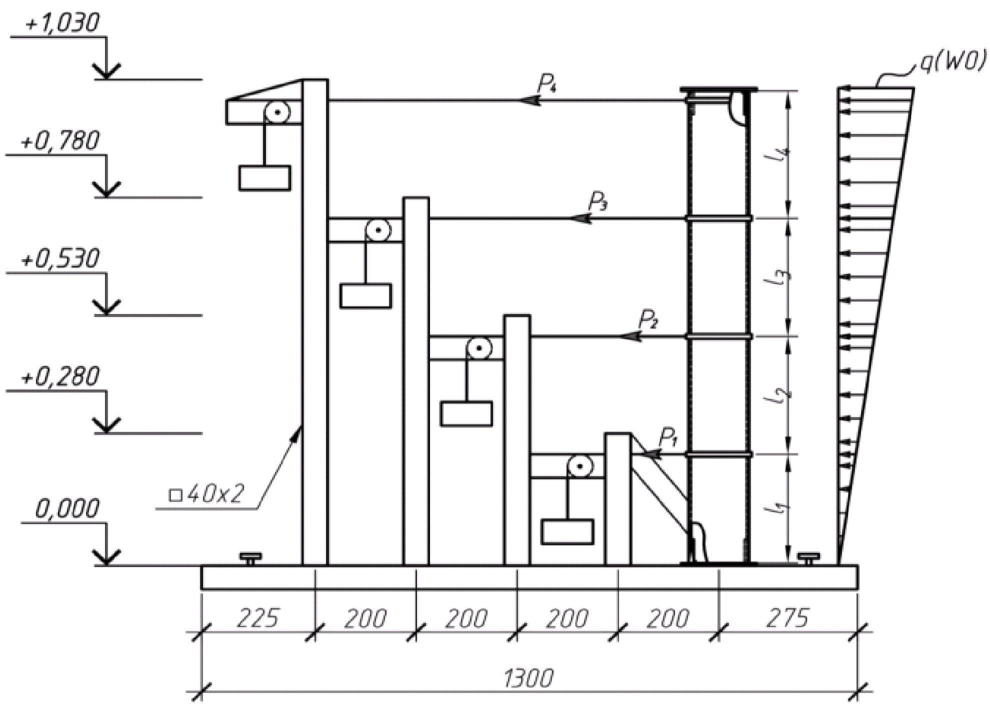

Figure 6. General dimensions of the laboratory model.

Application of the load will be carried out step by step, with equal steps, until the destruction of the studied model.

The equivalent stresses in the area with a local dimple, as well as the critical buckling force, will be determined on the basis of the obtained results.

Conclusions

1. The basic geometric deviations, namely, local concavity, eccentricity and ellipticity have been identified and defined on the basis of surveys of metal chimneys.
2. The value and type of the equivalent wind load is determined on the basis of the numerical studies. The given equivalent load is recommended to use in further experimental studies.
3. The laboratory setting, which allows to investigate the influence of local dimple on the stress-stain state of shells of metal chimneys are designed and manufactured for laboratory experiments.

b) a) c) d)

Figure 7. General view of the laboratory setup and main structural elements: a) laboratory setup with a studying model; b) roller for load transfer; c) support rings; d) support part.

References

1. ДБН В.2.6-163:2010. Конструкції будівель і споруд. Сталеві конструкції. Норми проектування, виготовлення і монтажу [Текст]. – На заміну СНиП II-23-81* окрім розділів 15*–19, СНиП III-18-75 окрім розділів 3-8, СНиП 3.03.01-87 у частині, що стосується сталевих конструкцій окрім п.п. 4.78–4.134 ; чинні від 2011-12-01. – Київ : Мінрегіонбуд України, 2011. – 127 с.
2. ДБН В.1.2-2:2006. Система забезпечення надійності та безпеки будівельних об'єктів. Навантаження і впливи. Норми проектування [Текст]. – Замість СНиП 2.01.07-85; надано чинності 2007-01-01. – К. : Мінбуд України, 2006. – 61 с. – (Державні будівельні норми).
3. Губанов, В. В. Уточнение методик расчета локальных напряжений в оболочках дымовых труб и газоотводящих стволов [Текст] / В. В. Губанов, А. В. Голиков // Будівельні металеві конструкції:

References

1. DBN V.2.6-163:2010. The constructions of buildings and structures. The steel constructions. Norms for design, fabrication and erection. Kyiv: Ministry of Regional Development of Ukraine, 2011. 127 p. (in Ukrainian)
2. DBN V.1.2-2:2006. National Structural Rules and Regulations. The system of reliability and safety provision of constructional projects. Loads and effects. Kyiv: Minbud of Ukraine, 2006. 78 p. (in Ukrainian)
3. Gubanov, V. V.; Golikov, A. V. Improvement of calculation procedure of local strain in shells of chimneys and gas outlet shank. In: *Construction metal structures: nowadays and future development. BMK-2006: Vth International scientific and technical conference (19–22nd of September 2006, Kyiv, Ukraine): Papers*. Kyiv: Stal, 2006, p. 118–121. ISBN 966-7589-68-4. (in Russian)

сьогодення та перспективи розвитку. БМК-2006 : V Міжнар. наук.-техн. конференція (19–22 вересня 2006 р., м. Київ, Україна) : Доповіді / В.о. ВАТ «Укр. наук.-дослід. та проект. ін-т сталевих конструкцій ім. В. М. Шимановського». – К. : Сталь, 2006. – С. 118–121. – ISBN 966-7589-68-4.

4. Губанов, В. В. Расчет и конструирование газоотводящих стволов с местными напряжениями [Текст] / В. В. Губанов, А. В. Голіков // Вісник Донбаської нац. академії будівництва і архітектури : зб. наук. праць / М-во освіти і науки України, ДонНАБА. – Макіївка, 2009. – Вип. 2009-4(78) : Баштові споруди: матеріали, конструкції, технології. – С. 215–220.
5. Губанов, В. В. Влияние локальной вогнутости на работу несущей оболочки высотных сооружений [Текст] / В. В. Губанов, А. В. Голіков // Металеві конструкції. – 2011. – Том 17, № 3. – С. 177–184.
6. Губанов, В. В. Выбор расчётной схемы для численного анализа свободностоящих дымовых труб [Текст] / В. В. Губанов, А. М. Кульчицький // Металеві конструкції. – 2012. – Том 18, № 3. – С. 197–208.
7. Дымовые трубы [Текст] / А. М. Ельшин, М. Н. Ижорин, В. С. Жолудов, Е. Г. Овчаренко ; Под редакцией С. В. Сатьянова. – М. : Стройиздат, 2001. – 296 с.
8. Лессиг, Е. Н. Листовые металлические конструкции [Текст] / Е. Н. Лессиг, А. Ф. Лилеев, А. Г. Соколов. – М. : Изд-во литературы по строительству, 1970. – 488 с.
9. Металлические конструкции [Текст]. В 3 т. Т. 3. Специальные конструкции и сооружения : Учебник для строит. вузов / Под редакцией В. В. Горева. – М. : Высш. шк., 2002. – 544 с.
10. СНиП 2.09.03-85. Строительные нормы и правила. Сооружения промышленных предприятий [Текст]. – Взамен СНиП II-91-77, СН 302-65, СН 471-75 ; введ. 1987-01-01. – М. : ЦИТП Госстроя СССР, 1986. – 56 с.
11. Солодарь, М. Б. Металлические конструкции вытяжных башен [Текст] / М. Б. Солодарь, М. В. Кузнецова, Ю. С. Плишкин. – Л. : Стройиздат, 1975. – 186 с.
12. EN 1993-1-6:2007. Еврокод 3. Проектирование стальных конструкций. Часть 1-6. Прочность и устойчивость оболочек [Текст]. – Введен впервые. – Минск : Министерство архитектуры и строительства Республики Беларусь, 2010. – 167 с.
13. BS EN 1993-3-2:2006. Eurocode 3 – Design of steel structures – Part 3-2: Towers, masts and chimneys - Chimneys [Текст]. – [S. l.] : BSi, 2006. – 34 p. – ISBN 978-0-580-54894-9.

4. Gubanov, V. V.; Golikov, O. V. Calculation and gas pipes with local stresses. In: *Proceeding of the Donbas National Academy of Civil Engineering and Architecture*, 2009, Issue 2009-4(78): Towers: building materials, structures, processes, p. 215–220. (in Russian)
5. Gubanov, Vadim; Golikov, Alexandr; Kulchitskiy, Artem. Effect of local concavity upon bearing shell of high buildings. In: *Metal Constructions*, 2011, Volume 17, Number 3, p. 177–184. (in Russian)
6. Gubanov, Vadim; Kulchytskyy, Artem. The selection of calculated scheme for self-supported chimney numerical calculus. In: *Metal Constructions*, 2012, Volume 18, Number 3, p. 197–208. (in Russian)
7. Elshin, A. M.; Izhorin, M. N.; Zholudov, V. S.; Ovcharenko, E. G. Edited by Satianov, S. V. Chimneys. Moscow: Stroiizdat, 2001. 296 p. (in Russian)
8. Lessig, E. N.; Lileev, A. F.; Sokolov, A. G. Shell steel structures. Moscow: Stroiizdat, 1970. 488 p. (in Russian)
9. Edited by Gorev, V. V. Metal Constructions. In three volumes. Volume 3. Special structures and constructions. Moscow: High school, 2002. 544 p. (in Russian)
10. SNiP 2.09.03-85. Construction rules and regulations. Constructions of enterprises. Moscow: TsITP Gosstroia USSR, 1986. 56 p. (in Russian)
11. Solodar, M. B.; Kuznetsova, M. V.; Plishkin, Yu. S. Steel constructions of stack. Leningrad: Stroiizdat, 1975. 186 p. (in Russian)
12. EN 1993-1-6:2007. Eurocode 3. Design of steel structures. Part 1-6. Strength and stability of shell structures. Minsk: Ministry of Architecture and Construction of Republic Belarus, 2010. 167 p. (in Russian)
13. BS EN 1993-3-2:2006. Eurocode 3 – Design of steel structures – Part 3-2: Towers, masts and chimneys – Chimneys. [S. l.]: BSi, 2006. 34 p. ISBN 978-0-580-54894-9.

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