Research and Discussion on Welding Mechanism of Reflow Furnace

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Abstract. The flexible grasp of automatic welding technology is very important for the production of electronic products such as integrated circuit board, and the most critical step is to accurately control the temperature of the welding area. This paper will establish the mechanism model of the influence of the temperature of each temperature zone of the reflow furnace and the speed of the conveyor belt on the temperature of the welding area through the relevant thermodynamic theory, so as to help the relevant electronic product manufacturers to accurately control the temperature of the welding area. The mechanism model of temperature change in the center of welding area is established, and the heat transfer process is divided into three steps. Firstly, according to the temperature field of the air in the furnace, the air temperature corresponding to the gap in the small temperature zone is determined, and then the heat convection process between the air temperature in the furnace and the surface of the welding area is described by using Newton's cooling law. Finally, Fourier law is used to study the heat conduction process in the welding area.

Keywords: Newton's law of cooling, Fourier theorem, welding mechanism of reflow furnace.

1. Introduction

Nowadays, automation technology has been popularized. The flexible grasp of automatic welding technology is very important to the production of electronic products such as integrated circuit board. If the temperature is controlled accurately, the printed circuit board can be placed in the reflow oven for heating, and the electronic components can be automatically welded to the circuit board. In order to accurately control the temperature of welding area, it is very important to set appropriate temperature for each temperature zone of reflow furnace. In this paper, the mechanism model of the influence of the temperature in each temperature zone of the reflow furnace on the temperature of the welding zone is established by the relevant thermodynamic theory, and the problem is studied and discussed in detail.
2. Establishment and solution of welding mechanism model for secondary welding furnace

According to the thermodynamic mechanism, it is a heat transfer process. There are three ways of heat transfer: heat transfer, convection and heat radiation. For the convenience of calculation, the influence of thermal radiation on temperature is not considered. The heat conduction process is divided into three steps: heat conduction to the center. Firstly, for the temperature of the gap in the small temperature zone, we establish the temperature field of the air in the furnace, and then obtain the Laplace equation of the one-dimensional temperature field. The second step is the heat transfer process of the air in the furnace to the surface of the welding area. Finally, for the internal part of the welding area, we establish the Fourier temperature heat transfer model.

2.1. Establishment of air temperature field in furnace

The analysis shows that the temperature of the air in the furnace is the same in the vertical direction, so only the temperature transformation in the horizontal direction needs to be considered, which is a "one-dimensional temperature field". According to Fourier Law:

\[ \frac{\partial^2 Q}{\partial s^2}(s,t) = \beta \frac{\partial Q}{\partial t} (s,t) \]  

(1)

Since the temperature of each part does not change with time when it is stable, there are:

\[ \frac{\partial Q}{\partial t} (s,t) = \beta \frac{\partial^2 Q}{\partial s^2} (s,t) = 0 \]  

(2)

The results are as follows:

\[ \frac{\partial^2 Q}{\partial s^2} (s,t) = 0 \]  

(3)

The above formula is the "Laplace equation" of one-dimensional temperature field, so it can be seen that the original function is a linear function, so the temperature changes linearly with distance in One-dimensional Steady-state temperature field. According to the above theoretical reasoning, when the temperature of the adjacent small temperature zone is the same, the temperature of the gap is the same, and it is consistent with the temperature of the adjacent small temperature zone.

2.2. Establishment of Newtonian cooling model

Due to the temperature difference between the surface of the welding area and the air in the furnace, according to the physical mechanism, there is heat transfer between the air and the surface of the welding area. Newton law of cooling can be used to establish a differential equation to describe the effect of air in the furnace on the surface of welding area. According to Newton cooling law, the Newton cooling model is established as follows:

\[ T'_1(t) = -\alpha(T(t) - H(t)) \]  

(4)

According to Newton law of cooling, for the heat transfer of two different media, the change of surface temperature is directly proportional to the temperature difference between the object and the ambient temperature. Where is the convective heat transfer coefficient. In the above model, the negative sign in front indicates that when the temperature of the object is higher than the outside temperature, the temperature of the object is a cooling process, and the negative sign has no practical physical significance. When the temperature of the object is lower than the external temperature, the
object is a heating process, such as the surface temperature change of the welding area in the preheating zone, constant temperature zone and reflow zone. According to the particularity of the air temperature in the furnace corresponding to the small temperature zone, the following derivation can be obtained:

\[ \int \frac{T'_i(t)}{T_i(t) - H(t)} \, dt = \int (-\alpha) \, dt \]  
\[ \rightarrow \ln(T_i(t) - H(t)) = -\alpha t + c \]
\[ \rightarrow T_i(t) = H + (T_0 - H) e^{-\alpha(t-t_0)} \]

2.3. Fourier temperature heat conduction model

According to the position of the center of welding area at different time. Take time as independent variable. After the surface temperature of the welding area passing through each position is determined, the temperature conduction mechanism in the welding area is transformed into the heat conduction problem of the bounded rod, and then the temperature of any point on the plate at any time is calculated by Fourier theorem. The temperature field is calculated. By using Fourier theorem, it is known that the curvature of temperature in space determines the change rate of temperature in time, and the partial differential equation of binary temperature function is obtained.

\[ \frac{\partial^2 T_2(x,t)}{\partial t^2} = \beta \frac{\partial^2 T_2(x,t)}{\partial x^2} \]  

**Boundary conditions:** Using the surface temperature of welding area calculated by Newton cooling law, the temperature of the end and end of the rod can be obtained, which is the boundary condition

\[ T_2(0,t) = T_2(d,t) = T_i(t) \]  

**The initial conditions are as follows:** At the initial moment, the temperature of all the points on the printed board tends to the ambient temperature of 25 degrees

\[ T_2(x,0) = 25, \ 0 \leq x \leq d \]  

Combined with formula (6) (7) (8), the temperature of any point on the plate at any time can be obtained, and then the temperature of the center of welding area at any time can be determined.

2.4. Solving problems

Taking time as abscissa and temperature as ordinate, the furnace temperature curve is drawn in blue. At the same time, the red line is used to draw the air temperature in the furnace corresponding to the gap between each small temperature zone, and the time to leave each small temperature zone is marked with a longitudinal dotted line, so as to prepare for the follow-up observation and fitting.
Figure 1. Furnace temperature curve

The block operation program is used to solve the problem and observe the consistency between the fitting results and the original curve, as shown in the following figure:

Figure 2. Schematic diagram of fitting results and original curve

In general, the model fits well. The parameters are input into the program, and the furnace temperature curve is obtained and drawn as follows:
3. Conclusion

The sensitivity analysis of the fitting function is carried out to analyze whether the fitting degree is still good when the parameters change.

About the temperature conduction model, the most important parameter is the heat conduction coefficient. Adjust the parameters of the model by ± 10% respectively, and observe the influence of the adjustment on the fitting effect.
According to the comparison of the above results, there is a positive correlation between the parameters and the temperature rise. When the parameters are increased, the temperature rise rate will be higher than the normal value, and when the parameters are down, the temperature rise rate will be lower than the normal value. And the effect of parameter increase is greater than that of decrease. In this paper, the models of dividing temperature field, heat conduction and heat convection based on thermodynamics theory can be widely used in all kinds of electronic automatic welding technology to accurately control the temperature of heat source.

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