



The development and performance of the high-power LED radiator



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ABSTRACT

The performance of a kind of pure aluminum heat sink with radicalized straight fins and a kind of aluminum heat sink with heat pipe are investigated through numerical simulation method. Based on the correctness of numerical simulation model verified by the experiment, the optimal design is preceded. The correlations for Nu without and with heat pipe are obtained. Results show that the junction temperature of LED components is efficiently reduced by raising the radiator height (100–200 mm), increasing the number of fins (16–32), increasing the fin height respectively and the limitations are strengthened at the same time. The influence of fin thickness considered in this paper on Nusselt number of the radiator is less than 1%. By the introduction of the heat pipe, the equivalent coefficient of rolled aluminum heat pipe composite radiator fin upper part increased from 70.8% to 73.1%, temperature difference between the top and bottom fins is reduced, heat dissipation is strengthened. At the same time, the increase of the length of heat pipe radiator is favorable to the heat dissipation of radiators and the reduction in radiators weight. Those all provide the theoretical basis for the design and prioritization of high-power LED module radiator.

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1. Introduction

LED (Light Emitting Diode), as the new type of luminescent solid material [1], has been widely applied in the signal, alphanumeric display [2,3], automobile [4], back light [5,6], and other fields. As lighting equipment, it was proposed due to the development of white-light LED in recent years [7,8]. And it has received extensive attention and concern since proposed [9].

As the lighting device, especially the mining lamp, street light and other powerful light sources, the power is often up to tens of watts or even hundreds of watts. With the increase of temperature, the light conversion efficiency of LED lamp declines, wavelength becomes longer and the forward voltage drops [10]. In this circumstance, the heat emitted from LED can't be ignored. If the heat cannot be dissipated efficiently, the performance of the device will decline even the device is burned. To make the matter worse, the life and property will be threatened. To obtain higher cost performance, dissipate the heat from LED effectively, control the junction temperature and improve the life and brightness of the use are the keys to making high-power LED lighting equipment further popularization and application [11].

Heat pipe, a kind of high-efficient heat transfer component, has been widely used in process industry [12], new energy, aerospace, electronic heat dissipation and so on. Lan et al. [13] have already tried to apply heat pipe into high-power LED. The results showed that heat pipe radiator can reduce the junction temperature of 24.3 °C, the thermal resistance of 0.91 °C/W compared with common radiator under the speed of the wind at 7 m/s. Li et al. [14] proposed a copper-water loop heat pipe (LHP) heat sink for high-power integrated LED. And under natural convection, the total thermal resistance range of copper-water loop heat pipe is 1.0 to 0.4 °C/W when heating loads range is from 30 W to 300 W. Lin et al. [15] indicated that the temperature of the LED significantly decreased when a plate oscillating heat pipe (OHP) was used. Zeng et al. [16] developed a novel phase change heat sink to improve the thermal performance of high-power LED package. Lu et al. [17] proposed a novel flat heat pipe (FHP) to improve the thermal characteristics of high power LED. The junction temperature, total thermal resistance of LED, different filling rates and inclination angles of the heat pipe were investigated experimentally. Cheng et al. [18] used the finite element method (FEM) to invest multi-fin heat sink. Park et al. [19] developed and numerically simulated a cooling system which consists of a chimney and a radial heat sink to improve the cooling efficiency. Jang et al. [20] numerically studied the orientation and geometric parametrics effect for a cylindrical heat sink used to cool a LED light bulb. And a correlation which is

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Nomenclature		v	y-velocity component
		w	z-velocity component
A	area (m ²)	<i>Greek symbol</i>	
c_p	specific heat at constant pressure	δ	thickness of the fin (mm)
D	diameter of heat sink (mm)	η	equivalent factor
d	diameter of mandril of heat sink (mm)	λ	conductivity coefficient (W/m·K)
Gr	Grashof number	μ	dynamic viscosity
H	Height of heat sink (mm)	ν	kinematic viscosity
L	characteristic length	ρ	Density (kg/m ³)
N	number of fins on heat sink	<i>Subscripts</i>	
Nu	Nusselt number	a	ambient
p	pressure	f	Fin
Pr	Prandtl number	hp	Heat pipe
Q	heat power (W)	j	junction
R	thermal resistance	max	maximum
T	temperature (°C)	1	bottom of fins
ΔT	temperature difference (°C)	2	top of fins
u	x-velocity component		
$\vec{V}$	velocity vector		

used to predict the Nusselt number around an inclined cylindrical heat sink was proposed. Li et al. [21] numerically simulated the copper/water miniature heat pipe (mHP) to cooling high power multi-chip LED packaging.

In the present study, a natural convection heat sink used to cooling high-power LED module is developed by combining heat pipe technology with rolling aluminum heat sink. The full passive high-power LED array is realized. The thermal performance was investigated by experiment and finite element numerical simulation. The effects of the radiator height, the number of fins, fin height, fin thickness, heat pipe and heat pipe length on thermal performance were studied in this paper. The correlations to predict the Nu without and with heat pipe are proposed. And the mathematical and physical model for further research is provided.

2. Model description

2.1. Geometric model

The radiator model, with straight fins along the diameter orient, consists of mandrel and radial type fins (presented in Fig. 1). The whole contour is cylindrical (represented in Fig. 1(a)). D and H are the outer diameter and the height of the heat sink; δ , H , and N are the thickness, length and number of the fins. For the radiator model with heat pipe: H_{hp} is the length of heat pipe, D_{hp} is diameter, other

sizes are the same as previously mentioned. The properties of geometric configuration are listed in Table 1.

2.2. Physical and numerical model

The base plate is placed between LED array and the radiator, both of which are contact with each other tightly. The heat emitted from LED during working process is conducted to the radiator through the base plate and then is spread into the environment by the extended surface. The parameters of radiator's material and air properties are presented in Table 2. The assumptions of the model are listed as follow:

- (1) The air is continuous Newtonian incompressible fluid. The flow is the fully developed steady state and laminar flow;
- (2) Radiation heat is neglected;
- (3) Physical properties parameters of radiator's material are constant and the air property obeys the Boussinesq assumption;
- (4) The heat pipe, in the present study, is simplified as a solid with both the density and the specific heat of 1 and equivalent heat conductivity of 20000W/(m·K).

The governing equations are as follows,
Air side,

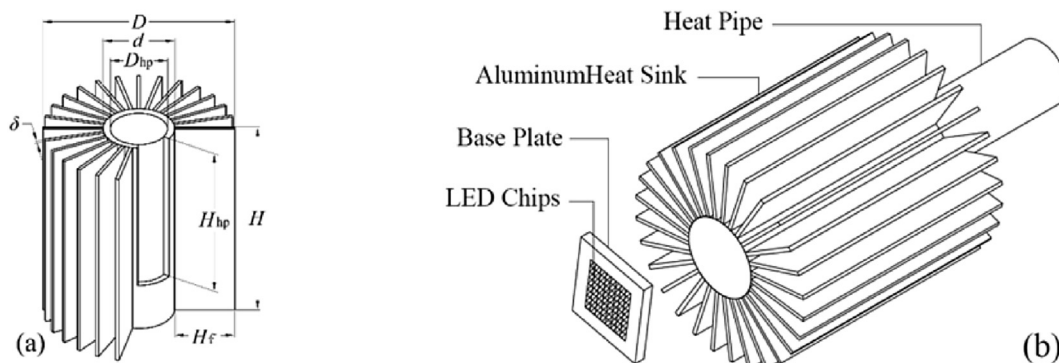


Fig. 1. Radiator model.

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