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INFLUENCE OF CONVECTOR LOCATION ON ROOM TEMPERATURE DISTRIBUTION

Розглянуто вплив різних варіантів розташування опалювальних приладів у приміщенні на енергозбереження і створення комфортного температурного поля для перебування людей. Для дослідження було вибране квадратне приміщення з похилим дахом, яке має світлові прорізи різного розміру з трьох сторін. Дослідження показали, що оптимальним з точки зору енергоефективності, комфорту та ергономічності є варіант приміщення з конвектором, розташованим під стіною з одним вікном.

Introduction

When designing heating systems for buildings, great attention is paid to energy saving. When trying to minimize heat loss, designers are not always able to provide comfortable zones in the room for people to stay in, as they do not always have sufficient information about such zones. If there is lack of power in the heating system, in order to eliminate the designers' errors, one has to use electric heaters, which results in additional material costs. Therefore, along with paying attention to energy conservation, the issue should be raised about providing the maximum comfort for people to stay in the room, depending on where the working or sleeping place is located. The most obvious solution is to manage the temperature distribution by changing the location of the heating devices.

In the room with similar characteristics [1], it was determined that the maximum energy conservation can be obtained by starting the room heating from its most heat-absorbing parts, i.e. from the walls, floor and the roof. In this case, however, the temperature distribution was not investigated. In [2] it was shown how various factors influence the energy conservation, such as the range of change and the value of the convector thermal conductivity while the room is being heated from the cold state, the room daily temperature mode, as well as the thermal protection of the enclosing structures. Research of the influence of the location of heating devices in the room on the economy of thermal energy were not carried out, and the temperature field was not obtained.

The purpose of the research was to determine an optimal option of locating a heating device in a room from the standpoint of conserving energy and creating conditions for maximum comfort of people in the room.

Research results

As an object for examination according to [1], a 4×4 m. room with 0.3 m thick concrete walls and a 2.7 − 3.7 m high inclined roof was chosen (Fig. 1). Three walls of the room had light apertures with double-glazed units having a known resistance to heat transmission. The area of the apertures was 12.6, 2.52 and 12.6 sq.m. The first one was a window with a door, the second one was a small window, and the third one was the window of about the wall size. As a heater, a 2,400×400×98 mm convector (Fig. 2) with four parallelepiped-type heating elements with a total performance of 1.5 kW was selected. The heating of the air was carried out mostly by natural convection. As initial and boundary conditions, the outdoor air temperature of 0°C and the coefficient of heat transmission (of 8.7 W/(m^2K)) from the air at the surfaces of the outer walls were accepted, which corresponds to windless weather. The influence of solar radiation was not considered.

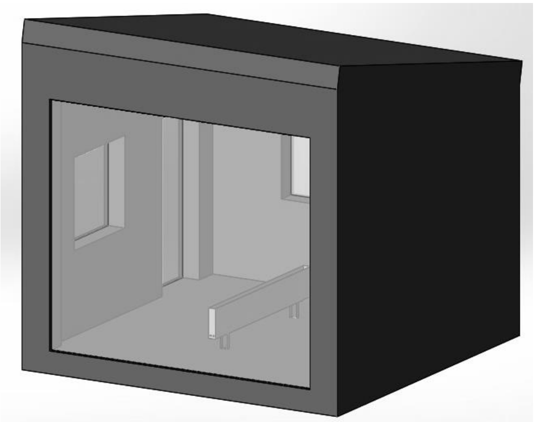
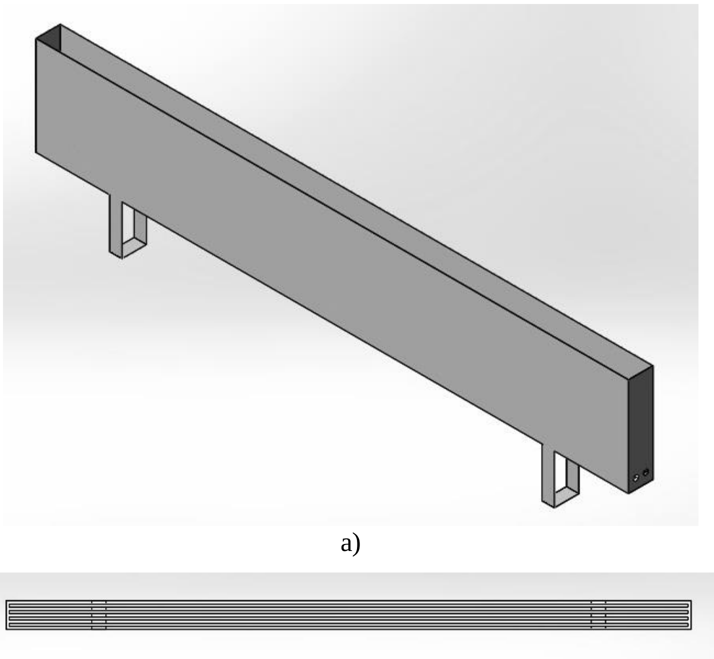


Fig. 1. Room model



a)

b)

Fig. 2. Convector model:
a) – appearance, isometry;
b) – embedment of the heating plates, top view

The problems were solved both in a stationary and non-stationary statements. This made it possible to obtain more accurate data on the distribution of temperature in the room. In total 4 different options of placing the heating devices were examined: in the middle of the room (option 1), against the wall without a light aperture (option 2), against the wall with a window (option 3) and against the wall with a window and a door (option 4). The option of heating the room with a warm floor having the performance of the convector was examined as well (option 5). As a criterion for determining the comfort (unevenness of air temperature distribution), the ratio of deviations of the maximum and minimum values of the air temperature in the horizontal section at a height of 1.3 m above the floor of the room to the average temperature in the same section was chosen. When processing the results, an analysis was also carried out against the average air temperature in the room and the temperature of the internal walls.

The research showed that for all the options of placing a convector, a rather uniform temperature distribution is observed at a height of 1.3 m above the floor level (Fig. 3). At the same time, above the heating devices the air turns out to be overheated, but at a slight distance from them this is no longer felt, indicating that the mixing of air in the room is good enough. As for the average temperature in the room (table), its largest value is observed when option 1 is used. This may be caused by the fact that the remaining methods imply placing convectors close to the walls, which results in the radiation part of thermal energy being selected by them. Installing screens will help to solve this problem, as a result of which the average air temperature in the room will increase. With regard to option 5, there is a direct contact with the floor, which has a finite thermal resistance, which causes a decrease in the average temperature in the room.

The average temperature dispersion for all the methods of placing a convector does not exceed 0.4 C. The lowest average temperature is observed in option 4, where the largest heat losses are present due to the closeness to the window, as well as in option 5, where there is a direct contact with the floor.

Table. Results of modelling

Option of placing a convector	Average air temperature, °C	Average aerial speed, m/s	Average temperature of external walls, °C	Average temperature of internal walls, °C	Average temperature of the convector plate surface, °C
1	11.9659	0.0858	0.9870	7.6273	59.1855
2	11.9273	0.0874	1.0459	8.0996	57.9192
3	11.8277	0.0833	1.0071	7.7911	61.5812
4	11.5856	0.0866	1.0030	7.7641	56.6596
5	11.7586	0.144	–	–	–

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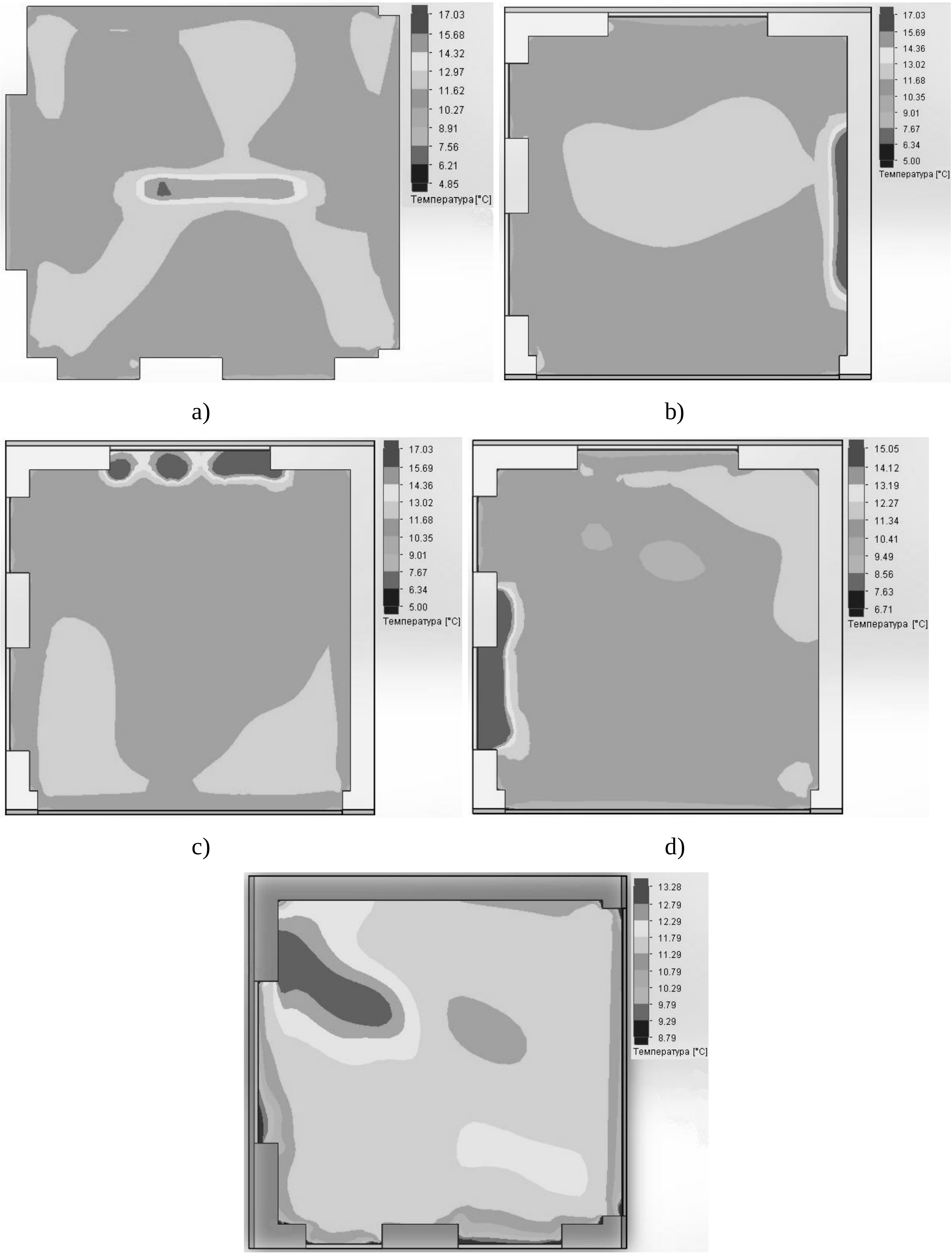
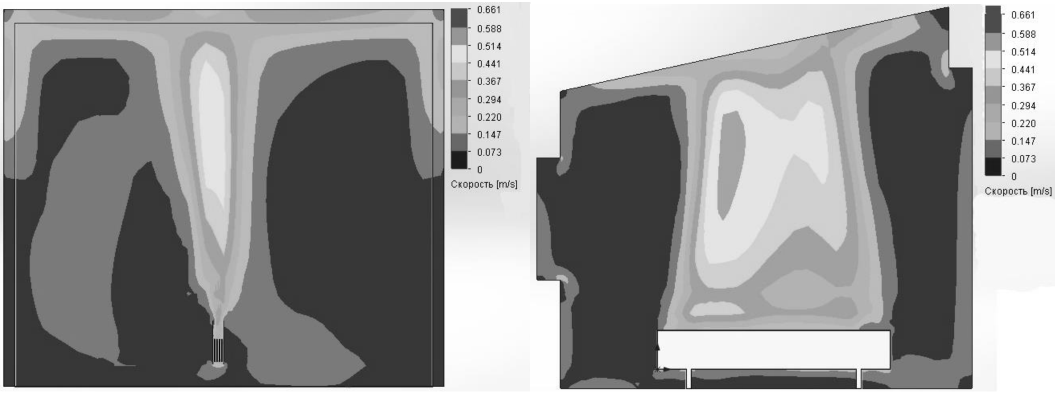


Fig. 3. Temperature distribution at a height of 1.3 m above the floor level for different options of placing convectors:
a) – 1, b) – 2, c) – 3, d) – 4, e) – 5



a) b)

Fig. 4. Distribution of air speed in the room for option 1:

a) – in lateral section of the room; b) – in longitudinal section of the room

Option 5 also showed the smallest uniformity of the temperature distribution at a height of 1.3 m above the floor, which can be explained by the fact that the share of heat transfer by convection for warm floors is much smaller, which results in poor air mixing. The temperature range at this height in different parts of the room reaches 2 °C (15 percent in relative units), while in other options it does not exceed 1 °C (7.5 percent).

Internal and external surfaces of the walls are heated less when the convector is located in the middle of the room, which can be fully explained by it being located significantly far from the walls. The air flows around the inner walls of the wall when already rather cooled, while for options 2 to 4 hot air with a temperature of about 50 − 60 °C almost immediately comes in contact with the nearby wall surface. Also, one should not forget about the heat exchange by radiation, as the case of the convector will warm up as well.

The speed of air movement in the entire room in the steady state for options 1 to 4 is of the order of 0.085 m/s. The greatest air movement can be felt both over the convector and near the ceiling (option 1 in Fig. 4). In order to improve the uniform distribution of temperature in the horizontal plane of the room (option 5), the density of the heat flow of the floor surface should be increased along the boundary with the walls in comparison with the rest of the floor surface.

Conclusions

1. Taking into account that all the options of placing a convector have practically the same efficiency, in order to achieve the maximum comfort of people staying in the room, it is worthwhile considering option 3. Due to the warm air coming out of the convector, it provides the cutting off of the inflow of cold air from the windows, which will make it possible for people to protect themselves against drafts.

2. For each of the considered option it is possible to achieve a greater energy saving effect. For example, installing screens on the wall behind the convector or additional warming of the load-carrying structures will reduce heat loss and increase the average room temperature.

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