Wind Energy Collection System Based on Phase Change System and Deformable Materials

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Abstract. The purpose of this paper is to design and discover a new system, which can realize the collection, transformation and storage of energy from wind energy in the environment → temperature / physical deformation → material phase change → energy storage, so as to achieve the effect of green energy saving. At the same time, it can provide theoretical support and design basis for the design of high-rise Garden residential suite in cold region. Wind energy is collected through the narrow channel effect. With the help of deformation induced ferrite phase transformation technology and memory alloy materials, the collected energy is stored in the new colloid / graphene battery equipment. With the help of the relevant content research parameters, a systematic digital model is formed, and the basic database is established to simulate the external environment of high-rise Garden residential buildings in cold areas. Through the design of a new wind energy collection system and embedded in the simulation environment, the wind energy utilization in cold, low sunshine, low wind speed or unstable wind speed areas is realized, and the green energy conservation, environmental protection and sustainable development in such areas are realized. Then, the feasibility and effectiveness of the system are demonstrated according to the experimental results, and a systematic theory is formed.

1. Introduction
At present, the world is increasingly affected by the disastrous impact of environmental damage (extreme weather such as fire, high temperature, rainstorm, flood and snow). How to make rational, environmental protection and safe use of natural resources has become the main research direction of energy conservation. Among many natural energy sources, wind energy is one of the natural energy sources widely existing around us, but the utilization rate of wind energy in cities is far lower than that of solar energy. The main reason is that the current wind energy conversion system has certain
condition requirements and objective environmental constraints on natural wind, coupled with the technical limitations of wind power conversion system (at present, the minimum starting wind speed of most wind turbines is not less than 3m / s, while the actual rated working wind speed is more than 13m / s [1]), resulting in the current large-scale wind power generation is mainly concentrated in open areas with sparse population. In the actual power distribution, it is necessary to support the ultra-long distance UHV power transmission and transformation system, which has the disadvantages of long construction period, high investment cost and low rate of return. At the same time, a large number of low-speed disordered wind in the city can not be fully developed and utilized. If this part of resources can be effectively utilized, it can not only reduce the current restrictions on regional sites caused by wind power generation, but also greatly reduce the cost of power transmission and transformation, so as to provide a certain degree of auxiliary support for urban daily power consumption, Even in some extreme cases, it can meet the basic power needs of users. Based on the above reasons, this paper mainly aims at the urban low-speed wind and the narrow channel wind between buildings, considers starting from the phase change materials and systems, and theoretically develops an energy-saving system that can effectively use the urban low-speed wind, which can not only fill the theoretical gap in this aspect, but also provide a new idea and direction for energy conservation and environmental protection.

2. Phase change and phase change system

2.1 composite phase change materials

As we all know, the physical and chemical properties of the material system are exactly the same, and the uniform place with obvious interface with other parts is called "phase". Corresponding to the three forms of solid, liquid and gas, substances have three phases: solid phase, liquid phase and gas phase; Phase transition refers to the process of matter changing from one phase to another.

Based on the existing phase change technology, the system formed for energy conversion and storage is called phase change system or phase change heat storage system.

Because substances exist in three forms: solid, liquid and gaseous, and gaseous and liquid can not be widely used in buildings as building related materials commonly used in buildings because they are not easy to preserve and maintain, solid-solid PCMs (hereinafter simply referred to as SS PCMs) have become the main research direction of the most preferred choice in building energy-saving technology.

Among the various SS PCMs, which one is selected as the building wind energy collection system is mainly considered from the following aspects:

1. Light weight: it is easy to install in different positions of various types of buildings, and will not have a great impact and structural burden on the form of building facade and main structure.
2. High thermal conductivity: selecting materials with high thermal conductivity can ensure that the energy loss in the system will be minimized and the system energy storage will be maintained at a high level.
3. Good weather resistance: considering that the materials are arranged at a fixed point or area of
the building for a long time and always in direct contact with the outdoor air environment, it means that the selected materials must have sufficient anti-corrosion, moisture-proof, high and low temperature resistance and other extreme environmental factors to ensure their long-term and effective normal operation.

Based on the above reasons, we subjectively selected two phase transition systems for research and analysis.

(1) MWCNT multi walled carbon nanotubes (multi walled carbon nanotubes)

MWCNT multi walled carbon nanotubes (multi walled carbon nanotubes) are nano materials with light weight, low density and high thermal conductivity. They are another allotrope of carbon discovered after C60. Their radial size is small. The outer diameter of multi walled carbon nanotubes is generally several nanometers to tens of nanometers, and the inner diameter of multi walled carbon nanotubes is smaller, some are only about 1 nm; The length of multi walled carbon nanotubes is generally in the micron level, and the ratio of length to diameter is very large, up to 103 ~ 106:1. Therefore, carbon nanotubes are considered as a typical one-dimensional nano material, which is suitable as a carrier for composite applications to enhance heat transfer. At present, the application mode of MWCNT multi wall carbon nanotubes has been relatively mature, and the composite technology with various building materials has also been widely studied. In the system, we take PEG / MWCNT as the basic material. The MWCNT of this material is synthesized by chemical vapor deposition, and the purity is more than 99%; MWCNTs modified by groups (hydroxyl, amino and carboxyl) were obtained by plasma treatment. Peg is chemically pure, and the average relative molecular weights are 2000, 4000, 6000 and 10000 respectively. Then, PEG / MWCNT qualitative phase change materials were prepared by physical co mixing and impregnation [2]. Its different PEG mass fraction (a, 0%; b, 30%; c, 60%; d. SEM photos of PEG6000 / MWCNT (90%) are as follows (Figure 1):

![Figure 1. SEM photos of intrinsic MWCNT and PEG6000 / MWCNT qualitative phase change materials with different PEG mass fractions](image-url)
According to the conclusion in the book "qualitative phase change heat storage materials", when adding additives with high thermal conductivity to organic phase change materials, it can effectively improve the thermal conductivity of composite phase change materials. In the experiment of the team, it is finally determined that the thermal conductivity of \( PEG / MWCNT – NH_2 \) is the largest, which is 0.81 \( W/(m\cdot k) \), the original thermal conductivity of phase change materials is greatly improved.

(2) Ultra fast singular deformation system of liquid metal droplets triggered by low temperature phase transition

Studies have shown that liquid metals can respond to various types of external stimuli, including electric field, chemical field, light energy, mechanical force and electrochemical stimulation; By adjusting the surface oxide, the surface tension of the material is changed, so as to realize various types of deformation. The research results of the team led by Sun Xuyang, postdoctoral fellow of the Institute of physics and chemistry of the Chinese Academy of Sciences, published in ACS appl. Mater. Interfaces under the title of “Low-temperature triggered shape transformation of liquid metal microdroplets” [3], show that under the stimulation of low temperature, the aqueous solution in the dual fluid system takes the lead in forming solid ice crystals, and as the system temperature further decreases, Liquid metal droplets undergo solid-liquid phase transformation, cooperate with volume expansion, and the rapid stress release promotes the violent deformation of liquid metal droplets. The experimental theory estimates that the low temperature stress release of micro droplets can reach 6.3MPa. Relevant experiments show that the cooling rate of the system and the composition of the solution can affect the deformation of micro droplets by changing the formation of surrounding solid ice crystals. As the cooling rate of the system slows down, the ice crystals become harder and the deformation of the material is significantly inhibited. The dual fluid system can be used as temperature control sensor in flexible liquid circuit.

The biggest feature of this study is the low-temperature environment, and the urban environment located in high latitudes is often in the low-temperature environment for a long time, so it is particularly important to be able to operate well in this environment, and even make use of this natural environment. This is also the reason why my research team chose MWCNT as the basic system and took the ultra fast singular deformation system triggered by low temperature phase transition of liquid metal droplets as the second scheme. With the further research of this technology and the advent of relevant achievements, the ultra fast singular deformation system of liquid metal droplets is expected to become the core energy collection system in the environment of low temperature and low wind speed in high latitude.

2.2 Preparation of SS PCMs physical substrates by chemical vapor deposition (CVD)

Since MWCNT has many excellent physical properties, such as good mechanical properties, high electronic conductivity, excellent field emission properties, metal and semiconductor properties, at present, the methods for preparing MWCNT into common physical substrates include arc discharge
method, laser gasification method, flame method, template method, hydrothermal method, chemical vapor deposition method, etc. among them, CVD method is simple It is a common method for preparing MWCNT with convenient operation and low cost [4].

The basic steps are as follows: first decompose the carbon containing gas on the metal nano catalyst, and then precipitate the carbon nanotubes on the catalyst surface [4]. According to reference [5], the specific method is: weigh a certain amount of \((Mg(NO_3)_2 \cdot 6H_2O, AR)\), \((Ni(NO_3)_2 \cdot 6H_2O, AR)\) and \((NH_4)_6Mo_7O_{24} \cdot 4H_2O, AR)\), dissolve in 1 g \((C_2H_6O_2, AR)\) glycol in proportion of 5:5:12, preparation of catalyst \(Ni – Mg – MoO_4\). Then, the catalyst, MWCNTs and physical substrate (vapor deposition attachment) are placed in the middle of the quartz tube of the tubular electric furnace in the chemical vapor deposition system. According to the experimental demonstration in the literature, when the reaction temperature is 900 ℃, the reaction time is 60 min and the flow rate of nitrogen and hydrogen is \(10 \text{ mL/min}\), when the \(CH_4\) flow rate is \(20 \text{ mL/min}\), the effect of vapor deposition is the best.

2.3 Multi wall carbon nanotube conductive paper / carbon fiber composites

After MWCNTs are prepared on the physical substrate by vapor deposition method, how to reasonably and effectively arrange them in the inner wall of the pipe of the air collection system and organically combine them with the whole energy-saving system is the focus of the next research.

Here, we refer to the relevant research of Qin Wenfeng's team [6]. Considering the internal conductivity demand of the whole wind collection system and that there will be no electromagnetic interference or reverse interference to the surrounding residents in the process of wind power conversion, multi wall carbon nanotube conductive paper can be arranged on the inner wall of the pipeline of the wind collection system, and MWCNTs are prepared on the physical substrate by vapor deposition method to form the internal environment of the air collection system.

Multi walled carbon nanotube conductive paper is easy to form a conductive network in the matrix due to the large aspect ratio and high conductivity of carbon nanotubes [7]; Paper fiber has the characteristics of high toughness, easy degradation and low pollution. It is widely used in life. It is a kind of green environmental protection material.

The results show that when the amount of carbon nanotubes is increased from 10% to 70% [8] (WT, mass fraction, the same below), the conductivity of conductive paper is increased from 9.92 S/m to 216 S/m, and the electromagnetic shielding efficiency is increased from 15 dB to 45 dB. Imai et al. [9] studied the performance of carbon nanotube / cellulose conductive paper and found that in the frequency band of 5 ~ 10 GHz, the conductive paper with 4.8% carbon nanotube addition has the highest electromagnetic shielding efficiency, which is -50 dB. The relevant research of Lee et al. [10] shows that the electromagnetic shielding efficiency of conductive paper with coating thickness of 170
\[ \mu \text{m} = 20.3 \text{dB}. \]

To sum up, it can be concluded that adding multi wall carbon nanotube conductive paper to the wind energy collection system can greatly improve the electromagnetic shielding effect of the whole system. In addition, it can also play a better role in conducting and protecting the basic circuit in the combined use of wind power conversion and AC / DC conversion circuit.

2.4 layout of circuit system

In the wind energy collection system based on phase change system and deformable materials, how to convert the collected and transformed electric energy through AC / DC conversion to form the available electricity that residents can use daily is the main work of AC / DC conversion circuit. In the system construction, it is considered to package the main control circuit and AC / DC conversion circuit in two layers of multi carbon wall nanotube conductive paper with a fireproof and insulating protective layer, and then conduct secondary overall packaging. This can not only ensure the safe and stable operation of the circuit, but also avoid the mutual electromagnetic interference between the circuit itself and the surrounding environment. The AC / DC conversion circuit (Figure 2) used adopts the conversion circuit developed by Shenzhen intefei Electronics Co., Ltd., which is mainly characterized by high conversion rate, fast response and good system stability. The specific circuit is as follows:

![Figure 2. AC / DC conversion circuit](image)

2.5 Application of phase change system in other aspects

In addition to the application of the above phase change system, in the wind energy collection system composed of phase change system and deformation material, the phase change system can also be
used to mix cement mortar [11] to improve its strength, and the material can be used to build air duct and even the whole building body to improve the material strength and other beneficial characteristics of the whole system and building. MWCNTs can also be combined with other waterproof paper bases to form a new waterproof and deicing material [12] wrapped outside the wind gathering energy-saving system to form a strong protection against the winter environment in high latitude areas. However, in view of the limited space, it will not continue in-depth in the current research.

3. Wind energy collection system based on phase change system and deformable material

After combining the above materials and systems, the undergraduate research aims to build an urban low-speed wind (0m / S ~ 3-5m / s wind speed) collection system to make up for the acquisition of free energy in some cities in this section and enhance the overall energy conservation and environmental protection effect of the city.

The basic construction idea of the system is: preset or add a special air duct in the building, and introduce the low-altitude and low-speed wind into the pipeline with the help of the narrow pipe effect affected by wind pressure. At this time, the phase change system prepared by PEG / MWCNT with the help of CVD method forms a basic power generation system with the pressure-sensitive strain system in a bionic way (imitating dandelion seeds or Mimosa leaves). It is placed in the prefabricated air duct, and the multi wall carbon nanotube conductive paper encapsulated and prepared in advance is laid in the pipe wall to link the power generation system and power storage equipment to form a complete wind energy collection system. The structural diagram (Figure 3) is as follows:

![Figure 3. Structural diagram of wind energy collection system](image-url)
4. Conclusion
By using for reference and synthesizing relevant scientific research data, a preliminary wind energy collection system based on phase change system and deformable materials is formed. In the city, due to the heat energy generated by daily operation (heat release from automobile engines, operation of various electrical equipment, etc.), as well as various heat energy absorbed by urban infrastructure, it will radiate to the surrounding energy in the form of long waves, which will produce a large amount of radiant heat and form a heat island effect. The temperature difference between this part of heat and the surrounding environment will form various forms of wind. In addition, there are many high-rise buildings in the city, forming a large number of irregular interchannel wind. In essence, the above phenomena are the concrete embodiment of various energies under the influence of physical rules. The wind energy collection system is to collect this part of energy and restore it from the form of wind to the energy itself again, although there will be various system losses in the process, and the system conversion rate can not reach the most ideal state. However, it does not affect the realization of the ultimate goal of energy conservation and environmental protection of the system. In addition, after forming a systematic digital model, establishing a basic database, simulating the external environment of high-rise garden houses in cold areas, designing and embedding a new wind energy collection system into the simulation environment, and gradually realizing the practical feasibility of wind energy utilization in areas with high cold, low sunshine, low wind speed or unstable wind speed; The green, energy-saving, environmental protection and sustainable development of such areas can be realized through a large number of layout and accumulation of more. Then, according to the actual use results, further demonstrate the feasibility and effectiveness of the system, and form a systematic theory.

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