Research on temperature curve and optimization of rewelding furnace based on lumped parameter method

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Abstract: The rewelding furnace is an important equipment for the production of integrated circuit boards, and its internal process temperature will affect the product quality. For the rewelding furnace with given equipment parameters, this paper establishes a mathematical model to study the temperature change in the center of the welding zone under different transmission speed and temperature zone temperature. According to the known parameters and the experimental data, the specific characteristics of the interaction between the temperature fields in each temperature zone are analyzed, and the temperature gradient distribution is obtained. Then according to the Fourier heat conduction law, the environmental temperature field of the rewelding furnace is obtained, and then the model of the environmental temperature field in the furnace is established. By calculating the Bevo number of the welding pad, it is found that the heat transfer process of the welding pad can be regarded as a zero-dimensional unsteady heat conduction process, and a lumped parameter model can be established to solve the temperature variation law in the center of the welding zone. The planning problem of finding the maximum value of transmission speed under the constraint of process limits. Through the environmental temperature field model and lumped parameter model, the solution results of the device meet the process requirements of weldment processing, and the furnace temperature curve can be solved very well, so as to facilitate the analysis and study of the processing technology of the rewelding machine.

1. Introduction

With the continuous development and progress of science and technology, there are more and more types and quantities of electronic products, and the scope of application of SMT technology is also expanding. SMT is the abbreviation of surface mount technology. (PCB) reflow soldering process of printed circuit board is an important kind of SMT technology in electronic manufacturing industry[1]. The furnace temperature curve records the change of temperature in the welding process in real time. According to the best solderability and balance index of solder paste and components, the temperature distribution on PCB is detected to avoid damage to components caused by high temperature and welding defects caused by insufficient temperature. Reliable furnace temperature curve can determine the process of tin paste and products, and welding quality can be guaranteed by strengthening furnace temperature monitoring. Therefore, it is particularly important to study the fitting of reflow soldering temperature curve and get the temperature curve which is suitable for our own equipment. Due to the different brands and types of reflow furnace, the type of heating, the number of temperature zone, hot air system, too high and low temperature in each zone will have a certain impact on the welding object. How to get the optimal furnace temperature curve by restriction is the main problem that the paper study[2].

2. Analysis of Environmental temperature change Model

First of all, the temperature field in the rewelding furnace is taken as the research object, and the distribution of the temperature field in the furnace is roughly analyzed according to the Fourier heat conduction law[3].

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$$\begin{cases} \dfrac{d^2t}{dx^2}=0 \\ x=0,t=t_1 \\ x=\delta,t=t_2 \end{cases} \tag{1}$$

Because the internal heating of the hot air rewelding furnace is uniform, the stable temperature field in the furnace is regarded as an one-dimensional steady-state temperature field, and the above formula is the mathematical description of the one-dimensional steady-state heat conduction problem by Fourier heat conduction law. That is, there are two stable temperature values that can solve the temperature field between the two points[4]. It can be approximately considered to be consistent with the actual temperature field distribution. Then through the temperature change characteristics of the experimental data, the specific characteristics of the temperature interaction between each temperature zone are analyzed.

In this study, the rewelding furnace is used as a blowing rewelding furnace, that is, in the case of thermal insulation of the inner wall of the rewelding furnace, the ambient temperature is a certain value at equal distance and is a function of distance. After obtaining the reliable furnace temperature curve, the welding quality can be guaranteed only by strengthening the furnace temperature monitoring.

3. Model building

3.1 Model segmentation processing

According to the structural characteristics of the rewelding furnace, the temperature field is established in four stages. There is no heating heat source in the front area of the furnace, and the distribution of the temperature field is affected by the temperature setting value of the initial section of the heating area in the furnace, and changes with the distance. For the first section, the heat transfer medium is air. In order to better fit the temperature field, the paper use the software to simulate the distribution of the temperature field before the furnace, which is a function related to the temperature set at the front of the heating zone in the furnace. For the second section, because the blowing device in the furnace can well fill the whole furnace with hot air, the temperature distribution is more uniform. According to the analysis of each small temperature zone combined with the experimental data, it can be considered that there is a core temperature zone and a boundary temperature zone in each small temperature zone. The temperature of the core temperature zone is mainly affected by the setting value, which can be approximately regarded as the setting value and is not affected by the adjacent temperature zone. The boundary temperature region is affected by both the local small temperature region and the adjacent small temperature region. Combined with the experimental data, it is found that the length of the core temperature zone is 20.5cm, which is in the center of the whole low temperature zone. The length of the boundary temperature zone on both sides is 5cm. For the third section, it is located in the connecting section of the heating zone and the cooling zone in the furnace.

3.2 Establish lumped parameter model

Taking the weldment as the research object, the heating condition of the weldment in the furnace is the step change of the boundary heat transfer of the weldment, which leads to the temperature of the weldment in the process of continuous change. According to the characteristics of the change of weldment temperature with time in the experiment, it can be defined as an aperiodic and unsteady heat conduction problem, that is, the temperature in the central area of weldment increases (decreases) continuously with time, or changes irregularly until it approaches a new temperature.

For the specific analysis of the heat transfer of the weldment, then use the Biewood number for analysis.

$$Bi=\frac{hl}{\lambda}=\frac{l/\lambda}{1/h} \tag{2}$$

The dimensionless parameter is the Biwauer number, which can qualitatively express the relative magnitude of the thermal resistance of heat conduction in the interior of an unsteady heat conducting body (l/λ) and the thermal resistance of heat transfer on the surface of the object ($1/h$). Among them, it is the characteristic length of the object.

In the process of unsteady heat conduction, the heat transfer model of lumped parameter method is obtained.

$$\begin{gathered}\rho c V \frac{dt}{d\tau} = -hA(t - t_{\infty}) \\ \tau = 0, t = t_0\end{gathered} \tag{3}$$

4. Temperature model solution

4.1 Solution of Environmental temperature change Model

First of all, the ambient temperature change model is solved, and the different temperature segments are solved according to the temperature setting values of each temperature zone.

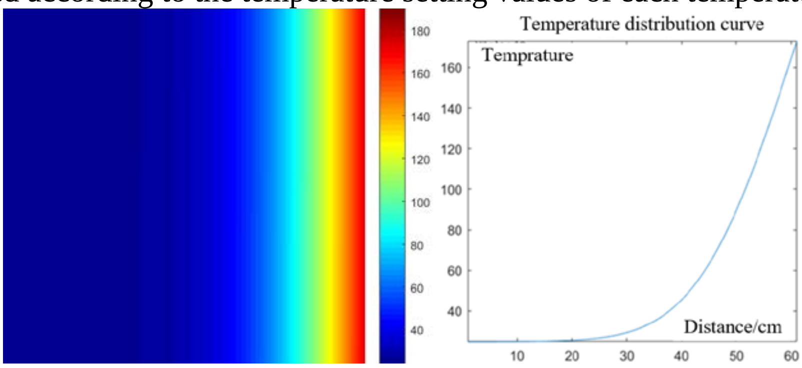

Fig.1 Temperature distribution curve

The lumped parameter model is solved below. According to the model, the original differential equation is simply solved.

$$\frac{\theta}{\theta_0} = \frac{t - t_{\infty}}{t_0 - t_{\infty}} = \exp\left(-\frac{hA}{\rho c V}\tau\right) \tag{4}$$

However, the above process is still too idealized, so according to the research results of the EMPF Center of the American ACI Research Institute, the lumped parameter model is reasonably simplified.

$$T_t - T_i = (T_s - T_i)\left(1 - e^{-\frac{t}{RC}}\right) \tag{5}$$

The heat flux will affect the mechanical properties of the solder ball. The temperature change and heat transfer coefficient at different points of the substrate are attributed to the uneven air distribution in the cooling stage. Considering that the thermal resistance and heat capacity will change during the heating process of the weldment, the paper combine them into one coefficient, that is

$$T_t - T_i = (T_s - T_i)(1 - e^{-\alpha t}) \tag{6}$$

In order to get the results, the paper substitute the experimental data, solve the variation curve, and find that there are obvious changes in the values of different temperature zones in the furnace.

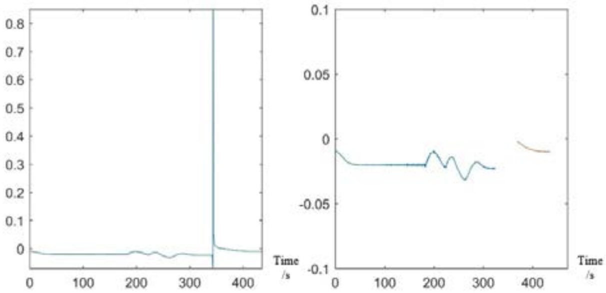

Fig.2 Variation curve of variable temperature coefficient

In the preheating zone, the variable temperature coefficient increases gradually, and the increasing rate decreases gradually until it reaches the constant temperature zone. In the constant temperature zone, the variable temperature coefficient is basically stable and only slightly increases. The variable temperature coefficient fluctuates greatly in the recirculation zone, and the numerical value changes rapidly due to the large temperature difference. In the cooling zone, the variable temperature coefficient turns to a negative value and begins to cool down.

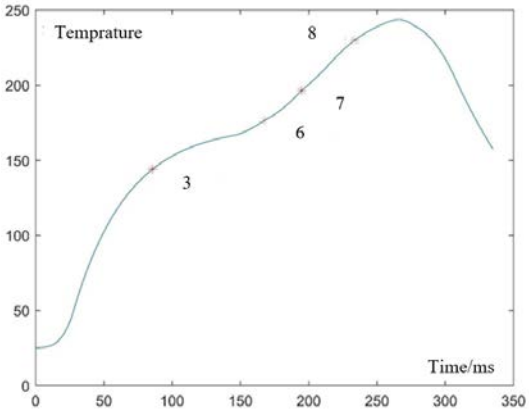

Fig.3 Furnace temperature curve

4.2 Finding the optimal solution in the temperature region

Based on the strategy of reducing the peak temperature and increasing the slope of the heating section in the reflux zone, the temperature of the small greenhouse in the preheating zone and constant temperature zone should be as low as possible, and the temperature in the reflux zone should be as high as possible. The setting value of each small temperature zone is optimized.

Using the temperature setting values of each small temperature zone obtained from the analysis, and then according to the heat transfer simulation software, the environmental temperature field model and the CFtool function, the temperature distribution in front of the furnace, the heating area and the rest of the furnace are obtained respectively. Finally, the method of matlab programming is used to select the speed of the conveyor belt in the case of minimum coverage area by replacing the speed of the conveyor belt into the lumped parameter model.

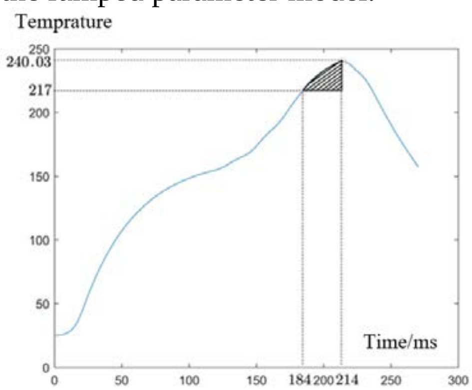

Fig.4 Optimal furnace temperature curve

The optimal furnace temperature curve can be obtained as shown above, and the shadow part is the required area. It consists of an interval from 184s to 214s. Use matlab to integrate the curve to get the area value.

Finally, the temperature setting values of each temperature zone are 165 °C (1 °5), 185 °C (6 °C), 225 °C (7 °C), 265 °C (8 °9) and 25 ℃ (10 °11), respectively. The furnace speed of the conveyor belt is 96.66 cm / min, and the shadow area is 388.479. The results show that the temperature setting values of each temperature zone are 165 °C (1 °5), 185 °C (6 °C), 225 °C (7 °C), 265 °C (8 °9) and 25 ℃ (10 °11). The above results are sorted out in Table 1.

Tab.1 Temperature setting value of each temperature zone

Temperature zone	1~5	6	7	8~9	10~11
Temperature/℃	165	185	225	265	25

5. Conclusions

In this paper, firstly, the lumped parameter method is used to simplify the complex model of the rewelding furnace, and the environmental temperature field is established to turn it into a solvable differential programming model. Through the lumped parameter method, then find out the main factors that affect the temperature curve, which not only simplifies but also ensures that the model has high accuracy, which is easy to improve the accuracy and accuracy of calculation. After comprehensively considering several constraint conditions, for the solution of the simplified variable new model, it is proved that the curve accords with the objective law of facts, and has high extensibility.

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