Design and Thermal Analysis of LED Lamp Cooling by using Optimization of Circular Fins

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Abstract
The selection of particular fin configuration in LED Lamp for heat transfer application depend on the weight and manufacturing technique consideration as well as the thermal characteristics it exhibits, Circular Fins are one of the most popular choice for enhancing the heat transfer rate to Minimize an junction temperature by minimizing the total thermal resistance of system. For actively cooled systems, this may essentially be achieved by simultaneously engineering the conduction through the heat sink and creating a well-designed flow pattern of Heat over suitable convective surface area. Finite element method (FEM) was used to compute the maximum temperature at junction of LED. An extensive study was carried out using ANSYS, a powerful platform for Heat flow through Led Heat sink. Results obtained were presented in a series of temperature along the length of fins.

Keywords: ANSYS, Circular Fins, FEM, Junction Temperature, Thermal Resistance.

INTRODUCTION
Light emitting diodes (LEDs) are solid state (P-N junction semi conductor) devices that convert electrical energy directly into light by a process called electroluminescence. LED is a solid-state technology. The latest solid-state lighting through light-emitting diodes (LEDs) has witnessed an inevitable trend to produce white light illumination. As one of the potential substitutes of traditional incandescence or fluorescent lamp, LEDs have the distinctive advantages in providing high quality luminescence efficiency, energy saving, and service life. For LEDs of higher luminous intensity, a higher injection current (20mA) or multi-chip packaging is often necessary in illumination applications. However, only less than 20% of injection energy was converted to light, while the remained was transferred into heat. Since the performance and the lifetime of LEDs strongly rely on its temperature, the allowable maximum junction temperature, which is always regarded as significant performance indicator of the thermal and lighting design, was usually specified as 150°C. Meanwhile, LED chip was limited thermally for light output, reliability, and phosphor conversion efficiency, and optically transparent epoxy or silicone based materials would change color if the temperature limits were exceeded. Therefore, removal of the large amount of the heat generated in LEDs remains a big challenge facing current LED designers and thermal management engineers.

Present Lightening Systems facing the same problem as mentioned above i.e. they want to optimize their thermal system design of 50 Watt LED so that they can improve quality of their LEDs by cost wise as well as design wise.

METHODOLOGY
Figure 1 showed the schematic diagram of a conventional LED package structure. The LED die was packaged with silicon or epoxy encapsulant. Phosphors were added into encapsulant to convert wavelength range from blue to yellow in order to get white light. Since silicon or epoxy encapsulant has low thermal conductivity, the heat flow path can be ignored. The temperature of the LED junction (Tj) can be expressed as 

\[ T_j = T_a + (R_{ja} \times P_d) \]

Fig. 1 Schematic diagram of a conventional LED package structure

Thermal management of LEDs is extremely critical and understanding it is essential when designing and developing LED systems. To prolong their lifetime and improve their performance, LEDs must be kept cool under all drive and operating conditions. The fundamentals of heat transfer and a full understanding of the heat...
path and thermal stack is needed to properly design an LED system. Thermal simulations and testing should be used to optimize and measure the performance of each LED system.

By utilizing thermal resistance networks, such as that of Figure 2, the most important factors in the thermal conductance of a system may be pinpointed. This research analyzed the impact of the heat sink and shroud geometries on the total system resistance, although the active cooling model that was used only included resistances from convection and within the heat sink. Radiation is typically responsible for less than 5% of heat transfer in forced convection and was assumed negligible for this study. The resistances from thermal interfaces and within the LED constitute research fields beyond the scope of this work.

![Fig. 2 Simplified thermal pathway of an array of down-lighting LEDs attached to a heat sink.](image)

In the light of the above, the present work deals with,

i) Developing a FEM methodology using ANSYS for the coupled-field analysis of circular fins by minimizing the total system’s thermal resistance.

ii) Studying the variation in junction temperature of the fin by varying number of nodes and carrying out a convergence study.

**FINITE ELEMENT ANALYSIS**

- The finite element analysis was based on the following common assumption:
  - Steady-state heat flow,
  - The material are homogeneous and isotropic,
  - There is no heat source,
  - The convection heat transfer co-efficient is same all over the surface,
  - The temperature of the surrounding fluid is uniform,
  - The thermal conductivity of the material is constant.

![Fig. 3 Circular Coarse mesh](image)
Fig. 4 Boundary conditions

Fig. 5 Heat Flux

Fig. 6 Convection
Result 1

Fig. 7 Circular Medium mesh

Result 2

Fig. 8 Circular Fine mesh
Result 3

Fig.9 Circular Tetra mesh

Result 4

Fig.10 Circular Auto mesh
Result 5

Fig. 11 Circular Tetra Fine mesh

Result 6

Graph 1
<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Type</th>
<th>Nodes</th>
<th>Elements</th>
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<td>17834</td>
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CONCLUSION

Thermal management of LED is extremely critical and understanding it is essential when designing and developing LED systems. To prolong their lifetime and improve their performance, LED must be kept cool under all drive and operating conditions. The fundamentals of heat transfer and a full understanding of the heat path and thermal stack is needed to properly design an LED system. Thermal simulations and testing should be used to optimize and measure the performance of each LED system.

Technological developments in the area of high power LED light sources have enabled their utilization in general illumination applications. Along with this advancement comes the need for progressive thermal management strategies in order to ensure device performance and reliability.

Minimizing an LED’s junction temperature is done by minimizing the total system’s thermal resistance. For actively cooled systems, this may essentially be achieved by simultaneously engineering the conduction through the heat sink and creating a well-designed flow pattern over suitable convective surface area.

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