

Analysis of light efficiency of classroom grille lamp from optical loss

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Abstract. One of the most important reasons is the influence of classroom lighting. Classrooms are places where students use their eyes for a long time. It is necessary to ensure that the light environment is healthy, comfortable and up to standard. At present, Classroom lamp is being updated, and many classrooms use new type of grille lamps as the main source of illumination. In this paper, from the perspective of light energy loss, the existing grille lamps on the market are studied, the transmittance of the diffusion plate, the light output rate and reflectivity of the grille are analyzed, and the theoretical light efficiency is calculated and verified. Combined with the classroom lighting standards and simulation results, this paper explores whether the light efficiency of grille lamps meets the standard, and puts forward suggestions for improvement.

1. Introduction

The detection rate of poor eyesight in Chinese students continues to rise, and there is a tendency to become younger. It is estimated that the total number of students with poor eyesight in China will be 152.4 million in 2020, and will be about 180.4 million in 2030. The problem of poor eyesight has attracted the attention of all departments of the country. On August 30, 2018, the Ministry of Education and the National Health and Health Committee jointly issued the "Integrated Prevention and Control Program for Children and Adolescents with Myopia". It proposes that the myopia rate of children aged 6 in China will be controlled at 3% in 2030, the myopia rate of primary school students will be reduced to below 38%, the myopia rate of junior high school students will be reduced to less than 60%, and the myopic rate of high school students will be reduced to below 70%[1].

For the students who are in the period of accumulation of knowledge, the classroom is the main place for daily study, and the outside environment where students are most exposed every day. Therefore, the quality of the lighting in the classroom directly affects the occurrence of myopia in students. According to relevant investigations and studies, there are a series of problems in school classroom lighting, such as illuminance values, glare, stroboscopic, etc. The existence of these problems can easily lead to the occurrence of students' myopia. At the same time, it will also cause two major drawbacks: high energy consumption and low efficiency, which do not meet the requirements of green lighting [2]. Therefore, it is self-evident to improve the lighting environment of school classrooms and reduce the incidence of eyesight.

To improve the lighting environment of school classrooms, we must first meet the local and national classroom lighting standards. As shown in Table 1, the main indicators include classroom average illumination, uniformity, power density, uniform glare value and lamp efficiency.



Table 1. Lighting Standard Requirements for Ordinary Classrooms.

Index	GB7793-2010[3]	GB50099-2011[4]	DB31/539-2011[5]	GB50034-2013[6]
Average Illumination in Ordinary Classrooms/lx	≥ 300	≥ 300	≥ 300	≥ 300
Evenness	≥ 0.7	≥ 0.7	≥ 0.7	≥ 0.6
Power density	Current value Target value	≤ 11 ≤ 9	Per 100lx ≤ 3 -	≤ 15 ≤ 8
Uniform glare value	≤ 19	≤ 19	≤ 16	≤ 19
Efficiency of classroom grille lamps/%	-	Efficient lamps	≥ 62	≥ 65

2. Principle of optical loss in grille lamp

At present, there are two methods to determine the luminous flux of lamps. The simulation is carried out by using TracePro and other optical design software, and the method to calculate the luminous flux of lamps is based on the principle of light intensity distribution, that is, the actual measurement is carried out by using the distributed photometer [7].

In order to analyze the change of luminous flux in lamps, this paper presents a method to calculate the luminous flux of grating lamp based on the principle of luminous energy loss, and puts forward suggestions for improving the grating lamp based on the principle of luminous energy loss.

In the grille lamp, when the light emitted by the LED chip passes through the diffuser plate and the grille, two kinds of optical phenomena, transmission and emission, occur, and energy loss is accompanied [8].

2.1 Reflection loss of transmission surface

When light passes through a diffuser plate, the reflection loss occurs first, which means that when light passes from one medium to another, it is accompanied by reflection loss at the interface.

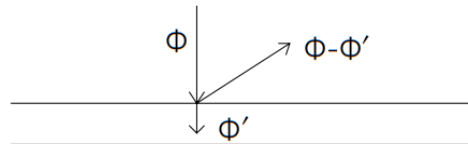


Figure 1. Reflection loss of transmission surface.

$$\phi' = \phi(1 - \rho_1) \quad (1)$$

$$\rho_1 = \left(\frac{n-1}{n+1} \right)^2 \quad (2)$$

Among them, ϕ' is the fluxes of outgoing light, ϕ is the fluxes of incident light, ρ_1 is the reflectivity of the material transmission interface, n is the refractive index of the material.

2.2 Absorption loss of optical materials

Secondly, the diffusing plate itself absorbs light energy, so absorption loss occurs. When the light passes through the optical material, the material itself absorbs light energy, and the luminous flux decreases as the thickness of the medium increases.

$$\phi'' = \phi' \times e^{-\alpha l} \quad (3)$$

Among them, ϕ'' is the outgoing light flux, ϕ' is the incident light flux, α is the light absorption coefficient of the material, l is the thickness of the medium.

2.3 Absorption loss of reflective surface of metal coating

In order to improve the reflection of the grille, the lamp manufacturer generally chooses to plate a metal reflective layer on the surface of the grille. However, the reflective surface of the metal coating does not completely reflect the incident light flux, but absorbs a small part of it.

$$\phi''' = \phi'' \times \rho_2 \quad (4)$$

Among them, ϕ''' is the output light flux, ϕ'' is the incident light flux, ρ_2 is the reflection coefficient of the metal coating.

3. Flux calculation of grille lamp

This paper selects a common grille lamp on the market for analysis. The lamp is equipped with a PS diffuser and a square dense grille, which basically meets the requirements of glare value. The lamp is 1.2m long and 0.29m wide. There are 324 LED chips inside. The luminous flux of a single chip is 17lm, that is, the total luminous flux of the bare light source is 5508lm, the whole lamp power is 36w, and the power factor is 0.9.

The diffusion plate uses a PS plate mainly composed of polystyrene, and has a refractive index of 1.59, a light absorption coefficient of 0.11, and a thickness of 2 mm. When the light from the light source passes through the diffuser, it passes through the interface between the air and the diffuser, passes through the inside of the diffuser, and finally exits through the interface between the diffuser and the air. Integrating equations (2), (3) and (4), the transmittance of the diffuser can be obtained.

$$\tau_1 = \left(1 - \left(\frac{n-1}{n+1} \right)^2 \right)^2 \times e^{-\alpha l} \quad (5)$$

Among them, τ_1 is the transmittance of the diffusion plate, n is the refractive index of the diffusion plate, α is the optical absorption coefficient of the diffusion plate, l is the thickness of the diffusion plate.

By the formula (6), the transmittance of the diffusing plate can be calculated to be 72.13%, that is, the light flux is 3972.92 lm after the light passes through the diffusing plate.

$$\phi_2 = \phi_1 \times \tau_1 \quad (6)$$

The surface of the grille is metal coated with a reflection coefficient of 0.9. Before analyzing the absorption loss of the reflective surface of the grille, it is necessary to calculate the ratio of the exit of the grille, that is, the ratio of the total area of the grille to the area of the exit aperture. The single grille exit is a square with a side length of 20 mm and the width of the grille is 3 mm. Remove peripheral side block by frame, and the light ratio is calculated to be 75.6%, that is, the luminous flux incident on the light exit of the grille is 3003.53 lm. It can be concluded from equation (5) that after the grating is reflected, the luminous flux emitted is 2703.18 lm.

Therefore, the total transmittance of the grille lamp can be finally obtained to be 49.07%, and the luminous efficiency is 75 lm/w.

4. Simulation and Error Analysis

In order to verify the analysis results, this paper simulates and performs error analysis through Tracepro.

4.1 Simulation

Figure 2 shows the whole lamp model of the grille lamp, and the material is edited according to the material parameters of each part of the grille lamp.

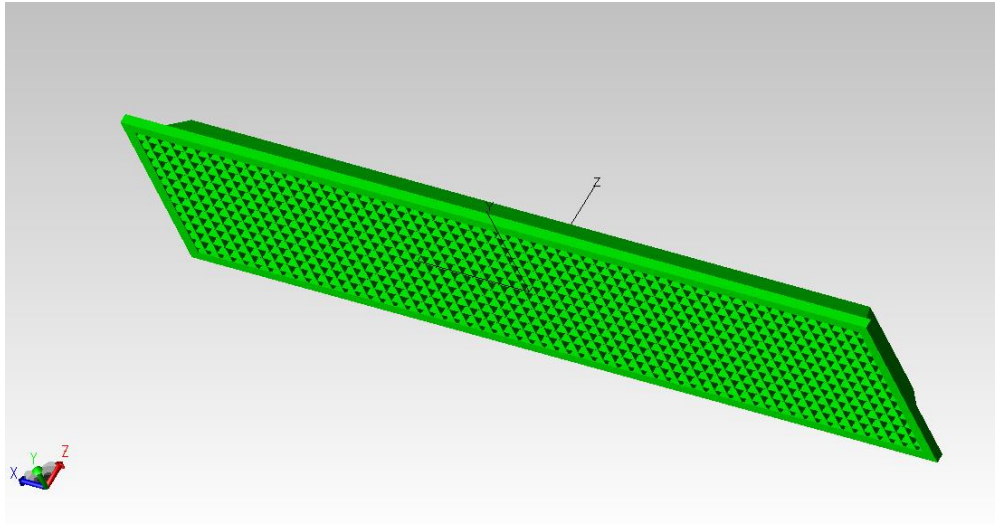


Figure 2. Model of the whole lamp.

The material parameters of diffusion plate are shown in Figure 3.

Temperature (K)	Wavelength (μm)	Index	Absorption [/mm]	Extinction, K [$\mu\text{m}/\mu\text{m}$]
300	0.55	1.59	0.11	4.8144370285298e-006

Figure 3. The material Parameters of Diffusion Plate.

The material parameters of grille are shown in Figure 4.

Temperature (K)	Wavelength (μm)	Incident Angle (deg)	Absorptance	Specular Refl	Specular Trans
300	0.55	0	0.1	0.9	0

Figure 4. The material parameters of grille surface.

In order to collect the luminous flux on the front side of the lamp as much as possible, the test surface size is set to 35000 mm long and 30000 mm wide. Figure 5 shows the simulation results of a bare light source, and the result is 5433.5 lm.

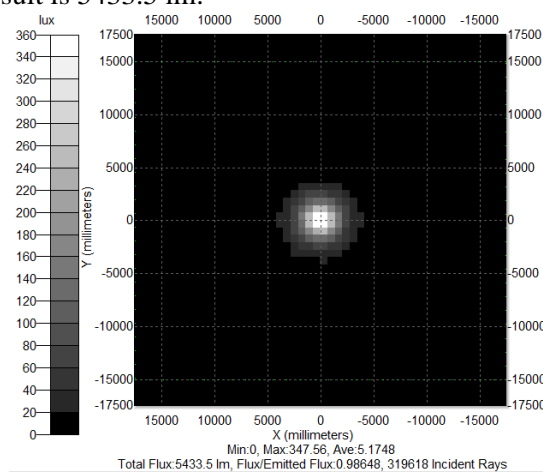


Figure 5. Simulation results of bare light source.

Figure 6 shows the simulation results of the flux loss of the diffuser plate, and the result is 3902.7 lm.

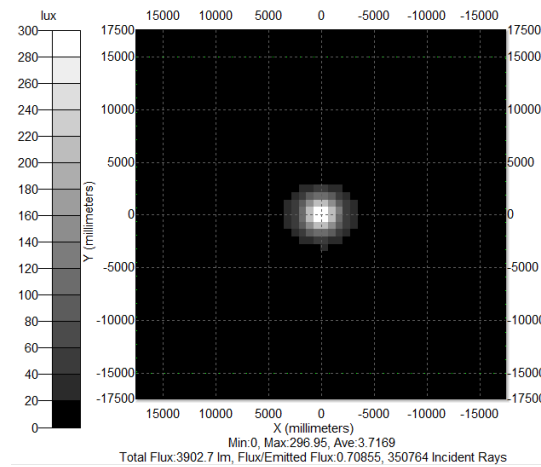


Figure 6. Simulation results of diffuser flux loss.

Figure 7 shows the simulation results of the whole lamp flux loss, and the result is 2624.2 lm.

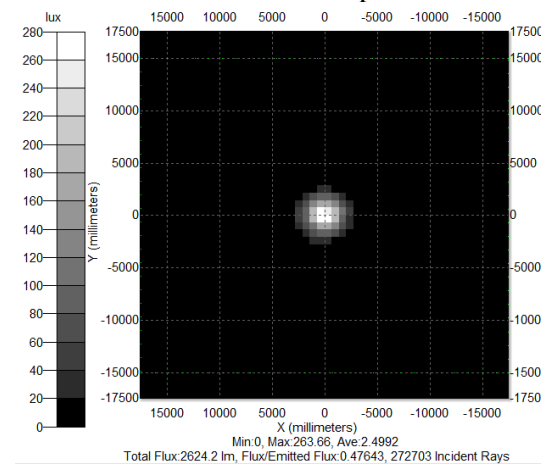


Figure 7. Simulation results of whole lamp flux loss.

4.2 Error Analysis

As shown in Table 2, by comparing the results of analytical calculation with those of simulation, it can be seen that the error between analytical calculation and simulation is small. The main reason for the error is that the shell reflects and absorbs part of the light, including the light emitted by the light source, the light reflected by the diffuser plate and the grille, and some of them are in contact with the shell. In order to improve the light efficiency, the surface of the outer casing is coated with a metal having a high reflectance, and the absorption of light is small, so the error is small.

Table 2. Errors between calculation and Simulation of grille lamp flux loss

	Bare light source	Diffusion plate	Whole lamp	Diffusion plate transmittance	Grille reflectance
Analysis result	5508	3972.92	2703.18	72.13%	68.04%
Simulation result	5433.5	3902.7	2624.2	71.83%	67.24%
Error	74.5	70.22	78.98	0.3%	0.8%

5. Summary

In this paper, a calculation method of grille lamp luminous flux based on the principle of light energy loss is proposed. Compared with the traditional measurement and simulation methods, the advantages of this method are that it can provide theoretical support for the research and development of lamp products and find the direction of improving the luminous flux of lamps through the principle formula.

In terms of the new grille lamps selected in this paper, the dilux simulation is used to arrange 9 lamps in an optimal way in a standard classroom with a length of 8.7m and a width of 6.8m, which can achieve an average illumination of 409lx. However, if the average illuminance is required to reach 500lx, the luminous flux of the whole lamp is required to reach 3450lm, that is to say, the transmittance of the whole lamp is required to reach 62.6%.

According to the principle of optical loss, the following measures can be taken to improve the light efficiency of the grille lamp:

- using an anti-reflection diffuser to reduce the reflection loss of the transmission surface
- using a lighter and thinner diffuser or reducing its light absorption coefficient to cause absorption loss Reduced
- use a higher reflectivity grille metal coating to reduce the absorption loss of its reflective surface

At the same time, the diffuser plate is too light and the reflection coefficient of the grille metal plating layer may be too high, which may result in the glare value not reaching the standard. Therefore, it is necessary to draw a design plan of both sides.

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