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CONTENTS

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Oleksandr Gorbenko,
Hryhorii Lapenko,
Taras Lapenko,
Samson Kolotii

DETERMINATION ON ENERGY EFFICIENCY IN CORN GRAIN DRYING

The object of research is the technological processes of corn grain drying, energy plants. One of the most problematic areas for agricultural producers is providing energy for technological processes of bringing grain material to the indicators of product sales. And during the war and post-war period in Ukraine, this requires non-standard approaches and ways of implementation. Therefore, for operation in autonomous mode, the technology involves the use of biomass, electricity from solar panels and/or a diesel generator to supply the coolant to the grain drying zone. The availability of biomass is ensured by cleaning grain material after harvesting and crop residues.

The study examined the technology of corn grain drying in "Agrotechservice" LLC of the Poltava district of the Poltava region (Ukraine) using the Saphir 2134 modular grain dryer with an improved biomass boiler.

The results of studies of the operation of a grain dryer using different types of fuel (gas, diesel fuel, alternative fuel) showed that the energy consumption for reducing humidity by 1 ton-percent was: for gas – 1.5 m^3; for diesel fuel – 1.8 l; for biomass – 3.4 kg. The total cost of drying on a Saphir 2134 grain dryer was obtained, which is 0.205 USD, which is 3.7 times less than when using natural gas and 9.2 times less than when using diesel fuel. This is due to the fact that the proposed technology involves the use of an improved biomass boiler and alternative energy sources. This provides the possibility of obtaining average daily savings using a grain dryer of this model with an improved biomass boiler, which will be about 1.1 thousand USD. Compared to similar corn grain drying processes, these studies have shown the economic feasibility of using biomass as an energy material for the production of thermal energy in the corn grain drying process.

Keywords: *corn grain drying, biomass, grain dryer, energy efficiency, biofuel boiler, alternative energy sources.*

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1. Introduction

Agriculture, in particular the grain industry, is one of the key sectors of the economy of many countries around the world. However, military operations in Ukraine have significantly affected the ability of the agricultural sector to function effectively due to the destruction of energy infrastructure, instability of fuel and electricity supplies, as well as problems with logistics. As a result, many enterprises face difficulties in ensuring the technological processes of post-harvest processing, drying, storage and preparation of grain for sale.

Additional challenges facing agricultural producers today:
– shortage and high cost of energy resources – caused by the destruction of power plants and energy supply systems, interruptions in the supply of gas and diesel fuel;
– dependence on centralized energy sources – agricultural producers are forced to look for alternative solutions due to the unreliability of traditional energy supply systems;
– the need to modernize grain processing enterprises – many elevators and granaries operate using outdated technologies that require significant energy costs;
– problems with logistics and exports – due to the destruction of transport infrastructure and the blocking of ports, the conditions for exporting grain are complicated, which forces the products to be stored longer, requiring additional resources for drying and maintaining quality.

Thus, possible ways to solve issues related to energy efficiency and energy independence of agricultural enterprises are the introduction of alternative energy sources, optimization of energy consumption, state support, development of local logistics and storage.

For the introduction of alternative energy sources, the optimal use of biomass-based installations is; the use of solar panels and wind energy systems to ensure autonomy; the use of combined technologies (solar + diesel generation) and biomass for the uninterrupted operation of enterprises.

To optimize energy consumption, it is necessary to switch to energy-efficient drying installations running on alternative fuels (pellets, wood chips, biomass) [1]. It is also advisable to use heat recovery technologies to reduce energy costs [2] and establish automation and digitalization of processes to increase the efficiency of energy consumption management [3].

Therefore, in the conditions of war and post-war conditions, the problem of energy supply to the agricultural sector of Ukraine is critical for the country's food security and economic stability. The introduction of non-standard approaches, such as the transition to renewable energy sources, modernization of technologies and the development of autonomous energy supply systems, will allow not only to overcome current challenges, but also to form a more stable and independent agro-industrial system for the future.

An analysis of literary sources indicates that scientists pay significant attention to increasing the energy efficiency of the corn grain drying process. In particular, in work [2], the authors investigated the effect of preheating corn cobs on drying efficiency. It was found that heating at a temperature of 50 °C for 6 hours allows to reduce the drying time

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by 7 hours, increase the moisture release rate by 10.9 % and increase the dryer productivity by 22.5 %. At the same time, the seed quality remains at a high level.

Studies [4] on parallel blowing of drying chambers showed that the use of this technology improves the filtration of the drying agent through the ear pile, increases the drying rate and increases the chamber productivity by 14.8 % compared to sequential blowing. This approach also has a positive effect on the quality of seeds, in particular on their germination and growth strength.

The introduction of differentiated temperature regimes, which include a gradual increase in the temperature of the drying agent depending on the grain moisture, allows to increase the average drying temperature by 2–3 °C without deteriorating the quality of the seeds. This ensures an increase in the productivity of the dryer.

It should be noted that the use of recycling of the spent drying agent [5] allows to improve the potential rate of improvement of the drying process without losing the quality of the seeds. This method involves increasing the energy efficiency of the process. In work [6], a sensitivity analysis of the input parameters of the drying process model, including different fractions of recycling, was performed, and their impact on the quality of the dried product was analyzed. The authors in work [7] investigated that using condensation in the drying of corn grain increases the drying efficiency by 32–56 % due to energy savings compared to conventional hot air drying.

The authors [8, 9] in their works focus on the use of renewable energy sources, such as solar collectors, wind power plants and heat pumps, to reduce dependence on traditional fuel resources in the grain drying process. This contributes to increasing energy efficiency and reducing energy costs.

A study published by the Bioenergy Association of Ukraine [10] considers the possibility of using corn residues as fuel for heat generators that provide heating and drying of grain. This approach allows for the effective utilization of agricultural waste and reduces costs for traditional energy carriers.

To obtain comparative results of different types of grain dryers in terms of their energy efficiency, the authors [11] conducted relevant studies. Thus, it was found that the drying efficiency for a mixed-flow dryer was lower (12 %), compared to a convection dryer (57 %). In this case, the use of pre-treatment provides for a reduction in energy consumption, an increase in drying efficiency and high quality of the resulting grain.

An important element is compliance with the appropriate drying temperature regime, which affects the quality of the resulting grain [12]. Exceeding permissible temperatures can lead to the formation of microcracks, reduced seed germination and loss of nutrients. On the contrary, insufficient heating prolongs the drying process, increases the risk of mold and mycotoxin development, which negatively affects the safety of the grain. To intensify low-temperature drying, it is possible to use short-term heating to 800 °C and use a heat pump [13]. This allows preserving the properties of grain seeds at the level of 99–100 %.

However, the considered works did not investigate the complex impact of using alternative energy sources in dryers and their impact on the energy efficiency of the drying process of grain of agricultural crops.

Thus, increasing the energy efficiency of the drying process of corn grain is possible through the implementation of complex measures, such as optimizing technological modes, upgrading equipment and using alternative energy sources. The application of these approaches will contribute to reducing energy consumption and ensuring high quality of the final product.

The aim of the research is to increase the energy efficiency and economic feasibility of the technological process of corn grain drying in autonomous operation, using alternative energy sources, in particular biomass, compared to traditional energy carriers, using the example of the Saphir 2134 modular grain dryer.

2. Materials and Methods

The object of research is the technological processes of corn grain drying, energy plants.

The subject of research is the interaction of the coolant with corn seeds, the influence of the parameters and operating modes of the dryer on the process indicators.

The scientific hypothesis is the existence of technical and technological solutions, the implementation of which will allow corn grain drying with a high level of energy efficiency.

The research of the drying process indicators was carried out based on the results of experimental studies on the Saphir 2134 grain dryer in the conditions of "Agrotechservice" LLC, Poltava region, Ukraine. The grain dryer was located in a special hangar. The process of supplying the coolant by fans to the perforated walls of the grain columns was stable and uniform. The coolant with the appropriate temperature was formed in a biofuel boiler unit [14].

To control the drying parameters in the Saphir 2134 grain dryer, humidity and temperature sensors are installed, which provide continuous monitoring of the process. The SMART LOOP humidity control system allows to accurately determine the level of grain moisture at the outlet, which allows to avoid both overdrying and underdrying of products. RTD temperature sensors located in different zones of the drying chamber provide high-precision temperature control with an accuracy of one degree Celsius. This level of automation helps optimize the drying process, increase energy efficiency and the quality of finished products. The electronic components in the grain dryer are manufactured by Schneider Electric (France).

To substantiate the economic efficiency of the corn grain drying process, the cost of a ton-percentage was used for drying one ton of grain by 1 %. A ton-percentage is a specific value in the grain elevator industry and is used to determine the cost of services or fuel consumption (gas, diesel fuel, biomass) for drying or cleaning grain. Accordingly, the value UAH/ton-percentage was used to determine the cost, and the value m^3/ton-percentage was used for the consumption of natural gas for drying one ton of grain by 1 %.

3. Results and Discussion

To ensure the autonomy and continuity of the technological process of grain drying for "Agrotechservice" LLC a technological process was proposed and implemented, which involves the use of alternative energy sources, the scheme of which is presented in Fig. 1.

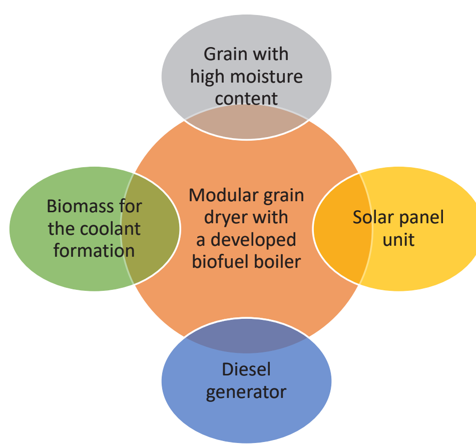


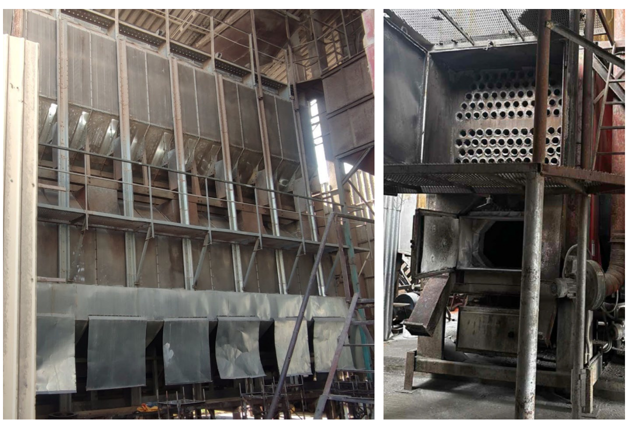
Fig. 1. Schematic of the technological process of grain drying of agricultural crops using alternative energy sources

Biomass (residues of corn stalks, sunflower, straw, chopped wood) for forming the coolant is stored in a special room (Fig. 2) and fed by a conveyor to a special bunker, from which it is fed by screws into the combustion chamber of the biofuel boiler. The screw pitch and its rotation frequency provide the necessary supply of biomass.

Fig. 2. Biomass storage room

The combustion chamber of the boiler (Fig. 3, *a*) is made of AISI 310S steel with a thickness of 10 mm, ensuring reliable operation of the grain dryer and extended service life. The boiler operation process is configured in such a way that when biomass is fed into the combustion chamber, air is supplied from the environment by appropriate fans. In parallel, another fan is turned on to remove smoky air to ensure traction and stable combustion of biomass. To improve the efficiency of the grain drying process, air is supplied to the grain cooling zone through special channels to the fan for heating and then to the grain drying zone.

The Saphir 2134 grain drying unit (Fig. 3, *b*) implements the "cross flow" grain drying technology, which involves blowing heated air perpendicular to the grain movement.



a *b*

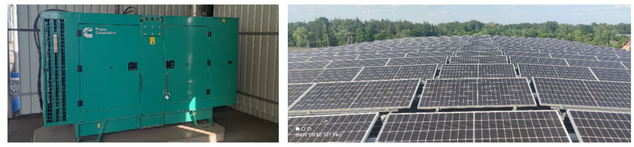
Fig. 3. General view of the elements of the grain dryer: *a* – Saphir 2134 grain drier; *b* – biofuel boiler for forming the coolant [14]

The technological process of grain drying is as follows. Grain is fed into the upper part of the grain dryer by means of a loading device, where the screw loads the columns in turn with a uniform distribution along the entire length. At the same time, the fans pump heated air into the drying chamber, removing heat from the pipe elements. Then, the heated air under the pressure of the fans is blown through the perforated walls of the grain columns, heating the grain and causing the evaporation of moisture from its surface.

Effective air mixing with effective biomass combustion ensures uniform temperature of the heated air at all points of the grain dryer.

In the absence of gas and electricity supply to the farm, the grain dryer will perform the technological process of grain drying in an autonomous mode, using a diesel generator (Fig. 4, *a*) and a solar battery unit (Fig. 4, *b*).

Given the experience of operating grain dryers, in further calculations it is necessary to take into account that the actual fuel consumption, as a rule, is from 1/2 to 2/3 of the maximum consumption declared by the manufacturers. This is explained by the fact that in the technical characteristics, manufacturers indicate fuel consumption for the mode when the burners operate at maximum power continuously for one hour. However, in real conditions of grain drying, the burners automatically switch between the "large" and "small" fire modes under the control of the control system, which maintains the required drying temperature.



a *b*

Fig. 4. General view of the elements that ensure the autonomy of the grain dryer, which are used in the process of corn grain drying at "Agrotechservice" LLC of the Poltava region: *a* – diesel generator; *b* – solar battery block

The results show that when the moisture content is reduced from the initial 21 % to the conditioned 13.5 % at a temperature of 65 °C for 23 hours, 295 tons were dried. The productivity of the Saphir 2134 grain dryer in the conditions of "Agrotechservice" LLC for corn, with a decrease in humidity by 7.5 % in the grain heating mode, was 12.83 t/h. The number of dried ton-percentages per hour was: 12.83 t/h×7.5 % = 96.2 t/%, and the total number of ton-percentages as a result of the experiment was 2212 t/%, while 7520 kg of biomass was consumed. To assess economic efficiency, it is possible to calculate the biomass consumption per 1 t/%, for this let's divide the amount of biomass consumed by the number of ton/percentages: 7520 kg/2212 t/% = = 3.4 kg/1 t/%.

Based on the fact that to reduce humidity by 1 t/%, it is necessary to spend 3.4 kg of fuel, it is possible to calculate the cost of biomass per 1 t/%, for this it is possible to multiply the cost of one kilogram of biomass by the amount of biomass required to reduce humidity by 1 t/%:2.5 USD·3.4 kg = 8.5 USD.

Organoleptic assessment of grain after drying using the proposed technology showed the preservation of the main quality characteristics that are essential for further storage and processing. Corn grain did not lose its natural color, remained uniform in shape and structure, without signs of overdrying, blackening or damage. Also, no foreign odors were observed that could indicate overheating or burning of biomass during drying, which confirms the stability of the heat supply mode. Taste characteristics (when determined within the framework of laboratory analysis) remained unchanged, without bitterness or other deviations that could arise from the destruction of organic substances. Thus, it can be stated that the use of an improved biomass boiler in conditions of autonomous energy supply provides not only economic efficiency, but also allows maintaining a high level of grain quality.

To compare the efficiency of the technological process of corn grain drying, "Agrotechservice" LLC conducted studies on the operation of the grain dryer on different types of fuel, the results of which are given in Table 1.

The results of the economic efficiency of corn drying using different types of fuel are presented in Table 2.

Analysis of the research results showed that to reduce the moisture content during grain drying in the conditions of "Agrotechservice" LLC by 1 ton-percent at a cost of 3.4 kg of biomass, the total cost of drying on the Saphir 2134 grain dryer is 0.205 USD, which is 3.7 times less than when using natural gas and 9.2 times less than when using diesel fuel.

The graph of the dependence of specific costs and cost of corn grain drying is shown in Fig. 5, and the cost of corn grain drying on different types of fuel is shown in Fig. 6.

The results indicate that natural gas has the lowest specific costs, which indicates its effective use, and biomass requires the rawest materials for drying 1 ton of grain. However, biomass provides the lowest drying cost per 1 ton/% – it is almost 4 times cheaper than natural gas and 9 times cheaper than diesel fuel.

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Table 1

Results of research on corn grain drying using different types of fuel

Indicators	Indicator value		
	Natural gas	Diesel fuel	Biomass
Fuel used, m^3/l/kg	3864	1872	7520
Moisture content of corn before drying, %	22	22	21
Moisture content of corn after drying, %	14	14	13,5
Grain temperature, °C	80	80	65
Drying time, h	23	10	23
Dried ton-percentage, t/%	2576	1040	2212
Dried, t	322	130	295

Table 2

Results of comparative studies of corn grain drying using different types of fuel at "Agrotechservice" LLC

Indicators	Indicator value		
	Natural gas	Diesel fuel	Biomass
Fuel consumption per 1 ton-percent, m^3/l/kg	1.5	1.8	3.4
Fuel cost, USD	0.5067	1.052	0.060
Drying cost per 1 ton-percent, USD	0.759	1.894	0.205
Drying cost per 1 t, USD	7.597	18.937	2.052

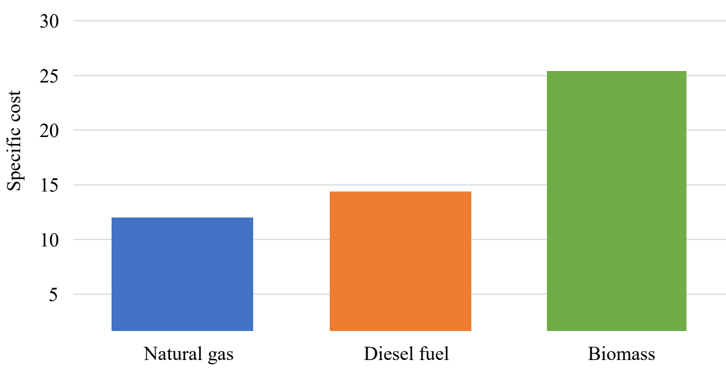

Fig. 5. Graph of dependence of specific fuel consumption when drying 1 ton of corn grain on different types of fuel

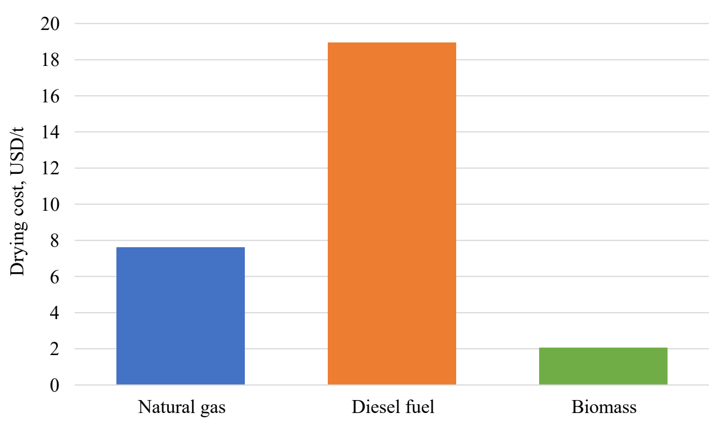

Fig. 6. Graph of dependence of cost of corn grain drying on different types of fuel in conditions of "Agrotechservice" LLC

It can be argued that natural gas is the most efficient, as it requires the least fuel to reduce moisture by 1 %. Diesel fuel has slightly higher costs, which makes it less attractive for drying. Biomass has the highest specific costs, which confirms its lower energy efficiency, but has the lowest cost.

As stated in [15], depending on the needs of the farm and the characteristics of the crop, the use of mobile dryers is the best solution for grain drying. However, the weather conditions of a particular year should be taken into account. For example, in 2022, in the conditions of "Agrotechservice" LLC, in order to lay grain for long-term storage, it was necessary to dry 50 % of early cereals, 70 % of sunflower, and 100 % of corn, which is impossible to do with mobile grain dryers. Therefore, the option of using the Saphir 2134 grain dryer with a biomass boiler is a more optimal and economically profitable option.

Thus, if there is a stable supply and storage of biomass, then it is the optimal option for use as an energy carrier for grain dryers, and the proposed option of a biomass boiler ensures the reliability and resource efficiency of the technological process.

The results obtained during the research were applied in practice at "Agrotechservice" LLC in the city of Reshetylivka, Poltava region during 2022–2024. The Saphir 2134 grain dryer with a biomass boiler provided drying of wheat, sunflower and corn harvested in the fields of the farm. The scope of application of this technology is not limited to a specific farm, the materials for the boiler design are patented and can be implemented in other farms.

Partial restrictions on the use of research results are associated with a certain level of smoke during biomass combustion in the boiler. However, these processes do not affect the quality of the resulting products. Therefore, additional research is being conducted to develop a gas emission cleaning system to improve the environmental performance of the boiler.

The introduction of martial law in Ukraine became the main factor in the development of a biomass boiler for grain drying and improving the technological process by ensuring its autonomy. And the biomass used as a heat source during drying solved the problem of energy supply interruptions.

4. Conclusions

An autonomous technological process of grain dryer operation using alternative energy sources is presented, which is relevant during periods of interruption of energy supply.

It was established that the decrease in humidity during grain drying in the conditions of "Agrotechservice" LLC by 1 ton-percent at a consumption of 3.4 kg of biomass, the total cost of drying on the Saphir 2134 grain dryer is 0.205 USD.

It is noted that natural gas has the lowest specific costs, and biomass requires the rawest materials for drying 1 ton of grain. However, biomass provides the lowest cost of drying per 1 t/% – it is almost 4 times cheaper than natural gas and 9 times cheaper than diesel fuel.

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Conflict of interest

The authors declare that they have no conflict of interest regarding this study, including financial, personal, authorship or other, that could influence the study and its results presented in this article.

Financing

The study was conducted without financial support.

Data availability

Data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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✉***Oleksandr Gorbenko,*** *PhD, Associate Professor, Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University, Poltava, Ukraine, e-mail: oleksandr.gorbenko@pdau.edu.ua, ORCID: https://orcid.org/0000-0003-2473-0801*

Hryhorii Lapenko, *PhD, Associate Professor, Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University, Poltava, Ukraine, ORCID: https://orcid.org/0000-0003-1435-5307*

Taras Lapenko, *PhD, Associate Professor, Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University, Poltava, Ukraine, ORCID: https://orcid.org/0000-0001-8055-6698*

Samson Kolotii, *Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University, Poltava, Ukraine, ORCID: https://orcid.org/0009-0002-1768-3111*

✉*Corresponding author*

ABSTRACTS AND REFERENCES

MECHANICAL ENGINEERING TECHNOLOGY

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DEVELOPMENT OF A METHODOLOGY FOR CALCULATING THE WORKING PROCESS OF THE ROTARY WORKING BODY OF MACHINES FOR EARTHWORKS AND ROAD WORKS

pages 6–12

Oleksandr Holubchenko, *PhD, Associate Professor, Department of Construction and Road Machinery, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0003-2971-1263*

Serhii Karpushyn, *PhD, Associate Professor, Department of Construction, Road Machinery and Construction, Central Ukrainian National Technical University, Kropyvnytskyi, Ukraine, e-mail: karp22.05.1972ksa@gmail.com, ORCID: https://orcid.org/0000-0001-9035-9065*

Roman Krol, *PhD, Associate Professor, Department of Construction and Road Machinery, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-7180-663X*

Volodymyr Panteleenko, *PhD, Associate Professor, Department of Construction and Road Machinery, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0001-5651-8616*

Andrii Chervonoshtan, *PhD Student, Department of Vehicle Operation and Maintenance, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0003-3458-0034*

The object of this research is the working process of high-speed separation of soil mass elements by the cutting elements of a rotor. The existing problem is that soil cutting by the rotor occurs during the translational movement of the base machine. This creates a complex trajectory of the cutting edge and leads to continuous changes in chip thickness. Considering the trajectory of the cutting edges and the function of chip thickness variation allows for a more accurate assessment of the energy characteristics of the rotor drive.

Key parameters, such as the torque on the drive shaft, drive power, and energy consumption, were analyzed as functions of the working body's geometry, rotational speed, base machine velocity, and soil properties. The obtained mathematical models account for the actual trajectories of the cutting elements and changes in soil cutting thickness. Additionally, the interaction conditions with the surrounding environment and the physical and mechanical properties of the soil were considered. A methodology for engineering calculation and optimization of the rotary working body's parameters was developed. It considers the rotor's design, size, interaction conditions, and environmental factors. Analysis of the working process of a rotary working body with specified parameters and soil properties led to the following conclusions:

– The power consumption for the drive and the energy intensity of the process in direct and reverse soil cutting are practically equal. The differences do not exceed 5 %.

– In reverse operation, the average horizontal component of soil cutting resistance increases by 1.15–1.25 times compared to direct cutting. However, the resistance force vector is directed toward the working body's movement, reducing the required traction force of the base machine.

– The average value of the vertical component of cutting resistance in reverse operation is 2.0–2.5 times lower than in direct cutting. This reduces the effort required to deepen the working body or adjust the soil development depth.

This study will be useful for machine-building enterprises specializing in the design and manufacture of earthmoving and road construction machines, particularly those with an active rotary working body.

Keywords: rotary working body, cutting trajectory, cutting knives, cutting thickness, absolute speed, energy consumption.

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METALLURGICAL TECHNOLOGY

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PERTURBATION OF THE FIRST FORM OF OSCILLATIONS OF LIQUID METALLURGICAL SLAG IN THE SLAG CAR BOWL IN TRANSIENT OPERATING MODES

pages 13–18

Viktor Povorotnii, *PhD, Department of Industrial Mechanical Engineering, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, e-mail: vicktorpovar@gmail.com, ORCID: https://orcid.org/0009-0000-9128-902X*

Oleksandr Yaichuk, *PhD Student, Department of Industrial Mechanical Engineering, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0009-0009-4034-4266*

Nataliia Karyachenko, *PhD, Associate Professor, Department of Technical Mechanics, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-3396-7221*

Iryna Shcherbyna, *PhD, Associate Professor, Department of Higher Mathematics, Physics and General Engineering Disciplines, Dnipro State Agrarian and Economic University, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0003-3968-4326*

Serhii Zdanevych, *PhD, Associate Professor, Department of Higher Mathematics, Physics and General Engineering Disciplines, Dnipro State Agrarian and Economic University, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0001-8594-3806*

Rodion Pohrebniak, *PhD, Associate Professor, Department of Higher Mathematics, Physics and General Engineering Disciplines, Dnipro State Agrarian and Economic University, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-4685-1818*

Tetiana Kimstach, *PhD, Associate Professor, Department of Material Science and Heat Treatment of Metals, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-8993-201X*

Nina Diachenko, *Lecturer, Department of Higher Mathematics, Physics and General Engineering Disciplines, Dnipro State Agrarian and Economic University, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-8506-9204*

The object of this research is the process of oscillation of liquid metallurgical slag in a slag bowl under the influence of acceleration. The work considers the oscillation processes in bowls used on railway and road slug cars, which differ in design and operating conditions. One of the key problems associated with the transportation of liquid slag is the dynamic instability of the melt, which leads to oscillations and splashing, which can pose a safety threat and reduce the efficiency of the transportation process. In this regard, the study of the dynamics of liquid slag in bowls of various designs is an urgent task aimed at optimizing transportation parameters and developing measures to reduce the risk of slag splashing.

Based on the results of numerical modeling, it was established that the nature of the oscillations of liquid slag in the bowl significantly depends on the magnitude of the acceleration, the type of slag and the design of the bowl. In particular, the acceleration ranges at which different oscillation modes are observed, from minor surface disturbances to intensive slag splashing, have been determined. At the same time, the differences in the nature of oscillations for different types of slag and bowl designs lie within the limits determined by their physicochemical properties and geometric parameters.

The results obtained allow to conclude that it is possible to develop measures for the operation of slag bowls, as well as their designs, in the direction of reducing the amplitude of liquid slag oscillations, which, in turn, contributes to increasing transportation safety and reducing dynamic loads on the bowl walls.

The obtained data can be used in the design of new bowl designs to optimize their shape and internal elements in order to minimize slag oscillations. In addition, the information provided can be useful for metallurgical enterprises to develop effective methods for controlling and monitoring slag stability during transportation.

Keywords: slag bowl, density, viscosity, transportation, acceleration, numerical modeling, liquid slag.

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CONSTRUCTION OF A KINETIC EQUATION OF CARBON REMOVAL FOR CONTROLLING STEEL MELTING IN THE METALLURGICAL SYSTEM "CUPOLA FURNACE – SMALL CONVERTER"

pages 19–23

Dmytro Makarenko, *Senior Lecturer, Department of Ecology and Technogenic Safety, National Aerospace University "Kharkiv Aviation Institute", Kharkiv, Ukraine, e-mail: d.makarenko@khai.edu, ORCID: https://orcid.org/0000-0002-4672-2880*

Tetiana Selivorstova, *PhD, Associate Professor, Department of Information Technology and Systems, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-2470-6986*

Yuriy Dotsenko, *PhD, Associate Professor, Department of Foundry Production, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-7734-7884*

Iryna Osypenko, *PhD, Associate Professor, Department of Foundry Production, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-7119-9278*

Oleksandr Dzevochko, *PhD, Associate Professor, Head of Department of Technological Systems Automation and Environmental Monitoring, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0002-1297-1045*

Alevtyna Pereverzieva, *Assistant, Department of Technological Systems Automation and Environmental Monitoring, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0003-2072-2521*

Alona Dzevochko, PhD, Associate Professor, Department of Technological Systems Automation and Environmental Monitoring, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0001-5988-5577

The object of research in the paper is the process of steelmaking in a small converter, which works in tandem with a cupola furnace.

The existing problem is that the control of the process of obtaining steel in an oxygen converter is complicated by the need to determine in real time the current chemical composition of the melt, in particular carbon. This is due to the fact that the rate of carbon removal is too high, as a result of which the process of carbon removal is transient. Therefore, it is too difficult to implement regulation based on feedback on continuous measurement.

The presence of the specified problem requires solutions related to the possibilities of developing or improving software control of the process.

It is shown that in certain sections of the process within each time section of oxygen purging of the melt in the converter, the kinetic curve has a linear form with a constant coefficient value in front of the inlet mine. But the value of the initial coefficient for each equation that describes the process within its limits changes. This allows to state that in case of a change in the initial condition, the kinetic curves shift relative to each other in parallel. On this basis, a system of equations has been constructed that describes the process of carbon removal in a small oxygen converter that receives liquid iron from a cupola furnace.

It has been shown that to use the obtained system of equations, it is necessary to know the initial carbon content in the melt discharged from the cupola furnace, and it depends on the method of oxygen supply to the cupola furnace. Based on the modeling of this process in two variants – using a "sharp blow" and supplying oxygen to the air blown into the tuyeres, a nomogram has been constructed. It allows to determine the initial carbon content for the practical use of the obtained system of equations.

Using the obtained system makes it possible to determine the time after which oxygen cutoff should be made. This will allow to decide to implement software control of the melt blowing process in the converter.

The presented study will be useful for machine-building enterprises that have foundry shops in their structure, where cast iron is smelted for the manufacture of castings.

Keywords: cupola melting, converter, oxygen blowing, sharp blast in a cupola furnace, kinetic equations.

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STUDY OF PHYSICOCHEMICAL AND GEOCHEMICAL ASPECTS OF ENHANCED OIL RECOVERY AND CO_2 STORAGE IN OIL RESERVOIRS

pages 24–29

Taras Petrenko, *PhD Student, Department of Oil and Gas Engineering and Technology, National University "Yuri Kondratyuk Poltava Polytechnic", Poltava, Ukraine, e-mail: Saynos2011@gmail.com, ORCID: https://orcid.org/0009-0005-1764-5256*

The object of research is the processes of multiphase filtration in porous media. These processes occur when carbon dioxide (CO_2) is injected into oil reservoirs to increase oil recovery. The object is also the interphase phenomena, geochemical interactions and technological operations for well control associated with these processes.

One of the most problematic areas is the lack of understanding of complex relationships. These relationships exist between physicochemical processes at the micro level (interfacial tension, wettability, solubility, adsorption, geochemical reactions) and macroscopic characteristics of the reservoir (permeability, porosity, heterogeneity). Technological parameters of CO_2 injection (pressure, temperature, speed, volume) are also important. This leads to suboptimal selection of technologies for increasing oil recovery technologies, premature CO_2 breakthroughs, low oil recovery ratios, and also complicates the prediction of the behavior of the "reservoir – fluid – CO_2" system in the long term, in particular, from the point of view of CO_2 storage safety. Another problematic area is the limitation of existing empirical models describing the impact of CO_2 injection on well productivity, which do not fully take into account the heterogeneity of the reservoir and the complexity of physicochemical processes.

A comprehensive overview of the mechanisms of CO_2 interaction with reservoir fluids and rock has been obtained. The impact of supercritical CO_2 on interfacial tension, wettability, swelling and viscosity of oil has been analyzed. Geochemical reactions and their impact on permeability have been considered. CO_2 mobility control has been investigated. Mathematical relations for the calculation of throttling devices have been developed. An analysis of industrial data has been conducted, which revealed a nonlinear response of wells and allowed to refine regression models.

This provides the possibility of obtaining increased oil recovery rates and long-term CO_2 binding. Compared with similar known methods, CO_2 provides a decrease in interfacial tension, a decrease in oil viscosity, dissolution of residual oil and a potential reduction in greenhouse gas emissions. Refined regression models allow for a more accurate prediction of well productivity. The developed mathematical relationships provide effective well management. The results obtained can be used in practice to optimize oil field development processes using CO_2 injection technologies, as well as to assess and ensure the safety of long-term CO_2 storage in geological formations.

Keywords: carbon dioxide, oil recovery, multiphase filtration, permeability, geochemical interactions, wettability, fittings.

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DETERMINATION OF THE DEPENDENCE OF THE FILTRATION PROPERTIES OF A BIOPOLYMER SYSTEM ON PRESSURE, TEMPERATURE AND CONCENTRATION OF COMPONENTS

pages 30–34

Victoriia Rubel, *PhD, Associate Professor, Department of Oil and Gas Engineering and Technology, National University "Yuri Kondratyuk Poltava Polytechnic", Poltava, Ukraine, e-mail: veca.rubel@gmail.com, ORCID: https://orcid.org/0000-0002-6053-9337*

Roman Slichenko, *PhD Student, Department of Oil and Gas Engineering and Technology, National University "Yuri Kondratyuk Poltava Polytechnic", Poltava, Ukraine, ORCID: https://orcid.org/0009-0008-6999-5508*

The object of study is the biopolymer system "X", which is used as a clay-free drilling fluid for development of productive horizons. Biopolymer system "X" is a clay-free drilling fluid for drilling directional and horizontal wells, development of productive horizons under high pressures and temperatures.

A distinctive feature of the biopolymer system is a high level of mineralization, increased heat resistance and high density, which significantly expands the scope of clay-free muds.

At the same time, this system has a number of significant advantages:

– high level of mineralization;

– increased heat resistance (operable up to 150 °C);

– high density, which expands the scope of application;

– provides a higher coefficient of recovery of reservoir permeability compared to traditional weighted solutions;

– low content of colloidal particles, which reduces the risk of deterioration of reservoir performance;

– ability to control filtration properties at high temperatures and pressures.

The following disadvantages can be identified based on the research:

1. Significant increase in the filtration rate with increasing temperature (nonlinear dependence with a correlation coefficient of 0.773).

2. The need to maintain a constant concentration of potassium chloride (~3 %) to ensure the development quality of productive formations.

3. Difficulty in controlling the properties due to the need to accurately select the concentrations of various components (sodium chloride and organomineral colmatant).

The optimal ratio of components to ensure the stability of the system at temperatures up to 150 °C was obtained: sodium chloride concentration 15–20 %, stabilizer 0.75–1 %. This is due to the fact that the proposed composition has a number of features of synergistic interaction of the components, in particular the formation of stable complexes between biopolymers and sodium ions, which prevents the thermal destruction of polymer chains at high temperatures. At the same time, the stabilizer forms an additional protective layer around the polymer molecules, ensuring their resistance to oxidation and hydrolysis under high pressure of up to 7 MPa.

The obtained research results indicate the possibility of effective use of the biopolymer system at high temperatures and pressures due to the thermostabilizing effect of sodium chloride and organo-mineral colmatant.

Keywords: biopolymer system, rheological properties, biopolymer stability, formulation optimization, high-temperature stability.

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ELECTRICAL ENGINEERING AND INDUSTRIAL ELECTRONICS

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DIAGNOSTICS OF THE TECHNICAL STATE OF HIGH-VOLTAGE EQUIPMENT UNDER OPERATING VOLTAGE

pages 35–44

Oleksandr Sakhno, *PhD, Executive Director, Chief Electrician, "ENERGY AUTOMATION" LLC, Zaporizhzhia, Ukraine, e-mail: asakhno@enera.com.ua, ORCID: https://orcid.org/0000-0002-3283-3731*

Liudmyla Skrupska, *Department of Electrical and Electronic Apparatus, National University "Zaporizhzhia Polytechnic", Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0002-9494-1009*

Kostiantyn Odiyaka, *Department of Electrical and Electronic Apparatus, National University "Zaporizhzhia Polytechnic", Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0009-0001-4583-3845*

Volodymyr Vasylevskyi, *PhD, Department of Electrical and Electronic Apparatus, National University "Zaporizhzhia Polytechnic", Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0002-6220-8398*

Serhii Shylo, *Department of Electrical and Electronic Apparatus, National University "Zaporizhzhia Polytechnic", Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0002-4094-6269*

The object of research is systems for online monitoring of the technical condition of oil-filled high-voltage electrical equipment during operation, which are used for automated diagnostics of the technical condition of equipment, resource forecasting and reducing of accidents.

The work is devoted to finding opportunities to reduce the cost of online monitoring systems, taking into account the military situation in Ukraine. The problem is caused by the need to use such systems to increase personnel safety and reliability of power grids, reduce the risk of failures due to deterioration of the technical condition of equipment due to unforeseen resource depletion or accelerated development of hidden defects due to military actions (excessive short-circuit currents, overvoltage). But taking into account the fact that the restoration of the power structure of Ukraine takes place in conditions of limited financial resources, one of the important tasks is to use online monitoring systems with an optimal price/diagnostic capabilities ratio to ensure the required level of diagnostics with a reduction in material costs for such systems.

The paper presents the results of an analytical study of the operation of online monitoring systems operated at various facilities over the past 20 years. The approach to diagnostics under operating voltage proposed in this study is aimed, first of all, at preventing emergency situations caused by the most frequent causes of accidents associated with: partial breakdown of capacitor insulation, increase in relative moisture saturation of transformer oil, appearance of dissolved gases in oil. The use of such an approach will increase the reliability of the power infrastructure and improve fault detection and preventive maintenance strategies

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while reducing the costs of organizing automated diagnostics in relation to "full-range" online monitoring systems of high-voltage equipment, which have been actively installed in Ukraine in recent years.

Keywords: online monitoring systems, transformer oil, accident prevention, dissolved gas analysis, partial insulation breakdown.

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TECHNOLOGY AND SYSTEM OF POWER SUPPLY

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DETERMINATION ON ENERGY EFFICIENCY IN CORN GRAIN DRYING

pages 45–49

Oleksandr Gorbenko, *PhD, Associate Professor, Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University, Poltava, Ukraine, e-mail: oleksandr.gorbenko@pdau.edu.ua, ORCID: https://orcid.org/0000-0003-2473-0801*

Hryhorii Lapenko, *PhD, Associate Professor, Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University, Poltava, Ukraine, ORCID: https://orcid.org/0000-0003-1435-5307*

Taras Lapenko, *PhD, Associate Professor, Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University, Poltava, Ukraine, ORCID: https://orcid.org/0000-0001-8055-6698*

Samson Kolotii, *Department of Agricultural Engineering and Road Transport, Poltava State Agrarian University, Poltava, Ukraine, ORCID: https://orcid.org/0009-0002-1768-3111*

The object of research is the technological processes of corn grain drying, energy plants. One of the most problematic areas for agricultural producers is providing energy for technological processes of bringing grain material to the indicators of product sales. And during the war and post-war period in Ukraine, this requires non-standard approaches and ways of implementation. Therefore, for operation in autonomous mode, the technology involves the use of biomass, electricity from solar panels and/or a diesel generator to supply the coolant to the grain drying zone. The availability of biomass is ensured by cleaning grain material after harvesting and crop residues.

The study examined the technology of corn grain drying in "Agrotechservice" LLC of the Poltava district of the Poltava region (Ukraine) using the Saphir 2134 modular grain dryer with an improved biomass boiler.

The results of studies of the operation of a grain dryer using different types of fuel (gas, diesel fuel, alternative fuel) showed that the energy consumption for reducing humidity by 1 ton-percent was: for gas – 1.5 m^3; for diesel fuel – 1.8 l; for biomass – 3.4 kg. The total cost of drying on a Saphir 2134 grain dryer was obtained, which is 0.205 USD, which is 3.7 times less than when using natural gas and 9.2 times less than when using diesel fuel. This is due to the fact that the proposed technology involves the use of an improved biomass boiler and alternative energy sources. This provides the possibility of obtaining average daily savings using a grain dryer of this model with an improved biomass boiler, which will be about 1.1 thousand USD. Compared to similar corn grain drying processes, these studies have shown the economic feasibility of using biomass as an energy material for the production of thermal energy in the corn grain drying process.

Keywords: corn grain drying, biomass, grain dryer, energy efficiency, biofuel boiler, alternative energy sources.

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ESTIMATION OF FUEL CONSUMPTION IN STANDARD DRIVING CYCLES AND IN REAL BUS OPERATION

pages 50–56

Dmytro Ruban, *Doctor of Technical Sciences, Department of Automobiles and Tractors, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv, Dublyany, Ukraine, e-mail: ruban_dimon@ukr.net, ORCID: https://orcid.org/0000-0002-0671-3226*

Lybomyr Krainyk, *Doctor of Technical Sciences, Department of Automobiles and Tractors, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv, Dublyany, Ukraine, ORCID: https://orcid.org/0000-0002-0524-9126*

Hanna Ruban, *Cherkasy State Business-College, Cherkasy, Ukraine, ORCID: https://orcid.org/0000-0002-8702-8430*

Miron Mahats, *PhD, Department of Automobiles and Tractors, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv, Dublyany, Ukraine, ORCID: https://orcid.org/0000-0001-5339-139X*

Oleg Sukach, *PhD, Department of Automobiles and Tractors, Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies of Lviv, Dublyany, Ukraine, ORCID: https://orcid.org/0000-0003-0867-335X*

Vladyslav Khotunov, *PhD, Department of Computer Engineering and Information Technology, Cherkasy State Business College, Cherkasy, Ukraine, ORCID: https://orcid.org/0000-0002-2093-1270*

Viktor Shevchuk, *PhD, Department of Vehicle Operation and Fire-Rescue Techniques, Lviv State University of Life Safety, Lviv, Ukraine, ORCID: https://orcid.org/0000-0002-8260-2165*

Oleksandr Artyukh, *PhD, Department of Automobiles, Heat Engines and Hybrid Power Plants, National University Zaporizhzhia Polytechnic, Zaporizhzhia, Ukraine, ORCID: https://orcid.org/0000-0002-5043-7038*

The object of research is the basic fuel consumption of a bus in standard urban cycles and identical conditions in real operation.

Standard driving cycles are used to estimate fuel consumption. This allows consumers to compare buses and choose the best one, and manufacturers in the process of improving buses also allow them to estimate fuel consumption. However, sometimes standards may not correspond to reality. Therefore, specific routes are developed for some cities, which requires significant development costs. This problem is solved by collecting reliable information on average fuel consumption with an operating period of 1 year and bus mileage of 40–90 thousand km. As a rule, operating organizations do not provide such information. The development of electronic control systems allows to obtain information from "black boxes" additionally installed by the manufacturer, which record information throughout the entire service life of the bus. This approach is implemented in this work.

Existing standards for determining fuel consumption in urban driving cycles are presented. The results of modeling and real tests are presented. Information

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was collected from the "black boxes" on fuel consumption on 12 buses for 1 year of operation with mileage from 40 to 90 thousand km on Ataman A092N6 buses. Fuel consumption was 16.4–21.2 l/100 km when operating buses in one city (the manufacturer claims up to 23 l/100 km). This makes it possible to solve the problem of collecting reliable information on fuel consumption based on year-round operation of buses, which has not been carried out in this format before.

The results of this study will allow operating organizations to see the real fuel consumption on Ataman A092N6 buses in the city. Implementation of this approach on other buses will allow obtaining data for interested organizations in a similar way. This will allow estimating fuel consumption without additional tests, which will reduce research costs.

Keywords: fuel consumption by buses, driving cycles, road tests, passenger transportation, urban cycle.

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INFLUENCE OF CORROSION OF THE FIRST CIRCUIT ELEMENTS ON THE DISTRIBUTION OF SEDIMENTS IN THE CIRCULATION TRACT OF THE SMR 160 REACTOR

pages 57–62

Igor Kozlov, *Doctor of Technical Sciences, Professor, Department of Nuclear Power Plants, Odesa Polytechnic National University, Odesa, Ukraine, e-mail: kozlov_i.l_@ukr.net, ORCID: https://orcid.org/0000-0003-0435-6373*

Vyacheslav Kovalchuk, *PhD, Associate Professor, Department of Nuclear Power Plants, Odesa Polytechnic National University, Odesa, Ukraine, ORCID: https://orcid.org/0000-0001-8696-4414*

Denys Stepura, *PhD Student, Department of Management, Kyiv National Economic University named after Vadym Hetman, Kyiv, Ukraine, ORCID: https://orcid.org/0009-0006-8334-6833*

Maksym Lysak, *PhD Student, Department of Nuclear Power Plants, Odesa Polytechnic National University, Odesa, Ukraine, ORCID: https://orcid.org/0009-0001-6807-1679*

Viacheslav Miliev, *PhD Student, Department of Nuclear Power Plants, Odesa Polytechnic National University, Odesa, Ukraine, ORCID: https://orcid.org/0009-0000-2289-2490*

The object of research is the circulation path of a water-water small modular reactor. The work is aimed at assessing the influence of corrosion intensity on the formation of sediments on the surfaces of the first circuit of the SMR 160 reactor module. The analysis of the circuit structure was performed, the intensity of corrosion destruction and the intensity of sediments on the local sections of the circuit are evaluated. The circulation circuit of vertical architecture, the movement of the coolant in which excites thermal pressure, created by heating in the core and cooling in the steam generator.

The methodology is based on the principle of material balance of the transition of corrosion products into the coolant and their sediment on the circuit surface. To estimate the speed of corrosion the results of complex studies conducted at stations in normal operation and on the physical models of sections of the first circuit in the laboratory were used. Estimation of the speed of sediments is performed according to the ratios that take into account the impact of the concentration of the sedimented substance in the coolant, the thermal load of the site and the consumption of the coolant.

The calculations showed that the main source of iron oxides in the circuit is the surface of the steam generator, causing the average value of their concentration in the final areas, and zirconium oxides come from the surface of the core and retain the concentration close to the average along the entire tract.

The research results showed that the high corrosion stability of the structural materials of the circuit significantly limits the transition and accumulation of corrosion products in the coolant. In turn, low concentrations of corrosion products in the coolant restrain the formation of their sediments on the surfaces of the core and steam generator. The values of the surface density of sediments and their average thickness are estimated.

Analysis of corrosion processes of structural materials and the distribution of their sediments in the circuit allow to predict the level of radiation contamination and to plan the service life of the system.

The presented technique allows to evaluate the effectiveness of the water-chemical regime used.

Keywords: modular reactor, water-chemical regime, corrosion, sediment, austenitic steel, zirconium.

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MATHEMATICAL MODELLING OF MIXTURE FORMATION IN THE COMBUSTION CHAMBER OF A DIESEL ENGINE

pages 63–68

Oleksandr Zhevzhyk, *PhD, Associate Professor, Department of Intelligent Power Supply Systems, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-8938-9301*

Iryna Potapchuk, *PhD, Associate Professor, Department of Intelligent Power Supply Systems, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, e-mail: i.y.potapchuk@ust.edu.ua, ORCID: https://orcid.org/0000-0002-5985-1040*

Vadym Horiachkin, *PhD, Associate Professor, Head of Department of Computer and Information Technology, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-8952-952X*

Serhii Raksha, *Doctor of Technical Sciences, Professor, Head of Department of Applied Mechanics and Materials Science, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0002-4118-1341*

Dmytro Bosyi, *Doctor of Technical Sciences, Professor, Head of Department of Intelligent Power Supply Systems, Ukrainian State University of Science and Technologies, Dnipro, Ukraine, ORCID: https://orcid.org/0000-0003-1818-2490*

Andrii Reznyk, *Director, Limited Liability Company "PromSpecEngineering", Dnipro, Ukraine, ORCID: https://orcid.org/0009-0001-8825-2186*

The object of research is the process of fuel mixture formation in a vortex combustion chamber located in the piston of a diesel engine.

Ineffective mixture formation leads to increased specific fuel consumption and harmful emissions into the atmosphere. The research addresses determining the conditions under which complete evaporation of droplets is achieved and the required ratio of the amount of fuel vapor and the available amount of air depending on the piston radius.

A mathematical model was created to describe the behavior of fuel droplets under the influence of aerodynamic forces, heat transfer, and phase transition processes. The calculations determined the radial fuel vapor concentration and air-fuel ratio distribution. The study found that fuel droplets with sizes ranging to 90.7 μm are completely evaporated which contributes to volumetric mixture formation. The model also identified regions where the mixture reaches stoichiometric conditions necessary for autoignition, particularly at a radius of $r/R_c = 0.22$.

This is explained by the rapid evaporation of small droplets, the number of which, as a function of the diameter distribution, is the majority, and their high speeds of movement relative to air and high mass transfer coefficients in the initial spraying area.

The study demonstrates that despite non-uniform fuel vapor distribution, volumetric mixture formation is achieved. The interaction between fuel droplets and the swirling air motion ensures adequate mixing, facilitating complete and efficient fuel combustion.

The results can be applied to optimize diesel engine designs by improving combustion chamber geometry and fuel injection strategies. The model is particularly useful for engines with high-pressure fuel injection systems. The work results contribute to developing more efficient diesel engines that comply with stricter emission regulations.

Keywords: droplet movement, evaporation, mixture formation, spray dispersion, volumetric combustion, excess air, steam unevenness.

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