# Research on the temperature field in refrigerated truck carriage with fresh pork in it

**Jiamin Wang[1,2], Zhaolei Ding[2], Chuanzhen Huang[1], Zhaoliang Jiang[1]**

[1] *Key Laboratory of High-efficiency and Clean Mechanical Manufacture (Shandong University), Ministry of Education, School of Mechanical Engineering, Shandong University, Jinan, 250061, PR China*

[2] *National agricultural modern logistics engineering technology research center, Jinan Shandong, 250103, PR China*

*Corresponding author's e-mail: gsxwjm@163.com*

*Received 10 October 2013, www.cmnt.lv*

**Abstract**

The CFD coupling flow model is established and refrigerated truck experimental platform is built. The internal temperature field in the refrigerated truck is studied by applying mathematical statistics and the fact that the internal temperature field varies with the environment temperature and the speed of the truck with fresh pork in it is analyzed. The conclusion that the variety of the external temperature has a greater influence on the variety of the internal temperature when the refrigerated truck is at a high speed is arrived. The raise of temperature in the top jet area inside the refrigerated truck is obvious and the internal area temperature near side walls of the refrigerated truck is relatively high.

*Keywords:* Refrigerated Truck, Coupling Flow, Temperature Field, Mathematical Statistics, Pork Transportation.

## 1 Introduction

The distribution of the temperature field of the refrigerated truck has a direct influence on the quality of pork when the fresh pork is on a long-distance transportation. The uneven distribution of temperature field can increase the speed of the rotten of pork as well as water evaporation. The distribution of the temperature field inside the refrigerated truck is mainly influenced by the air-flow organization inside the refrigerated truck carriage and external environment. With the fact that the refrigerated truck is a moving cold storage and the external wind speed and environment temperature varies with the moving of the refrigerated truck, this paper establishes the CFD coupling flow model. The variety of the temperature filed inside the refrigerated truck with the change of the environment is studied with the aid of mathematical statistics.

## 2 CFD simulation model

The fundamental reason why there is heat transfer from the inside of the refrigerated truck to the outside environment is that there is temperature difference between the both sides of the thermal insulation. The heat flows from the external side to the internal side across the thermal insulation in the form of heat conduction. If solar radiation is regarded as constant, the heat exchange in the external side is carried in the form of heat convection and the same between the internal side of the truck and the internal air.

This paper is not directly investigating of boundary condition of the external side of the refrigerated truck as constant heat flux or temperature. Instead it establishes a coupled numerical model of the internal and external flow field as is shown in Figure 1. The refrigerated truck is put in a 17m×8m×10m area and the parallel even temperature is set in the entrance of this area in order to simulate the relative motion between the environment air and the refrigerated truck carriage. The even temperature jet is set in the air outlet of the evaporator of the truck. Since the fact that there is temperature difference between the internal truck and external environment, the coupling heat transfer between the internal and external field as is discussed above occurs spontaneously.

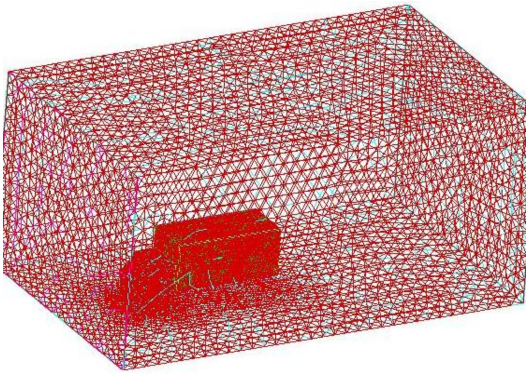


FIGURE 1 Simulation grid of coupling flow model.

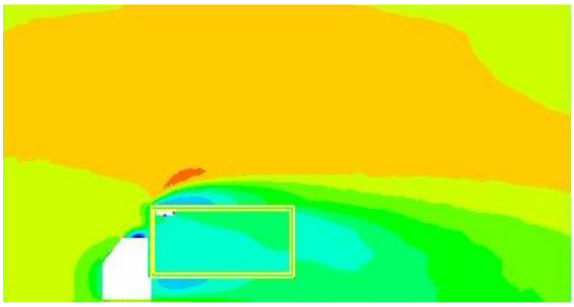
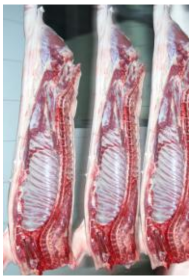
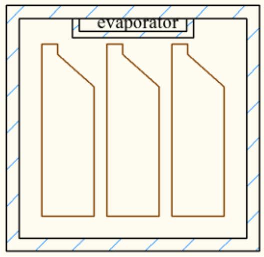


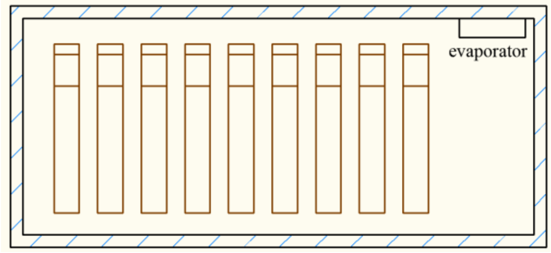
FIGURE 2 Simulation of coupling flow velocity field.



a)




b)




c)

FIGURE 3 Half pork model:
a) Physical map of half pork,
b) Rear view of the pork distribution,
c) Side view of the pork distribution.

The abstract model of half pork is proposed for the convenience of numerical simulation. This model is legitimately arranged in the internal truck and the air flow in the internal truck can be accurately reflected.

## 3 Refrigerated Truck Experiment

In order to prove the accuracy of numerical model, the automatic test system of the air flow in the refrigerated truck is designed. The sensor placed on the 3D electric control movable mechanism, measuring flow field parameter, moves in the loading area of the truck and tests tens of thousands of flow field parameter layer by layer. However, the refrigeration system in the traditional refrigerated truck has an temperature control accuracy within ±2℃. Once it is stopped in order to defrost, there will be great temperature raise and the temperature can't be tested by the 3D electric control movable mechanism. Thus refrigerated truck experimental platform, which can simulate the variety of external temperature and the speed of wind, is established. The refrigerated truck applies new refrigeration system, making temperature control accuracy within ±0.2℃ and establishing a relatively steady heat transfer with the environment which is simulated.

a)

b)

c)

d)

FIGURE 4 The refrigerated truck experimental platform:
a) Maintenance structure,
b) Environment simulation room,
c) Automatic test system,
d) Refrigeration and heating equipment.

## 4 Simulation and Experiment Analysis

In order to reflect the temperature field inside the refrigerated truck more fully and accurately, this paper divides the entire pork loading area into tens of thousands of differential unit according location. The temperature data of simulation and experimental is rearrange by differential. The centre point temperature of each differential unit is the representative temperature, which is analyzed.

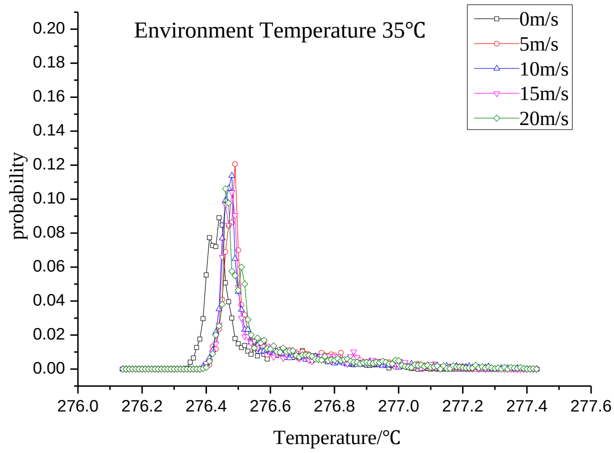



FIGURE 5 probability of distribution
with the environment temperature of 35℃.

Fig. 5 shows the variety of probability distribution of the internal temperature of the refrigerated truck carriage with the environment temperature of 35℃ when the speed of the truck changes. As is shown in Fig. 5, with high environment temperature and low truck speed, the internal temperature field of the refrigerated truck will make some changes on raise of the speed of the truck. The peak probability raises and the probability distribution moves to the right, which indicates that the raise of the speed of the truck makes the entire temperature field raise and the distribution of temperature more concentrate. When the speed reaches 5m/s, the change of the temperature field is no longer obvious with the raise of speed, which indicates that when the environment temperature is relatively high, there is some kind of limit of the influence of speed on the temperature in the internal refrigerated truck.

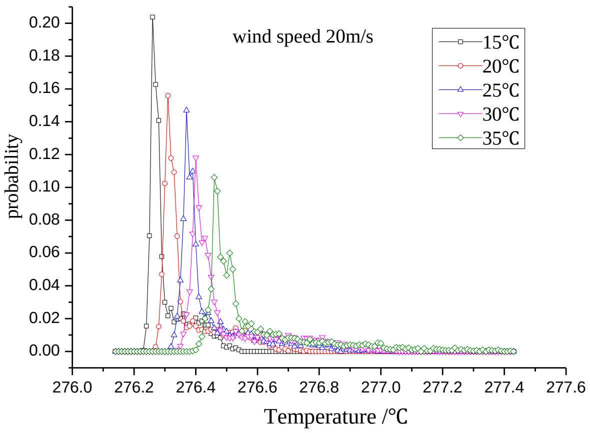



FIGURE 6 Probability distribution with the speed of the truck at 20m/s

Fig. 6 shows the variety of probability distribution of the internal temperature of the refrigerated truck with the speed of the truck at 20m/s when the environment temperature changes. As is shown in Fig.6, when the speed is 20m/s, probability distribution of the temperature field of the internal refrigerated truck would be changed obviously with the change of the environment temperature. It moves to the right and the peak probability drops, which indicates that the temperature field has an entire raise and a more even distribution.

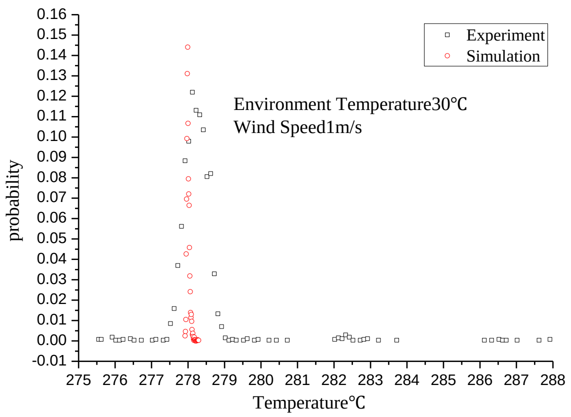



FIGURE 7 Comparative Analyses of the Simulation and Experiment

By comparing these data, it is found that the experimental value coincides with the simulation value, both of which appear as Gaussian distribution with the same position of peak and relatively same peak distribution. The experimental value has a wider distribution than the simulation value, the reason of which is that the test instrument has some kind of measurement errors and the outlet temperature in experiment can't be accurately constant. What's more, it is the loading area instead of the entire inside refrigerated truck carriage area that is compared. The simulation value is based on steady state; however, there are many vortexes in the experiment, making the temperature at some places changes dramatically. These vortex changes are working quickly on-time, so the experimental sensor can't catch them effectively. All of these makes the deviation possible.

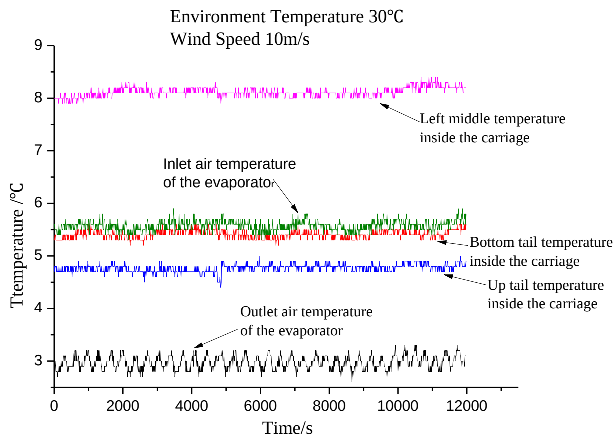



FIGURE 8 Dynamic data analysis

The above analysis are all based on the loading area, which mainly lies in the central area of the refrigerated truck carriage. In order to analyze the entire distribution of the temperature field in the refrigerated truck carriage, some temperature sensors are set at air outlet, the middle part of left side wall of the carriage, the bottom and tail part of the back wall of the carriage, the up and tail part of the back wall of the carriage and air inlet. It can be seen that the entire experimental station operates at a steady state, with the fluctuation of jet air temperature within ±0.2℃ and that of other position even smaller. It can also be seen that with the environment temperature 30℃ and speed 10m/s, the temperature raises from air outlet, the upper part of the back wall of the carriage, the lower part of the back wall of the carriage to air inlet. It explains that the temperature in air jet area raises relatively high and the temperature raises relatively low in air return area. It can also explain that jet air and return air has little influence on the area near the side wall inside the carriage and that the environment has a relatively high influence on its temperature.

## 5 Conclusions

When the refrigerated truck runs at a low speed, the variety of the temperature field in the internal refrigerated truck carriage is comprehensively influenced by the speed of the truck and the environment temperature. When the refrigerated truck runs at a high speed, the variety of the temperature field in the internal refrigerated truck carriage is comprehensively influenced by the environment temperature.

The temperature in the air jet area rises relatively high and it is easily influenced by inside and outside high speed flow field, so special attention should be paid to this part in order to reduce heat transfer. Since the pork doesn't have respiration and there's no obvious heat release, however, when fruits and vegetables are transported, return air channel should be set.

The jet air and return air has little influence on the side wall inside the carriage, so the temperature of these parts is relatively high. When the goods are transported, the refrigerated goods should be kept away from these parts.


## Acknowledgments

The Project Supported by National Key Technology Research and Development Program of the Ministry of Science and Technology of China (Grant No. 2012BAD38B06).


## References


[1] Wieslaw Zwierzycki, Krzysztof Bienczak, Maciej Bienczak, et al. 2011 *Thermal damage to the load in cold chain transport* J Procedia Social and Behavioral Sciences **20** 761-6

[2] 1995 International Institute of Refrigeration *Guide to refrigerated transport* Z

[3] Ming Liu, Frank Bruno et al. 2011 *Thermal performance analysis of a flat slab phase change thermal storage unit with liquid-based heat transfer fluid for cooling* applications J Solar Energy **85** 3017-27

[4] Ming Liu,Wasim Saman. 2012 *Development of a novel refrigeration system for refrigerated trucks incorporating phase change material* J Applied Energy **92** 336-42

[5] Mashud Ahmed, Oliver Meade, Mario A. Medina 2010 *Reducing heat transfer across the insulated walls of refrigerated truck trailers by the application of phase change materials* J Energy Conversion and Management **51** 383-92

[6] Oro E, Miro L, Farid M M et al. 2012 *Improving thermal performance of freezers using phase change materials* J international journal of refrigeration **35** 984-91

[7] Eduard Oro, Laia Miro, Mohammed M Farid et al. 2012 *Thermal analysis of a low temperature storage unit using phase change materials without refrigeration system* J International journal of refrigeration **35** 1709-14

[8] Laguerre O, Hoang H M, Flick D 2012 *Experimental investigation and modelling in the food cold chain: Thermal and quality evolution* J Trends in Food Science & Technology 1-11

[9] Moureh J, Tapsoba S, Derens E et al. 2009 *Air velocity characteristics within vented pallets loaded in a refrigerated vehicle with and without airducts* J International Journal of Refrigeration **32** 220-34

[10] Hoang M H, Laguerre O, Moureh J et al. 2012 *Heat transfer modelling in a ventilated cavity loaded with food product: Application to a refrigerated vehicle*J . Journal of Food Engineering **113** 389-98

[11] Mitoubkieta Tapsoba, Jean Moureh, Denis Flick 2007 *Airflow patterns in a slot-ventilated enclosure partially loaded with empty slotted boxes* J International Journal of Heat and Fluid Flow **28** 963-77


## Authors


**Jiamin Wang, February 1976, PR.China**

**Current position, grades:** Director Assistant of The National Engineering Research Center for Agricultural Products Logistics
**University studies:** Cooperative design and manufacturing
**Scientific interest:** Digital manufacturing technology, Cold chain Equipment,heat pump
**Publications:** 5
**Experience:** 1995-1999 Study in Shandong University for bachelor's degree on Mechanical & Electrical Integration; 2003-2006 Study in Shandong Normal University for master's degree on Management Science and Engineering; 1999-2010 Teaching and Researching in Shandong Institute of Commerce and Technology; 2010-now Director Assistant of The National Engineering Research Center for Agricultural Products Logistics

**Zhaolei ding, January 1987, PR.China**

**Current position, grades:** Manager of Cold chain Equipment Dept, Assistant
**University studies:** Refrigeration and cryogenic engineering
**Scientific interest:** Cold chain Equipment,heat pump
**Publications:** 4
**Experience:** 2006-2010 Study in Shandong Jianzhu University for bachelor's degree on Refrigeration and cryogenic engineering; 2010-2013 Study in Shandong Jianzhu University for master's degree on Refrigeration and cryogenic engineering; 2013–now Work in National agricultural modern logistics engineering technology research center

**Chanzhen Huang, November 1966, PR.China**

**Current position, grades:** Changjiang Scholar Chair Professor
**University studies:** cooperative design and manufacturing
**Scientific interest:** High efficiency and precision machining technologies, precision abrasive air/waterjet micro-machining technologies, Advanced ceramic tool materials and structural ceramics, Machining technologies for novel materials
**Publications:** 260
**Experience:** 10/1997 - Professor in Mechanical Engineering, SDU, China; 01/2000 - Vice Dean of School of Mechanical Engineering, SDU; 07/2004 - Director of Centre for Advanced Jet Engineering Technologies, SDU; 06/2001 - : Member of Academic Committee in Engineering Department, SDU; 04/2008 - Director of Key Lab. of High-efficiency and Clean Mechanical Manufacture, MOE; 01/2008 - hangjiang Scholar Chair Professor, SDU

**Zhaliang Jiang, October 1971, PR.China**

**Current position, grades:** Associate Professor
**University studies:** cooperative design and manufacturing
**Scientific interest:** Digital manufacturing technology, such as Product configuration solution, Balance and sequencing of assembly line
**Publications:** 16
**Experience:** 2007.12 - 2008.12: Worked at Engineering school of University of Michigan as Visiting Scholar; 2004,7 - present: Teaching and Researching at School of Mechanical Engineering, Shandong University; 1994, 8 - 1998, 8: Working in China National Heavy Duty Truck Group Corp., Mainly focus on fixture design and product process planning