

# Simulation Study of Dual Source Heat Exchange Evaporator

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**Abstract.** This article proposes a dual source heat exchange (DSHE) evaporator, which adopts a sleeve type heat exchanger design with external fins. A dual source heat exchange evaporator was simulated using Fluent software under different inlet velocity and temperature parameters. Analyzed the simulation results under typical working conditions. The temperature difference between the inlet and outlet of antifreeze is 1.93°C~4.28°C, The temperature difference between the inlet and outlet of the refrigerant is 6.39°C~12.53°C, The temperature difference between the inlet and outlet of air is 0.66°C~1.7°C.

**Keywords:** dual source heat exchanger; heat pump; numerical simulation; heating; energy utilization

## 1. Introduction

Against the backdrop of the global energy crisis, China's coal shortage and other issues are becoming increasingly prominent<sup>[1]</sup>. The environmental pollution caused by coal combustion is becoming increasingly serious, especially during the winter heating period in northern China, where the pollutants and duration caused by coal combustion are more severe<sup>[2]</sup>. According to statistics, the heating area of buildings in northern China reached 20.6 billion square meters, and approximately 400 million tons of standard coal were consumed each year, of which approximately 200 million tons are loose coal, mainly distributed in rural areas<sup>[3]</sup>.

Energy security is the basic guarantee of national security. In order to improve national energy security, the country has actively promoted the transformation of energy structure and vigorously developed the application of renewable energy since the 13th Five Year Plan. The Action Plan for Carbon Peaking before 2030 issued by the State Council in the field of urban and rural construction points out the need to continue promoting clean heating in rural areas. Ten national ministries and commissions have successively issued policy plans to promote clean heating, requiring the completion of clean replacement of heating energy in areas with severe environmental pollution within five years<sup>[4]</sup>. During the 14th Five Year Plan period, the country vigorously developed the rural revitalization strategy. The northern rural areas have a wide area, and improving the rural living environment and developing clean heating are the basic guarantees for people's livelihood. Vigorously developing clean heating in rural areas is of great significance in helping carbon peak and rural revitalization strategies.

Jin Jianguo et al<sup>[5]</sup> The strong heat transfer characteristics of finned condensers in solar air source heat pumps were studied through experiments and numerical simulations. The results indicate that under certain operating conditions, increasing the height and angle of the fins can improve the heat transfer performance of the condenser.

Wei Yongming et al<sup>[6]</sup> A review was conducted on the strong heat transfer theory of solar air source heat pumps. Among them, they analyzed the strong heat transfer mechanism, mathematical model, and numerical calculation method of the solar air source heat pump, and explored the impact of strong heat transfer on the performance of the solar air source heat pump.

Simone Bianchi et al<sup>[7]</sup> By testing the solar air source heat pump system manufactured in the laboratory, the system performance and energy consumption using finned tube evaporators and

finned tube heat storage tanks were studied. The experimental results show that the system can improve the hot water generation rate and heat pump efficiency while reducing energy consumption. This indicates that the application of finned tube heat exchanger design in solar air source heat pump systems is feasible and effective.

Kunio Hijikata et al.<sup>[8]</sup> Using computational fluid dynamics simulation technology, the heat flow pattern inside the solar air source heat pump heat exchanger was analyzed, including the velocity distribution, temperature distribution, and heat transfer coefficient distribution of airflow and liquid flow. This article analyzes the heat transfer performance of a DSHE through simulation, and provides a basis for optimized design and system research.

Cao et al.<sup>[9]</sup> established a two-dimensional physical and mathematical model of the phase change process of a three-tube heat exchanger by using the enthalpy method. Its dynamic characteristics were studied. They numerically simulated the melting process of PCM in a three-tube heat exchanger, and the results show that the heat exchanger is enhanced by the fin structure, and the number, length and thickness of the fins will be affected ring PCM completely melted time.

Bhag et al.<sup>[10]</sup> studied the phase transition process in PCM by using numerical models combined with enthalpy technique. Studies have shown that the number of fins and the thickness of fins significantly affect the heat transfer performance of PCM heat exchangers, while fins of high thermal conductivity materials, and the heat transfer enhancement is negligible.

Gharebaghi et al.<sup>[11]</sup> conducted a corresponding study on the influence of the number of fins on the heat storage performance. Table of findings, and the number of fins is not positively correlated with the heat transfer effect. Increasing the number of fins will reduce the heat of the heat accumulator to some extent flow density.

## 2. Operational Principle

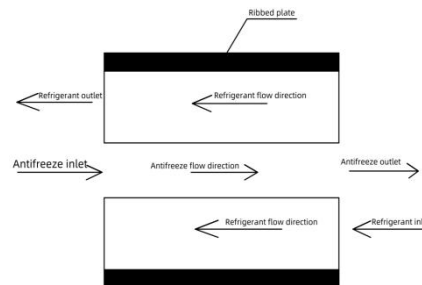


Figure 1 Flow direction diagram of various working fluids in dual source heat exchange evaporator

As shown in Figure 1, the flow direction of each working fluid in the DSHE is shown. The refrigerant flows in from below the outer tube and out from above the outer tube; The antifreeze flows in from above the inner sleeve and out from below, forming a reverse flow between the refrigerant and antifreeze. The DSHE is composed of a tube type heat exchanger with external fins. The inner tube of the tube uses antifreeze as the heat exchange medium to absorb solar heat. The outer side of the tube uses a ribbed heat exchange surface to convective heat exchange with outdoor air. The outer tube is the refrigerant of the heat pump system. The heat pump refrigerant exchanges heat with the air outside the DSHE and the antifreeze in the inner tube through convective heat exchange.

## 3. Building Geometric Models

The antifreeze and refrigerant fluids flow through the inner and outer pipes, and the outer pipe fluid undergoes a phase change process. The inner sleeve uses antifreeze as the heat exchange medium to absorb solar heat, while the outer sleeve is the refrigerant of the heat pump system. The two flow in reverse, and there is also air flow outside the outer sleeve. The physical model of the

serpentine tube dual source heat exchange evaporator established is shown in Figure 2. Table 1 shows the geometric parameters of the DSHE evaporator.

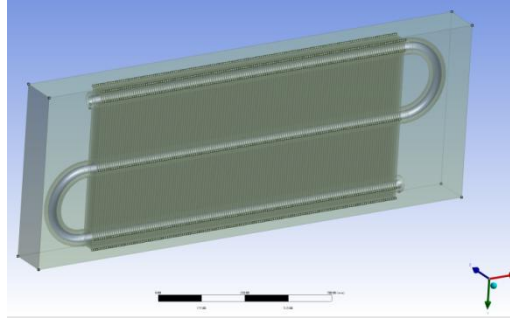


Figure 2 Model diagram of dual source heat exchange evaporator

Table 1 Geometric structure dimension table of dual source heat exchange evaporator

Geometric structure	symbol	numerical value
Snake shaped casing length	$L_1$	1500mm
Inner tube pipe diameter	$R_1$	35mm
Outer tube pipe diameter	$R_2$	70mm
Pipe wall thickness	$d_1$	1mm
Rib spacing	$L_2$	10mm
Rib thickness	$d_2$	2mm
Rib length	$L_3$	690mm
Rib width	$h_1$	70mm
Air domain length	$L_4$	750mm
Air domain width	$H_2$	80mm

#### 4. Initial Simulation Parameters Of Dual Source Heat Exchange Evaporator

This chapter conducts numerical simulation analysis on the serpentine tube dual source heat exchange evaporator. Firstly, the inner tube uses antifreeze ( $C_2H_6O_2$ ) as a heat exchange medium, it absorbs solar heat, the refrigerant inside the outer casing is used for the heat pump system ( $R410A$ ), the two flow in reverse, and there is also air flow on the outer side of the outer sleeve. The range of feed rate and temperature selection for the three is shown in Table 2 below.

Table 2 Temperature and velocity selection table for working fluids

Working fluid	temperature range ( $^{\circ}C$ )	Speed range (m/s)
$C_2H_6O_2$	10~40 $^{\circ}C$	0.3~1.2m/s
$R410A$	-40~-30 $^{\circ}C$	1.2m/s
air	-25~5 $^{\circ}C$	2m/s

#### 5. Simulation Analysis Of Dual Source Heat Exchange Evaporator

The inlet temperature of the antifreeze in the dual source heat exchange evaporator is 20  $^{\circ}C$  with a speed of 1.2m/s, the inlet temperature of the refrigerant is -40  $^{\circ}C$  with a speed of 1.2m/s, and the inlet temperature of the air is -25  $^{\circ}C$  with a speed of 2m/s. By providing inlet velocity and temperature, observe the temperature change at the outlet using Fluent simulation. The simulation results are shown in the figures.

As shown in Figure 3, the temperature variation diagram of the outlet wall surface shows a maximum temperature of 17.99  $^{\circ}C$  and a minimum temperature of 17.87  $^{\circ}C$ . The temperature

fluctuation amplitude is relatively small, only changing within the range of 0.12 °C. The average temperature at the entire outlet is 17.93 °C, and the temperature at the inlet of the antifreeze is 20 °C. Throughout the simulation process, the temperature of the antifreeze has decreased, and the temperature at the inlet and outlet of the antifreeze has a range of 2.07 °C.

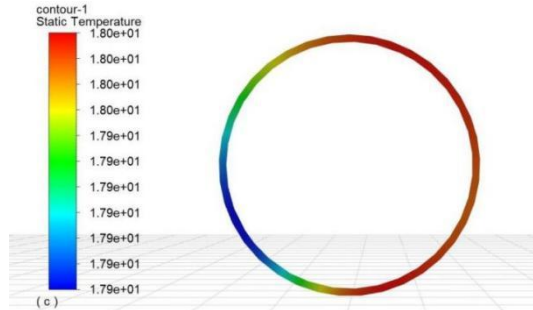


Figure 3 Temperature variation diagram of the outlet wall surface

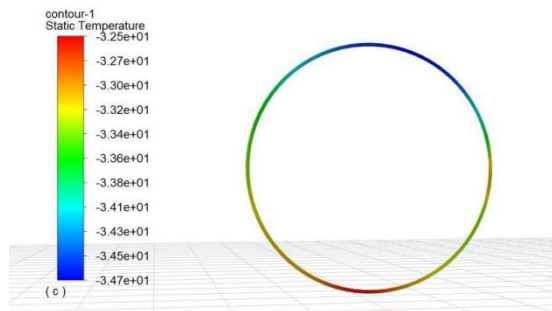


Figure 4 Temperature variation diagram of the wall surface of outlet 2

From Figure 4, it can be seen that the temperature at the air outlet shows a significant change, ranging from -26.32 °C to -24.99 °C, with the highest temperature reaching -24.99 °C and the lowest temperature being -26.32 °C. The overall average temperature is -25.66 °C. Set the temperature at the air inlet to -25 °C, and compare the temperature variation range between the inlet and outlet. The temperature difference between the two is 0.66 °C.

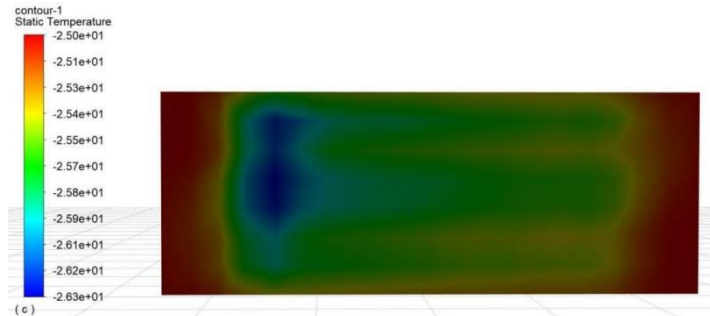


Figure 5 Temperature variation diagram of outlet wall surface

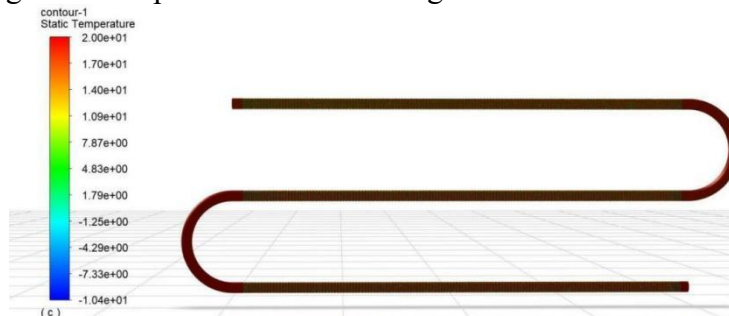


Figure 6 Temperature variation diagram of inner casing

As shown in Figure 5, the temperature distribution inside the inner sleeve shows a large range of changes, ranging from -10.37 °C to 20.04 °C. The minimum temperature change is -10.37 °C, and

the maximum temperature value reaches 20.04 °C. The average temperature inside the inner sleeve is 4.84 °C. The antifreeze and refrigerant flowing in the sleeve form a reverse flow inside the pipe.

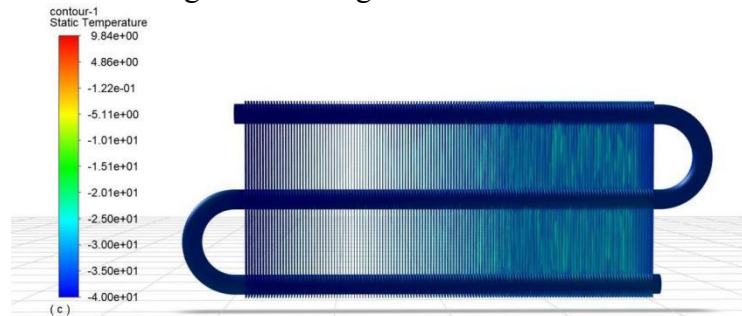


Figure 7 Temperature variation diagram of outer casing under typical working condition one

The temperature change of the outer tube is shown in Figure 6. The refrigerant flowing inside the outer tube is R410A, which forms a reverse flow with the antifreeze inside the tube. The temperature change range inside the outer tube is quite wide, from the lowest -39.99 °C to the highest 9.84 °C. This indicates that during the heat exchange process, the outer tube undergoes significant temperature fluctuations, with the maximum temperature value of 9.84 °C appearing in some local areas where the antifreeze exchanges heat. The minimum temperature value of -39.99 °C reflects the state in which the refrigerant absorbs a large amount of heat during the flow process. The average temperature of -15.08 °C indicates that the outer tube is in a low-temperature state as a whole. The reverse flow design allows the refrigerant and antifreeze to fully contact, thus achieving rapid heat transfer. Transmission improves the heat exchange efficiency of the entire system.

## 6. Conclusion

This article conducts numerical simulation analysis on dual source heat exchange evaporators and investigates the effects of different inlet velocities and temperature parameters on evaporator performance. The simulation results show that the temperature difference between the inlet and outlet of the antifreeze is 2.07 °C, the outlet temperature of the refrigerant increases by 6.39 °C, and the temperature difference between the inlet and outlet of the air is 0.66 °C.

## Acknowledgements

This work was supported by Science and Technology Development Plan Project of Jilin Province(No.20230402065GH) and (No.20240304094SF).

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