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Energy Conservation of Building Energy Storage Materials in Computer Simulation Mode

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This paper describes the energy conservation effect of energy storage materials used in buildings. Firstly, the microencapsulated energy storage materials are prepared and analyzed by the Bruker 550 Fourier transform infrared spectrometer manufactured by Bruker. The analysis results reveal that the energy conservation efficiency of energy storage materials can reach up to 27.56%. It is concluded the energy storage temperature of the microencapsulated energy storage material reaches 30°C. In relation to the MicroPCM building materials, the two have a peak temperature difference of up to 1.70°C, which suggests that this material has a high energy efficiency.

1. Introduction

Modern energy conservation and environmental awareness has increased over the years. The community people will be all more inclined to demand a more ecological and intelligent build environment, while this has become a new trend of China's modern building construction. In order to better respond to the needs of modern population, many construction projects all resort to some energy storage materials with many advantages, for example, they feature well integration with traditional building materials, and higher global heat storage, and temperature control. If energy storage materials are arranged in the buildings in accordance with the appropriate specification, they can effectively reduce the use of cold and warm air and achieve the energy conservation.

In order to demonstrate the function of energy storage materials, this paper mainly uses the interfacial polymerization method to explore the microencapsulated energy storage materials synthesized with polyurea resin as wall material and n-octadecane energy storage material, and also systematically discusses the behaviors of MicroPCM material. Ultimately, a test is conducted for characterizing its properties in an attempt to prove the excellent functions of energy storage materials by the infrared absorption spectrum analysis. A statistical analysis is also performed with the spectrum reaction results. In this way, energy storage materials can effectively exhibit much higher energy efficiency than others in the final test. It can also reflect the concept of energy conservation in many ways. Therefore, it is confirmed that the energy storage materials prepared in this paper have a higher application value in modern construction projects with good reliability.

2. Literature review

In recent years, the problems of energy and environment are becoming more and more prominent, and higher requirements for building energy conservation are put forward. When the conventional energy saving design method cannot effectively improve the efficiency of energy saving and emission reduction of the whole building, the optimization transformation of energy saving design method is of great urgency. In view of this, a systematic and integrated design method is explored, which is applied to the design phase of the project, and the multidimensional design factors of urban and architectural design - the energy conservation of building energy storage materials under computer simulation is taken into account. As we all know, practicality, beauty and economy are the basic principles and objectives of architectural design, which was expounded in Vitrurius's works hundreds of years ago. In the traditional sense, a building that meets the requirements of function and comfort, and is beautiful and economical, is no doubt a good building. However, with the progress

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of society, the current situation of energy and environment requires that buildings should be sustainable. In the architectural design, the concept of energy conservation is added, and the energy-saving building emerges as the times require. In order to meet the requirements of practical, economic and aesthetic, it is the main work of building energy saving design to reduce the energy of building, improve building energy efficiency and use renewable energy as far as possible. International regulations, policies and market mechanisms have created a good environment for energy conservation. Nevertheless, energy saving design is limited by concepts, methods and design tools, and is facing bottlenecks in development.

Since the 70s of last century, energy crisis and environmental problems have become the focus of global attention. The progress of science and technology since the industrial revolution and the continuous improvement of people's living standards have consumed a great deal of energy, especially the limited reserves of fossil energy, which has prompted attention to the research on energy conservation, energy efficiency and the development of alternative energy. Therefore, reducing energy consumption, improving energy efficiency and developing renewable energy have become the main means to solve energy and environmental problems in various countries. In recent years, the work of energy conservation and emission reduction in the world has been carried out in succession, which has produced two important documents marking the stage of progress, namely, the Kyoto Protocol and the Copenhagen Agreement. Although the Kyoto Protocol aims to restrict greenhouse gas emissions from developed countries, the impact is global, and the Kyoto Protocol has also been signed by developing countries, such as China, India, and other countries outside the framework of the treaty control. The agreed Book expired in 2012, but was extended to the eighteenth session of the United Nations Conference on climate change until 2020. In 2009, the European Union established the 20-20-20 target, which required 2020, compared to 1990, to achieve 20% reduction in greenhouse gas emissions, 20% of renewable energy in energy use and 20% of total energy consumption. Britain has asked for at least 80% reduction in greenhouse gas emissions by 2050 (compared with 1990). China's "12th Five-Year" plan requires that compared with 2010, by the end of 2015, the energy consumption of per unit of GDP is reduced by 16%, and the carbon dioxide emissions per unit of GDP is reduced by 17%, and the corresponding "12th Five-Year 'energy saving and emission reduction comprehensive work plan" is put forward. It can be seen that energy conservation and emission reduction, as the main content of the work of governments, has been mentioned to a new height.

Ko and others simulated and analyzed the energy consumption performance and carbon dioxide emissions of a typical office building in central London under different climate conditions (Ko et al., 2017). Sharifi and so on, explored the impact of Tokyo metropolitan area urban heat island (UHI) on the energy consumption of residential buildings and commercial buildings, comprehensive consideration of the heat island effect caused by the increase in summer air conditioning energy consumption and winter heating energy consumption (Sharifi et al., 2017). Dogan and Reinhart proposed the urban canopy and building energy model (resistance-capacitance network model) based on the heat network (composed of fixed heat resistance and heat capacity). The model is operated by building the basic physical relationship between the energy flow of the building and the urban environment. The method is simple and efficient, and it is easy to evaluate the simulated hypothetical scenario and the sensitivity of different design parameters (Dogan and Reinhart, 2017). Worz and Bernhardt took Milan as an example to explore an energy performance evaluation method applied to the planning level. On the basis of large amount of information collection and analysis, this method combined energy consumption simulation technology and GIS platform, classified urban buildings, built architectural prototype, simulated different energy consumption of single body, and assessed the impact of different energy saving design strategies on building energy use (Worz and Bernhardt, 2017). From the perspective of solar energy utilization, Shin and others explored building energy efficiency by integrating architectural forms. Based on the urban design level, the research took 48 degrees north latitude as an example, compared two traditional architectural layout forms, and put forward the concept of Residential Solar Block (RSB) (Shin et al., 2017).

Tucker et al. studied, quantitatively analyzed and predicted the energy saving performance of buildings in a given urban environment by integrating the microclimate model ENVI-met and the building energy simulation software EnergyPlus. The microclimate factors involved included solar radiation, long wave radiation, air temperature, air humidity and wind speed (Tucker et al., 2017). Yazici and so on developed an integrated internal model of the building group on the study of neighbourhood community communication affecting building energy conservation. They also took into account the impact of inter building connections, social connections and neighbourhood facilities on energy saving performance of the block (Yazici et al., 2017). Davoudi and Sturzaker interpreted the influence of urban form and climate change on building energy consumption by studying the cooling energy consumption of office buildings in central London, and put forward the importance of urban form in the design of building energy saving (Davoudi and Sturzaker, 2017).

The research on energy saving of building energy storage materials under computer simulation expects to help designers expand their thinking, explore the transformation of original design thinking mode, and provide methods and technical support for the maximum efficiency of energy saving, so as to rationally control and guide the design of energy saving. The integration design method of building energy conservation is proposed mainly based on the theory of architectural integration design and modern design methodology. The integrated design decision and optimization method under computer simulation is the concrete development of the integrated design method of building energy conservation which is applicable to the national conditions of China. The construction of energy saving integration design method is a systematic design method. It integrates the theoretical results related to architectural integration design and the second generation design method. Because of its overall, systematic and organic consideration of the related factors affecting the building energy, using this method for energy saving design, the efficiency of energy saving above the conventional energy saving design method can be obtained.

3. Method

3.1 Preparation of microencapsulated energy storage material

For the sake of the convenience, the interfacial polymerization is introduced here to prepare this material. The schematic diagram of interfacial polymerization is shown in Figure 1.

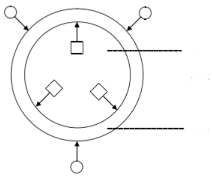

Figure 1: Schematic diagram of interfacial polymerization

The interfacial polymerization synthesizes the macromolecular polymer capsule wall using interfacial polycondensation. It can be used to prepare both hydrous and oleiferous capsule cores. First, two types of monomers containing a bis (poly) function group are separately dissolved in two immiscible PCM emulsifying systems, generally a water-organic solvent emulsion. During polymerization reaction, the two monomers move from the dispersed phase (the PCM emulsified liquid droplet) and the continuous phase to its interface where rapidly polymerization occurs. The resulting polymer film clads the PCM into microcapsules. During emulsion dispersion, the relative proportions of the aqueous phase and the organic phase are chosen according to the PCM dissolution properties. Whichever comes the less in quantity is generally used as the dispersed phase, and the more as the continuous phase. The PCM is in the emulsified liquid droplet of the dispersed phase.
Although the interfacial polymerization is simple, it requires a relatively high properties of wall material. Only when the cladded monomer must have a high reactivity can the polymerization reaction occur. While the microcapsules prepared by this method are inevitably mixed with a trace of unreacted monomers. The wall film formed by interfacial polymerization generally has high permeability, and is not applicable to those core material that requires strict cladding.
Therefore, this paper also adopts a single / complex agglutination to expand the scope of preparation, see Figure 2 for the process of complex agglomeration microencapsulation in the single / complex agglomeration.

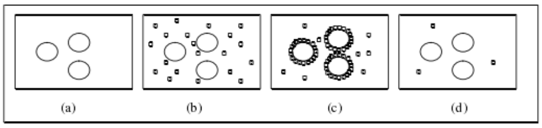

Figure 2: Pool complex process of microcapsule

3.2 Selection of core materials

The energy storage material in the microcapsule material, called a capsule core, is a substance that can carry out thermal energy storage and temperature control during the process of endothermic and exothermic processes. The study focuses more on the solid-liquid energy storage materials. Currently, the core materials of the energy storage microcapsules include straight chain alkanes, fatty acids, paraffins, and the like. There are more studies on straight-chain alkanes and paraffins based microcapsule energy storage materials since these materials feature a higher energy storage capacity of latent heat, good stability, and wide range of temperature control. We can choose different energy storage materials. Given that the prepared microcapsule energy storage material is used as a building wall thermal insulation material, mainly for indoor temperature regulation, the energy storage temperature of the core material used should fall within a room temperature variation range.

3.3 Selection of wall materials

Wall materials are generally polymer materials, mainly including gelatin formaldehyde, melamine resin, polyurethane, polymethyl methacrylate, and aromatic amines. Microcapsules made from polyurethane, polyester, polyurea, polyamide, and melamine resins as wall materials have a good compactness; while those products produced by physical methods have a poor compactness; and microcapsules that are made by aqueous phase solution separation using gelatin as a wall material are poor in strength and have a slow release effect. Therefore, when selecting wall materials, the difference between the preparation methods should be considered. Concerning all factors, here we select polyurea as the wall material, which is an artificially synthetic polymer material with good compactness, high thermal insulation property, high chemical stability, and good resistance to hydrolysis and corrosion, good environmental performance. For this material, no harmful gas will be produced, no detrimental to environment. While synthetic raw materials are easily available and the synthesis process is relatively simple.

3.4 Preparation of polyurea resin microcapsules

The reaction procedure of the shell formation is shown in Figure 3. The polyurea shell is generated after reaction of the DETA with the isocyanate and the isocyanate of toluene-2,4-diisocyanate (TDI). Interfacial polymerizations of TDI and EDTA can react rapidly at room temperature. While the TDI monomer slowly dissolves on the water interface and polymerizes with itself to form an amine as the shell of the polyurea microcapsule. As shown in Figure 4, the interfacial reaction takes place at the oil phase side.

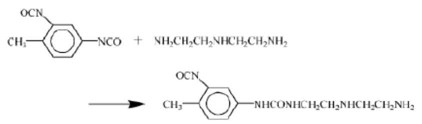

Figure 3: The polycondensation reaction between DETA and TDI

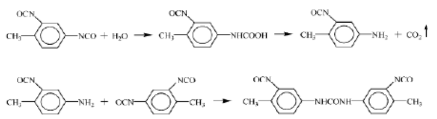

Figure 4: The hydrolysis and polycondensation reaction of TDI

3.5 Preparation of microcapsules

It is prepared by the following 4 procedures:
Weigh a certain amount of emulsifier and 80ml distilled water, add them to a three-necked flask clamped on an iron stand with an electric stirrer.
Weigh a certain amount of n-octadecane, 10 ml cyclohexane and 3 g TDI solution, add mixture to a three-necked flask, stir them at a constant rate for 10 minutes to form a uniform O/W solution.
Measure out the 20ml distilled water, place it in a flask, use this flask as a container to weigh a certain amount of DETA solution.
Pour the mixed solution into a separatory funnel. The solution in the three necked flask is stirred at 500 r/min, while adding the DETA aqueous solution slowly to the three-necked flask to induce the interfacial polymerization between TDI and DETA. Control the whole dropwise adding process around 15min. After the DETA solution is added dropwise, the turbid liquid is heated to a certain temperature by means of a constant temperature water bath and incubated for 2 hours.
The heated reaction emulsion is filtered using a recycled water vacuum pump while washing it away filter residue for three times with distilled water, absolute ethanol and the petroleum ether respectively and in turn. Wash it clean and make it dry by suction filtration. At last, the filter residue should be placed in a crucible and dry it in an electric thermostatic blast drying oven set to 50°C for 48 hours. Then the microcapsules of energy storage material with polyurea as the capsule wall and octadecane as the core material are available, as shown in Figure 5 and 6.

Figure 5: Urea is the wall of the capsule

Figure 6: Microcapsules of phase change materials with eighteen alkanes as core materials

4. Results and analysis

4.1 Infrared absorption spectrum analysis

The molecular structure of the microcapsules measures up by a Bruker's 550 Fourier transform infrared spectrometer. The infrared spectrum of the material contains plenty of structural information that collectively presents the vibrational modes of various chemical bonds. FT-IR is a type of molecular absorption spectrum. When irradiating the sample with infrared light at continuously varying frequency, the molecules absorb radiation of certain frequencies to generate transitions of molecular vibrations and rotation energy levels, weakening the transmittance light intensity that corresponds to these absorption zones. In the study of microcapsules, infrared spectroscopy technology can be used to analyze how the capsule and core materials interact with each other and what the surface structure of the microcapsules looks like. Compounds and molecular structures can be identified by recording infrared absorption spectra. The capsule wall and core materials have their own infrared absorption spectra, and their specific absorption peaks correspond to their respective molecular structures. As compared to the infrared absorption spectrum of the capsule material, it can be judged whether the recombination between the capsule wall and core is chemical reaction or physical blending. While in the thermal cycle experiment, it is likely to analyze how the heat storage capacity of the energy storage material changes after multiple cycles, and whether the capsule core energy storage material and the capsule wall polymer composite material are compatible and stable, and so on.

4.2 Determination of microcapsule molecular structure

Given that the finished product is a solid sample, the 1~2mg sample and 200mg pure KBr are uniformly ground by squash technique and placed into a mold. Apply (5~10)×107Pa pressure on the hydraulic press to make them into a transparent sheet, it can be used for determination. Both the specimen and KBr should be dried and ground to avoid effects from scattering light.

Further, from the resultant microcapsule product, specific absorption bands of the core material and the polyurea can be seen, so that it is proved that there are both molecular structures specific to core and wall materials in the product. While it is suggested that prepared microcapsule energy storage material contains core and wall materials, forming a certain cladding effect. A detailed analysis based on the temperature data of the model house under the irradiation of the infrared lamp shows that the construction materials doped with

MicroPCM can effectively retard the change trend of the ambient temperature. In light of the definition of home-made glass energy conservation efficiency, compared with the model house without added energy storage materials, the difference between peak temperatures of the two reaches 1.70°C, and the energy efficiency can hit upon 27.56%, so, it is better; the energy storage temperature of microcapsules is 30°C, the energy storage enthalpy is 95.66kJ/kg, and the corresponding cladding efficiency is 72.15%; the analysis results show that the particle size of the microcapsules basically falls between 1μm~7μm, and the microcapsule particle sizes are relatively even at an average of 3.5 μm. In addition, TG suggests that the microcapsules will decompose at 150°C~230°C, respectively, and the capsule wall impede the volatilization of the capsule core to a certain extent.

5. Conclusion

In order to realize the functional effects of energy storage materials, the interfacial polymerization is used here to prepare the microencapsulated energy storage materials by synthesizing polyurea resin as wall material and n-octadecane energy storage material. Then the properties and structure of this material are explored by using the Bruker 550 Fourier Transform Infrared Spectrometer manufactured by Bruker. Study results reveal that, in accordance with the definition of home-made glass energy efficiency, its peak temperature will be 1.70°C higher than that of the model house without added energy storage material. 1.70°C, energy efficiency reaches up to 27.56%, and the energy conservation effect is good; the storage temperature of the microcapsule gets to 30°C, energy storage enthalpy is 95.66kJ/kg, the corresponding thermal insulation efficiency is 72.15%; particle size analysis results show that the particle size of the microcapsules remains between 1~7μm. This microcapsule has a relatively uniform particle size of 3.5 μm, and decomposes at 150°C~230°C, respectively. Its capsule wall will retard the volatilization of the capsule core to a certain extent. As above, it is suggested that energy conservation materials have a higher promotion significance in modern projects by its higher energy-saving value.

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