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Temperature Field Probability Distribution Analysis Method for Refrigerated Compartment

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In this paper, the distribution law of the temperature field in a city transportation reiterated truck is simulated by CFD simulation (Yi et.al,2015). The temperature distribution is analyzed, and the probability density is solved. It is found that the Gaussian distribution can be used to express and analyze the temperature field(Fel'dman, 1990). The Gaussian distribution model (Víctor,2006) is established, and the probability distribution of the temperature field data measured by the Gaussian distribution model is analyzed. Finally, the accuracy of temperature field probability distribution statistics is verified through experiments.

1. CFD model's establishment and simulation

The research object of this paper is refrigerated truck compartment, as shown in Figure 1. The external dimensions of the carriage are 4.2m, 1.9m and 1.9m, respectively. The low temperature mainly depends on the airflow to maintain; cold source is the overhead evaporator located in the front of the carriage. As shown in Figure 1, the evaporator outlet is toward the tail of the compartment, mostly rectangular; the wind in part of the evaporator is at the bottom, mostly round.

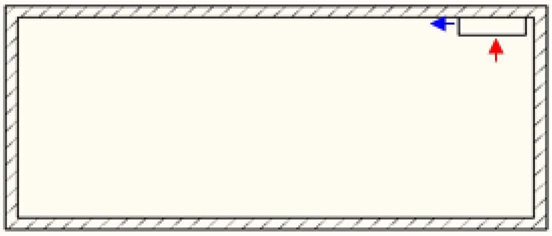

Figure 1: Refrigerated compartment top view

The air supply mode can form an approximate circulation flow organization in the compartment. The cold air passes through the bottom of the car to form a jet. When meeting the rear inner wall, the air flows downward and flows toward the front of the car when hits the bottom. Finally, it returns to the return air grille. The main circulation brings the cold air to the whole compartment, so that the car can maintain a certain low temperature. At the same time, this model will form a more complicated nonlinear flow field, which will be unstable in some locations, forming local eddy currents.
It is not the temperature field of any area in the refrigerated compartment that will directly affect the goods, the closer the temperature of the air flow to the goods will have a greater impact on the goods. The temperature field inside the refrigerated compartment has a certain instability. At the same point the temperature may change over time. A certain range of airflow will form a certain mixing in a certain range from the surface of the goods. Therefore, a certain distance away from the location of goods as the boundary is selected, and the boundary covers all the goods. In the study, it is assumed that the closed space 5cm away from the whole

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outer boundary of the cargo is the stacking area to be researched (Zhao, 2016). As shown in Figure 2, the green box area is the stacking area to be studied in the simulation.

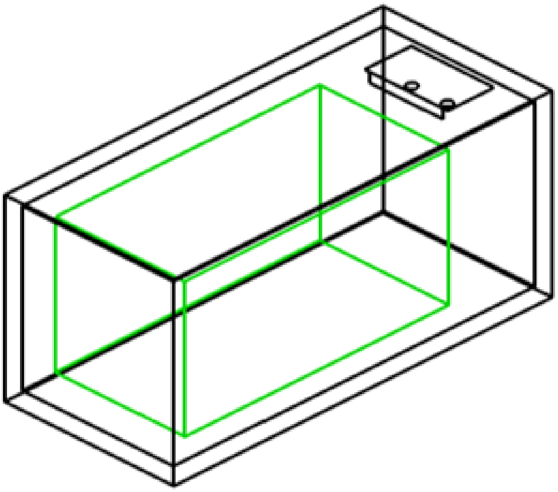

Figure 2: Research area of temperature field in the compartment

2. CFD simulation

Figure 3 is the internal temperature field of the refrigerated compartment simulated with CFD (Xia and Sun,2002), at 35℃ with vehicle speed of 10m/s. Cross sections are taken in the middle position of the X, Y and Z axes of the refrigerated compartment.

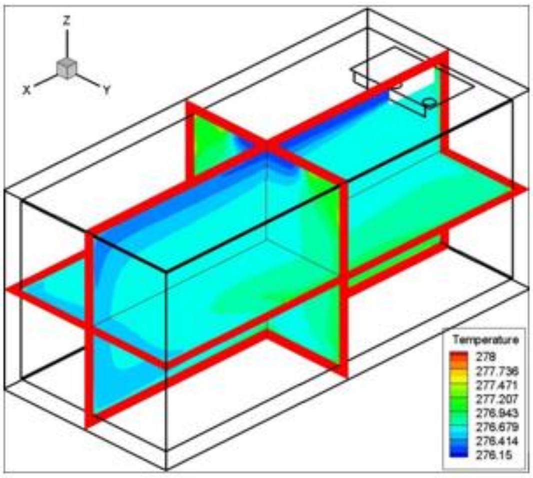

Figure 3: Temperature field CFD simulation of refrigerated compartment

As can be seen in Figure 3, there is a certain uniformity of temperature field in the refrigerated compartment (Moureh et.al, 2004; Moureh et.al, 2002) under the condition of the empty compartment. The cooling air flow has a main direction, and the temperature of the air stream is gradually increased along the main direction (Hoang et.al, 2000). The cold air is emitted from the evaporator (Salman and Soteriou,2004), and then gradually spread. The compartment has an impact on the internal temperature field (Wang et.al, 2015), but the impact of the environment temperature is greater.

3. Study on the probability distribution of temperature field simulation results

In the study, the stacking area is divided in 6750 elements, and the average temperature of each element is calculated(Xie,2006). The average temperature is extracted, in the order from small to large. Their values are

t_1, t_2, t_3, ……t_{max}。The maximum temperature is defined as t_{max}, the minimum temperature ast_{min}. Between t_{max} and t_{max} is divided into m temperature ranges, with 0.01℃ interval. m is assigned to the following value:

$$m = \left\lceil \frac{t_n - t_1}{\Delta t} \right\rceil \tag{1}$$

means round up to an integer; $\triangle t=0.01$, assign t_1 as the initial endpoint. Use N to express the total amount of data 6750. T_m represents an arbitrary endpoint of a given interval, $t_m - t_{m-1} = 0.01$. The number of points at which the temperature is less than n is recorded as n. Then the probability that the temperature is less than N in the temperature field is:

$$P(t_n \le t_m) = \frac{n(t_n \le t_m)}{N} , \tag{2}$$

Its probability distribution function is:

$$F(t_m) = P(t_n \le t_m) \tag{3}$$

By using the method above, the temperature field of the stacking area under different conditions is obtained, and the probability distribution is obtained as Figure 4.

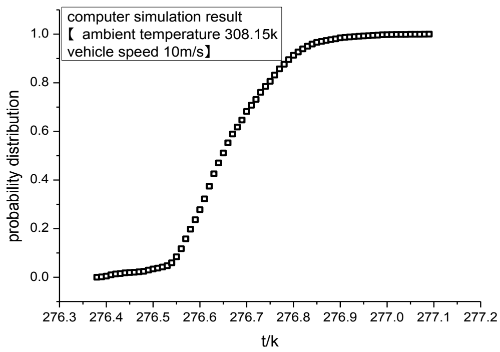

Figure 4: Probability distribution of temperature field

Figure 4 is the probability distribution of the temperature field in the stack. It can be found that the temperature field of the stacking area has a certain regularity, which can be divided into three phases. The first phase of the slow rise period, the second period of rapid rise period, the third period of the slow rise period. In order to find the regularity, the probability density of the data above is solved, and the mapping analysis is shown in Figure 5.

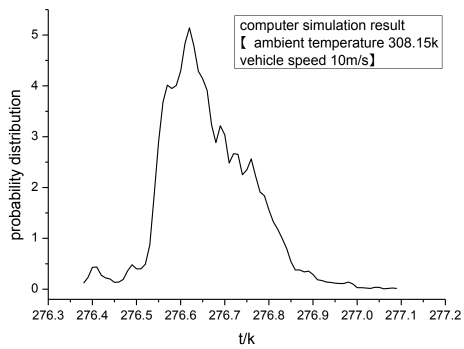

Figure 5: Probability density of the temperature field in the stacking area

Figure 5 shows the probability density of the temperature field in the stacking area, and it's the differential of the probability distribution. As can be seen from the graph, the probability density exhibits a single peak distribution, which is close to Gaussian distribution. The distribution of the temperature field in the stacking area is close to the Gaussian distribution. The peak value and the peak value of the temperature can reflect the characteristics of temperature distribution. The temperature field distribution can be expressed and analyzed by the method of data fitting using Gauss distribution. Therefore, the Gauss distribution model is established, and the temperature field of the stacking area in the conditions above is fitted.

$$f(t) = m + \frac{n}{\sqrt{2\pi}\sigma} e^{-\frac{(t-\mu)^2}{2\sigma^2}}$$

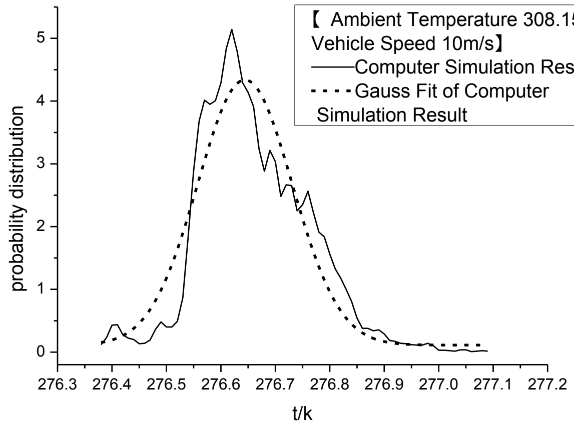

Figure 6: Probability density curve and fitting curve of temperature field

The fitting parameters are summarized as shown in Table 1.

Table 1: Gauss fitting parameter table

Ambient temperature (℃)	Vehicle speed (m/s)	m	n	μ	σ	$m+\frac{n}{\sqrt{2\pi}\sigma}$
35	10	0.2672	0.7570	276.46	0.0418	7.4815

In this study, the temperature field of the compartment of the CFD simulation (Chen Q, 1995) is verified by experiments.

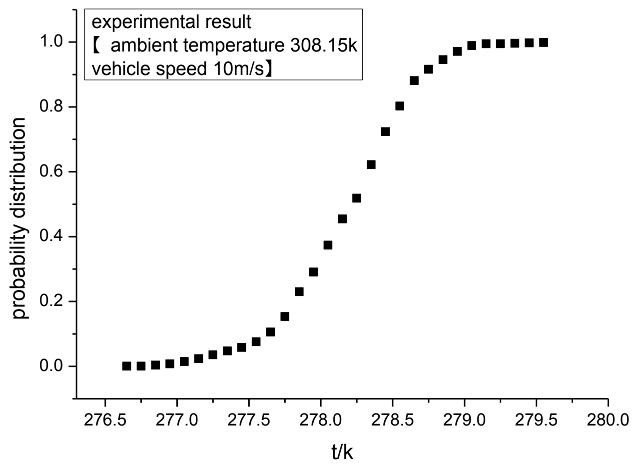

Figure 7: Temperature distribution of temperature field in refrigerated compartment

Figure 7 shows the temperature field of the experimental compartment in the compartment of the refrigerated truck. Using the temperature data of different spatial positions in the compartment obtained by 3D scanning system, probability statistics is researched, shown in Figure 8. It be seen from figure 8 that its probability distribution between Figure 4 are the same, which can also be divided into three sections: the first phase slow rise period, the second phase rapid rise period, the third phase slow rise period. The temperature distribution of the temperature field obtained from the experiment is slightly larger than that of the CFD simulation(Li, 2015).

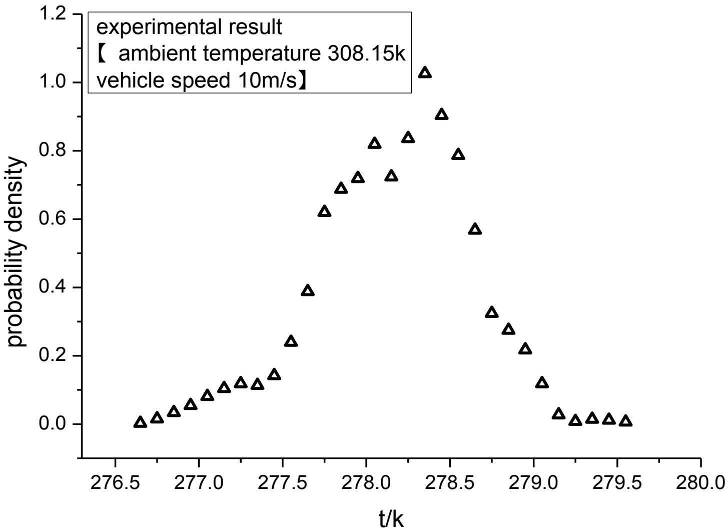

Figure 8: Probability density of temperature distribution in the compartment of the experiment

In order to more intuitive reaction temperature field with the proportion of different temperature, the probability density of the temperature in the test is obtained, as shown in figure 8. In experimental data processing, the temperature at each point is taken by the distance difference method. Therefore, temperature distribution, also reflects the distribution of temperature field in space. The greater the probability density of a temperature band, indicates that the temperature zone in the space has a larger volume. From the temperature field of probability density distribution, it can be seen that the overall temperature distribution shows an obvious trend of Gauss distribution. The temperature field is mainly concentrated at 4.5 ℃ ~5.5 ℃ , with width about 1 ℃ temperature zone.

4. Conclusions

Through CFD simulation, refrigerated compartment internal temperature field exits non-uniformity. The air flow is a mainstream direction, and gradually increases along the mainstream direction of air temperature. This paper proposes a method for analyzing the temperature field of the probability density of the refrigerated compartment. Through the probability density analysis of simulated and experimental data, the refrigerated compartment stacking zone temperature field showed certain regularity. The curve shape is basically the same, which can be divided into three sections. The overall temperature distribution showed an obvious trend of Gauss distribution, in which the curve has only one peak. The temperature field is mainly concentrated in the width of about 1℃ temperature zone.

Acknowledgments

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