Journal of Kryvyi Rih National University

Journal homepage: https://journal-knu.com.ua/en

Vol. 22, No. 2, 2024

Article's History:
Received: 15.06.2024
Revised: 30.09.2024
Accepted: 24.12.2024

UDC 621.3.016.2

DOI: 10.31721/2306-5451-2024-2-22-37-47

# Assessment of the quality of the microclimate in the EKG-12K excavator cab

**Serhiy Sakhno***

PhD in Technical Sciences, Associate Professor
Kryvyi Rih National University
50027, 11 Vitalii Matusevich Str., Kryvyi Rih, Ukraine
https://orcid.org/0000-0003-3757-2646

**Lyudmila Yanova**

PhD in Technical Sciences, Associate Professor
Kryvyi Rih National University
50027, 11 Vitalii Matusevich Str., Kryvyi Rih, Ukraine
https://orcid.org/0000-0001-5050-5881

**Olena Pyshchykova**

PhD in Technical Sciences, Associate Professor
Kryvyi Rih National University
50027, 11 Vitalii Matusevich Str., Kryvyi Rih, Ukraine
https://orcid.org/0000-0002-0843-3498

**Volodymyr Kozariz**

PhD in Technical Sciences, Associate Professor
Kryvyi Rih National University
50027, 11 Vitalii Matusevich Str., Kryvyi Rih, Ukraine
https://orcid.org/0000-0002-7578-6090

**Abstract.** This research addresses critical issues within the construction and mining sectors, encompassing operator health and safety, productivity, equipment durability, and regulatory compliance. In addition, the research focuses on microclimate management, ergonomics, and technology, and can improve the safety, comfort, productivity, and sustainability of the industry. The objective of this study was to evaluate the quality of the microclimate within the EKG-12K excavator cab, specifically examining airflow, temperature, operator comfort, and safety. Using ANSYS Fluent, the microclimate was modelled under warm and cold conditions in accordance with international standards. The findings revealed deficiencies in ventilation and air conditioning. During warmer periods, the positioning of fans fails to facilitate adequate circulation of cooled air within the domain of the operator. Under colder conditions, the interaction between fans and heat curtains generates air circulation around the axle at the level of the driver's seat. Temperature analyses demonstrated that during warm periods, the temperature ranges between 23-25°C, necessitating substantial effort from the air conditioning system. During cold periods, certain areas experience temperatures as low as 5°C, posing the risk of condensation and mould growth. Additionally, there are concerns regarding dust circulation and the potential for glass breakage owing to temperature variations. The conclusions underscore the necessity of optimising the microclimate within a cab to ensure operator comfort,

**Suggested Citation:**

Sakhno, S., Yanova, L., Pyshchykova, O., & Kozariz, V. (2024). Assessment of the quality of the microclimate in the EKG-12K excavator cab. *Journal of Kryvyi Rih National University*, 22(2), 37-47. doi: 10.31721/2306-5451-2024-2-22-37-47.



*Corresponding author

safety, and excavator efficiency. The practical importance of this work lies in offering solutions to enhance the safety, comfort, productivity, and longevity of the equipment

**Keywords:** cabin airflow dynamics; thermal comfort optimisation; dust particle suspension; computational fluid dynamics simulation; ventilation system efficiency; temperature gradient analysis; condensation risk assessment

## Introduction

Improving the health and safety of heavy mining and construction equipment operators through improved microclimate management is an important task. It is inextricably linked to labour productivity and overall production efficiency. I. Mehmood *et al.* (2022) show that working with construction equipment for long periods can lead to mental fatigue and, as a result, an increased risk of accidents related to human error, as well as health problems for operators. E.C. Kayar & H. Özcan (2024) emphasised that the ambient temperature is one of the main factors that negatively affects the working conditions of excavator operators. The authors emphasise that it is difficult to provide comfortable air conditioning in excavator cabs because the weather conditions are unpredictable. Therefore, before installing an air-conditioning system, it is necessary to calculate the efficiency of airflow distribution in the cab. The authors Yu. Voichyshyn *et al.* (2023) emphasise that the microenvironment in the excavator cab consists of a number of physical parameters, including temperature, humidity, air velocity and thermal radiation, which affect the operator's well-being. These parameters depend on several external and internal factors. External determinants that affect the cab microenvironment include meteorological conditions, geographical location of the work site, seasonal periods of work, and daily cycles.

As cabs have become an integral component of modern excavators, the need to maintain thermal comfort has significantly increased. The main challenge associated with this is the regulation of ambient temperature, which is crucial for providing a favourable working environment for excavator operators. Maintaining a proper level of air conditioning in excavator cabs is particularly challenging because of the unpredictability of weather conditions. F. Lan *et al.* (2023) and V. Aulin & M. Mahopets (2024) noted that evaluating the efficiency of airflow distribution in an excavator cab before installing an air conditioning system facilitates further optimisation. These system optimisation studies have several benefits. Developing systems that maintain optimal conditions accelerates project completion, thereby saving financial resources and time. In addition, these studies aimed to improve air conditioning by assessing the specific cooling needs of the excavator based on the expected workload.

The reviewed studies highlight the importance of providing a favourable working environment for excavator operators and other mining and construction equipment. One of the ways to solve this problem is to create an optimal microclimate in the cab. These studies emphasise the need to model the distribution of airflow at the design stage of microclimate systems. At the same time, the above studies do not sufficiently cover the issues of temperature and air velocity distribution in different areas of the cabin. In addition, no studies have modelled the air distribution in machines used in quarries and construction sites. Standards of Ukraine do not regulate the distribution of air flows, but only their temperature and speed. Manufacturers ensure compliance with the operating conditions of the operators of these machines by supplying the calculated amount of air at the calculated temperature. In this regard, the aim of this study was to analyse the microclimate of a mine excavator cab, paying particular attention to air flow, temperature conditions, operator comfort, and safety.

## Materials and Methods

An EKG-12-K open-pit excavator was chosen for this study. This type of excavator is widely used in the Kryvyi Rih basin mining sector. The excavator is operated under challenging conditions. In quarries, there are often significant temperature fluctuations throughout the day and seasons. There can be extreme heat in summer and frost and snow in winter. Strong winds kick dust and small particles that enter the cab and can lead to respiratory illnesses. Numerical simulations were developed utilising ANSYS Fluent software (Ansys fluent theory guide, 2021) (Fig. 1). The analysis was executed in transient mode. The realisable k-epsilon model (Shaheed *et al.*, 2019) was chosen to simulate turbulence, and the energy option was enabled.

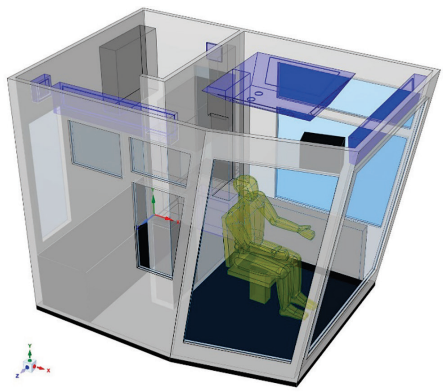

**Figure 1.** A mathematical representation of the operator's compartment of the EKG-12K excavator
**Source:** compiled by the authors

The simulations adhered to ISO No. 10263-4 (2009), which delineates the minimum performance thresholds for air conditioning systems within earthmoving equipment. This standard elaborates a methodology for evaluating the influence of a heating system on the ambient temperature within the operator's cabin and explicates the fundamental heating criteria. Figure 2 illustrates the positioning of the measurement points relative to the cabin floor. The simulation was executed utilising the finite element method (Hou *et al.*, 2021), incorporating a mathematical model of the cabin airspace, which comprised 364,666 nodes and 1,865,048 finite elements (Fig. 3).

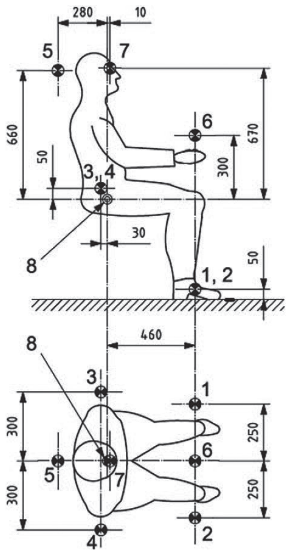


**Figure 2.** The parameters of the excavator operator model that were utilised within the study
**Source:** ISO No. 10263-4 (2009)

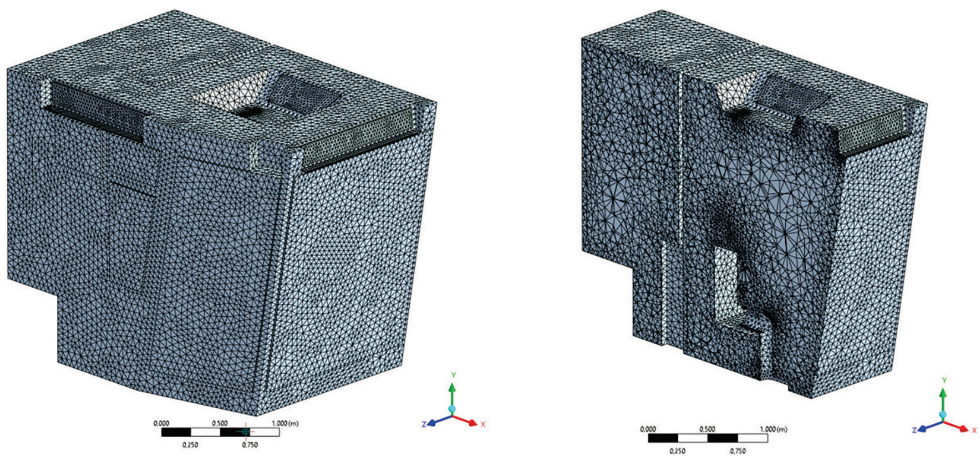

**Figure 3.** A mathematical representation of the airspace within the operator's cabin of the EKG-12K excavator, encompassing both a general overview and sectional analysis
**Source:** compiled by the authors

The simulation process accounted for the turbulent characteristics of the airflows, as well as the heat exchange occurring within the airflows themselves and between the air, the cabin walls, and the glazing. The analysis excluded radiation heat transfer effects during calculations. The parameters of the model, as obtained for both warm and cold seasons, were thoroughly examined. This simulation enabled the estimation of the velocity, orientation, and temperature of the airflows within the excavator cabin. Calculations have been conducted considering the optimal functionality of heat-generating equipment, neglecting the intermittent automatic deactivation of the heating system.

## Results

The EKG-12K excavator is engineered for the excavation and loading of rocks classified under categories I-II, based on the level of excavation difficulty without requiring loosening, category III with partial loosening, and categories IV-V with full loosening. The driver's cab of the EKG-12K excavator possesses dimensions of 2×2.8×2.2 metres. The front facade of the cab is constructed with a 15° inclination to enhance visibility. The cab is systematically divided into two distinct zones: the excavator control zone and the rest zone. A stationary partition delineates these zones. The excavator control zone is equipped with video surveillance apparatus and devices for monitoring the status of the primary excavator components, in addition to mechanisms for controlling the excavator's rotation, boom, and bucket positions. Conversely, the rest zone is furnished with a sofa, a dining table, a microwave oven, and an electric kettle. Furthermore, both zones are furnished with communication devices and electrical apparatus. The working zone features comprehensive glazing, while the rest zone is outfitted with two blind light openings.

The cabin features a mechanically assisted ventilation system comprising both supply and exhaust components. The air is introduced into the cabin via a WildWind fan, which possesses a capacity of 185 cubic metres per hour. Before entering the cabin, the air is subjected to filtration. In conditions of cold weather, there is provision for heating the incoming air. The supply fan is installed on the rear wall of the cabin, directing airflow along the right wall towards the occupational zone. Air extraction is conducted through a VENTS Ukraine fan situated in the recreation area, located at the upper section of the left wall. The operational capacities of both the supply and exhaust fans are equivalent.

During periods of elevated temperatures, the cabin's air is regulated by a Coleman-Mach air conditioning unit. This unit employs a split system configuration, with the external component positioned atop the cabin's roof and the internal component affixed to the ceiling. The air conditioning system possesses a maximum air capacity of 118 litres per second. Air intake within the internal unit is facilitated via lateral air intakes, which are fitted with mesh dust filters. The conditioned air is distributed through the front outlet channel and two lower rotary deflectors. During colder periods, the air within the cabin is warmed by two air curtains and an electric convector. Both air curtains are manufactured by OLEFINI. Specifically, the L/REN-13S model air curtain is positioned above the front glass, while the MINI 700 model air curtain is installed above the entrance door. Additionally, the cabin's recreation area is equipped with a "Thermiya" electric convector produced by the "Vinnytsia Mayak Plant".

An examination of the direction and velocity of airflows during the warm and cold seasons revealed deficiencies in the arrangement of ventilation and air conditioning systems. These deficiencies become particularly pronounced during the hot season when there is a necessity to activate the air conditioning unit. The issue lies in the placement of both the supply and exhaust fans, which are situated at the rear of the cabin and positioned at an identical height from the floor (Fig. 4).

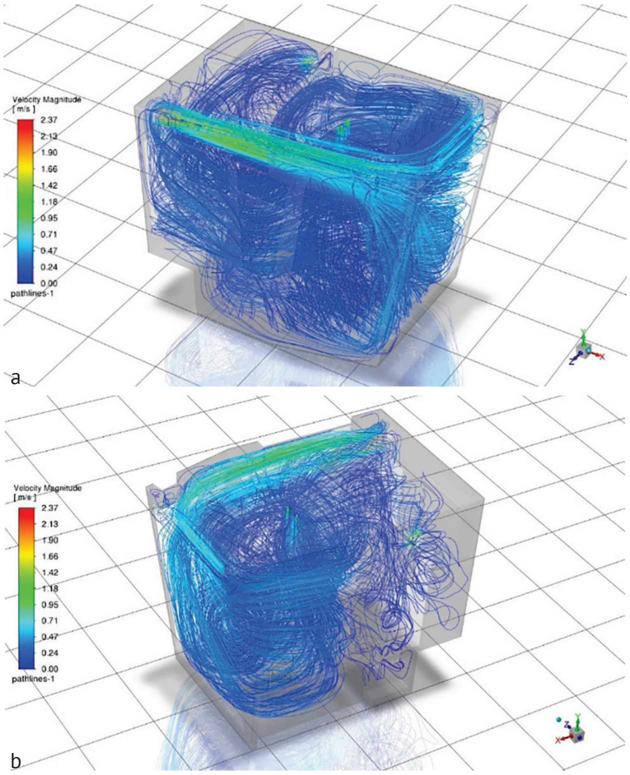


**Figure 4.** The orientation and velocity of air currents within the operator's cabin of the EKG-12K excavator under conditions of elevated temperatures

**Notes:** a – perspective from the anterior right corner of the cabin; b – perspective from the front-left corner of the cabin
**Source:** compiled by the authors

The supply fan generates a confined airstream with a velocity range of 2.37 to 1.2 metres per second. This airstream progresses along the upper right quadrant of the cabin and converges at the windscreen, at which point it diverges into multiple branches. One specific branch extends along the upper section of the windscreen and, upon integration with the airflow from the air conditioning unit, facilitates a circular air circulation within the operational area of the cabin. An alternate branch descends and proceeds along the anterior right corner of the cabin, reaching the cabin floor, where it bifurcates and integrates with additional airflows. Another segment of the airflow traverses from the upper to the lower section and from right to left along the diagonal of the cabin's front window. Upon arriving at the front left corner of the cabin, this airflow alters its trajectory towards the rear and, in conjunction with the initial branch, contributes to the establishment of a circular airflow pattern within the operational section of the cabin. During this rotational movement, the air gradually descends to the cabin's lower area, where it redirects towards the cabin's rear. In the rear section, a portion of the air ascends within the cabin, becomes engulfed by the primary airflow generated by the supply fan, and subsequently re-engages in the recirculation within the cabin's operational zone. The remainder of the air gradually advances to the exhaust fan and is expelled from the cabin. The velocity of the circulating air ranges from 0.2 to 0.6 m/s. During winter, the nature of air movement is slightly altered, attributed to the lack of airflow from the air conditioner and the introduction of airflow from air curtains and an electric convector (Fig. 5).

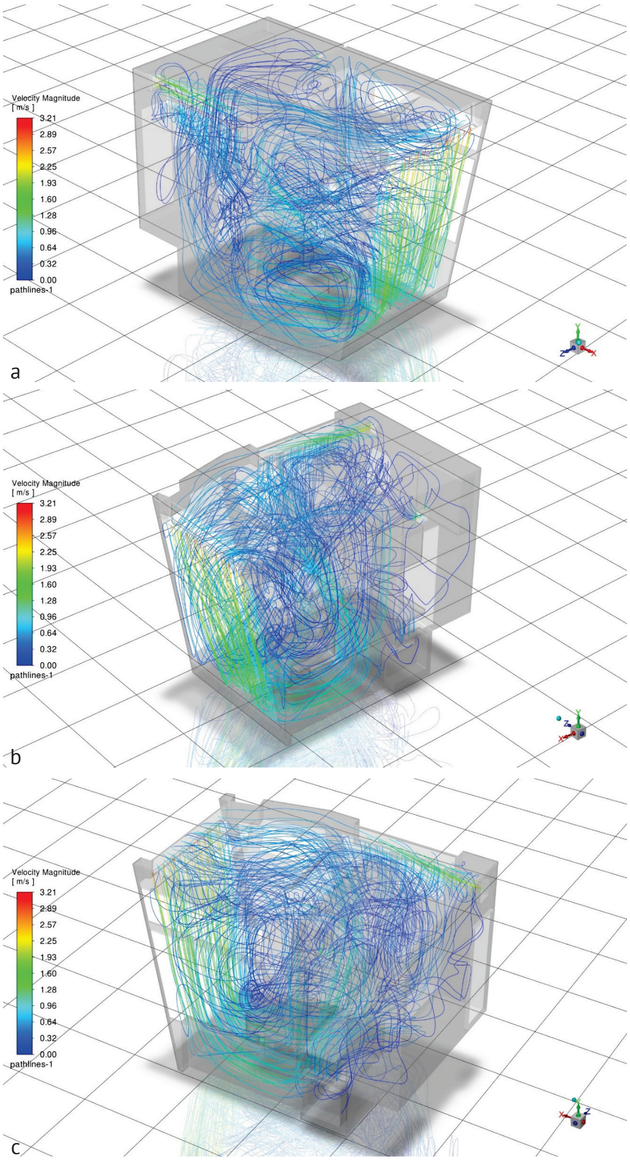


**Figure 5.** An analysis of the direction and velocity of air currents within the operator's cabin of the EKG-12K excavator under cold climatic conditions

**Notes:** a – perspective from the front right corner of the cabin; b – perspective from the anterior left section of the cabin; c – perspective from the rear left corner of the cabin

**Source:** compiled by the authors

The airflow originating from the supply fan intersects with the airflow from the heat curtain located above the entrance door, subsequently dividing into two principal branches. One branch progresses along the cabin's ceiling into the working area, where it is intercepted by the heat curtain above the front glazing and directed towards the lower section of the cabin. The alternative branch, merging with the air from the heat curtain above the entrance door, advances towards the floor of the working area within the cabin, where it further combines with the air from the heat curtain above the front glazing. This process culminates in air circulation. Notably, during warmer periods, air circulation is oriented around a vertical axis that traverses the centre of the cabin's working area, whereas in colder periods, circulation predominantly orients around a horizontal axis extending from the left to the right wall of the working area, corresponding to the excavator driver's seat level. The frequency of air circulation within the working area is significantly reduced during colder periods compared to warmer ones; however, the air velocity is substantially increased, ranging between 0.5 and 1.8 metres per second.

The current ventilation system facilitates extensive air circulation within the confines of the cabin's workspace. Concurrently, a substantial proportion of the circulating air interacts with the floor surface. Considering that the velocity of air flows is documented to be within the range of 0.2-0.6 m/s during summer and 0.5-1.8 m/s in winter, it is unavoidable that dust particles are dislodged from the cabin floor and subsequently transported to the respiratory zone of the excavator operator. Analogous to assessing velocity, the air temperature within the cabin was examined for both hot and cold periods. The computed external temperature for summer was 30°C, whereas for winter it was -15°C. The thermal conductivity values of the walls, inclusive of the thermal insulation, were considered to be 0.033 W/(m·°K). Meanwhile, the thermal conductivity of the cabin windows was assumed to be 1.22 W/(m·°K). The analysis excluded radiation heat transfer effects during calculations. The temperatures of both the airflow and the internal surfaces of the cabin, including the glazing, were systematically evaluated. Figure 6 illustrates the temperature of air flows observed during the hot period.

Figure 7 illustrates that the active air circulation within the cabin inhibits the distribution of air cooled by the air conditioning system from reaching the area occupied by the excavator operator. The primary concentration of the cooled air, maintaining a temperature range of 22-23°C, is situated in the vicinity of the cabin's front window. Air at a colder temperature, ranging from 19-21°C, extends along the upper portion of the cabin, approaching the partition that separates the work and rest areas. The temperature of the air within the operator's area remains between 23-25°C.

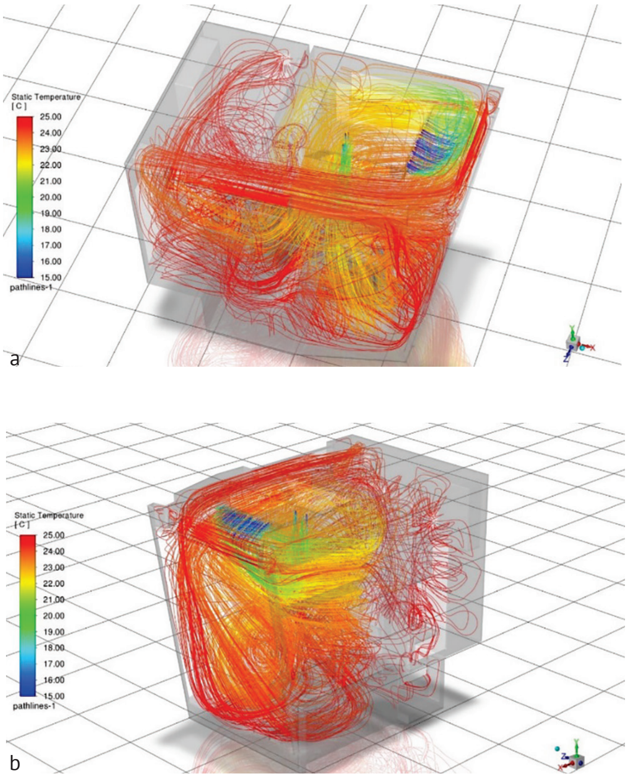


**Figure 6.** The orientation and thermal characteristics of air currents within the operator's cabin of the EKG-12K excavator during elevated ambient temperatures

**Notes:** a – perspective from the front right corner of the cabin; b – perspective from the anterior left section of the cabin

**Source:** compiled by the authors

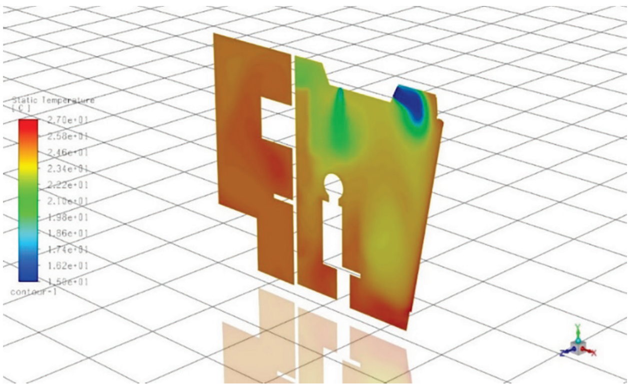

**Figure 7.** Ambient temperature inside the operator's cabin of the EKG-12K excavator under conditions of elevated external temperatures

**Notes:** measurement conducted along the central axis of the cabin

**Source:** compiled by the authors

The temperature distribution across the cabin walls within the working area exhibits variability, ranging from 26°C at the floor level to 20°C at the ceiling level, as illustrated in Figure 8. Typically, due to its higher density, the cooler air is situated in the lower regions of the premises. However, as the air circulates and descends, it undergoes heating by the warm surfaces of the cabin glazing, as depicted in Figure 9. A differential of 6°C in wall temperature, when considering the effect of active air circulation, may result in moisture condensation in cooler regions, consequently facilitating the proliferation of mould and fungal organisms.

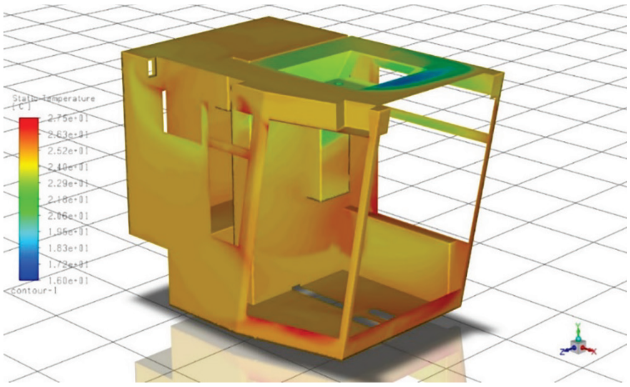

**Figure 8.** Thermal conditions of the interior surface of the walls within the driver's cabin of the EKG-12K excavator during periods of elevated ambient temperature

**Source:** compiled by the authors

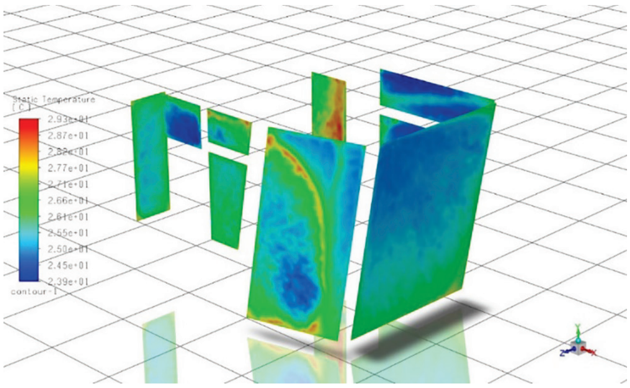

**Figure 9.** The thermal characteristics of the internal surface of the glazing within the driver's cabin of the EKG-12K excavator during elevated temperature conditions

**Source:** compiled by the authors

During cooler periods, the cabin microclimate proves to be more conducive to the driver's operational efficiency. Figures 10-11 demonstrate that, under maximal heat curtain performance, the air temperature surpasses the minimum acceptable thresholds. Nevertheless, the driver maintains the ability to adjust the temperature as needed.

The thermal condition of the walls within the working area surpasses the dew point temperature for moisture condensation (Fig. 12). Nonetheless, within the recreational zone located in the lower left quadrant, there exist regions where the temperature falls to 5°C, consequently facilitating potential moisture condensation and the associated risk of mould and fungal proliferation.

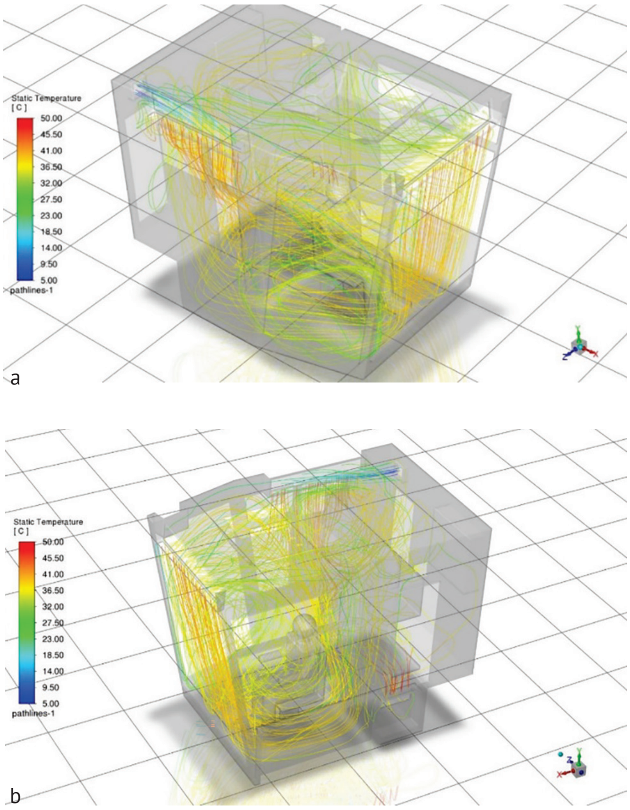


**Figure 10.** Orientation and thermal characteristics of airflow within the operator's compartment of the EKG-12K excavator under cold climate conditions

**Notes:** a – perspective from the front right corner of the compartment; b – perspective from the anterior left corner of the cabin

**Source:** compiled by the authors

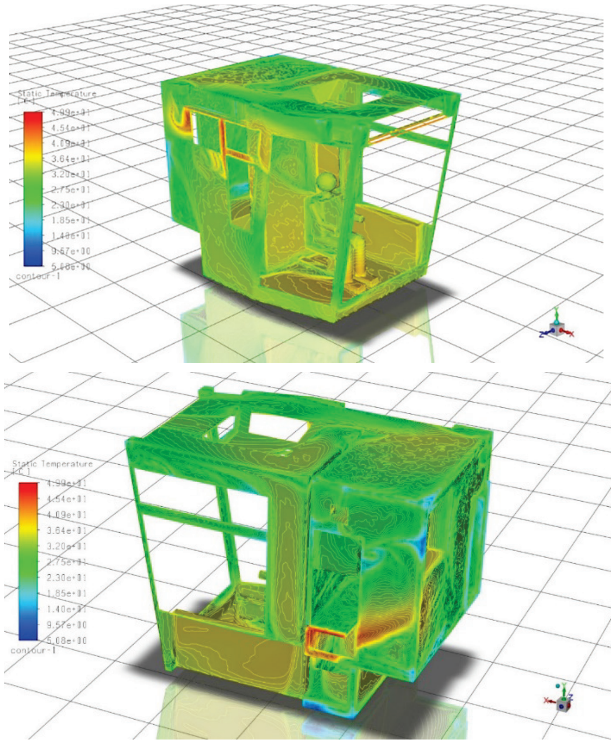

**Figure 12.** Temperature measurements of the internal surface of the operator's cab walls of the EKG-12K excavator during the colder season

**Notes:** a – perspective from the front right corner of the cab; b – perspective from the rear left corner of the cab

**Source:** compiled by the authors

The temperature of the cabin glass ranges from 7 to 46°C (Fig. 13). The maximum temperatures are observed in the area of thermal curtain operation, with the temperature variation within a single glass panel reaching 22°C. Under conditions of cyclic activation and deactivation of the heating system, these disparities can contribute to the potential failure of the glass.

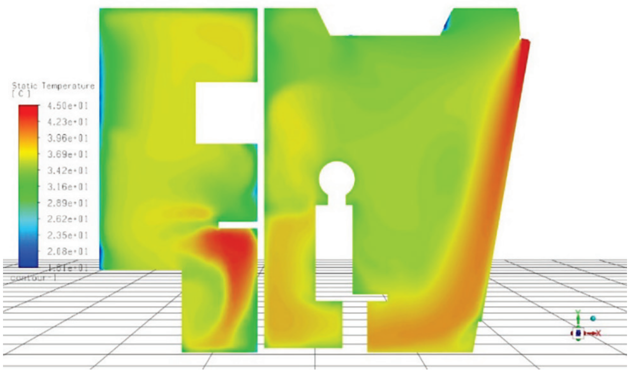

**Figure 11.** The air temperature within the driver's cabin of the EKG-12K excavator during cold conditions

**Notes:** measured along the axis of the cabin

**Source:** compiled by the authors

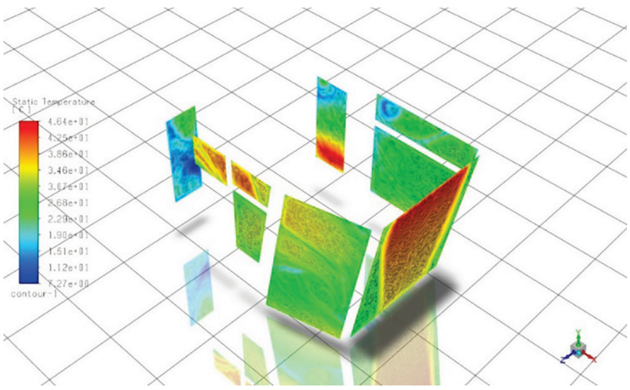

**Figure 13.** Thermal characterisation of the interior surface of the glazing within the driver's cabin of the EKG-12K excavator during periods of low ambient temperature

**Source:** compiled by the authors

Thus, the analysis of the microclimate in the cab of the EKG-12K excavator has revealed several key issues that affect the operator's comfort, safety and potential productivity. The study provides valuable information on air circulation patterns, temperature distribution, and potential health hazards in both warm and cold conditions.

## Discussion

The current design of the ventilation system, featuring supply and exhaust fans located at the rear of the cab, results in problematic circular air circulation patterns under both warm and cold conditions. This design flaw aligns with the findings of F. Lan *et al*. (2023), demonstrating that improper placement of air intakes and exhausts can lead to undesirable air circulation in vehicle cabs. Furthermore, the system generates high air velocities ranging from 0.5 to 1.8 m/s in cold weather, which exceeds the recommended velocity range of 0.1 to 0.3 m/s for optimal thermal comfort in vehicle cabins, as suggested by I. Mehmood *et al*. (2022). This inefficiency prompts consideration of alternative designs. J.H. Hwang *et al*. (2013) propose a system where air exchange is achieved exclusively through exhaust ventilation, which may offer improved air distribution and comfort. Such redesign strategies could mitigate the identified circulation issues and align the system with recommended air velocity guidelines for enhanced thermal comfort. In the study by B. Pirouz *et al*. (2021), the focus was on airflow rates with respect to infection prevention, but it did not address how airflows affect cabin elements or the constraints related to comfortable air velocity. F. Arpino *et al*. (2021) expanded on these ideas by employing the Euler-Lagrange model to explore the transient non-isothermal dispersion of aerosols in air, also from the perspective of infection prevention. Their findings, related to air and heat exchange, are applicable mainly to small cabins like those of passenger cars. It is noteworthy that such findings may not be directly applicable to larger or more complex environments, such as excavator cabs, which have significantly larger volumes, larger glazing areas, and are composed of two separate rooms. These differences highlight the need for further research to understand airflow dynamics and infection prevention measures specific to larger and more complex cab environments like excavators.

In environments with high temperatures, the interaction between the air supplied by the fan and the power of the air conditioning unit is inadequate for effective cooling in the operator's area, maintaining temperatures at around 23-25°C. This results in temperature gradients as large as 6°C on the cab surfaces. These observations align with U. Arora *et al*. (2022), who identified difficulties in ensuring consistent temperatures within excavator cabs. In contrast, research by K. Koushik Balaji & M.S. Alphin (2016) suggests that optimising vent locations through computer modelling can lead to more even cooling distribution. Further experimentation by Y. Mao *et al*. (2018) measured air and surface temperatures in an electric vehicle's cabin during both heating and cooling phases, establishing high correlation between simulated and experimental data. Notably, these analyses are pertinent only to single-volume cabins. Current research extends this framework by examining a two-volume cabin characterised by extensive glazing, providing new insights into the complex dynamics of air distribution and temperature regulation within such environments.

A significant concern during both seasons is the potential respiratory hazard posed to operators by the high-speed, circular airflows that pick-up dust particles from the floor. This issue aligns with the findings of M. Palega & D. Rydz (2018), who highlighted the crucial role of adequate filtration in excavator cabs to minimise dust exposure. B. Xu *et al*. (2018) identified the primary air pollutants within vehicle interiors, which include ultrafine particles, aromatic hydrocarbons, carbonyls, semi-volatile organic compounds, and microbes. These pollutants stem from various sources, such as emissions from interior materials and exhaust gases entering through the ventilation system. Consequently, there is a call to enhance filtration and air distribution systems to tackle these health concerns. Furthermore, improved air filtration systems are proposed to reduce health risks, as emphasised by B. Xu *et al*. (2018). However, this proposal does not fully consider the potential for secondary pollution caused by unorganised high-speed air flows at the floor level. Therefore, addressing this issue requires a comprehensive approach that includes optimising air distribution to prevent such secondary pollution. Significant temperature fluctuations were observed on the interior surfaces, especially on the glass, with measurements showing up to a 22°C difference. These findings align with observations by J.H. Hwang *et al*. (2013) and I. Yakymenko *et al*. (2022), who also reported notable temperature variations on vehicle interior surfaces and their implications for thermal comfort. Such fluctuations can induce thermal stress and potentially cause failure of interior components, particularly as the heating system cycles.

The study identified regions susceptible to condensation and mould proliferation due to temperature gradients, particularly in recreational areas during the colder seasons. Mold growth is predominantly determined by humidity, temperature, and the availability of appropriate substrates (Lai *et al.*, 2024). In confined environments, such as operator cabins, condensation may occur when warm, moist air interfaces with cooler surfaces, thereby facilitating conditions conducive to mould growth (Bastien & Winther-Gaasvig, 2018). The propensity of mould development escalates in environments with elevated relative humidity, generally exceeding 75% RH at 25°C (Qiao *et al.*, 2024). This aligns with the issues articulated by M. Perišić *et al*. (2024)

regarding the management of humidity in enclosed operator cabins. To mitigate these risks, it is imperative to ensure effective ventilation and temperature regulation. The adoption of dehumidification systems and the maintenance of uniform temperatures throughout the area can aid in preventing condensation and diminishing the probability of mould proliferation. Moreover, systematic inspections and maintenance of potential problem zones, such as corners, joints, and inadequately insulated surfaces, are essential for identifying and rectifying issues prior to their escalation. The utilisation of mould-resistant materials and coatings in areas at elevated risk may offer supplementary protection (Doroshenko *et al.*, 2022). By addressing these factors, operators can cultivate a healthier and more comfortable environment, thereby mitigating the risk of mould-associated health complications and potential damage to equipment and structures. Consequently, the study underscores the essential requirement for practical design enhancements and environmental controls to ameliorate these risks in vehicular and cabin environments.

In cold weather conditions, maintaining a favourable cab microclimate is crucial for driver performance, as it often requires the temperature to exceed minimum thresholds for comfort and effectiveness. This finding presents a contrast to the previous study by J. Bonehill (2010), which highlighted issues with sustaining a comfortable temperature within excavator cabs during extreme cold conditions. However, the current study points out that ensuring optimal comfort may necessitate the operator adjusting cab settings. This flexibility in temperature control within the cab environment can enhance driver performance and safety by accommodating individual comfort needs and maintaining a suitable working atmosphere.

## Conclusions

Based on the study findings, the current ventilation system design in the EKG-12K excavator cab generates suboptimal circular air circulation patterns in both warm and cold conditions, resulting in inefficient temperature distribution and potential health risks. Air velocities within the cab exceed recommended ranges for optimal thermal comfort, particularly in cold weather conditions (0.5-1.8 m/s compared to the recommended 0.1-0.3 m/s). The interaction between the supply fan and air conditioner is insufficient for effective cooling in the operator's area during hot conditions, resulting in temperatures of 23-25°C and temperature gradients up to 6°C on cab surfaces. High-velocity circular airflows present a potential respiratory hazard by suspending dust particles from the floor, emphasising the necessity for improved air distribution and filtration. Significant temperature fluctuations were observed on interior surfaces, particularly on the glass (up to 22°C difference), which may result in thermal stress and potential component failure. Areas susceptible to condensation and mould growth were identified, especially in the recreational area during colder seasons, due to temperature gradients. In cold weather, the cab microclimate can exceed minimum temperature thresholds, allowing for operator adjustment to maintain comfort and performance. These conclusions underscore the necessity for design enhancements in ventilation, air distribution, and temperature control systems to improve operator comfort and safety. While this study provides valuable information on the specific microclimate issues in the EKG-12K excavator cab, it confirms the findings of other researchers on the challenges of maintaining an optimal microclimate in heavy equipment cabs. The results of the study emphasise the need for further research and development in the design and optimisation of HVAC systems for these special conditions to ensure operator comfort, safety, and productivity.

## Acknowledgements

None.

## Conflict of Interest

None.

## References

[1] Ansys fluent theory guide. (2021). Retrieved from https://surl.li/tgepdf.

[2] Arora, U., Luebke, A., & Duffy, V.G. (2022). Computer-aided ergonomic analysis for excavator using RAMSIS software. In V.G. Duffy & P.L.P. Rau (Eds.), *HCI international 2022 – late breaking papers: Ergonomics and product design* (pp. 3-22). Cham: Springer. doi: 10.1007/978-3-031-21704-3_1.

[3] Arpino, F., Cortellessa, G., Grossi, G., & Nagano, H. (2021). A Eulerian-Lagrangian approach for the non-isothermal and transient CFD analysis of the aerosol airborne dispersion in a car cabin. *Building and Environment*, 209, article number 108648. doi: 10.1016/j.buildenv.2021.108648.

[4] Aulin, V., & Mahopets, M. (2024). Formation of the microclimate in the cabins of motor vehicles by heaters of various designs. *Central Ukrainian Scientific Bulletin. Technical Sciences*, 9(40(2)), 146-157. doi: 10.32515/2664-262X.2024.9(40).2.146-157.

[5] Bastien, D., & Winther-Gaasvig, M. (2018). Influence of driving rain and vapour diffusion on the hygrothermal performance of a hygroscopic and permeable building envelope. *Energy*, 164, 288-297. doi: 10.1016/j.energy.2018.07.195.

[6] Bonehill, J. (2010). Working environment. In *Managing health and safety in the dental practice* (pp. 240-250). Hoboken: Blackwell Publishing Ltd. doi: 10.1002/9781444324983.ch23.

[7] Doroshenko, V., Yanchenko, O., & Lysyi, M. (2022). Cast modular trawls and promising methods of making castings for earthmoving and tillage equipment. *Journal of Mechanical Engineering and Transport*, 8(2), 23-29. doi: 10.31649/2413-4503-2022-16-2-23-29.
[8] Hou, X., Wang, Y., Liu, S., Chen, X., & Zhang, X. (2021). CFD simulation and test of unconventional pollutant emissions in tractor cab. *Transactions of the Chinese Society of Agricultural Engineering*, 37(24), 22-29. doi: 10.11975/j.issn.1002-6819.2021.24.003.
[9] Hwang, J.H., Jeong, C.S., Ko, J.H., & Yang, S.Y. (2013). A study on air-conditioning system for excavator using forced exhaust. *Journal of Drive and Control*, 10(2), 23-29. doi: 10.7839/ksfc.2013.10.2.023.
[10] International Standard (ISO) No. 10263-4 "Earth-Moving Machinery – Operator Enclosure Environment". (2009, February). Retrieved from https://www.iso.org/standard/42456.html.
[11] Kayar, E.C., & Özcan, H. (2024). Air quality optimization in excavator cabinets using CFD. *Orclever Proceedings of Research and Development*, 4(1), 19-29. doi: 10.56038/oprd.v4i1.436.
[12] Koushik Balaji, K., & Alphin, M.S. (2016). Computer-aided human factors analysis of the industrial vehicle driver cabin to improve occupational health. *International Journal of Injury Control and Safety Promotion*, 23(3), 240-248. doi: 10.1080/17457300.2014.992351.
[13] Lai, Q., Liu, H., Feng, C., & Gao, S. (2024). Comparison of mold experiments on building materials: A methodological review. *Building and Environment*, 261, article number 111725. doi: 10.1016/j.buildenv.2024.111725.
[14] Lan, F., Chen, H., Chen, J., & Li, W. (2023). Effect of urban microclimates on dynamic thermal characteristics of a vehicle cabin. *Case Studies in Thermal Engineering*, 49, article number 103162. doi: 10.1016/j.csite.2023.103162.
[15] Mao, Y., Wang, J., & Li, J. (2018). Experimental and numerical study of air flow and temperature variations in an electric vehicle cabin during cooling and heating. *Applied Thermal Engineering*, 137, 356-367. doi: 10.1016/j.applthermaleng.2018.03.099.
[16] Mehmood, I., Li, H., Umer, W., Arsalan, A., Saad Shakeel, M., & Anwer, S. (2022). Validity of facial features' geometric measurements for real-time assessment of mental fatigue in construction equipment operators. *Advanced Engineering Informatics*, 54, article number 101777. doi: 10.1016/j.aei.2022.101777.
[17] Palega, M., & Rydz, D. (2018). Work safety and ergonomics at the workplace an excavator. *International Scientific Journal "Trans Motoauto World"*, 3(1), 25-29.
[18] Perišić, M., Spasojević-Brkić, V., Mihajlović, I., Brkic, A., & Janev, N. (2024). Excavators' cabins ergonomic design influential factors modelling: Preliminary study. In I.L. Nunes (Ed.), *Human factors and systems interaction*. Nice: Université Côte d'Azur; AHFE. doi: 10.54941/ahfe1005351.
[19] Pirouz, B., Mazzeo, D., Palermo, S.A., Naghib, S.N., Turco, M., & Piro, P. (2021). CFD investigation of vehicle's ventilation systems and analysis of ACH in typical airplanes, cars, and buses. *Sustainability*, 13(12), article number 6799. doi: 10.3390/su13126799.
[20] Qiao, J., Zhang, X., Xiao, F., Li, Y., & Gao, W. (2024). Experimental investigation of mold growth risk among typical residential indoor materials: Case study in coastal city, China. *Energy and Buildings*, 304, article number 113885. doi: 10.1016/j.enbuild.2024.113885.
[21] Shaheed, R., Mohammadian, A., & Kheirkhah Gildeh, H. (2019). A comparison of standard k-ε and realizable k-ε turbulence models in curved and confluent channels. *Environmental Fluid Mechanics*, 19(2), 543-568. doi: 10.1007/s10652-018-9637-1.
[22] Voichyshyn, Yu., Holenko, K., Horbay, O., & Honchar, V. (2023). Methodology of analytical research of the microclimate of the bus drivers cab using the ANSYS-FLUENT software environment. *Scientific Journal of the Ternopil National Technical University*, 109(1), 90-98. doi: 10.33108/visnyk_tntu2023.01.090.
[23] Xu, B., Chen, X., & Xiong, J. (2018). Air quality inside motor vehicles' cabins: A review. *Indoor and Built Environment*, 27(4), 452-465. doi: 10.1177/1420326x16679217.
[24] Yakymenko, I., Lysenko, V., & Witaszek, K. (2022). Methodology of development of intellectual energy efficient system of control of temperature-humidity regime in industrial heat. *Machinery & Energetics*, 13(1), 18-25. doi: 10.31548/machenergy.13(1).2022.18-25.

# Оцінка якості мікроклімату в кабіні екскаватора ЕКГ-12К

**Сергій Сахно**

Кандидат технічних наук, доцент
Криворізький національний університет
50027, вул. Віталія Матусевича, 11, м. Кривий Ріг, Україна
https://orcid.org/0000-0003-3757-2646

**Людмила Янова**

Кандидат технічних наук, доцент
Криворізький національний університет
50027, вул. Віталія Матусевича, 11, м. Кривий Ріг, Україна
https://orcid.org/0000-0001-5050-5881

**Олена Пищикова**

Кандидат технічних наук, доцент
Криворізький національний університет
50027, вул. Віталія Матусевича, 11, м. Кривий Ріг, Україна
https://orcid.org/0000-0002-0843-3498

**Володимир Козаріз**

Кандидат технічних наук, доцент
Криворізький національний університет
50027, вул. Віталія Матусевича, 11, м. Кривий Ріг, Україна
https://orcid.org/0000-0002-7578-6090

**Анотація.** Дослідження вирішує ключові питання будівельної та гірничодобувної галузей, зокрема здоров'я і безпеку операторів, продуктивність, довговічність обладнання, і відповідність нормативним вимогам. Крім того, дослідження зосереджене на управлінні мікрокліматом, ергономіці і технологіях, і може поліпшити безпеку, комфорт, продуктивність і стійкість галузі. Мета – оцінка якості мікроклімату кабіни екскаватора ЕКГ-12К, з акцентом на потоки повітря, температури, комфорт і безпеку оператора. Використовуючи ANSYS Fluent, проведено моделювання мікроклімату в теплих і холодних умовах згідно з міжнародними стандартами. Результати вказують на недоліки вентиляції і кондиціонування. У теплий період розміщення вентиляторів не забезпечує належної циркуляції охолодженого повітря в зоні оператора. У холодних умовах взаємодія вентиляторів з тепловими завісами створює циркуляцію повітря навколо осі на рівні сидіння водія. Температурний аналіз показав, що в теплі періоди температура становить 23-25 °C, хоч це і вимагає значних зусиль системи кондиціонування. У холодні періоди існують зони з температурою до 5 °C, що викликає ризики конденсації і плісняви. Крім того, є занепокоєння щодо циркуляції пилу і ризику руйнування скла через температурні коливання. Висновки підкреслюють необхідність оптимізації мікроклімату в кабіні для захисту комфорту оператора, безпеки і ефективності екскаватора. Практична значимість роботи полягає у наданні рішень для поліпшення безпеки, комфорту, продуктивності і терміну служби обладнання

**Ключові слова:** динаміка повітряного потоку в салоні; оптимізація теплового комфорту; зваженість частинок пилу; моделювання обчислювальної гідродинаміки; ефективність системи вентиляції; аналіз градієнта температури; оцінка ризику утворення конденсату