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Research Article

Study on Heat Insulation Performance of External wall of Low Temperature Grain Storage Granary

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Abstract: Based on a low temperature grain storage granary in Beijing zone, an unsteady two-dimensional model of heat transfer on external wall is set up in the study. The heat-transfer model is simplified reasonably. According as the heat-conduction differential equation, initial and boundary conditions, the temperature fields of external walls in south with different kinds of heat insulation are simulated and calculated with CFD software. The numerical results are compared and analyzed. The results show that the attenuating role of external wall with interior heat insulation to the outdoor air temperature fluctuation is smaller than which with exterior heat insulation and that the heat storage capacity of external wall to prevent of the temperature fluctuation is weaker, too. At last, it is pointed that external wall heat insulation offers a guarantee to achieve low temperature grain storage and energy-saving and the heat insulation performance of external wall with exterior heat insulation layer is better than which of interior heat insulation layer and during the energy-saving design of the granary external wall, the technology of exterior heat insulation should be used as far as possible.

Keywords: CFD, external wall heat insulation, heat insulation performance, low temperature grain storage granary, unsteady two-dimensional heat transfer

INTRODUCTION

Along with the increasing improvement of living standards, people put forward higher and higher requests on grain quality and are eager to obtain grain of excellent quality, fresh and delicious from supply departments. At the same time, as the basis of life and production, grain is not only closely related to everyone's life, but also the essential raw material of food, medicine, chemical, brewing and many other industrial productions. So, if there is no grain storage, daily life and expanded reproduction could not be guaranteed (Pang, 2012; Liu and Wu, 1988; Fang, 1997).

Low temperature grain storage is one of the very promising storage methods of modern storage technology, and the indoor temperature of granary is usually controlled in 15 to 30°C. By maintaining grain in lower temperature, it can inhibit the respiration of grain, control the growth of insects and mildew and postpone the aging process of grain. In this way, the quality of stored grain would be maintained and improved and the aim of safe storage of grain would be achieved. In order to reduce the influence of external environment on the temperature of grain in granary, realize low temperature grain storage better and reduce energy consumption, heat insulation and moisture-proof measures are needed to take on the building envelope of granary.

Seeing from the proportion of energy consumed for heat-transfer in each part of the building envelope, the consumption of external wall is the maximum. So, external wall is the key location of energy saving design.

In recent years, many specialists and scholars have done lots of researches on heat transfer process and performance of external wall. Ozel and Pihtili (2007) researched the location and distribution of insulation layers on building walls with various orientations by using an implicit finite difference method. Hamdan (2002) performed the theoretical analysis on the attenuation of a heat wave through five different walls and analyzed the effect of the thermal resistance of the insulation layer on the attenuation of the heat wave traveling through the walls, on the wall inside surface temperature and on the relative humidity inside the room. Aslihan (2004) evaluated the thermal performance of masonry walls with different materials and insulation strategies with the software DOE-2.1E. Tsilingiris (2003, 2004, 2006) investigated the influence of heat capacity and its spatial distribution on the transient wall thermal behavior under the effect of harmonically time-varying driving forces. Nussbaumer *et al*. (2006) investigated the thermal performance of a protected vacuum-insulation system applied to a

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concrete wall in building constructions by experimental and numerical methods. Li and Jin (2004) researched on the temperature field of typical daily variation of roof and walls by finite element numerical simulation method. Li *et al*. (2004) performed the numerical analysis on the temperature field of periodic changed boundary conditions of typical roof and walls by finite element numerical simulation method. In China, some kinds of practical method for energy-saving wall have been used in lots of engineering (Wang, 2002; Yu, 2005).

At present, the widely used heat insulation technology of external wall at home and abroad mainly includes interior heat insulation and exterior heat insulation. The temperature fields of external walls with two different kinds of heat insulation are simulated and calculated with CFD software in this study. Under the same conditions, the heat insulation performances and temperatures of interior surface of external walls with two different kinds of heat insulation are compared and analyzed.

MATERIALS AND METHODS

Calculating element of heat-transfer model: A tiny part of south external wall of the granary is picked out and used as a calculating unit of the heat-transfer model. The size of the model is defined as X×Y = 283 mm×250 mm. The structure layers of the external wall with exterior heat insulation from outside to inside are: high elastic coating, polymer mortar, expanded polystyrene panel, adhesive, cement mortar layer, reinforced concrete and mixed mortar layer (Hu and Fang, 2005). The structure layers of the external wall with interior heat insulation from outside to inside are: high elastic coating, polymer mortar, cement mortar layer, reinforced concrete, adhesive, expanded polystyrene panel and mixed mortar layer. The parameters of all kinds of wall material are shown in Table 1. The two kinds of calculating unit of external wall heat-transfer model with interior heat insulation and exterior heat insulation are shown in Fig. 1 and 2.

Model assumptions: The heat-transfer process of the external wall is very complex in fact. But to facilitate solving and analyzing, the heat-transfer model is simplified and assumed reasonably. These assumptions are as follows: Firstly, when the outdoor temperature changes periodically, the heat-transfer process of the external wall is assumed to be an unsteady two-dimensional heat conduction process. Secondly, the thermal contact resistance between each layer, the thermal resistances of the high elastic coating and adhesive and the moisture transfer are all assumed to be negligible. Lastly, materials in the same structural layer of external wall are assumed to be homogeneous, isotropic and with constant physical properties.

Equation and boundary conditions: The research object is the south external wall of a granary in Beijing zone in this study. There is not heat source in the external wall, so the unsteady state two-dimensional differential equation of heat conduction of the calculating unit of the heat-transfer model may be described as follow:

$$\frac{\partial t}{\partial \tau} = a\left(\frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2}\right) \quad (1)$$

The boundary conditions of the calculating unit are defined as follows. The boundary condition of the exterior surface of external wall is:

$$-\lambda \frac{\partial t}{\partial x}\Big|_{x=0} = \alpha_{w,\tau}\left(t_{w,\tau} - t_{wb}\right) \quad (2)$$

The boundary condition of the interior surface of external wall is:

$$-\lambda \frac{\partial t}{\partial x}\Big|_{x=L1} = \alpha_n\left(t_b - t_o\right) \quad (3)$$

In the calculating unit as shown in Fig. 1, the two boundary surfaces of the model in Y-direction are approximately seemed as adiabatic surfaces and the boundaries are:

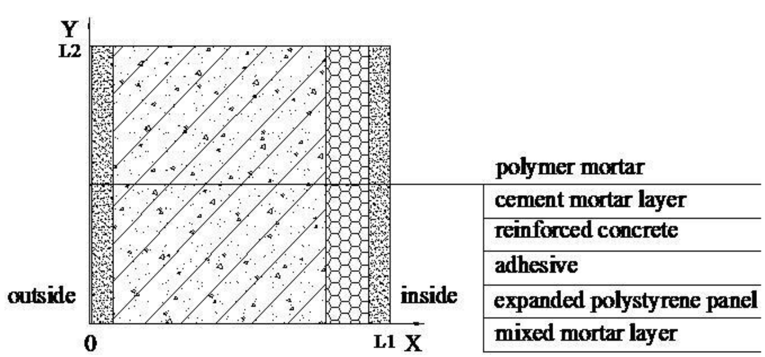

Fig. 1: The calculating unit of external wall heat-transfer model with interior heat insulation

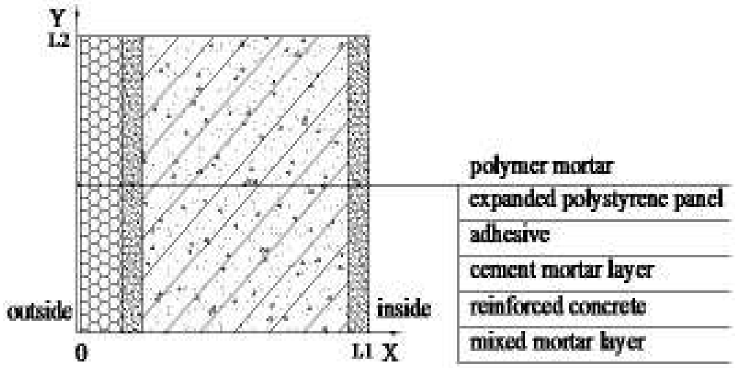

Fig. 2: The calculating unit of external wall heat-transfer model with exterior heat insulation

Table 1: The parameters of all kinds of wall material

Name of the material	Thickness (mm)	Density (kg/m^3)	Coefficient of heat conductivity (W/m·K)	Specific heat (J/kg·K)
Polymer mortar	3	1800.0	0.93	1050.0
Expanded polystyrene panel	40	20.0	0.042	1400.0
Cement mortar layer	20	1800.0	0.93	1050.0
Reinforced concrete	200	2500.0	1.74	920.0
Mixed mortar layer	20	1700.0	0.87	1050.0

$$\frac{\partial t}{\partial y}\Big|_{y=0} = \frac{\partial t}{\partial y}\Big|_{y=L2} = 0 \quad (4)$$

where,

- λ = The heat conduction coefficient of each kind of material (W/m·°C)
- $\alpha_{w,\tau}$ = The heat convective coefficient of the exterior surface of external wall (W/m^2·°C)
- $t_{w,\tau}$ = The outdoor air temperature at the moment of τ in date of calculating
- t_{wb} = The temperature of the exterior surface of external wall (°C)
- α_n = The heat convective coefficient of the interior surface of external wall (W/m^2·°C)
- t_b = The temperature of the interior surface of external wall (°C)
- t_o = The indoor air temperature (°C)

At the initial moment of calculating date, 0:00, on July 21, the internal temperature of the external wall is assumed to be uniform and is equivalent to the indoor temperature, 28°C. The working time of the numerical simulation calculation is 48 h.

RESULTS AND DISCUSSION

Simulation results of the heat-transfer model: When the thickness of heat insulating material is 40 mm and the other simulation conditions are unchanged, numerical simulations of the heat transfer model of the external wall with interior heat insulation and exterior heat insulation are performed for 48 h using CFD software. The obtained temperature fields of the wall of the model in each case are shown in Fig. 3 and 4. The comparison of interior surface temperatures of wall with interior and exterior heat insulation during the 48 h is shown in Fig. 5.

As shown in Fig. 5, during the 48 h, the maximum temperature of the interior surface of external wall with 40 mm interior heat insulation is 28.85°C, the minimum temperature is 27.90°C and the temperature difference is 0.95°C. When the 40 mm heat insulating material is placed in the outside of external wall, the maximum temperature of the interior surface of external wall is 28.64°C, the minimum temperature is 27.94°C and the temperature difference is 0.7°C.

When the thickness of heat insulating material is enlarged from 40 to 55 mm and the other simulation conditions are unchanged, numerical simulation of the heat transfer model of the external wall with interior heat insulation is performed for 48 h using CFD software. The obtained temperature field of the wall with 55 mm heat insulating material is shown in Fig. 6. The comparison of interior surface temperatures of wall with 40 mm interior heat insulation, 40 mm exterior heat insulation and 55 mm interior heat insulation during the 48 h is shown in Fig. 7.

As shown in Fig. 7, when the thickness of heat insulating material is enlarged from 40 to 55 mm, during the 48 h, the maximum temperature of the interior surface of external wall is 28.65°C, the minimum temperature is 27.93°C and the temperature difference is 0.72°C.

Numerical results analyzing: In terms of the obtained temperature distribution figures, the numerical results are analyzed. When the thickness of heat insulating material of wall is 40 mm, the location of heat insulating layer is different and the material and

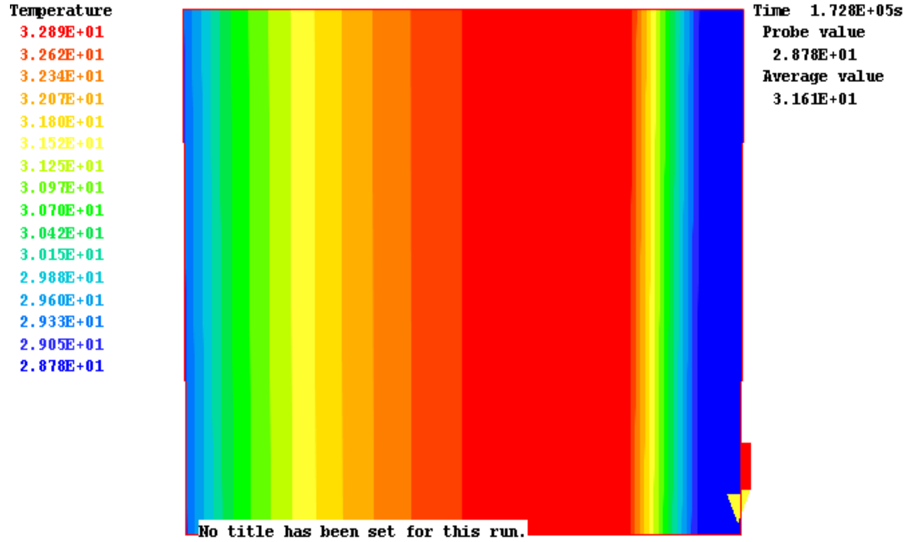

Fig. 3: The temperature field of wall with 40 mm interior heat insulation

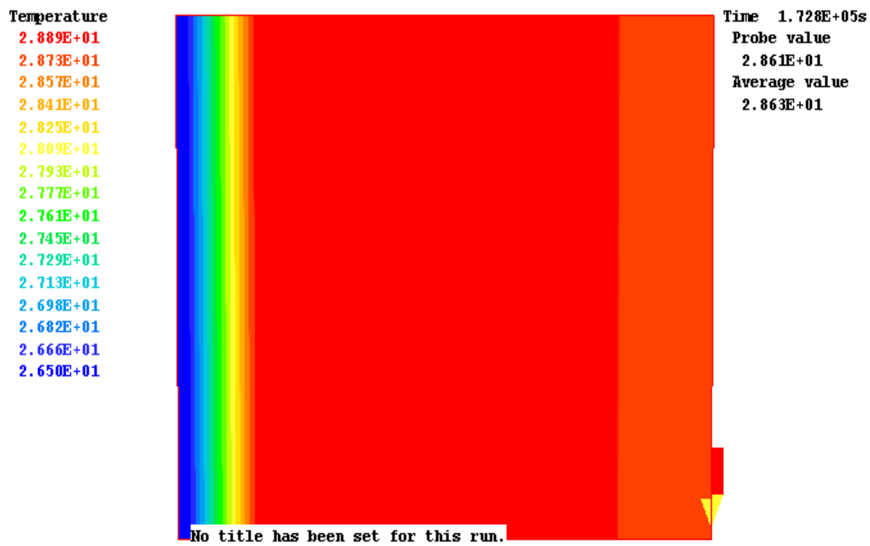

Fig. 4: The temperature field of wall with 40 mm exterior heat insulation

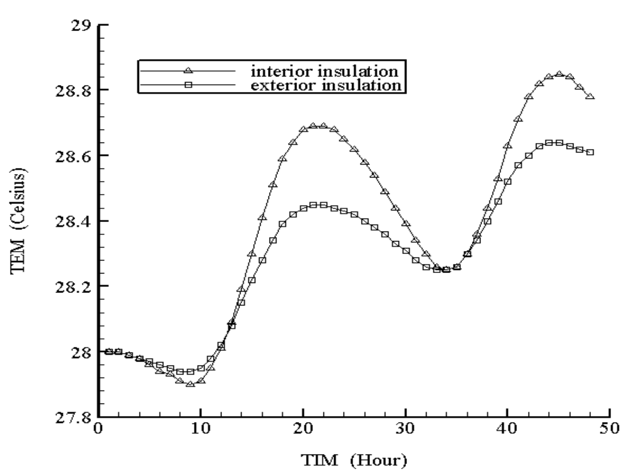

Fig. 5: The comparison of interior surface temperatures of wall with interior and exterior heat insulation

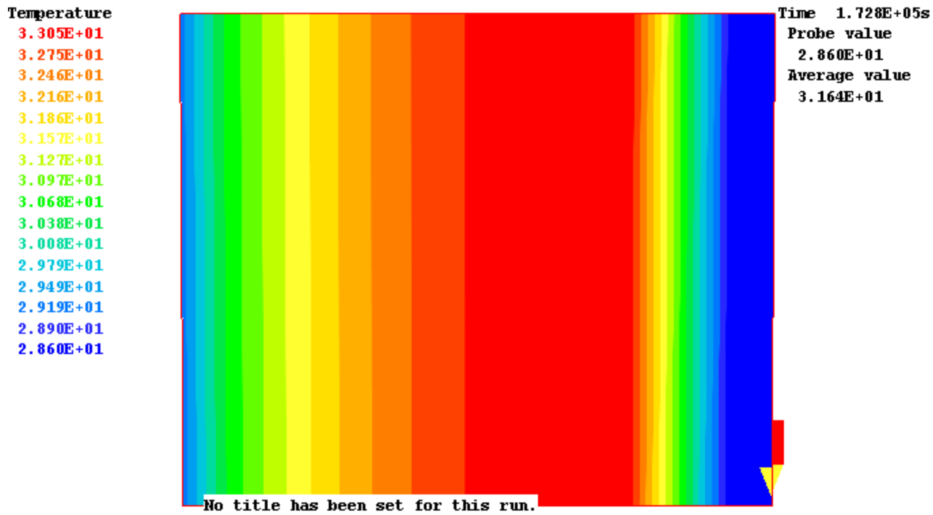

Fig. 6: The temperature field of wall with 55 mm interior heat insulation

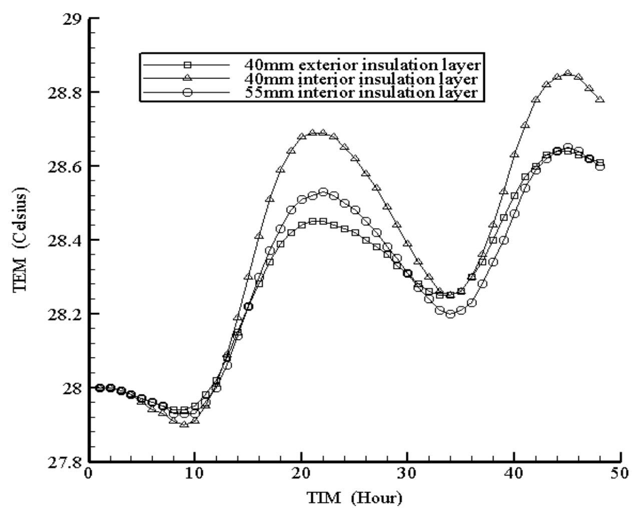

Fig. 7: The comparison of interior surface temperatures of wall in different calculating models

thickness of the structure layers of wall and other simulation conditions are all the same, the interior surface temperature of wall of the model in each case is different, too. The obtained interior surface peak temperature of external wall with interior heat insulation is higher than which of wall with exterior heat insulation and the temperature fluctuation amplitude of which is bigger, too. This indicates that the attenuating role of external wall with interior heat insulation to the outdoor air temperature fluctuation is smaller and the heat storage capacity of external wall to prevent of the temperature fluctuation is weaker, too.

When the thickness of heat insulating material is enlarged from 40 to 55 mm and the other simulation conditions are unchanged, the interior surface peak temperature of external wall with interior heat insulation is reduced and the temperature fluctuation amplitude is decreased, too. According to the results shown in Fig. 7, the interior surface temperature of external wall with 55 mm interior heat insulation and which of external wall with 40 mm exterior heat insulation are very similar. It indicated that to achieve the same interior surface temperature of external wall, the thickness of heat insulating layer of external wall with exterior heat insulation is much smaller than that of external wall with interior heat insulation.

CONCLUSION

Based on the unsteady two-dimensional model of external wall of a granary in Beijing zone, through performing numerical simulations by CFD software and analyzing the obtained temperature distributions, some conclusions are summarized as follows:

In both of these simulation cases, the indoor temperature of granary can all be controlled under

30°C. It offers a guarantee to achieve low temperature grain storage and energy-saving.

Among the widely used heat insulation technology of external wall at home and abroad presently, exterior heat insulation is the better way. While choosing the exterior heat insulation of external wall, the peak of air conditioning load could be significantly cut down and the outdoor air temperature and solar radiation would rarely affect other inside structure layers of the external wall except exterior heat insulation. These are beneficial to maintain the stability of the indoor temperature of granary. So, the heat insulation performance of external wall with exterior heat insulation layer is better than which of interior heat insulation layer.

While choosing the exterior heat insulation of external wall, the amount of heat insulation material would be less than which of the external wall with interior heat insulation and it would take up less space. Moreover, the technology of exterior heat insulation of external wall has some remarkable advantages, such as saving energy, being widely applied, protecting the main structure of external wall, etc. (Lv, 2006).

Therefore, based on an overall consideration of various factors, during the energy-saving design of the granary external wall, the technology of exterior heat insulation should be used as far as possible.

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