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A Study on Heatsink Temperature Distribution according to the Installation Angle of a 30W LED Floodlight

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30W급 LED 투광등 설치각도에 따른 히트싱크 온도분포에 관한 연구

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ABSTRACT

This study investigated the heat dissipation characteristics of a heat-sensitive LED. The results of the empirical test showed that the best temperature intensification was found at 90 with 15-fins, and the heatsink installed perpendicular to the direction of the flow of air was directly connected to the air in the largest heat shield area, leading to the best cooling, and the number of fin also resulted increase in the heat discharge area, resulting in the largest cooling action with 15 fins. It was found that the rate of air flow changed in the range of 1.5m/s to 2.5m/s, but only by a deviation of about 2℃ to 3℃ from the current state of 15 fins at 2.5m/s, and the rate of air flow increased, but the performance of the heat release was not significantly increased. As a result wind speed with minimum air flow conditions of 1.5m/s can greatly contribute to the heat dissipation performance.

Key Words : LED Floodlight(LED 투광등), Heatsink(히트싱크), Forced Draft(강제송풍), Wind Speed(풍속)

1. Introduction

Electronic equipment is decreasing in size and increasing in performance with the development of electronics and machinery. In addition, as the national interest in environmentally friendly energy is rising, the uses of incandescent bulbs and fluorescent lights are decreasing. Furthermore, the production and import of incandescent bulbs has been stopped by the Ministry of Trade, Industry and Energy in 2014, and incandescent bulbs have disappeared to memories of history.

LED elements convert 80% or higher of the supplied power to thermal energy, and the rising temperature of the LED chip lowers the illuminance, causes flicker phenomenon, and rapidly decreases lifetime. Therefore, cooling technology to maintain the internal temperature to an appropriate temperature for chips has emerged as a critical issue

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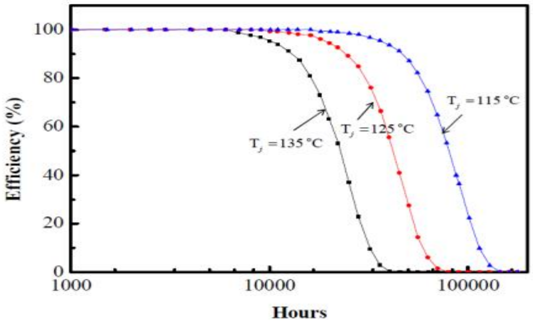


Fig. 1 Effect of junction temperature on useful life time of LED

for achievement of illumination efficiency and reliability. Fig. 1 shows a graph of the lifetime of LED according to the temperature of the LED chip junction Tj. The lifetime of the LED product is defined as the time until the performance of a new product becomes 50%, reflecting the decrease of LED performance over time. At Tj = 115℃, the lifetime is roughly 100,000 hours, but when the temperature increases to 20℃, the lift time sharply drops to 20,000–30,000 hours. Therefore, heat release design is critical to prevent many adverse effects of the heat generation of the chip, such as light output degradation and flicker phenomenon [1-4].

Currently, LEDs are not only used for illumination in industries and homes, but also applied to a variety of fields including displays, automobiles, and industrial sites. In particular, LEDs used for lighting have become widely expanded to medicine, fire protection, and advertisements, as well as for architectural lighting. Heat is considered the most serious problem in the use of LEDs. More than 80% of the supplied power is converted to thermal energy, and the resulting temperature rise causes degradation of optical output and wavelength shift, which have fatal effect on the lift time of LEDs. Consequently, cooling technology to maintain an appropriate LED temperature has emerged a serious issue for illumination efficiency and reliability of high brightness, high power lighting equipment of several hundreds of watts such as security lights and street lamps [5-9]. Verification of cooling problems has been ceaseless conducted even until now, but most of them focus on optimal design in basic installation method. Therefore, this study investigates the effective heat release characteristics of high-efficiency LEDs when forced convection is applied with the heat sink angle and number of pins as variables, and experimentally examines the thermal transmission characteristics.

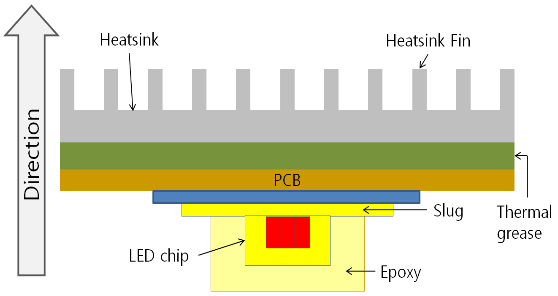


Fig. 2 LED thermal transfer structures

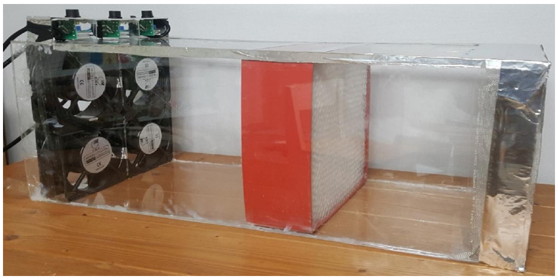


Fig. 3 Experimental device for forced draft

A honeycomb and mesh net were attached to the blower to deliver a constant air velocity from the blower to the heat sink. Furthermore, a speed control device was attached to the top of the fan to facilitate the adjustment of air velocity, and four fans were used to prevent the concentration of air volume. As a result, the air velocity could be measured from 1.0m/s at the minimum to 3.0m/s at the maximum.

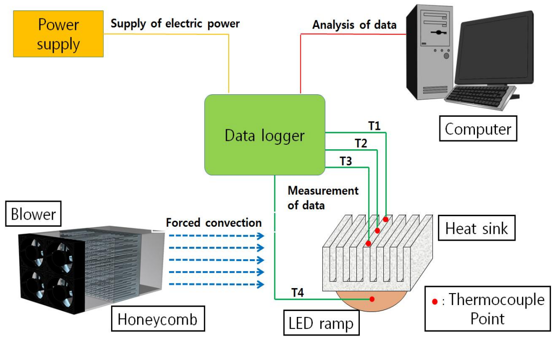


Fig. 4 Schematic of experimental setup

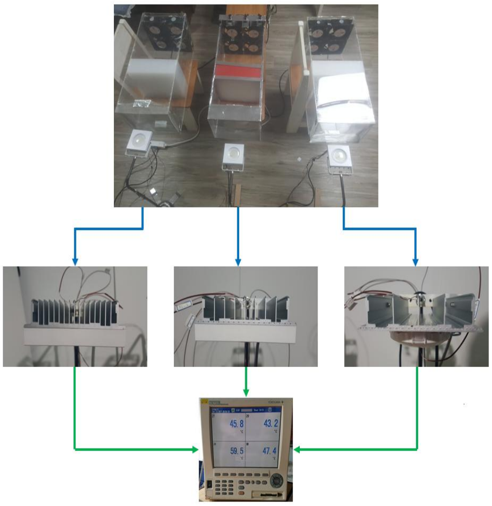
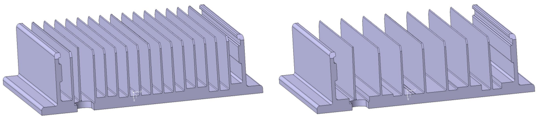


Fig. 5 Configuration of experiment settings

Table 1 Specification of 30W LED

Item	Value
Power dissipation	30W
Forward Voltage	200 ~ 240V
Forward Current	0.14A
Number of LED	(0.6W) × 64 EA
Weight	520g
Dimension	129×120×55 mm
Heatsink materials	Aluminum/anodizing


(a) 15 fins (b) 7 fins

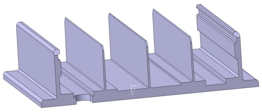

(c) 3 fins

Fig. 6 Experimental parameter for heatsink number

The schematic of the experimental setup in Fig. 4 shows that thermocouples were attached at T1, T2, and T3, where temperature change is predicted according to the angle variable to measure the temperature of the heat sink pins; one thermocouple, T4, was attached to the LED chip.

Fig. 5 shows the experimental setup for heat release characteristic with an LED floodlight and a blower for forced convection according to three experimental values for the number of pins.

The 30W LED floodlight applied in this study consists of a PCB substrate installed in a heat sink, with 64 0.6W LED elements mounted on the substrate. The material of the heat sink for heat release is 6061 aluminum alloy. The cooling pins consist of three types: 15 pins, 7 pins, and 3 pins. The gap between pins is constant, and there are supports for fixing and mounting the floodlight at both ends of the pins. Table 1 lists the specifications of the 30W LED floodlight for this experiment.

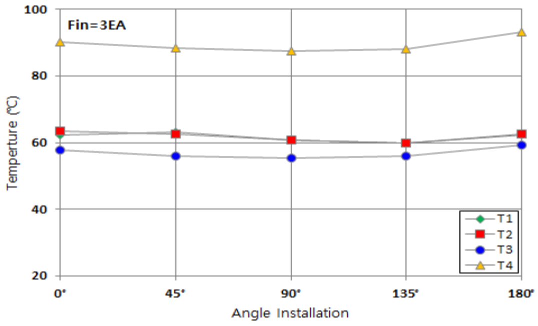
Fig. 6 shows the experimental variables for the number of pins of the heat sink in 3D. The number of pins that can maintain a constant gap between pins was calculated based on 15 pins, 7 pins, and 3 pins, which were fabricated accordingly. In addition, after machining the pins with a machine tool, the bottom of the heat sink with machined pins was smoothened using sandpaper and a file. The reason for this is that if any machined pins remain, it can affect heat release. Six values of the wind velocities of the blower were applied: 0m/s, 1.0m/s, 1.5m/s, 2.0m/s, 2.5m/s, and 3.0m/s. As shown in Fig. 6, the junction angle 0° at which the heat sink faces upward while the LED light illuminates the ground was used as the reference for experiment.

Four thermocouples were installed from (a) to (d). (a) and (c) are located at the edge of the heat sink, and when the installation angle is 0°, their heights from the ground are the same. However, (a) is at the shortest distance from the blower and (c) at the farthest.

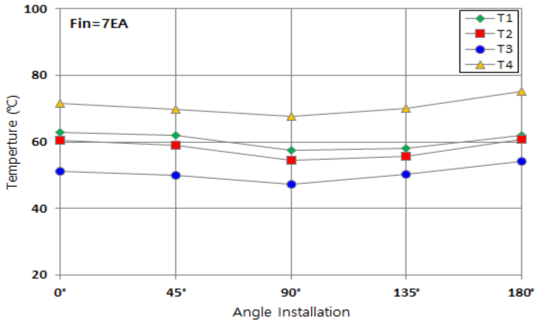
Thermocouple (b) is located at the center of the heat sink pin, and (d) is at the center of the PCB on which the LED is mounted, thus measuring the LED's heat and internal temperature. The temperature range of the graph was indicated up to 100℃ because the temperature is higher compared to those of other measuring points.

3. Experiment Results and Discussion

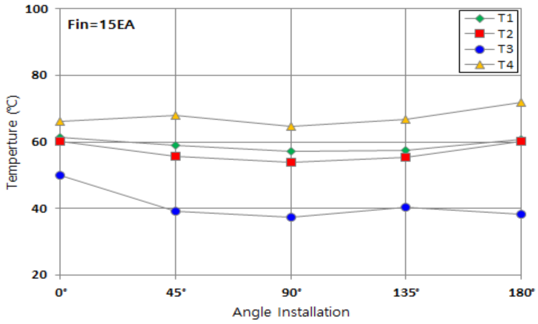
Fig. 7 shows a graph comparing the temperature by angle for the heat sink pin variable. It is the result of analyzing heat release at the heat sink installation angles of 0° and° with no air flow by external factor. It can be seen that the temperature of T4 at the center stays above 90℃ and that as the number of pins was higher, the heat release area increased and the temperature decreased. In the case of T3 for 15 pins, additional heat release is necessary because the heat sink chip maintains high temperatures, even though the heat sink temperature is low (38℃) at 90°. Fig. 8 analyzes the heat release air velocity at each installation angle at the air flow condition of air velocity of 1.5m/s with 3, 7, and 15 heat sink pins. The left and right sides of the graph are high and the center is concave. The highest temperature is 90°, and the temperature rises toward the left and right. This directly shows the effect of the installation angle on heat release. Even a small temperature change can cause large variations in lifetime and optical output. Thus, setting the air flow of the ambient conditions at 45°, 90°, and 135°, which can reflect the optimal heat release characteristics, will be helpful for heat release.



(a) Fin number=3EA

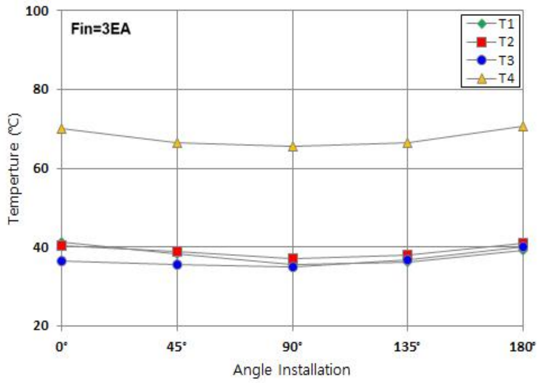


(b) Fin number=7EA

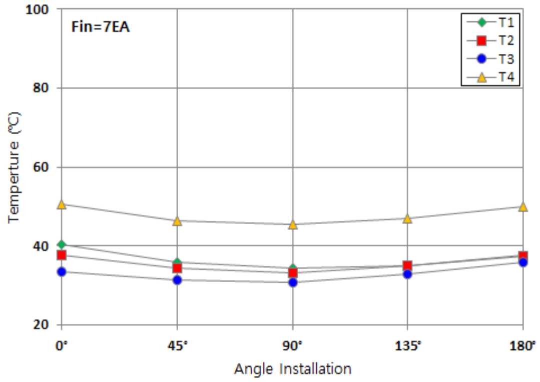


(c) Fin number=15EA

Fig. 7 Thermocouple temperature graph by wind speed 0m/s.



(a) Fin number=3EA



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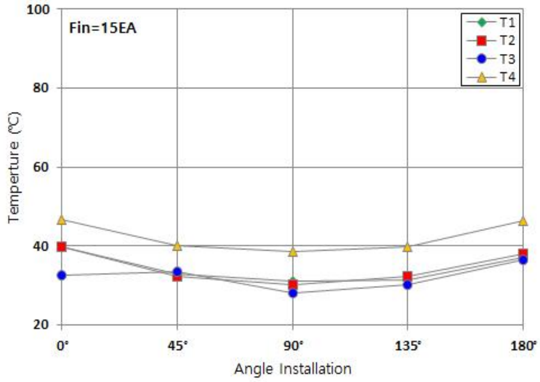
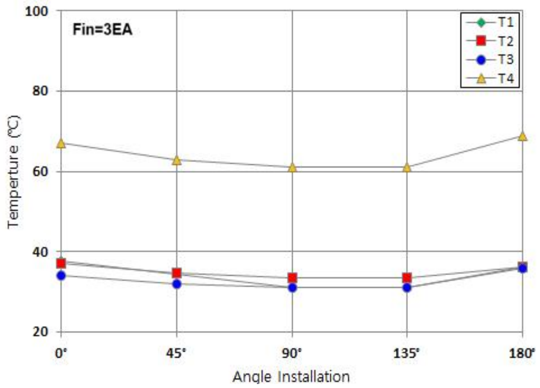
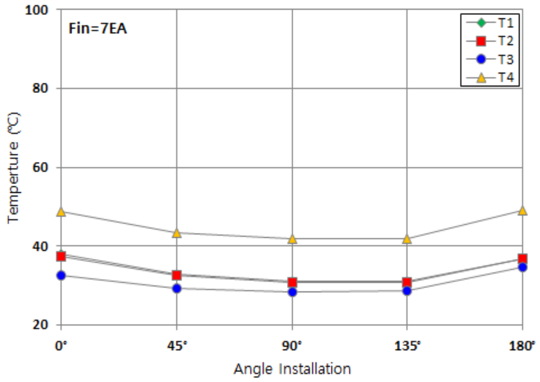


(c) Fin number=15EA

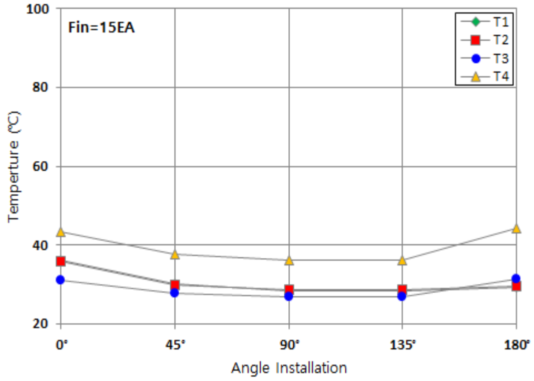
Fig. 8 Thermocouple temperature graph by wind speed 1.5m/s.



(a) Fin number=3EA

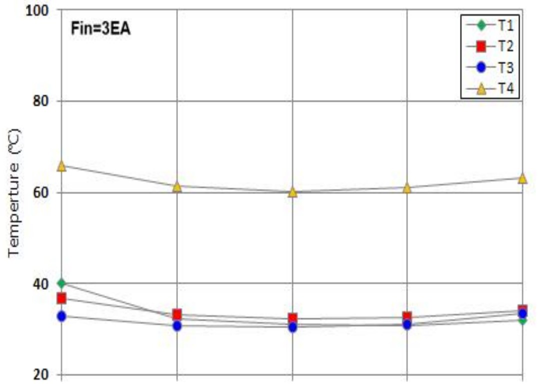


(b) Fin number=7EA

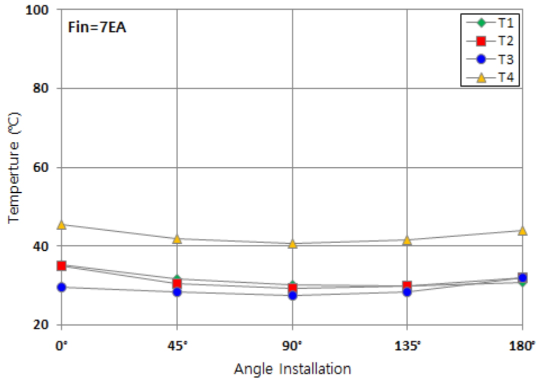


(c) Fin number=15EA

Fig. 9 Thermocouple temperature graph by wind speed 2.0m/s.



(a) Fin number=3EA



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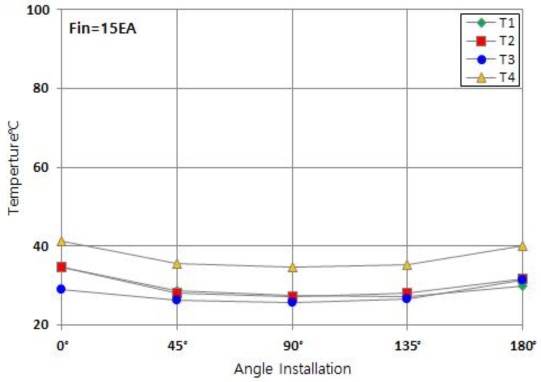

(c) Fin number=15EA

Fig. 10 Thermocouple temperature graph by wind speed 2.5m/s.

In Fig. 9, in the case of 3 pins, the temperature is high, at around 70°C, at 0° and 180°, even in the air velocity of 2.0 m/s, and the temperature at 90° is high, at approximately 61°C. However, at T1 to T3, differences of approximately 30°C appear. In the heat sink, the heat release is not large due to the effect of air flow, but the heat release is not good at T4. As the number of pins increased, the temperature of T4 decreased, to nearly 40°C at the maximum at 15 pins. This confirms that the number of heat sink pins has a greater effect than air velocity in increasing the heat release effect of chip temperature.

Fig. 10 shows a graph comparing the temperatures with an air velocity of 2.5m/s at each angle with three values of the number of heat sink pins. The temperature changes slightly compared to the case of 2.0 m/s. T4 ranges from 90° to near 6 0°C at the minimum, but the temperature changed very little, even though the air velocity increased. It was found that if the air velocity and the number of pins for the optimum heat release condition were selected, the air velocity under the natural convection condition was approximately 0.6 m/s. At this condition, there is limitation in heat release at T4. Thus, sufficient heat release will be possible just with the air velocity of 1.5 m/s. Since the angle is also an important factor, the product needs to be improved to raise the heat release performance so as to receive the optimal air velocity.

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4. Conclusions

Even when the air velocity increased from 1.5

m/s to 2.5 m/s by the ambient air, the temperature changed little compared to 1.5 m/s. An air velocity of approximately 0.6 m/s was found by the effect of the buoyant plume in natural convection state. When compared with the ambient air velocity of 1.5 m/s, the heat release was higher by approximately 37.5%.

The effect of installation angle of the LED floodlight on the heat release performance was high, even in the air flow condition. It was found that the number of heat sink pins had a greater effect on temperature drop than the air velocity. In this study, the maximum efficiency appeared at the largest number of pins (i.e., 15), and the cooling effect did not increase proportionally due to the effect of thermal resistance.

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