Research on the Effects of the Structure of Air Inlets and Outlets of Porcelainous PTC Heater

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***Abstract*—The porcelainous PTC heater is used in electric locomotive cab to improve thermal comfort. In this paper, experiments were taken to test the heat transfer performance of the porcelainous PTC heater in the aspects of heat propagation distance and the interference between air inlets and outlets. The structure of the heater is optimized accordingly. In the operating condition of air outlet louvers angle 30° and air inlet louvers angle 15°, the retrofitted heater not only diminishes the mutual interference of air inlets and air outlets but also extends heat propagation distance.**

Keywords-PTC heater; thermal comfort; louver angle

I. INTRODUCTION

In recent years, with the development of high-speed railway, researchers begin to focus on the cab thermal comfort. Different from the diesel locomotive that uses cooling water from internal combustion engine to heat the cab, the electric locomotive cab mainly uses electric heater to heat the cab. Various vehicle models produced by leading manufacturers around the world are now equipped with PTC auxiliary heaters.[1] In 2007, 65% of all diesel vehicles in Europe were equipped with an auxiliary heater and this is expected to rise to 90% in the future.[2]Train cab heater heating element at this stage is divided into two types, electric heating tube type and porcelainous PTC thermistor. The electric heating tube would cause some problems such as overheating aging and heating power decline after a period [3]. With rapid power increasing, long life and automatic temperature control, the porcelainous PTC thermistor heater gets a wider range of applications [4][5][6] [7]. As PTC technological development, it is likely that lower cost PTC elements will be created which can replace resistance style elements.[8]

When the heater works, the electric is converted into heat energy by porcelainous PTC thermistor. Driven by the cross flow fan, heat is transmitted to cabin mainly in the form of forced convection. Heat transfer performance of the electric heater directly affects drivers' thermal comfort.

But in the actual heating conditions, drivers generally reflect that the heated range is limited, and heat can not be efficiently transmitted to the driver's seat area, resulting in poor heating effect and poor thermal comfort. Therefore, it is necessary to research the effects of the structure of air inlets and outlets.

II. EXPERIMENT DEVICE AND STRUCTURE OF HEATER

In this experiment, the heater is placed in the experimental platform in a sealed room. The height relative to ground of the heater is the same as the relative height of heater in the locomotive cab in order to simulate the heater in the cabin. Series power meter and voltage regulator in the circuit to determine the power change of the heater. The temperature of the heater was measured by K thermocouples, and the thermocouples are connected to a static strain test system as data collection.

The heater is divided into several parts, such as PTC heating element, external shell, internal air duct and so on. The fresh air is drained into the heater through the cross flow fan and the air duct, and the air is heated by PTC heating element, and is finally flew out from the air outlet.

Compared with the original heater, the retrofitted heater's outlet and inlet louver angle can be adjusted, which can change the wind direction into and out of heater. Study the influence of the wind angle on the temperature field, and the improvement of the thermal short-circuit effect. Grille consists of three louvers, so the grille air has a larger width, which has a good diversion effect in adjusting angle.

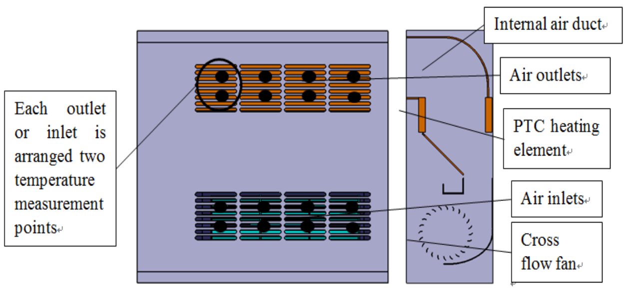

FIGURE I. STRUCTURE OF HEATER AND TEMPERATURE SENSORS ARRANGEMENT.

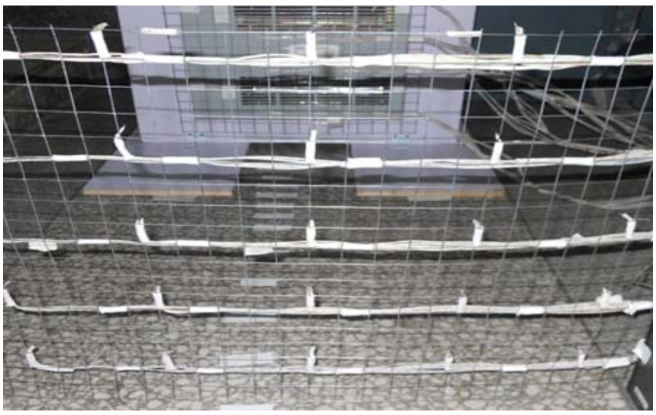

FIGURE II. THERMOCOUPLE TEMPERATURE MEASUREMENT NETWOR.

III. TEMPERATURE SENSOR ARRANGEMENT

As shown in Figure I, air outlets in the upper part of the heater are consist of four columns, each 8 length 60mm, width 5mm grids. Adjacent grids are 4.3 mm apart from left to right, are 3.14 mm apart from top to bottom. To measure temperature variation regularity of air inlets and outlets, Each column grid (from top to bottom) from the third and sixth grid center arrange two thermocouples; The structure and the thermocouple distribution of air inlets and outlets are same. 16 thermocouples are arranged in the outlet and return air outlet area. In outlets, the first right column of thermocouples upper position is measure point 1, lower position is measure point 2, and so on. In inlets, the first right column of thermocouples upper position is measure point 9, lower position is measure point 10, and so on.

In order to compare the experimental data from different operating conditions, when test the retrofitted heater, arrange thermocouples in the same position of those in the original heater. Meanwhile, in order to understand the effect of heating space, make thermocouple network, to measure air temperature 5cm, 10cm, 15cm, 20cm, 25cm, 30cm, 40cm, 50cm, 60cm, 70cm, 80cm in front of heater. There are 25 thermocouples on the thermocouple temperature measurement network.

Adjacent thermocouple are 12.5 cm apart from left to right, are 10 cm apart from top to bottom. The first up row of thermocouples from right to left are measure point 21, measure point 22, and so on. measure point 33 is aligned with the center of the heater.

IV. RESULT OF EXPERIMENT

A. *Experiment of Temperature Variation Regularity of Air Inlets and Outlet*

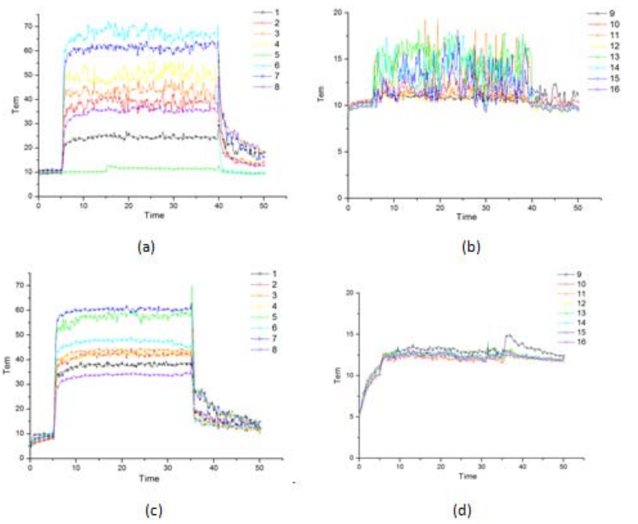

FIGURE III. TEMPERATURE VARIATION REGULARITY OF AIR INLETS AND OUTLETS.

Figure III shows the temperature variation regularity of air inlets and outlets of original heater and retrofitted heater with time. In the first 5 minutes heater does not work. Between 5 to 35minutes heater works. Between 35 to 50minutes heater stops heating.

As shown in Figure III(a), at the first 5 minutes, origin heater does not work. Ambient temperature is measured by thermocouple , which is stabilized at about 10℃. At fifth minute PTC heater start heating, the temperature of each measure point rising rapidly, and fluctuate near their maximum temperature. The point of maximum temperature fluctuations is measure point 7, and the difference between the lowest temperature and the highest temperature is 6.50℃. The higher temperature measure points are measure point 4(50.03℃), measure point 6(67.71℃), measure point 7(61.29℃). The Arithmetic mean difference of each temperature in measure point is 14.05.The main reason of temperature fluctuations in heating process is that, after blowing over PTC heating element, the flow of air is turbulent flow state, which leads to temperature of air that flow through the same temperature thermocouple position not exactly the same. In addition, because of the uneven temperature of PTC heating element, the uniformity of the wind temperature has a negative effect. After the cessation of heating the temperature quickly reduced to around 25℃, and then decreased slowly. The reason is that after fan stop running, lead to shed PTC heat can not be timely through the form of convection, and the temperature of the air around the point temperature rises. As shown in Figure III(c), the temperature variation regularity of air inlets and outlets in retrofitted heater is almost same. Each temperature measuring point measures temperature difference value are smaller, and the fluctuations are smaller. The Arithmetic mean difference of each temperature in measure point is 7.14.

As shown in Figure III (b), when the original heater is working, temperature of air near the outlets fluctuated remarkably. The difference between measured maximum temperature with minimum temperature is about 9℃. This phenomenon shows that the high-temperature air is close to inlets in original heater. Under the action of negative pressure, high temperature air is sucked into inlets before it heat the cabin. That is, the obvious phenomenon of the heat short circuit occurs. Figure III (d) shows temperature of air near the outlets in the retrofitted heater fluctuates, but the fluctuation range decreased obviously, which means heat short-circuit phenomenon basically eliminated.

B. *Experiment of Temperature Variation Regularity with Change of Heating Distance*

Figure IV(a) shows temperature variation regularity of measure point 21-30 with change of heating distance. As measure point 21-30 are above the inlets and outlets of original heater, the temperature are always near the ambient temperature.

Figure IV(b) shows temperature variation regularity of measure point 31-40 with change of heating distance. Measure points 33-35s' temperature fluctuations is very intense, especially within the range of the range of 30cm. However, with the mixing of cold air, the temperature gradually drops. Because measure points 31 and 35 are relatively far from the outlets, there is no effect of the high temperature air in the area.

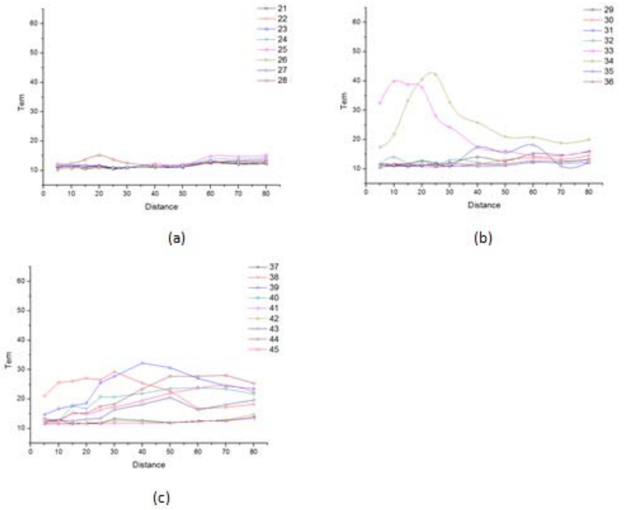

FIGURE IV. TEMPERATURE VARIATION REGULARITY OF ORIGINAL HEATER.

Figure IV (c) shows temperature variation regularity of measure points 41-45 with change of heating distance. The temperature at point 38 is the highest, when thermocouple temperature measurement network is in the range of 5-25cm. The temperature at point 39 is the highest, when thermocouple temperature measurement network is in the range of 30-50cm.

Figure V(a) shows in the operating condition of air outlet louvers angle 30°and air inlet louvers angle 15°, temperature of measure points located along the central part of the thermocouple temperature measurement network are higher than the temperature at the two side temperature measure points 21 25, and the temperature of the central temperature measure points are located at the highest temperature of 50cm, reaching about 25. The temperature of the five temperature measurement points can be stabilized near the 80cm at about 20. In 27-29 of the temperature measurement points of the central temperature was significantly higher than that on both sides of the measuring point 26 30, the temperature of central points for measuring temperature of the highest temperature is at 5cm. With the distance increasing from heaters, temperature decreased rapidly with increasing eventually stabilize at 18℃.

As shown in Figure V(b), V(c), in the operating condition of air outlet louvers angle 30° and air inlet louvers angle 15°, In the experimental range, 15 temperature of measure points temperature are basically stable at around 11℃. Compared with the original heater heating condition, the retrofitted heater reflects the superior diversion characteristics, and significantly reduces the thermal short-circuit phenomenon.

V. CONCLUSION

Experimental data show that the temperature distribution of the air near inlets of the original heater is not uniform, and air distribution near the outlets receive the influence of outlet air temperature shows that there has been a serious thermal short-circuit phenomenon. The retrofitted machine overcomes this problem, the air temperature distribution is more uniform, and temperature effect from outlet becomes weaker, which is conducive to improve the thermal efficiency. Such an invalid heating is reduced.

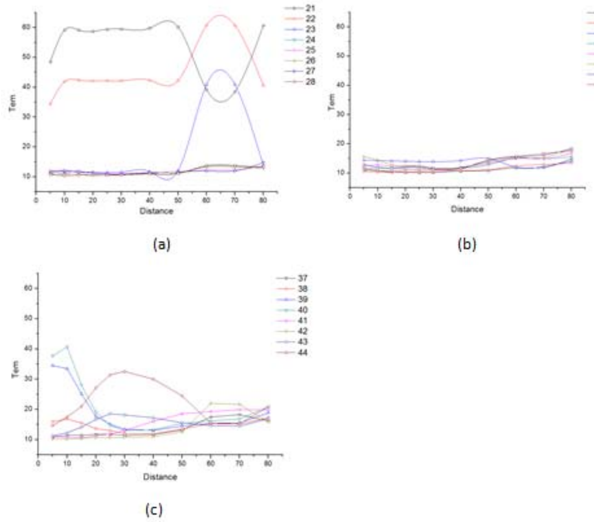

FIGURE V. TEMPERATURE VARIATION REGULARITY OF RETROFITTED HEATER.

In the experiment of temperature variation regularity with change of heating distance, the wind direction of the original heater is downward sloping and it is difficult to effectively transfer heat to the human body. In the operating condition of air outlet louvers angle 30°and air inlet louvers angle 15°, the retrofitted machine is able to heat the further position, improve the heating range of the heater.

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