THERMAL MODELLING SYSTEM FOR GREEN ENERGY APPLICATION OF EXTERIOR WALL UNDER SMART HOME BUILDING

by

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Original scientific paper
https://doi.org/10.2298/TSCI2302041G

In order to better solve the problems of heating and environment, the author proposes a new Generation 5 heating technology wall green energy application thermal energy system, its main feature is a coating type carbon fiber, which heats up by connecting the electrode, so that the indoor temperature can be kept comfortable. The stability and accuracy of the heating thermal energy system are demonstrated through specific experiments. The experiment shows that the system can maintain the stability of indoor heat energy and keep the temperature in the wall between 20-25 ℃. Conclusion is that the thermal energy modelling system of the green energy application of the exterior wall under the smart home building effectively solves the heating and environmental problems.

Key words: *smart home, green energy, thermal modelling, recycling, people and environment*

Introduction

The future green integrated home product design is based on the core *3R* principle of green design, that is, reduce, recycle and reuse. Starting from the development of green, integrated and intelligent systems, we use diversified thinking to create a two-way unity between people and living room products, and re interpret the co-ordinated development of human and environment [1].

The future integrated smart home product design follows the green design concept, strengthen energy conversion and sustainable development from the perspective of material design, structural design, recycling design, energy-saving design, minimalist design, and recycling design. In this process, the *three modernizations* theory of design – modularization, standardization and serialization, the combination of green design ideas and modular design methods can meet the functional and environmental attributes of products, on the one hand, it can shorten the product development and manufacturing cycle, on the other hand, it can reduce or eliminate the adverse impact on the environment, and facilitate the upgrading and maintenance of products, and the disassembly and recycling of discarded products [2].

The starting point of system optimization research is the design method and means dominated by the universality of transformation design. In terms of design concept, the design of green integrated smart home products strives to optimize the matching relationship of *peo-*

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ple, products and environment. First of all, the design of green integrated smart home products must start from the standardization of products to verify, and improve its multiple features such as portability, simplicity, practicality, durability, easy replacement and maintenance, reuse and accessibility. Secondly, the optimized ecological energy system of integrated smart home products is also the focus of green design, the use of natural green energy can truly benefit the public, thus demonstrating innovation at the technical and ideological levels, and actively realizing the current interactive demands. Explore the design of green integrated smart home products, it is a manifestation of human demand rising to the high level of Maslow's pyramid theory of demand levels – the stage of self realization under the support of rapid economic development, enjoy the convenient life of returning to nature in the true sense is a affirmation of the realization of the survival value [3]. At that time, the green integrated smart home will show every family room a green look of intelligence, flexibility, integration and ecological energy, people will enjoy a natural and healthy slow life under the background of huge scientific and technological achievements, and maximize the dialogue and exchange between people and things, things and things.

Therefore, the author puts forward the concept of a new Generation 5 heating technology and its main technical features, and describes the thermodynamic characteristics of this far-infrared system through a case study, as well as the resulting changes in body perception, the author also enumerates the matters that should be paid attention in the construction of this system, and demonstrates the superiority of the heating thermal energy system through experiments [4].

Literature review

Research on heat energy technology of personalized smart home heating. Huang *et al.* [5] designed a direct expansion solar heat pump floor radiant heating system, the solar energy is used as the low temperature heat source of the heat pump, after absorbing the solar energy, the refrigerant directly flows through the floor heating coil to release heat to the room. The system was studied under three meteorological conditions: sunny, cloudy and snowy. Lu *et al.* [6] compared the heating performance of air source heat pump, direct expansion solar heat pump and indirect expansion solar heat pump systems, and analyzed the influence of evaporator heat transfer area on system performance when the ambient temperature and solar radiation change, the results show that, when the ambient temperature is between 5 °C and 15 °C, COP is 2.78-3.31. When the solar radiation is between 100-300 Wm^2, the COP is 271-3.2. Camboim *et al.* [7] designed a double heat source composite heat pump. The evaporator of the heat pump is a double channel heat exchanger with fins, which can absorb the heat in water and air at the same time. Combining the flat plate solar collector with the heat pump, the TRNSYS model of the hybrid heating system is established, and the best energy efficiency area maps of different connection modes are drawn, which verifies the energy-saving characteristics of the hybrid heating system. Wu *et al.* [8] designed a new solar air dual heat source hybrid heat pump system, the results show that the daily average COP of its air source heat pump subsystem can reach more than 38 when the ambient temperature is 24.24 °C. The system mathematical model is established, and the results show that the water heater can efficiently produce 55 °C hot water under different weather conditions. Mansur *et al.* [9] proposed a solar air source heat pump heating system, and applied it to cold regions to study its operation performance, the research shows that when heating at a low temperature of –20 °C, the average indoor temperature is 1945 °C, which can meet the requirements of indoor thermal comfort. Zarzycki *et al.* [10] applied the solar heat pump heating system to the greenhouse, and experimentally studied the heating performance of the system in winter, the results showed that when the air source heat pump operates

alone, the COP is between 22-35, and when the solar heat pump operates, the COP is between 2.960, the heating performance of the system has been greatly improved. Dhahri *et al.* [11] aimed at the characteristics of abundant solar energy resources but cold winter climate in Gaoyuan cold region, a solar air source heat pump hybrid heating system is proposed, and the main parameters are optimized, the results show that the area of the solar collector, the installation angle and the volume of the water tank are the key parameters. A solar air source heat pump double water tank hybrid heating system is designed for northern cold regions, through the combination of simulation and experiment, the best form of the system for Beijing is obtained.

On the basis of current research, the author puts forward the concept of a new fifth generation heating technology and its main technical features, and through a case, the thermodynamic characteristics of this far-infrared system and the changes in body sense brought about by it are described, the author also lists the matters that should be paid attention in the construction of this system, and demonstrates the advantages of this heating heat energy system through experiments.

Research methods

Brief history of heating technology development in human history

The history of human development, some extent, is the history of rational use of energy. In the primitive tribes, the human ancestors learned to *drill wood to make fire*, the use of fire made mankind bid farewell to the barbaric era and entered the process of civilization. As people moved to their own houses, they invented heating facilities such as the heated kang and fireplace, this is the second generation technology. With the industrialization process, human beings have invented radiator central heating system with water as the medium, and air conditioning system using electric energy, which is the third generation technology. Then, in the process of research and development of new materials, the individualized floor heating technology with cable carbon fiber as the heater and wall mounted furnace gas as the heat source has been favored by the public, which has evolved to the fourth generation. Recently, with the implementation of the concept of low carbon, energy conservation and environmental protection all over the world and people's pursuit of a higher quality of life, a far-infrared heating technology that is close to the natural heating of the human body and has a uniform and warm heat source came into being, this is the 5^{th} generation technology [12]. Main features of Generation 5 technology: the heat source is uniform and the plane is heated, and the surface temperature is moderate and does not burn people. The power supply adopts ultra-low voltage 24 V to ensure safety. It does not occupy room space, can be invisible, and has super stable performance, it basically requires no maintenance, and has a long service life. The wavelength of far-infrared light emitted has the highest concentration at 8-11 μm, which is easy to promote cell metabolism and bring the function of health care and physical therapy to the human body [13].

Source of technology

In order to protect the environment and reduce energy consumption, some improvements have been made to the heating equipment in the market, such as the use of new clean energy, solar energy, wind energy, geothermal energy and other renewable energy as the power source to reduce the consumption of non-renewable resources and environmental pollution. In some areas, wind power generation has been used instead of combustion power generation, but the use of wind power is also limited by the region. Some have modified the control of boilers or heating equipment, and some have used dual energy systems alternately to better respond to emergencies. In terms of biomass energy, compared with ordinary electric air conditioners,

air conditioners using biogas as energy have more advantages in seasonal energy efficiency, which can further achieve the goal of energy conservation. In contrast, biogas can be produced by self heating boiler, and its raw materials are bioenergy such as straw and wheat husk, which are widely sourced and have more practical significance for closed energy cycle. However, it is obvious that this traditional way cannot achieve the mute mode, and the blowing mode is easy to cause discomfort to the human body [14].

In 1985, Richard Smalley, Robert Cole, and Harold Croto suddenly burst out of wisdom in the experiment and obtained a new method. They used laser (artificial nuclear reaction) on graphite to evaporate it into carbon black, the carbon clusters obtained after purification were analyzed in a mass spectrometer, they found two unknown substances, 60 and 70 times of carbon, respectively, therefore, these two unidentified substances are called C60 and C70. Their groundbreaking work started a worldwide upsurge in the research of carbon isotopes, and led to the prelude to the progress in the research fields of nanomaterials and superconducting materials. In 1996, the three of them won the Nobel Prize in Chemistry. In 2010, Andre Heim and Konstantin Novoselov, professors of the University of Manchester in the UK, won the Nobel Prize in Physics that year for their *pioneering experiment in studying 2-D graphen*e. While conducting basic research in the field of these new materials, countries have also actively carried out research in various application fields. Among them, Germany, the USA, Japan, and South Korea are in the forefront of carbon fiber manufacturing and application. Using the mechanical strength characteristics of carbon fiber, various mechanical components have been manufactured, such as sports equipment, even aviation components, and various fabrics. By using its conductive and heating characteristics, various heating rods and ground heating heating wires are manufactured [15].

In one application, the filament like carbon fiber is woven into cloth form, and then connected to the electrode to generate heat, showing a state of heating surface. Compared with linear heating, the uniformity is improved a lot, however, more customization is still required in practice, so researchers further fragmented carbon fibers and introduced coatings as carriers. The fragmented carbon fiber is saturated into the coating, and the length of the fragment is determined as 3 mm, so that the coated carbon fiber with both heat generation and uniformity can be obtained [16].

As the low carbon energy conservation and environmental protection strategy is widely implemented as a basic national policy, the Ministry of Construction has issued a mandatory national standard, the Design Standard for Energy Efficiency of Residential Buildings in Severe Cold and Cold Regions (JGJ262018), which requires developers to meet the requirements of local thermal standards for their houses in the region, average heat transfer coefficient for the heated and non-heated intervals:

$$k \leq 12 \ [\mathrm{Wm^{-2}K^{-1}}] \tag{1}$$

However, in the south, the structure of the wall is very different from that in the north, the wall is thinner, and people are very weak about the concept of thermal insulation, it is easy to ignore the existence of the indoor thermal insulation layer, or even dismantle the indoor thermal insulation layer artificially to make room for indoor space. Based on this, for coated carbon fiber system, customized thermal insulation design must be made:

– the thickness of indoor thermal insulation layer shall not exceed 15 mm to retain the advantages of invisibility and space saving and
– the average heat transfer coefficient of indoor enclosure structure shall not be less than 1.2, so that the average power configuration per square meter shall not exceed 80 W.

Design of automatic control system

- Design flow of PLC control system.
- Explain the requirements of the automation system for parameter setting, and define the types of functions that the system needs to achieve during operation.
- Scientifically select the components required during system design, such as controller, I/O module, power module, control mode, floor heating system module, *etc*.
- Specify the number and digital quantity of the incoming and outgoing points of analog quantity, and list the Arduino input and output sub table based on the aforementioned data information.
- Draw the schematic diagram of the control cabinet line connection, and conduct the line connection on the site in combination with the data information in the diagram.
- The system design and construction process shall be developed and debugged in combination with the sequence function diagram, once the system is found to have problems during operation, the process shall be targeted for rectification until the co mmissioning is successful or the hardware problems are completely solved [17].
- The input and output points of Arduino system are combined with the functional requirements of the automatic control system, after analysis, it is found that the system belongs to the switch control system, and the corresponding number of input points and output points are 8 and 4, respectively, at this time, selecting anduino can fully meet the functional design requirements of the system.
- Arduino's external line connection design combines the specific configuration of input points and output points, as well as the planning of external equipment and facilities, the external circuit connection diagram of the intelligent floor heating system is planned, because the Arduino controller has its own ADC converter, the analog signal of the sensor can be directly transmitted to the controller, and the wiring for starting the floor heating is regulated by the unified relay switch.

In the design process, there are three operation states: automatic shutdown, heating, and maintenance. The system is in the original state when there are no strange clouds. Starting from the original state, press the start button of the system, under the automatic operation state, the controller will be in the operation state as a whole, with the difference of the received sensor signals, the controller will use the prepared system program to transmit the corresponding indication signals, thus achieving the goal of effective control of the indoor ambient temperature of the home. When the indoor environment has no difficulty <18 °C, that is, in the low temperature state, the controller will give an external indication according to the received signal. At this time, the relay starts the high current circuit R1, and the system will be heated. When the indoor temperature rises to a certain value (in the range of 18-30 °C), the controller transmits an indication combined with the received signal, at this time, the small current circuit R2 is connected, and the system will maintain the operating state of thermal insulation. With the continuous rise of the indoor temperature, when reaching a peak value (when the indoor temperature is ≥ 30 °C), the controller will send out an indication disconnect the circuit. At this time, when the R3 branch is connected, the system will stop heating and be in the shutdown state [18].

Main construction process

In the construction process, the main focus is to adapt the circuit to the film shape of the heating layer of the paint. In order to this end, 0.2 mm thick copper tape is used as the main carrier of current, and a specific adapter is used to connect the current from the round cable to the copper tape. The copper tape is protected by spraying primer with adhesion and anti-corro-

sion function, the distance between two electrodes shall be protected on both sides of the bottom and surface, it is determined that 60 cm is the best, the comprehensive balance of heating uniformity and efficiency is the best.

The coating shall be brushed manually with a long hair roller, the biggest precaution is to avoid hot spots caused by uneven thickness. The whole process flow is prepare the base surface → draw lines and position → spray primer → paste double-sided tape → brush reflective paint on the heating surface → paste copper tape → paste grid cloth → brush carbon fiber coating → crimp the adapter → power on test. Of course, in engineering practice, each step of the previous process needs to be carefully controlled to achieve the goal of normal heating.

Next, we use a typical room case to illustrate the construction of a project and its final results. Design objective: the room temperature is above 16 ℃, and there is no dry heat, such as a warm room with warm sunshine in winter. According to the enclosure structure of the room, we have configured a special insulation board with a thickness of 13 mm, which is pasted with insulation mortar and fixed with insulation nails. Among them, 13 mm insulation board is made of three layers of structural bonding, the first layer is 3 mm aerogel, the second layer is 9 mm low density wood fiber board, and the third layer is 1 mm nanoglass bead reflective layer. The total heating power we configured for this room is 1050 W. The size and location of the coated heating strip are shown in fig. 1, analysis of the temperature measurement points shown in tab. 1.

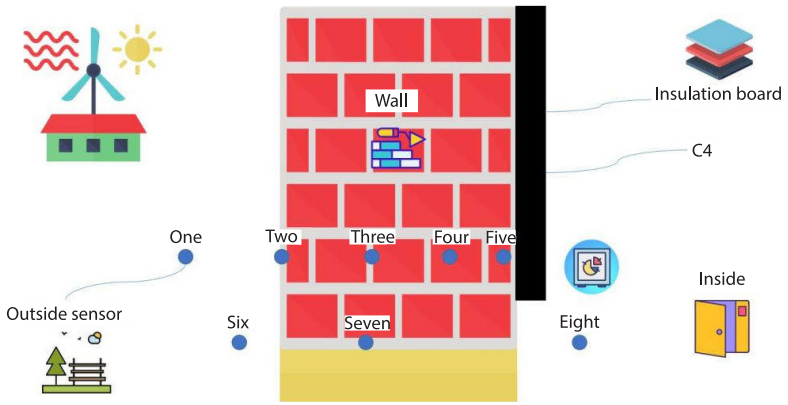

Figure 1. Schematic diagram of temperature measuring points

Table 1. Analysis of temperature measurement points

Temperature measuring point	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
details	Outdoor air point	Outdoor wall point	Middle point of wall	Interior wall point	Indoor hot spots	Outdoor air point	Middle point of wall	Indoor air point

Result analysis

First of all, after the power on test, we used an 8-channel temperature test recorder to collect the temperature change data of each point and the buried point of the temperature sensor [19].

Power on for 4 hours, current 42.1 A, voltage 25 V, temperature data of each point are shown in tab. 2 and fig. 2.

Table 2. Point temperature data

Time	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
9:00	16.2	21.4	23.6	22.6	23.5	20.8	22.6	20.1
9:20	15.1	20.9	22.6	24.6	33.2	20.2	21.6	20.5
9:40	14.3	19.1	22.8	22.6	40.6	19.5	21.8	22.5
10:00	14.3	17.3	22.9	30.7	42.9	18.7	21.9	23.5
10:20	13.9	16.7	22.6	32.8	46.1	17.5	21.6	24.2
10:40	12.2	16.2	22.5	33.7	47.8	16.6	21.5	24.2
11:00	11.5	16.1	22.4	35.8	49.1	15.7	21.4	24.6
11:20	11.3	16.2	22.8	36.0	50.0	15.2	21.8	25.0
11:40	11.3	16.0	22.6	36.4	50.1	14.9	21.6	25.1
12:00	12.3	16.2	22.5	36.4	50.4	15.0	21.5	25.0

In fact, if it is opened in 24 hours, the temperature controller will automatically control and switch between the set temperature range of 20-25 °C, and the actual power consumption time of the system is about 8 hours. It is a good choice for energy conservation. Of course, the most important thing is comfort and enjoyment, it is quiet, there is no itching in the respiratory tract, and the face is easy to be ruddy. It can also be seen from the figure that the temperature at Point 8 will make people feel very comfortable, and it will be kept between 20-25 °C earlier [20-22].

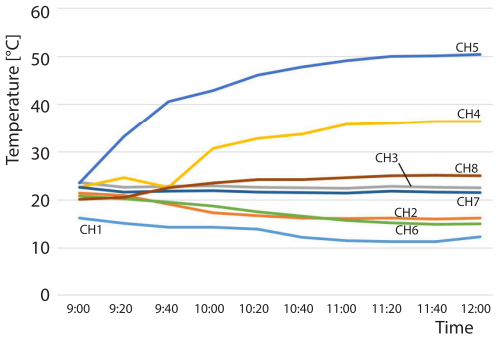

Figure 2. Temperature curve

Conclusion

To sum up, the system can maintain the stability of indoor heat energy, which is between 20-25 °C. This also shows that the thermal energy modelling system of the green energy application of the exterior wall under the smart home building effectively solves the heating and environmental problems.

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Paper submitted: June 28, 2022
Paper revised: August 24, 2022
Paper accepted: August 31, 2022