A Study on Aspect Ratio of Heat Dissipation Fin for the Heat Dissipation Performance of Ultra Constant Discharge Lamp

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Abstract. In this study, we analyzed the heat dissipation performance of UCD lamp ballast fin with various aspect ratios. The minimum grid size was 0.02 mm and the number of grid was approximately 11,000. In order to determine the influence of the aspect ratio on the heat dissipation performance of UCD lamp ballast fin, the heat transfer area of the fin was kept constant at 4 mm². The aspect ratios of the fin were 2 mm: 2 mm (basic model), 1.5 mm: 2.7 mm and 2.7 mm: 1.5 mm, respectively. The heat flux and heat flux time at fin were kept constant at 1×10⁵ W/m² and 10 seconds, respectively. The heat dissipation performance by the fin was the best at an aspect ratio of 1.5 mm: 2.7 mm.

Keywords: Aspect ratio; Heat dissipation performance; Computational Fluid Dynamics (CFD)

1. Introduction

Currently, carbon dioxide emission regulation and energy saving are the real challenges facing our society. As a carbon dioxide abatement technology, there is a need for technology development of the highly efficient and environmentally friendly light source. In order to reduce electrical energy, the LED (Light Emitting Diode) lamp is developed. This LED Lamp is used in various fields because of the low electric capacity and long life. On the other hand, this has disadvantages of the glare and heat emission issues. So, as one of the carbon dioxide abatement technologies, there is a high interest in Ultra-Constant Discharge (UCD) due to the need for technology development for efficient and eco-friendly light source [1-3]. Therefore, in this study, we analyzed the heat dissipation performance of the ballast fin that the aspect ratio of fin was varied.

2. Experimental & Numerical Analysis

2.1. Experimental Apparatus Configuration and Method

Figure 1 shows a schematic diagram of an experimental apparatus for measuring the surface temperature of the UCD lamp and ballast using a thermal imaging camera. In this study, a heat
dissipation experiment was conducted using a UCD lamp combined with a ballast fin. The experimental results were compared with the analytical results to verify the validity and to ensure the reliability of the analytical results.

![Figure 1. Schematic illustration for measurement of temperature at the UCD lamp and ballast.](image)

### 2.2. Shape of Ballast fin

Figure 2 shows the shape of the fin and the assembly part fastened to the lamp. The shape of the ballast used in the analysis simplified the overall shape of ballast considering the analysis time and convergence. The number of mesh was 11,022, and the minimum mesh size was 0.02 mm.

Figure 3 shows the aspect ratio of the ballast fin, and the heat transfer area of the fin was kept the same as the basic model of 4 mm$^2$. Therefore, the ratio of width to height was 2 mm: 2 mm (basic model), 1.5 mm: 2.7 mm, and 2.7 mm: 1.5 mm, respectively.

![Figure 2. Shape of assembly part and fin inside the ballast.](image)

(a) 2mm : 2 mm  
(b) 1.5mm : 2.7mm  
(c) 2.7mm : 1.5 mm

![Figure 3. Aspect ratio of the ballast fin.](image)
2.3. Numerical Analysis

The energy equation used for thermal analysis of ballast is the same as (1).

\[ \rho_b C_b \frac{\partial T}{\partial t} = \nabla \cdot (k_b \nabla T_b) \]  

(1)

Where \( \rho_b \) is the density of the ballast (kg/m\(^3\)), \( C_b \) is the specific heat (J/kg·K), \( k_b \) is the thermal conductivity (W/m·K), and \( T_b \) is the temperature (K). Discrete Ordinate (DO) method was used as a radiative heat transfer analysis technique to solve the energy equation when the heat transferred to the fin. The main material of the fin is aluminium and its emissivity (\( \varepsilon \)) is 0.047, the convective heat transfer coefficient (\( h \)) is 10 W/m\(^2\)·K considering natural convection.

3. Results and Discussion

Figure 4 shows a graph for verifying the validity of the numerical results through the comparison of the analytical value and the experimental data, before predicting the heat dissipation performance of fin. The grid numbers used for grid dependency test was 8,096, 10,118, and 11,022, respectively. The experimental value was similar to the analytical value within the maximum error rate of 2.8\% for 2.0 seconds. Therefore, this study used the structure grid of 11,022 numbers considering the convergence time and accuracy of the solution, and the minimum size of grid was 0.02 mm.

Figure 5 shows the temperature distribution of the fin and the assembly part when the heat flux time was increased to 10 seconds. The heat flux was kept constant at \( 1.0 \times 10^5 \) W/m\(^2\) in case of the heat flux time of 0.1 second and 10 seconds. The temperature distribution of the fin and assembly part showed a similar tendency regardless of the aspect ratio change for 0.1 second. When the heat flux was applied for 10 seconds, the temperature on the assembly part was similarly low, but the temperature on the fin rapidly increased and also varied. The temperature distribution on the fin was the highest and the lowest at 2.7 mm: 1.5 mm when the aspect ratio was 1.5 mm: 2.7 mm. Therefore, it was found that the heat dissipation performance on the fin was more affected by the height than the width of fin.

![Figure 4](image-url)

*Figure 4*. Comparison of experimental results and numerical analysis in the case of \( Q=1.0 \times 10^5 \).
Figure 5. Temperature distribution on the fin and assembly part at various heat flux times.

Figure 6 shows the thermal conductivity according to the change of the aspect ratio of the fin when the heat flux was kept constant at $1.0 \times 10^5$ W/m$^2$. The thermal conductivity varied depending on the shape and thickness of material. The temperature distribution was affected by the heat flux time. When the heat flux time was the 0.1 second, the amount of heat transfer was different. And the value of the thermal conductivity greatly increased when the aspect ratio was 1.5 mm: 2.7 mm. On the other hand, the lowest value of thermal conductivity showed at the aspect ratio of 2.7 mm: 1.5 mm, and the tendency of temperature decrease was similar regardless of the aspect ratio. And the best heat dissipation performance was obtained at the aspect ratio 1.5 mm: 2.7 mm. Therefore, it was necessary to design for shape of thin and high fin. And also, the additional study on the shape of fin is necessary to improve the heat dissipation performance of UCD Lamp.

Figure 6. Thermal conductivity according to the aspect ratio of fin when the heat flux was $1.0 \times 10^5$W/m$^2$
4. Conclusion
When the heat flux is applied for 10 seconds, the temperature on the assembly part appeared a similarly low distribution, while the temperature on the fin rapidly increased. It was found that the heat dissipation performance was the best when the aspect ratio was 1.5 mm: 2.7 mm under the same heat transfer area of fin, and the height of the heat dissipation fin affected a significant influence on the life extension of the ballast. Therefore, the additional study on the shape of fin is necessary to improve the heat dissipation performance of UCD Lamp.

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6. Reference
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