

Based on the Theory of TRIZ Solving the Problem of 18650 Battery Electrolyte Filling

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Abstract. As a type of standardized battery cylindrical 18650 lithium-ion battery is widely used in new energy vehicle industry, It can be produced in large quantities without changing type. Because of its special advantages than others. But due to the pressure of rising capacity, electrolyte filling (which is short for E/L) process has become more and more difficult. While reducing the production efficiency eases the problem of E/L, it also poses performance and security problems. So the issue cannot be solved using the common knowledge of the industry. In this paper, This article does not use lean manufacturing or 6Sigma methods, we use TRIZ theory to analyze the E/L difficulty problem in detail (using causal analysis, technical contradiction analysis, substance – field analysis, physical contradiction analysis and other tools). By creating an atmosphere of vacuum and pressure replace the existing E/L tooling for single cell mechanical structure, through blowing hot air method to increase the temperature of electrolyte, Dissolving the J/R into a electrolyte tank which is full of 0.3Mpa nitrogen. Under the premise of not reducing the production efficiency, at the same time ensuring performance and safety, we try to find out a method to solve the E/L difficulty problem, and would get better application in the construction of new production lines in the new factory.

1. Introduction

TRIZ theory was established by G.S. Altshuller, a USSR inventor, in 1940s. The Russian counterpart of TRIZ is теории решения изобретательских задач. Its phonetic transcription is Teoriya Resheniya Izobreatatelskikh Zadatch, which is the source of the short form of TRIZ [1]. It means the theory of solutions of invention issues. According to G. S. Altshuller, there are objective scientific principles and rules in the process of solving issues during invention and such principles and rules are repeatedly used in various inventions, only differing in technical fields of their application. Upon over 50 years of collecting, studying, sorting out, summarizing and extracting millions of patent literatures, a whole set of systemized and practical system of theories and method for solving invention-related problems is established.

Currently, TRIZ tools have been widely used in high-tech field. In this paper, TRIZ Theory would be used to solve practical issues in production of the E/L Procedure of 18650 Battery.

Cylindrical 18650 lithium-ion battery is a standard battery used in new energy vehicles industry, having the advantage of large-scale automated production, a single model, high safety factor, low cost etc. As the driving energy, under the premise of weight and space restrictions, it requires that the battery capacity is rising gradually. Because 18650 battery has a standard external dimensions (its structure is shown in Figure 1), the internal space is very limited, so that the battery need more and



more positive and negative material and the amount of electrolyte liquid of positive and negative also increase, as a result the 18650 battery E/L process becomes more and more difficult. E/L difficulty problem will directly lead to the electrolyte's leaking, which would corrode the production equipment, and the electrolyte's leaking also result in lower amount of E/L that would cause the degradation of capacity and safety performance. To solve this problem, now it extends E/L time to settle, but the expense of productivity does not bring improvement in battery performance. Since the electrolyte prolong the time to expose in the air which would absorb moisture from the air, electrolyte composition will change, causing the battery self-discharge. Therefore it is posing an urgent need to address this problem.

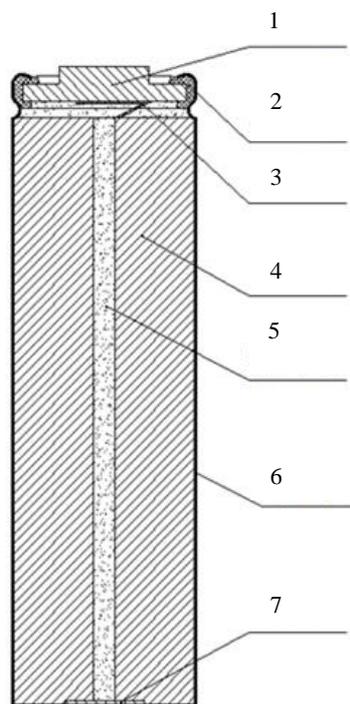


Figure 1. Battery 18650 structure

1:Cap;2:Seals;3:Positive tab;4:Positive/Negative electrode ;5:Free electrolyte;6: Battery shell;7:Negative tab

2. Analysis

As to 18650 E/L difficulty problems, we will use TRIZ theory to analyze and find the solutions.

2.1. Problems existence in current technology systems

Firstly, owing to the rising capacity, positive and negative material have been full of space inside the battery, it can only be evacuated the air within the cell as much as possible, and inject the electrolyte into the battery by pressurizing. Then repeatedly pressurizing and standing in order to inject the electrolyte into the battery. Secondly, the vacuumization mainly relies on E/L sealing fixture which may lose efficiency after many repeated times' opening, thus lower its effect of vacuumizing and pressurizing. Further, for E/L difficulty, it can be solved by repeatedly pressurizing and E/L filling and prolonging standing time, but all these will reduce productivity.

From the establishment of functional model (Figure 2), the power-driven pump make stored electrolyte in E/L tools into electrode plate, and the impact of the electrolyte to electrode plate is a short action. It is determined the relationship between the system and its components by functional model analysis, and found the functional factors of E/L difficult problems.

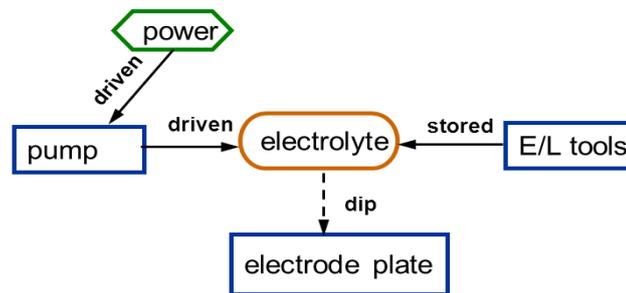


Figure 2. The establishment of functional model

2.2. Causal Analysis

As to E/L difficulty, we use causal analysis method (as shown in Figure 3). Through the analysis of the reasons step by step, we can draw a conclusion: the small space of positive and negative, the short time of E/L and the mass amount of E/L are the main reasons to E/L difficulty. These variables need to be further verified whether they are the key factors.

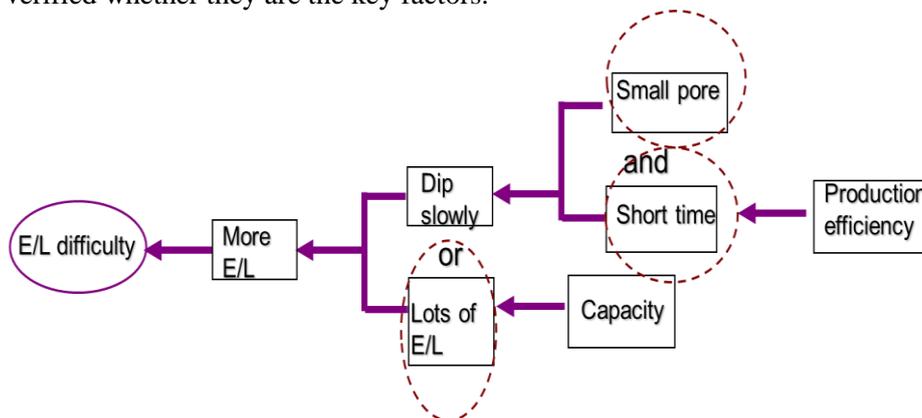


Figure 3. The causal analysis chart of 18650 battery E/L difficulty

Through causal analysis, we can determine the problem spots: 1: The pore between positive and negative material is too small for the electrolyte to enter. 2: The large amount of electrolyte has difficulty in entering into the jellyroll (which is short for J/R). 3: Due to the short time, electrolyte cannot be fully absorbed. Obviously, reducing the production efficiency is not an ideal solution, for which could enhance and eliminate both the beneficial and harm function. So the issue is not a regular problem that would not be solved within the expertise, we need to use TRIZ theory to solve it. Therefore we start our experiment with question 3.

2.3. Technical contradiction analysis

It can be determined that capacity and production efficiency are technical contradiction with the theory of technical contradiction analysis. While the E/L amount is increasing, so the capacity, the production efficiency is reducing; on the contrary, the E/L amount is reducing, so the capacity, the production efficiency is increasing. Therefore, we make E/L amount increase, capacity increase and production efficiency reduce as the main technology contradiction to solve [2] (as one can see in figure 4).

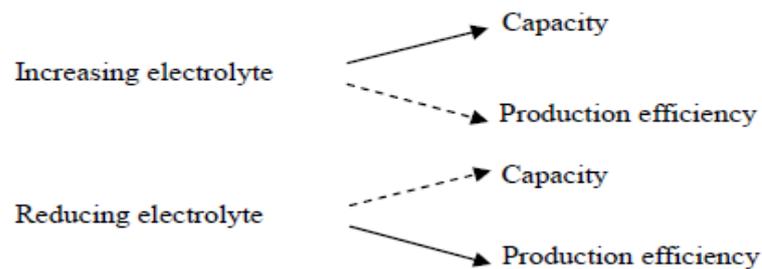


Figure 4. Technical contradiction model

Determine the engineering parameters: Improving parameters: Power; Deteriorating parameters: production efficiency. Based on the contradiction matrix, we obtained the following principles of the invention: No.28 the replacement of mechanical system, No.34 abandonment and repair, No.35 parameter changes. Then we come to the following plan: No.28 the replacement of mechanical system: creating an atmosphere of vacuum and pressure replace the existing E/L tooling; No.34 abandonment and repair: taping to form a cylinder on the mouth of the cell replace the existing E/L tooling, and after electrolyte absorption discard it; No.35 parameter changes: changing the electrolyte temperature to improve the absorption efficiency.

2.4. Substance field analysis

Through the substance field model, as shown in Figure 5, it can be seen that under the effect of dissolved chemical field force F_{Ch} , electrolyte S_2 is a shortage that cannot enter into the J/R easily, so we introduced a new field F_{Ch2} to improve the procedure E/L, then it would make the shortage to a standard effect.

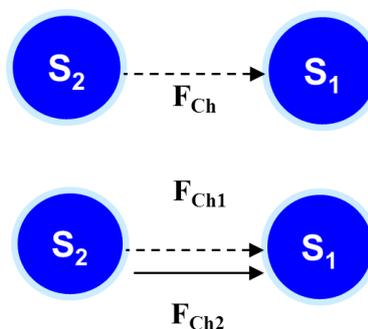


Figure 5. Substance field analysis model

S_2 : Electrolyte; S_1 : J/R; F_{Ch} : dissolved chemical field

According to the substance field model and the application of 76 standard solutions, the standard solution is obtained: No.2.25, No.3.1.2, No.3.1.4 [3]. Then we come to the following plan. Based on No.2.2.5 standard solution: by moving field instead of static field to give the solution of the problem as follows: high frequency alternation of vacuum and pressure to replace long time static vacuum and high pressure; Based on No.3.1.2 standard solution: changing the connections between the dual-system or multi-system to give the solution of the problem as follows: designing a new tooling, to ensure that no excess liquid floating instead of evacuated to vacuum and high-pressure, floating liquid is an obstacle; Based on No.3.1.4 standard solution: simplifying the solution of the dual-system and multi-system to give the solution of the problem as follows: putting large number of batteries into a vacuum and high-pressure tank to vacuumize and pressurize instead of the way used before.

2.5. Physical contradiction analysis

Through establishing a physical contradiction analysis model (Figure 6), it is found that the

microstructure of the electrode plate must be both loose and compact. The electrolyte has easier access to the inner with loose microstructure, but too loose may cause cracking; so the electrode plate need to have dense microstructure, which would result in E/L difficulty. Therefore the electrode plate's microstructure is the physical contradiction [4].

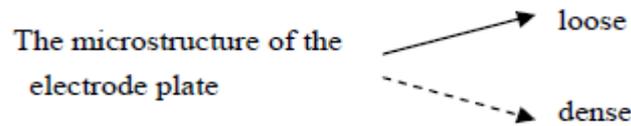


Figure 6. Physical contradiction analysis model

According to the physical contradiction analysis model and the application of 76 standard solutions, the standard solution is obtained: No.5.1.1, No.5.1.3. Then we come to the following plan. Based on No. 5.1.1 standard solution: the introduction of substance to give the solution of the problem as follows: when the electrolyte filled with nitrogen enters into the J/R, vacuumizing to expand the positive and negative pore making electrolyte easier to enter. Based on No. 5.1.3 standard solution: additives disappearing to give the solution of the problem as follows: mixing electrolyte composition in positive and negative material, after the electrolyte enter into the J/R, the composition melt, expanding the pore to make it easier to the J/R.

3. Results

This paper comes to three results.

- 1) To overall vacuumize and pressurize 1000 batteries by creating an atmosphere of vacuum and pressure replace the existing E/L tooling for single cell mechanical structure [5]. Thus ensuring the stability and reliability of the system, E/L time for single cell is longer than the existing time, but operating 1000 batteries at one-time, overall productivity is not reducing, but increasing.
- 2) Changing the electrolyte's temperature: in the experiment, through blowing hot air method to increase the temperature of electrolyte to 35 ~ 40 °C [6], the E/L absorption time is shortened by 14%, thereby the electrolyte absorption efficiency is improving.
- 3) Dissolving the J/R into a electrolyte tank which is full of 0.3Mpa nitrogen, the pore of J/R is expanded after vacuumization in order to create easier access for the electrolyte to get in, finally the J/R is back to normal as its pore shrink after pressurization.

4. Conclusions

Based on the TRIZ theory system, we have found a solution to solve the E/L difficulty of 18650 battery in production process. Product performance and security have improved, while the production efficiency is not reducing, and the system does not become complicated, but easier to operate and maintain. Improvement effect has experienced production test, and would get better application in the construction of new production lines in the new factory.

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