Transient Analysis of Thermal Management for High Power Led Street Lights Using CFD

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***Abstract*- Energy crisis, global warming, energy saving and emission reduction have become some of the most concerned topics in the world. As a new generation green solid-state light source, LED has been widely regarded due to its distinctive advantages such as high luminous efficiency, energy saving, long lifetime, and being environment-friendly. Today, light emitting diodes (LEDs) market is one of the most rapidly growing markets. LEDs are replacing conventional light sources such as incandescent lamps and fluorescents, because of their superiority in many properties like efficiency, reliability, short response time, durability, color variability, compactness and lightness. During the heat generation, the p-n connection point has the highest temperature in the device. The temperature at this point is called the junction temperature. Junction temperature in LEDs is a very crucial parameter. If the junction temperature exceeds the maximum permissible value, the LED will either fail or be damaged over time. As a result, improper thermal management causes the maximum operating temperature to be exceeded.**

In this work the existing model compared with proposed design of LED street light fins, also analysis the cooling of LED fins over the existing design model with the help of ANSYS. The temperature distribution, heat flux and directional heat flux have been analyzed by ANSYS and make a comparison between them. From the simulation results the heat transfer rate increased about 41.6%.

Index Terms- High-Power LEDs, Heat Pipe, Numerical Simulation, Thermal Management, ANSYS 16.0, Fins.

I. INTRODUCTION

Light emitting diode (LED) differs from standard lightweight sources; it provides an instantaneous transfer of voltage into lightweight. Though there are several lighting technologies, Light-Emitting Diode has been expected as Associate in nursing 'ultimate lamp' for the longer term. [1]

Theoretically, Light-Emitting Diode has several distinctive blessings admire high potency, smart dependable, long life, variable color and low power consumption. Recently, Light-Emitting Diode has begun to play a crucial role in several fields, so Light-Emitting Diode product are currently getting used in several fields together with traffic lights, vehicle headlights and tail lamps, LCD displays and street lamps and then on [2]. Light-Emitting Diode is anticipated to be utilized in general lighting that consumes regarding V-day of the overall energy round the world. It's believed those high-energy light - emitting diodes are going to be the dominant lighting technology by 2025 [3].

High-power LEDs operation will manufacture for high Luminas; however they additionally generate important heat at an equivalent time. It's been rumored that the optical output of the Light-Emitting Diode is sharply degraded with the rise in junction temperature [4] as a result of the warmth considerably influences the dependable and sturdiness of the Light-Emitting Diode [5].Therefore effective thermal style and reliable thermal characterization of Light-Emitting Diode system are some key factors in style issues. For top dependable, it's vital that most specific in operation junction temperatures don't seem to be exceeded. So far, Light-Emitting Diode street lamps are typically composed of the many high-energy Light-Emitting Diode modules. With higher chip densities, thermal management of the Light-Emitting Diode lamp proposes an enormous challenge to the road lamp style and producing. There's a requirement to outline the junction-to-ambient and junction-to-case thermal resistances for multi-chip modules during a lot of rigorous manner and supply data to predict junction temperatures beneath discretionary powering of individual chips.

II. LITERATURE REVIEW

In the past few years, LED lamps have been assuming a large role in the illumination market, mainly due to their potential in creating not only light but interesting light environments, associated with low power consumption even when compared with other energy-saving lamp types. Numerous parameters may influence the heat dissipation effect of fin heat sinks. Some studies can be found in the literature concerning the cooling of LED lamps which are given below.

Tony Tan et al. [2013] present hollow geometry introduced inside the rectangular fins and used three kinds of hollow geometries (circular, rectangular, and trapezoidal). The results show that the “hollowed” fins have better heat dissipation efficiency compared to the solid fins.

Shung-Wen Kang et al. [2014] proposed to replace traditional street lamps with an LED street lamp containing a multilayered substrate structure for heat dissipation. Used simulation software to analyze the heat distribution for the proposed model. The simulation showed that our model would be effective at dissipating heat in the LED lamp. We tested temperature changes at 120 and 180 W of inputted power. The LED heat sink slug’s average temperature remained in safe ranges. Less than 5 oC difference existed between actual and simulated results. The average thermal resistance values were 0.24 oC/W at 120 W and 0.22 oC/W at 180W. The data showed that a multilayered substrate structure is not only able to improve LED efficiency but also to solve the heat dissipation issue in LED lamps.

Luo et al. [2016] studied a micro jet array cooling system for thermal management of a high-powered LED lighting supply. Experimental and numerical investigations were conducted. AN infrared measuring device was wont to Measure the on-line temperature, and thermocouples evaluated the cooling performance of the planned system. The experimental and numerical results explained that the micro jet-based cooling system has smart cooling performance.

Lai et al. [2017] proposed an indoor LED lighting prototype that used pressed-flat grooved heat pipes as heat transfer channels to conduct heat emitted by LEDs to heat-sink fins. Single layered heat dissipation module in the above design cannot provide a reliable solution in high power LED streetlamps.

X. Luo, T. Cheng, W. Xiong, Z. Gan and S. Liu et al. [2017] experimented thermal analysis of an 80 W LED street lamp was presented. Sixteen thermocouples were used to measure the temperature points at the aluminum base and fins. The experiments demonstrated that the temperatures near the chip were nearly the same; no obvious temperature difference existed in this area. A numerical model was also proposed based on the experiment. The numerical results were compared with the experimental results to ensure the feasibility of the numerical model. The numerical results of the thermal resistance analysis showed that at an environment temperature of 458C, the maximum junction temperature of the LED chips on the present 80 W LED street lamp would be equal to the critical temperature 1208OC, which leads to poor reliability and lower life and optical efficiency of the LED street lamp.

Kim et al. [2018] investigated the thermal management system for associate degree semiconductor diode light in a very rear projection TV. Their results showed that decreasing thermal resistance between LEDs and substrate was the foremost effective thanks to dissipate heat, and also the applicable limit of thermal resistance existed for varied heat-dissipating conditions of LEDs. They additionally steered that the warmth transport system uses red, inexperienced and blue Light-Emitting Diode lights to confirm product quality.

Lall et al. [2019] performed some experiments for non-uniform powering of a multiple-chip module mounted on a vertical board in natural convection. The common chip temperature thanks to multiple sources at intervals the module was thought of because the reference temperature for evaluating the junction temperature rise of a specific chip. This approach offered an additional refined methodology for analysis of no uniformly battery-powered multi-chip modules compared to previous strategies.

Zahn et al. [2019] mentioned however a central composite style of experiments may be applied to produce an additional correct thermal characterization of a multi-chip module package. The tip product was a series of linear or polynomial equations that would be used by the client to calculate individual device junction temperatures over a good variation of convection cooling environments and multiple device power dissipations.

III. METHODOLOGY

3.1 CAD Geometry

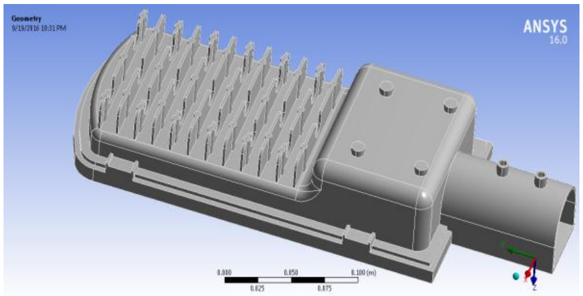

Figure 1: CAD Geometry of Actual LED Frame

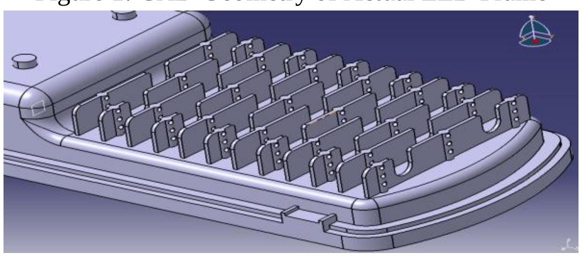

Figure 2: CAD Geometry of proposed LED frame

3.2 Meshing

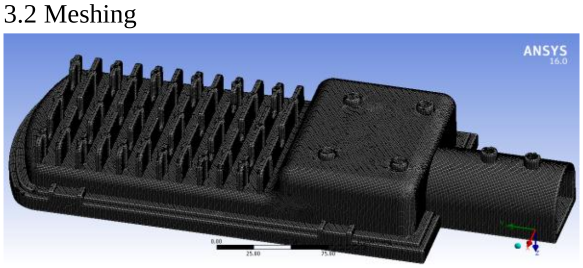

Figure 3: Meshing Total No. of Nodes: 247454 & Elements: 246190 in actual LED model

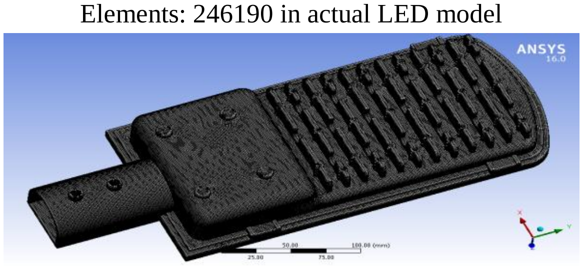

Figure 4: Meshing Total no. of nodes: 254461& Elements: 253459 in proposed LED

3.3 Material Selection

For any kind of analysis material property are the main things which must be defined before moving further analysis .There are thousands of materials available in the ANSYS environment and if required library is not available in ANSYS directory the new material directory can be created as per requirement. For the present work aluminum used as a material of LED heat sink. The material properties of the present in Table 5.1:

Table 5.1: Mechanical Properties of Existing Material

Mechanical Properties	Values
Density	2770 kg m^{-3}
Coefficient of Thermal Expansion	2.3 x 10^{-5} C^{-1}
Specific Heat	875 kg^{-1} C^{-1}.

3.4 Boundary Condition

1. The maximum temperature generated on inside face of the LED heat sink as predicted during the experimental reading.
2. Since this LED heat sink is used for street lighting situated in open space that is why there is normal air flow hence it is assumed that in this open space the normal air temperature available and its convective coefficient value is lies between 0-25 W/m^2. For the present work the value of convective coefficient is taken as 18 W/m^2.
3. The value of conductive coefficient of the material is taken as 235 W/m^{o}C.
4. The maximum temperature recorded during the experimental reading was 138.19 ^{o}C.
5. Atmospheric temperature taken 22 ^{o}C.

IV RESULTS AND DISCUSSIONS

4.1 Transient thermal analysis for actual LED design

Transient or unsteady heat transfer in time also requires the material properties of specific heat at constant pressure c_p in [k J/kg-K] and the mass density ρ in [kg/m^3].

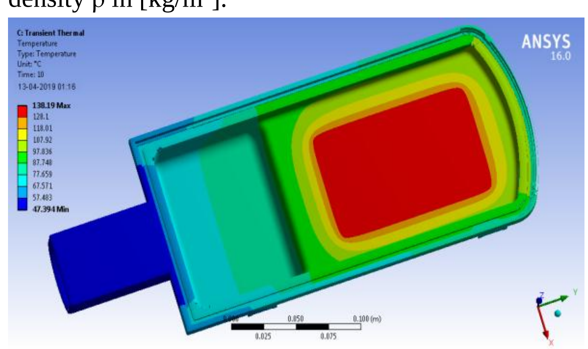

Figure 5: Temperature distribution inside the entire LED frame (A)

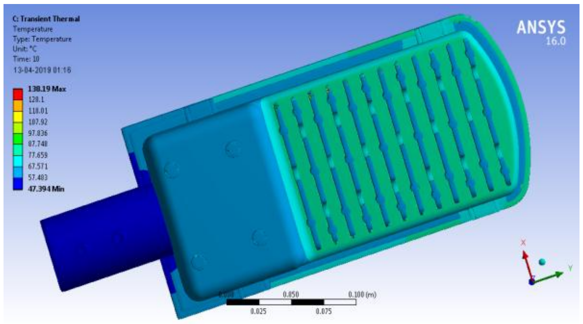

Figure 6: Temperature distribution outside the entire LED frame (B)

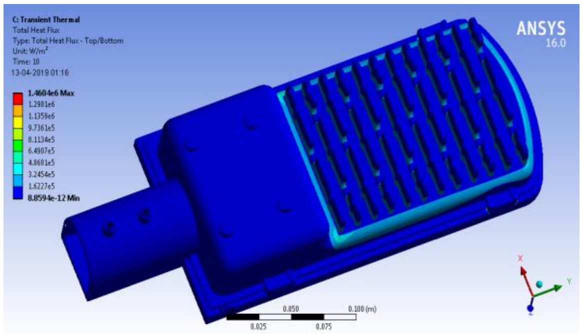

Figure 7: Total Heat flux of actual LED model

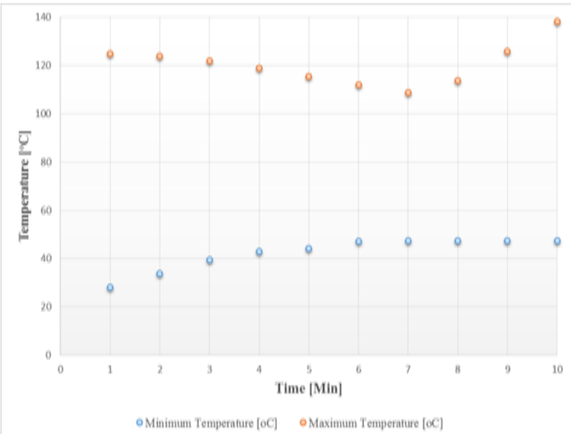

Figure 8: Temperature distribution over the actual LED Heat sink

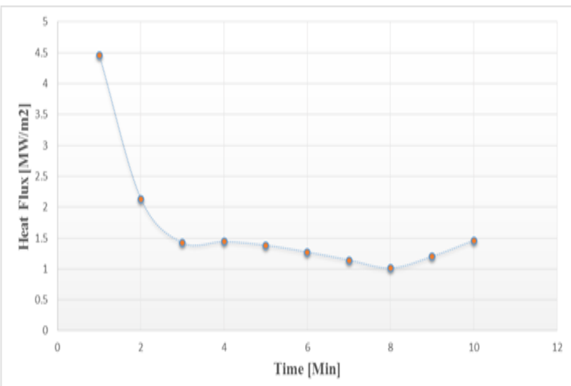

Figure 9: Total heat flux for actual heat sink

4.2 Transient thermal analysis for proposed design

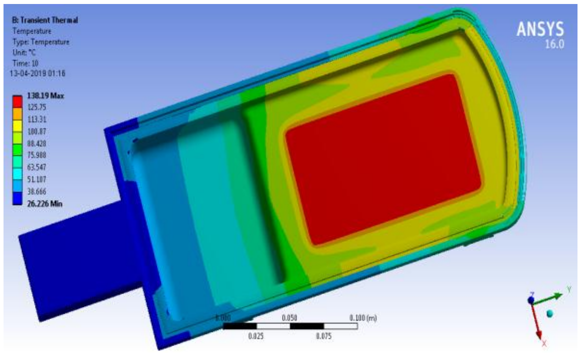

Figure 10: Temperature Distribution inside the Entire LED Frame

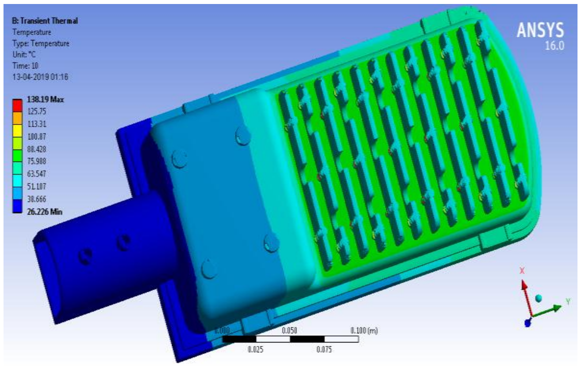

Figure11: Temperature Distribution outside the Entire LED Frame

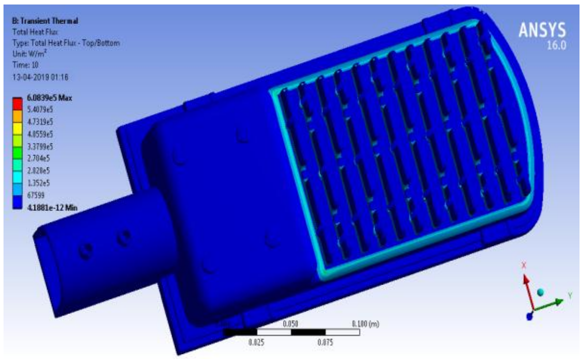

Figure 12: Total Heat flux in proposed LED design

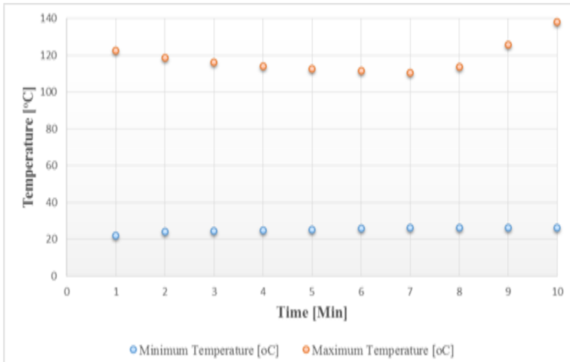

Figure 13: Temperature distribution of Proposed Design over the LED Heat sink

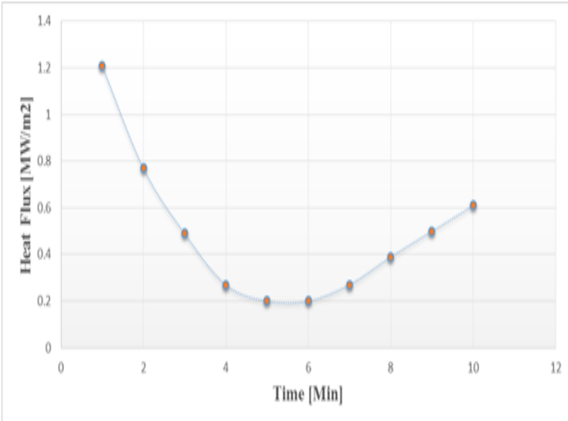

Figure 14: Total Heat Flux of Proposed Design over the LED Heat sink

4.3Comparison between existing and proposed model

We compare the existing data with our proposed data.

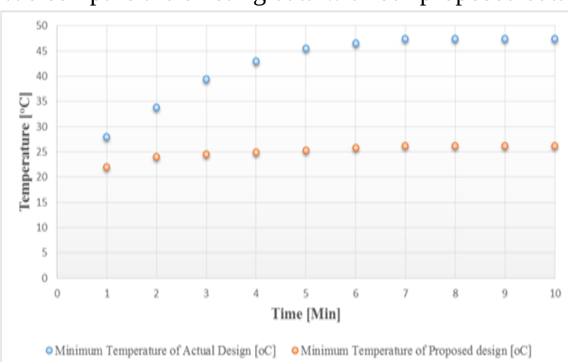

Figure 15: Comparative Result of Minimum Temperature Distribution

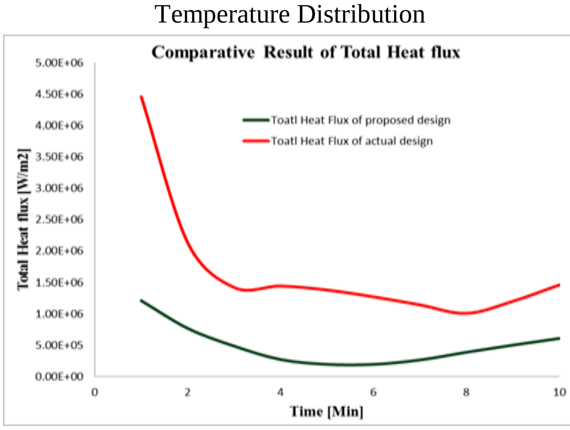

Figure: 16: Comparative Result of Total Heat flux

V. CONCLUSIONS

Experimental and analytical studies were performed in order to optimize geometrical fin parameters for natural convective heat transfer from Actual LED heat sink and proposed design of LED Frame Heat sink for geometrical and cost effective material optimization.

As per analytical results it has been conclude that the temperature drop in proposed design is about 21.168 ^{o}C which is the 55.34% drop as compared with actual design. and the total heat flux difference is 0.852 MW/m^2 in 10 min. which show that heat transfer rate about 41.6% temperature drop = minimum temperature of actual design - minimum temperature of proposed design.

47.394 - 26.226 = 21.168

Temperature drop is about 55.34%.

Difference in heat transfer rate = Total heat flux of actual design - Total heat flux of proposed design.

1.46 - 0.608 = 0.852 MW/m^2

Heat transfer rate increased about 41.6%.

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