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Floor Heating, Benefits and Solutions to Increase System Efficiency

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ABSTRACT

The present article examines a new method of heating from the floor. After introducing this method of heating, its variations and how it corresponds to the process and mechanism of energy release from the human body and the comparison of these two cases were considered. In another part of this preliminary research, the general structure and components of the underfloor heating system and its implementation including the insulating layer and the pipes used were investigated. Furthermore, with the help of simulation software, a room with floor heating was simulated and the thermal comfort parameter was checked.

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Introduction

Many researchers have provided research on energy [1-4]. To heat the environment, systems with different efficiency and effectiveness have been built. The subject discussed in this article is the underfloor heating system. As its name suggests, this system is a type of modern heating system that is installed on the floors of buildings and emits heat from the floor. Today, because approximately 90% of the world's energy consumption is obtained from the combustion of fossil fuels and the world's increasing need for energy, the limited, rapid reduction of fossil fuel resources and environmental problems have caused the use of high efficiency and more efficient systems to be considered by designers [5]. The underfloor heating system in Iran has been welcomed by designers for several years and is used in the design of buildings. Unlike radiators and other heating devices that heat our environment from top to bottom, in this system, the heat is exactly where we need it, that is, on the floor of the building. Since this system has attracted the attention of designers, in this article the method of its implementation and increase in efficiency will be examined. The heating system of the building is divided into different categories. This division can be based on the type of fuel used or the type of heat transfer and exchange. Today's heating systems are divided into three categories according to the type of fuel: (1) common fossil fuels such as gas and diesel; (2) renewable fuels such as solar energy; and (3) electricity. They are also divided into three categories according to the type of heat transfer: (1) radiation; (2) convection; and (3) hot air.

Hesaraki et al. [6] reported that low-temperature radiant heating (LTH) and high-temperature cooling (HTC) have become popular due to their high energy efficiency, thermal comfort, and improved indoor air quality. In their review article, LTH/HTC systems were analyzed and discussed based on their results in energy consumption, thermal comfort, indoor air quality, design and control. Oravc et al. [7] showed that a comprehensive comparison of radiant heating systems that would help make an informed decision about choosing the most convenient system for a particular application does not exist. Therefore, the application of six floors of wall and ceiling radiant heating systems was compared in terms of thermal efficiency and required surface area, controllability, short-term and long-term heat storage, suitability for building retrofitting and their investment. Zhang et al. [8] stated that building thermal inertia and operation control strategies affect the thermal performance of a radiant floor heating system. In their study, they presented the potential of numerical simulation in evaluating the effects of radiant floor heating on the internal thermal environment, taking into account the thermal inertia of the building and transient external climatic conditions. Xu et al. [9] stated that the combination of phase change energy storage materials with floor radiant cooling and heating systems has become one of the main technical means of energy-saving buildings. Larwa et al. [10] studied the underfloor heating system with Phase Change Materials (PCMs); they showed that the use of high thermal conduction in mortar increases the overall performance of the PCM-integrated underfloor heating system much faster. Furthermore, Lu et al. [11] stated that phase change materials (PCM) can be integrated with underfloor heating systems to store excess heat and release it when needed, thus effectively reducing the mismatch between energy supply and demand.

Today, researchers have concluded that the best type of heating for living beings is radiant heating. Figure 1 shows that the temperature profile of floor heating is very close to the ideal temperature profile [12]. Convection heating ranks second (in the radiator system and corner radiator heat transfer is by convection) while heating through hot air is the most inappropriate type of heat transfer and causes fatigue and illness in humans (Fan Coil And Zent systems are of this type). The underfloor heating system also has its disadvantages, which can be due to the slowness of the system and the need for precise control to reach suitable conditions not examined in this article due to the limitation of pages.

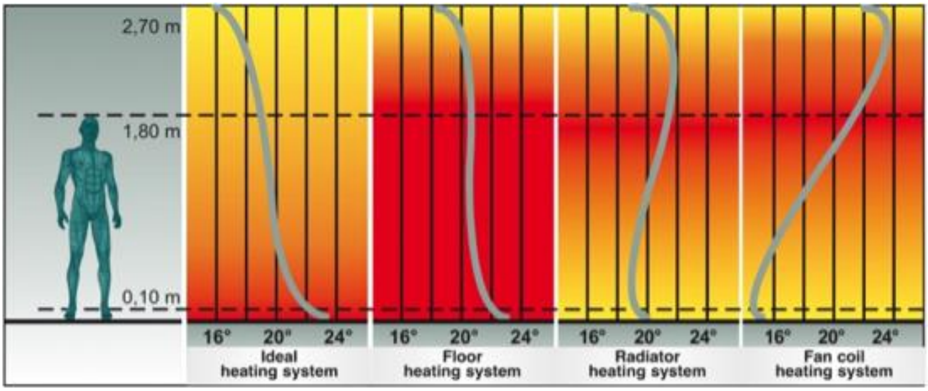

Figure 1. Comparison of the temperature profile of floor heating with other heating systems [12].

In the present research, a CFD analysis was performed to clarify the effect of design parameters on the performance of the underfloor heating system. For this purpose, a simple model was created for a typical room with a floor heating system. The mechanisms of transient transfer, convection and radiation of heat transfer were considered in this analysis. It was observed that different design parameters have different effects on the performance of the radiant heating system. Finally, the thermal comfort parameter was investigated.

Underfloor heating system and how it works

Floor heating is a method of producing heat in cold seasons indoor. As its name suggests, this system produces heat from the floor. One of the major problems of Iranian houses, especially those with ceramic and stone floors, is the coldness of the floor in winter which forces residents to use carpet flooring over ceramic and stone or use shoes and sandals. Thus, the floor heating system is a very suitable option. The problem with houses that are on the first floor (above the parking lot) is that the floor of the house gets cold in winter, and in some cases, a feeling of cold emanates from the floor. In this category of houses, which does not have floor insulation or is not correctly carried out, it is very appropriate and wise to use the floor heating system. In this method, heat is produced in the following ways: (1) heating through hot water circulation (wet method) and (2) heating through electric current (dry method).

Types of floor heating design and arrangement

1- **Spiral design:** This method is special for rooms with a cold wall, a window or places with a small width (such as a corridor) where the first incoming hot water passes by the side of the cold wall or window and the pipes will be more compressed in this area. The closer it is to the center, the less compact it is. This design is used in corridors.
2- **Double-sided or L design:** This type of design is mostly for rooms with two cold walls or two windows, and the pipes first pass through the cold walls where compression is higher.
3- **Three-way design or U:** This type of design is more for rooms with three cold walls where the compression towards the center is less.
4- **Four-sided design or loop:** This design is one of the best types of layouts in the design of the floor heating map, which can be used in all cases. Usually, halls and guest rooms are arranged in this way, and the highest thermal efficiency is achieved [13; 14].

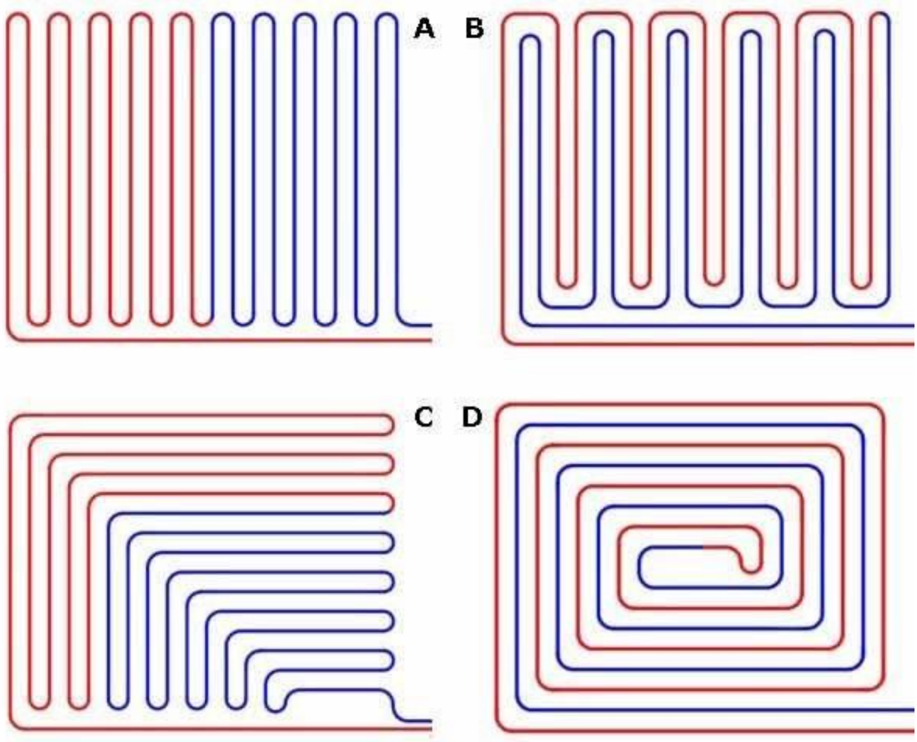

Figure 2. Types of floor heating arrangements [14].

In the design of the floor heating map, factors such as minimum and maximum area, expansion joint, heat uniformity, cold boundary, toilet, and kitchen must be observed. A floor heating map is one of the most important elements of a good and efficient system. If the map is unprincipled or if there is no map, the floor heating will not work well and the temperature balance will not be established.

The benefits of using a floor heating system

1- Comfort and relaxation at the highest possible level: There will be constant and permanent temperature near the floor of the building and where one is located throughout the winter. This is a very pleasant situation when the environment around the feet is warm and the air to be breathed is not too hot. The temperature profile of the floor heating system is very close to the ideal profile, the heat spreads slowly from the floor to the ceiling, and warm feet and cool heads aid health.

2- Constancy of heat: Due to the mass of the floor covering of the building, in case of any power outage or other factors that cause the central heating to stop, the cooling time of the apartment is much longer than other methods. In this system, it first takes some time for the floor to reach the desired temperature, but after warming up, this heat is used more stably during the winter.

3- Light weight of the building and increasing the height of the rooms: Due to the use of the same type of pipe with a low size and also the elimination of the passage of the installation pipes over each other (which generally causes the floor of the floors to rise), the thickness of the coating is greatly reduced. This, while reducing the weight of the building, also increases the height of the floors.
4- Economy in fuel consumption: Due to the direct contact of people with the heating source, the temperature of the room is set at lower degrees. This will save 25 to 40% in fuel consumption.
5- Freedom of action in interior decoration: Due to the location of this system inside the floor, the furniture can be placed in any corner of the building. This will be more tangible, especially in smaller buildings and bedrooms with limited space.
6- Cleaner air and not drying the air: In the radiator system, the air in the room generally becomes dry. In many cases, by placing a container of water on the radiator, an attempt is made to increase the humidity in the room. This problem will not appear in the underfloor heating system.
7- Cleaning the walls and home furniture: In houses where heating systems such as radiators and heaters are used, the walls around and above the radiators and heaters are black and dirty due to the burning of dust in the air resulting from the heat of the radiator. This problem is one of the most common radiator problems that have been completely solved in the floor heating system.
8- Increasing the value of the house: It is common knowledge that the use of new and useful systems such as underfloor heating in houses increases their value.
9- Use of different heat sources: The floor heating system is an ideal system for building heating, this system can be used in different places and is compatible with different heat sources.
10- Drying of wet parts: In newly built buildings, dampness and humidity (in the first few years) are some of the concerns of the residents of the building. This humidity is low or high depending on the conditions. However, in houses where underfloor heating is used, this dampness disappears in a short time and the ground remains dry.
11- Low depreciation and no maintenance cost: Underfloor heating is one of the lowest depreciation heating systems available. The lifespan of the

five-layer pipes used in this system is more than 100 years; these pipes are resistant to pressure, decay and sediment [15].

The reasons for the optimality of underfloor heating

1- Radiative energy transfer: One of the reasons for reducing energy consumption in the underfloor heating system is that hot air is not produced in this system and more than 60% of the ambient heat is transferred as radiation, which is the best type for living creatures. However, in other systems, hot air is produced and transfers energy by convection.

2- Using energy in the right place: This issue reduces energy consumption in the underfloor heating system. In heating systems such as radiators and fan coils, the ambient air is heated, and the hot air goes up due to its lightness and gathers under the roof replaced by cooler air. This causes a lot of energy to be used to heat the space around us. However, floor heating, where heat is needed (on the floor of the building and around us) is hotter than in other places. Using other heating systems, the center of heat production is formed in a corner of the desired space, and the farther the distance from the center point, the less heat there will be. However, in underfloor heating systems, hot pipes are arranged uniformly in all the desired spaces, creating uniform heat in the environment.

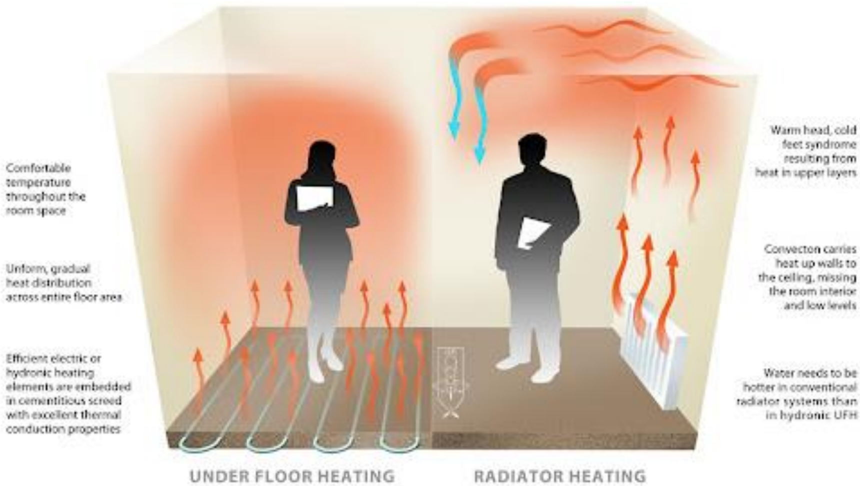

Figure 3. Comparison of heat transfer in floor heating with radiator [2].

3- Low water temperature of the underfloor heating system: In the underfloor heating system, the incoming water is between 35 and 50 degrees Celsius. In this system, unlike radiators and fan coils, water with a lower temperature is needed (about 40 degrees Celsius). Producing water with a lower temperature practically saves fuel consumption. In similar systems, this number reaches 80 degrees Celsius. Creating a temperature higher than 40 degrees Celsius will require additional fuel consumption [16].

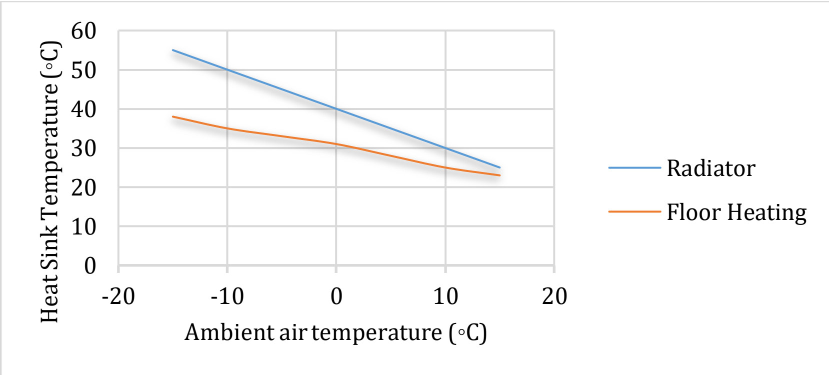

Figure 4. Comparison of water temperature in floor heating with radiator.

Governing equations

Equation of conservation of mass or continuity:

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho\vec{v})=0 \tag{1}$$

Equation of conservation of momentum:

$$\frac{\partial}{\partial t}(\rho\vec{v}) + \nabla.(\rho\vec{v}\vec{v}) = -\nabla p + \nabla.(\bar{\bar{\tau}}) + \rho\vec{g} + \vec{F} \tag{2}$$

The energy equation should be written as follows:

$$\frac{\partial}{\partial t}(\rho h) + \nabla.(\rho h\vec{v}) = \nabla.((k + k_t)\nabla T) + S_h \tag{3}$$

In this equation, k is the conductivity coefficient, k_t is the conductivity coefficient due to turbulence transfer and S_h is the source term, which includes any type of volumetric heat source. With the aid of fluent simulation software, a room with underfloor heating was investigated.

The temperature profile at different points of the plane x=2.5 (in the middle of the room) is shown in Figure 5. The temperature was high at the beginning and decreased with the increase in height due to the existence of a heating system on the floor of the room and the high level of heat transfer. As a result, the temperature decreased with increasing height and there was less heat at the top of the room where people were not present, which reduced energy loss [17; 18].

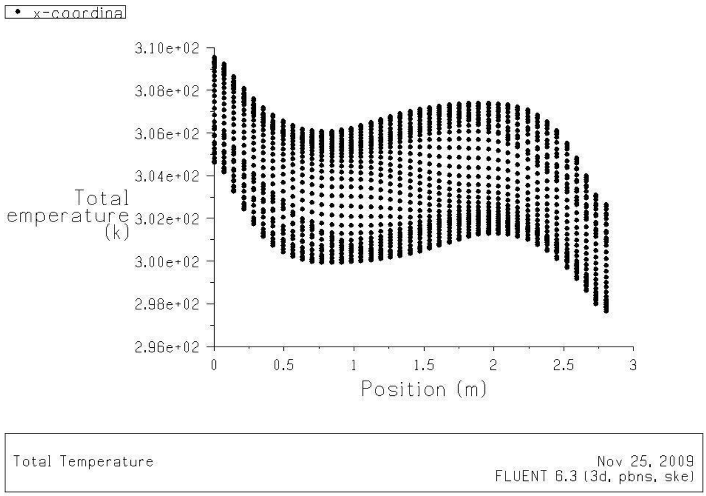

Figure 5. Temperature changes according to height in the middle plane of the room.

The velocity of the airflow in different parts of the room is plotted in Figure 6, demonstrating that the lowest velocity is in the middle of the room and the velocity of the flow increases with distance from the middle. This was because at the bottom of the room, as the temperature increases, the air density decreases and moves upwards. At the top of the room, as the temperature decreases, the air density increases and moves downwards. A rotating flow occurs due to the difference in density and the velocity decreases near the ceiling and the floor, which is in return due to the shear stress near the surface.

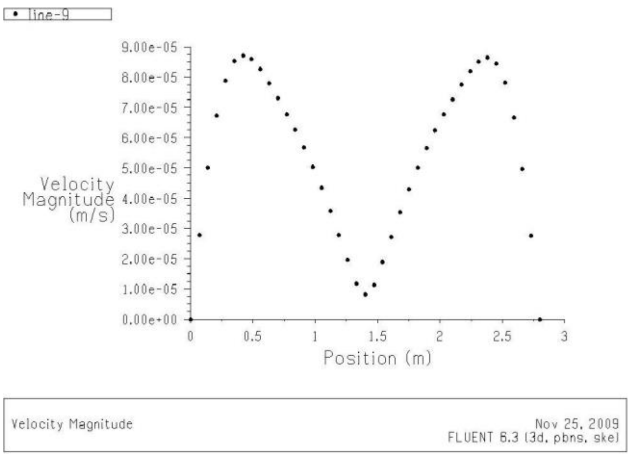

Figure 6. Velocity changes according to height in the center line of the room.

In Figure 7, the air velocity vector is drawn in the center line of the room, which shows the velocity changes. This diagram depicts a slow movement of the airflow in the room, which is very suitable for living.

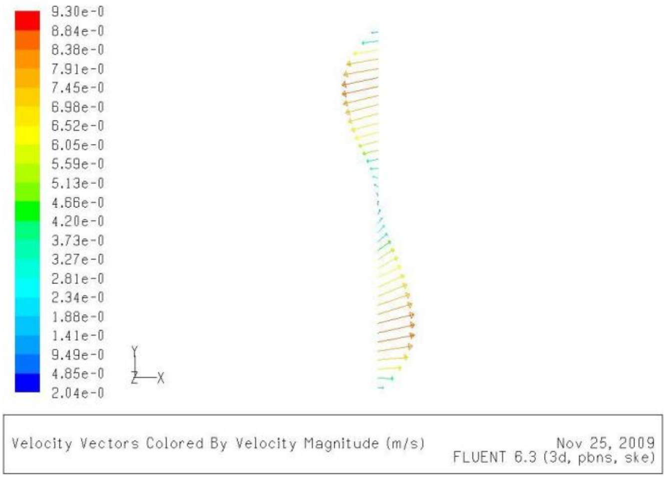

Figure 7. Air velocity vectors in the center line of the room.

The Predicted Mean Vote (PMV) according to the height of the room is plotted in Figure 8 which illustrates that the conditions of comfort are more at the bottom of the room and less at the top of the room where no one is present, and this indicates proper comfort conditions while reducing energy consumption in the room.

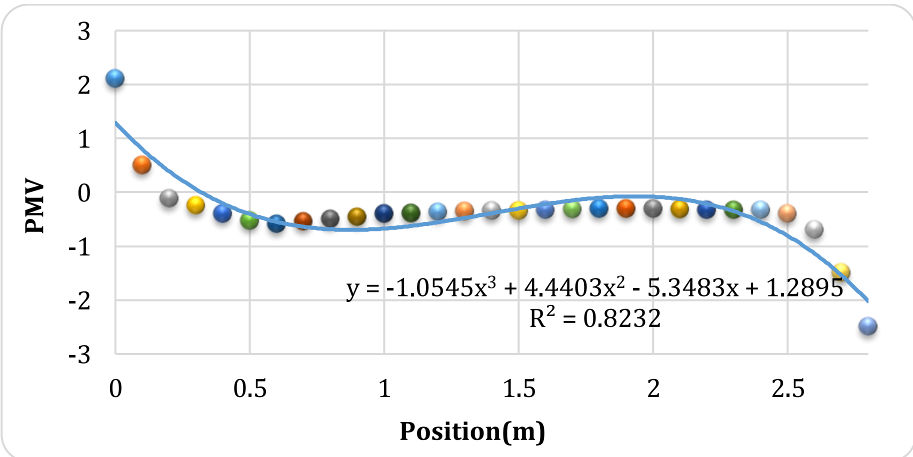

Figure 8. PMV changes according to height.

Conclusion

In this paper, a CFD analysis was performed to illustrate the influence of the design parameters of a floor heating system on its performance. The simulation method was used for the solution of a typical considered domain. Three heat transfer mechanisms; conduction, convection and radiation were considered to operate in this domain. Based on the results it was concluded that different design parameters have different effects on the performance of the floor heating system in a room. Below is a summary of the findings of the present research:

1- The floor heating system is the only heating system that has the best conditions.
2- This system can be implemented with any type of fuel, whether fossil fuels, solar energy, or electric energy.
3- A large part of its heat is transmitted as radiation and is suitable for human physiology.
4- Considering that in the underfloor heating system, over 60% of the heat transfer is radiation, it can be considered the best heat transfer system for residential, commercial and industrial projects.
5- In this system, due to its suitability in terms of PMV and comfort conditions, it is a good choice.
6- Pipe type and diameter have the minimum effects on the thermal performance of the heating floor system.
7- The most important design parameters for the heating floor system are the type and thickness of the cover. This finding also demonstrates that radiation is the dominant mechanism of heat transfer in a floor heating system. Among these two parameters, cover thickness has a more significant effects on the floor heating system performance. It was also concluded that the most sensitive regions of the room are far from the floor heating system.
8- The number of pipes does not have a considerable impact on floor heating system performance.

From a design point of view, it is noteworthy that an optimum floor heating system includes the minimum number of pipes required to supply a specific hot water flux and consists of a cover made from an appropriate material with good radiation emission behavior.

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