Light color performance analysis of LED take-off and landing signal lights in special weather conditions

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Abstract: The take-off and landing signal light is an integral part of the ship's helicopter surface-assisted lighting system and light attenuation under special weather conditions are different. In this paper, the light color performance of an actual take-off and landing signal light are tested and the transmission characteristics under special weather conditions are analyzed. The methods of increasing the forward current and turn on the standby light source are studied. In this paper, the mathematical relationship between increasing current and increasing transmission distance is studied. The calculation of the example shows that the variation of the transmission distance of the take-off and landing signal by changing current is effective to adapt to weather conditions. For an example, the transmission distance of the given lamp is increased about 300 meters when the current is increased from 350 mA to 400 mA in sunny weather.

1. Introduction

Take-off and landing lights are important luminaires to ensure that the ship's helicopters take off and land safely in different weather conditions. Due to the application of LED light source technology, the light color characteristics of signal light are very different from those of traditional light sources. Based on the Light transmission under different weather conditions, the optical design of the traffic signal light system has been researched to adapt to the lighting requirements under special conditions [1-4]. However, there are few studies on the application of take-off and landing signal lights under special weather conditions. This paper studied the transmission performance of signal lights in special environments and improved the application performance in special weather conditions.

2. take-off and landing lights

The take-off and landing signal light studied in this paper is a component of the ship helicopter's surface-supporting lighting system. It is suitable for all kinds of helicopter-equipped ships and offshore drilling platforms for helicopters at night. The lamp is suitable for ambient temperature -25 ° C ~ +50 ° C, protection level IP66. The input voltage of the lamp is AC220V/50Hz~60Hz. The light source adopts LED light source, which is divided into three sets of used light sources and three sets of standby light sources. The power of each set of light sources is 5W. The red light means that the carrier aircraft is forbidden to land, the yellow light represents the carrier aircraft waiting for the landing, and the green light indicates that the carrier aircraft is allowed to land.

The light source of the take-off and landing signal light is red, yellow and green light source from top to bottom. There are six sets of take-off and landing signal lights working independently, three of which are ordinary light sources and three sets of alternate light sources. Each set of signal lamps has a luminous power of 5W and a current of 350mA.

The colorimetric performance of the take-off and landing signal is the basis of studying transmission distance. In this paper, the monochromatic light of the signal lamp is sampled by a 0.3m sampling integrating sphere and analyzed by a 380nm~780nm band spectrum analyzer with the sampling interval 5 nm.

The test environment temperature is 21°C and the humidity is 60%. Using the sampling integrating sphere and the spectrum analyzer to perform the spectral test, the spectrum of the red, yellow and green lights of the take-off and landing signal lights is shown as follows:

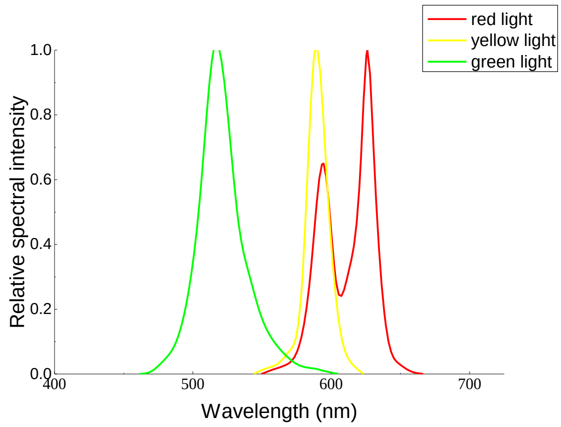

Fig. 1. Relative spectral intensity – wavelength image

According to the spectrogram analysis of Figure 3, the wavelength range of red light is 625 nm to 740 nm with the central wavelength 625 nm, 492 nm to 577 nm for green light with the central wavelength 515 nm, 570 nm to 585 nm for blue light with the central wavelength 590 nm.

The photometric characteristics are measured in a darkroom using a distributed photometer. The intensity of the central light is calculated by inverse law of irradiance square:

$$E = \frac{I_0}{r^2}\cos\theta \tag{1}$$

I_0 is the central intensity of the luminaire and r is the distance from the luminaire to the illuminated area. I_0 is the central intensity of the luminaire and r is the distance from the luminaire to the illuminated area. After testing the photometric information of different color light sources, the results are as follows:

Table 1. The illuminance and light intensity parameters of red, yellow and green light

	Red light	yellow light	green light
The dominant wavelength	$\lambda = 625$nm	$\lambda = 590$nm	$\lambda = 515$nm
$E(lx)(2.3\text{m})$	7.0	7.9	14.8
I_0（cd）	35.3	40.9	75.9

3. Transmission distance

The transmission distance of the take-off and landing signal light is an important parameter determining the performance of the ship's take-off and landing signal light. The transmission distance of the light is greatly affected by the weather. In order to analyze the transmission distance of light, the atmospheric transmittance formula using light to propagate in the atmosphere is:

$$T = I/I_0 = \exp\left(-\int_0^L \beta dl\right) \tag{2}$$

Where T is the atmospheric transmittance, β is the large attenuation coefficient, L is the maximum transmission distance, I is the attenuated light intensity, and I_0 is the light intensity of each color.

Among them, β has different values for different weather. Several typical weather are analyzed, including sunny, fine, light haze, haze, light fog, moderate fog, thick fog [6-9]. The attenuation coefficients for visible light (350~750nm) under different weather conditions are as follows:

Table 2. The attenuation coefficient of light in different special weather conditions

Weather condition			attenuation (*dB/km*)
	snow	rain	
Thick fog	-	-	-84.95
Moderate fog	√	-	-33.96
Light fog	√	√	-21.3 ~ -14.54
Haze	√	√	-6.6 ~ -3.13
light haze	√	√	-3.05 ~ -1.13
Fine	√	√	-1.53 ~ -0.56
sunny	-	-	-0.7 ~ -0.21

From Table 2, the attenuation coefficient of light in different degrees of smog weather and sunny weather and the attenuation coefficient of rain or snow weather with close visibility can be obtained.

According to the central light intensity obtained by the experimental test and the attenuation coefficient of different weathers [10-12], the relationship between the light intensity I(cd) and the transmission distance L(m) of the take-off and landing signal light after attenuation in different weather conditions is as follows:

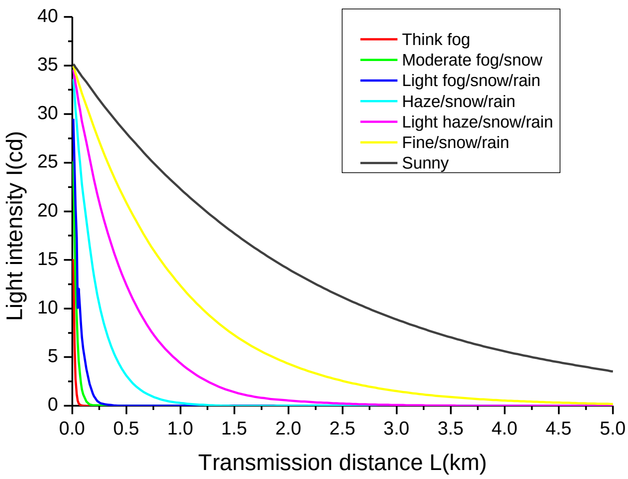

Fig. 2. Relationship between red light intensity and transmission distance

The intensity of the light attenuation according to the transmission distance in the different weather is shown in Figure 2. Transmission distances of the light in the weather of thick fog, moderate fog/snow, light fog/snow/rain, haze/snow/rain, light haze/snow/rain, fine/snow/rain and sunny are showed by the yellow, purple, blue, red, green, blue and black line respectively. As can be seen from the figure, the light intensity gradually decreases along with the transmission distance increasing. In the thick fog weather it decreases fastest and in the sunny weather it decreases slowest. The heavier the haze, the smaller the atmospheric transmission distance of the three color lights. The weather has great impact on the transmission distance.

4. Compensation of Light Intensity under Different Weather Conditions

4.1 Compensation analysis

In order to ensure the take-off and landing signal to take effect, the following methods can be used to compensate the color of the light and ensure the transmission distance, which are to increase the current and turn on the standby light source.

4.2 Increase the current

Since the light source is a Lambertian emitter $\mathrm{I} = I_0 \cos\theta$, the relationship between the luminous flux $\varnothing$ and the light intensity I_0 can be expressed as follows:

$$\emptyset = I_0 \int_0^{2\pi} d\varphi \int_0^{\frac{\pi}{2}} \cos\theta \sin\theta \, d\theta = \pi I_0 \tag{3}$$

The luminous flux of LED can be enhanced by increasing the current. In Fig. 8, the relative luminous flux of red, yellow and green light is showed by the red, blue and green line. As required by the specifications of red, yellow and green LED, the maximum forward currents are 700mA, 500mA and 1000mA respectively.

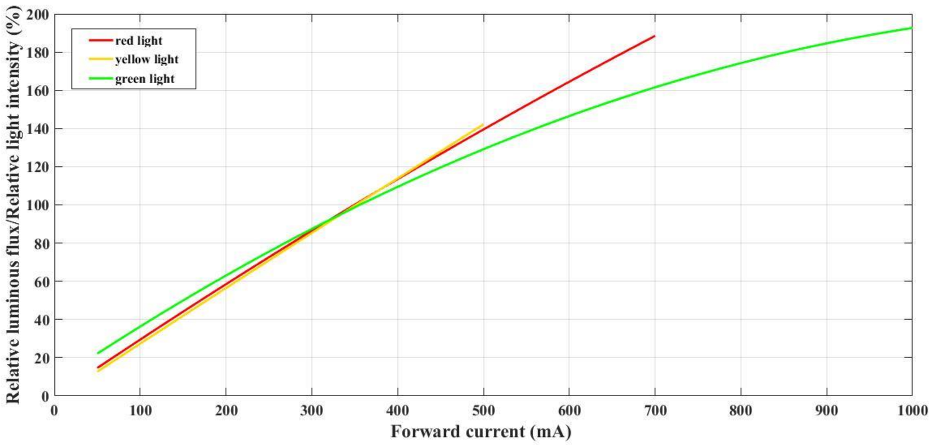

Fig.3. Relative luminous flux / relative light intensity - forward current relationship image

From the figure 3, with the current increasing from 138.8 mA to the maximum current, the relative luminous is increased. According to the formula（2）, the transmission distances in different weather are calculated along with the increasing of forward current. For the three color light the maximum forward current are different and the results are shown in Figure 4 to Figure 6 are as follows:

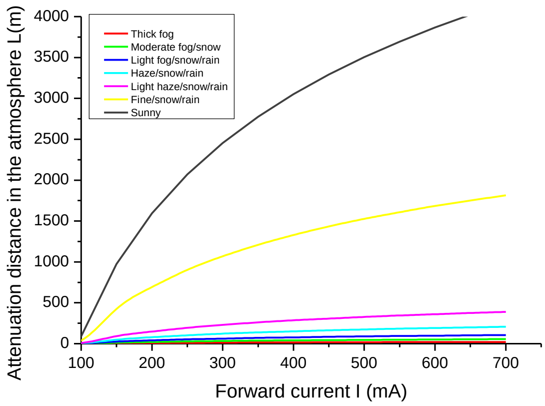

Fig. 4. The relationship between forward current and transmission distance for red light

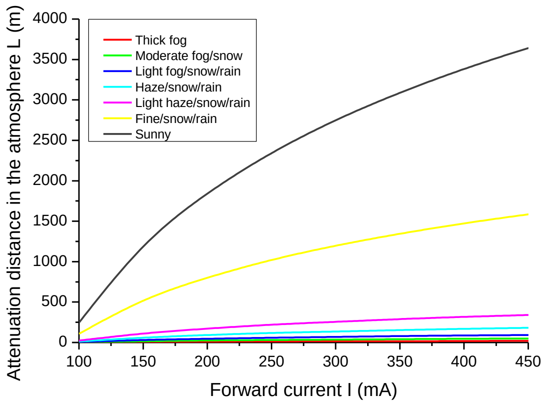

Fig. 5. The relationship between forward current and transmission distance for yellow light

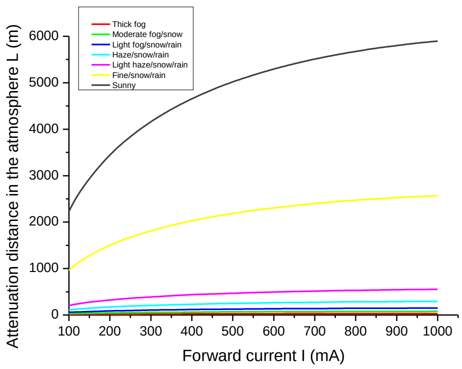

Fig. 6. The relationship between forward current and transmission distance for green light

In Figure 4 to Figure 6, the transmission distance of the light in the weather of thick fog, moderate fog/snow, light fog/snow/rain, haze/ snow/rain, light haze/snow/rain, fine/snow/rain and sunny is showed by the green, purple, ice blue, red, yellow, blue and black lines; the transmission distance of the light in the weather of sunny is showed by the black line. It can be seen from the figure that the clearer the weather, the greater the influence of the forward current value on the transmission distance. Taking the case of sunny days as an example, the influence of increasing positive current is analyzed. Under the normal condition, while the forward current of signal lamp is 138.8mA in the sunny weather, the transmission distances of red light, yellow and green light are 2772m, 3096m and 4454m respectively. When the increased forward current is 400mA, the transmission distances are 3088m, 3364m and 4733m respectively. It can be seen that the light transmission distance can be effectively increased in different degree by increasing the forward current.

5. Conclusion

In this paper, the chromaticity performances test of the red, yellow and green light sources of the take-off and landing signal lights are tested and analyzed. According to the attenuation coefficient of visible light in several typical weather conditions, the transmission distances of the light source under different weather conditions are calculated. It is found that the light transmission distance can be effectively increased in different degree by increasing the forward current. It is necessary to compensate the light color performance under the special weather environment by the forward current.

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