Application of Phase Change Heat Storage Technology in Vehicle Engineering Field

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Abstract: With the development of human economy and science and technology, and the problem of energy shortages has become increasingly prominent. New energy research is the focus of attention worldwide, and phase change heat storage technology is one of the main means to improve the efficiency of new energy utilization, it is a hot area of research in recent years. This paper briefly introduces the importance of phase change heat storage technology, and briefly summarizes the classification, enhanced heat transfer technology and application fields of phase change materials. The application of phase change heat storage technology in vehicle engineering is prospected and discussed.

1. Introduction

With the development of human economy and science and technology, the demand for energy is also increasing. Information shows that in the past 20 years, the production of major energy has increased by 49%, while the emission of major emission CO2 has increased by 43%[1]. In recent years, energy conservation and environmental protection has been the focus of attention and discussion in the world, and the development and utilization of new energy is the key research topic of researchers in various countries. Using heat storage materials to realize energy conversion and balance is one of the main means to improve the efficiency of new energy utilization. It has broad application space in the fields of construction, chemical industry, aerospace and so on. A material heat storage principle is to store a specific form of energy in the material under certain conditions and to release or utilize the energy in the material under specific conditions[2]. At present, there are three forms of heat storage, namely, chemical heat storage, sensible heat storage and latent heat storage[3-4]. Among them, latent heat storage uses phase change materials (phase change material, PCM) to absorb and release energy, also known as phase change heat storage process. Compared with the other two heat storage methods, it has the characteristics of high heat storage density, constant temperature, easy control and remarkable energy saving effect.

With the rapid development of the global economy, the level of science and technology and the living standard of the people in China are also improving. By the end of 2019, the number of cars in China has reached 260 million, and China has always been the largest automobile production and consumption country in the world. With the continuous development of automobile industry, the proportion of automobile energy consumption in total energy consumption is also increasing. The waste heat and related substances emitted by automobile not only bring certain influence to the...
environment, but also cause a lot of energy waste. In the working process of the engine, the heat discharged from the exhaust gas to the outside world accounts for 30-45% of the total heat generated by the fuel combustion. If the relevant measures are not taken, it will cause a huge energy waste. According to this part of heat, experts at home and abroad have studied a variety of automobile exhaust gas recovery and utilization technology, but the application of phase change heat storage technology in the field of automobile exhaust is still less.

2. Phase Change Thermal Storage Material

2.1. Classification of phase change materials
According to the different characteristics of phase change materials, phase change materials can be divided into many kinds. Figure 1 shows the classification of phase change materials [5-7].

![Figure 1. PCM Classification](image)

According to the phase change type of phase change material, it can be divided into four phase change types: solid-solid, solid-liquid, gas-liquid and solid-gas; according to the package size of phase change material, it can be divided into nanometer, microcapsule and macroscopic size; according to the chemical properties of phase change material, it can be divided into organic, inorganic and eutectic; according to the phase change temperature of phase change material, it can be divided into low temperature, medium temperature, medium temperature and high temperature.

2.2. Phase change material selection requirements
According to the practical application conditions, different heat storage systems should choose different phase change materials. Under the selected temperature conditions, the materials with larger phase change enthalpy (latent heat value) are preferred, which can ensure that the phase change materials can store more heat at the same volume. When selecting phase change materials, we also need to consider the requirements of thermodynamics, phase change kinetics, chemical properties and economy of phase change materials. At present, there is no specific phase change material that can meet all the conditions and performance requirements. Therefore, the indexes and requirements should be considered comprehensively when selecting phase change materials. In addition, in order to overcome the shortcomings of phase change materials in a certain aspect, researchers need to design and optimize the heat storage system, and improve the composition of phase change materials.

3. Heat Transfer Enhancement Technology
There are still many shortcomings and shortcomings in the practical application of phase change materials, but low thermal conductivity is the main disadvantage of most phase change materials, which restricts the application of phase change materials to a certain extent, and can not be widely
used. Therefore, in view of the shortcoming of low thermal conductivity of phase change materials, many researchers have put their research direction in the field of enhanced heat transfer of phase change materials. At present, the commonly used phase change materials to strengthen heat transfer research mainly have the following methods: adding metal, graphite, carbon fiber and other materials to phase change materials; designing ribbed sheets in heat storage devices, increasing heat conduction area, etc.; combining different phase change materials together to form composite materials to change the characteristics of phase change materials; capsule packaging of phase change materials, etc.

In addition to the single enhanced heat transfer mode of phase change materials mentioned above, many researchers have begun to study the composite enhanced heat transfer technology of phase change materials. Compared with the single enhanced heat transfer technology, its advantages are more obvious. For example, TIARI et al.[8] numerically study the thermal characteristics of the LHTES system of fin-coupled heat pipes. The principle is shown in figure 2. One or more heat pipes are embedded in the phase change material, and the condensing part of the heat pipe is fitted with different length fins. Experimental results show that increasing the fin length will reduce the temperature difference in the inner PCM of the vessel, so the temperature distribution in the phase change material is more uniform, and the effect of natural convection on the melting process is quite great. Increasing the number of heat pipes (reducing heat pipe spacing) will lead to increased melting speed and lower bottom wall temperature.

![Fig 2. Principle of Device](image)

The research on compound enhanced heat transfer technology is not mature, but it can be found that the effect of enhanced heat transfer is better than that of single enhanced heat transfer technology, which can overcome the shortcomings of single enhanced heat transfer technology. In the future has a great space for development, but also has a great research and application value.

4. Application of Phase Change Heat Storage Technology

With the further study of phase change materials, phase change heat storage technology has been applied in many fields, and the effect gain can meet the practical requirements. According to the purpose of application, the application fields of heat storage technology can be summarized into three categories: constant temperature control, improving energy efficiency and developing and utilizing new energy sources[9-10].

(1) Constant temperature control. Temperature control is a basic function of phase change heat storage technology. In practical application, phase change materials can absorb and release heat according to the set temperature range, and have a certain regulating effect on the temperature of working environment. Therefore, its application in the field of temperature control is very wide. For example, in the field of basic building energy saving, phase change heat storage technology can automatically adjust indoor temperature according to actual needs, improve people's comfort, and reduce indoor gas emissions. In modern agriculture, phase change heat storage technology is also used to control the temperature in various crop sheds and raise the environmental temperature for the growth of various crops.
(2) Utilization of new energy sources. As an alternative energy source for human beings, solar energy has been paid close attention to and studied all the time, but solar radiation is intermittent and time dependent, so it is a new energy that can be used. How to store and utilize solar energy is the focus of research. Many researchers at home and abroad, based on phase change heat storage technology design and development of a variety of solar heat storage systems, and achieved breakthrough results. Nallusamy N and other[11], for example, establish a PCM based solar heat storage system. Paraffin as a PCM is filled in insulated cylindrical storage tanks, which has better thermal performance than traditional solar heat storage systems.

(3) Improving energy efficiency. There are two main aspects in the research of phase change heat storage technology to improve energy utilization: one is to recycle industrial waste heat and waste heat; the other is to fill the valley with the peak shift of electric power load. Phase change heat storage technology plays an important role in the recovery and utilization of industrial waste heat and waste heat. The phase change heat storage system can store the waste heat and waste heat produced in industrial production into related devices, and can reuse the relevant heat according to the practical application needs. It can greatly improve thermal efficiency, improve energy utilization, save fuel cost and reduce operation cost. For power peak displacement and valley filling, it refers to the use of phase change energy storage technology to convert surplus electricity into relevant equipment when the supply is sufficient, and when the user's peak power consumption is reached, The previously stored energy can be converted and released to relieve the peak power pressure.

5. Conclusion
Since the phase change heat storage technology has been studied and developed, its unique advantages have been the focus of attention of all countries in the world. With the rapid development of science and technology in the world, the problem of energy shortage is becoming more and more serious. Although the research of phase change heat storage technology has made many achievements, there are still many problems that have not been solved.

In the application of phase change heat storage technology, it can continue to expand its application field and direction. According to the above simple analysis and discussion of phase change heat storage technology, it is also feasible to apply phase change heat storage technology in vehicle engineering field. With the continuous research and development of phase change heat storage technology, a specific phase change heat storage system can be designed to absorb and store the waste heat of vehicle exhaust gas and the waste heat of engine operation, and then release the heat according to the actual needs. For example, in winter, vehicle waste heat and waste heat can be stored, which can heat the engine and improve the start-up performance of the engine. It can also use related technology to store electric energy to improve the vehicle's endurance. In a word, with the continuous improvement of scientific health, the application value of phase change heat storage technology will become more and more important, and the weight will be more and more heavy in people's life in the future.

References
[1] Chen, J.L., Duan, Y., Wang, Z.X. Current status and application of phase change heat storage technology. Guangdong Chemical Industry, 2 (47): 101-104.
[2] Li, Y.L., Jin, Y., Huang, Y. (2013) Base of Heat Storage Technology - Basic Principles of Heat Storage and New Trends in Research. Energy storage science and technology , 2 (01): 69-72.
[3] Chen, Y., Jiang, Q.H., Xin, J.W. (2019) Research progress on phase change energy storage materials and their applications. Materials Engineering, 47 (7): 1-10.
[4] IEA-ETSAP and IRENA.(2013)Thermal energy storage. Technology Brief E17, Bonn.
[5] Yuan, K.J., Zhang, Z.G., Fang, X.M. (2016) Advances in the study of hydrated inorganic salts and their composite phase change heat storage materials . Material guide , 35 (6): 1820-1826.
[6] Chen, J.L., Duan, Y., Wang, Z.X. (2020) Current status and application of phase change heat storage technology. Guangdong Chemical Industry, 47 (2): 101-110.
[7] Charalambos, N.E., Vassilis, N.S. (2019) A comprehensive review of recent advances in materials aspects of phase change materials in thermal energy storage. Energy Procedia, 161:385-394.

[8] Ren, Q.L., Meng, F.L., Guo, P.H. (2018) A comparative study of PCM melting process in a heat pipe-assisted LHTES unit enhanced with nanoparticles and metal foams by immersed boundary-lattice Boltzmann method at pore-scale. International Journal of Heat and Mass Transfer, 121: 1214-1228.

[9] Zhang, H.L., F, X.D., Zhao, Y.J. (2014) Advances in Phase Change Thermal Storage Materials and Technologies. Guide to Materials A: Summary, 28 (7): 26-32.

[10] Jin, G., Xiao, A.R., Liu, M.Y. (2019) Research Progress of Phase change Energy Storage and enhanced Heat transfer Technology. Energy storage science and technology, 8 (6): 1107-1115.

[11] Nallusamy, N., Sampath, S., Velraj, R. (2007) Experimental investigation on a combined sensible and latent heat storage system integrated with constant/varying (solar) heat sources. Renewable Energy, 32 (7): 1206-1227.