Engineering Structures 132 (2017) 531–539

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

New obstruction lighting system for aviation safety

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ARTICLE INFO

Article history:
Received 5 October 2015
Revised 18 November 2016
Accepted 21 November 2016

Keywords:
Beacon
Repair
Maintenance ease
Work safety
Availability
LEDs
Integrating spheres
Optical fibers

ABSTRACT

Signposting and illuminating obstacles is meant to reduce risks to aircraft by aiding the pilot in locating dangers. However, many of the obstacles to air transport, such as telecommunication towers, can surpass heights of 45 m. This implies that the installation or repair of the beacon system can involve serious risks to the personnel in charge of such work, as the tower must be climbed with the use of harnesses, helmets, and other means of protection with the hazards that these involve. To avoid these drawbacks, in this study we have designed an obstruction lighting system in which the light source lies at the base of the structure and the light, travelling through a bundle of optical fibers, rises to any point of the telecommunication tower, pole, chimney, stack or similar skeletal structures. Therefore, the proposed system would provide a major improvement in safety, not only for air traffic, but also for workers.

1. Introduction

The rapid development of LEDs (light-emitting diodes) as new sources of light emission have made them the current light indicators in electronic devices and systems, light-signalling systems, and exterior and interior illumination systems.

As the characteristics of LEDs have improved with the introduction of new manufacturing and design technology, in-depth studies have been made regarding the application of these as signalling and illumination systems in general [1–6]. These studies have been made by companies which specialize in the manufacture of illumination systems based on LED technology, such as traffic lights and street lights.

Illumination systems with LEDs constitute an effective and low-cost alternative for signalling fixed obstacles (chimneys, telecommunication towers, high buildings, etc.) and even mobile ones, although the position of these signalling devices, as with conventional beacons, poses problems.

The signalling and illumination of obstacles is intended to lower the risks for aircraft, as it helps the pilot to locate potential dangers. This does not necessarily diminish the limitations of operation imposed by an obstacle, but when it is not possible to eliminate the obstacle and it does not affect the safety or regularity of air service, the obstacle should be properly signposted and illuminated to be seen clearly by pilots under any weather and visibility conditions.

Markers displayed on or adjacent to objects shall be located in conspicuous positions so as to retain the general definition of the object and shall be recognizable in clear weather from a distance of at least 1000 m for an object to be viewed from the air and 300 m for an object to be viewed from the ground in all directions in which an aircraft is likely to approach the object [7].

It should be taken into account that many of the obstacles for air transport, such as telecommunication towers, high-voltage towers, or wind turbines can reach heights of more than 45 m. This implies that the installation or repair of any beacon system can involve serious risks to the workers in charge of these tasks, as the tower must be climbed with harnesses, helmets and other protective devices that in themselves represent hazards and discomfort for the worker. In addition, the tools used (usually heavy) can fall from considerable heights and injure operators at the foot of the tower. Furthermore, the beacons of the telecommunication towers can weigh between 5 and 20 kg, so that a 300 m-high tower with 14 beacons could bear weights of more than 280 kg in light signalling alone.

To avoid the above drawbacks, in this study we have designed an obstruction lighting system for fixed obstacles. The new system consists of placing a LED matrix at the bottom of the obstacle; by

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http://dx.doi.org/10.1016/j.engstruct.2016.11.054
0141-0296/

means of integrating spheres and optical fibers, the light is conducted from the bottom to the top of the structure that needs to be illuminated. In this way, when it is necessary to make a repair, operators do not have to climb the structure, since the repair is made on the ground. Finally, we have calculated the parameters of the new obstruction lighting system that meets the International Civil Aviation Organization (ICAO) lighting requirements [7,8].

2. Materials: LEDs, integrating spheres, and optical fibers

In this study, we have used materials that comply with the rules of the FAA (Federal Aviation Administration) of the U.S. Department of Transportation [9], which are more restrictive than international regulations in terms of working at certain temperatures and humidity, etc.

2.1. Red LED

For the design of the system, we propose an encapsulated LED that permits the formation of matrices in a practical, convenient way. The LED, chosen for its characteristics, was SST-90-R LEDs from Luminus Devices, Inc. This LED is used in many applications, for instance, as beacons and obstruction lighting.

The LED emission area is 9 mm^2, the luminous flux is 1500 lm at 9 A, the radiant efficacy at this wavelength is 269.0 lm/W, and the dominant wavelength 618 nm. It has a DC forward voltage of 2.5 V (system operating on DC volts 24–48 V [9]), a DC forward intensity current of 350 mA (current 75–500 mA [9]), an operating temperature of between −40 °C and 120 °C (−40° to 55 °C [9]), and a limit maintained temperature of 217 °C.

2.2. Integrating sphere

To collect all the luminous flux which exits the LED into the optical fiber, we have incorporated an integrating sphere into our design. The 2″ (50.8 mm diameter) sphere used are from Edmund Optics Ltd.

The reason for using this device is to collect the spatial radiant flux in order to spatially integrate the flux to maximize its injection into the optical fiber.

The sphere is coupled with the LED in a port, and in a second port in front of it, we couple the optical fiber with a SMA connector to inject as much light as possible within the optical fiber.

The inner reflectance of the integrating sphere is 0.95.

2.3. Optical fiber

The optical fiber proposed is the FV100010501250 from Polymicro Technologies™. The core diameter, cladding, and buffer are 1 mm, 1.05 mm, and 1.25 mm, respectively. It is an optical fiber with a profile-step index, high —OH silica core, doped silica clad, and high-temperature acrylate buffer. The optical fiber can operate between −65 °C and 300 °C (intermittently up to 400 °C). It has a numerical aperture of 0.22 and its full acceptance cone is 25.4°. The attenuation is 30, 15, and 10 dB/km around 457, 586 and 630 nm, respectively.

A silica optical fiber was chosen because the degradation is less than for plastic optical fiber (POF) [10].

The LED emits a light beam which enters the integrating sphere and then the light enters the endface of the optical fiber (changing the refractive index); at the exit, again, there is a change in the refractive index, from optical fiber to air. Therefore, it is essential to take into account the Fresnel reflection loss twice. The calculated Fresnel reflection loss is 0.74 dB.

3. Results and discussion

The general scheme is shown in Fig. 1. More specifically, we have developed our design for a telecommunication tower, although it could be applied to any fixed structure mentioned in Annex 14 of the Convention on International Civil Aviation [7,8].

As mentioned in Section 2.3, the LED emits a light beam which enters the integrating sphere and then the light enters the endface of the optical fiber.

Therefore, it is essential to take into account the Fresnel reflection loss due to the change in the refractive index. The calculated Fresnel reflection loss is 0.74 dB.

We have simulated all the radiation process with Zemax-EE V. 2005. Dimensions of the LED are shown in Fig. 2.

We then modelled the integrating sphere with Zemax in the same way.

Fig. 3 shows the shaded model of the 2″ integrating spheres.

Fig. 4 shows the power injected into the optical fiber at the exit of the integrating sphere.

The peak of irradiance is 5.22 W/cm^2 and the total power 5.05 W.

Fig. 5 shows the general schematic of the device, as well as the situation of the elements for a telecommunication tower.

Following the amendment 11 to Annex 14 [8], for poles, radio, and television towers and similar skeletal structures, the light must be type B fixed of low-intensity and type C fixed of medium-intensity. We present the results for the different heights in Fig. 6.

3.1. Tower up to 45 m

The power at the endface of one optical fiber is:

$$P_o = P_i e^{-\alpha L} - A_F = 3.21\ \text{W} \quad (1)$$

where P_i is the entrance power in the optical fiber, α is the attenuation coefficient, L the length of the optical fiber for tower up to 45 m, and A_F is the Fresnel reflection attenuation.

The luminous flux is:

$$F_v = F_r 683 = 2192.43\ \text{lm} \quad (2)$$

Now we have to calculate the luminous intensity of the far-field pattern (FFP) and we need to know the N.A. of the optical fiber. It depends on the distance of the optical fiber [11,12].

In the articles of Losada et al. [11,12] for optical fibers longer than 60 m, the asymptotic trend for the exit N.A. is 0.46, corresponding to a full angle of 54.77°. For this angle, the relative intensity is 5%. The luminous intensity in the endface of the optical fiber is:

$$I_v = \frac{F_v}{\Omega} = 313204.29\ \text{cd} \quad (3)$$

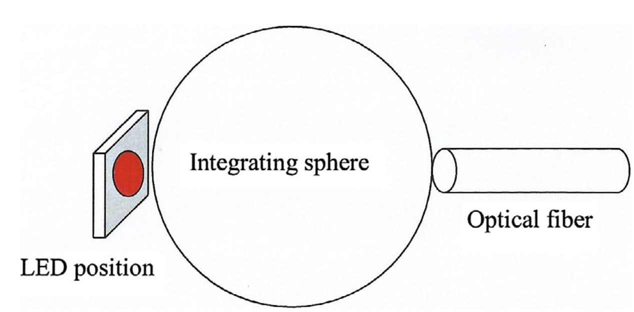

Fig. 1. General scheme of the device. The LED emits a light beam which enters the integrating sphere, and the beam is focused on the endface of the optical fiber.