Research on Liquid Cooling Technology and its Application in Wireless Charging

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Abstract. With the increasing thermal density and the limited installation space of wireless charging device, there are higher requirements for the external dimension and heat dissipation performance of wireless charging device. In order to improve the cooling efficiency of wireless charging device, combined with the disadvantages of traditional wireless charging device and air-cooled wireless charging device, the positive influence and Prospect of liquid cooling technology in wireless charging device are studied.

1. Introduction
With the development of electronic technology and the increase of high-power electronic devices, the use of wireless charging equipment is more extensive. In order to improve the user experience and shorten the charging time, manufacturers generally increase the wireless transmission power to improve the charging point speed. Due to the disadvantages of high-power wireless charging device, such as high heat flux density and narrow heat dissipation space, the charging device is overheated locally. In order to ensure the safety of wireless charging process, the output power has to be reduced, resulting in longer charging time and lower user experience.

At present, wireless charging devices generally have no cooling module or adopt air-cooled wireless charging. However, for devices with higher charging rate and higher heat flux density, air-cooled wireless charging is generally difficult to meet the cooling requirements, which slows down the charging speed, thus affecting the user experience. Nowadays, liquid cooling technology is widely used in many fields, especially in the field of electronic technology. Liquid cooling technology can provide stronger cooling mode and efficiency, reduce temperature and improve charging speed. This paper mainly discusses the principle of liquid cooling technology, its advantages and application prospects in wireless charging field.

2. Principle of liquid cooling and heat dissipation
At present, water cooling is widely used in liquid cooling technology. Water cooling is one of the forms of liquid cooling system. In addition, there are many other media that can be used in liquid cooling system. From a technical point of view, the working principle of liquid cooling technology is to use a water pump to pump water out of the water reservoir, and then enter the water tank through the water pipe, and then come out through another port of the water tank, and then return to the water reservoir from the water pipe. The reciprocating cycle can take the heat away from the surface of the components with large heat dissipation such as graphics card, motherboard and CPU.
Water cooling block is a kind of metal block with internal water circuit, which is made of copper or aluminum and contacts with CPU to absorb heat of CPU. Therefore, the function of this part is the same as that of air cooling. The difference is that the water cooling block must leave a channel for the circulating liquid to pass through and completely close, as shown in Figure 1. This ensures that the circulating liquid will not cause electrical short circuit due to leakage. The function of circulating liquid is similar to that of air, but it absorbs a lot of heat and the temperature changes little. If the liquid is water, it is known as the water cooling system. The function of water pump is to promote the flow of circulating liquid. In this way, the liquid absorbing CPU heat flows out of the CPU, and the new low-temperature circulating liquid continues to absorb the CPU heat. The water pipe is connected with the water pump, water-cooling block and water tank, and circulates in the closed channel of the circulating liquid without leakage. In this way, the liquid cooling system can be used normally.

Figure 1. Schematic diagram of water cooling block channel

The water tank stores the circulating fluid, which releases heat from the CPU. The cryogenic circulating liquid enters the assembly line again. When the heat of CPU is small, the temperature of circulating liquid will not increase obviously by using the large capacity circulating liquid stored in the water tank. If the power of CPU is large, it needs to be distributed by adding thermal switch. The heat of the CPU is similar to the thermal switch here. The circulating liquid transfers the heat to the radiator in large area, and the fan of the radiator takes away the heat from the air.

If it is a small sealed liquid cooling system, the open water tank is omitted. The liquid flows between the pump, the cooling block and the heat exchanger, and the circulating liquid flows in the air to prevent exposure deterioration.

It can be seen that liquid cooling and cooling are essentially the same. Only when the liquid is cooled, the heat of the CPU is transferred from the cooling block to the heat exchanger through the circulating liquid. The heating area and heating environment of the heat exchanger are much better than ordinary air conditioners, and the cooling effect is obvious.

As a mature cooling technology, liquid cooling technology has been widely used in industrial ways, such as aircraft engine cooling, airborne chassis cooling, automobile engine cooling and so on. Because the cooling speed of liquid is far greater than that of air, the liquid cooling radiator often has good heat dissipation effect, and has a good control effect on noise. Due to its advantages in noise control and heat dissipation efficiency, liquid cooling technology is gradually popularized. Nowadays, liquid cooling technology is widely used in the field of personal computers. In recent years, liquid cooling technology has gradually developed in the field of smart phones, such as black shark game phones, red devil game phones.

3. Technical advantages of liquid cooling compared with air cooling

3.1. Ultra quiet
Compared with the current mainstream air-cooled heat dissipation, the liquid cooling system uses the cooling liquid circulation in the heat sink to dissipate heat. The biggest advantage of liquid cooling is
that it can absorb and transfer heat without raising the temperature inside the gas, instead of cooling computer components with liquid. In order to achieve no fan cooling, there will be no vibration, to achieve ultra quiet state.

3.2. Rapid heat dissipation

Liquid cooling heat dissipation has the characteristics of large heat capacity and slow temperature rise, which is conducive to ensure that electronic components will not heat up instantaneously in case of emergency, break through the upper limit of temperature that electronic components can bear and even burn out, thus playing a buffer role.

When Zhao Luyi analyzed the advantages of water cooling and heat dissipation, assuming that the power of electronic components is 40W, the heat of $860.076 \times 40 = 3443.04$ calories can be generated in one hour. If the water flow through the water cooling device is 100 L/h, the water temperature will rise by 0.344 ℃ without considering other aspects of heat dissipation. The proper amount of water is the key to affect the heat sink. Once again, the appropriate amount of water is selected, assuming that the power of electronic components is about 40W, 15L water is used without fan, and 10W submerged pump is used. When the ambient temperature is 25 ℃, after 2 hours, the water temperature rises by 3 ℃ and reaches the equilibrium state. It can be explained that water cooling can effectively dissipate heat.

4. The way of liquid cooling

Taking the liquid cooling and heat dissipation of the data center as an example, the liquid cooling and heat dissipation system of the data communication equipment can be understood as a liquid circuit, in which the cooling liquid exchanges with the parts needing cooling, such as CPU. Generally, the liquid of the cooling system is provided by the CDU, or the external CDU serving multiple racks. In order to effectively solve the heating problem of data center, the industry has made a lot of attempts. At present, liquid cooling technology mainly includes immersion, spray and cold plate.

4.1. Immersion liquid cooling and heat dissipation

Submerged liquid cooling is a widely concerned cooling technology this year. At the SC14 global computer conference, a number of related enterprises at home and abroad have launched and displayed submerged liquid cooling products, which have attracted great attention.

Because in the submerged liquid cooling heat dissipation, the heating equipment is in direct contact with the coolant, with high heat transfer coefficient, low convective thermal resistance, relatively high specific heat capacity and thermal conductivity of the coolant, small change rate of operating temperature, and no fan is required for the immersed liquid cooling heat dissipation, so the noise and power consumption are reduced, and the refrigeration efficiency is high. Therefore, this liquid cooling technology is suitable for high heat flux density, high energy-saving computer and large data center. It is a green and efficient cooling solution.

4.2. Spray liquid cooling and heat dissipation

The main characteristic of spray type liquid cooling is that the non corrosive coolant is sprayed directly on the surface of the thermal element or the expansion surface in contact with the thermal element. After absorbing the heat, the thermal fluid is discharged and the heat exchange is conducted with the cold source of the external environment.

The spray type liquid cooling cabinet system includes spray type liquid cooling cabinet system (including liquid distribution system, liquid return system, pipeline, PDU and other components), liquid cooling server and coolant. The spray type liquid cooler is connected with the indoor heat exchanger through pipes, that is, the residual heat of semiconductor in the cabinet is absorbed by cooling water and then transported to indoor heat exchanger and outdoor heat exchanger. In this system, the heating parts inside the server adopt the distributed structure. The heating surface direction of the heating part is different from the gravity direction. The recommended power of components in the cabinet should not exceed 56kw. There is no fan inside the server, so it is necessary to protect and
isolate the hard disk when saving it. Spray type liquid cooling system has the characteristics of high heat dissipation efficiency, high integration, quiet and high efficiency and energy saving, which is an effective means of heat dissipation.

4.3. Cold plate liquid cooling and heat dissipation

The main arrangement of cold plate liquid cooling is to install water distribution device in liquid cooling box, set outlet branch pipe on liquid cooling calculation node, connect inlet and outlet of branch pipe with inlet and outlet of liquid cooling calculation node, so as to realize liquid cooling cycle in liquid cooling calculation node. The liquid in the liquid cooling calculation node converges in the tank. The storage tank has a total of two connections connected with the external pipeline. The connecting channel is connected with the external CPU, and liquid cooling is carried out in the liquid cooling node of the liquid cooling system of the refrigeration board. Large consumables such as CPU are cooled by the liquid cooling plate, and a small number of other heating components (such as hard disk interface card, hard disk, etc.) still use air-cooled cooling system.

Compared with air-cooled cooling, cold plate liquid cooling has higher heat dissipation efficiency and better anti noise effect. Because the cold plate liquid cooling technology does not require high water cooling devices, all costs are reduced after the layout, and the energy efficiency of the data center is significantly improved. Therefore, the total energy consumption of each cabinet with cooling density of 45KW can only be achieved under the cooling density of 45KW in each cabinet, so that the total energy consumption of each cooling cabinet can reach up to one minute.

5. Application of liquid cooling scheme

In 1966, IBM introduced the system / 36091 computer. With its advantages of high speed and high performance, this giant product has been used in large-scale scientific computing, such as predicting the global climate and exploring the universe, so as to ensure the stability and efficiency of unprecedented large-scale machines. IBM specially developed liquid cooling systems, and later developed dozens of them. For many years, under the condition of low heat load, the cost of air cooling is low, the technology is simple, and the liquid and cold air gradually disappear. Although IBM has successively adopted 3081 large-scale machines and new water-cooling technology with 575 second power, its real systematic and mature application was still in July 2010. IBM's "warm water" surpassed Aquasar. His debut opened a new era of liquid cooling era and helped IBM reach the climax of liquid cooling. At present, IBM has deployed the super MUC of the Super Computing Center (LRZ) in Munich, Germany, using 40 °C warm water as the cooling medium for it equipment. As a cooling medium, its cooling efficiency is 4000 times that of ordinary wind. In LRZ Supercomputer Center Park, hot water can heat other living buildings, saving about $1.25 million a year.

Unlike IBM's direct use of water for air conditioning, Intel and green revolution cooling (GRC) launched a mineral oil cooling system a year later. GRC is the initial support of the National Union of Sciences. The company was founded in 2009, less than 10 years old, but has certain achievements and reputation in cooling technology solutions. The specific heat of mineral oil introduced by the system is 1200 times that of air. The experimental data show that the cooling effect of the system is 90% - 95% lower than that of the traditional air cooling.

In addition to Tel and GRC, 3M has also made breakthroughs in immersed liquid cooling. Compared with the boiling point of mineral oil, NOVEC can carry out boiling gasification at a lower temperature. In the 3M liquid cooling system, NOVEC absorbs heat and boils, and the steam condenses at the upper end, releasing heat into liquid. The temperature of the reciprocating cycle gradually decreased.

At the I / O Developers Conference in 2018, Google launched three generations of semiconductor TPUs for learning machines. The deployment of TPU 3.0 provides more than 100 petaflops of computing power, high-density design and high-performance computing speed. Let Google only introduce liquid cooling technology in the data center, this is the first time we have used liquid cooling
technology in the data center. From the published product photos, Google has a great possibility of using cold plate heat dissipation, but the specific technology has not been disclosed.

6. Conclusion
With the rapid development of wireless charging technology, it is developing in the direction of small size, high power consumption and high density. It is urgent to solve the heating problem in the use of wireless charging device. It is believed that with the development and maturity of liquid cooling technology, it will play a due role in the field of wireless charging.

Liquid cooling technology plays an irreplaceable role in solving the problem of thermal control. By understanding and analyzing the function, principle, characteristics and application of liquid cooling technology, the development direction of liquid cooling technology in the field of wireless charging is pointed out. Liquid cooling technology will have a very broad prospect in the field of wireless charging.

Acknowledgments
Thank you Li Yuping for your help, and thank you Shandong Huayu University of Technology for your support.

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