Design & Development of Thermal Management of LED Street Light

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***Abstract*— Use of LED based lighting product has been increased after 2006 (invention of white LED). There are numbers of research are going on for improvement in energy efficient LED based lighting by reduce junction temperature. Hence, it is required to develop efficient thermal management. For good thermal management it is needed that the thermal resistance of luminaire body should be as low as possible. This can be achieving by increasing the area of heat dissipation, which increase the size of luminaire body. This is not the desired condition. Hence it is required to find other way like mechanical design, heat sink material, mounting arrangement and driver current etc, by which one can achieve energy efficient thermal management. That work will include the detail study of LED, LED luminaire, searching of energy efficient material for design and Development and also Simulate efficient thermal management for LED based street Light.**

Keywords— — Heat dissipation path, Material property, SMD Type LED, Impact of thermal resistance, comparison of design in Ansys software.

I. INTRODUCTION

Light-emitting diodes (LEDs) are used and usual in many areas of lighting technology today. They are light sources of the upcoming, and previously represent the latest state of technology for several applications. Thanks to the direct conversion of electrical current to light (optical radiation) in the semiconductor, LEDs are highly efficient – more efficient than most established light sources [1, 4].
However, even in the case of LEDs, nearly most of the electrical power is converted to heat rather than light. To put it simply, the higher the current, the more heat is created in the component. This heat loss must be conducted away from the LEDs, since the used semiconductor material is subject to a maximum temperature limit and because its characteristic properties such as forward voltage, wave length, and service life may vary with the temperature. In particular in the case of novel, miniaturized high-performance LEDs, the dissipation of heat is centrally important in order to keep temperatures down – and is regarded as the leading challenge. Only adequate thermal management across all system levels can allow the full exploitation of LED performance and efficiency during operation. This paper is to be significant and prove with design simulation how to improve thermal management with changing the heat-sink design and also include comparison of material cost, weight of heat-sink.

II. LED THERMAL MANAGEMENT

LED is temperature sensitive device its performance is mainly depends on the good thermal management. Impact of thermal management is mainly affecting the life of LED, its reliability mainly affects the life of LED, its reliability performance output, light output, heat transfer point, maximum junction temperature point importance of overcoming thermal resistance.

A. Reason behind poor Thermal Management

Excess heat is to be directly affects short term and long-term LED performance. The short-term effect is to be on colour shift and reduces light output while the long-term effect is to be on accelerated lumen depreciation and shorted useful life. However, exceeding the maximum operating temperature specification, which is typically a 12^0C junction temperature, can cause permanent and externally harmful damage of LEDs, So care must be taken to operate LEDs below this limit of ambient temperature. Selection of some important parameter which helps us in improves the good thermal management, these parameters are mentioned below.

1. Proper LED selection
2. Selection of Driver circuit at lower.
3. Thermal management parameters selection (conduction , convection ,radiation)
4. Proper Dimension of Heat sink selection

III. LED DRIVER'S

The significance of LEDs driver is to connect arrays of LEDs with supply voltage. Single LED is operating at typically 3 to 3.7 V DC, 250-350 mA, accordingly depending upon number of LEDs connected in series the input voltage to LEDs array required. In this project in one parallel circuit 4 LEDs are connected in series and accordingly constant 12 V DC supply required from output terminal of LEDs Driver. Also, LEDs driver should capable of delivering required input current to LEDs array, in this project 6 parallel circuit are designed accordingly driver should capable of delivering minimum 250-350 mA. It step down AC input voltage and convert in to DC voltage and also regulates output voltage so that constant DC voltage delivers to LEDs array. According the ideal LEDs driver shall meet following most significant requirement.

1. It should provide constant DC input voltage to arrays of LEDs for vide range of input voltage i.e. it should regulate its output voltage against changes in the input voltage and deliver Constant DC voltage to LEDs array.
2. The output voltage waveform should be ripple free and pure DC because for long life of LEDs and low depreciation in light output of LEDs it is most important parameter.
3. It should provide protection to LEDs against over voltage, low voltage and S.C current.
4. It should capable of delivering required input current to LEDs array.
5. It should capable of delivering required input current to LEDs array. The LEDs array shall meet required of Maximum permissible Harmonic current per Watt in (mA/W) as per IEC: 61000-3-2-2005.

A. *Basically, LED drivers are divided in 2 parts.*

1. Constant Current
2. Constant Voltage

B. *Basically, Principles of Heat transfer is divided in 3 parts.*

1. Conduction
2. Convection
3. Radiation

Whatever transfer the heat through heat sink is also depend on its material emissivity ($0<\varepsilon<1$). now hear we are using SMD based LED Light and its basic impact of that's type of LEDs are describe below.

1. The junction temperature of an LED increases with the generation of heat, with the rate of increase dependent upon the amount of heat that is removed to the ambient.
2. The heat is transferred from the junction to the ambient via all elements that make up the thermal management system.
3. Crystal is SMD LEDs generate less than 3.6 W of heat in addition to UV light, depending on the current within the suggested operating range.
4. When increases ratio of heat dissipation from the backside of led so that SMD led included copper slug in its packaging because of low thermal resistance which has been directly contact with led die.
5. The low thermal resistance of the copper slug allows it to quickly transfer heat from the die.
6. It is strongly recommended to attach a heat sink to the copper slug with thermal paste to facilitate further thermal transfer to them.
7. Heat is generated to the semiconductor chip which is sub mount to the copper slug at bottom of the SMD LED, then TIM (thermal pad thermal paste) then heat sink then to ambient temperature.

IV. MEASURE THE JUNCTION TEMPERATURE USING VARIOUS METHODS.

Criteria	RTD	Thermistor	Thermocouple	IC sensor
Temperature range	-250°C to +750°C	-100°C to +500°C	-267°C to +2316°C	-55°C to +200°C
Accuracy	Best	Depends on calibration	Good	Good
Linearity	Good	Worst	Good	Best
Sensitivity	Less	Best	Worst	Good
Circuitry	Complex	Depends on accuracy/power requirements	Complex	Simplest
Power consumption	High when taking measurement		Low-high	Lowest
Relative system cost	\$\$-\$\$\$	\$-\$\$\$	\$\$-\$\$\$	\$

Fig.1: Table of Different methods

And most important parts of this paper are how to select the heat sinks and improves thermal management of LED Street light. When selection of heat sinks some basic thermal criteria is necessary but various parameter that affect to the thermal performance of the system not only heat sink performance. When special of specific one of the heat sinks depend on thermal economical acceptable for the including outer nearby heat sink condition. When selecting a heat sink, it is required to classify the air flow as natural,

ISSN NO: 0898-3577

low flow mixed, or high flow forced convection. In case of natural convection, no need of any external cooling facility but forced convection to be included external device like fan/blower. In a schedule of heat sink, finest fin spacing is strongly related to 2 parameters flow velocity and fin length in the direction of the flow.

Flow condition m/s	volumetric resistance cm3
Natural convection	50-800(30-50)
1.0(200)	120-250(10-15)
2.5(500)	80-150(5-10)
5.0(1000)	50-80(3-5)

Table 1: Range of volumetric R_{th}

C. *Design Parameters*

A list of design limitations for a heat sink may contain parameters, such as below.

1. Induced method flow velocity
2. Presented pressure drop
3. Cross sectional geometry of external flow
4. Amount of mandatory heat dissipation
5. Maximum heat sink temperature
6. Ambient fluid temperature
7. Maximum size of the heat sink
8. Location with respect to the gravity

V. MODELING AND SIMULATION RESULTS

Considering below Simulation Design or Another Design Via ANSYS and measurement of Temperature and reduces Temperature of LED and Getting good output using Different Design or Material as soon as possible.

A. *Thermal equipment circuite of Luminaries*

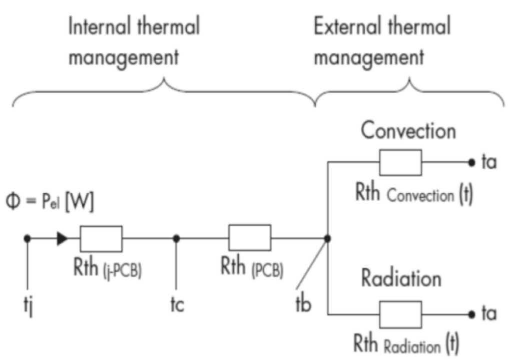

Fig.2: Internal circuite diagram of Luminaire

B. *Calculation*

Per LED Calculation

PerLED Wattage = 49*0.9/24	1.83 Watt
2 Watt LED consume 1.83 watt in form of light(radiation) and heat(convection)	30% in form of light =1.83*30%=0.555 70% in form of heat=1.83*70%=1.295
1 LED CONSUME 1.295 watt heat so,24 LED = ?	1.295*24 = 31.08 Watt
1 LED area is 12.25 mm^2 * 24 LED area=?	294 mm^2
Heat flux = watt/led area	31.08/294 = 0.105714 W/mm^2
Convection area (total area of removal heat in air)	0.168115 $W/mm^2 * {}^0C$
Now selected convection of area at that stagnated air is selected of natural convection .	$5*10^{-6} W/mm^2 * {}^0C$
Weight = Volume × Density	$1.743 \times 2770 \times 10^{-5} \times 10^{-9} = 483$ gm
1 kg AL6063 material cost in Indian Rs.300 accordingly existing design weight(483gm)	So that cost is 144.9 Rs.

Table 2: LED Calculation table

C. *Material Property*

Various Kind of Material properties as below: Subcategory: Aluminium Alloy, Metal.

Material	Specific Thermal conductivity of material
Copper	400
Aluminium	200
Silicon	149
Tin	67
Silver	429
Air	0.0231
AL6063	218

Table 3: Various Material Properties

D. *Ansys Steady State Thermal Tools*

ANSYS was developed by ANSYSinc. USA is dedicated Computer Aided Finite Element Modelling and Finite element tools. The Graphical user interface (GUI) of ANSYS enables the user to work (3-D) model and also help generate results from them. The following are the list of analysis that we can perform of ANSYS.

1. Structural Analysis.
2. Thermal Analysis.
3. Fluid Analysis.
4. Electromagnetic field Analysis.
5. Acustic Analysis.
6. Cougled field Analysis

E. Ansys analysis path

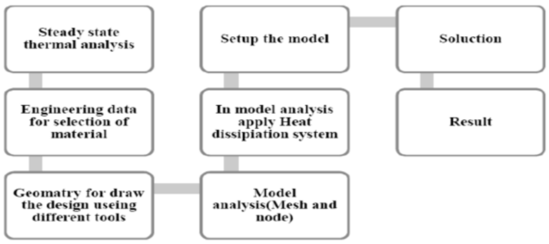

Fig.3 Ansys simulation working path

I. Simulation results

Existing Design

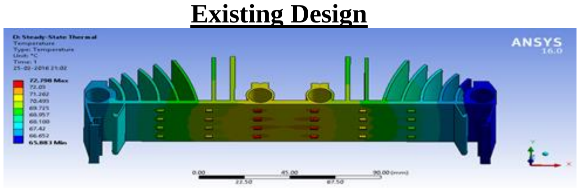

Fig.4 existing design

Parameter	49Watt	55Watt	57Watt	60Watt
Heat flux	0.10571	0.1208163	0.124897	0.132244
Convection area	0.16812	0.16812	0.16812	0.16812
Temp(max.).	72.79 ^{0}C	79.19 ^{0}C	80.92 ^{0}C	84.04 ^{0}C
Weight	483gm	483gm	483gm	483gm

Table 4: All parameters for existing design

Design – A

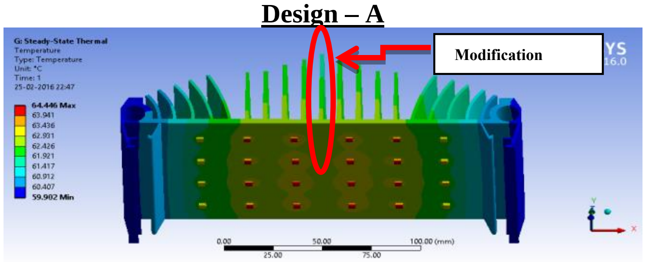

Fig.5 Design-A

Parameter	49Watt	55Watt	57Watt	60Watt
Heat flux	0.10571	0.1208163	0.124897	0.132244
Convection area	0.208618	0.208618	0.208618	0.208618
Temp(max.).	64.44 ^{0}C	69.65 ^{0}C	71.06 ^{0}C	73.59 ^{0}C
Weight	583gm	583gm	583gm	583gm

Table 5: All parameters for design-A

Parameter	Weight(gm)	Cost(Rs.)				
			49W	55W	57W	60W
Existing Design	483	144.9	72.79	79.19	80.92	84.04
Design-B	583	174.9	64.44	69.65	71.06	73.59

Table 6: Comparison of two Designs

Now see the above table about new Design –A for the comparison of existing design where weight and cost both are increases but temperature is to be decreases. When temperature is to be deceases so finally number of life cycle increases.

VI. CONCLUSION

Maximum Heat Generated is at the centre of the Heat-sink body and it need to dissipate efficiently. Two Designs are made for heat sink for improving thermal management from the original manufacture design. Design (A) improves thermal management by this much 73.59 ^{0}C in comparison with original manufacturer design and however this increases the weight of the design by 100 gm (for 60watt). Based on Software simulation results of existing design which is compared with hardware and it's verified with less tolerable error. So Improved designs are also validated via simulation for another three Designs. From TM-21 calculation Report and its calculation table refer and another Literature is defined as LED Junction temperature reduces output power and forward voltage. For every 10 ^{0}C rise in junction temperature, the luminous efficacy decreases by about 5 percentages (at constant operating current). Validation of all of Simulation results and finally conclude that Weight and cost are increases and also increases Reliability.

VII. REFERENCES

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