Feasibility of BYD blade batteries in electric vehicles

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Abstract. Due to the global trend of energy saving and emission reduction and the rapid development of new energy vehicles, the global lithium battery market is experiencing rapid growth in demand, mainly for power lithium battery. Among the many power batteries, ternary cathode material battery (NCM battery) and lithium iron phosphate battery s are the most installed. Although the safety of lithium iron phosphate battery is very good, it is not satisfactory in terms of energy density and range. In order to improve these shortcomings and allow for further security improvements, BYD blade battery with a new structure has received attention. This article analyzes the feasibility of BYD blade battery as a power battery by presenting the advantages and disadvantages of BYD blade battery. It can be concluded from the nail penetration test that BYD blade battery has good safety and is not easy to catch fire and explode. In addition, the unique structure of BYD blade battery allows it to have the advantages of high energy density, long cycle life and wonderful safety performance. In today's electric vehicle market, NCM still occupy most of the market. In the future, it is necessary to highlight the advantages of the blade battery and put it into application. This paper integrates current information about BYD blade battery and compares the cars using the blade battery with the cars using other power batteries, so as to play a role in the promotion of BYD blade battery in the future.

Keywords: BYD, Blade battery, Electric vehicle, Lithium battery

1. Introduction

With the development and popularity of new energy vehicles, the requirements for power batteries are getting higher and higher. Higher energy density, higher range and better safety are what the developers have been pursuing. Among the many types of power batteries, ternary lithium batteries and lithium iron phosphate batteries are the two types that account for a relatively large number of vehicles. In the past few years, ternary cathode material battery (NCM battery) has been occupying most of the market for the new energy vehicle industry. Ternary cathode material battery has higher energy density, long cycle life, and advantages in both range and resistance to low-temperature decay [1]. However, in the nail penetration test, the ternary cathode material battery will instantly catch fire and explode due to internal short circuit. Many companies have led to irrational competition in power batteries because of the over pursuit of range optimization [2]. In order to make the power battery safer and avoid catching fire on impact, BYD blade battery was developed. The technology of lithium iron phosphate battery is still applied to the BYD blade battery. Instead of changing the material, the structure of the cell is changed. The space layout of the battery pack has been optimized, with a greater number of cells set in the same volume of space. This greatly improves the energy density of the battery and also increases the range. In addition, the special structure allows the safety performance of the battery to be substantially improved again.

On July 1, 2022, the Tesla Model Y, equipped with BYD blade batteries, passed the EU type approval. It's reported that blade batteries supplied by BYD have been delivered to Tesla's super factory in Berlin, Germany. Compared to the 2,153 kg weight of the 60 kWh Model Y that Tesla applied for in the EU last year, the new Model Y weighs 66 kg less, which is 2,087 kg, and its combined energy consumption is down to 155 watt-hours per 100 km. In addition, the special structure allows the safety performance of the battery to be substantially improved again.

The main purpose of this article is to analyze the feasibility of BYD blade battery as a power battery for new energy vehicles. First, the safety of the BYD blade battery is analyzed from the perspective of experimental results and battery structure. Then, through the technology used in the

BYD blade battery, the reason why it can increase the energy density and thus the range of the car is introduced. The advantages of BYD blade batteries in other aspects are also listed, such as wind resistance, low temperature resistance, price, etc. Aside from these, the data of electric vehicles using BYD blade batteries and other batteries in the market are also compared. At last, there is a discussion on whether BYD blade battery can completely replace the ternary lithium battery or not.

2. Performances of BYD blade battery

2.1. Safety performance

With the gradual promotion of new energy vehicles, more and more attention is paid on the safety of vehicles. Lithium-ion batteries are commonly used as the power source of electric vehicles. The batteries of new energy vehicles have a great risk of spontaneous combustion in collisions. And because of the special material of the battery, the fire cannot be extinguished by traditional fire extinguishers. This leads to new energy vehicles prone to spontaneous combustion accidents, and the lack of response methods [3]. Thus, the performance of the battery plays a very important role in measuring the quality and safety of the electric vehicles. In order to verify whether the battery is safe or not, the performance of the battery in some extreme situations need to be recorded, especially in some flammable or explosive situations such as electric car collisions or other car accidents. As a result, the nail penetration test is conducted to determine the safety of the battery. In this experiment, the short circuit circumstance is simulated by using a steel nail. The steel nail is directly inserted into the lithium-ion battery and through the entire battery. The negative and positive electrodes are partially connected inside the jelly roll by the electric conducting nail. The electrons are able to use the steel nail as a bridge and free to move between the negative electrode and the positive electrode. As a result, a short circuit circumstance will take place on the nail and the jelly roll interface, causing the generation of both joule heat and entropic heat. The temperature will increase soon and the thermal decomposition reactions of the jelly roll materials start [4]. A direct observation of the battery's smoke generation, ballooning of the pouch and the real time change of layered structure of electrodes can be observed [5]. During the nail penetration experiment for BYD blade battery and ternary cathode material battery (NCM battery), experimenters used steel nail with diameter of 5 mm and the speed for penetrating is 25 mm/s. For NCM lithium battery, there was severe burning and the temperature at the surface exceeded 500 degrees Celsius. For the cubic lithium iron phosphate battery, there was smoke but no obvious fire. The surface temperature is between 200 degrees Celsius and 400 degrees Celsius. For BYD blade battery, there was neither obvious fire nor smoke and the surface temperature was merely 30 to 50 degrees Celsius. The results shows that BYD blade battery has better safety than NCM lithium battery.

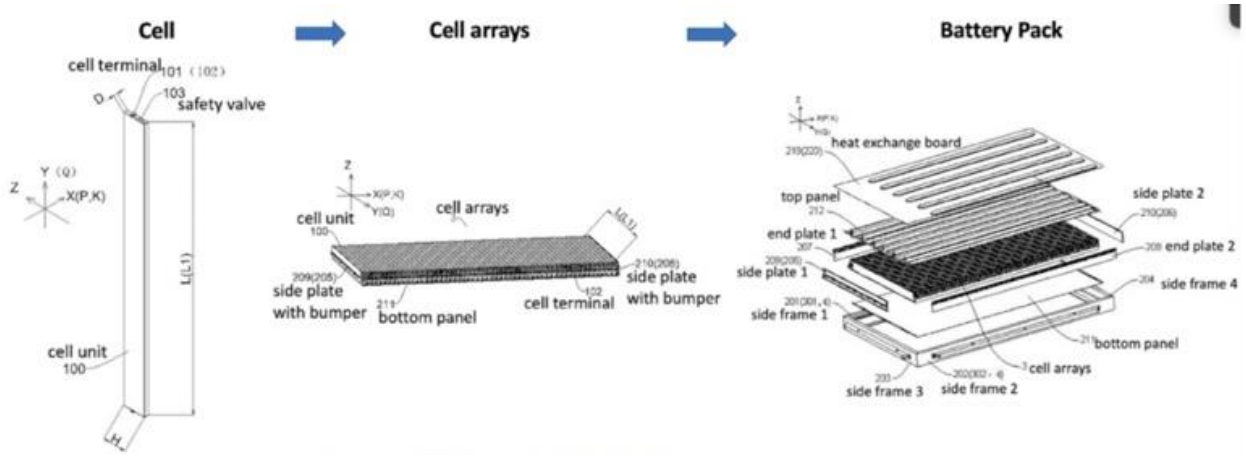

Figure 1. The structure of BYD blade battery [6].

The BYD blade battery get its name from its razor-like cells, which is shown in figure. 1. The large cells developed by BYD are about 0.6 meters long and 13.5 mm thick, and they are inserted into the

battery pack. Compared with the traditional shape, BYD blade battery increases the space utilization efficiency largely, placing more cells in the space. The volume utilization efficiency of BYD blade battery is increased by more than 50%, which means the range will be increased as well. The BYD blade battery can be regarded as the improved lithium iron phosphate battery and it's mainly structural innovation, rather than innovation on materials [3]. BYD blade battery changes the traditional cylindrical shape of a single cell into a long and thin cell, eliminates the module design to save more space and reduces the number of secondary parts by around 40%. It's an innovation on the base of lithium iron phosphate battery and it abolishes the shell structure of traditional battery. The cell uses a laminated structure and ceramic coating technology, which can save the places of cell shell [2]. The cells are arranged between the upper and lower sides of the high-strength aluminum plates, which can increase the space utilization efficiency and energy density per unit cell. With the increase of the number of cells and energy density, the range for the electric vehicles is improved as well. Among the spontaneous combustion cases of new energy vehicles, 60% are caused by ternary lithium batteries while 5% are caused by lithium iron phosphate batteries. It can be seen that lithium iron phosphate batteries have lower possibilities of self ignition than ternary lithium batteries.

2.2. Range

Ordinary lithium iron phosphate batteries have lower cell density compared to NCM battery. In order to acquire good safety and range, BYD blade battery has been greatly optimize its structure. The previous battery pack consists of many cylindrical cells, while BYD blade battery consists of electric cells which are thin as blade. This is not only a change in the shape of the battery, but more critically, the layout of the space inside the battery pack is optimized. A larger number of cells can be accommodated in the same space with the same volume, which also makes the energy density of the battery and the range of the vehicle much higher. The volume utilization efficiency of the previous battery's stacking method is only 80%. When considering the necessary supporting parts and the heat dissipation parts, the entire volume utilization efficiency is only about 40%. However, for BYD blade battery, its structure is denser and better. The volume utilization efficiency can reach 60%. With denser structure and higher volume utilization efficiency, the number of cells in one pack increases greatly, which means the energy density and range increase as well. In order to design module-less battery pack, BYD uses the cell-to-pack (CTP) technology. Compared to traditional battery packs, CTP technology eliminates battery modules and additional wiring, making them easier and cheaper to produce [7]. Lithium iron phosphate cells are packaged in an array of lengths in a battery pack with a first dimension between 600 mm and 2500 mm. The ratio of energy density and weight of BYD blade battery can be up to 180 Wh/kg, which has about 9% improvement over battery with module design. The increase in volume utilization efficiency also solves the problem of low energy density, increasing the charge capacity and range by 20% to 30% [2]. The charge capacity of the battery pack for BYD Han is nearly 79 KWh and its range can reach 605 km [8].

2.3. Advantages and improvements

Most of the battery packs are installed under the floor of the car. If the battery pack is too low, the ground clearance becomes smaller, which will increase the chance of the battery pack knocking on the bottom. In order to increase the ground clearance, ensure the comfort of passengers and maintain a small wind resistance coefficient at the same time, a relatively small battery thickness is required. The structure of BYD blade battery meets this requirement perfectly. For BYD blade battery, the vertical height of its battery pack is nearly 50 mm shorter than the block shape battery pack, ensuring ample sitting space while maintaining the beautiful coupe shape and creating a wind resistance coefficient of 0.233 Cd, which is the top 10 in the world for cars. Not only is it beautiful and comfortable, but the smaller wind resistance coefficient also allows for a higher range. In addition, BYD blade battery also improves the poor low-temperature resistance of lithium iron phosphate battery by having a more scientific thermal management system. The performance of the battery is still stable in cold surroundings. Even in the cold condition of -20 degrees Celsius, BYD blade battery

still has at least 90% of its discharge capacity at room temperature [2]. BYD blade battery uses the world's first battery pack heat pump direct cooling and heating technology, which means that the technology of intelligent automatic heating of the battery and the efficiency of battery heat dissipation have been significantly improved, allowing the battery to achieve the best charging and discharging performance in low and high temperature environments. Battery energy density has also been significantly improved, ordinary lithium battery energy density is about 250Wh/kg, while the BYD battery energy density reached 332Wh/kg. When considering the cost, as the raw materials for lithium iron phosphate batteries are produced in large quantities in China, the cost for BYD blade batteries is relatively low [8]. In contrast, ternary lithium battery materials are more scarce and more expensive. Also, BYD blade battery uses the CTP technology, which can reduce the number of parts by 70% and increase the volume utilization efficiency by 50%. Thus, the overall cost is reduced by about 30% [9]. Compared with the NCM battery, BYD blade battery has a longer cycle life, with more than 3000 cycles of charging, which is nearly 1000 times more than that of the NCM battery [3].

3. BYD blade cells in practice and market

BYD blade batteries are now used in BYD Han series models and have attracted a lot of users. Table.1 listed several types of electric cars and their performances. It's obvious that using BYD blade battery will not increase the cost. The fast charging time for BYD series is shorter than Tesla Model 3, Tesla Model Y and NIO ET7. Also, when considering all the factors together, BYD Han Qian Shan Cui 610 km limited version has the best overall performance and the best value for money. Both of these two BYD series cars have their advantages and their prices are not too high. Their maximum torque and CLTC pure electric ranges are excellent at their price level. To compare BYD blade battery and NCM battery, Tesla Model Y and BYD Han Qian Shan Cui limited version have similar prices but BYD Han has much better performance in acceleration, range, maximum power and maximum torque. According to a survey, when battery capacity is kept at 76.8 kW, BYD Han EV can maintain a high power charge of 100kw for a long time through high voltage charging technology, and it only takes about 25 minutes to fast charge to 80%. For Tesla Model 3, fast charging to 80% takes about 45-60 minutes [10]. BYD blade battery makes up for the shortcomings of lithium iron phosphate battery's low energy density. Electric car users are most concerned about range and safety issues, and BYD blade battery finds a good balance these two factors. However, it still have flaws and disadvantages. Although its overall performance is good, it cannot completely replace NCM because its charging speed and range have not yet reached the most ideal state [11]. Although its special structure brings many benefits, it also causes problems. For example, it's hard to repair after being hit because it's too thin and the protecting barrier of supporting structure is lost. Under the impact of external forces, it is very difficult to ensure the integrity of the electric core [2].

Table 1. Comparison between several types of electric cars [12-16].

	BYD Han QianShanCui 610km limited version	BYD Han ChuangShi version 715 km	Tesla Model Y	Tesla Model 3	NIO ET7(75kWh)
Battery type	BYD blade battery	BYD blade battery	NCM	NCM/LFP	NCM
Price (RMB)	330,000	287,500	317,000	300,000	460,000
Time needed to accelerate from 0 to 100 km/h (s)	3.9	7.9	6.9	6.1	3.8
CLTC pure electric range (km)	610	715	545	556	530

Power consumption per 100km (kWh/100km)	14.9	13.5	12.7	12.5	16.2
Fast charging time (hours)	0.5	0.5	1	1	-
Maximum power(kW)	380	180	194	194	480
Maximum torque(N-m)	700	350	340	340	850

4. Conclusions

By using cell-to-pack (CTP) technology, BYD blade battery has a great innovation in structure. This paper discusses that the special structure of BYD blade battery improves the energy density of the battery, the range of the new energy vehicle and its safety. Compared to ternary cathode material battery, BYD blade batteries have a longer life, higher durability, high battery recycling value and slightly lower overall cost. The high temperature performance is better. In addition, it also improves the disadvantage of poor low-temperature resistance of lithium iron phosphate battery. In the market, both BYD and Tesla's electric cars have been equipped with blade batteries. This paper also compares the price and other automotive performance parameters of BYD cars with BYD blade batteries and Tesla cars with regular NCM/LFP batteries, and it can be seen that BYD cars have better performance at the same price. The fast charging time and CLTC pure electric range of BYD cars are larger than that of other cars. With a relatively low price, an electric car with better safety, range and power can be bought. Although BYD blade batteries have improved in many aspects, there are still some defects and shortcomings. Because of its special structure, it is more difficult to repair after a collision, and the integrity of the battery cell cannot be guaranteed. In the future, researchers should focus on solving the problems caused by the special structure of the blade battery. Also, in order to promote BYD blade batteries to the market, its advantages over other power batteries need to be explored more. At present, NCM still occupy a large portion of the power battery market. As a very emerging creation, the application of BYD blade battery in the market is still to be developed.

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