Research and Design on Indoor Heating Model

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Abstract: Choosing a good radiator installation location is very essential for indoor insulation, and it may also significantly improve people's working environment. Firstly, the article considered the three most popular radiators on the market that meet the standards. A model of the heat dissipation performance of the radiator was established which considers the volume, cost, heat dissipation and radiating area. Then, the article calculates how many heat sinks are needed in a room. Based on the reasonableness of the location of the radiator, we proposed that it should be placed near the wall and near the floor. The article also assume the unclosed windows as a heat sink. Through testing the model, the article analyzes the reliability and versatility of the model, and summarizes the shortcomings of the model.

1. Introduction

Choosing the type of radiator and the layout of the radiator is very important to improve the comfort of the office. As shown in Figure 1, take the floor plan of the administrative building of a Northern University as an example. Each floor has two rows of offices of the same size, and there are aisles between the two rows of offices. The office is 3.5 meters wide, 4.8 meters long and 3 meters high. The windows are installed on the outer wall of the house. The windows are 1.5 meters wide, 1.3 meters high, and 1.1 meters above the ground. The window glass is tempered glass with a thickness of 5mm. The outer wall and the aisle wall are load-bearing walls, the outer wall is 45 cm thick, and the aisle wall is 40 cm thick, and is a reinforced concrete structure. The outer wall is protected by an external insulation wall. The thickness of the lightweight wall between the two offices is 25 cm. The wood door is 1.2 meters wide, 2 meters high and 5 cm thick. As a northern university, it is very important to install radiators in the office.

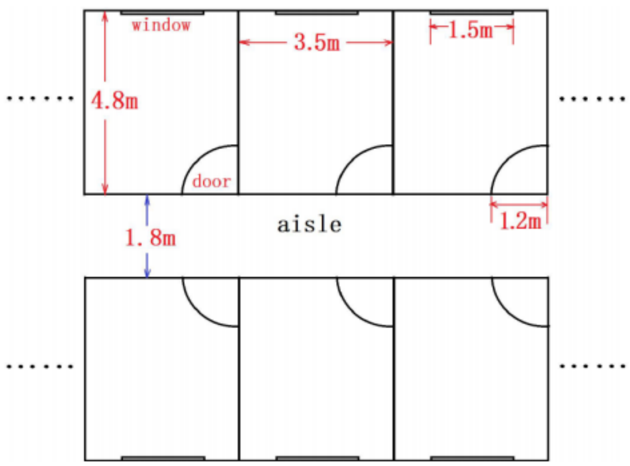

Figure 1 Sketch of School Building

By studying three mainstream radiators with heights ranging from 60 cm to 80 cm on the market, this article analyzes their heat dissipation performance and selects the best radiator. Considering the floor plan and heat dissipation of the office, determine the installation location of the radiator in the

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office, so that the office room has the best heat preservation effect when heating in winter (the temperature of the water entering the radiator is about 85°C). In order to better simulate the actual situation, this article considers that when the window is not closed tightly and the leak is about 0.3 cm, this seam will affect the temperature distribution in the office.

Before modeling, we make the following assumptions.

1) The material of each type of radiator has a negligible effect.

2) It is assumed that the indoor temperature of the house in the north is about 18 degrees Celsius, and to ensure that the house maintains an average temperature, the heating method is continuous heating.

3) Lightweight walls do not absorb much heat from the radiator. It can be assumed that the lightweight walls do not reduce the heat dissipation of the radiators from one room to another. While the outer wall, which is protected by an external insulation wall, has an ability to prevent heat from escaping. It also means that it can absorb heat from both inside and outside.

4) The intensity of light can be considered to be stable, and the totally time of light intensity is 12hours.This can simplify the model.

5) For the solution of the room temperature, we need to make the following assumptions:

(a) The room and all objects (doors, Windows, lightweight walls, corridor walls, external walls, indoor air) initial temperature is 0℃.

(b) The initial temperature of heating is equal to the inlet water temperature 85℃, the initial value of outdoor air is -8℃.

(c) Radiator is the only inside heating heat source.

(d) Because the winter is cold, so people are consciously to close the door. So assuming office wooden door always closed.

2. Modeling the performance of the radiator

We will determine the three mainstream radiator brands according to the the top ten radiator brands announced by China pp in 2020. To ensure the authenticity of the data, the link to the China pp survey statistics is available[1].

According to this survey, we selected three mainstream radiator manufacturers. We also selected radiators that height between 60cm-80cm among three mainstream radiator manufacturers. Table 1 lists the main parameters of radiators that satisfied requirements.

Table 1 Three mainstream radiators

Band	Model	Height (cm)	Width (mm)	Thickness (mm)	Radiating Area(m^2)	Heat Dissi-pation(W)	Cost (CNY)
ST.LAWRENCE[2]	SG60C	60.0	60	90	1.60	100	83
KING ADMIRAL[3]	6030F	60.0	60	90	1.55	124	99
KING ADMIRAL[3]	6030F	80.0	60	90	1.80	144	114
ZEHNDER[4]	JU2067	66.6	58	80	1.18	107	147

Obviously, using the Heat Dissipation per Radiating Area to characterize the heat dissipation area of the radiator is intuitive and accurate. We can get the function of Heat dissipation performance as:

$$Heatdissipationperformance = P/S = \eta\,(\frac{W}{m^2}) \tag{1}$$

While P means the Heat Dissipation and S means the Radiating Area. η means the Heat Dissipation per Radiating Area. We want η to be as small as possible. Let ζ define as Cost divided by V. We want ζ to be as great as possible. Consider the economics, heat dissipation performance will be defined as[2]:

$$Heatdissipationperformance = \frac{1}{\frac{Cost}{V}}\frac{P}{s} = \eta/\zeta \tag{2}$$

The comprehensive results reveal that "KING ADMIRAL2" can effectively work in indoor environment, it cost less but outperform other radiators in terms of thermal power consumption. Our model also got the same conclusion.

3. Optimum placement of radiators

The first thing that should be determined is the number of radiators in each room. Then simulating the radiator heat conduction to find the radiator heat range. Finally, the maximum ambient temperature is selected as the objective function, and the radiator placement is the decision variable, and the optimal placement of the radiator is obtained by using the optimization algorithm.

3.1 The model of radiators' number

When there is a difference in indoor and outdoor temperature, there is a heat exchange. House through the heat transfer structure to the outside of the heat and the heat of the infiltration of cold air become the house heat. The heat a house receives from a source other than its heating system becomes its heat gain. Heating load of a room refers to the difference between heat loss and heat gain in a room. The heating load is generally provided by the heating system.

The heating load is usually estimated by equation 3.

$$Q_j = (1 + \Sigma B_i)qF \quad (3)$$

While q means the thermal index per unit area and F is the area of one room. Bi is the correction coefficient.

According to Thermal test report of radiator in China. The heat gain of a room can be estimated by equation 4.

$$Q_i = k\Delta t^n \,(ten\ bar) \quad (4)$$

While k is a coefficient of equation and Δt is the difference between the average temperature of the water passing through the radiators and the indoor temperature. n is a coefficient too.

Finally, the number of radiators can be calculated as:

$$N = \frac{Q_j}{Q_i} = 10\,\frac{(1 + \Sigma B_i)qF}{k\Delta t^n} \quad (5)$$

3.2 Optimal radiators placement model

The total width of radiators equals to the number of radiator in one radiators times the width of one radiator and the spacing between each radiator.

$$Width = N \times (w + spacing) \quad (6)$$

We may as well use the KING ADMIRAL2 radiator we recommend to the university, its height is 0.8m which is lower than the height between windows and ground. So it's possible to install under windows. There are three conditions limiting the location of the radiator installation:

1) Radiators contains floating water, they generally installed on the ground.

2) For more convenient installation and more stable fixation, they generally installed near wall.

3) For air convection and heating of cold air, radiators are usually installed under windows or on either side of the walls of windows.

Therefore, where the radiators allowed to be placed is shown in the Figure 2.

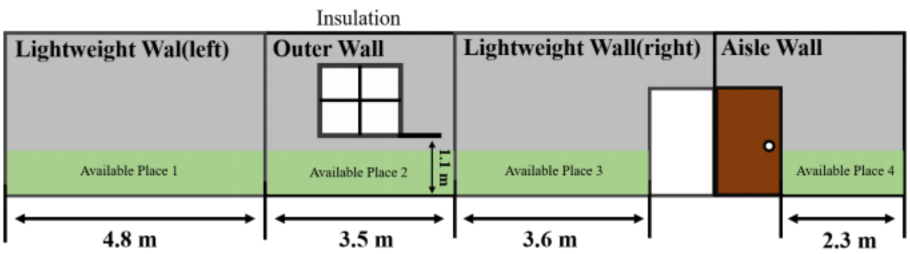


Figure 2 Available places for radiators

Furthermore, the utilization should take into account. The best location of radiators is decided by the following equation:

$$max\ Z = e^{-d}\frac{S'}{S} \tag{7}$$

Where e^{-d} is the cold air convection rate. d is the distance between radiators and windows. When radiators is under windows, the cold air convection rate equals to 1. S'/S is the utilization of radiators which is defined by the utilized area.

3.3 Result

All the parameters will be set accordingly. According to reference[3], because this room is used for working, parameter q in equation 3 will be considered as 50-70.Might as well to chose the greatest value —— 70W/m^2 and set ΣBi to 0.2.

According to Thermal test report of radiators in China, parameter k in equation 4 will be considered as 5.8259 and parameter n will be considered as 1.268.

Take the rest parameters showed above, we can calculate the number of radiators that we need is:

$$N = \frac{10 \times 1.2 \times 70 \times 3.5 \times 4.8}{5.8259 \times (85-20)^{1.268}} \approx 12 \tag{8}$$

That is the total radiators we need in one room. The width of radiators is 0.84m according to equation 6. Figure 3 shows the utilization of radiators in different places. According to all the rules, it is obviously and clearly the best places is the red area in the picture. For the first room and the last room, only one place is available. For the rest rooms, there are two available places. To simplify the model and speed up calculating, we design to place all the radiators on the middle of right or left lightweight walls.

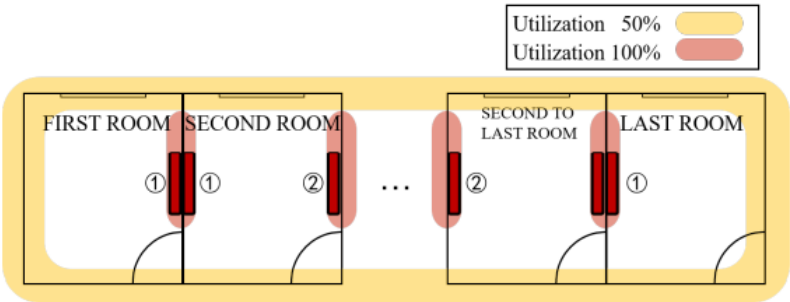


Figure 3 Utilization and all available places in rooms

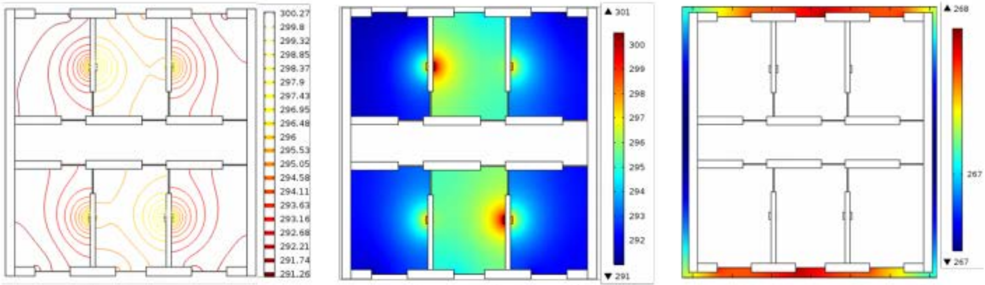
4. Heat sink-Windows model

The fact that the window is not closed indicates that heat will be exchanged at the window with the outside world. Since the outside temperature is low and fixed, the gap of window can be regarded as a heat sink.

We construct the gaps by reducing the length of the windows in a geometric model and assume that all Windows have leak gaps. In addition, we applied a velocity field (temperature 265.15K(-8℃), velocity direction parallel to the window, velocity size 8m/s (wind force level4).)

As other conditions remain unchanged, after setting the heat sink at the position of all windows, we simulated the temperature changes caused by heat sink as Figure 4.

The results indicate that due to the leakage of the windows, the heat loss in the office resulted in the indoor maximum, minimum and average temperature dropping by 3℃compared to the previous temperature. And the air layer of the outer wall absorbs the leaked heat, so the minimum temperature increases by 1.85℃and the maximum temperature increases by 2.85℃.It can be seen that our simulation is successful, and more in line with the reality.



a) Isotherm　　b) Hot map-indoor air　　c) Hot map-outdoor air

Figure 4 Temperature of rooms (windows open)

5. Test the Model

We conducted more studies on our model and presented experiments train. Our focus is on the sensitivity of parameters λ_i, $i \in [1,3]$. So we modify these three parameters and use them to train the model individually in 3 times. The result has been shown below the table 2.

Table 2 Parameters sensitivity analysis

factors weights λ_1 λ_2 λ_3	exp groups	estimated position (m)	estimated rotation (rad)	optimal value
1 1 1	1	$(2.573, 3.487)$	1.40	-307.205
	2	$(2.570, 3.424)$	1.430	-303.378
	3	$(2.571, 3.450)$	1.420	-304.488
1 2 4	1	$(0.961, 2.330)$	0.759	-1153.8
	2	$(1.004, 2.176)$	0.953	-1161.6
	3	$(0.925, 2.271)$	0.7533	-1156.3
4 2 1	1	$(2.566, 3.425)$	1.461	-1005.4
	2	$(2.546, 3.472)$	1.464	-1005.8
	3	$(2.550, 3.362)$	1.396	-1001.8

Furthermore, with the position data, it enable us to measure its RMSE (root mean square error) [4].

$$RMSE = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(d(x_i, y_i)_{test} - \hat{d}(x_i, y_i)_{test})^2} \tag{9}$$

Firstly, we defined ˆd (xi , yi) test as the centroid of all the estimated position.
Then, put the data into the formula, the error results are listed in the table below:

Table 3 Root mean square error analysis

Experiment groups	$\lambda_1 = 1$ $\lambda_2 = 1$ $\lambda_3 = 1$	$\lambda_1 = 1$ $\lambda_2 = 2$ $\lambda_3 = 4$	$\lambda_1 = 4$ $\lambda_2 = 2$ $\lambda_3 = 1$
RMSE value	0.0001	0.0001	0.0001

Base on the fact that RMSE << 1, we believe it shows the stability and accuracy of our model.

6. Conclusion

In summary, our model is very sensitive to weight parameters, so it can better control the impact of different factors. Also, the model convergent very well so that it has very excellent stability performance. All the parameters in the model are not specific, which shows that our model is universal, extensive and universal. The simulation results of all models are very close to reality, which shows that our model establishment is successful.

But our model also has some shortcomings, such as:

1) It can be considered more deeply when considering the placement of the radiator. Only simple

assumptions and a few considerations are made here.

2) When considering the energy of sunlight, we set it to a fixed value in order to simplify the model, but its energy should be increased and decayed over time.

References

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