Optimization design and analysis of classroom light grid

Bin Hao[1], Min Cheng[2], Xiangfeng Li[1], Yini Zhang[1], Chenyu Zhao[1], Chuanxi Wang[1], Bingrui Shan[1] and Xiaoyang He[1*]

[1]Dalian Polytechnic University, Dalian, Liaoning Province, 116000, China

[2]CQC Standard Testing Technology (Shanghai) Co., Ltd.

[*]Corresponding author's e-mail: hexy@dlpu.edu.cn

Abstract. Today's classroom lamps are mostly aluminium-plated grille lamps with plastics, and most of the grids are regular rectangles or squares. According to the standard, the common grid is optimized. By increasing the shading angle of C0°-180° and reducing the shading angle of C90°-270°, it can reduce the glare and achieve the classroom light environment while achieving good light extraction efficiency. In this paper, through mathematical model analysis, I use SOLIDWORKS, tracepro, DIALux for modelling, ray tracing and classroom light environment simulation, it is verified that the grid designed in this paper has a great improvement in glare control compared with common grids.

1. Introduction

According to the special press conference held by the International Health and Health Commission in 2018, the number of myopias in China has exceeded 450 million. And according to the data, the proportion of primary school students in China is 45.7%, that of junior high school students is 74.4%, that of high school students is 83.3%, and that of college students is 87.7%. The year-on-year rise in myopia is already a big problem in the future of the country [1]. To this end, General Secretary Xi Jinping published an important instructional spirit on the issue of students' myopia. The Ministry of Education also issued a notice on the implementation plan for the comprehensive prevention and control of myopia for children and adolescents.

Most grids are square or rectangular, it not only in a single style, but also because of the different sizes, such rectangular grids still need improvement in classroom glare processing. In this paper, the relationship between the length of the rectangular grid is obtained by simulation and calculation, and the optimal grid scheme is obtained.

In this paper, the shell, diffuser and other properties are unchanged. Only SOLIDWORKS is used to redesign the grid to ensure the accuracy of the data. The optimal grid size is calculated by the formula. Then using tracepro and DIALux for classroom simulation and classroom light environment design, and the UGR value in the improved classroom was reduced by 12%. Verify existing grid problems and propose improvements.

2. Current status of classroom lighting

The grille in the classroom grille lamps present on the market today is mostly a square grille. Figure 1shows a common classroom light. Square grille has some unavoidable problems [2]. Since the grid is square, the light-shielding angles of the C0°-180° and C90°-270° faces of the lamps are both 33°, and the UGR value in the classroom is about 16.

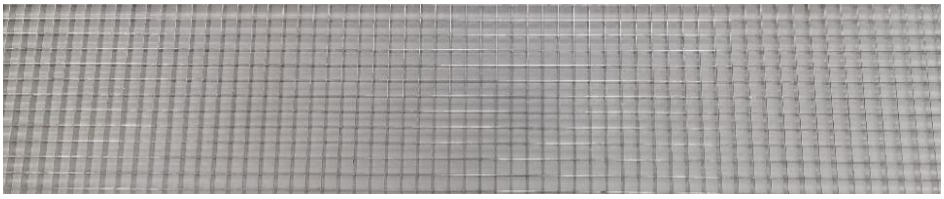

Figure 1. a common classroom lights

3. luminaire model establishment and data measurement

3.1 luminaire model establishment

Here, the length of the C0°-180° surface of the grid unit module is set to x, the length of the C90°-270° surface is set to y, the width of the grid rib is set to a, and the thickness of the grid is set to h. And the variables a and h can be regarded as constants. So, we can get the following formulas.

The shading angle of the C0°-180° surface and the C90°-270° surface is

$$\alpha_{0^\circ} = tan^{-1}\frac{h}{x} \tag{1}$$

$$\alpha_{90^\circ} = tan^{-1}\frac{h}{y} \tag{2}$$

The grid unit area and the light exit area are

$$S_1 = xy \tag{3}$$

$$S_2 = ax + ay + 2a^2 \tag{4}$$

Where S1 is the grating light-emitting area and S2 is the grid unit area, so that the light-emitting ratio of the grid is

$$k = \frac{S_1}{S_2} = \frac{xy}{ax+ay+2a^2} \tag{5}$$

According to the following constraints

$$y > x \tag{6}$$

$$\alpha_{0^\circ} > 33.69^\circ \tag{7}$$

$$30^\circ < \alpha_{90^\circ} < 33.69^\circ \tag{8}$$

$$k \geq 0.85 \tag{9}$$

It can be concluded that

$$y = \frac{85ax+170a^2}{100x-85a} \tag{10}$$

$$x < \frac{h}{0.67}\ ;\ \frac{h}{0.67} < y < \frac{h}{0.57} \tag{11}$$

In the paper, SOLIDWORKS 2108 was used to build the model of the grid luminaire. In the modelling process, the grid is first modelled. The grid pattern a is square, and the single grid unit is 18mm. We set the C0°-180° face of the grille pattern b to 16mm, and the C90°-270° face to 21mm. And according to the actual situation, in the actual production process of the grid, the grid ribs need to be set to a certain angle to be successfully produced, and there are excess materials in the parting line position in the actual production process. Therefore, during the modelling process, the grid rib size is set to 1 mm, and a certain draft angle is set. The grid pattern b part model is shown in Figure 2.

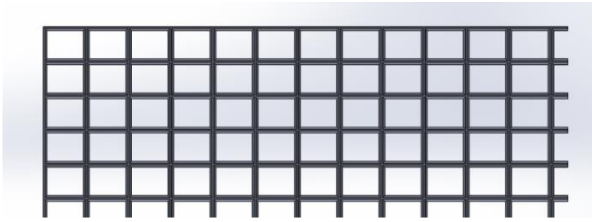

Figure 2. Grill pattern b part model

For the grille, the shading angle needs to be measured. The shading angle is the angle between the line connecting the edge of the light source and the line connecting the light exit of the lamp. For the grille lamp, the shading angle is measured as the angle between the line of the grille closest to the side edge of the light source and the line of the grille exit and the horizontal line. The designing in this paper is square, mainly considering the shading angle of 0° to 180° and 90° to 270°. Through the data measurement and calculation of the grid, the shading angles of the 0° to 180° plane and the 90° to 270° plane are equal, both being 33.69°. The grid pattern b is a rectangle, the light-shielding angle of the C0°-180° surface is 36.87°, and the light-shielding angle of the C90°-270° surface is 30.00°.

In addition, we need to measure the light-emitting area of the grid. Here I use the sampling method to calculate, first I select a certain sampling area, then calculate the light-emitting area of the grid in the area, and the ratio is the whole grid. The light output area of the luminaire. The sampling area selected in this paper is 38.97mm long, 38.86mm wide, and the sampling area is 1514.37mm^2. By calculation, the grid pattern a has a light-emitting area of 1296 mm^2 in the sampling area, and the light-emitting ratio is 85.6%; the grid pattern b has a light-emitting area of 1308 mm^2 in the sampling area, and the light-emitting ratio is 86.4%. The modelled grid is placed in the model of the lamp housing. After assembly, the overall model of the grid lamp can be obtained, and then the model can be imported into the simulation software to obtain the IES file of the lamp.

3.2 luminaire simulation

The finished grid lamp model is imported into Tracepro, and then the material properties of the lamp housing and the diffuser plate need to be set. Most of the grid lamp housings and diffusers on the market today use PS boards. This material has the advantages of high strength, heat aging and the like, and can replace the original material. For the diffuser, the surface property of one side close to the light source is set to a frosted surface, and the coating on one side of the grid is more uniform for the light emitted from the light source to pass through the diffuser.

I create 324 light sources at the specified position of the grille lamp, and set a total of 3.24 million light rays, then set all the parameters to trace the simulation. Since the grid pattern a is a square, theoretically, the exit angles of the 0° to 180° plane and the 90° to 270° plane are the same size, and the actual test results are consistent with the theoretical analysis results.

First I explain how the angle of the light is obtained by lighting the light distribution curve. We use the Cartesian coordinate system to represent the light distribution curve. In the Cartesian coordinate system, the unit of the abscissa is the degree, and the unit of the ordinate is the light intensity. Here, we choose a straight line to calculate. Let us take the C0°-180° plane as an example, first I determine the light intensity value corresponding to the curve peak, and then take the half of the corresponding light intensity value to calculate the horizontal curve of the half-light intensity value. The degree corresponding to the abscissa is a half-angle value, and expanding it by 2 times is the light-emitting angle of the luminaire.

It can be seen from the light distribution curve of the classroom lamp that the exit angles of the C0°-180° plane and the C90°-270° plane in the grill pattern a are all 110°. Through the calculated angle of light, we can conclude that in the actual classroom, the shape of the classroom luminaire is roughly the shape of the luminaire casing. During the installation of the luminaire, we need to calculate the distance between the lateral and vertical directions of the luminaire. It can not only meet the requirements of uniformity of illumination in classroom lighting standards, but also reduce the waste of light. It is obvious that the square grid needs further improvement in this respect

4. Light environment calculation and analysis

Illumination in classroom lighting is a parameter that characterizes the classroom lighting environment. In this paper, according to the measurement method proposed in the standard GB/T 5700-2008 "Lighting Measurement Method" [3], the central point method is used to measure the classroom illumination.

In the illuminance measurement area, the measurement area is divided into rectangular grids, the grid is the best square, and then the illuminance should be measured at the center point of the rectangular grid. The test point layout is shown in Figure 3.

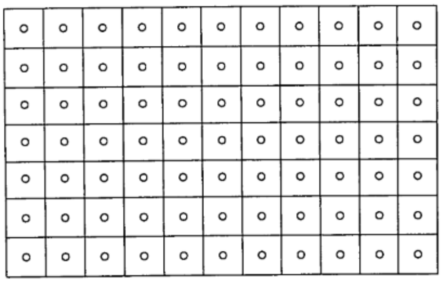

Figure 3. Grid center layout diagram

The average illuminance calculation formula is

$$Eav = \frac{\sum Ei}{M \times N} \tag{12}$$

In the middle

Eav - the average illuminance in lux (lx);

Ei - the illuminance at the i-th test point, in lux (lx);

M - longitudinal test point;

N - lateral test point.

Illumination uniformity in classroom lighting is an important indicator of classroom lighting standards, and its value is the ratio of the minimum illuminance to the average illuminance on the surface. According to national standards, the illumination uniformity of the classroom work surface should not be less than 0.7.

The unified glare value calculation formula is

$$UGR = 8lg\frac{0.25}{L_b}\sum\frac{L_\alpha^2 \times \omega}{p^2} \tag{13}$$

In the middle

Lb - background brightness in cd/m2;

ω - the solid angle formed by the illuminating part of each luminaire to the observer's eyes;

La-the brightness of the luminaire in the direction of the observer's eyes, in cd/m2;

P - the position index of each luminaire.

In this paper, the common grid lamp is tested for light distribution, and the IES files of the two grid style test results are imported into DIALux software according to the standard requirements for uniform glare worthy simulation calculation [4].

First, we build a classroom model. According to the standard GB 7793-2010 "Standards for Lighting and Lighting in Primary and Secondary Schools" [5], we set the reflectivity of the classroom ceiling, wall, work surface and blackboard to the national standard value. The size of the classroom is the standard size of the primary and secondary classrooms, and the position of the fixture is set [6]. After setting them all, import the fixture files, as shown in Figure 4. According to GB 50034-2013 "Architectural Lighting Design Standards" [7], I install a 1 UGR calculation point, place in the back wall of the center line 1.2m from the ground.

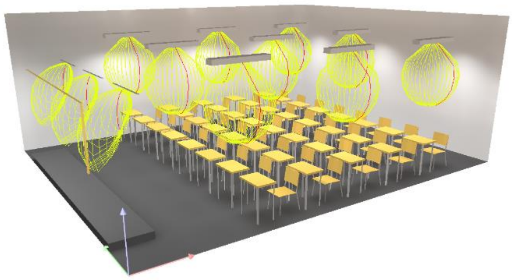

Figure 4. Classroom light environment simulation analysis diagram

Through simulation calculation, it is concluded that the UGR value of the grid pattern a in the classroom is 17, and the UGR value of the grid pattern b is 15. It can be concluded that the UGR value is reduced by nearly 12%. And through the simulation calculation of the two schemes, the illumination and uniformity of the working surface in the classroom are in line with national standards.

5. Conclusion

Through the comparison of the UGH value of the classroom working surface calculated by the classroom lighting simulation and the calculation of the mathematical formula of the classroom light environment, we can get the grid pattern a C0°-180° and C90°-270° surface. Although the light-emitting angle is the same, the light-emitting angle of the C0°-180° surface is too large, which causes the students in the back row to have a large UGR value, and it is easy to affect the students' vision. However, the grid angle of the C0°-180° surface of the grille pattern b is smaller than that of the grille pattern a. By comparison in the table, it can be concluded that the UGR value is smaller than the grille pattern a, which is reduced by 12%, and the vision for the students. The impact is smaller.

After the simulation calculation and comparative analysis, the paper suggests that the shading angle of the C0°-180° surface grille of the luminaire should be increased, which can reduce the UGR value of the classroom and reduce the influence of the classroom luminaire on the students' vision. At the same time, the angle of the C90°-270° face should be increased, so that the light output area of the lamp will not change greatly, and the light is reduced. The shading angle of the surface grille, so that the illumination angle of the Classroom work surface is better after the light angle is increased, and the installation position can be adjusted to save costs.

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