

Investigation and Research on the Light Environment of Cinema Projection Hall

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Abstract: In order to study the current situation and problems of cinema projection halls, through the survey questionnaire and practical measurement, it is concluded that: (1) there are many types of cinemas, and the light environment of cinema projection halls lacks relevant national norms and regulations; (2) Most of the screening halls are mainly direct lighting and warm light to meet the functional lighting, and only emergency lighting is reserved during the viewing process; (3) The brightness and brightness contrast of the cinema affect the visual comfort of the audience. In the light environment design of cinema projection hall, it is necessary to improve the environmental illumination, flexibly adjust the brightness of the screen, and improve the light environment of the cinema hall.

Keywords: Cinema Projection Hall; Cinema Light Environment; Brightness and Contrast; Cinema; Investigation and Research

1. Introduction

The vigorous development of the global film industry has produced huge economic benefits and has a broad consumer market and social value. In 2022, the global box office is \$25.9 billion, the North American box office is \$7.5 billion, the UK box office is 978 million, and the Chinese box office is \$7.169 billion, accounting for the majority of the box office proportion. The 14th Five-Year Plan for the Development of Chinese Film pointed out that the development and prosperity of the film industry is of great significance for promoting the construction of a strong culture. As of October 12, 2023, according to the data of the Maoyan Professional version of the national cinema business board, it can be learned that the total number of cinemas in the country reached 11,258, the operating rate was as high

as 84.57%, the online passenger flow of cinemas reached 22.91 million people, and the box office of the day was 55.38 million people, maintaining a rapid growth as a whole. At present, there are 23 types of screening halls in domestic cinemas, including: IMAX hall, CGS China giant Screen Hall, CINITY Hall, Dolby Cinema, 120 frame, MX4D hall, etc., respectively from the acoustic sound technology, optical special effects, personality needs of three aspects to divide the screening hall types. It can be predicted that the future development of the global film industry will show a better trend, and a more high-quality and healthy experience model.

During the movie-watching process, viewers are immersed in the high-brightness contrast and high-frequency flashing light environment, and the human eyes keep converging and adjusting changes, working for hours on overload. After watching the movie, there are generally symptoms such as eye fatigue, dry eyes, sour eyes, dizziness, and slow adjustment ability of distance and distance, etc. These symptoms usually last for several hours or are difficult to recover [1,2]. How to reduce the visual problems caused by watching movies has become an urgent problem to be solved in the light environment of cinema. In this paper, the IMAX hall and 3D hall of cinemas in Chongqing are investigated, the lighting mode of the cinema, illuminance, brightness and color temperature of each area during the screening process are measured, and the viewer's satisfaction with the visual experience of the light environment of the cinema is investigated by questionnaire, so as to explore the existing problems of the light environment of the cinema.

2. Research on the Development Status of Light Environment of Cinema Projection Hall

2.1 Study on the Current Regulations and Standards for the Light Environment of Cinema Projection Halls

At present, different countries have no direct guidance for the lighting design of movie theater special effects halls, and refer to the standards of performance building audience halls. CIE S 008/E-2001 Lighting of Indoor Work Place recommends that the illuminance value of the multi-function hall in the theater is 200-300, the glare value is 22, and the color temperature is 80. Other more extensive, such as the North American cinema Lighting standards refer to the "Lighting Hand book" [3], Japan's JIS-Z 9110-2010, etc., for each location of the cinema for a clear illuminance value are recommended. Domestic cinema construction refers to the "Architectural design lighting standard GB50034-2013" [4]. When the horizontal plane is 0.75m, the standard illumination value of the theater is 100lx, and the standard illumination value of the audience hall is generally 100xl-150xl.

The lighting design of the cinema screening hall can be contrasted with different colors and light and shadow, and even some special theme light can be used to bring users not only physical comfort, but also psychological pleasure [5]. In order to improve the immersive effect of movie-watching, a large number of optical technologies and new modes have been applied in movie projection [6]. In the past, due to the insufficient ability of projection technology, the projection hall of a movie theater required no light to shine onto the screen, which led to the focus of research on the light environment of the projection hall on the display effect of the screen. In terms of lighting methods, it can be divided into general lighting and local lighting. For cinemas, general activity areas of audience hall, audience rest hall, rehearsal hall, dressing room, screening room and other areas are general lighting areas [7]. Most of the auditoriums now use mixed lighting. The local light source is often set at the steps, signs, etc., as an auxiliary role. When designing these light sources, it is necessary to avoid glare. When the movie opens and ends, the auditorium lights go out and light up, and human vision has a process of adaptation to light and dark. Transitional light is needed to reduce the visual stimulation, and at the same time, it is necessary to create a unique and

immersive viewing atmosphere.

2.2 Auditorium and Its Dimensions and Shape

From the perspective of the layout of cinema halls across the country, most of the seating layout of the auditorium is sloping and flat. The space layout of the cinema screening hall is the audience area and the projection machine room area. The screen is the design basis of the auditorium, and different types of special effect halls have different requirements for the screen [8]. The size of the screen determines the size of the theater and the capacity of the audience. The shape of the screen determines the shape of the auditorium. Generally, the audience hall of the cinema with flat screen is rectangular or trapezoidal, the ground has a certain slope, and the audience area is arranged according to the spatial sequence of short row method and long row method [9]. The layout is generally based on the application of projection technology and film technology, and does not involve consideration of the visual health of the user. The plane form of the audience hall can be summarized into the following basic forms: rectangle, bell, fan, hexagonal and curve [10]. (e.g., Figure 1. Analysis of the shape of the auditorium).






Name	Draft	Advantage	Shortcoming	Example
Rectangle		The plane is regular, the structure is simple, and the sound energy distribution is uniform. It can effectively use the first reflection of the side wall	When the length exceeds 30 meters, it has a severe echo	Boston Concert Hall
Bell-shaped		It helps to adjust the sound field distribution, weaken the frame sense of the platform mouth, and is an improvement of the rectangular plane	The construction cost of curved partition wall is high. Large space between auditoriums	Shanghai Grand Theatre
Sector		At a certain capacity, its maximum distance of sight is short	The span before and after changes greatly, and the structure layout and construction are more complicated	Great Hall of Caracas, Venezuela
Hexagon		The sound field distribution is more uniform, and many remote seats are reduced	The body shape is more complex, and may increase the auxiliary area, and the central anterior area may echo	The Barbican Concert Hall, London, England
Curviline		Good sight line, magnificent momentum	Acoustic processing is more troublesome, easy to cause reflection along the edge, and even sound focusing, so that the sound	Chongqing Grand Theatre

Figure 1. Analysis of the Shape of the Auditorium

3. Investigation of Light Environment of Cinema Special Effects Hall

3.1 Research Object

By the end of 2022, there are 257 operating theaters in Chongqing, with a box office of 759 million yuan. By investigating the IMAX hall and the special effects hall of UME Cinema,

two well-known cinema chains in the main city of Chongqing, the lighting mode and optical index of the audience hall are summarized. At the same time, collect the satisfaction and comfort of the light environment of the cinema special effects hall, so as to find the current situation and problems of the cinema light environment. The main feature of the IMAX store is its IMAX Laser Hall, which can accommodate 332 people at the same time. In this research, IMAX Hall 1 is chosen as the representative of the IMAX Hall of the store: The plane shape of Hall 1 is rectangular, the space presents a slope seating layout with low front and high back. The main color of the wall is ochre red, the ceiling is stone gray, and the saturation is low. UME Cinema Group has opened a total of 14 cinemas in the main urban area of Chongqing, which is currently the largest and modern multiplex cinema in southwest China. Hall 13 (3D screening Hall) for this research is a medium-sized hall with a total of 6 rows and 81 seats. Its plane shape is rectangular, the space presents a low-front and high-back slope seating layout, the main color of the wall is brown, the seat is ochre red, the ceiling is stone gray, and the overall saturation is low.

3.2 Research Instruments and Methods

The illuminometer, luminance meter and color temperature measuring instrument were used to measure the 3D hall of Chongqing Jinyi IMAX Hall and UME Cinema, and the illuminance, brightness and color temperature of the cinema projection hall were obtained by direct measurement.

In addition, a subjective survey was conducted on audiences under the age of 60. The questionnaire content was the audience's satisfaction with the ambient light of the theater and the subjective evaluation of the eye comfort during the movie watching process, including the satisfaction with the brightness of the screen, the brightness of the ambient light and its color. A total of 325 valid questionnaires were collected. At the same time, Likert scale was used to analyze [11] the eye moderation of viewers, including slow distance adjustment, eye fatigue, dry eyes, sore eyes, headache and dizziness, and a total of 219 valid questionnaires were collected, with numbers 1-5 representing none, mild, moderate, obvious and severe respectively.

3.3 Data and Analysis of Light Environment of Cinema Projection Hall

3.3.1 Light environment data and analysis

(1) Jinyi IMAX

Table 1. Photometric Data Measurement Results of IMAX Hall 1 in Jinyi Cinema

Position	Measuring point	Illuminance value /lx	Color temperature /k	Brightness /cd/m ²
Entrance	①	3.26	3558	0.1
Onscreen	②	8.88	3278	0.3
Auditorium front	③	4.31	6307	0.3
In the auditorium	④	5.81	6109	7.36
Behind the auditorium	⑤	4.19	7158	5.1
staircase	⑥	0.25	2059	0.1

According to the lighting function area measurement method, the measurement point of IMAX Hall 1 in Jinyi Cinema City is a total of 6 points, the measurement mode is the lighting state of admission and exit, the measurement height is 0.75m height of the ground, and the measurement content includes illumination, color temperature and brightness. There are some differences among different measuring points, which are related to the installation position of the luminaire. According to (e.g., Table 1 Photometric data measurement results of IMAX Hall 1 in Jinyi Cinema), when the entrance is relatively far away from the luminaire, the illuminance of measuring point 1 is lower than that of other points. The average illumination value of the auditorium is 4.77lx, and the national lighting standard for cinema buildings is 100lx, which is significantly lower than the standard value of the specification. After entering the theater, the overall environment is relatively dim, and the audience will have a large contrast between light and dark, and there will be eye discomfort and blurred observation objects, but it can meet the needs of finding the corresponding seat and sitting down to watch the movie.

In terms of color temperature distribution, the first half of the hall is warmer than the second half of the hall, which is greater than the

middle value of 3500k, and the color temperature of the hall is in the cold light range, giving people a cold, quiet and technological atmosphere. In terms of brightness distribution, affected by the material, ground and seat of the cinema, different positions formed different brightness Spaces, except for the back part of the auditorium is relatively bright, the brightness of other positions is between 0.1-0.3cd/m², in a relatively dim state.

(2) UME Cinema

Table 2. Measurement Results of Luminosity Data in Hall 13 of UME Cinema (Jiulongpo Store)

Position	Measuring point	Illuminance /lx	Color temperature /k	Brightness /cd/m ²
Entrance	①	8.10	4154	0.3
Onscreen	②	7.10	4622	0.9
Auditorium front	③	9.00	2259	7.1
In the auditorium	④	14.00	2206	5.7
Behind the auditorium	⑤	11.00	2260	4.3
staircase	⑥	2.50	4651	0.1

According to the lighting function area measurement method, there are 6 measuring points in Hall 13 of UME Cinema City. The measuring mode is the lighting state of entrance and exit. The measuring height is 0.75m above the ground, and the measuring content includes illumination, color temperature and brightness (e.g., Table 2 Measurement results of luminosity data in Hall 13 of UME Cinema (Jiulongpo Store)).

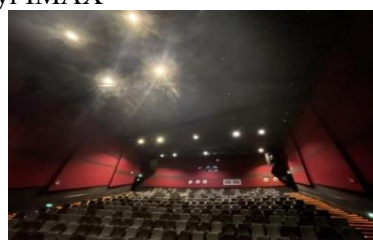
It can be seen from the sampling data that the flatness illuminance value of the audience hall is 11.33lx, which is significantly lower than 100lx. After entering the cinema, the overall environment is bright and the light source is concentrated.

In terms of color temperature distribution, the entrance, screen front and stairs are greater than the middle value, giving people the feeling of being cold and cold white, while the color temperature of the auditorium area is lower than the middle value as a whole,

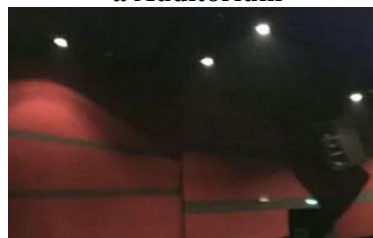
belonging to the warm light range, and the visual experience is relatively mild. In terms of brightness distribution, different positions form different brightness Spaces, the overall brightness of the auditorium is higher, and the remaining positions are affected by the reflection of the wall and ceiling.

2.3.2 Analysis of lighting mode

(1) Jinyi IMAX



a Auditorium



b Ceiling light



c. Screen light

Figure 2. Hall 1 of Jinyi IMAX

The hall is mainly direct lighting and functional lighting, with two types of lighting (e.g., Figure 2. Hall 1 of Jinyi IMAX): recessed downlights on the ceiling to meet the lighting requirements for entry and exit, and strip lights on the stairs to assist ascending and descending stairs. When the movie starts, turn off all overhead lights so that the audience's eyes are focused on the screen, leaving only the staircase strip light and the emergency sign light.

(2) UME Cinema



a. Auditorium



b. Ambient wall Light



c. Ceiling Light

Figure 3. Hall 13, UME Cinema City

The hall is mainly direct lighting, which is divided into functional lighting and artistic lighting. There are four kinds of lighting: ceiling embedded downlights and suspended spotlights on both sides, wall spot mounted wall lights, letter embedded wall lights, and stairway strip spot lights (e.g., Figure 3. Hall 13, UME Cinema City). When the movie starts, all the lights are turned off, leaving only the stair strip light and the emergency light.

3 Data of Satisfaction and Comfort in the Light Environment of the Projection Hall

3.1 Analysis of the Survey Results of Audience Hall Light Environment Satisfaction

Table 3. Survey Results of Audience Satisfaction with Auditorium Light Environment

Latitude	Statistical quantity	Quite satisfied	Satisfaction	Normal	Dissatisfy	Very dissatisfied
Screen brightness	quantity	71	94	57	54	49
	frequency	21.85%	28.92%	17.54%	16.62%	15.08%
Ambient brightness	quantity	71	75	62	71	46
	frequency	21.85%	23.08%	19.08%	21.85%	14.15%
Ambient light color	quantity	63	89	54	68	51
	frequency	19.38%	27.38%	16.62%	20.92%	15.69%

Appropriate light environment is an important condition to enhance the audience's visual experience, which can enhance the three-dimensional effect and highlight the picture details of the film, so that the audience can be better immersed in the film plot [12]. According to Table 3, 103 viewers (31.7%) were dissatisfied with the brightness of the screen. The main reason was that the contrast between the screen and the ambient brightness was too high, which caused eye irritation and reduced the viewing experience. In terms of ambient brightness and contrast, 117 viewers (36.0%) expressed dissatisfaction; In terms of ambient light color, 119 viewers (36.61%) expressed dissatisfaction (e.g., Table 3 Survey results of audience satisfaction with auditorium light environment), which may be due to the single color of the theater light.

freedom), and its significance probability is 0.000, indicating that the data is suitable for factor analysis. Finally, the loading results of the influencing factors of visual fatigue in cinema light environment were obtained, which were composed of 2 principal components -- mild and severe visual fatigue and 7 dimensions -- eye discomfort, slow adjustment of distance and distance, eye fatigue, dry eye, sore eye, headache and dizziness (e.g., Figure 4. Visual fatigue of the audience in the light environment of cinema is affected by the factor load), and the cumulative explained variance ratio was 61.807%.

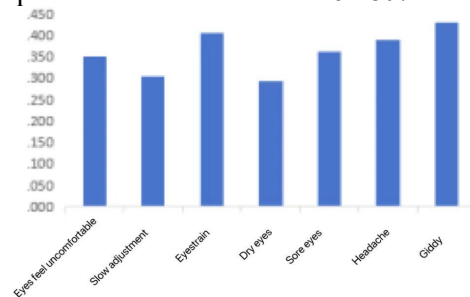


Figure 4. Visual Fatigue of the Audience in the Light Environment of Cinema Is Affected by the Factor Load

3.2 Comfort Survey Results Analysis

For the recovered questionnaire data, SPSS software was used to analyze and Barlett sphere test was adopted. The analysis results show that the KMO value of exploratory factor analysis is 0.862, the Chi-square value of Barlett sphere test is 2734.396 (21 degrees of

According to the data, various eye discomfort symptoms produced by the audience during the viewing process have a greater impact. Among them, the factor analysis load of "eye fatigue" and "dizziness" exceeds.400, which has a strong correlation. Most of the audience will

have a certain degree of visual fatigue in the process of watching movies, how to reduce this kind of visual fatigue has become an important consideration in the improvement of the light environment of the theater audience hall.

Table 4. Score Results of Audience's Eye Comfort During Viewing

Latitude	Statistical	Severity	Obvious	Moderate	Slight	None
Eyes feel uncomfortable	quantity	71	94	57	54	49
	frequency	21.85%	28.92%	17.54%	16.62%	15.08%
Slow adjustment	quantity	71	75	62	71	46
	frequency	21.85%	23.08%	19.08%	21.85%	14.15%
Eye strain	quantity	63	89	54	68	51
	frequency	19.38%	27.38%	16.62%	20.92%	15.69%
Sore eyes	quantity	71	75	62	71	46
	frequency	21.85%	23.08%	19.08%	21.85%	14.15%
Dry eyes	quantity	63	89	54	68	51
	frequency	19.38%	27.38%	16.62%	20.92%	15.69%
Headache	quantity	71	75	62	71	46
	frequency	21.85%	23.08%	19.08%	21.85%	14.15%
Giddy	quantity	63	89	54	68	51
	frequency	19.38%	27.38%	16.62%	20.92%	15.69%

The viewing time is generally about 2 hours, and the light environment of the audience hall has an important impact on the audience's eye comfort (e.g.,Table 4 Score results of audience's eye comfort during viewing). After watching the movie, most of the audience generally suffer from eye fatigue, dry eyes, sour eyes, dizziness, slow adjustment ability and other symptoms [13]. The survey results show that about 85% of the audience have different degrees of visual fatigue in the process of watching the movie, which is closely related to the brightness of the screen and the brightness of the environment, and the brightness contrast of the movie theater is too high, which needs to be paid attention to.

3.3 Comfort Survey Results Analysis

The eye has a strong sensitivity to the external light environment. Different light parameters of the light source also have great differences in the stimulation of the human eye. The light parameters of the light source are mainly illuminance, color temperature and stroboscopic [14]. Therefore, the light environment of the movie theater has a direct impact on human vision, and even affects the cognitive ability of the brain.

In terms of illuminance, according to the research of Xin Song, Hu Songtao, Liu Guodan et al. [15], under the conditions of

indoor light environment, under the three color temperature modes of 3000K, 4000K and 6000K, increasing illuminance is beneficial to improving human light comfort and improving human eye sensitivity. However, as the illuminance increases, the degree of improvement decreases (Figure 5). According to the survey data, the color temperature of the theater special effects hall is in this range. Under the premise of the illumination standard of the indoor architectural theater, appropriately improving the illumination can ensure the good lighting effect of the theater and improve the visual comfort of the audience.

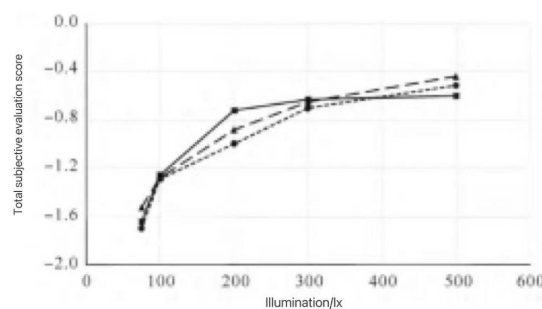


Figure 5. Relationship between Illumination Improvement and Visual Comfort Evaluation under Three Color Temperature Modes

In terms of brightness, according to the study of Sun Guilei et al. [16], when the continuous viewing time exceeds 45 minutes in a dark

environment, the cumulative fatigue degree of the subjects is the lowest when the display brightness of 58.24 cd/m² is selected. Therefore, the cinema can flexibly adjust the brightness of the screen with the viewing time to reduce the visual fatigue of the audience.

4. Results and Discussion

Through the summary of the nature and mode of the audience hall, and the field investigation and questionnaire analysis of the IMAX hall and 3D screening hall of the representatives of two cinemas in Chongqing, the following conclusions are drawn:

(1) Most of the special effects halls in the main urban area of Chongqing are mainly direct lighting, and the lamps are generally installed on the ceiling and wall. The main types are downlights or spotlights, and some wall lights and strip lights are assisted. More is the functional lighting, to meet the audience's demand for seats before the opening of the movie, some theaters contain artistic lighting, to meet the audience's demand for seats before the opening of the movie, some theaters contain artistic lighting, in order to highlight the brand and cinema characteristics and increase the role of atmosphere.

(2) From the perspective of illuminance data, the cinemas of the two cinemas are significantly lower than the standard value of the national audience hall. From the perspective of the actual screening function of the cinema, all the lights need to be turned off and on during the screening and the end of the film, so it is speculated that the illumination value of the cinema is obviously low when entering and leaving the theatre, so as to reduce the dark adaptation process of the audience and avoid sudden changes in light and shade, which will cause the audience's eye discomfort. Only basic functions need to be met.

(3) From the point of view of color temperature and brightness value, the color temperature of the theater affects the visual and psychological feelings of the audience. The overall color temperature of Jinyi IMAX Hall 1 is greater than 3500k, which belongs to cold white light, giving people a serious and cold feeling. In contrast, the color temperature of the audience hall of UME Cinema Hall 13 is lower, giving people a warm feeling and higher visual comfort, and the rest of the

location is cold white light. As a place for leisure and entertainment, the cinema should bring the audience a relaxed and comfortable experience, and it is recommended to use warm tone lighting.

(4) From the perspective of spatial brightness data, the brightness of the cinema affects the visual comfort of the audience. The brightness of the two cinemas is slightly higher than that of other areas, in order to ensure a good viewing effect for the audience, and the brightness of other areas should also be appropriately improved.

(5) The audience's satisfaction with the auditorium and eye comfort are closely related to the light environment. In the construction of the light environment of the multiplex cinema, the subjective feelings of the audience should be fully considered, and the comfort and satisfaction of the lighting design should be improved. It can be improved by improving the ambient illumination, flexibly adjusting the brightness of the screen, and improving the ambient atmosphere of the cinema.

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