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Experimental Study of Orientation Effects on Natural Convection Around New/Old LED Package

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***Abstract*— Light emitting diode (LED) light source is increasingly used for general lighting and seems to replace the fluorescent and incandescent source. However LED suffers from thermal problem. Thermal management of LED is essentially based on natural convection cooling. Experimental study of the orientation effects on the heat transfer of fin heat sink under natural convection conditions, for both new and old LED are carried out. The experimental results show that the horizontal upward is the best position for the heat sink to provide higher heat transfer rate. Comparison between the old and new LED is conducted and indicates that the new LED heats 10% more than the old LED in the case of vertical position. However, when turning off the lamp, the new one cools faster and better than the old one.**

***Keywords*— new LED, old LED, heat sink, natural convection, orientation effect.**

I. Introduction

Light emitting diodes (LED) are solid state lighting source, producing light by electroluminescence. In recent years, LED is increasingly used and becomes the focus for both research and commercial applications. In fact, LED has many advantages compared to other traditional light sources, such as long lifespan (>50000hours), high luminous efficiency (ten times more efficient than incandescent lamp) [1], low power consumption, no thermal radiation and no toxic gas emission. Thanks to all these advantages, the use of LED for general illumination is steadily on the rise. Nevertheless, thermal management is a critical factor for the high performance of LED packages. In fact, about 80-85% of power consumption is converted into heat which participates widely in the junction temperature increase [2]. The heat will greatly affect luminous output, luminous efficiency, lifetime and optical power of LED packages. Therefore, thermal management is a key parameter to guarantee lower operating temperature and benefit from LEDs system.

Natural convection cooling is an important challenge for LED. To address the thermal problem of LED, numerous researches have been focused on cooling LED packages through heat sink. Numerical and experimental studies have been carried out to optimize the heat sink design in order to provide lower junction temperature. Parametric studies of geometric parameters (such as fin length, fin height, fin space...) and correlations predicting the Nusselt number have been proposed [3-7]. Other researches were interested in the effect of orientation on the heat transfer rate to ambient and the junction temperature decrease [8-10].

In the current work, our aim is to study experimentally the effect of the package orientation on the heat transfer rate. three positions were studied: horizontal upward orientation, horizontal down orientation and vertical orientation. A comparison between the orientation effect on new and old LED is also our aim to study the effect of operation time of the package on the heat transfer rate.

II. Experimental equipment and instrumentation

The experimental setup is shown in Fig.1. It consisted of commercial LED chip (BXRA-W3500) [11], aluminium rectangular heat sink, power source, data acquisition device and computer. The LED chip was carefully attached in the middle of the heat sink base. To fix all, the assembly (LED mounted on heat sink) was fastened by an engineer vice, which is properly stable and has no effect on the heat conduction. For the temperature measurement, type K thermocouples were attached to the heat sink. Fig.2 shows the thermocouples location. Using the symmetry of the geometry is a reasonable way to reduce the number of thermocouples and the experimental uncertainty. The assembly (LED + heat sink) can be divided into four equal parts. Then, thermocouples are distributed on the quarter of the model.

The heat sink base size is 408mm*120mm*5mm, and composed of eight fins that are distributed symmetrically on the base plate. More information about the heat sink geometry are in [12].

By setting the engineers vice in a certain angle, the heat sink was set in the corresponding orientation. In this work we are interested in the effect of the luminary orientation on the heat transfer. The positions studied are horizontal upward position, horizontal downward position and vertical position.

Two LEDs are used in this work: a new LED and an old LED which has an operating time more than 1500hours. The aim is to compare the effect of LED ageing process on the temperature rise when turning on the lamp, and the temperature drop when turning off the lamp.

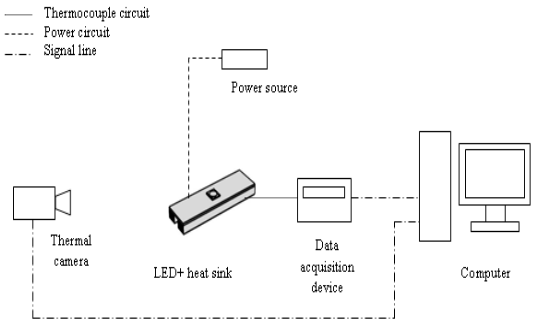

Fig. 1 Experimental setup

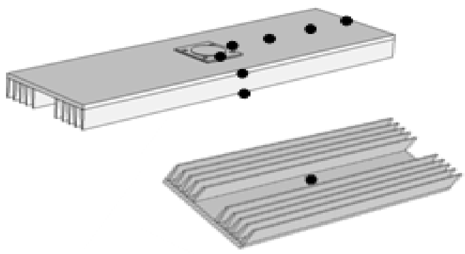

Fig. 2 Thermocouples location

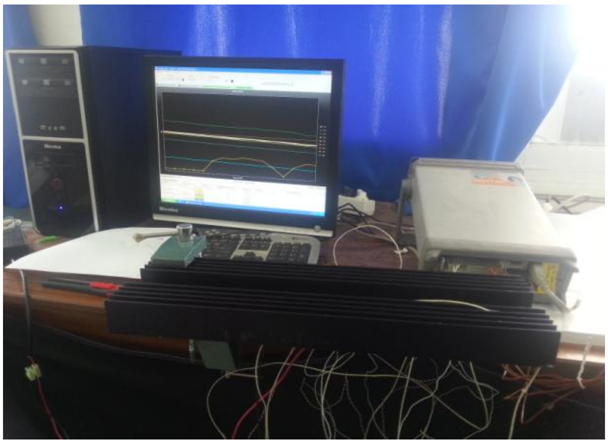

Figure 3 Experimental setup: horizontal upward position

III. RESULTS AND DISCUSSION

Experience has been conducted for the new LED then for the old LED respectively. The package is initially at the ambient temperature of the room 21˚C.

A. Orientation effect on natural convection heat transfer

1) Effect on heat sink average temperature

The orientation effect on natural convection heat transfer through the heat sink is resumed in both Fig.4 and Fig.5. The variation trends with the orientation show that the downward orientation yields the lowest heat transfer for both new and old LED and gives the highest heat sink average temperature. However, the upward orientation provides the lowest heat sink average temperature and the highest rate of heat transfer to ambient. Thus, as clearly seen, the upward facing orientation gives the highest heat transfer rate, followed by the vertical orientation and the downward orientation respectively. In fact, for the upward facing, the buoyancy induced flow is coming from the four edges of the heat sink, and freely rise up. In contrast, the air flow is coming from the bottom edge of the heat sink, for the downward orientation, and it is blocked by the heat sink base plate. This acts as a flow barrier and gives less heat transfer rate in this case. For the vertical orientation, the air flow is coming only from the bottom of fins and rise up freely to the outside.

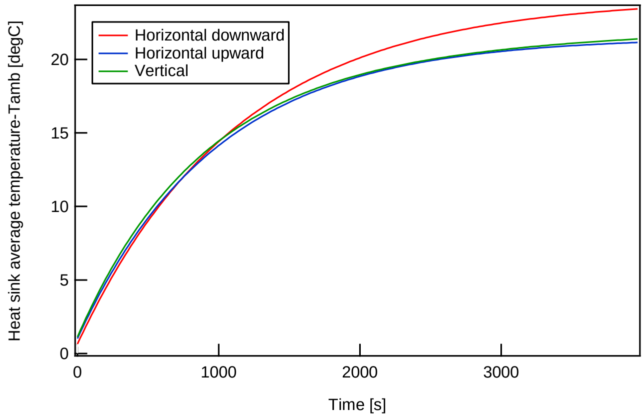

Fig. 4 Orientation effect on new LED package

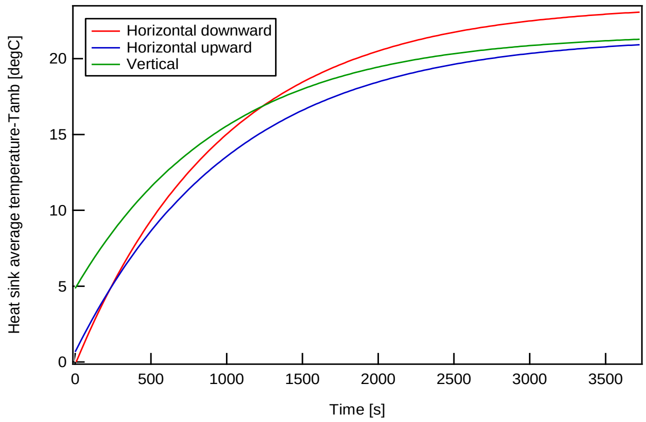

Fig. 5 Orientation effect on old LED package

2) Effect on LED temperature

The orientation effect on the LED temperature is shown in both Fig.6 and Fig.7. As shown, the LED temperature fluctuates with the orientation angle. The upward orientation stills the best orientation that maximizes the heat transfer rate and guarantees the lower LED temperature. However, one can see that the new LED temperature is higher than the old LED temperature for all the orientation.

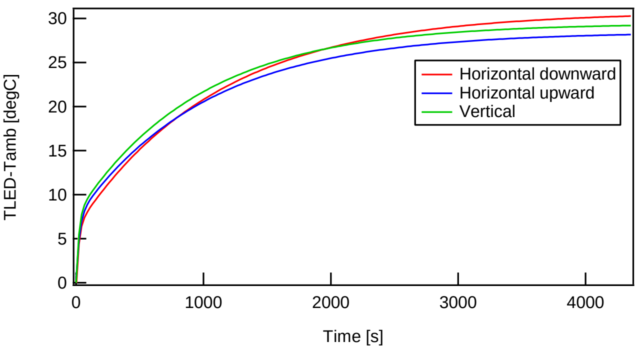

Fig. 6 Orientation effect on new LED temperature

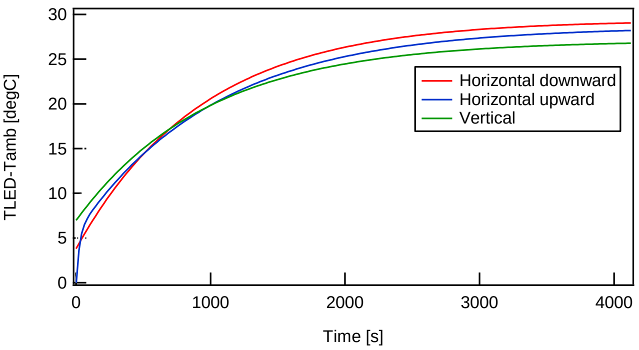

Fig. 7 Orientation effect on old LED temperature

B. Comparison between new and old LED

1) Down ward orientation

Fig.8 and Fig.9 illustrate a comparison between new and old LED, for the horizontal downward orientation. As it is seen in Fig.7, when turning on the lamp, the LED temperature increases with time until the steady state reached. The new LED heats more than the old LED. In fact, for the new LED, 80-85% of the power input is converted to heat. However, this percentage decreases with the operating time. When turning off the lamp, the new LED is cooled better than the old one.

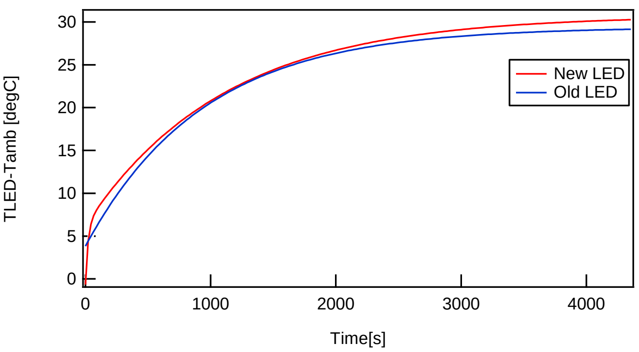

Fig. 8 New LED vs. old LED: horizontal downward orientation, turning on

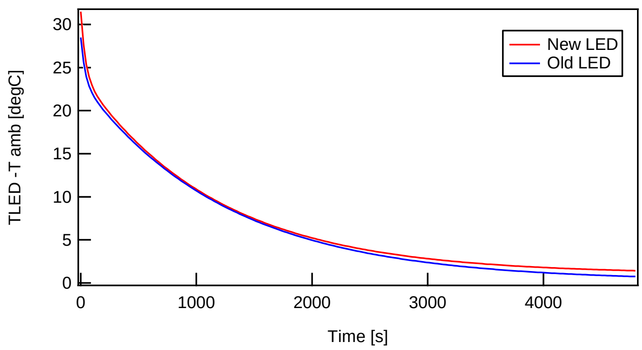

Fig. 9 New LED vs. old LED : horizontal downward orientation, turning off

2) Upward orientation

Fig. 10 and Fig.11 shows the turning on and off of both new and old LED. For the horizontal upward orientation the new and old LED have nearly the same temperature. This is because the upward facing is the best position to exchange more heat with the outside. When turning off the lamp, the old LED needs more time to achieve the steady state.

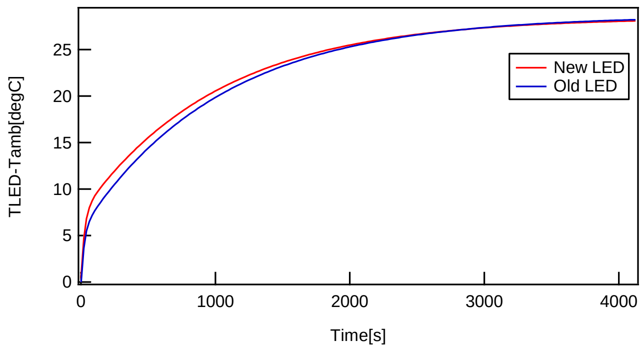

Fig. 10 New LED vs. old LED: horizontal upward orientation, turning on

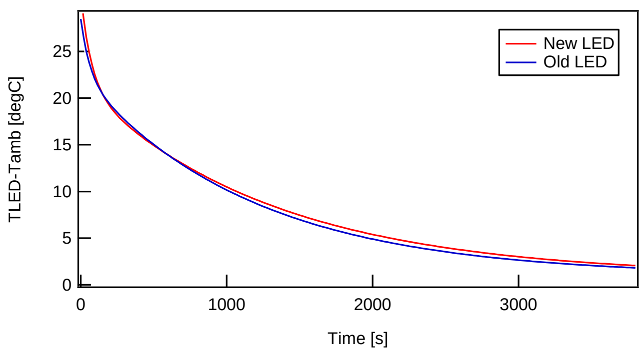

Fig. 11 New LED vs. old LED: horizontal upward orientation, turning off

3) Vertical orientation

Fig.12 and Fig.13 illustrates a comparison between new and old LED for the vertical orientation. It is found that the vertical orientation provides more heat transfer than the horizontal downward orientation since the air flow is moving better, while the buoyancy flow is blocked by the heat sink base in the case of downward orientation. The new LED achieves higher temperature than the old one (about 10%

more than the old LED). So, with the increase of operating time, the luminous flux decreases. However, as it is clear in Fig.13, the new and old LED achieve the ambient temperature at the same time.

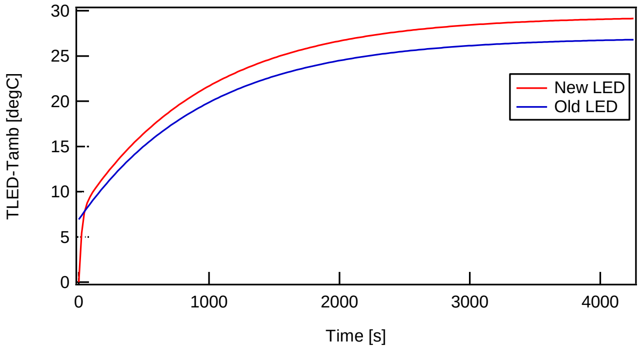

Fig. 12 New LED vs. old LED : vertical orientation, turning on

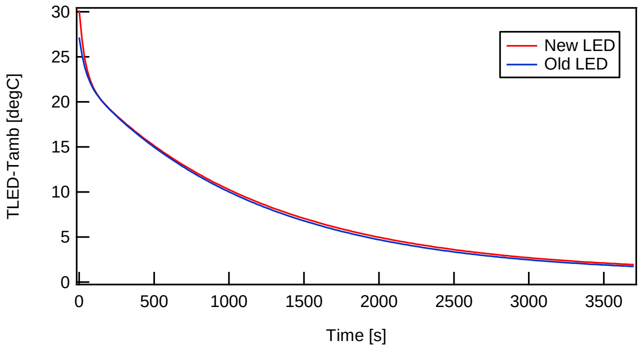

Fig. 13 New LED vs. old LED : vertical orientation, turning off

IV. Conclusions

In this work, the effect of the LED package orientation on natural convection heat transfer was experimentally studied. The results showed that the best heat sink position is the horizontal upward facing. In fact, it was found that this position provides the higher heat transfer rate through the heat sink, followed by the vertical position and the horizontal downward position. A comparison between new and old LED package was also carried on. It was found that, when turning on the lamp, the new LED temperature is higher than the old LED temperature. Especially for the vertical position, it was observed that the difference in temperature is more than 10%. However, when turning off the lamp, the new LED is cooled better than the old one. In the whole, the operation time of the LED affects widely not only the luminous flux, but also it deteriorates heat dissipation.

Accordingly, numerical study must be investigated for the case of a new LED, to study the effect of orientation on the fluid flow, and propose a simple Nusselt correlation for each orientation.

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