Calculation of the Thermal Mode of the LED Device

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Abstract— **The problem of heat removal from the substrate of LED light sources is considered. Modern methods of cooling of LEDs are reviewed. The calculation method is given and the radiator area for passive heat removal is calculated. The radiator was selected according to the given criteria.**

Keywords— LED; radiator; heat removal.

I. Introduction

Recently, the problem of heat dissipation has been put at the forefront when designing LED Lighting Devices. The reason for this is the nature of the LEDs. For a long time, LEDs considered "cold" light sources, because when working, the crystal itself is hardly heated. In fact, when operating the LED DS, only 5% of the heat is emitted in the form of thermal radiation, but the rest of the heat released by the crystal, which is more than 90%, is transferred to its metal substrate due to thermal conductivity.

The calculation of the thermal mode plays an important role in the quality of the LED's operation and in its lifetime. Without a heat sink, the LED can overheat and malfunction. Also, as the temperature rises, the luminous flux decreases and the color of light changes [1].

That is why accurate calculation of heat removal from the crystal of LED is required.

II. Setting objectives

To cool LED light sources, aluminum radiators are commonly used, which are designed for natural convection. Such radiators solve two major cooling problems: heat removal from an LED source and heat dissipation into the environment. The intensity of convection and radiation increases with increasing temperature, so that at a constant power of the heat flux from the LED light source, the radiator is heated only to a set temperature at which the total power of convection and radiation is equal to the power of the radiating light from the radiator.

The intensity of convection and radiation is proportional to the area of the radiator participating in the heat exchange. The surface area of the radiator heat exchange is less than the surface area of the radiator. If you increase the radiator area by plates or pins, the distance between these elements must be taken into account. If the distance between the pins is less than 4mm, it will not give the expected cooling effect.

Also for cooling of a surface of a crystal use the radiator with air cooling (fan). Then the radiator area can be significantly reduced.

The physics of the heat dissipation process implies that the amount of heat absorbed by the air is determined by the parameters of the air (temperature, humidity, velocity), not the material from which the radiator is made. Ambient air is unable to receive more than 5… 10 W of thermal energy from a single reflector surface. That is, the thermal conductivity λ of the material for heat dissipation devices must be within the range of 5… 10 W / (m • K); it is necessary and sufficient, since the higher thermal conductivity is technically excessive [2].

Recently, aluminum has become a worthy competitor - heat-dissipating plastic. Such plastic allows to reduce the dimensions, weight and cost of luminaires based on it. Until recently, the thermal conductivity of λ plastics was 0.1-0.2 W / (m • K), and the development of a new class of polymer composites - heat dispersive polymer composites (HDPCs) improved thermal conductivity by 10-100 times.

The thermal dispersion properties of TPPC are sufficient for the qualitative removal of heat from the LED crystal, and a number of advantages, such as low weight, increased accuracy of execution, the possibility of making complex shapes, low cost, make this type of material the most optimal for use in the industrial production of LED lighting devices.

Ensure efficient heat removal from the LED by passive or active cooling. LEDs with a power consumption of up to 10 watts should be installed on aluminum (copper) radiators, as their overall dimensions will be acceptable.

The use of passive cooling for LED arrays with power of 50 W or more becomes difficult; the size of the radiator will be tens of centimeters, and the weight will increase to 200-500 grams. In this case, it is worth considering using a compact radiator with a small fan. This tandem will reduce the weight and size of the cooling system, but will create additional difficulties. The fan must be provided with an adequate supply voltage, as well as take care of the protective disconnection of the LED lamp in case of failure of the cooler.

III. Research methodology

There are two methods for calculating the radiator for an LED:

- design, the essence of which is to determine the geometric dimensions of the structure at a given temperature;
- check, which involves acting in reverse order, that is, with known parameters of the radiator, you can calculate the maximum amount of heat that it is able to effectively dissipate.

The application of this or that variant depends on the available raw data. In any case, accurate calculation is a complex mathematical problem with many parameters. In addition to the ability to use the reference literature, take the necessary data from the graphs and substitute them in the appropriate formulas, you should take into account the configuration of the rods or edges of the radiator, their orientation, as well as the influence of external factors. Also worth considering is the quality of the LEDs themselves. Most often, in Chinese-made LEDs, the real characteristics differ from those stated.

To calculate the heat sink for high-power LEDs, you can use the source method [3].

Modern LEDs have an efficiency of about 30-40%, that is, on average 60-70% of the power consumed is converted to heat. In the XLampThermalManagement document, CREE recommends using the assumption that 75% of the power consumed is converted into heat; The power to be dissipated is calculated as follows (1) [3]

$$Pt=0.75\cdot Vf\cdot If \tag{1}$$

where P_t is the thermal capacity (W); V_f is a direct voltage drop across the LED (B); I_f - current through LED (A).

During the work, the thermal calculation of the CREE CXA1507 LED was carried out (Fig. 1).

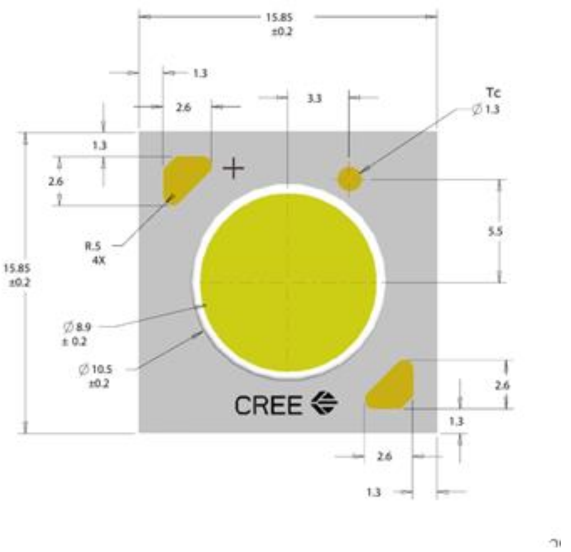

Figure 1. Mechanical characteristics of the CXA1507 LED

This LED belongs to the class COB (clip-on-board) and is mounted on the radiator (Fig. 2).

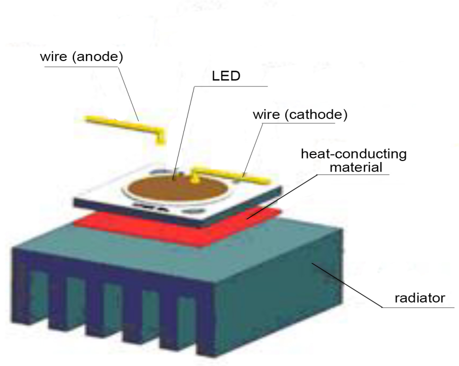

Figure 2. Installation of CXA1507 LED on the radiator

The equivalent scheme for calculating the thermal regime for this case consists of thermal resistance "transition-contact pad of the LED", thermal resistance "contact pad - thermal conductive material", resistance "thermal conductive material-radiator" and thermal resistance "radiator-air" (Fig.3)

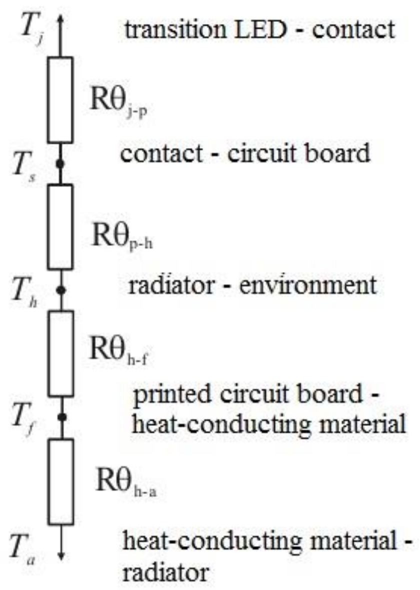

Figure 3. Equivalent circuit for LED CXA1507

IV. Research results

The calculation was performed for an ambient temperature of 25°C and 55°C. For the optimum lifetime of the LEDs, it is necessary that the temperature of the heat-conducting surface of the substrate does not exceed 85°C [4].

Assuming that the LED operates at a transition temperature of 85°C and at maximum current, using a software PCT calculator from CREE, we obtain a voltage value for a given transition temperature at maximum current (Table 3.3). As a thermal conductive material, a thermal paste such as KPT-8 is commonly used, and thermal conductivity is assumed to be 0.7W / (m•°C).

To determine the value of maximum thermal resistance between the LED contact and the air, you can use the schedule provided in the LED documentation (Fig.4)

TABLE I. DATA FOR THE CALCULATION OF THE LED CXA1507

№	Initial data	
1	Transition temperature, ° C	85
2	I_f, A	0,37
3	Vf, V	36,77
4	P = If x Vf, ,W	13,61
5	P_t = 0,75 x P, W	10,02
6	Contact area of the LED, mm^2	251,22

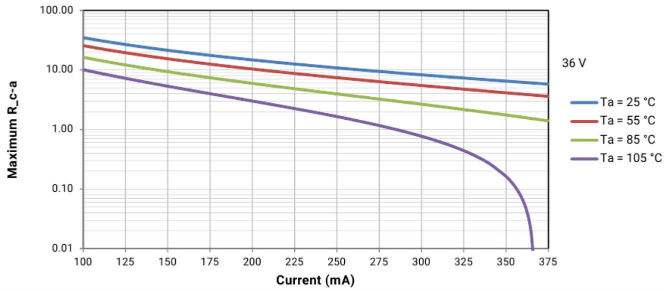

Figure 4. Maximum thermal resistance between contact and air

The graph shows that at 25°C the maximum resistance is 6°C/W, and at 55°C - 3.5°C/W. Let the thickness of the thermal paste layer be 0.1 mm. The value of thermal resistance is calculated by the following expression(2)

$$Q_{tim}=L/(k{\cdot}A) \tag{2}$$

where Qtim is the thermal resistance of the heat-conducting material (°C/W); L is the thickness of the layer (m); K - thermal conductivity (W/m·K); A is the contact area (m2).

Hence Qtim = 0.8°C/W.

Given all of the above, for a temperature of 25°C, the radiator resistance should be less than 5.2 ° C / W, and at 55°C 2.7°C/W.

For example, you can use the MechaTronix LPF6768-ZHP radiator, whose thermal resistance is 2.1 ° C / W (Fig.4).

Figure 5. MechaTronix LPF6768-ZHP radiator

CONCLUSIONS

The calculation of the thermal mode plays an important role in the quality of the LED's operation and in its lifetime. Without a heat sink, the LED can overheat and malfunction. Also, as the temperature increases, the luminous flux decreases and the luminescence changes

The problem of heat removal from the substrate of LED light sources is considered. Modern methods of cooling of LEDs are reviewed. Requirements for the design and parameters of the heat sink system of the LED luminaire were formulated on the basis of the analysis of existing systems, taking into account the experimental studies of the heat transfer properties of radiators of different design.

The calculation method is given and the radiator area for passive heat removal is calculated. The radiator was selected according to the given

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