Current situation and Countermeasures of power battery recycling industry in China

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Abstract. At present, China has entered the stage of centralized decommissioning of power batteries. If the retired power battery can not be effectively recovered, it will pose a serious threat to the ecological environment and public safety. At present, China's power battery recycling industry has not yet formed a very mature technology line. Against this background, China's government needs to further strengthen the policy system and standard system, increase support for power battery recycling enterprises, and promote the rapid development of power battery recycling industry.

1. The necessity of power battery recycling

From 2013 to 2015, with the introduction of subsidy policy, China's new energy vehicle production and sales volume ushered in explosive growth. After 2016, the growth rate of China's new energy vehicle production and sales slowed down, but also maintained an annual growth rate of more than 50%. By June 2020, the number of new energy vehicles in China has reached 4.17 million. The design life of power batteries used in new energy vehicles is generally 5-8 years[1]. China has entered the stage of centralized decommissioning of power batteries. Against this background, it is of great practical significance to promote the development of power battery recycling industry.

1.1. Reduce environmental pollution and potential safety hazards

Although compared with lead-acid batteries and nickel cadmium batteries, the lithium ion power batteries are less polluted, but if not handled properly, they may still cause serious pollution to the environment.

As for the cathode materials of lithium-ion batteries, when LiCoO₂ is burned or decomposed by heat, toxic lithium and cobalt oxides will be produced. The reaction of LiMnO₂ with strong oxidant and metal powder can produce toxic gas. In addition, nickel, cobalt and manganese will increase the environmental pH. Negative electrode materials of lithium ion batteries will cause dust pollution. At the same time, the mixture of dust and air may explode when encountering fire source.

The electrolyte LiPF₆ of lithium ion battery has strong corrosiveness and can decompose HF by water. LiPF₆ reacts with strong oxidant or burns to produce p205 and other toxic substances. The electrolyte solvents, separators and adhesives of lithium-ion batteries will also produce organic pollution.

In addition, if an internal or external short circuit occurs in the decommissioned power battery, a large current will be generated between the positive and negative poles, resulting in a large amount of heat, which may cause combustion or explosion, which poses a serious threat to public safety.
Therefore, if garbage disposal methods such as landfills and incineration are used for decommissioned power batteries, they will pose a serious threat to the natural environment and public safety. Vigorously developing the power battery recycling industry will help more power batteries to enter the recycling channels on the right track, and reduce the impact of decommissioned power batteries on the natural environment and public safety.

1.2. Achieve new energy vehicle industry chain closed loop

The development of new energy vehicle industry is an important measure for China to accelerate the transformation of energy strategy and realize low-carbon green development. With a large number of power batteries reaching the service life, how to deal with the retired batteries is related to the sustainable development of China's new energy vehicle industry.

China's lithium resources are mainly distributed in Sichuan, Qinghai and Tibet. The ecological environment of Qinghai and Tibet is fragile and far away from the demand areas. The possibility of large-scale exploitation and utilization in a short period of time is extremely low, and its own capacity can not meet the surge demand of domestic power batteries. Therefore, 70% of China's lithium demand relies on imports. In addition, China's reserves of cobalt ore are about 80000 tons, accounting for only 1% of the world's reserves, and the import dependence is as high as 90%[2].

Retired power batteries contain a large number of lithium, cobalt, nickel and other metals, as shown in Table 1. The retired power battery can be used to produce power battery again after disassembly, separation and purification, so as to reduce the dependence on foreign raw materials and make the price of raw materials more controllable.

| Battery type | Lithium | Cobalt | Nickel | Manganese | Aluminum |
|--------------|---------|--------|--------|-----------|----------|
| LFP          | 1.60%   | /      | /      | /         | /        |
| LMO          | 2.85%   | /      | /      | 22.40%    | /        |
| NCM111       | 2.45%   | 6.87%  | 6.82%  | 6.41%     | /        |
| NCM523       | 2.82%   | 4.75%  | 11.78% | 6.65%     | /        |
| NCM622       | 3.01%   | 5.07%  | 15.09% | 4.73%     | /        |
| NCM811       | 3.29%   | 2.78%  | 22.03% | 2.59%     | /        |
| NCA          | 3.04%   | 3.84%  | 20.31% | /         | 0.59%    |

Taking cobalt as an example, by 2025, the cobalt that can be recovered from retired lithium-ion batteries can meet 70% of the demand for lithium-ion battery production in that year. Through the recycling of power battery, most of the materials except diaphragm and anode can be recycled, which can solve the problem of shortage of raw materials in China.

In short, promoting the development of lithium-ion battery recycling industry can not only reduce environmental pollution, but also help to realize the closed-loop of the new energy vehicle industry chain, which will greatly promote the healthy and stable development of the new energy vehicle industry.

2. Policy analysis of power battery recycling

China has attached great importance to the scrapping problems of power batteries, and has issued a series of corresponding documents at the macro policy and technical standards, providing policy support for the healthy development of power battery recycling industry.

2.1. Macro policy of power battery recycling

At the macro policy level, the Ministry of industry and information technology, the national development and Reform Commission, the Ministry of finance, the State Council and other departments have issued more than 40 policies related to power battery recycling. At the same time, with the rapid development of the new energy vehicle industry, the frequency of the release of the
macro policy of power battery recycling has gradually increased. At present, the macro policies on power battery recycling mainly focus on the following aspects[3].

2.1.1. Pilot project of power battery recycling.
It is necessary to carry out the pilot project of recycling power batteries for new energy vehicles, establish and improve the standard system for recycling waste power batteries, and promote the echelon utilization of waste power batteries. Focusing on Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta and other new energy vehicle development gathering areas, the Chinese government supports the establishment of a recycling mode with strong universality and good economy, and carries out demonstration application.

2.1.2. Clarify the responsibilities of all parties in the industrial chain
It is stipulated that power battery manufacturers should adopt standardized, universal and easily disassembled product structure design, and timely provide technical information of power battery disassembly and storage to automobile manufacturers. At the same time, the relevant policies clarify the main responsibility of automobile manufacturers to undertake the recycling of power batteries.

2.1.3. Establish traceability management system
It is required to establish a comprehensive traceability management platform for power battery, collect information from the whole process of power battery production, sales, use, scrap, recovery and utilization, and monitor the implementation of recycling responsibilities in all links of the industrial chain.

2.2. Technical standards for power battery recycling
In addition to the macro policy, the Chinese government has issued a series of industry standards to regulate the behavior and indicators of a certain stage of retired power battery recycling. These industry standards include power battery residual energy detection method, power battery disassembly specification, power battery waste liquid treatment method, power battery wet recovery treatment method, etc.

3. Current situation of power battery recycling

3.1. Technical route of power battery recycling
The power battery recycling process mainly includes pretreatment, disassembly and separation and material recovery. Although China's power battery recycling industry has mature equipment and technology, there are still some problems in the industry, such as low metal recovery rate, poor process compatibility and low automation level.

3.1.1. Pretreatment
The pretreatment process includes collecting the information of the model, manufacturer, voltage, nominal capacity, size and quality of the retired power battery. Drain the cooling liquid of power battery with special pumping system and conduct insulation test. Paste the recycling traceability code, and input the preprocessing collection information into the recycling traceability management system. Disassemble the power battery pack and power battery module. Check the appearance of power battery module and monomer, such as deformation, crack and leakage.

A voltmeter is used to detect the terminal voltage of the power battery and distinguish the polarity of the battery. According to the information of the battery, the charging and discharging current is determined, and the capacity attenuation of the cell is tested. The battery in good health can be used in other energy storage fields, and the battery in poor health can be directly disassembled and recycled. The flow chart of power battery pretreatment is shown in Figure 1.
3.1.2. Disassembly and separation
The purpose of dismantling and separating the battery is to disassemble the single battery into various valuable components, so as to facilitate the fine recovery in the later stage. Based on the characteristics of lithium-ion battery materials, the combined processes of hammer vibration, crushing, vibration screening and air separation were used to preliminarily separate and recover the constituent materials of retired lithium-ion batteries. At present, there are some problems that are difficult to solve in the process of dismantling and crushing, for example, toxic gas may be produced in the process of dismantling, and the separation efficiency is low.

3.1.3. Material recovery
The dismantling and recovery of power battery is mainly focused on the recovery of cathode materials. The recovery methods include dry recovery, wet recovery and biological recovery.

Dry recovery mainly refers to the recovery of valuable metals by mechanical separation and high temperature pyrolysis. However, the disadvantages of dry recycling are obvious, which is easy to cause secondary pollution and high energy consumption, which is not in line with the national environmental protection policy of energy conservation and emission reduction[4].

Wet recovery is the process of acid dissolution, impurity removal, extraction, concentration crystallization and centrifugation to obtain cobalt sulfate, nickel sulfate, manganese sulfate, lithium carbonate and by-products copper sulfate, aluminum hydroxide and graphite powder. The advantage of this method is that the product has high purity, many chemical reactions and low requirements for operation and equipment, but the disadvantages are slow reaction speed, complex process and high cost.

Biological recovery is mainly based on bioleaching, transforming the useful components of the system into soluble compounds and selectively dissolving them, recovering valuable metals such as lithium, cobalt and nickel, but at present, it is difficult to cultivate microorganism, and the leaching environment is highly demanding.

3.2. Technical difficulties of recycling
At present, there are two main technical difficulties in power battery recycling. The first technical difficulty is that the overall structure and connection mode of different power battery packs are different, which makes it difficult to disassemble battery packs. The second technical difficulty is the detection of residual energy in the echelon utilization of power batteries, the compatibility treatment of various batteries in recycling, and the reuse of materials such as negative electrode, etc., which has not formed a very mature technical route[5].
4. Development suggestions of power battery recycling

4.1. Further strengthen the construction of policy system and standard system
At present, most of the power battery recycling policies introduced by China are not mandatory, and lack of a clear fiscal incentive policy. In addition, China's battery manufacturers have not yet achieved standardized production, their raw materials and production processes are different, which will bring great difficulty to subsequent battery recovery. Therefore, China needs to further improve the power battery recycling policy system.

At the macro policy level, we should clarify the long-term planning of the power battery recycling industry, and improve the laws and regulations of power battery transportation, storage, cascade utilization and regeneration cycle. At the level of standard construction, we should carry out the standard and specification of life cycle for power battery structure design, connection mode, process technology and integrated installation to ensure consistency, safety and economy of power battery dismantling, detection and recombination.

4.2. Increase support for power battery recycling enterprises
The state should further strengthen the support for specialized companies of energy storage battery recycling, encourage enterprises to build or participate in the construction of recycling system by using tax exemption and financial subsidies, so as to make these companies have preferential policies, guarantee funds and preferential tax revenue, so as to promote these companies to be better and stronger in specialization, and guide them to benchmark international standards and increase their independent research and development efforts, Development of automatic dismantling equipment, efficient separation equipment, wet recovery process, harmless treatment of organic electrolyte, etc [6].

Finally, we should give full play to the coordination role of battery recycling industry associations, organizations and alliances, realize the exchange and sharing of information, resources, knowledge and technology, standardize the industry market, and prevent malicious competition and price war.

5. Conclusion
The power batteries of the first batch of electric vehicles in China have reached the service life, and it is inevitable that the power batteries will be scrapped on a large scale. Whether from the perspective of environmental protection or industrial development, it is necessary to develop the power battery recycling industry. Although the power battery recycling industry is still in its initial stage in China, with the continuous efforts of the state's intensive policies and the efforts and cooperation of the relevant enterprises such as automobile production enterprises and battery recycling enterprises, we believe that in the near future, the recovery of power battery will soon become mature.

Acknowledgement
This work was financially supported by the Research Project on Teaching Reform of Vocational Colleges in Hunan Province (ZJGB2020306).

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