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CFD SIMULATION OF THERMAL AND THERMALLY STRESSED STATE OF THE DKVR-10-13 BOILER DRUM

[1] **Olha Yu. Chernousenko**
chernousenko20a@gmail.com
ORCID: 0000-0002-1427-8068

[1] **Artur Yu. Rachynskyi**
arturrachinskiy@gmail.com
ORCID: 0000-0001-6622-1517

[1,2] **Oleksandr V. Baraniuk**
olexandr.baranyuk@gmail.com
ORCID: 0000-0001-6008-6465

[1] National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute",
37, Beresteiskyi ave., Kyiv, 03056, Ukraine

[2] Thermal Energy Technology Institute of NAS of Ukraine
19, Andriivska str., Kyiv, 04070, Ukraine

The urgency of the paper is dictated by the problems that arise during the operation of power boiler drums. As a result of exposure to high pressure, elevated temperature, cyclic loads, and a corrosive environment, the formation of various defects and damages, such as cracks, fatigue failures, corrosion, and others, might occur. These defects can cause accidents and even catastrophic destruction, which threaten the safety and efficiency of boiler units. Therefore, it is important to carry out regular inspections, maintenance and repairs to ensure the safety and reliability of the equipment. Work on extending the period of safe operation of the boiler, which has served its intended service life, is carried out in accordance with the provisions of SOU 40.1-21677681-02:2009 approved in Ukraine, which recommend performing calculations on the strength of boiler units elements. These calculations can be performed using modern CFD methods of computational fluid dynamics. The presented paper is devoted to the CFD modeling of the thermoelastic state of the drum-separator installed above the DKVR-10-13 type boiler fuel tank, which is equipped with burners operating using jet-niche technology. The burners differed in the type of fuel supply. In one of the burners, fuel is supplied through rectangular slits, in the other one - through round holes arranged in a row. Air is supplied to both burners through rectangular slits. The research was carried out for two operating modes of the boiler unit - nominal and at 60% capacity with numerical methods using the ANSYS-Fluent application program package. The object of the study is a boiler drum of the DKVR-10-13 type with all weakening holes. The subject of the study is the processes of thermal strength of the shell structure, which is inherent in the boiler drum, as a result of the influence of pressure, temperature and heat flow from the heated gases moving into the fuel chamber of the boiler equipped with jet-niche burners both at nominal and 60% heat load. It was determined that the nominal wall thickness of 10 mm for the drum of the DKVR-10-13 boiler, both at the nominal and at 60% heat load, is quite sufficient to ensure the strength of the drum, since the difference between the highest and lowest temperature on the surface of the drum is within 30 °C. Moreover, during gas distribution through round holes, the temperature field of the drum wall is more uniform than in the case of fuel supply through rectangular slits. The maximum equivalent Mises stress that occurs between the rows of holes on the drum reaches 75 MPa. It was also determined that the maximum deformation of the drum walls was 1.1 mm, which could not lead to the destruction and rupture of the drum under internal pressure.

Keywords*: gas distribution, jet-niche technology, ANSYS-Fluent, thermal stresses, gaseous fuel, combustion, methane, boiler fuel.*

Introduction

As of now, most heating boiler houses, which were put into operation in the 60s and 70s of the last century, use the DKVR-type steam boilers. All of them have been operating for more than 40 years and have exhausted their resource long time ago. In order for them to continue their operation, the operating pressure in the boilers is reduced to 0.6–0.8 MPa, and in reality, during operation, many boilers maintain a pressure of 1–2 atm. The operation of steam boilers at such low pressures negatively affects the stability of the circulation due to a decrease in the saturation temperature and an increase in the proportion of vaporization. In the screen tubes, intensive scale formation occurs and the probability of tube burnout increases. In addition, when the boiler is operating at a pressure of 1 to 3 atm due to the low saturation temperature, it is necessary to turn off the cast-iron water economizer, since vaporization may occur in it, which is unacceptable under conditions of reliable operation. All of the above leads to the fact that the efficiency of these steam boilers does not exceed 80–82%, and in some cases, when the pipes are heavily contaminated, the boiler efficiency decreases to 70–75%. In view of this, such boilers require regular technical inspections, and therefore, they are transferred to the water-heating mode. After the end of the standard operating period of water-heating boilers, their resource is extended based on the conclusion of the industrial safety examination. In this regard, in accordance with the Resolution of the Cabinet of Ministers of Ukraine dated May 26, 2004 No. 687 "On approval of the procedure for conducting an inspection, testing and expert examination (technical diagnostics) of machines, mechanisms, equipment of increased danger" (NPAOP 0.00-8.18 (НПАОП 0.00-8.18)) and NPAOP 0.00-1.08 (НПАОП 0.00-1.08) "Rules for the construction and safe operation of steam and water-heating boilers", the standard "Procedure for extending the service life of high-pressure boiler drums" was put into effect [1]. It establishes the equipment resource (established service life) of high-pressure boiler drums, defines the main requirements for the procedure for performing their technical diagnostics, as well as the norms and criteria for assessing the quality of drum elements when extending their service life after the equipment resource has been exhausted. The designated service life of water-heating boilers in the event that manufacturing enterprises have not indicated them in the boiler passport is 16 years. Among the boiler equipment, drum separators, which are an extremely important and expensive part of the boiler equipment, should be noted separately. Work on the continuation of the safe operation of a boiler that has reached the established service life is carried out in accordance with the provisions of [1] and includes calculations of the elements' strength. These calculations can be performed using numerical modeling. For example, a mathematical model is presented in [2] to describe the dynamics of the drum level of a boiler with natural circulation. The drum boiler is divided into two parts: the upper one contains saturated steam, while the lower one contains a steam/water mixture. The steam ratio in such a mixture is defined in the mentioned paper as the volumetric steam ratio. At the same time, the balance equations are applied to the drum. The obtained equations are used to model the drum level. The importance of the obtained model is explained by the possibility of direct modeling of the drum level, which is usually calculated in an offline mode using empirical formulas and assumptions. The results of [2] show that an ideal level controller cannot be designed without appropriate modeling, and the safe operation of boilers depends on it. In [3], the authors apply nonlinear modeling methods to evaluate the dynamics of the boiler drum in terms of a nonlinear model, which is one of the important requirements for the development of water level control schemes in the drum. The studies were conducted for a 210 MW boiler.

However, during the operation of a steam boiler, it is very important to evaluate multiple accident scenarios in real-world conditions of the enterprise [4]. We believe that the use of realistic computer codes, such as RELAP5/Mod3.2, will help to understand the thermal-hydraulic behavior of the plant under normal and emergency conditions.

The authors of [5] were studying the long-term low-cycle fatigue of a steam drum of a supercharged boiler. They proposed a simplified calculation method that can be used to calculate the variable stress range of a steam drum of a supercharged boiler. This calculation method (compared to the Chinese standard calculation method) can not only reduce the computational burden, but also significantly simplify the calculation steps.

There is quite little information on the extension of the service life of Soviet-era boiler equipment in foreign literature. Therefore, the closest to the presented paper is the one published by the authors of [6, 7], devoted to the development of a methodology for studying the possibility of further operation of boiler drums of thermal power plants after their equipment resource is exhausted. Based on the method of calculating spatial-three-dimensional thermoelasticity coefficients using finite element analysis, the authors proposed a methodology for computer modeling of deformation processes of a high-pressure boiler drum under different operating modes. The specified methodology will allow to establish the residual operating resource of drums of boiler units of thermal power plants and to outline ways of their more economical operation. It is important to add that the authors of [6, 7] studied the drum of a high-pressure boiler of the TP-100 system of Burshtyn TPP (Fig. 1).

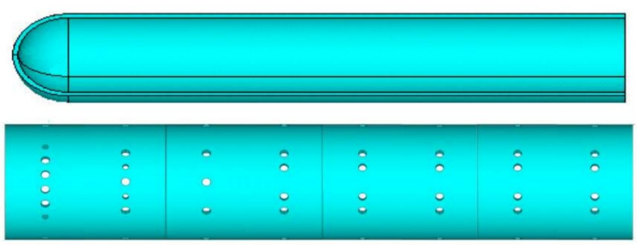

Fig. 1. Geometric model of the high-pressure boiler of the TP-100 thermal power plant system [6]

The most radical method is the replacement of the main separator of steam boilers, but thanks to it, their maximum service life is ensured. The paper [8] is devoted to its study, where the possible technical solutions for the replacement of spent drum boilers are analyzed from a technical and economic point of view. Three options were selected for replacing the separator: a similar drum made of imported WB36 steel; an alternative option with a small drum and a bank of remote cyclones; a drumless option based on a multistage evaporation cycle and a bank of cyclones. The materials currently used in the separators, i.e. 16GNM and 16GNMA, are compared with imported WB36 steel. It was established that each option has its own advantages and disadvantages, which should be analyzed according to the following parameters: mass and overall dimensions; expected need for lifting equipment; hydraulic losses; expected changes in automatic boiler equipment; relative costs associated with design, analysis and risk management.

As evidenced by the study of available literature, it is impossible to come up with a universal methodology for analyzing the damageability and extending the service life of power boiler drums that would be suitable for all types of drums.

Purpose and objectives of the study

The aim of the paper is a computational study of the thermal and stress-strain state of the drum of a water heating boiler of DKVR-10-13 type.

To achieve the set goal, the following tasks were solved:

– development of a fuel tank model and parts of the drum-separator of the boiler of DKVR-10-13 type, which provides for equipping with burners of various configurations;

– development of a model of a slot burner and a burner manufactured using jet-niche technology;

– study of the thermal and stress-strain state of the boiler drum taking into account the effect on the bottom f the drum of flame flares from a slot burner and a burner manufactured using jet-niche technology.

Research objects and features of finite element models

ANSYS strength calculation software allows to solve complex engineering problems and make better and faster design decisions. With the help of finite element analysis (FEA) solvers available in the package, it is possible to configure and automate the solution of structural mechanics problems and parameterize them for the analysis of several design scenarios.

The presented paper is a continuation of research [9], on the basis of which heat flows from incandescent flue gases moving into the DKVR-10-13 boiler fuel tank to the bottom of the drum separator located above the DKVR-10-13 fuel tank were determined (Fig. 2). The finite element mesh of the CFD model of the drum separator is tetrahedral, since the developers of ANSYS [10] recommend using a tetrahedral mesh for modeling the thermal stress state of structures.

The independence of the solution from the density of the computational mesh was achieved by repeatedly calculating the temperature field of the drum depending on the step between the nodes of the computational mesh. The step between the nodes of the mesh was changed until the type and value of the temperature field changed. It was determined that the optimal value of the distance between the nodes of the model mesh (Fig. 2) is 3 mm, since a further decrease in the distance between the nodes while simultaneously increasing the number of finite elements will not lead to a change in the distribution of the temperature field of the drum. Therefore, the maximum number of model nodes reached 200 thousand, which is quite acceptable when using the ANSYS-Student version.

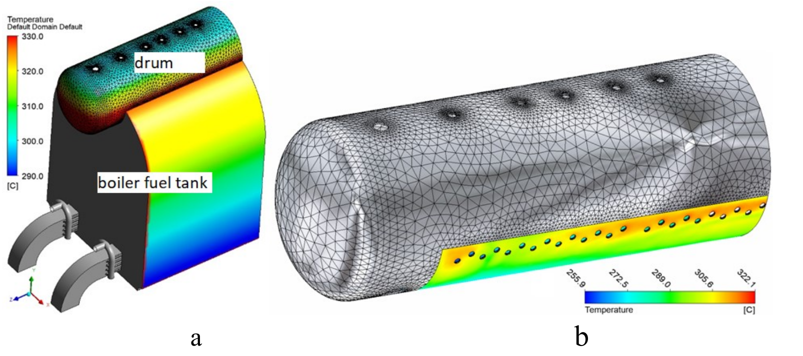

Fig. 2. Temperature field of the DKVR-10-13 boiler drum (a) and finite element mesh of the drum with a display of the temperature field of the drum wall, which is in contact with the incandescent gases moving into the boiler fuel tank (b)

The boundary conditions on the inner surface of the drum were the distribution of the heat transfer coefficient (Fig. 3, a) and temperatures (Fig. 3, b) depending on the circumferential coordinate θ, which were chosen according to the recommendations of [11]. Also, a uniform pressure distribution of 1.4 MPa was set on the inner surface, according to the boiler passport. The outer surface of the drum is thermally insulated. The temperature of the air surrounding the drum is assumed to be 40 °C.

To analyze the thermal and stress-strain state of the drum in this paper, the results of thermal-hydraulic calculations of stabilized combustion without preliminary mixing [9] for two operating modes of the boiler unit - nominal and at 60% capacity were used as starting points. As a result of changing the type of gas distribution in the jet-niche burner, four different temperature fields of the shell structure of the drum, which were selected as the initial data in the Static Structure ANSYS calculation, were obtained.

Temperature distributions (Fig. 4) and local heat flows (Fig. 5) were converted onto the drum wall, which is in contact with the hot gases moving into the boiler fuel tank (Figs. 5, 6).

It should be noted that the temperature field of the drum (Fig. 4) varies within 30 °C, and when gas is distributed through round holes it is more uniform.

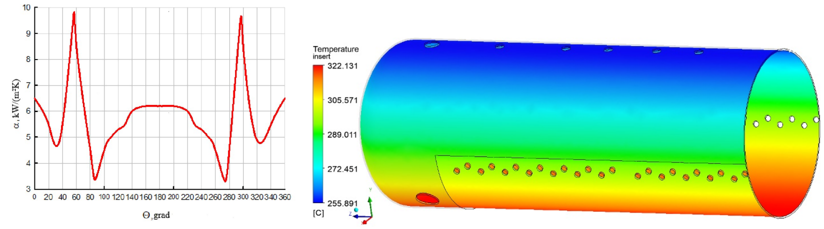

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Fig. 3. Graph of the change in the heat transfer coefficient in the circumferential direction (a) and the temperature of the inner surface of the drum (b)

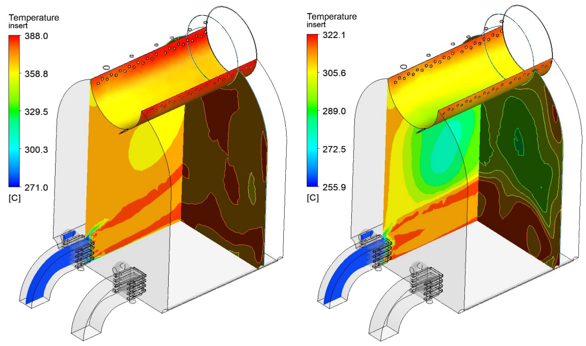

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Fig. 4. Temperature distribution both in the fuel tank volume and on the drum wall in contact with the hot gases at nominal thermal load for the case when fuel is supplied through a series of round holes in a jet-niche burner (a) and when fuel is supplied through rectangular slots (b)

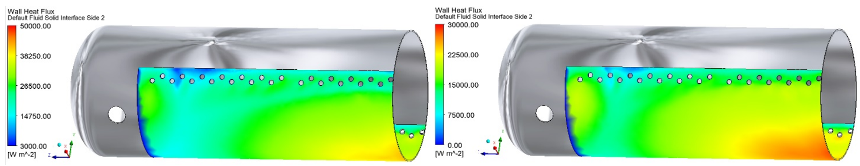

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Fig. 5. Distribution of local heat flows on the drum wall, which is in contact with the incandescent gases moving into the fuel tank of a boiler equipped with jet-niche burners in which fuel is supplied through a series of round holes at nominal thermal load (a) and when operating at 60% capacity (b)

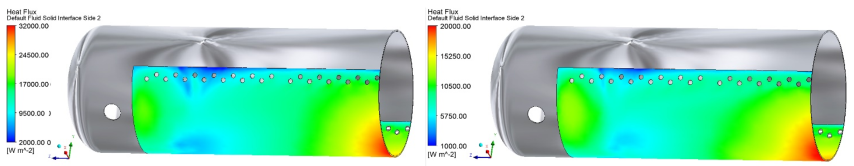

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Fig. 6. Distribution of local heat flows on the drum wall in contact with the hot gases moving into the fuel tank boiler, equipped with jet-niche burners in which fuel is supplied through rectangular slots at nominal heat load (a) and at 60% capacity (b)

The results of ANSYS modeling are given in the form of distributions of the Total deformation parameter and Mises stress. *Total deformation* – is a scalar value of the deformation value along all coordinate axes

$$U_{total} = \sqrt{U_x^2 + U_y^2 + U_z^2}\ .$$

Stress: *equivalent* (*von-Mises*) – a stress value based on the Mises-Hencky theory, also known as the strain energy theory. The theory states that a plastic material begins to fail at points where the Mises stress σ_v becomes equal to the ultimate stress σ_y or greater than it: $\sigma_v \geq \sigma_y$.

The Mises stress is calculated from the principal stress components (the formula is written in the absence of shear stresses) [10]

$$\sqrt{\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]} = \sigma_v\ .$$

Steel grade 12Kh1MF was used to model the drum material.

Results of modeling the stress-strain state of the DKVR-10-13 boiler drum depending on the type of gas distribution in the burner and the level of thermal load on the boiler

The simulation result is presented in Figs. 7–10. As the figures show, the distribution of stress fields is significantly inhomogeneous. Stress concentration occurs on the inner part of the pipe surface at the point of its greatest curvature. The level of stresses arising in the loaded element is within 50–100 MPa, which is significantly lower than the allowable stress ([σ]≤540 MPa for steel 12Kh1MF), at a given temperature.

As can be seen from Figs. 7–10, the distributions of stresses and strains are almost the same, which indicates the absence of a visible effect of the type of gas distribution in the burner on the thermally stressed state of the drum. In all the figures given, the highest stress occurs near the weakening holes with a diameter of 100 mm, which correspond to the downpipes for the lower distribution manifold. The stress reaches only 25 MPa near a row of holes arranged in a checkerboard pattern and which correspond to the side screen pipes. Analyzing the distribution of deformation of the drum walls, we note that due to the action of pressure and heating, the material "bends" between the rows of holes, and, in fact, the area of the drum shell with the rows of holes "bends" into the middle of the drum. Therefore, in this context, a row of these holes can play

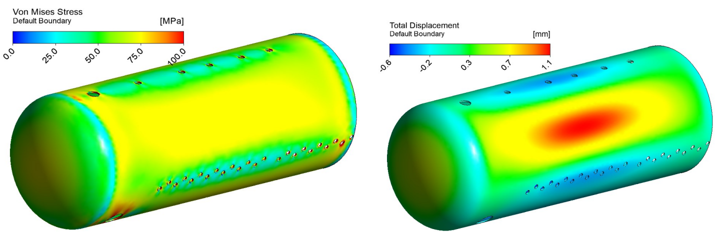

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Fig. 7. Distribution of Mises stress (a) and total deformation of the walls of the drum (b), located above the fuel tank of a boiler equipped with jet-niche burners, in which fuel is supplied through a series of round holes at nominal thermal load

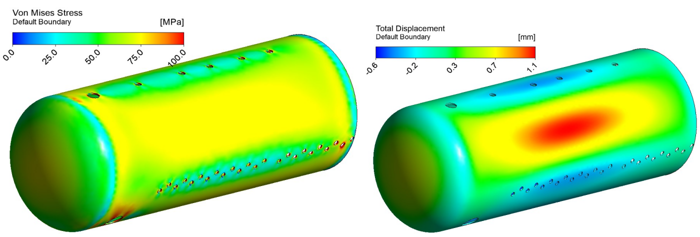

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Fig. 8. Mises stress distribution (a) and total deformation of the walls of a drum (b), located above the fuel tank of a boiler equipped with jet-niche burners, in which fuel is supplied through a series of round holes when operating at 60% capacity

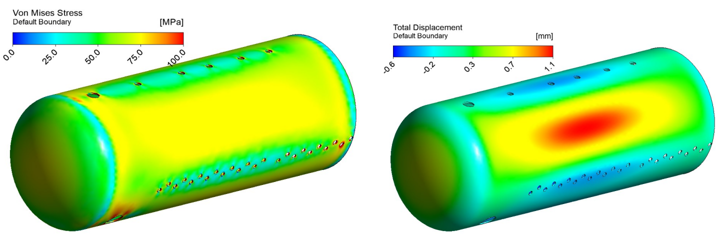

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Fig. 9. Distribution of Mises stress (a) and total deformation of the walls of the drum (b), located above the fuel tank of a boiler equipped with jet-niche burners, in which fuel is supplied through rectangular slots at nominal thermal load

the role of a so-called stiffening edge. However, the maximum deformation of the drum walls at an operating stress of 75 MPa is 1.1 mm, which cannot lead to destruction and rupture of the drum under internal pressure. In confirmation of the above, the deformed state of the drum cross-section due to the action of internal pressure and temperatures is shown in Fig. 11, a. The thick black line corresponds to the real image of the deformation of the boiler drum model. The colored image shows what the deformation of the drum surface will look like if the internal pressure is increased by 200 times. As can be seen in Fig. 11, a, the drum surface "bends" inward at the location of a row of holes. If there is an area of surface bending", then there will also be areas where the wall "bends" – between the rows of holes. At the nominal internal pressure of the coolant in the drum, the maximum deformation is 1.1 mm.

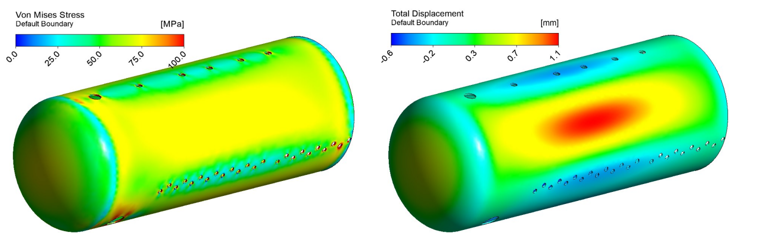

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Fig. 10. Mises stress distribution (a) and total deformation of the walls of the drum (b), located above the fuel tank of a boiler equipped with jet-niche burners, in which fuel is supplied through rectangular slots when operating at 60% capacity

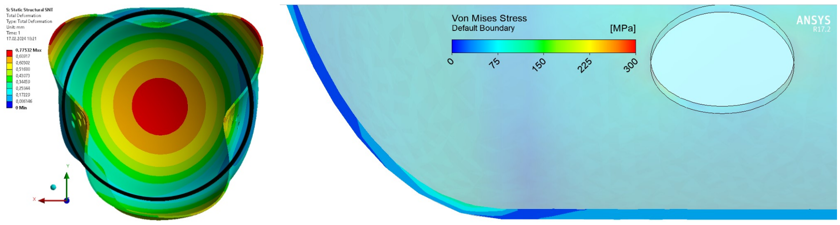

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Fig. 11. Deformed state of the DKVR-10-13 boiler drum with an increase in internal pressure from 1.4 MPa to 280 MPa (a) and the distribution of equivalent Mises stresses in the cross-section of the drum wall (b)

In the longitudinal section of the drum (Fig. 11, b) the most loaded area is the transition of the cylindrical part of the drum shell into the elliptical part. However, at an operating internal pressure of 1.4 MPa, the nominal wall thickness of 10 mm is quite sufficient to ensure the strength of the drum.

Conclusions

1. The temperature field of the drum wall, which is in contact with the incandescent gases moving into the boiler fuel tank, equipped with jet-niche burners, in which the fuel is supplied through rectangular slots, varies in the range of 290–322 °C, and for burners in which the fuel is supplied through a series of round holes – in the range of 358–388 °C. Moreover, when gas is distributed through round holes, the temperature field of the drum wall is more uniform than in the case of fuel supply through rectangular slots. This indicates more favorable conditions for ensuring the drum strength.

2. The type of gas distribution affects the level of heat fluxes from the hot gases moving into the boiler fuel tank. The heat flux over the fuel tank equipped with jet-niche burners, in which the fuel is supplied through rectangular slots, at the nominal heat load is 36% lower than for the case of gas distribution through round holes. For the case of 60% heat load, fuel supply through rectangular slots reduces the heat flux over the fuel tank by 32%, compared to the case of gas distribution through round holes.

3. There is no visible effect of the type of gas distribution in the burner on the thermally stressed state of the boiler drum.

4. The highest stress occurs near the 100 mm diameter weakening holes, corresponding to the downpipes from the drum to the lower distribution manifold. Near a series of staggered holes, corresponding to the side screen pipes, the stress reaches only 25 MPa.

5. Modeling deformation when increasing internal pressure by 200 times allows predicting the shape of a destroyed drum and determining the location of destructive cracks on the drum surface.

6. The calculation shows that the nominal wall thickness of 10 mm for the drum of the DKVR-10-13 boiler, both at nominal and at 60% thermal load, is quite sufficient to ensure the strength of the drum.

References

1. (2009). SOU 40.1-21677681-02:2009 *Poriadok prodovzhennia terminu ekspluatatsii barabaniv kotliv vysokoho tysku* [Procedure for extending the service life of high-pressure boiler drums]: Instruction: regulatory document of the Ministry of Fuel and Energy of Ukraine. Kyiv: Ministry of Fuel and Energy of Ukraine, Association of Energy Enterprises "Industrial Reserve and Investment Fund for the Development of Energy", 10 p. (in Ukrainian).
2. Tawfeic, S. R. (2013). Boiler drum-level modeling. *Journal of Engineering Sciences*, vol. 41, no. 5, pp. 1812–1829. https://doi.org/10.21608/jesaun.2013.114911.
3. Sumalatha, A., Sudha Rani, K., & Jayalakshmi, Ch. (2023). Dynamic modeling of boiler drum using nonlinear system identification approach. *Measurement: Sensors*, vol. 28 (9), article 100845. https://doi.org/10.1016/j.measen.2023.100845.
4. Deghal Cheridi, A. L., Dadda, A., Bouam, A., & Dahia, A. (2022). Transient simulation of an industrial steam boiler. *Algerian Journal of Signals and Systems*, vol. 7, no. 2, pp. 77–83. https://doi.org/10.51485/ajss.v7i2.164.
5. Zheng, X. W., Li, Z., Chen, X. H., Sun, Y., Wang, H., & Wen, X. Y. (2011). Stress problems at the steam drum fatigue checking point of a supercharged boiler. *Advanced Materials Research*, vol. 383–390, pp. 7682–7690. https://doi.org/10.4028/www.scientific.net/AMR.383-390.7682.
6. Drobenko, B., Budz, S., Kuzo, I., Sholovii, Yu.,& Budz, I. (2022). *Vplyv nakopychuvanoi poshkodzhuvanosti na ekspluatatsiinyi resurs barabana kotloahrehata teploelektrostantsii* [The influence of accumulated damage on the operational resource of the drum of the boiler unit of a thermal power plant]. *ISTCIPA*, iss. 56, pp. 19–26 (in Ukrainian). https://doi.org/10.23939/istcipa2022.56.019.
7. Budz, S. & Budz, I. (2023). *Otsinka ekspluatatsiinoho resursu barabana kotloahrehatu enerhobloku TES, poshkodzhenoho pry yoho ekspluatatsii* [Assessment of the operational life of the drum of the boiler unit of the TPP power unit damaged during its operation]. *Fizyko-matematychne modeliuvannia ta informatsiini tekhnolohii – Physico-Mathematical Modelling And Informational Technologies*, no. 38, pp. 5–10 (in Ukrainian). https://doi.org/10.15407/fmmit2023.38.005.
8. Okhlopkov, A. V., Popov, N. V., Moiseev, D. O., & Bitney, V. D. (2023). Technical solutions for selecting an option for replacing overaged boiler steam drums. *iPolytech Journal*, vol. 27 (1), pp. 147–160. https://doi.org/10.21285/1814-3520-2023-1-147-160.
9. Chernousenko, O. Yu., Rachynskyi, A. Yu., Baraniuk, O. V., & Siryi, O. A. (2024). CFD simulation of the influence of the type of gas distribution in the burners on thermal aerodynamic processes in the DKVR 10-13 boiler. *Journal of Mechanical Engineering – Problemy Mashynobuduvannia*, vol. 27, no. 3, pp. 16–24. https://doi.org/10.15407/pmach2024.03.016.
10. (2012). ANSYS FLUENT 14.5 Theory Guide. ANSYS Help. ANSYS Inc. https://ansyshelp.ansys.com.
11. (2014). *Teplovyi i termonapruzhenyi stan barabanu kotla TP-100 na riznykh rezhymakh roboty* [Thermal and thermal stress state of the drum of the TP-100 boiler at different operating modes]: research report (final) by Holoshchapov, V. M. (supervisor). Kyiv: Publishing House "Akademperiodika" NAS of Ukraine, 29 p. (in Ukrainian).

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CFD-модель теплового і термонапруженого стану барабану котла ДКВР-10-13

[1] О. Ю. Черноусенко, [1] А. Ю. Рачинський, [1, 2] О. В. Баранюк

[1] Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського»
03056, Україна, м. Київ, пр. Берестейський, 37

[2] Інститут теплоенергетичних технологій НАН України
04070, Україна, м. Київ, вул. Андріївська, 19

Актуальність роботи підтверджується наявністю проблем, які виникають при експлуатації барабанів енергетичних котлів. Внаслідок впливу високого тиску, підвищеної температури, циклічних навантажень і корозійно-активного середовища можуть виникати різні дефекти і пошкодження, такі, як тріщини, втомні руйнування, корозія та інші. Це у змозі спричинити аварії та навіть призвести до катастрофічних руйнувань, які загрожують безпеці й ефективності роботи котельних агрегатів. З огляду на це для забезпечення безпеки й надійності роботи обладнання важливо проводити регулярні інспекції, технічне обслуговування й ремонт. Роботи з продов-

ження терміну безпечної експлуатації котла, який відпрацював призначений строк служби, здійснюються відповідно до затверджених в Україні положень СОУ 40.1-21677681-02:2009 які рекомендують проводити розрахунки на міцність елементів котельних агрегатів і які можна виконати засобами сучасних CFD-методів обчислювальної гідродинаміки (Computation Fluid Dynamics). Представлена робота присвячена CFD-моделюванню терамонапруженго стану барабан-сепаратора, встановленого над паливнею котла типу ДКВР-10-13, яка оснащена пальниками, що працюють за допомогою струменево-нішевої технології. Пальники відрізнялися типом подачі палива. До одного з пальників паливо подається крізь прямокутні щілини, до іншого – через розташовані в ряд круглі отвори. Повітря в обидва пальники подається через прямокутні щілини. Дослідження виконувалося для двох режимів роботи котельного агрегату – номінального і на 60% потужності за допомогою чисельних методів при використанні пакета прикладних програм ANSYS-Fluent. Об'єктом дослідження є барабан котла типу ДКВР-10-13 з усіма ослаблюючими отворами. Предметом дослідження є процеси термічної міцності оболонкової конструкції, яка притаманна барабану котла, внаслідок впливу тиску, температури і теплового потоку від розжарених газів, що рухаються в паливні котла, оснащеної струменево-нішевими пальниками при номінальному й 60 %-му тепловому навантаженні. Визначено, що паспортної товщини стінки 10 мм для барабана котла ДКВР-10-13 як при номінальному, так і при 60% тепловому навантаженнях цілком достатньо, щоб забезпечити міцність барабану, оскільки різниця між найбільшою і найменшою температурою на поверхні барабана знаходиться в межах 30 °С. Причому при газороздачі крізь круглі отвори температурне поле стінки барабана є більш рівномірним, ніж у випадку подачі палива крізь прямокутні щілини. Максимальне еквівалентне напруження по Мізесу, що виникає між рядами отворів на барабані, досягає 75 МПа. Також визначено, що максимальна деформація стінок барабана становила 1,1 мм, що не зможе призвести до руйнації і розриву барабана під внутрішнім тиском.

***Ключові слова**: газороздача, струменево-нішева технологія, ANSYS-Fluent, термічні напруження, газоподібне паливо, горіння, метан, паливня котла.*

Література

1. СОУ 40.1-21677681-02:2009 Порядок продовження терміну експлуатації барабанів котлів високого тиску. Інструкція: нормативний документ Мінпаливенерго України. Київ: Міністерство палива та енергетики України, Об'єднання енергетичних підприємств «Галузевий резервно-інвестиційний фонд розвитку енергетики», 2009. 10 с.
2. Tawfeic S. R. Boiler drum-level modeling. Journal of Engineering Sciences. 2013. Vol. 41. No. 5. P. 1812–1829. https://doi.org/10.21608/jesaun.2013.114911.
3. Sumalatha A., Sudha Rani K., Jayalakshmi Ch. Dynamic modeling of boiler drum using nonlinear system identification approach. Measurement: Sensors. 2023. Vol. 28 (9). Article 100845. https://doi.org/10.1016/j.measen.2023.100845.
4. Deghal Cheridi A. L., Dadda A., Bouam A., Dahia A. Transient simulation of an industrial steam boiler. Algerian Journal of Signals and Systems. 2022. Vol. 7. No. 2. P. 77–83. https://doi.org/10.51485/ajss.v7i2.164.
5. Zheng X. W., Li Z., Chen X. H., Sun Y., Wang H., Wen X. Y. Stress problems at the steam drum fatigue checking point of a supercharged boiler. Advanced Materials Research. 2011. Vol. 383–390. P. 7682–7690. https://doi.org/10.4028/www.scientific.net/AMR.383-390.7682.
6. Дробенко Б., Будз С., Кузьо І., Шоловій Ю., Будз І. Вплив накопичуваної пошкоджуваності на експлуатаційний ресурс барабана котлоагрегата теплоелектростанції. ISTCIPA. 2022. Вип. 56. С. 19–26. https://doi.org/10.23939/istcipa2022.56.019.
7. Будз С., Будз І. Оцінка експлуатаційного ресурсу барабана котлоагрегату енергоблоку ТЕС, пошкодженого при його експлуатації. Фізико-математичне моделювання та інформаційні технології. 2023. Вип. 38. С. 5–10. https://doi.org/10.15407/fmmit2023.38.005.
8. Okhlopkov A. V., Popov N. V., Moiseev D. O., Bitney V. D. Technical solutions for selecting an option for replacing overaged boiler steam drums. iPolytech Journal. 2023. Vol. 27 (1). P. 147–160. https://doi.org/10.21285/1814-3520-2023-1-147-160.
9. Chernousenko O. Yu., Rachynskyi A. Yu., Baraniuk O. V., Siryi O. A. CFD simulation of the influence of the type of gas distribution in the burners on thermal aerodynamic processes in the DKVR 10-13 boiler. Journal of Mechanical Engineering – Problemy Mashynobuduvannia. 2024. Vol. 27. No. 3. P. 16–24. https://doi.org/10.15407/pmach2024.03.016.
10. ANSYS FLUENT 14.5 Theory Guide. ANSYS Help. ANSYS Inc., 2012. https://ansyshelp.ansys.com.
11. Тепловий і термонапружений стан барабану котла ТП-100 на різних режимах роботи: звіт про НДР (заключний) / кер. В. М. Голощапов. Київ: ВД «Академперіодика» НАН України, 2014. 29 с.