Research and application of cooling technology by water for whole lithium battery of RTG

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Abstract. RTG is used in port terminals as common tools for handling containers. The traditional diesel RTG with high energy consumption and high pollution has become the key target of energy-saving and emission-reduction in port. Lithium battery with high work voltage, high specific energy, long life, low self-discharge is widely used in energy-saving reconstruction of RTG. However, the lithium battery is affected by the temperature, and the heat dissipation has a direct impact on the application of lithium battery. The existing RTG lithium battery cooling system is not perfect, which affects the application and promotion of energy saving technology of lithium battery in RTG. In this paper, a new cooling system of water-cooled lithium battery is introduced. It could enable the lithium battery to stay at the optimum temperature range during the normal operation of the RTG, keep the temperature difference between the cores and improve lithium battery life lower. After actual testing, the system could be applied to the energy saving reconstruction of real RTG, and has a good effect. Due to its superior performance such as low maintenance cost and high saving rate of fuel consumption, it is advantageous to promote the application and promotion of RTG full lithium battery energy saving and transformation technology.

1. Introduction
In recent years, China's port container throughput has become the first in the world for many years. Rubber tyre gantry crane (RTG) has become the main loading and unloading equipment of the container port depot in China. Due to flexible mobile operation requirements, the traditional RTG is generally equipped with a diesel engine with large energy consumption, high cost of oil and gas emissions. It inevitably produced a large number of nitrogen (NOx), sulfide (SOx), carbide (COx) mixed flue gas in the process of operation, which has been the main pollution source of container port. Because lithium ion battery has the advantages of high working voltage, high energy, long charge and discharge life, low self-discharge rate and no memory effect, it is widely used in energy saving reconstruction [1, 2]. But in the process of lithium ion batteries, the inside of the battery produces heat, especially under heavy load conditions. The heat of the battery increases rapidly and the battery temperature rises, affecting the battery life and capacity. The heat of the battery increases rapidly and the battery temperature rises, which could influence the the battery life and capacity [3, 4]. Therefore, the heat dissipation design of the battery pack greatly influences the performance and cycle life of the
single battery and the whole battery pack. At present, the cooling mode of lithium battery pack is cooled by air cooling, liquid cooling and phase-change material[5]. The air cooling structure is simple, and harmful gas could be discharged in a timely manner, and the cooling speed is slower. When the heating quantity is larger, the temperature difference between the inlet and outlet is larger resulting in the uneven distribution of the battery temperature. Phase change materials own low thermal conductivity and slow thermal response. However, the vibration and gravity in the vehicle may result in uneven material distribution, and make the temperature distribution uneven. It also needs to be absorbed by the phase-change materials of heat transferred to the outside world in wonderful condition.

Liquid cooling heat transfer efficiency is high, the cooling effect is obvious, the cooling speed is fast, the temperature distribution of the battery is relatively uniform, but the structure is relatively complex[5-7]. Natural cooling, forced air cooling, and cooling by air conditioning are commonly used in the heat dissipation of RTG lithium batteries. In coastal port, the use of natural cooling and forced air cooling have a major drawback. Due to the high salt fog in the coastal areas, the corrosion of the inner plate of the battery system is caused. In addition, heat dissipation of cooling by air conditioning is unsatisfactory, which could make regional temperature unevenness. The high temperature may keep lithium batteries at elevated temperature, which seriously affects their safety and cycle life. At the same time, the activity of lithium battery decreased due to low temperature, which could not meet the normal operation of the machine. In current heat dissipation conditions, high charging current may make lithium battery temperature rise. It needs to increase the capacity of the battery to meet the normal working demand, which increases the cost of transformation and maintenance.

This paper mainly introduces a kind water cooling system of lithium batteries, which could be applied to the RTG. The research results are expected to improve the working temperature of lithium battery, battery power and battery life, to reduce the battery capacity and maintenance costs.

2. RTG cooling system of lithium battery by water
This paper introduces a new type of RTG lithium battery cooling system by water. Compared with the self-cooled lithium battery, the new requirements of the water cooling system in the lithium battery have been put forward for the sealing and insulation of the battery. The stability and reliability of the external water cooling system of the lithium battery is also very important. The lithium battery water-cooled temperature control system consists of a 2.8kw air-cooled chiller and the internal cooling pipe of the battery pack, which could make the internal temperature of the battery less than 35 °C during the working process. At the same time, the system also has a heating device, which could guarantee lithium battery internal environment temperature more than 5 °C in winter. The system schematic diagrams are shown in Figure.1 and Figuer.2.
Figure 1. Schematic diagram of RTG lithium battery cooling system by water
3. Calculation of service life of water-cooled lithium battery.
Due to the use of water-cooled lithium battery, the heat dissipation effect is good, the battery capacity is reduced by half, and the battery life is estimated by using a large current charge. In the process of project design, the life of water-cooled lithium battery was recalculated according to the calculation method of the existing self-cooled lithium battery, as shown in Table 1.

Table 1. Calculation of Lithium battery life

| Battery life calculation |
|-------------------------|
| 1 | Total Energy of Battery System | 46650 | wh |
| 2 | Using Range | 35 | % |
| 3 | Available Energy | 16327.5 | wh |
| 4 | Number of Containers Using 85%-50% SOC (The generator is stopped.) | 10 |
| 5 | Continuous Use Time Using 85%-50% SOC (The generator is stopped.) | 40 | Min |
| 6 | Energy per Hour | 24000 | wh |
| 7 | Charging time from 50% to 85% SOC in working process | 61 | Min |
| 8 | Charge and Discharge Cycles per Day. | 12 | Cycles |
| 9 | Charge and Discharge Cycles per Year | 4080 | Cycles |
| 10 | Number of Charge and Discharge Cycles in 6 Years | 24480 | Cycles |

Cell parameters

| | |
|---|---|
| 1 | Cycle times core of DOD 35% at 25°C | 43000 | cycles to 80% SOH (or 20% capacity loss) |
| 2 | Cell aging rate batteries at 30 °C | 1% | loss per year |
Result

|   | capacity loss using 6 years (%) | 11% | capacity loss |
|---|---------------------------------|-----|---------------|
| 2 | aging decay for 6 years (%)     | 6%  | capacity loss |
| 3 | Estimated remaining capacity orSOH (%) after 6 years | 83% | remaining capacity |

4. Energy Efficiency Test

In order to further test water cooling performance of the system, the lithium battery cooling system by water is appropriate to the RTG. The working parameters of lithium battery, such as temperature, current and SOC, are monitored in real time. The results are presented in Fig. 3.

![SOC vs Time](image1)

![Current vs Time](image2)

![Temperature vs Time](image3)

Figure 3. Working parameters of lithium battery, such as temperature, current and SOC
It is shown that lithium battery is used as the power source, whose charging and discharging curves are normal. The RTG lithium battery cooling system by water could meet the normal working requirements, and the battery capacity could always remain between 50-82%. The temperature using lithium battery cooling system by water is controlled well always staying between 22 and 32 °C, which is helpful to extend battery life.

5. Conclusion
A new type of lithium battery cooling system by water is introduced herein, which could realize the stability of the temperature during the operation of the lithium battery by adding a water circulating system inside the battery. The system effectively avoids the difference in life span caused by the temperature difference between the cores, which could improve the service life of the lithium battery. The system could be applied in RTG through test to meet the normal operation of RTG. During the operation, the temperature of the lithium battery is always controlled in the optimal temperature range, which could be the new direction for the energy saving of RTG full lithium battery in the future.

References
[1] P. He. Equip. Manuf. Technol. 157, 3 (2017)
[2] T. Huang, L. Xu, X.X. Huang, W.Q. Niu, Chin. J. Power Sources, 1399 (2016)
[3] K. Zeng, Electrokinetic Tool, 12 (2014)
[4] C.S. Xu, L.G. Lu, D.S. Ren, F.C. Jiang, M.G. Ouyang, Automot. Eng., 1141 (2017)
[5] Y.H. Lu, G.L. Duan, Chin. J. Power Sources, 2476 (2016)
[6] J. Chen, C. Yang, R.Z. Dou, D.G. Li, Chin. J. Automot. Eng., 167 (2017)
[7] Z.G. Yang, S. Huang, L.P. Zhao, Cmput. Aided Eng., 1141 (2017)