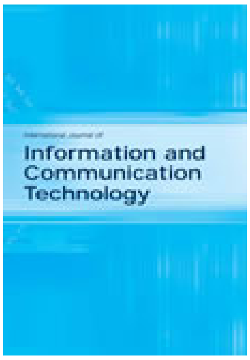


International Journal of Information and Communication Technology

ISSN online: 1741-8070 - ISSN print: 1466-6642
https://www.inderscience.com/ijict

Three dimensional temperature field modelling and simulation for the deicing of post insulators

Shenli Wang, Song Xie, Di Zhang, Jun Wu, Yi Shi, Jin Li, Zhenqiang Liao

DOI: 10.1504/IJICT.2025.10074671

Article History:

Received:	02 January 2025
Last revised:	20 February 2025
Accepted:	20 February 2025
Published online:	17 December 2025

Three dimensional temperature field modelling and simulation for the deicing of post insulators

Shenli Wang, Song Xie, Di Zhang, Jun Wu,
Yi Shi and Jin Li

State Grid Hubei Extra High Voltage Company,
Wuhan, 430050, China
and
Hubei Super-Energic Electric Power Co., Ltd.,
Wuhan, 430050, China
Email: 2470131105@qq.com
Email: 1359556879@qq.com
Email: 1052195360@qq.com
Email: 465100379@qq.com
Email: 1241054924@qq.com
Email: 1545393017@qq.com

Zhenqiang Liao*

Hubei Key Lab of Micro-Nanoelectronic Materials and Devices,
Faculty of Microelectronics,
Hubei University,
Wuhan, 430062, Shanghai, 200240, China
Email: zqliao@stu.hubu.edu.cn
*Corresponding author

Abstract: The icing of pillar insulators in actual substation operating environments can lead to potential hazards such as power outages. Effective deicing of pillar insulators is of great significance. As an emerging deicing method, jet heating deicing lacks existing models. This study innovatively explores the temperature field distribution through advanced numerical simulation methods based on COMSOL, unlike traditional methods that rely mainly on experimental measurements or simple theoretical models. It further describes the process of establishing a three-dimensional model in detail. Through simulation analysis, the three-dimensional temperature field distributions of post insulators under different working conditions or heat source parameters are obtained, visually presenting the change trends and distribution characteristics of temperature. The research results provide a theoretical basis for in-depth understanding of the heat transfer mechanism during the deicing process of post insulators.

Keywords: pillar insulator; three-dimensional temperature field distribution; distribution characteristics; heat transfer mechanism.

Reference to this paper should be made as follows: Wang, S., Xie, S., Zhang, D., Wu, J., Shi, Y., Li, J. and Liao, Z. (2025) 'Three dimensional temperature field modelling and simulation for the deicing of post insulators', *Int. J. Information and Communication Technology*, Vol. 26, No. 47, pp.1–19.

Biographical notes: Shenli Wang focuses on the research and application of power transmission line operation and maintenance technologies. His core research directions include transmission line operation and maintenance and intelligent operation and maintenance technology for transmission lines, where he has dedicated efforts to optimising routine inspection processes, developing intelligent monitoring systems, and improving the reliability and efficiency of transmission line operations. His work aims to integrate advanced sensing and data analysis technologies into traditional maintenance workflows, providing technical support for the stable operation of power grids.

Song Xie centres his research on live working technology for transmission lines and intelligent operation and maintenance technology for transmission lines. He has in-depth expertise in designing safe and efficient live working schemes, developing specialised tools for live maintenance, and exploring the integration of intelligent technologies (such as UAVs and robotics) into live operation scenarios. His research contributes to minimising power outages during maintenance, enhancing the safety of on-site operations, and promoting the intelligent upgrading of live working in power systems.

Di Zhang is a Senior Engineer with a focus on intelligent power system design and key technology research for smart grids. His work involves the overall design of intelligent power systems, including the planning of grid structures, the integration of renewable energy resources, and the development of smart grid dispatch and control platforms. He also conducts in-depth research on core technologies of smart grids, such as energy storage integration, demand response, and grid stability control, aiming to build a more flexible, efficient, and sustainable modern power system.

Jun Wu, a Senior Engineer in the power industry, specialises in transmission line live working technology and intelligent operation and maintenance technology for transmission lines. His research focuses on solving practical challenges in live working, such as adapting to complex terrain and extreme weather conditions, and optimising the performance of live working equipment. He also explores the application of AI and digital twin technologies in transmission line inspection and maintenance, striving to realise the automation and intelligence of live operation and maintenance processes.

Yi Shi is a Senior Engineer dedicated to key technology research for smart grids and intelligent power system design. His research interests cover the development of smart grid communication networks, the application of big data analytics in power system management, and the design of microgrid systems for distributed energy integration. He works to promote the innovation and industrialisation of key smart grid technologies, supporting the transformation of traditional power grids into intelligent, green, and user-centric energy systems.

Jin Li focuses on transmission line operation and maintenance and intelligent operation and maintenance technology for transmission lines with extensive experience as a Senior Engineer. His research involves the development of condition-based maintenance strategies for transmission lines, the improvement of fault diagnosis accuracy using advanced sensor technologies, and the construction of digital management platforms for transmission line assets. His work aims to reduce maintenance costs, extend the service life of transmission line equipment, and ensure the safe and stable operation of the power transmission network.

Zhenqiang Liao is currently a Master candidate majoring in Electronic and Information Engineering at Hubei University. His research focuses on 3D reconstruction technology.

1 Introduction

Electrical energy is one of the most commonly used energy in our production and life. In recent years, Chinese power industry has developed rapidly, and the normal and safe operation of the power grid is the basis for providing stable, continuous, and reliable power supply. In the field of thermal analysis of power equipment, relevant studies provide important support for theories and applications. Arjona et al. (2012) constructed a two-dimensional thermal fluid transient characteristic-based-split finite element model for distribution transformers, which offers an accurate finite element method reference for the numerical simulation of thermal fluid fields in power equipment. Houda et al. (2017) established a model for simulating complex urban flow based on CFD and COMSOL, and their experiences in modelling ideas and boundary condition handling provide cross-domain methodological references for the simulation of hot gas flow during insulator deicing. Khaleel et al. (2024) realised the simulation and experimental validation of a high-efficiency induction heating system using COMSOL, and their research paradigm provides a technical path for the simulation of heating systems for insulator deicing. Scholars such as Liu et al. (2020) have used COMSOL software to conduct simulations of the transformer temperature field. This has laid a practical foundation for the application of this software in this field and opened up new research perspectives. When exploring the issue of how contamination affects the performance of insulators, many scholars have carried out analyses from different dimensions. For example, Raya et al. (2023) have provided diverse ways of thinking for a comprehensive understanding of the insulator contamination phenomenon. Regarding the complex phenomenon of insulator icing, researchers like Zhang et al. (2024) have conducted in-depth analyses of its icing conditions and processes. This has greatly enhanced our understanding of the icing characteristics of insulators and provided a solid basis for subsequent related research. In the research on insulator heating and cleaning technologies, on the one hand, scholars such as Kovac and Melnykov (2021) have used COMSOL to simulate induction heating. On the other hand, Li et al. (2024b) have introduced the method of laser cleaning of insulator contamination. These two aspects have jointly enriched the research directions in this field. In terms of the pipeline heat transfer model, scholars such as Chen and Pan (2021) have constructed models that can effectively simulate the heat transfer process. This provides a clear reference framework for understanding the complex heat transfer mechanism. In the comparative study of insulator temperature measurement methods, Liu et al. (2023) have conducted a systematic and in-depth discussion on a variety of measurement methods, providing scientific guidance for the selection of appropriate measurement methods. When analysing the transient temperature rise process of insulators under the action of heat sources, the research results of Zhang et al. (2022) provide strong support for researchers to grasp the dynamic changes of the thermal process. When simulating the low-temperature fracture of insulators, Li et al. (2024a) have provided detailed and crucial information, which helps to gain an in-depth understanding of the mechanical properties of insulators in extreme environments. In the study of the environmental temperature field distribution during laser cleaning of insulators, Ma et al. (2021) have given targeted analyses, providing important basis for optimising the laser cleaning process. In addition, Ramachandran et al. (2022) have constructed different fluid models based on COMSOL. Their research results provide effective means for simulating complex fluid phenomena.

In summary, these studies have conducted comprehensive and in-depth explorations of insulator-related aspects such as temperature measurement, thermal process simulation, and fluid model construction from multiple dimensions. They have provided rich and solid knowledge bases for the research in this paper and strongly promoted the development and progress of research in this field.

Existing studies on insulator deicing may have limitations such as using one-dimensional or two-dimensional models that cannot fully capture the complex three-dimensional heat transfer and fluid flow phenomena. Some methods also neglect the influence of environmental factors on the deicing process. FEM, FDM, FVM, and CFD each have limitations like high complexity, poor handling of complex regions, or high learning costs. Convective, conductive, and radiative heating tests also have drawbacks such as high costs or low-precision control. This paper's use of COMSOL Multi-physics software offers multi-physics field coupling, efficient modelling, and easy parameter adjustment, better supporting insulator jet temperature field simulations and deicing strategy optimisation. COMSOL's powerful multi-physics field coupling capabilities allow us to simultaneously simulate the fluid flow of hot gas from the deicing nozzle (using the 'fluid flow' module) and the heat transfer during jetting (using the 'heat transfer' module). This enables a more realistic representation of the actual deicing process. For example, by accurately setting the boundary conditions and material properties, we can precisely analyse how different environmental temperatures, outlet wind speeds, and outlet temperatures affect the temperature field around the insulator. This comprehensive simulation approach provides a more accurate prediction of the deicing effect, which is crucial for optimising deicing strategies.

Aiming at the deicing problem of post insulators, this paper constructs a three-dimensional temperature field model using the COMSOL software and conducts simulation analysis. It elaborates on the model establishment process in detail, including key steps such as geometric modelling, setting of material properties, determination of physical fields, definition of boundary conditions and meshing. Through solving the model, the three-dimensional temperature field distribution on the insulator plane during the deicing process is obtained. The results are visually displayed and deeply analysed, and the influences of different factors on the deicing temperature field are discussed, providing theoretical basis and data support for the research and application of the deicing technology for post insulators.

2 Experimental method

2.1 Plan and steps

Based on the structural parameters of the actual post insulator, use the geometric modelling module of COMSOL to construct its three-dimensional model. The deicing nozzle is of a circular tube type and is modelled according to the actual parameters. During the modelling process, fully consider the symmetry and simplicity of the model. On the premise of ensuring that it can reflect the actual physical process, reduce the complexity of the model and improve the computational efficiency. With the help of the 'fluid flow' module, the turbulent model when the nozzle sprays hot gas can be simulated, and the flow field and pressure field of the fluid can be simulated, such as the influence of different forms on the flow velocity. Use the 'heat transfer' module to simulate the fluid heat transfer model during jetting. The wind speed and temperature distribution from the nozzle to the insulator mainly utilise the turbulent model and fluid heat transfer module of COMSOL multi-physics. The experimental steps are as follows:

1 Model two different types of nozzles according to the experiment, construct model parameters, and set material parameters and variables.

2 Set the environmental temperature, including temperature and air pressure; set the temperature and wind speed at the air outlet; set the boundary conditions.

3 Conduct a steady-state analysis of the model.

2.2 Parameter settings

2.2.1 Geometric modelling

Construct the shape of the air outlet and the air domain as shown in Figures 1 and 2. The length of the cuboid is 3,000 mm, which represents the distance of 3 m between the nozzle and the deicing working surface of the insulator. The small circle or small rectangle in the large cuboid represents the gas outlet of the nozzle, from which the gas is ejected. Since the attenuation on the side of gas-jetting is relatively large, only a square with a side-length of 0.2 m is set for observation. The nozzles are set as a circle with a radius of 25 mm and a rectangle with a length of 50 mm and a width of 25 mm respectively.

Figure 1 Circular nozzle geometric model with a radius of 25 mm (see online version for colours)

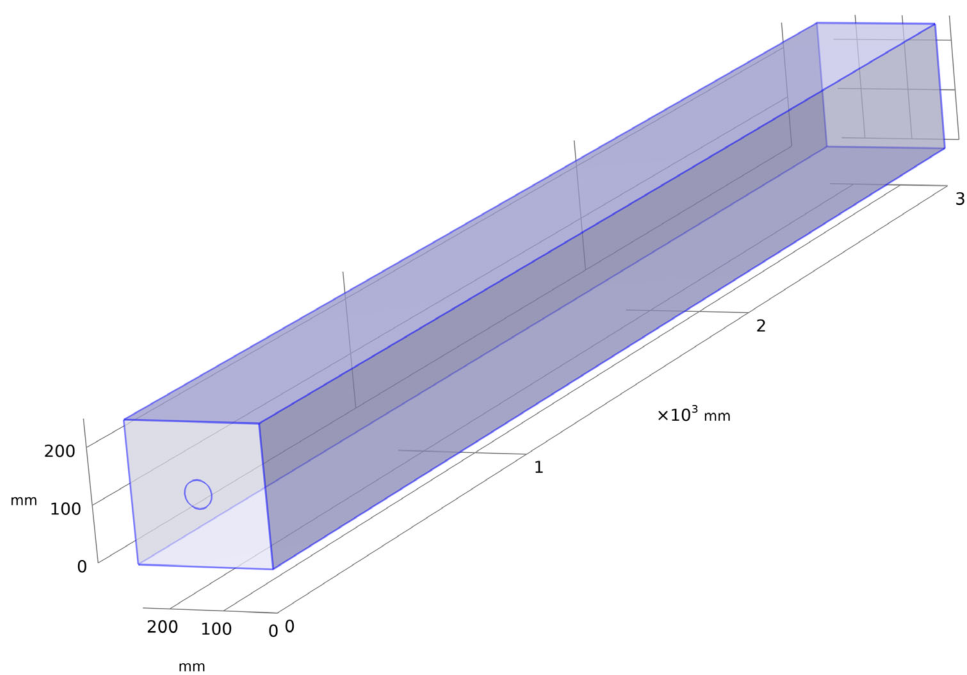
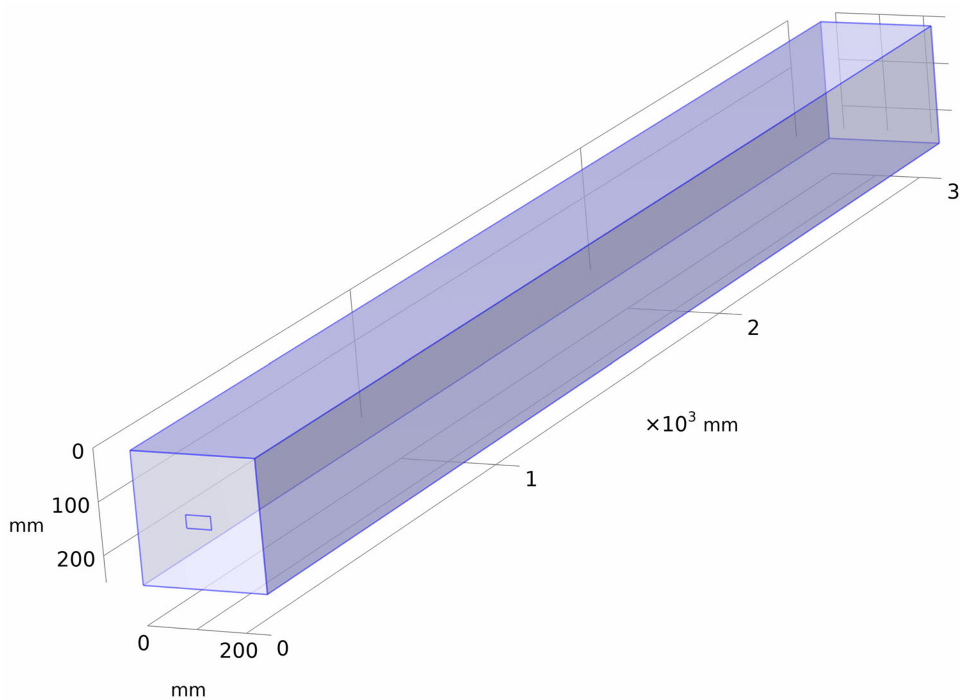


Figure 2 Square nozzle geometric model with a length of 50 mm and a width of 25 mm (see online version for colours)



2.2.2 Materials and environmental parameter

In this experiment, the gas sprayed from the nozzle is hot air, and the 'air' material that comes with the model is selected for simulation and analysis. This material selection is based on its ability to accurately reflect the physical properties of actual hot air in the experimental environment. At the same time, it is also convenient to utilise the pre-set relevant parameters and attributes of the model, reducing the complex parameter settings and uncertainties brought about by custom-defined materials.

The environmental temperature is set as a variable, with the unit being degrees Celsius (°C). This setting provides great convenience for studying the temperature field distribution of the nozzle under different environmental temperature conditions. In the actual operating environment of a substation, the environmental temperature can change significantly with factors such as seasons, day and night, and weather conditions. This change is likely to have an impact on the heat transfer efficiency of the nozzle and the temperature distribution on the surface of the insulator. By setting the environmental temperature as a variable, the propagation law of heat from the hot air ejected from the nozzle in the air, its mixing situation with the surrounding cold air, and the characteristics of the temperature field finally formed on the insulator surface can be systematically analysed under different temperature conditions.

2.2.3 Setting of boundary conditions

Set the initial conditions of the model. Specifically, set the fluid environment when there is no wind speed interference in the environment and the heat transfer environment when the environmental temperature is low. The details are as follows:

1 For the turbulence model, the entire domain of the model is in a turbulent state. The initial values are that the wind speed in all directions is 0 and the pressure is 0 Pa. The reference pressure level is one standard atmosphere. Enable the effect of gravity and use the RANS turbulence model type.

2 For fluid heat transfer model, the entire domain of the model is for fluid heat transfer. Set the initial temperature to the environmental temperature, and set the inlet temperature as a user-defined variable to simulate the temperature fields under different outlet air temperatures.

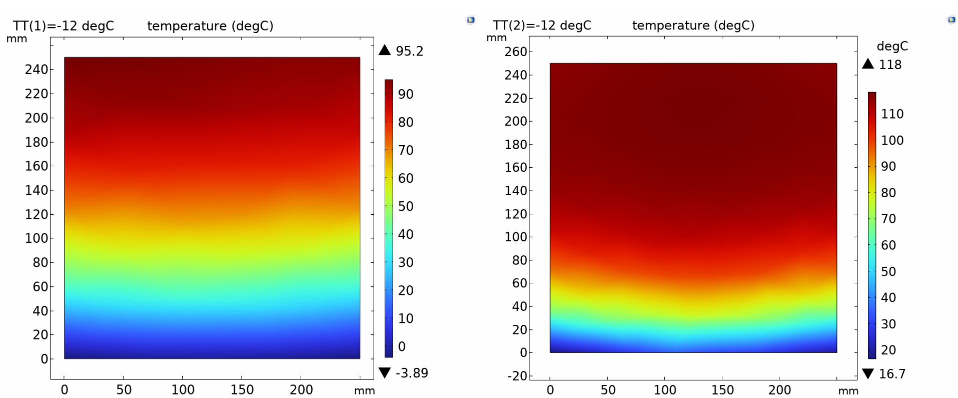
3 Set the boundaries around the four sides and in the distance of the turbulence module as open boundaries. Also set the boundaries around the four sides and in the distance of the fluid heat transfer module as open boundaries, and set the upstream temperature to the environmental temperature.

3 Results and analysis

3.1 The influence of environmental temperature on the temperature field distribution

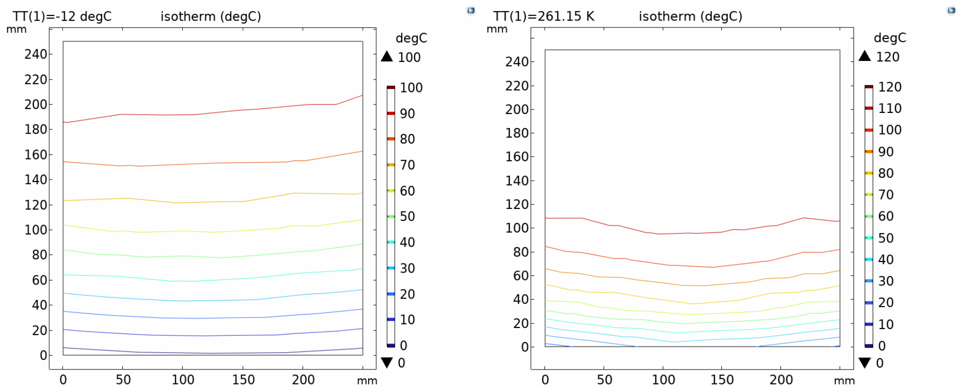
When the wind speed at the outlet of the circular nozzle is 30 m/s, the temperature is 175°C, and the environmental temperature is –12°C, the temperature three metres away from the outlet of the circular nozzle is shown in the figure. On the left is the temperature distribution diagram and isothermal line diagram of the circular nozzle at a distance of three metres, and on the right is that of the square nozzle.

Figure 3 Temperature distribution of the circular nozzle (left) and square (right) at a distance of three metres (see online version for colours)



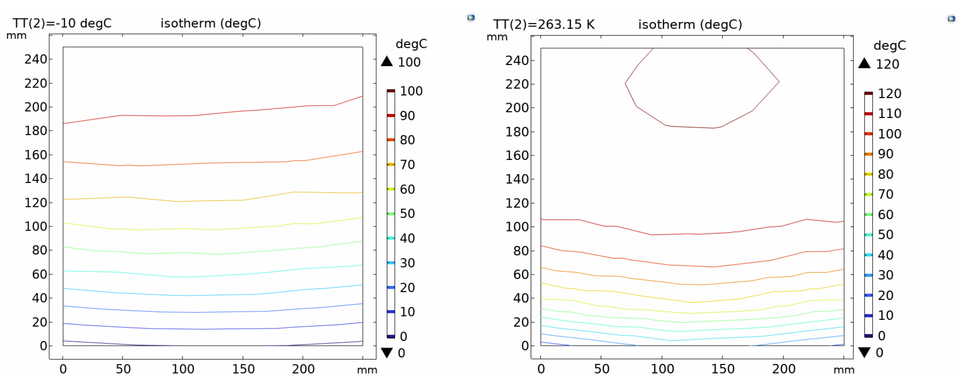
(a) (b)

Figure 3 Temperature distribution of the circular nozzle (left) and square (right) at a distance of three metres (continued) (see online version for colours)

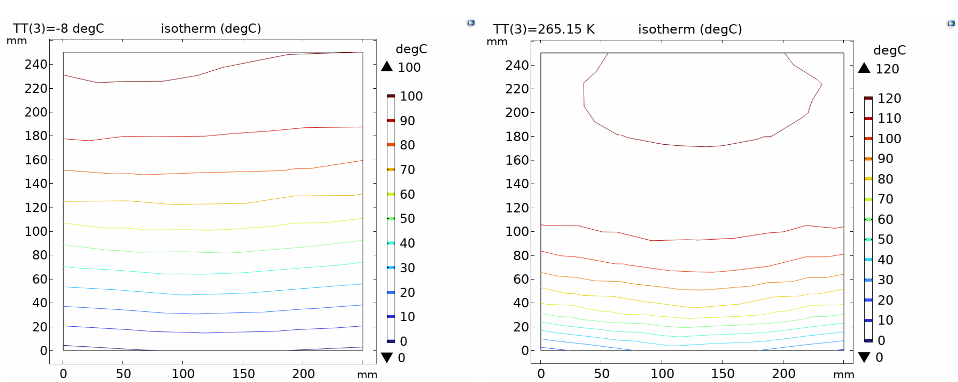


(c) (d)

Figure 4 Temperature distribution of the circular (left) and square (right) nozzle at a distance of three metres when the environment temperature changes, (a) environment temperature is –10°C (b) environment temperature is –8°C (c) environment temperature is –6°C (d) environment temperature is –4°C (e) environment temperature is –2°C (see online version for colours)

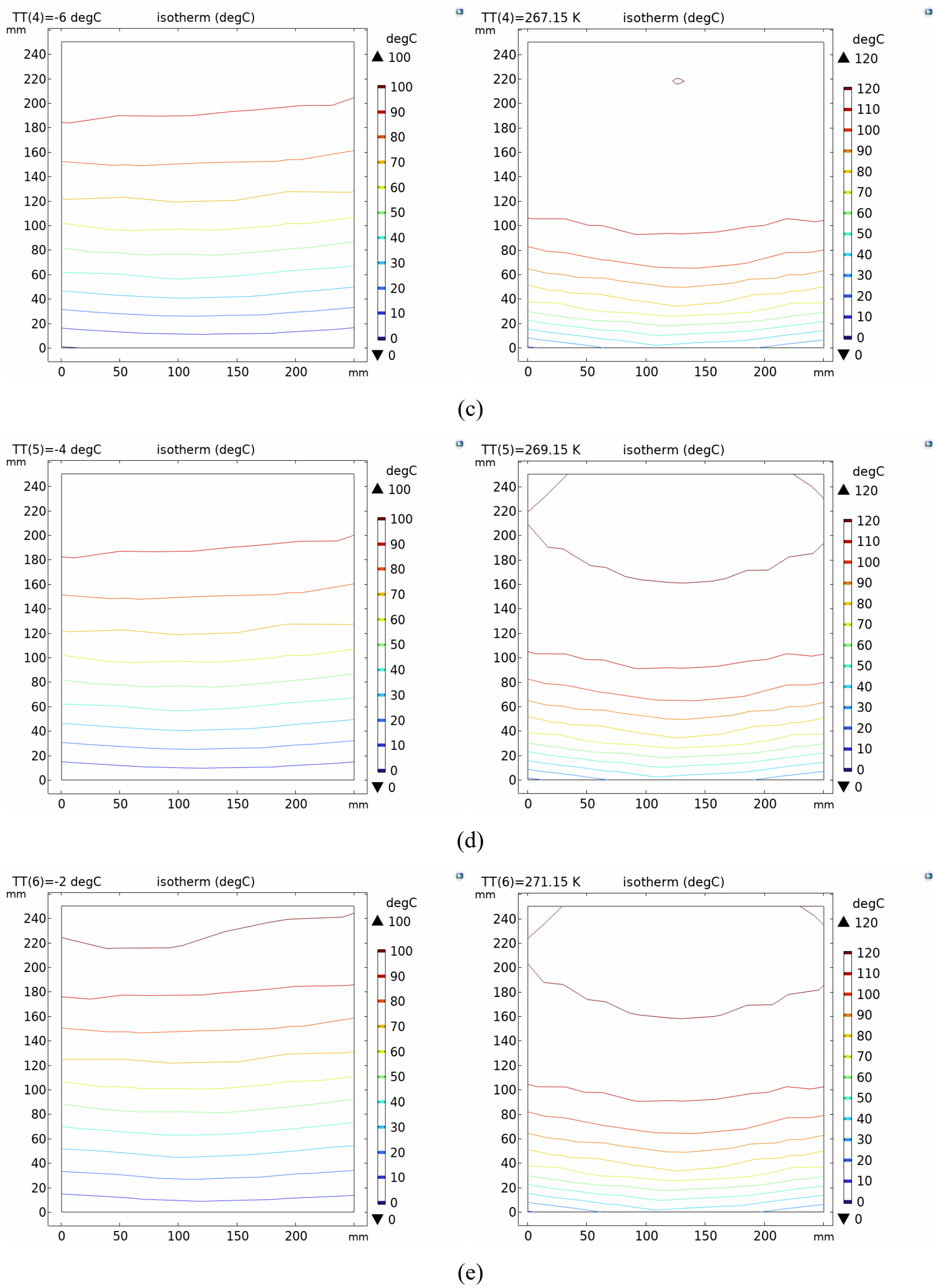


(a)



(b)

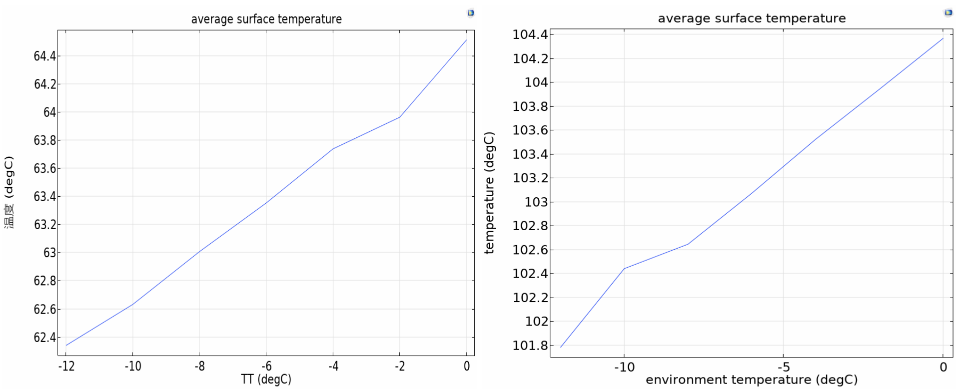
Figure 4 Temperature distribution of the circular (left) and square (right) nozzle at a distance of three metres when the environment temperature changes, (a) environment temperature is –10°C (b) environment temperature is –8°C (c) environment temperature is –6°C (d) environment temperature is –4°C (e) environment temperature is –2°C (continued) (see online version for colours)



Under different environmental temperatures, the distribution of isotherms is shown in Figure 4.

The average temperature on the surface is in Figure 5.

Figure 5 The average temperature of the circular (left) and square (right) nozzle at a distance of three metres when the environment temperature changes (see online version for colours)



When the environmental temperature gradually rises from –12°C to –2°C, the isotherms representing higher temperatures only show a very slight downward trend. This means that when the wind speed at the outlet of the circular nozzle remains unchanged at 30 m/s, the change in environmental temperature has a relatively weak impact on the temperature distribution three metres away from the nozzle. In other words, under this specific wind speed condition, when the environmental temperature varies within the range from –12°C to –2°C, it does not cause significant changes to the temperature field distribution three metres away from the circular nozzle.

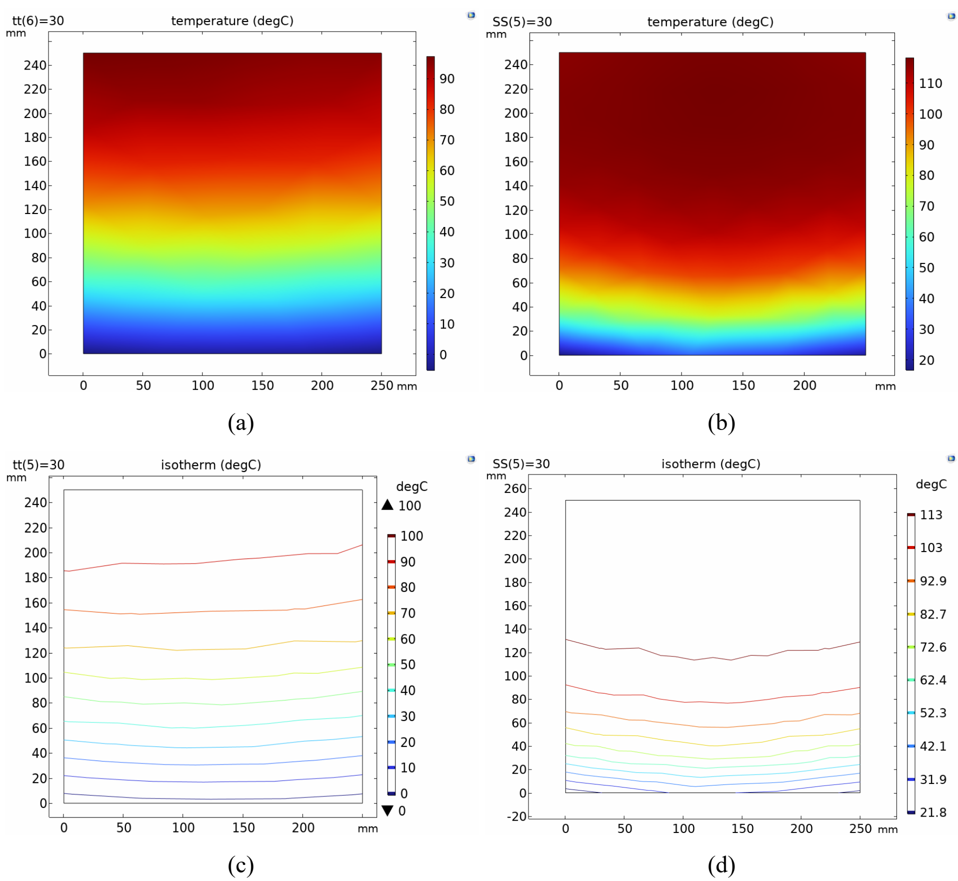
Figure 5 shows the changes in the average surface temperature at a distance of three metres from the circular and square nozzles when the environmental temperature gradually rises from –12°C to –2°C. It can be seen from the figure that the average temperature generally shows a slightly downward trend, but the change is minimal. This is consistent with the description in the paper that “when the environmental temperature gradually rises, the isotherms representing higher temperatures only show a very slight downward trend.” It indicates that under the condition that the outlet wind speed of the circular nozzle remains at 30 m/s, the change in environmental temperature within this range has a relatively weak impact on the temperature distribution at a distance of three metres. The same pattern is also observed in the square nozzle, suggesting that the temperature field distributions of both are less affected by fluctuations in environmental temperature.

Compare these results of the square holes with the experimental results of the circular holes obtained previously. It can be found that whether it is the circular holes or the square holes, when the wind speed at the outlet remains at 30 m/s, as the environmental temperature changes within the range from –12°C to –2°C, there is no significant change in the distribution of their temperature fields. In other words, under this specific wind speed condition, the fluctuations in environmental temperature have a relatively small impact on the temperature fields of both the circular holes and the square holes at a distance of three metres, and this phenomenon shows consistency in holes of these two different shapes.

3.2 The influence of outlet wind speed on the distribution of temperature field

When the circular nozzle is at an environmental temperature of –14°C, an outlet temperature of 175°C and an outlet wind speed of 30 m/s, the temperature three metres away from the outlet of the circular nozzle is shown in the figure.

Figure 6 Temperature distribution of the circular nozzle (left) and square (right) at a distance of three metres (see online version for colours)

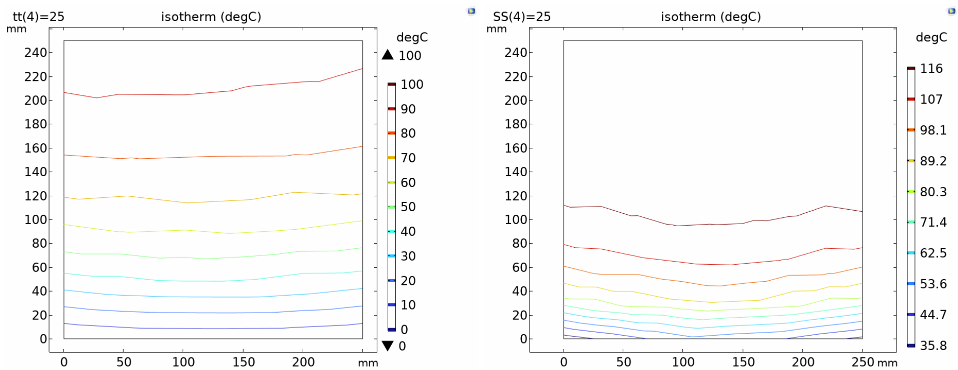


Under different outlet speeds, the distribution of isotherms is shown in Figure 7.

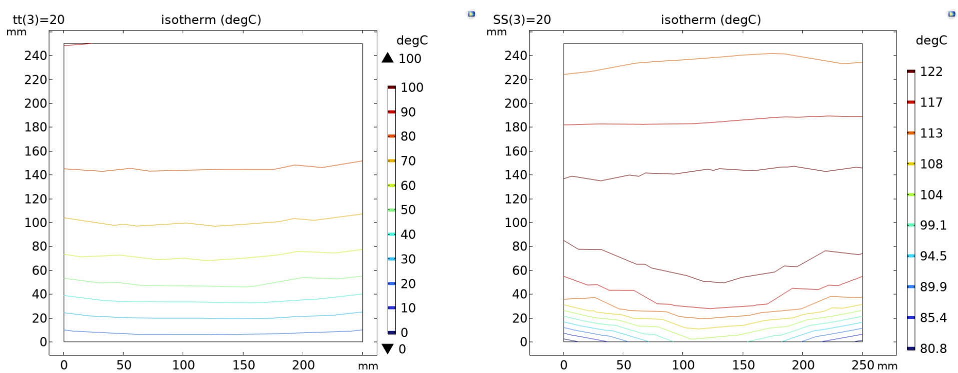
The average temperature on the surface is in Figure 8.

Through careful observation and analysis of the images of the isotherm distribution under these different wind speeds, a pattern can be clearly found: as the outlet wind speed gradually decreases, the isotherms show a tendency to move upward. This means that the high-temperature areas also move upward accordingly. For example, when the wind speed is relatively high (such as 26 m/s), the high-temperature area is at a relatively low position, and when the wind speed drops to 10 m/s, the high-temperature area obviously moves upward to a higher position. This phenomenon indicates that the outlet wind speed has a significant impact on the distribution of the temperature field at a certain distance around the circular nozzle (here, three metres away), and the decrease in wind speed will cause the high-temperature area to have an obvious displacement in the vertical direction.

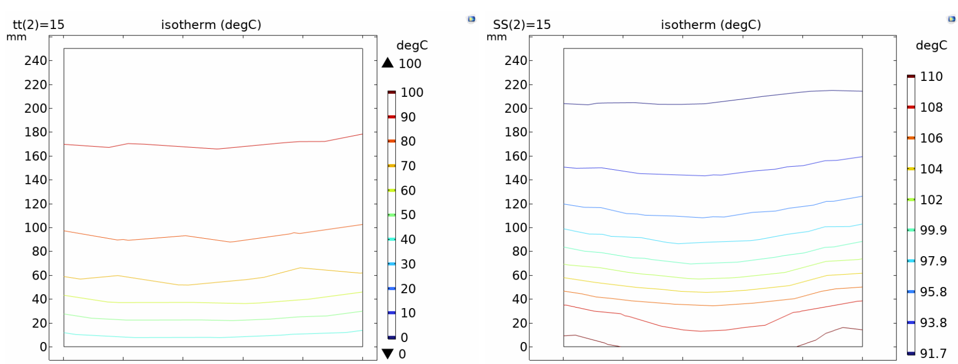
Figure 7 Temperature distribution of the circular (left)and square (right) nozzle at a distance of three metres when the outlet speeds changes, (a) outlet speeds 25 m/s (b) outlet speeds 20 m/s (c) outlet speeds 15 m/s (d) outlet speeds 10 m/s (see online version for colours)



(a)

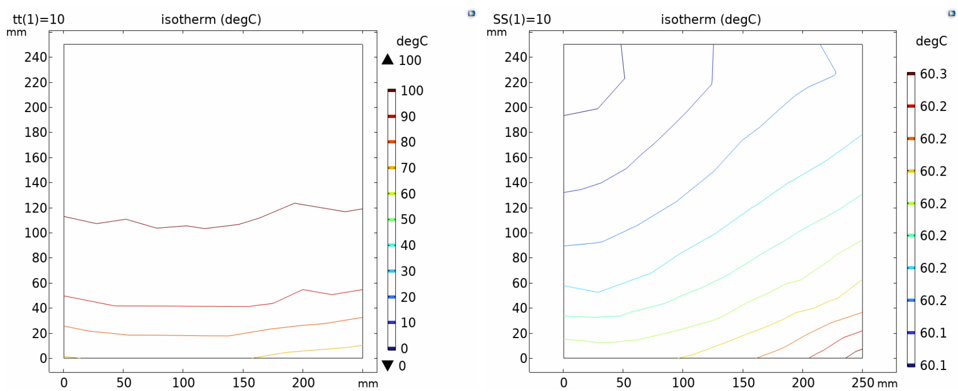


(b)



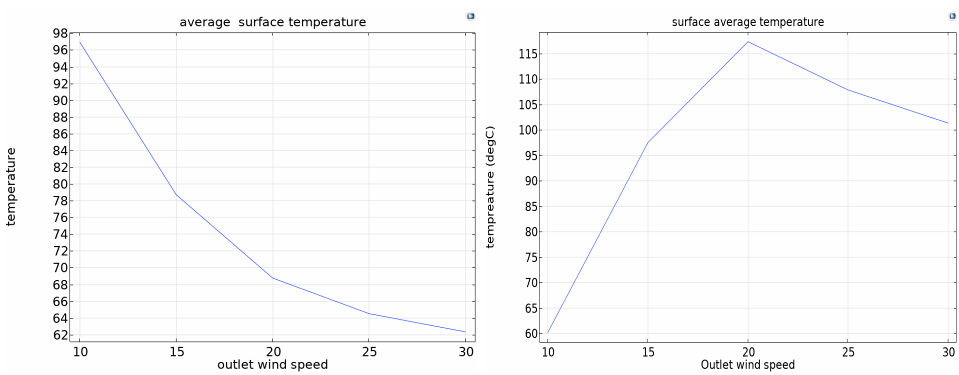
(c)

Figure 7 Temperature distribution of the circular (left)and square (right) nozzle at a distance of three metres when the outlet speeds changes, (a) outlet speeds 25 m/s (b) outlet speeds 20 m/s (c) outlet speeds 15 m/s (d) outlet speeds 10 m/s (continued) (see online version for colours)



(d)

Figure 8 Average surface temperature of the circular (left) and square (right) nozzle at a distance of three metres when the outlet speeds changes (see online version for colours)



By carefully observing these isotherm diagrams that show the temperature distribution of the square-hole nozzles under different working conditions, a phenomenon can be clearly identified. When the outlet wind speed gradually decreases from the critical point of 20 m/s to the range of 15 m/s, the changing trend of the temperature field is extremely significant. Judging from the density of the isotherms and the markings of the represented temperature values, a relatively large attenuation of temperature occurs.

When the wind speed is 20 m/s, the high-temperature area can still maintain a relatively large range and relatively high temperature values. The isotherms are relatively densely distributed around the outlet of the nozzle, indicating that the heat is diffusing outward in a relatively concentrated manner, and the temperature gradient is relatively steep within a certain range, which means that although the temperature drops from the vicinity of the nozzle to a slightly farther position, the decrease is still within a certain range. However, once the wind speed drops to 15 m/s, the isotherms quickly become sparse and contract to a closer distance to the nozzle. The high-temperature area is greatly reduced, and the covered temperature values also drop sharply. The originally continuous isotherms of higher temperatures have multiple breaks or even disappear, intuitively indicating that during this speed change process, a large amount of heat can no longer be effectively diffused as before but quickly dissipates into the surrounding environment, resulting in a sharp reduction in temperature. From this, it can be clearly seen that the variable of wind speed plays a crucial and decisive role in the temperature distribution around the square-hole nozzle. Even slight changes in it can lead to completely different manifestations of the temperature field and profoundly affect the propagation path, range, and final distribution pattern of heat.

Figure 9 Temperature distribution of the circular nozzle (left) and square (right) at a distance of three metres (see online version for colours)

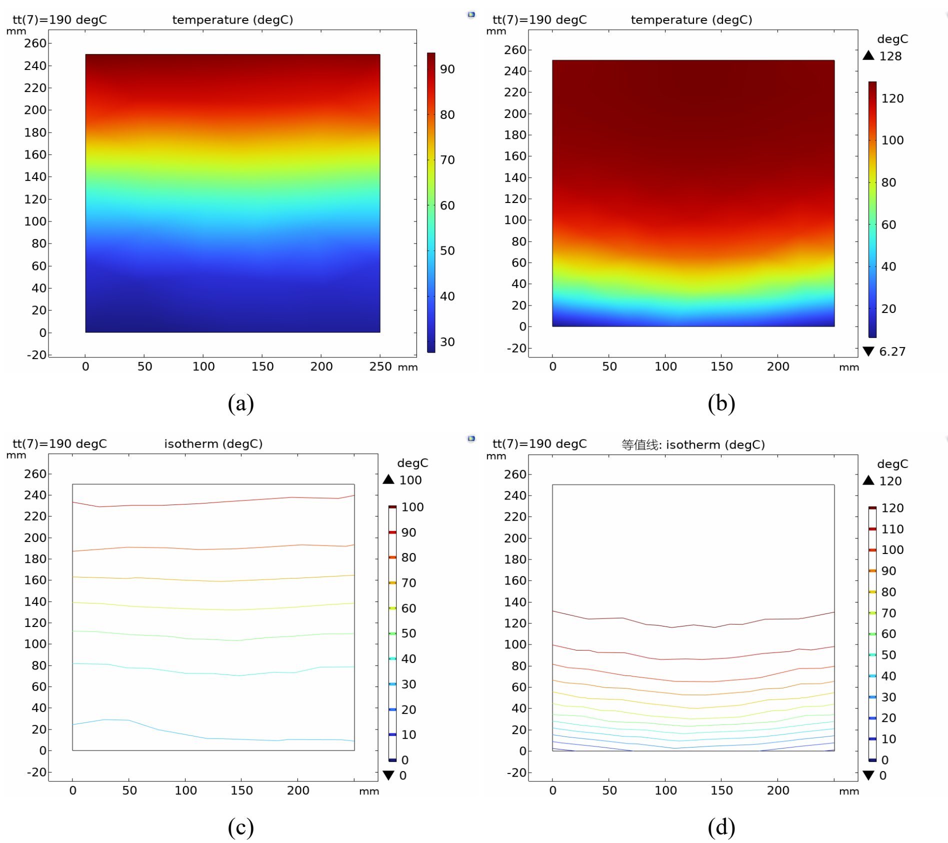
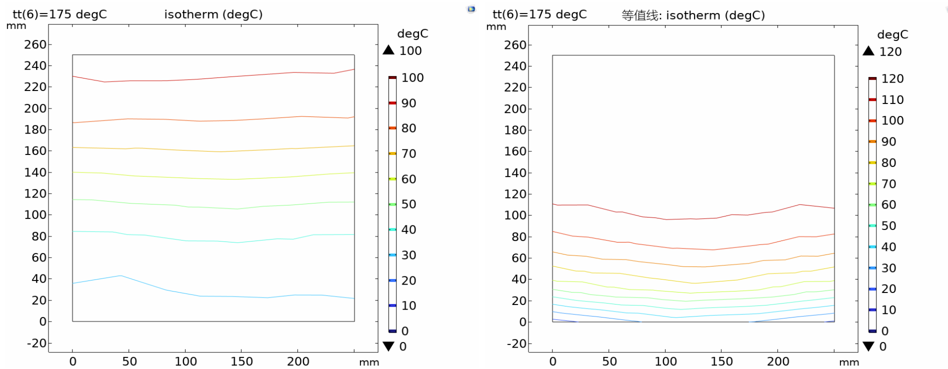
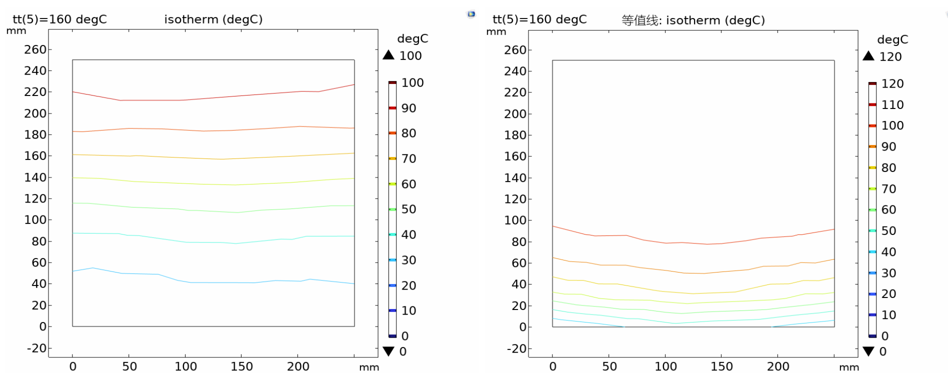


Figure 8 presents the average surface temperature at a distance of three metres from the circular and square nozzles under different outlet wind speeds. As the outlet wind speed gradually decreases from 30 m/s, the average surface temperature of the circular nozzle gradually drops, and the square nozzle shows a similar trend. This indicates that the outlet wind speed has a significant impact on the temperature field distribution. When the wind speed decreases, the amount of heat carried is reduced, resulting in a temperature drop at a distance of three metres. This is consistent with the conclusion that "as the outlet wind speed gradually decreases, the isotherms show a tendency to move upward, and the high-temperature areas also move upward accordingly", further explaining the mechanism of the impact of wind speed changes on the temperature field.

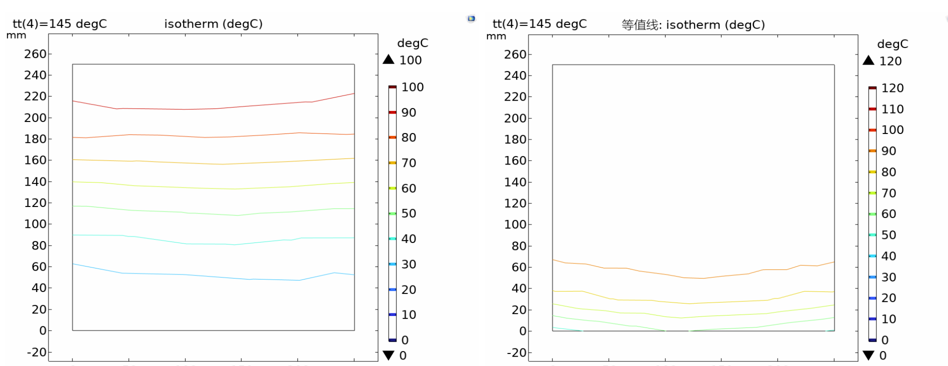
Figure 10 Temperature distribution of the circular (left) and square (right) nozzle at a distance of three metres when the outlet temperature changes, (a) outlet temperature 175°C (b) outlet temperature 160°C (c) outlet temperature 145°C (d) outlet temperature 130°C (e) outlet temperature 115°C (f) outlet temperature 100°C (see online version for colours)



(a)

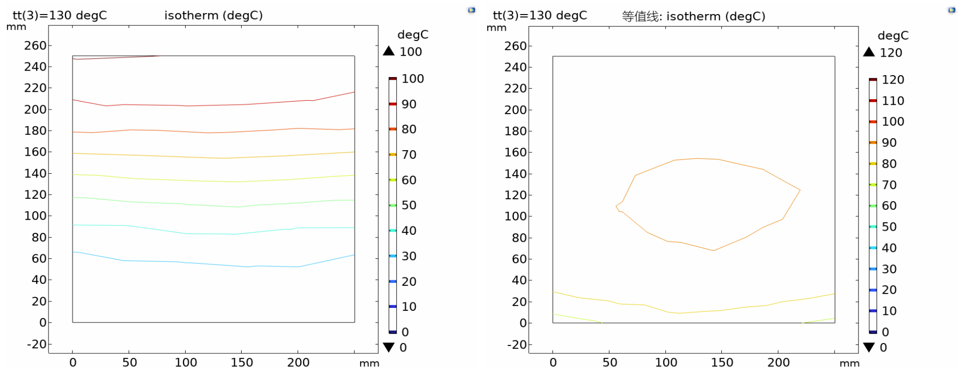


(b)

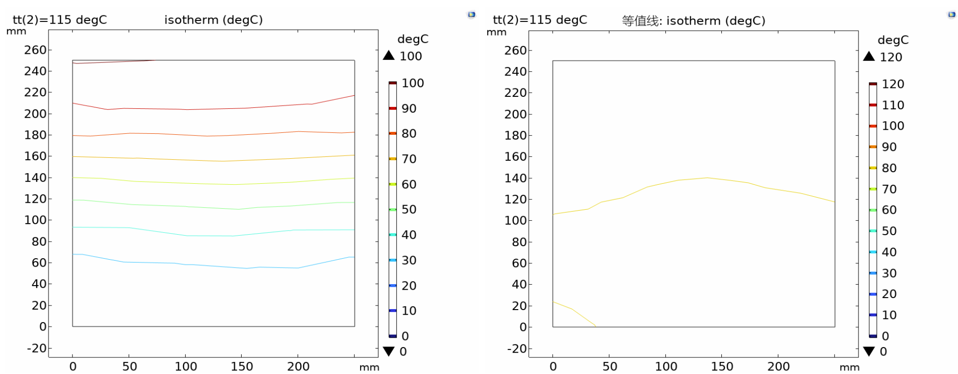


(c)

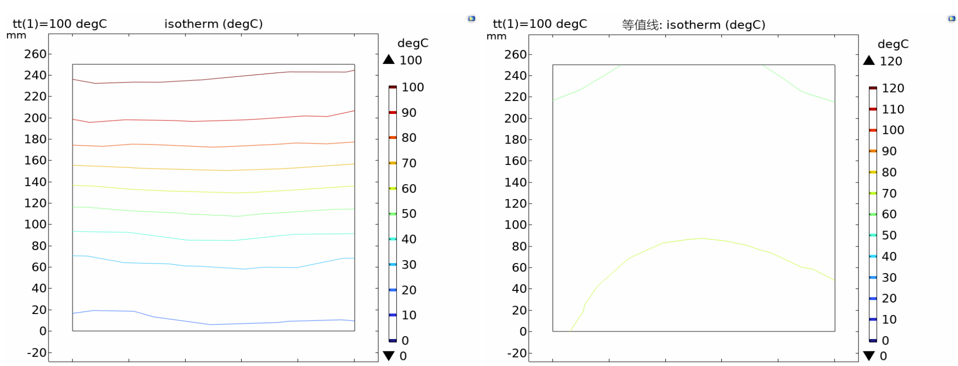
Figure 10 Temperature distribution of the circular (left) and square (right) nozzle at a distance of three metres when the outlet temperature changes, (a) outlet temperature 175°C (b) outlet temperature 160°C (c) outlet temperature 145°C (d) outlet temperature 130°C (e) outlet temperature 115°C (f) outlet temperature 100°C (continued) (see online version for colours)



(d)



(e)



(f)

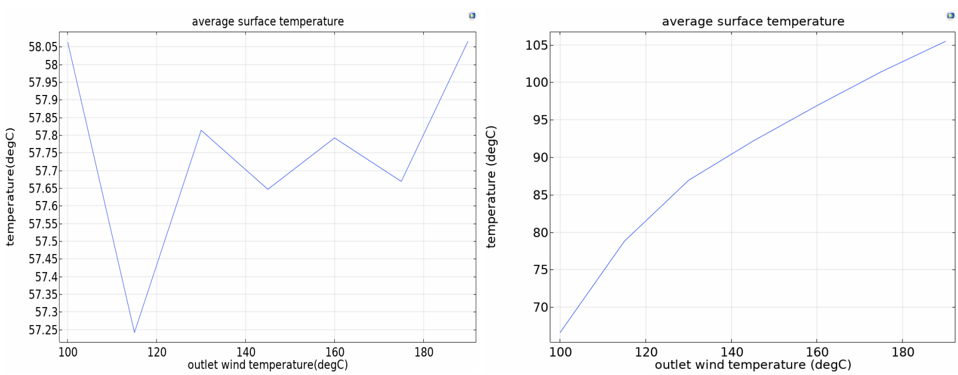
3.3 The influence of outlet temperature on the temperature field

When the temperature of the circular outlet is 190°C, the outlet wind speed is 30 m/s, and the environmental temperature is –14°C, the temperature three metres away from the outlet of the circular nozzle is shown in Figure 9.

Under different outlet temperatures, the isotherms of the temperature field are as in Figure 10.

The average temperature on the surface is in Figure 11.

Figure 11 Temperature distribution of the circular (left) and square (right) nozzle at a distance of three metres when the outlet temperature changes (see online version for colours)



This phenomenon can be directly perceived from a series of isothermal line diagrams of the temperature field at a distance of three metres, which were recorded and drawn under different set outlet air temperature conditions. Even when the outlet air temperature undergoes relatively large adjustments, for example, switching between a certain high-temperature range and a relatively low-temperature range, the distribution patterns of the isothermal lines at the three-metre position do not show significant differences. The density, the trend of the isothermal lines and the ranges of the high-temperature and low-temperature areas outlined by them remain largely similar.

This means that under the specific situation of high-speed outlet air at 30 m/s, the process of heat being carried and diffused outward by the air flow seems to be dominated by the powerful wind speed, weakening the temperature field fluctuations that might be caused by the differences in the outlet air temperature itself. The high-speed air flow enables heat to be dispersed rapidly and relatively evenly in all directions, effectively buffering the drastic changes in the temperature field that should have been caused by fluctuations in the outlet air temperature. As a result, the outlet air temperature can hardly play a key role in shaping the final appearance of the temperature field at the three-metre position, and can only cause extremely slight and hardly noticeable changes.

As the temperature of the air outlet gradually decreases, the isothermal lines in the area at a distance of three metres from the air outlet show a regular downward migration trend.

From the perspective of the basic theories of heat transfer and energy diffusion, when the temperature of the air outlet drops, it means that the total amount of thermal energy initially carried by the air flow decreases accordingly. According to the second law of thermodynamics, heat spontaneously transfers from high-temperature areas to low-temperature areas. In the current situation, as the air flow diffuses into the surrounding environment, the energy available to maintain a relatively high temperature level rapidly decays, making it difficult for the isothermal lines to maintain their original heights. As a result, they show an evolutionary trajectory of gradually descending in spatial positions as the energy decreases.

Figure 11 shows the changes in the average surface temperature at a distance of three metres from the circular and square nozzles when the outlet temperature changes. When the outlet temperature is adjusted within a certain range, the average temperature at a distance of three metres from the circular nozzle changes insignificantly. The average temperature of the square nozzle also changes, but the amplitude is relatively small. This means that under the condition of a high-speed air flow of 30 m/s, the outlet temperature has a relatively small impact on the temperature field far from the circular nozzle. It also has a certain impact on the temperature field of the square nozzle, but compared with factors such as wind speed and environmental temperature, the degree of influence is weaker, reflecting the characteristics of the impact of the outlet temperature on the temperature field under the dominance of high-speed air flow.

In the future work, the models of insulators and their surrounding environment will be refined, considering more practical factors such as surface roughness, ice thickness and shape, as well as humidity, air pressure changes, and natural wind interference. Expand the model to include multi-physics field coupling, like the interaction between the electric field, thermal field, and flow field.

4 Conclusions

This paper focuses on the deicing problem of post insulators and conducts an in-depth study using COMSOL software. Firstly, a three-dimensional model is constructed based on the actual structural parameters of the insulator. Meticulous consideration is given to the symmetry and simplicity of the model, environmental and boundary conditions are reasonably set. The ‘fluid flow’ and ‘heat transfer’ modules are utilised to simulate the hot gas injection process. Subsequently, through steady-state analysis, a comprehensive exploration is carried out on the influence of environmental temperature, outlet wind speed and outlet temperature on the temperature field distribution. When the environmental temperature fluctuates within a certain range, it has a weak impact on the temperature fields outside a certain distance of both circular and square nozzles. The change in outlet wind speed significantly affects the temperature field patterns around the circular nozzle and at a specific distance of the square nozzle. A decrease in wind speed will cause the high-temperature area to shift or the temperature to change drastically. In terms of outlet temperature, under high-speed airflow, it has little effect on the temperature field at a distance from the circular nozzle, while for the square nozzle, as the outlet temperature decreases, the isotherms show a downward trend. These findings provide crucial theoretical bases for optimising the deicing schemes of post insulators.

References

Arjona, M.A., Ovando Martinez, R. and Hernandez, C. (2012) 'Thermal fluid transient two dimensional characteristic-based-split finite-element model of a distribution transformer', *IET Electric Power Applications*, Vol. 6, No. 5, pp.260–267.

Chen, P. and Pan, Z. (2021) 'Heat transfer analysis of flat heat pipe with enhanced microchannel shape', in *IEEE Access*, Vol. 9, pp.120833–120843, DOI: 10.1109.

Houda, S., Belarbi, R. and Zemmouri, N. (2017) 'A CFD COMSOL model for simulating complex urban flow', *Energy Procedia*, Vol. 139.s

Khaleel, D., Tang, X. and Abu-Zaher, M. (2024) 'Advanced simulation and empirical validation of high-efficiency induction heating system via COMSOL multiphysics', *2024 IEEE 10th*.

Kovac, D. and Melnykov, V. (2021) 'Simulation and laboratory model of induction heating in COMSOL multiphysics', *2021 IEEE International Conference on Modern Electrical and Energy Systems (MEES)*, Kremenchuk, Ukraine, pp.1–6.

Li, G., Yue, K., Fan, L., Bi, X. and Han, Z. (2024a) 'Simulation and experimental analysis of insulator fracture failure at extremely low temperature', *2024 IEEE 7th International Electrical and Energy Conference (CIEEC)*, Harbin, China.

Li, X., Qin, Y., Tian, J., Zhou, W. and Ren, B. (2024b) 'Simulation and experimental research on laser cleaning of glass insulators', *Optics & Laser Technology*, Vol. 170, p.110198, DOI: 10.1016.

Liu, R., Jia, R., Shen, H., Zhou, C., Zhang, Y. and Shen, Q. (2023) 'Research on infrared temperature measurement technology of insulators based on reflection temperature compensation method', *2023 IEEE 6th International Electrical and Energy Conference (CIEEC)*, Hefei, China.

Liu, Y., Wang, J., Li, H., Yin, J., Li, X. and Fan, X. (2020) 'Temperature field simulation of transformer based on COMSOL multiphysics', *2020 IEEE International Conference on High Voltage Engineering and Application (ICHVE)*, Beijing, China, pp.1–4.

Ma, Z., Li, X., Tian, J., Wei, C., Zhou, W. and Wang, A. (2021) 'Temperature field distribution characteristics of ceramic insulator during laser cleaning', *2021 3rd Asia Energy and Electrical Engineering Symposium (AEEES)*, Chengdu, China.

Ramachandran, A.V., Zorzano, M-P. and Martín-Torres, J. (2022) 'Numerical heat transfer study of a space environmental testing facility using COMSOL', *Multiphysics, Thermal Science and Engineering Progress*, Vol. 29.

Raya, N.Y., Tumiran and Setiawan, N.A. (2023) 'Temperature analysis of fan-shaped contaminated porcelain insulators using thermal imaging', *2023 International Conference on Advanced Mechatronics, Intelligent Manufacture and Industrial Automation (ICAMIMIA)*, Surabaya, Indonesia.

Zhang, H. et al. (2022) 'Transient temperature rise process of composite insulator under interface and surface heat sources', *2022 IEEE International Conference on High Voltage Engineering and Applications (ICHVE)*, Chongqing, China.

Zhang, Z., Zhang, H., Yue, S., Zhang, X., Li, C. and Zeng, W. (2024) 'Growth characteristics and influence analysis of insulator strings in natural icing', *Electric Power Systems Research*, Vol. 228, Art. No. 110097, DOI: 10.1016.