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Research on Heat Dissipation System Based on High Power LED-UV Curing Equipment

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Abstract. LED-UV printing curing system is a new green printing curing technology for curing UV ink. Compared with the traditional UV curing device UV-LED curing device, the light source can be stabilized and ready to use without preheating, and the energy consumption is lower. It does not produce ozone and voc, and it is a green curing method. However, since a part of the energy of the LED chip is lost in the form of heat, the temperature of the PN junction is increased to lower the service life and light decay. The heat sink model was established by Solid Works and simulated analysis was performed using Fluent. A heat dissipation system for high-power LED-UV curing device was designed based on the simulation results.

1. Introduction

LED-UV curing is an emerging printing and curing technology. Compared with traditional UV mercury lamps and halogen curing methods, high-power LED-UV has high efficiency, low temperature, convenient installation, stable light source, ready-to-use and energy consumption. Low, green and environmentally friendly, ultra-low noise does not produce many advantages such as ozone and heavy metal pollution. Because of its advantages, LED-UV curing technology has been applied to the fields of screen printing, inkjet printing, flexible printing, lithography and the like.

However, because some of the input energy of the LED chip will be lost in the form of thermal energy, this will cause the temperature of the PN junction of the chip to rise, which will lead to a series of negative effects, such as the failure of the light failure to meet the curing requirements and the greatly reduced service life [1]. So how to improve the heat dissipation efficiency of the system has become one of the urgent problems to be solved in high-power LED-UV curing systems.

2. LED-UV curing system cooling method

At present, the heat dissipation methods widely used in LED-UV curing systems at home and abroad mainly include three types: air-cooling heat dissipation, heat pipe cooling, and liquid cooling. Air-cooling heat dissipation usually uses heat-dissipating materials to make heat-dissipating fins, and heat-dissipating fins and LED chip substrates are bonded together by silicone grease, and air is used as a cooling medium for heat transfer [2]. The performance of air-cooling heat dissipation is closely related to the number of heat dissipation fins, the spacing between the fins, and the shape of the heat dissipation fins. The air-cooling heat dissipation structure is simple, the energy consumption is low, but it is easily interfered by the ambient temperature. Due to the low thermal conductivity of air, air-



cooling heat dissipation cannot meet the heat dissipation requirements of high-power LED-UV curing systems. The heat pipe heat dissipation device is composed of a liquid absorbing core, a sealing pipe and a steam passage. When the heat pipe radiator operates, the evaporation passage absorbs heat generated by the heat source, and the heat causes the liquid in the liquid suction core tube to vaporize. The steam with heat moves from the high temperature section of the heat pipe radiator to the low temperature section, and the steam condenses into a liquid when the low temperature section absorbs the heat of the high temperature section steam. The condensed liquid is returned to the high temperature section through the capillary action of the wick on the tube wall, and the heat is continuously dissipated through the above cyclic working mode [3]. This type of heat dissipation is based on purely physical means, without the need for additional external power, low equipment costs, no need for personnel to operate at a time, and high reliability due to metal manufacturing, which requires no maintenance. However, since the erection of the LED-UV curing device needs to be adapted to the compact structure of the printing press, the heat pipe heat dissipating device is usually large in size and cannot meet the requirements. Liquid cooling this heat dissipation method works by circulating a coolant along a cooling pipe that is in close contact with the LED substrate under the push of a cooling pump to remove heat for heat dissipation. The liquid cooling system usually uses water as the cooling liquid. Because the water has a thermal conductivity much larger than that of the air, it can efficiently absorb the heat generated by the LED substrate, and can meet the heat dissipation requirements of the high-power LED-UV system. This heat dissipation method requires external refrigeration equipment to assist the temperature difference between the coolant temperature and the room temperature to be no more than 5°C to avoid condensation damage to the LED substrate. The structure of the heat sink is also relatively more complicated, and the overall cost is higher. However, the heat dissipation efficiency is high, the effect is small, the volume is small, and no noise is generated [4]. Therefore, liquid cooling is used as the heat dissipation method of the heat dissipation system.

3. Thermal performance parameters of the heat dissipation system

The heat dissipation system consists of a light source array, copper foil pads, an aluminum nitride substrate, silicon grease, and a heat dissipation plate. Heat is transferred from the PN junction in the light source array to the heat dissipation substrate. A schematic diagram of the components of the heat dissipation system is shown in Figure 1.

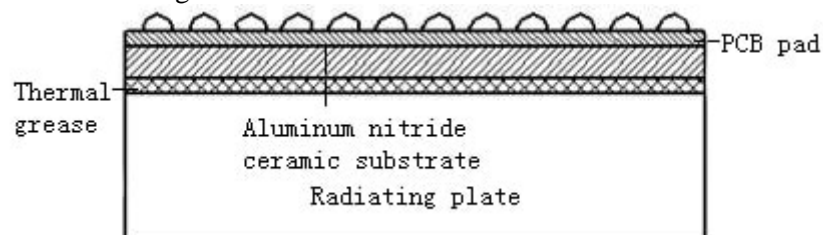


Figure 1. Schematic diagram of the components of the heat dissipation system

The heat in this system will migrate in the form of heat conduction due to the temperature gradient in each component. The thermal resistance values R_1 , R_2 , R_3 and R_4 respectively represent the light source array, PCB pad, aluminum nitride substrate and heat dissipation paste (silicone grease). Because the packaging material and structure of LED determine the thermal resistance of each lamp bead to be $3.5^{\circ}\text{C}/\text{W}$, $R_1=0.00417^{\circ}\text{C}/\text{W}$ is calculated by the light source array in parallel. Since the distance between individual lamp beads in the light source array is extremely small, it is ignored in the calculation, and the substrate area is directly used as the heat conduction area for calculation. The substrate area is $S=0.01461\text{ m}^2$, and the dimensions, thermal resistance and thermal conductivity of other components are shown in Table 1.

Table 1. Thermal parameters of various components in heat conduction

Part name	PCB pad	Aluminum nitride ceramic substrate	Thermal grease
size(mm)	0.08	0.675	0.225
Thermal resistance($^{\circ}\text{C}/\text{W}$)	0.000015	0.000186	0.003345
Thermal conductivity($\text{W}/\text{m}\cdot\text{K}$)	368	247	3.8

The power of each lamp bead in the light source array is about 1.7W, and the total power of the system is 1360W with a total of 800 lamp beads in the light source array. The thermal energy conversion rate of the lamp bead is 30%, and the power of the light source array due to heat generation is $P=408\text{W}$. The total thermal resistance during the entire heat transfer process is:

$$R = R_1 + R_2 + R_3 + R_4 = 0.007716 (^{\circ}\text{C}/\text{W}) \quad (1)$$

The temperature difference between the heat sink and the light source array:

$$\Delta T = P * R = 408\text{W} * 0.007716^{\circ}\text{C}/\text{W} = 3.148^{\circ}\text{C} \quad (2)$$

4. Heat dissipation structure design

At present, the main way of designing the heat dissipation structure is to establish the model and thermal analysis by using software, and optimize the design through the model of the improved heat dissipation structure [5-7]. The simulation results are analyzed by orthogonal test, and finally the result data is analyzed to complete the optimal design of the heat dissipation structure. In this paper, Solid Works is used to model the heat sink, and then ICFM CFD is used for structural meshing. Finally, the simulation boundary conditions and initial conditions are set by ANSYS Fluent to solve the final analysis conclusion.

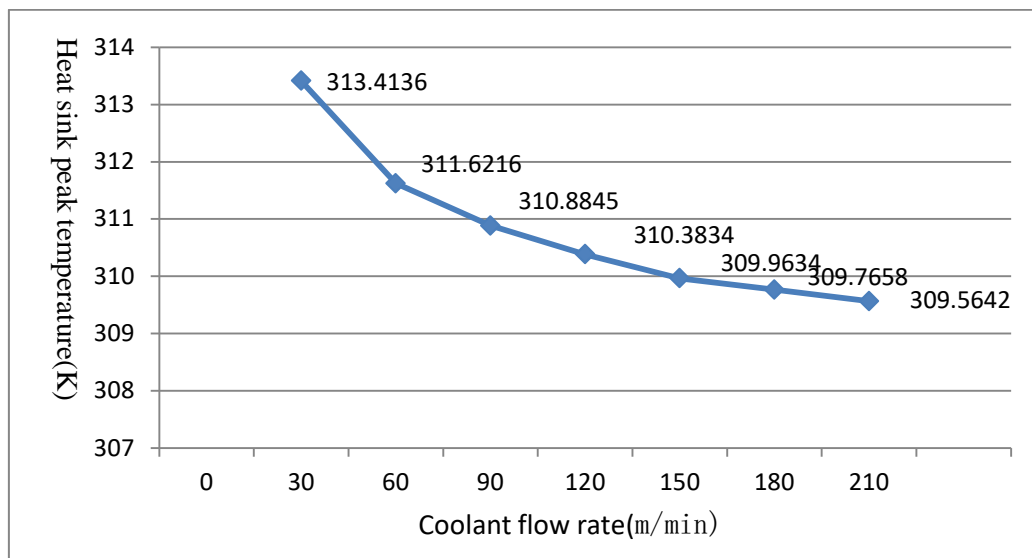
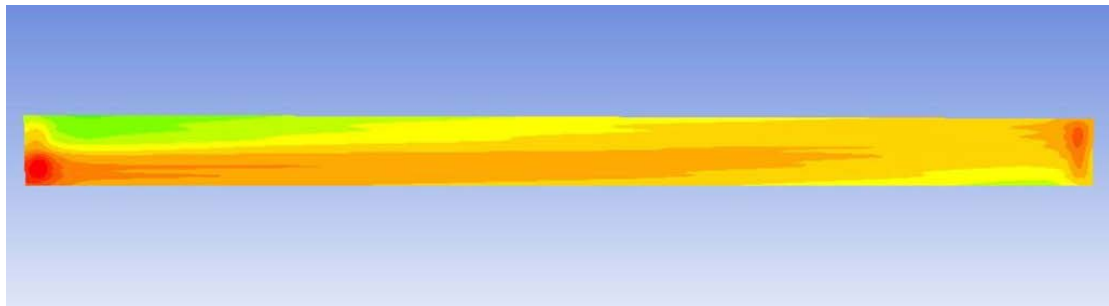
The heat sink in this paper adopts the design of baffled parallel cooling channel. The design has only one inlet and one outlet. When the coolant enters from the inlet due to the cooling fins in the cooling channel, the coolant will flow in parallel and flow into each small. Cooling track. The separation of the heat dissipation fins not only increases the contact area between the coolant and the heat sink, but also increases the heat dissipation efficiency. It also increases the turbulence intensity of the coolant in the cooling passage to further enhance the heat transfer effect, thereby making the overall performance of the cooling plate larger. Improvement. The parallel cooling passages have the same size structure, so that the flow rate and the flow rate of the coolant are substantially the same, and the heat dissipation uniformity of the heat dissipation plate is better. The inlet cross-sectional area of the heat sink is 0.785cm^2 , and the flow rate of the coolant is set to 30m/min, 60m/min, 90m/min, 120m/min, 150m/min, 180m/min, 210m/min, corresponding to the coolant. The flow rates were 2.4 L/min, 4.8 L/min, 7.2 L/min, 9.6 L/min, 12.0 L/min, 14.4 L/min, and 16.8 L/min, respectively. The parameter information and initial conditions used in the software simulation are shown in Table 2. The maximum temperature of the surface of the heat sink at different coolant flow rates is as shown in Table 3. The highest temperature profile of the heat sink surface at different flow rates See Figure 2.

Table 2. Simulation parameters and initial conditions

Coolant initial temperature(K)	Effective heat dissipation area(m^2)	Heat flux(W/m^2)	Cooling hydraulic pressure(Pa)	Lamp beads generate thermal power(W)
300	0.01375	30029.2	102136	408

Table 3. Peak temperature changes of coolant entering the heat sink at different speeds

Coolant flow rate(m/min)	30	60	90	120	150	180	210
Heat sink peak temperature(K)	313.4136	311.6216	310.8845	310.3834	309.9634	309.7658	309.5642

**Figure 2.** The highest temperature profile of the heat sink surface at different flow rates**Figure 3.** Heat sink temperature profile

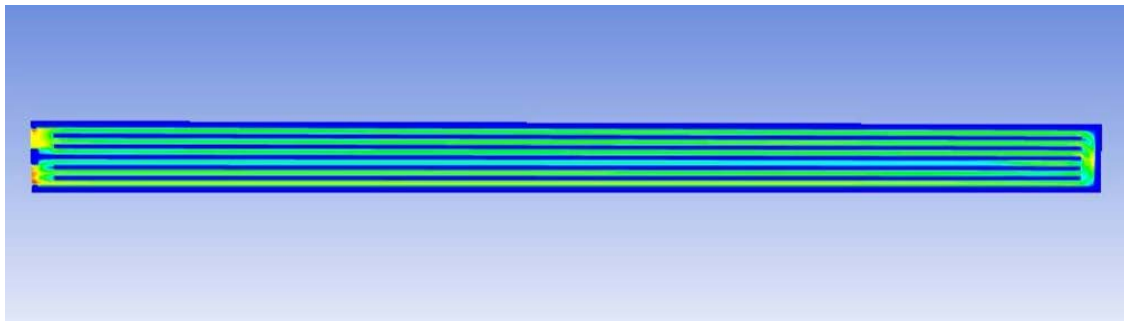


Figure 4. Heat sink cooling channel cross-section velocity distribution

As shown in the temperature profile of the heat sink in Figure 3, the temperature of the heat sink is basically uniform. Only the temperature at the inlet end of the coolant is slightly lower and the temperature at the outlet end of the coolant is slightly higher. The overall temperature of the heat sink is consistent. As shown in the velocity profile of the cooling plate cooling section of Figure. 4, the flow rate of each coolant to be cooled is basically the same, and the flow rate of the coolant is good. According to the highest temperature profile of the surface of the heat sink at different flow rates in Figure 2, the temperature of the surface of the heat sink is inversely proportional to the flow rate of the coolant, but the higher flow rate also means an increase in energy consumption because of the optimal coolant inlet flow rate. It should be selected between 90m/min and 120m/min, and the corresponding flow rate is 7.2L/min~9.6L/min. The maximum temperature of the heat sink is about 310.85K, and the PN junction temperature of the light source array is the sum of the best temperature of the heat sink and the temperature rise of the heat conduction path. The maximum temperature $T=(310.88+3.25)K=314.1K$, which is about 41.3°C, and the temperature of the PN junction is lower than 50°C. The heat dissipation structure meets the design requirements.

5. Summary

In this paper, a heat dissipating device that can be used in the LED-UV curing system is designed. The air cooling method is adopted as the heat dissipating method by comparing the air cooling heat dissipation, the heat pipe heat dissipation and the liquid cooling. The heat resistance of each part of the heat dissipation system is analyzed, and the heat dissipation system with good heat dissipation performance is designed by modeling and finite element analysis.

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