Analysis of electrolytic process parameters based on orthogonal test method

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Abstract. In the process of electrolysis of rare earth metals, there are many factors that affect the final electrolytic production. These process parameters are usually determined by the workers in the factory according to their own experience, there is no statistical analysis of the scientific data to the final establishment. This chapter will design a set of multi factor and multi level orthogonal experiment through the actual production data of a factory in Hezhou, In order to study the influence of factors on the production results.

1. Introduction

In actual production practice, there are many factors that affect the experimental results. We often have to do a lot of factor tests, How to arrange the multi factor experiment is a question which is worth studying. If we test the level of each factor, In a number of factors, the number of trials to do is amazing.

Figure 1 as an example

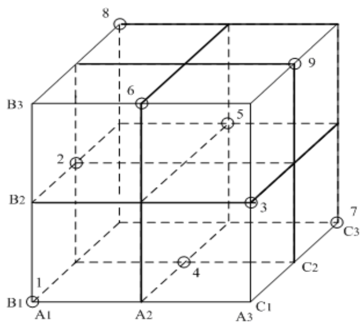

Figure 1.Test point distribution of two experimental design methods

Figure 1 represents a test design for three factors and three levels, Assuming that three vertical X axis, Y axis, Z axis of the three planes were the representative factors of A, factor B, factor C three levels. The intersection of each three lines represents a combination of three factors, 27 nodes in a cube represent the 27 test. This kind of experiment is called comprehensive test method. But with the use of orthogonal test is only 9 times the test, Specifically speaking, From any direction of the cube is divided into 3 levels, each plane contains 9 intersections, there are exactly 3 test points that are arranged by the orthogonal table. The 9 test points are uniformly distributed in the three-dimensional space. The orthogonal test method is aimed at the above situation, In reducing the number of tests to complete a number of parameters optimization, it is a kind of design method of multi factor and multi level by orthogonal table, in place of all the tests to reflect the overall situation.

2. Analysis method

2.1 Range analysis

Range analysis method, also known as visual analysis method. It has the advantages of simple calculation, easy to understand, and so on, it is the most commonly used method for the analysis of the results of orthogonal test. Range analysis method is called as R method. Let T be the sum of all the index values, $T=\sum_{i=1}^{n} x_i$, T indicates that the test parameters and the corresponding I (i=1,2,3,4) on the level of any column. $t_i=\frac{T_i}{r}$, r indicates the number of times the level of each column appears. R is called range, R=max（T1,T2,T3,T4）-min（T1,T2,T3,T4）or R= max（t1,t2,t3,t4）-min（t1,t2,t3,t4）。The range analysis method includes two steps: Calculation and Judgment.

2.2 Variance analysis

The key of variance analysis is the decomposition of deviation square sum.

Total deviation square and total degree of freedom:

$$SSE=\sum_k SS_j,\quad f_e=\sum_k f_j \qquad 2.3.1$$

Sum of squares of deviations in each column and degree of freedom:

$$SS_j = r\sum_{i=1}^{m}(t_i-\bar{X})^2=\frac{1}{r}\sum_{i=1}^{m}T_i^2-\frac{T^2}{n},\quad (j=1, 2, \ldots, k),\ f_j=m-1 \qquad 2.3.2$$

Here, r=n/m。

Table 2.1 analysis of variance table

Source of variance	Sum of squares	freedom	Mean square deviation	Value of F	Fa	Significant
factor 1	SS1	f1	MS1= SS1/ f1	F1=MS1/MSE		
factor 2	SS2	f2	MS2= SS2/ f2	F2=MS2/MSE		
…	…	…	…	…		
error	SSE	Fe	MSE= SSE/ fe			
the sum	SST	n-1				

For factor j, given a significant level of a, Check list for value of Fa.if Fj > Fa，We believe that the impact of J on the test results is significant.

2.3 Orthogonal test analysis

Based on the reference of domestic and foreign literature and the actual production situation in the factory practice, The test selects the main influencing factors: electrolytic voltage, electrolytic temperature, reaction time, feeding frequency, polar distance. Each group of factors to take four process level. Detailed factor levels are classified as shown in Table 2.2

Table 2.2

Factor level	A electrolytic voltage（V）	B electrolytic temperature（^{0}C）	C reaction time（min）	D polar distance（mm）	E feeding frequency（min）
1	9.0	950	30	8.5	5
2	9.5	1000	40	9.5	10
3	10.0	1050	50	10.5	15
4	10.5	1100	60	11.5	20

According to the table 2.2 factors of the level of the division, we decided to use the five factor four level orthogonal test matrix to design L_{16}（4^5）orthogonal table. Results of orthogonal test are shown in Table 2.3

Table 2.3

Test number	electrolytic voltage（V）	electrolytic temperature（0C）	reaction time（min）	polar distance（mm）	feeding frequency（min）	Qualified rate（%）
1	9.0	950	30	85	5	78.6
2	9.0	1000	40	95	10	86.7
3	9.0	1050	50	105	15	91.8
4	9.0	1100	60	115	20	82.1
5	9.5	950	40	105	20	80.3
6	9.5	1000	30	115	15	83.6
7	9.5	1050	60	85	10	98.1
8	9.5	1100	50	95	5	92.2
9	10.0	950	50	115	10	79.3
10	10.0	1000	60	105	5	82.9
11	10.0	1050	30	95	20	94.8
12	10.0	1100	40	85	15	89.9
13	10.5	950	60	95	15	83.1
14	10.5	1000	50	85	20	87.5
15	10.5	1050	40	115	5	93.2
16	10.5	1100	30	105	10	84.7

Based on the results of the above statistics.Using the orthogonal test, the results are as follows:

	A	B	C	D	E
K1	339.2	321.3	341.4	354.1	346.9
K2	353.9	340.4	350.1	356.8	348.8
K3	346.9	377.9	350.8	339.7	348.1
K4	348.5	348.9	346.2	337.9	344.7
R	14.7	56.6	9.4	18.9	4.1
Excellent level	9.5	1050	50	95	10

The analysis of variance is shown in Table 2.4

Table 2.4

Source of variance	Sum of squares	degree of freedom	Mean variance	value of F	Fa	Significant
factor A	27.6619	3	9.2206	11.4217	9.2766;29.4567	Remarkable
factor B	415.6019	3	138.5340	171.6034	9.2766;29.4567	highly significant
factor C	13.9969	3	4.6656	5.7794	9.2766;29.4567	
factor D	70.6219	3	23.5406	29.1600	9.2766;29.4567	Remarkable
factor E	2.4219	3	0.8073	1.0000	9.2766;29.4567	
error	2.4219	3	0.8073			
sum	530.3044	15				

In order to be more intuitive, the horizontal coordinate is used as the factor, the calculated value of K is used as the vertical coordinate to make the trend chart of the relationship between indicators and factors. These representing factors of electrolytic voltage (A), electrolytic temperature (B), reaction time (C) and polar distance (D), feeding frequency (E) the trend chart is as follows.

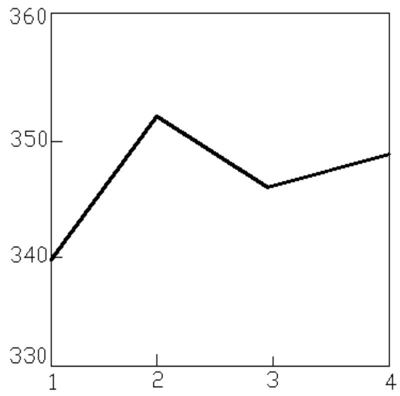

Figure 2 factor A

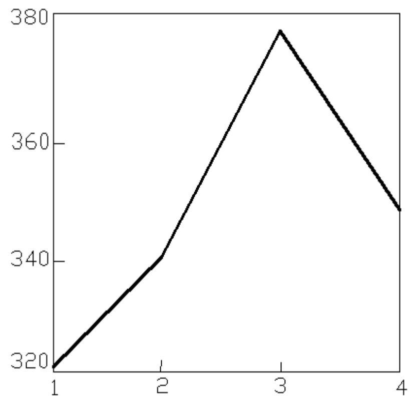

Figure 3 factor B

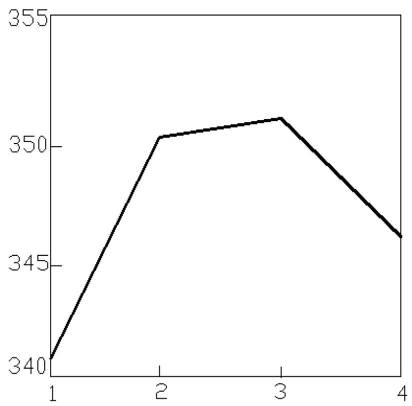

Figure 4 factor C

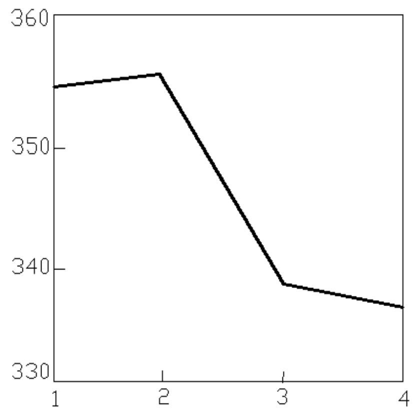

Figure 5 factor D

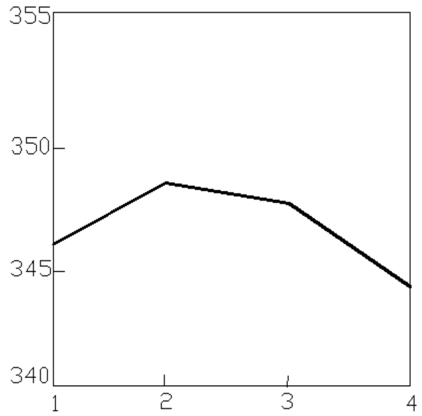

Figure 6 factor E

2.4 Result analysis

From the results of the above range and variance analysis, Carbon content (qualified rate) as evaluation index, Based on the calculated R value, The factors of praseodymium neodymium alloy production qualification rate of the final order of influence: B>D>A>C>E, According to the factors of the horizontal trend chart can be more intuitive to determine the level of the best factors: $B_3D_2A_2C_3E_2$, The results of analysis of variance showed that, Factor C had no significant effect on the results of production, Factors A, B and D had significant influence on the production results, Among these factors, the effect of B on the results was highly significant, In order to improve the production efficiency, save production time, Combined with visual analysis results, We finally determine the optimal process parameters for $B_3D_2A_2C_2E_2$.

3. Verification test

Based on the results of the above analysis, we choose $B_3D_2A_2C_3E_2$、$B_3D_2A_2C_2E_2$ two groups of process parameters combination, 3 parallel experiments were made for each group, The average eligible rates of the two groups were 98.7% and 98.1%, respectively, Two groups of tests have higher pass rate and almost no big difference, But from the improvement of production efficiency, shorten the production time, $B_3D_2A_2C_2E_2$ combination can bring more economic benefits to enterprises.

4. Conclusion

There is no uniform standard for electrolytic production in the factory, This experiment uses the scientific data processing method. To establish a multi factor and multi level orthogonal experiment to find out the best level of the production process parameters. Practice proves that this method is correct and effective. These can provide reference for the enterprise's production operations.

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