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Lamination Test and Result Analysis Based on Orthogonal Test Method

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Abstract

Based on the orthogonal test, this paper mainly studied the influence of the lamination temperature, lamination time and vacuum degree of the plate solar cell component laminator on the lamination quality. The experimental scheme was set up by L4（23）orthogonal table, and then the battery components are laminated by the model prototype, and battery components completed lamination were analyzed, at the same time, the following conclusions were reached: when the lamination temperature was 148℃ to 150℃, the lamination time was 15-18 minutes, and when the vacuum degree reached 60-80Pa, laminated high-quality battery components, which provides a theoretical basis for lamination of high-quality battery components in the future.

Keywords

Panel solar cell component laminator;orthogonal test; lamination temperature; lamination time;vacuum degree.

1. Introduction

At present, China ' s photovoltaic industry is mostly concentrated in the packaging link. Because packaging technology is the most important and difficult factor in the production process of solar cell components. The vacuum hot pressing method is used in packaging process. Among many equipment for producing solar cell components, the laminator is an indispensable equipment [1]. The plate type solar cell component laminator is used in the production process of double glass photovoltaic curtain wall and photovoltaic tile, which can ensure the smoothness of the layer pressure and better adapt to the needs of modern photovoltaic products. In order to better laminate out high-quality battery components and reduce the reject rate of lamination, studying the influence of the lamination temperature, lamination time and vacuum degree of the plate solar cell component laminator on the lamination quality based on the orthogonal test. Seeking the optimal combination of influencing factors to laminate high quality battery components.

2. Construction of test platform

According to the actual operation of the plate solar cell component laminator, the simulation test was carried out. In the whole test process, the required test equipment includes the test prototype, glass plate, battery plate, POE plastic, TP9000 multi-channel data recorder, ZD0 -

54D thermocouple vacuum gauge, stopwatch, vernier caliper. The test prototype is shown in Fig. 1.

Fig. 1Test prototype

3. Design of test platform

The purpose of the test is to seek an optimal lamination process of solar cell components, so as to optimize the lamination quality of solar cell panels without damage. In this laminated test, the qualified rate of laminated battery components can be used as the test index, and it is a quantitative index. The qualified rate of the battery pack will be determined by three test parameters, namely, no bubbles inside the battery pack, the offset of the battery plate in the battery pack and the thickness uniformity of the four top angles of the battery pack. The lamination temperature, lamination time and vacuum degree of upper and lower chambers of the solar cell component laminator are the three test factors.

According to the determined three factors of the test, namely, the lamination temperature, lamination time and the vacuum degree of the upper and lower chambers, they are represented by A, B and C respectively, in the meanwhile, each test factor selects two levels, and the other factors are treated as the test conditions regardless of whether they are controllable or not. The factor level table of the solar cell component lamination test is shown in table 1.

Table 1 Factor level table

Factor / level	A lamination temperature /(℃)	B lamination time /(min)	C vacuum degree /(Pa)
1	148-152	12-15	60-80
2	145-148	15-18	40-60

This experiment will adopt the $L_4(2^3)$ orthogonal table, the different numbers of each column in the table are replaced by the corresponding level of the corresponding factors, and then constitute the test plan table, as shown in table 2.

Table 2 Test plan

Factor / test number	(1) A lamination temperature /(℃)	(2) B lamination time /(min)	(3) C vacuum degree /(Pa)

1	A_1	B_1	C_1
2	A_1	B_2	C_2
3	A_2	B_1	C_2
4	A_2	B_2	C_1

4. Process of test

Laminate 100 groups of battery components, and then after completing the lamination, detect the number of bubbles, the offset of the battery plate and the thickness uniformity of the battery components at four angles. The laminated battery components are shown in Fig. 2. In this test, because the test conditions are restricted, the test can only be carried out one by one. In order to make the test results random and eliminate other interference, the test sequence is determined by drawing lots. Like this, so as to reduce the test error, 25 groups of experiments were conducted in each group, in other word, 25 groups of solar cell components are laminated in each case.

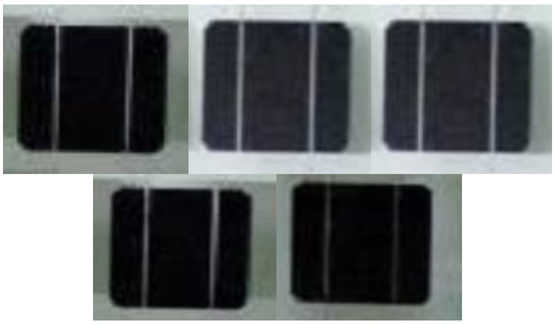

Fig. 2 Battery components

5. Results and analysis of test

At the end of the pressure test, the test results are recorded in the following test indicator column. According to the first case for that 24 combination are qualified in the 25 battery components laminated, the qualified rate reached 96 %, followed by laminated the other three states of battery components, the qualified rate was 92 % under the context of the second condition, the qualified rate was 80 % in the third situation, the qualified rate was 88 % in the fourth condition. And the analysis of test results is shown in Table 3.

According to the test results, the range analysis method is used to analyze the test results in detail. This method is also called R method. The related algorithms of this method are shown in Fig. 3. In the figure, Y_{jk} is the test index corresponding to the j factor and k level, $\overline{Y_{jk}}$ is the average Y_{jk}, because the optimal level of j factor can be judged by the size of $\overline{Y_{jk}}$, the optimal combination is the combination of the optimal levels of each factor ; R_j is the range of factor j, the calculation formula is [i]:

$$R_J = \max[\overline{Y_{J1}}, \overline{Y_{J2}}, \dots] - \min[\overline{Y_{J1}}, \overline{Y_{J2}}, \dots]$$

R_j reflects the change range of test index when j factor level changes. The greater R_j, the greater the impact of this factor on the test indicator, at the same time, this indicates that this factor is the most important in the test. In this solar cell component lamination test, $R_A > R_C > R_B$, so it can be seen from table 3 that the lamination temperature has the greatest influence on the test index, followed by the lamination time, and finally the vacuum degree.

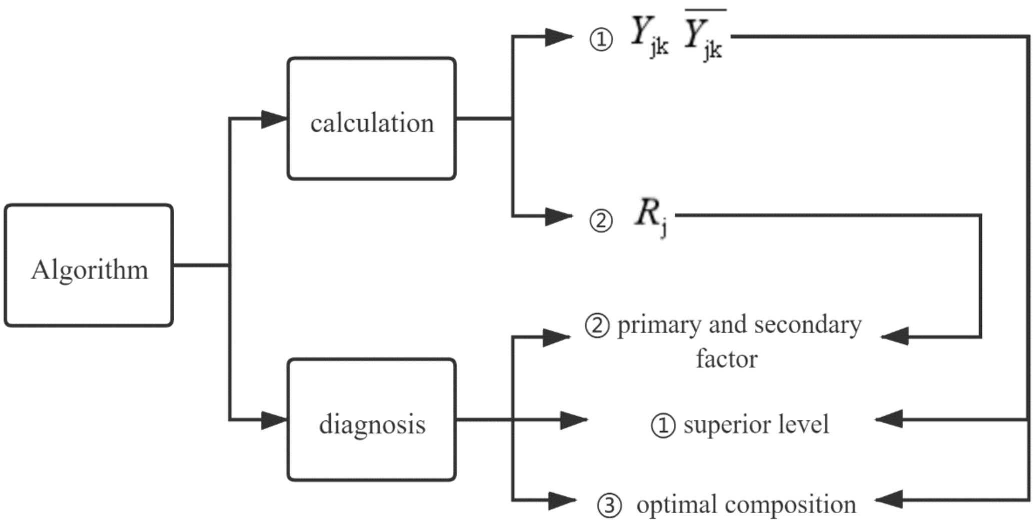

Fig. 3 R method schematic diagram

Table 3 Test results analysis

test number / factor	(1) A lamination temperature/ (℃)	(2) B lamination time /(min)	(3) C vacuum degree /(Pa)	qualified rate Y_i
1	A_1	B_1	C_1	96
2	A_1	B_2	C_2	92
3	A_2	B_1	C_2	80
4	A_2	B_2	C_1	88
Y_{j1}	188	176	184	$\sum_{i=1}^{4} Y_i = 356$
Y_{j2}	168	180	172	
$\overline{Y_{j1}}$	94	88	92	
$\overline{Y_{j2}}$	84	90	86	
R_j	10	2	6	
superior level	A_1	B_2	C_1	
secondary factors	ACB			

optimal composition	$A_1 B_2 C_1$	

In this lamination test, the calculation and judgment of R method are directly displayed by the table of the test scheme, as shown in table 4-4. In the first and second groups of tests, it is obvious from the table that each level of B lamination time and C vacuum degree is set as one, in the meanwhile, there is no interaction between lamination time and vacuum degree, and their combination have never effect on the test index. So, speaking for A1 and A2, the previous test conditions of the first and second groups are basically the same. If the lamination temperature of factor A has no effect on the test index, then $\overline{Y_{A1}} = \overline{Y_{A2}}$, however, the test results show that $\overline{Y_{A1}} \neq \overline{Y_{A2}}$, which is caused by the change level of factor A. The value of $\overline{Y_{A1}}$ and $\overline{Y_{A2}}$ reflects, from the side, the influence of A1, A2 lamination temperature on the test index. In this test, the results show $\overline{Y_{A1}} > \overline{Y_{A2}}$. Therefore, it can be concluded that A1 is the optimal level of factor A. Similarly, it can be judged that B2 and C1 are the optimal levels of factors B and C respectively. As a result, the combination of the optimal levels in this experiment is $A_1B_2C_1$, which is the optimal lamination process condition. In terms of this lamination test, when the lamination temperature is 148 °C ~ 150 °C, the lamination time is 15-18 min, and the vacuum degree reaches 60-80 Pa, the lamination quality of battery components is the best.

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