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Research Article

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A new energy-saving floor drain

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ABSTRACT

This paper designs an energy-saving floor drain to collect the heat of wastewater. It has a good heat transfer performance which was proved by mathematical models and experimental data. The models include the heat exchanger model of spiral flow and the heat exchanger model of serpentine tube. The model of spiral flow shows the process of exchanging heat between the water in the energy-saving floor drain and its wall. The model of serpentine tube shows the process of exchanging heat between the wall of floor drain and wastewater. Besides, an experiment is introduced to verify its ability of absorbing heat. The experiment responses the energy-saving capabilities of floor drain. Finally, its performance of energy-saving and emission reduction ware analyzed with experimental data and statistical data.

Keywords: Serpentine tube, Spiral tube, Energy-saving floor drain, Heat recovery, Environmental protection.

INTRODUCTION

Nowadays, with the energy sustainable development, the energy recovery and recycling has been penetrated into various fields. A variety of energy-saving measures continue to be applied to energy saving. The energy-saving systems are used in the current building. They are used in the whole building system as well as manifested in the daily lives of residents. In people's daily life, water is a kind of indispensable resource. Water is used for drinking, irrigation and sanitation. Everyday, people use a large amount of water to bath. This part of water is discharged into drains directly after bathing. But, this part of water has a lot of heat, so this causes a significant heat loss. Generally speaking, the temperature is about 35 degrees. In this paper, researchers designed a new type of floor drain device. It can absorb the heat of wastewater to achieve the purpose of energy saving.

There are other heat recovery floor drains on market. However, compared with the floor drain in this article, they have many shortcomings. The new type of floor drain in this paper can do heat recovery to fill the defect of others. At the same time, researchers verified the ability of this new type of floor drain by theoretical models and experimental data.

2 INTRODUCTION OF NEW FLOOR DRAIN

The new type of floor drain is shown in Fig.1. In the figure, 1 is the subject of floor drain; 2 is the core of this floor drain; 3 is the filter in it; 4 is the cover; 5 is the interface of tap water; 6 is interface of heater; 7 is heat exchange tubes; 8 is the panel which is used to meet the function of deodorant and pest control; 9 is the support; 10 is the shaft.

In the installation process of floor drain, the interface of tap water and the water pipe are connected by hose. At the same time, the interface of heater and the heater are connected by tube. Using this floor drain, heat could be recovered while bathing. The core can absorb a part of heat of the bathing water which drops from the cover. After that, the bathing water is filtered by filter. Then, the heat exchange tubes absorb the heat from the filtered water.

Then, the most of heat in the bathing water could be recovered to heat the tap water. Furthermore, this floor drain can prevent odour and insects from entering the room by its cover when people do not use the bathroom.

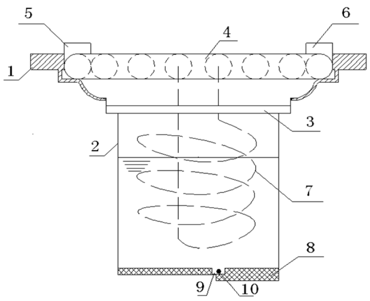

Fig.1 the dimensional sketch of floor drain

3 THEORETICAL MODELS

The heat recovery process of bathing water is divided into two processes. One is the heat transfer process between the copper tube and bathing water. This process occurs under the cover of this floor drain. Another process occurs between the helical copper tube and the hot water which is filtered. This process is carried out in the floor drain core. There are two theoretical models to explain the processes, which include the model of serpentine tube heat exchange and the spiral tube heat exchange model.

3.1 Serpentine tube heat exchange model

In this paper, the process of the heat exchange of serpentine tube is a simple heat transfer. It occurs between the water inside and outside. The heat transfer inside is a forced convection heat transfer while the heat transfer outside is about the heat exchange of cross flow.

The formula used in the forced convection heat transfer could refer to the formula of Dittus-Boelter. It is used to solve the convective heat of straight tube. So the form of the formula must be changed into another form [1]. The formula after deformation is shown as Eq. (1) and Eq. (2).

$$Nu_f = 0.0025 \mathrm{Re}_f^{1.04} \mathrm{Pr}_f^{n} \tag{1}$$

The heat transfer coefficient is:

$$h_f = \frac{\lambda Nu_f}{d_i} \tag{2}$$

The symbols in those formulas are interpreted in Table.1 (Re_f=10^4~$1.2*10^5$ and Pr_f=0.7~120).

Table.1 symbol table

Symbol Table			
Nu	Nusselt number	K	Heat transfer coefficient (W/(m^2.ºC))
Re	Reynolds number	d_i	Diameter of brass (mm)
Pr	Prandtl number	h	Convective heat transfer coefficient (W/(m^2.ºC))
D	Diameter of coil (mm)	λ_c	Thermal conductivity of copper (W/(m^2.ºC))
λ	Thermal conductivity of water (W/(m.k))	n	Number of theoretical calculation
ε_n	Correction factor of tube row	Δt	Temperature difference (ºC)
$\Delta\tau$	Average bath time of person (s)		

The formula of the heat transfer outside is shown as Eq. (3) [2].

$$Nu = C\,\mathrm{Re}^n\,\mathrm{Pr}^{1/3} \tag{3}$$

The heat transfer coefficient is shown as Eq. (4).

$$h = (\lambda Nu)/d_o \tag{4}$$

The *C* and *n* in Eq. (3) are selected from Table.2.

3.2 Spiral tube heat exchanger model

The heat transfer between tap water and waste water could be divided into three parts. One of them is the heat exchange between the tap water and the wall of tube. It accompanied by strong flow disturbances. This flow process can be illustrated with the vortex of dean. The function of this vortex is to enhance the disturbances of fluid. It makes fluid moves constantly to the tube wall and back at the same time. Thus, it improves the heat transfer coefficient [2]. The second process is the transfer between the inner and the outer wall of this tube. The third process is the transfer between the outer wall of tube and the waste water. In this paper, the process is explained as the exchange model of tube bundles with cross flow.

Table.2 data sheet

Re	C	n
0.4~4	0.989	0.330
4~40	0.911	0.385
40~4000	0.683	0.466
4000~40000	0.193	0.618
40000~400000	0.0266	0.805

There are several formulas used to show the transfer form by comparing to other heat process. In such conditions that $5000<Re<10^5$ and $0.7<Pr<5$, the heat transfer correlation that occurs in the inside of tube is shown to Eq. (5) [3].

$$Nu = 0.00619\,\mathrm{Re}^{0.92}\,\mathrm{Pr}^{0.4}(1+3.455\frac{d_i}{D}) \tag{5}$$

The heat transfer coefficient of inside is shown to Eq. (6).

$$h_i = \frac{\lambda Nu}{d_i} \tag{6}$$

In the conditions, $10^3<Re<2*10^5$ and $0.6<Pr<500$, the heat transfer correlation that occurs in the outside of tube is shown to Eq. (7) [4].

$$Nu_f = 0.27\,\mathrm{Re}_f^{\ 0.63}\,\mathrm{Pr}_f^{\ 0.63}(\mathrm{Pr}_f/\mathrm{Pr}_w)^{0.25} \tag{7}$$

The Eq. (7) which is used for tube rows is greater than or equal to the row 16. Thus, it must be corrected as Eq. (8).

$$Nu'_f = Nu_f\varepsilon_{\mathrm{n}} = 0.27\mathrm{Re}_f^{\ 0.63}\mathrm{Pr}_f^{\ 0.63}(\mathrm{Pr}_f/\mathrm{Pr}_w)^{0.25}\varepsilon_n \tag{8}$$

The heat transfer coefficient of outside is shown to Eq. (9).

$$h = \frac{\lambda Nu'_f}{d_o} \tag{9}$$

The symbols in those formulas are interpreted in Table.1. The temperature used during calculation is the average temperature of import and export. Pr_w is decided by the average temperature of the wall of tube.

3.3 Overall heat transfer coefficient

The whole heat transfer coefficient could be shown as Eq. (10).

$$k = \frac{1}{\frac{d_0}{d_i}\frac{1}{h_i} + \frac{1}{h_o} + \frac{\delta}{2\lambda_c}\ln\left(\frac{d_o}{d_i}\right)} \tag{10}$$

The Eq. (10) can be used to express the heat transfer coefficient of the serpentine tube heat exchanger model and the spiral tube heat exchanger model. Thus, the heat transfer coefficient is shown as:

$$kA\Delta t = k_l A_l \Delta t_l + k_s A_s \Delta t_s \tag{11}$$

4 EXPERIMENTAL STUDY

The experiment was made in winter. The system diagram is shown as Fig.2.

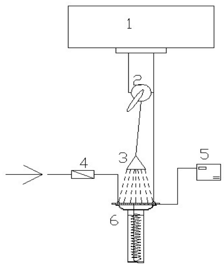

Fig.2 the diagram of system

In this system diagram, 1 is the electric heater; 2 is valve of mixing water; 3 is the sprinkler head; 4 is the flow meter; 5 is the temperature logging devices; 6 is the new type of energy-saving floor drain.

First, the tap water flows through the new type of energy-saving floor drain. At the same time, it absorbs heat from the bathing water. Then it flows into the electric heater.

4.1 data analysis

The heat absorption of tap water from the bathing water is calculated by Eq. (12).

$$Q = c_p m \Delta t' \tag{12}$$

The overall heat transfer coefficient can be calculated by Eq. (13).

$$k = \frac{Q}{A\Delta t} \tag{13}$$

The experimental data is shown in Table.3

Table.3 experimental data

time (s)	Temperature 1 (℃)	Temperature 2 (℃)	Time (s)	Temperature 1 (℃)	Temperature 2 (℃)
0s	73.3	73.8	104s	62.8	57.3
8s	72.8	73.3	112s	61.0	53.8
16s	72.5	72.7	120s	58.7	49.3
24s	72.0	72.3	128s	55.6	44.3
32s	71.4	71.7	136s	52.3	39.1
40s	71.0	70.9	144s	48.4	33.8
48s	70.3	70.0	152s	44.6	29.6
56s	69.5	69.2	160s	40.6	26.3
64s	68.7	68.4	168s	36.9	23.7
72s	67.8	66.7	176s	34.1	21.7
80s	67.0	65.1	184s	32.0	20.4
88s	65.5	63.3	192s	30.0	19.3
96s	64.3	60.8	200s	28.7	18.5

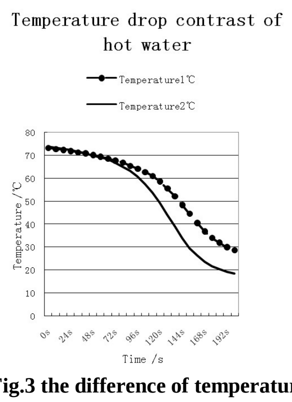

Fig.3 the difference of temperature

In the Table.3, the temperature 1 is the temperature of the tap water which does not through floor drain. The temperature 2 expresses the tap water which through floor drain. The difference of temperature 1 and 2 is shown in Fig.3. The new type of energy-saving floor drain has a good heat recovery capacity from Table.3 and Fig.3. This energy saving floor drain can use the heat of bathing water to heat the tap water. This process reduces the usage of energy.

5 ACTUAL ENERGY SAVING

In order to illustrate the ability of energy-saving floor drain, an actual data is introduced in this paper. The data is got from a public bathroom in a university. The data is used to analyze the floor drain`s energy-saving capability.

5.1 Energy saving effect

The recovered heat of floor drain is calculated as Eq. (14).

$$Q = K \cdot A \cdot \Delta t \cdot \Delta \tau \tag{14}$$

The average quantity of energy saving is 1645KJ. Furthermore, the heat recovery of the whole year is about 131638KW*h.

5.2 environmental benefits

In addition to saving energy, the new type of energy-saving floor drain contributes to environmental protection. In the example above, there is a grate boiler of coal-fired for the public bathroom. The ratio of ash of coal is about 12%. The annual amount of coal of this bathroom is calculated by Eq. (15).

$$M = Q \;/ Q_{net} / \eta \approx 31.5t \tag{15}$$

Where: Q is the heat consumption of bathroom. Q_{net} is the calorific of coal.

The content of various ingredients of coal are selected from the experimental values [5].

The formations of hazardous substances are shown as follow. The ash is about 1228Kg. The quality of CO_2 is 53784Kg. The quality of SO_2 is 1223Kg. Thus, it can reduce the value of PM*2.5*.

CONCLUSION

In this paper, researchers have designed a new type of energy-saving floor drain. It can control insects and odour, recover heat and protect the environment. Its recovery capacity is verified by mathematical model and experimental data. Finally, the ability of protecting the environment is expressed by the data from a public bathroom. In the process of data analysis, it was demonstrated an excellent ability to heat recovery. It can save 131638KW/h every year. This energy can be converted into the heat release of 31.5*t* bituminous coal of II. These coals reduce a lot of pollutant emissions about CO_2 and SO_2 and ash. Thus, it is an environment friendly invention. It also has the feature of control pest and odour.

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REFERENCES

[1] Xiaoyan Wang, Yongqi Liu, Zhenqiang Gao, Wang Yao. `*Agricultural Equipment and Vehicle Engineering*. 5(13), pp.46-49, **2011**

[2] Zhu Hui. Study on Dean Vortices and its Heat transfer Enhancement Characteristics in Helical Tubes. Hunan University of Technology, China, **2010**

[3] Xin RC，Ebadian MA. *Heat Transfer*, 119, pp. 3-7,**1997**

[4] Yang Shiming, Tao Wenquan. Heat Transfer. Higher education press, China, pp, 197-219, **2006**

[5] Ding Chonggong, Dou Guangxiao. Industrial Boiler Equipment. Machinery Industry Press, China, pp, 321-361, **2005**