# Application of Nanofluidic Materials in the Cooling System of New Energy Vehicle Power Battery

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**Abstract.** As the primary power source of electric vehicles, the performance of new energy vehicle power batteries is critically dependent on their operating temperature. To maintain optimal temperature conditions and ensure efficient operation, a cooling system is necessary. However, current enhanced air-cooling systems pose several challenges such as increased ventilation loss, reduced battery efficiency, higher temperatures in stator and rotor windings, and shortened insulation life. To address these issues, a new approach involving the use of nanofluid materials in the coolant of electric vehicle power battery cooling systems is proposed in this paper. This approach has been shown to significantly enhance the cooling effect, improve the working environment and performance of power batteries, and effectively guarantee the safe, stable, and efficient operation of new energy vehicle power sources.

**Keywords:** Cooling System, Lithium Battery, Nanofluidic

## 1 Introduction

Carbon dioxide emission reduction is one of the most effective ways to avoid climate deterioration and greenhouse effect, which is also one of the effective measures to create a beautiful green earth. Although the world 's various evils of renewable energy production is increasing, these renewable energy sources are sustainable and have little or no impact on the environment, but the main power source is still dominated by traditional fossil fuels. Automobile energy consumption is considered to be one of the main sources of pollution. Therefore, electric vehicles have great potential advantages in reducing environmental pollution and greenhouse gas emissions. In 2011, the European Union proposed electric vehicles as an effective way to reduce greenhouse gas emissions in the transportation sector. At the same time, countries around the world have introduced policies to support the development of electric vehicles [1].

Energy issues have always been at the forefront of countries' attention. The concerns and challenges posed by global climate change and rising temperatures urgently demand sustainable resources and renewable energy applications. Electric vehicles are one of the

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mainstream methods that can help solve the energy crisis. By using green-produced electric energy as an energy source, they reduce the emission of fossil fuels, achieving the effect of energy conservation and emission reduction [2]. Furthermore, the continuous development of electric technology has led to significant improvements in electric vehicles, including higher comfort and safety when compared to traditional oil vehicles [3]. The revolutionary progress in battery technology has played a pivotal role in the rapid development of electric vehicles.

Since the turn of the 21st century, lithium-ion batteries (LIBs) have been a favorite of electric vehicle giants such as Tesla, General Motors, Honda, Ford, Nissan, BMW, and BYD [4]. Research shows that compared to other batteries, LIBs have the highest energy density (450 Wh/kg) and incredible cycle stability, capable of maintaining a steady capacity after thousands of charge and discharge cycles [4,5]. Additionally, LIBs have remarkable design flexibility and adaptability, allowing them to be used under extreme conditions through specialized designs [6]. Moreover, due to the abundance and easy extraction of lithium, the cost of producing LIBs is relatively low [7].

However, as modern battery technology produces increasingly high specific energy and power values, the heat generation rate of power battery packs also rapidly increases [8]. Unfortunately, this excess heat is detrimental to the battery's performance, necessitating cooling systems to maintain optimum operating temperatures. Currently, there are four mainstream lithium-ion battery cooling systems, including liquid cooling, air cooling, heat pipe cooling, and phase change materials [9]. While these cooling systems have been widely adopted, each has its limitations, as detailed in Table 1 [10]. To enhance the cooling system's efficiency, scientists propose leveraging nanotechnology to help overcome these limitations and maximize the cooling system's potential.

The most mature nano-cooling system currently available on the market is the nanofluidic system which enhances coolant conductivity by incorporating solid nanoparticles with high thermal conductivity. The high specific surface area of these nanoparticles prevents clogging, settling, and erosion, making them more stable. Furthermore, their high specific surface area facilitates convection between the liquid surface and high thermal conductive solid particles, resulting in higher thermal conductivity of the coolant [11].

This paper provides a detailed analysis of the operating temperatures of lithium batteries, the necessity of cooling systems, and the specific application and effectiveness of nanofluidic systems in lithium-ion batteries. It serves as a theoretical reference for those seeking to better understand these topics.

**Table 1.** The disadvantages of 4 cooling system

| | Liquid cooling | Air cooling | Heat pipe cooling | Phase change materials |
|---|---|---|---|---|
| Disadvantages | High Maintenance requirements Expensive systems | Low efficiency Susceptible to environmental influences | Too low efficiency | Low thermal Conductivity Volume expansion |

## 2 Method

This paper conducts an analysis, based on online research and academic articles provided by the professor, of the impact of temperature on lithium-ion battery efficiency, the production process of nanofluids, and the evidence from multiple experiments verifying the enhanced cooling capabilities of nanofluids. The paper will include a list of references at the end.

## 3 Result and Discussion

### 3.1 The Effect of Overheating on the Lithium Battery

As an advanced type of battery, lithium batteries have precise temperature requirements. The theoretical operating temperature range for lithium-ion batteries is relatively small, between 20°C to 50°C. However, the optimal operating temperature range is even narrower, ranging from 30°C to 45°C, which is smaller than the temperature range allowed by other battery types, such as lead-acid batteries [12]. Excessively high temperatures can significantly reduce battery performance, and severe overheating can even cause explosions [13]. Fig.ure 1 illustrates the change in lithium battery capacity at different temperatures (ranging from 25°C to 55°C) and cycle cycles (from 50 cycles to 250 cycles). It can be observed that at 45°C, battery capacity reaches its peak before beginning to gradually decline. The impact of temperature on battery capacity becomes more apparent with increased cycles, whereby a battery with 250 cycles shows a significantly steeper decline in capacity after reaching 45°C, compared to a battery with only 50 cycles [14].

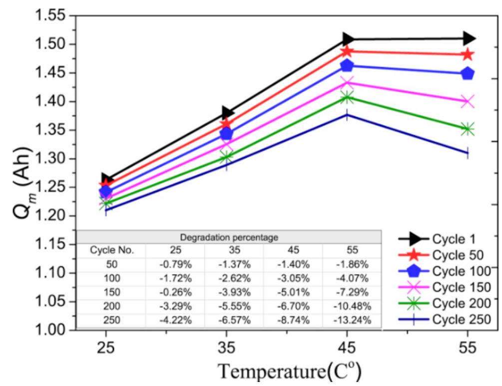



**Fig. 1.** The electric capacity of lithium batteries with different cycle lives at different temperatures

### 3.2 The Nanofluidic Cooling System

A brief introduction to nanofluidic: It can be seen that the temperature has a huge impact on the performance of the battery, and the mainstream cooling system has more or fewer defects. So, is there a way to solve the problem of a certain cooling system to the greatest extent and improve its efficiency? With the rise of nanotechnology, more and more people realize the magical effect of nanotechnology. With a very high specific surface area, nanomaterials of the same mass can have a larger contact area [14]. Can this feature be used? The answer is yes. Scientists have discovered that nanotechnology and liquid cooling systems can be cooled together, and nanoparticles with high thermal conductivity can be added to the cooling liquid. Under the larger contact area between the nanoparticles and the cooling liquid, they can conduct heat better and achieve better cooling efficiency [14]. In addition, the unique nanostructure of nanomaterials gives the material better stability. Compared with general granular materials, nanomaterials will not deposit on the bottom of the container to block the channel, which improves the service life of the overall cooling system [14].

Manufacture process of nanofluidic: At present, there are many manufacturing processes for nanofluids, among which the two-step method is the most widely used. The so-called two-step method, as shown in Fig.ure 2, is to first pour the nanoparticles into the base liquid, and then form a stable and uniform nanofluid by adding appropriate surfactants and ultrasonication. Among them, the role of the surfactant is to reduce the surface tension of the interface to form nanoparticles with a more stable shape, while the ultrasonic wave is used to uniformly disperse the nanoparticles. Through a two-step process, a nanofluid cooling liquid with good properties can be obtained [15].

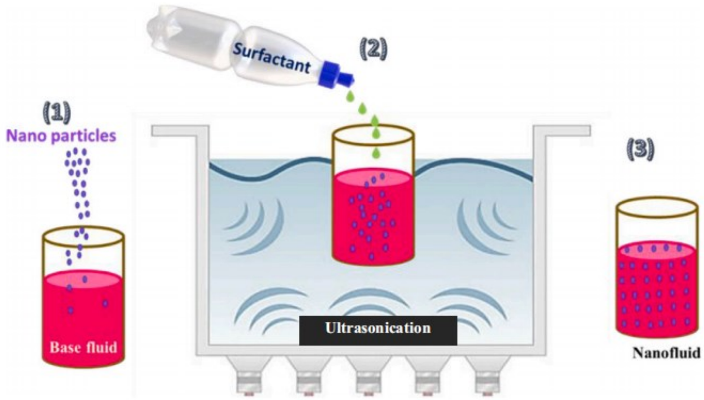
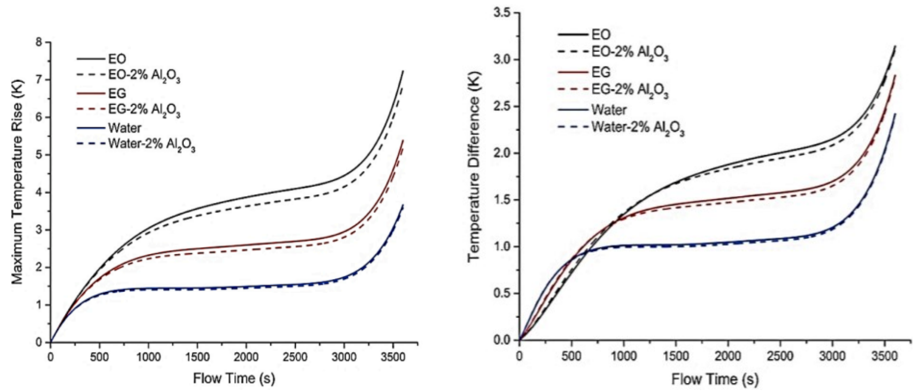



**Fig. 2.** Two-step method to manufacture the NFs

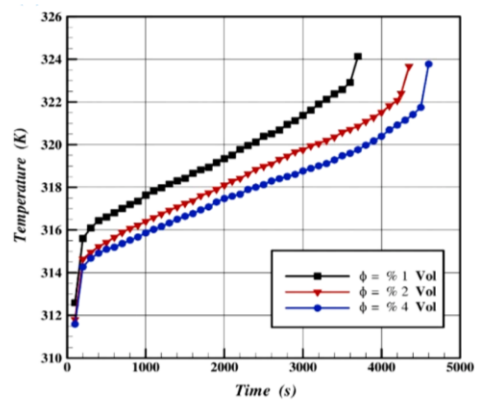
Al2O3 nanofluidic: Al2O3 has good thermal conductivity and stable chemical properties, which can be used as a nanofluid [16]. To find out whether Al2O3 nanofluid has a cooling-enhancing effect on the maximum temperature rise under different flow times, the researchers conducted experiments. Purified water, engine oil (EO) and ethylene glycol (EG) were selected as coolants, and the additional amount of nanofluid was selected as 2%. As shown in Fig.ure 3 (a), the addition of nano-alumina can significantly reduce the maximum temperature rise of the coolant and enhance the cooling effect of the coolant, among which the improvement of EO and EG is the most obvious. The possible reason why the cooling reinforced effect of water is not obvious is that the specific heat capacity of water itself is very large, while the specific heat capacity of EO and EG is small, leading to the obvious enhancement effect of nano-alumina. In addition, to verify that nano- Al2O3 can effectively improve the temperature distribution uniformity of the cooling liquid (without local overheating), the researchers also measured the temperature differences at multiple points under the same experimental conditions, and the results were still the same. Fig.ure 3 (b) shows that nano-alumina has played a role, significantly reduced the local temperature difference and effectively improved the uniformity of temperature distribution [14].



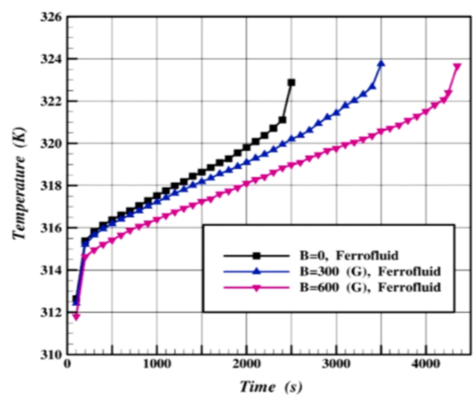

(a) (b)

**Fig. 3.** The effect of Al2O3 nanoparticles on (a) the maximum temperature rise and (b) temperature difference

Fe3O4 nanofluidic: Fe3O4 nanoparticles can also be used in coolants. To explore the effect of nano-Fe3O4 particles on the cooling effect of coolant, the researchers used pure water as the coolant, added different volume fractions of nanoparticles (1%-4%), heated slowly, and observed the rate of temperature rise. As shown in Fig.ure 4 (a), the larger the volume fraction of nano-Fe3O4 particles, the slower the temperature rise rate of the coolant, with a maximum difference of 1K in the 2000s and a difference of 1.5K in the 3000s, showing a trend of increasing gradually. Such experimental results fully illustrate the enhancement effect of Fe3O4 nanofluid. At the same time, the researchers were surprised to find that since Fe3O4 particles are magnetic, the magnetic field may affect the cooling enhancement of the ferric oxide. To explore whether this effect is positive, the researchers set up three groups of experiments to compare each other, in which the only variable is the magnetic flux (0, 300G, 600G), and observe the effect on the coolant temperature. In Fig.ure 4 (b), the results show that the magnetic field can indeed positively affect the cooling ability of Fe3O4 nanofluid, which is a feasible method.




(a)




(b)

**Fig. 4.** The cooling effect of Fe3O4 with different contents and Fe3O4 nanofluid enhanced by a magnetic field

# 4 Conclusion

To address the current research focus on cooling materials for power batteries in new energy vehicles, this article introduces the latest nanofluid material into the coolant of electric vehicle power battery cooling systems to improve the working environment and enhance battery performance. Conclusions drawn from experimental research are presented below.

(1)In Lithium-ion batteries are a rapidly developing technology with unique advantages such as high energy density and cycle stability, making them widely used in the field of electric vehicles. However, they have a relatively strict operating temperature range, and overheating and runaway are potential crises. Therefore, an efficient and convenient cooling system is required to control temperature appropriately.

(2)Nanofluid technology, an emerging approach that combines nanotechnology with battery cooling systems, adds nanoparticles with high thermal conductivity to the cooling liquid to achieve enhanced cooling effects. The representative nanoparticles, such as Al2O3 and Fe3O4, exhibit excellent properties.

(3)However, there are still certain limitations and challenges associated with nanofluids, including complex production processes and uncontrollable nanoparticles, which have hindered their widespread use. Nonetheless, nanotechnology is rapidly being integrated into the cooling systems, not just for liquid cooling, but also for phase change materials and other fields. It is worth noting that in the future, it is believed that this problem will ultimately be solved, leading to the development of highly efficient and safe battery cooling systems.

(4)The technology of new energy vehicles is constantly improving, the energy density of the battery is gradually increasing, the mileage is also increasing, and the charging time of the battery is gradually shortened. The power performance and safety performance of new energy vehicles are also constantly improving.

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