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Study on furnace temperature curve model based on least square method

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Keywords: least square method, Data fitting, Nonlinear programming

Abstract: Data fitting based on the least square method was adopted. Through the analysis of relevant data, the data were divided into five sections: small temperature region 1-5, small temperature region 6, small temperature region 7, small temperature region 8-9, and small temperature region 10-11. Then the least square method can be used to fit the five formulas, and then find out their corresponding derivative function, because the heat conduction effect of the back weld furnace on the circuit board is basically fixed, so it is assumed that the heat conduction effect of different temperatures and transmission speeds is consistent. Finally, according to the derivative function, the furnace temperature curves of the five sections can be calculated. Thus, the temperature of the midpoint 3, midpoint 6, midpoint 7 and edge 8 of the small temperature zone are 109.3℃, 155.6℃, 166.8℃ and 190.4℃, respectively. Nonlinear programming is used to solve the problem. First, constraint conditions are established according to the process boundary, and the objective function can be obtained by combining the obtained temperature acceleration. The problem is transformed into a nonlinear programming problem, and the final solution can be obtained: 182°C (small temperature range 1~5), 203°C (small temperature range 6), 237°C (small temperature range 7), 254°C (small temperature range 8~9), and the maximum speed of the conveyor belt passing through the furnace is 83cm/min.

1. Foreword

In the production of electronic products such as integrated circuit boards, printed circuit boards with various electronic components need to be placed in the back weld furnace, and the electronic components are automatically welded to the circuit boards through heating. In this production process, it is very important for the quality of the product to keep the temperature of each part of the back weld furnace at the required process temperature. At present, much of this work is controlled and adjusted through experimental tests. The purpose of this thesis is to analyze and study through the mechanism model.

2. Research and analysis

(1) Based on statistics

Method description: most statistical outlier detection methods are to construct a probability distribution model and calculate the probability of an object conforming to the model. Objects with low probability are regarded as outliers.

Method evaluation: the premise of statistical model-based outlier detection method is to know what distribution the data set obeys; For higher dimensional data, the validation may be poor.

(2) Based on proximity

Method description: Proximity measures can often be defined between data objects, with objects that are far from most points considered outliers.

Method evaluation: simple, two-dimensional or three-dimensional data can be observed in scatter plots; Large data sets are not applicable; Sensitive to parameter selection; Has a global threshold and cannot process datasets with regions of different densities.

3. Model building

3.1 Temperature acceleration model

The furnace can be divided into five areas. The temperature of the conveyor belt in each area is constant, so the temperature acceleration in each area is constant. According to the table data given in the question, the temperature acceleration in each area can be obtained.

The circuit board enters the furnace heating area from the front area of the furnace, and its own temperature rises from 25℃ to 30℃ for 19s. According to the hypothesis, the temperature acceleration during this period is:

According to the table data given by the question, it can be known that there is a one-to-one correspondence between time and temperature. By fitting and analyzing these data, the relationship between temperature and time can be obtained, and then the temperature acceleration can be obtained by taking the derivative of the relationship. The basic principle of data fitting used here is the least square method.

3.1.1 Introduction to least square method

The least square method (also known as the least square method) is a mathematical optimization technique. It looks for the best functional match of the data by minimizing the sum of squares of the error.

3.1.2 Conclusion

The data in the topic is divided into five regions, namely: small temperature region 1-5, small temperature region 6, small temperature region 7, small temperature region 8-9, and small temperature region 10-11. Then, the fitting analysis of these data is adopted respectively based on the least square method, and finally the fitting curve and fitting formula can be obtained.

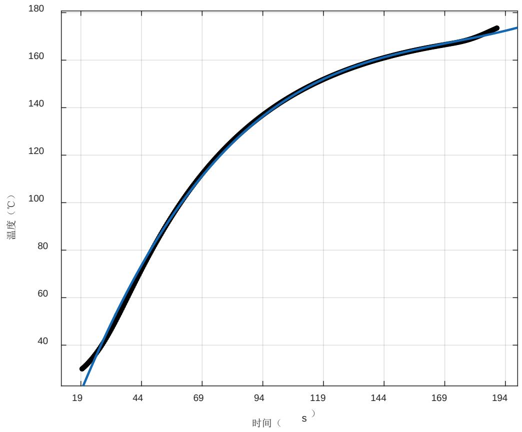

Figure. 1 Fitting curve 1-5 in small temperature region

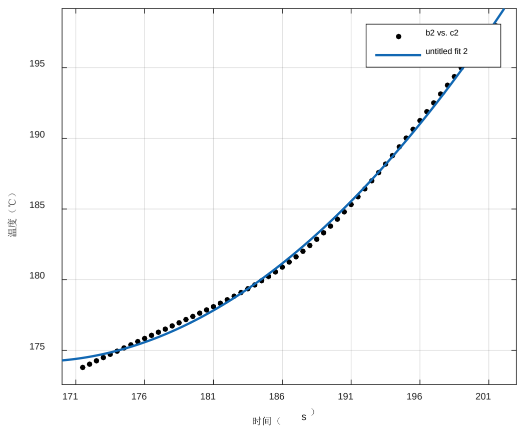

Figure. 2 Fitting curve of small temperature region 6

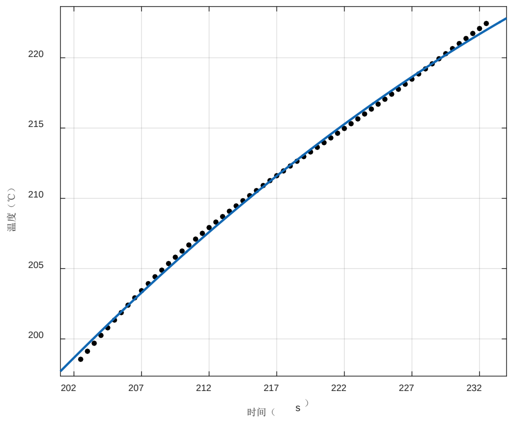

Figure. 3 Fitting curve of small temperature region 7

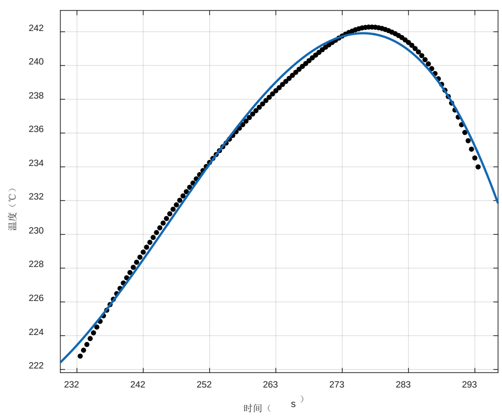

Figure. 4 Fitting curve 8-9 in small temperature region

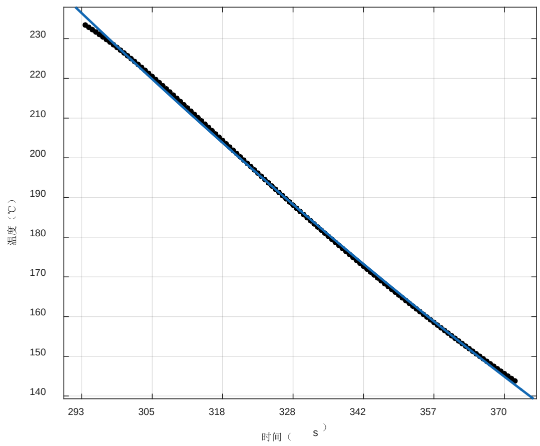

Figure. 5 Fitting curve of 10-11 in small temperature region

According to the fitting curves in Fig. 2-6, the fitting formulas corresponding to the data of the five regions can be obtained, from which the functional relationship between time and temperature can be known, and then the formulas can be further solved.

$$\begin{cases} T_2 = 20.52 + 1.238x - 0.0037x^2 + (4.029e-6)x^3 \\ T_3 = 174.4 + 0.0643x + 0.00537x^2 \\ T_4 = 198.7 + 0.4787x - 0.00158x^2 \\ T_5 = 223.4 + 0.2169x + 0.00242x^2 - (2.836e-5)x^3 \\ T_6 = 236.4 - 0.8434x + 0.00067x^2 \end{cases}$$

After the derivative of the fitting formula, the temperature acceleration can be obtained as follows:

$$\begin{cases} a_2 = 1.238 - 0.0074x + (1.09e-5)x^2 \\ a_3 = 0.0643 + 0.011x \\ a_4 = 0.4787 - 0.00316x \\ a_5 = 0.2169 + 0.00484x - (8.508e-5)x^2 \\ a_6 = -0.8434 + 0.00134x \end{cases}$$

By calculating the temperature acceleration, the furnace temperature curves of 173°C (low temperature range 1~5), 198°C (low temperature range 6), 230°C (low temperature range 7) and 257°C (low temperature range 8~9) can be obtained at the conveyor belt speed of 78 cm/min. The calculated timing time is 19s at the beginning and 335s at the end. The calculation results are shown in the figure below.

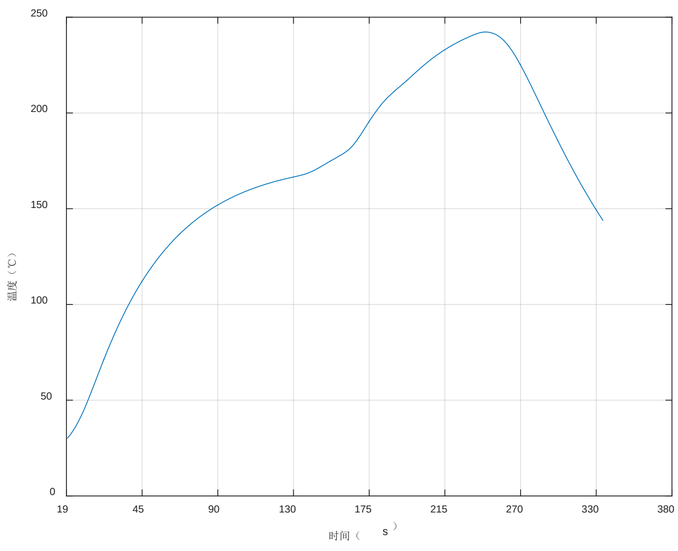

Figure. 6 Furnace temperature curve

4. Furnace temperature curve model

The temperature set values of each temperature zone were 182°C (small temperature zone 1~5), 203°C (small temperature zone 6), 237°C (small temperature zone 7) and 254°C (small temperature zone 8~9), and the maximum speed of conveyor belt passing through the furnace was required. What is worth mentioning here is the process boundary. According to the small table, the constraint condition can be obtained as follows:

$$\begin{cases} t = \frac{s}{v} \\ T = at \\ 3 \le a \le 3 \\ \frac{1}{3} \le a \le \frac{2}{3} \qquad 150 \le T \le 190 \\ 240 \le T_{MAT} \le 250 \end{cases}$$

After the derivative of the fitting formula, the temperature acceleration can finally be obtained. According to the temperature acceleration, the furnace temperature curve with time variation can be obtained. Finally, the final function relation can be obtained.

$$\begin{cases} a_2 = 1.238 - 0.0074x + (1.09e - 5)x^2 \\ a_3 = 0.0643 + 0.011x \\ a_4 = 0.4787 - 0.00316x \\ a_5 = 0.2169 + 0.00484x - (8.508e - 5)x^2 \\ a_6 = -0.8434 + 0.00134x \end{cases}$$

The transmission speed is limited by the maximum and minimum furnace temperature. After calculation, the fastest speed can be obtained as 83cm/min. After quantitative processing of the obtained data, the surface graph can be obtained finally, with the highest temperature of 250℃ and the lowest temperature of 240℃, corresponding speeds of 83cm/min and 65cm/min respectively.

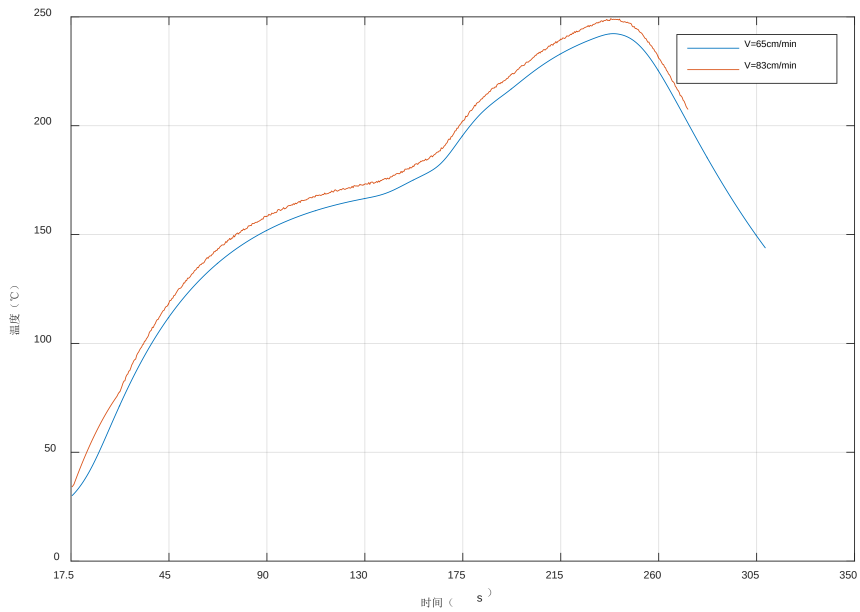

Figure. 7 Furnace temperature curve corresponding to maximum velocity and minimum velocity

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