한국산학기술학회논문지
Vol. 8, No. 3, pp. 477-482, 2007

Development of Basking Neodymium Lamp Improving Reflector Globe and Rhenium Filament

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레늄 필라멘트와 반사 글로브를 개선한 Basking Neodymium Lamp의 개발

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Abstract This paper examines and analyzes improvement of structure of bulb, increase of luminous efficiency through application of reflector globe through aluminum coating and development of 60[W] basking neodymium lamp through optimum insertion ratio of krypton gas and nitrogen gas. The results of this development shows that the life of the lamp was 7,200 hours, and the luminous flux was 620[lm]. This brings in superior color temperature and superior color rendering index, which allows us to use that lamp for agricultural or general purpose.

Key Words : Basking neodymium lamp, Rhenium Filament, Krypton, Reflector

요 약 본 논문은 램프의 벌브 형태 개선과 알루미늄 코팅에 의한 리플렉터 글로브의 적용으로 광을 집적하여 증가시키고, 레늄 필라멘트의 적용에 따른 장 수명과 크립톤 가스와 질소가스의 최적 주입 비율을 통한 60[W]급 Basking Neodymium Lamp 개발에 관한 것으로 이를 측광, 분석하였다. 개발결과 수명은 7,200시간, 광속은 620[lm]이며 색온도와 연색성 또한 우수한 것으로 나타나 농업용과 일반용 램프로써의 그 가능성을 확인하였다.

1. Introduction

Neodymium bulb is made of a special bluish glass known as neodymium glass. Light blue filter materials that slightly attenuate a broad range of the spectrum from green through red, neodymium glass has a narrow absorption band in the yellow and yellow orange. A neodymium bulb glows with a whiter color like that of some halogen lamps.

The special effect of the neodymium glass filtering is to achieve more red and green output than usual for a light source of a given brightness and overall color. This causes red and green objects to look slightly brighter and more intensely colored than usual. The "triphosphor" type fluorescent lamps, including most compact fluorescent lamps, have a similar effect except that its fluorescent composition makes bright pure reds look slightly orangeish. Neodymium bulbs are dimmer than unfiltered incandescent bulbs of the same wattage and life cycle[1][5].

Filament bulbs has a slightly lower efficiency but offers warm color temperature required in dwelling spaces as well as not requiring a lightning device, and also does not use harmful gases such as mercury and neon. This research increases light efficiency through use of reflector globe in addition to basic characteristics of neodymium bulbs, which increases life expectancy through use of rhenium filament. And by mixing krypton gas and nitrogen gas at an optimal ratio, high efficiency and long life expectancy shall be realized.

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2. Background

2.1 Overview of neodymium lamp

Neodymium lamp, unlike ordinary lamp, emits a blue light from the neodymium bulbs as seen in [Fig. 1] The amount of neodymium contained in the glass material constituting the front lens is preferably in the range of 0.5 to 5[%] by weight. In case where the weight is less than 0.5[%] the absorption of yellowish lights would be insufficient with a result that we failed to obtain a desired effect which can be expected from causing neodymium to be contained in the glass material. Further, in the case of more than 5[%] by weight, the absorption of yellowish light is excessive, so that the other colors such as red become too impressive and the lamp has unnatural colors as a whole. Therefore, appropriate amount should be selected by adjusting the weight with considerations to the specific purpose of the lamp. To maximize the efficiency, krypton gas was used, and for aluminum coating of the lamp bulb, an aluminum piece was placed at a temperature of 2,500[℃], which was spontaneously disintegrated in vacuum air pressure and high efficiency was achieved through reflector globe. The material of the filament is either the usage of pure tungsten with 99.99[%] purity or the use of thorium tungsten (1[%] or less thorium) or rhenium tungsten (3[%] or less rhenium). In this research the filament of the latter case was utilized to improve the life expectancy.

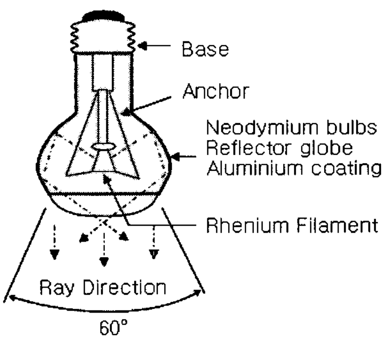

Fig. 1 Construction of the neodymium lamp

2.2 Reflector Globe

Looking at [Fig. 2] if luminous intensity of the sphere at the center is $I(\gamma)$, zonal factor is Ω, then calculation of luminous flux

$$F = I_{\gamma}\int d\Omega \quad (1)$$

the summation of the products gives the flux value required:

$$F = \sum I_{\gamma}\Omega \quad (2)$$

the zone defined by angles γ_1 and γ_2 can be considered to be the difference in the solid angle for γ_2 and that for γ_1:

The solid angle related to $\gamma_2 = 2\pi I(1-\cos\gamma_2)$. The solid angle related to $\gamma_1 = 2\pi I(1-\cos\gamma_1)$

The required solid angle is given by :

$$2\pi I(1-\cos\gamma_2) - 2\pi I(1-\cos\gamma_1) \quad (3)$$

$$\Omega_{\gamma 1,\gamma 2} = 2\pi I(\cos\gamma_1 - \cos\gamma_2) \quad (4)$$

$F = 2\pi(\cos\gamma_1 - \cos\gamma_2)$ is called the zonal constant and the value of each sections differs according to the angle[2][7].

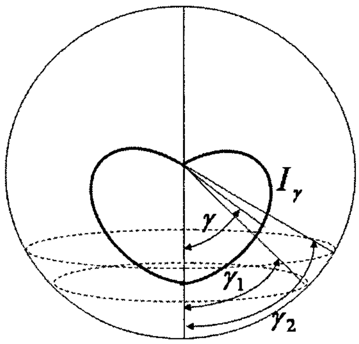

Fig. 2 Flux calculation of the zone factor

If luminous intensity value is I in all γ then luminous flux $F = 4\pi I$ (5)

The comparative calculation of luminous flux reflected into identical zones in the case of a reflector being used where an identical light source reflects the light in all directions at a brightness of 1,000[cd] is

-With reflector (Pass through reflector)

$F_{(60\rightarrow180)} = 2\pi \cdot 1,000(\cos60 - \cos180) = 3,000\pi[lm]$

Considering the effect of the reflection ratio (approximately 80[%])

$F_{60\rightarrow180(reflected)} = 0.8(3,000\pi) = 2,400\pi[lm]$

-With reflector (Non pass through reflector)

$F_{(0\rightarrow60)} = 2\pi \cdot 1,000(\cos0 - \cos60) = 1,000\pi[lm]$

Therefore,

$= 2,400\pi + 1,000\pi = 3,400\pi[lm]$

-Without reflector

$F_{(0\rightarrow180)} = 2\pi \cdot 1,000(\cos0 - \cos180) = 4,000\pi[lm]$

if until 60°

$F_{(0\rightarrow60)} = 2\pi \cdot 1,000(\cos0 - \cos60) = 1,000\pi[lm]$

In conclusion, inclusion of a reflection panel increases luminous flux by 3.4 times.

3. Experiment and discussions

3.1 Calculation of Rhenium Filament

Filament is a critical part of a bulb, and its quality differs greatly according to the processing procedure or heat process from the original tungsten metal. In particular, the filament coil should be constructed after analysis of pulling during processing, growth of crystal during heat treatment, crystal dislocation after bulb assembly, vacuum ratio, pureness of the sealing gas and pressure. Due to this, production conditions of the bulb process such as initial characteristics of the bulb, life cycle, stretching during lighting and blackening should be comprehensively examined and designed. In designing a filament coil, the main factors include the thickness of tungsten line, differences in thickness, length of tungsten line, thickness of mandrel, coil pitch and its number of times, in particular the relations between the thickness and length of double tungsten and the decision on mandrel and pitch. There are many factors effecting the characteristics of neodymium lamp, and the construction of the filament is different from the experience and method of the creator rather than depending on some theoretical formulae or rule[3]. The important factors of a tungsten for a filament are specific resistance (ρΩ-mm), whole radiation(μw/㎟), and luminous efficiency (lm/W). A filament should have large specific resistance. As seen in [Fig. 3] if the temperature of the lamp is known the corresponding values can be calculated. Also, as efficiency and life expectancy of the filament is an important variable, the following straight filament calculation may be worked out with the value of the temperature of the filament.

$$lm/W\ (Efficieny) = (1-a) \times (1-\nu-g) \times Z \qquad (6)$$

where,

a : light absorption factor of the bulb (approximately 0.02)

v : loss factor due the heat conduction of the electrode and anchor (approximately 0.035)

g : loss factor due to heat convection of the gas (0.05~0.4) and g=0 in case of vacuum lamp.

Z : blackening factor(0.91~0.95)

lm/W lamp : efficiency (per 1000 hours) in regulations of IEC and KS, while [lm/W] is the efficiency of straight tungsten line in vacuum. Filament diameter G[mg/200mm] and length L[mm/volt] may be calculated as follows.

$$G = 1,665 \times \{\frac{\rho}{\eta} \times \frac{1-\nu-g}{\varphi} \times I^2\}^{2/3} \qquad (7)$$

$$L = 0.43 \times \{\frac{1}{\rho\eta^2} \times \frac{1-\nu-g}{\varphi^2} \times I\}^{1/3} \qquad (8)$$

where,

ρ : efficiency

η : sum value of infra-red, ultra-violet ray and heat

I : currency of the lamp [A]

ϕ : reduction coefficient (0.65~0.7) due to whole radiation of the coil filament

G and L in formula (7) and (8) is calculated depending on efficiency and current. To this additional factors such as the model of the lamp, mandrel wire and the length of the pitch and the coil should also be considered. A coiled coil gas lamp of 220[V]-60[W], the lamp current is 0.27[A] and according to [Fig. 4] the efficiency [lm/W] Lamp and the values of G and L may be calculated.

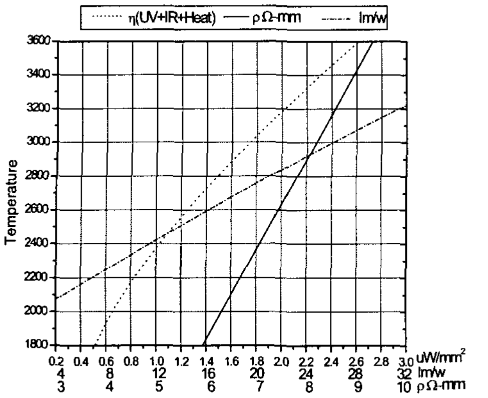

Fig. 3 Relation with factors according to the temperature

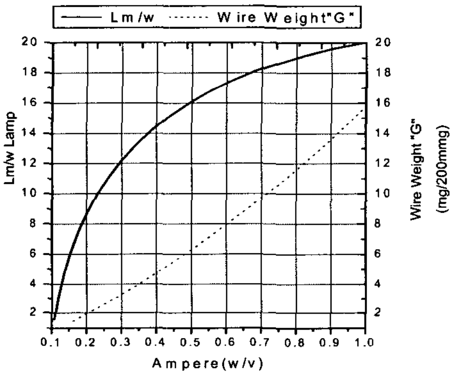

Fig. 4 Coiled coils gas-filled 0.15~0.8[A] efficiency & wire weight

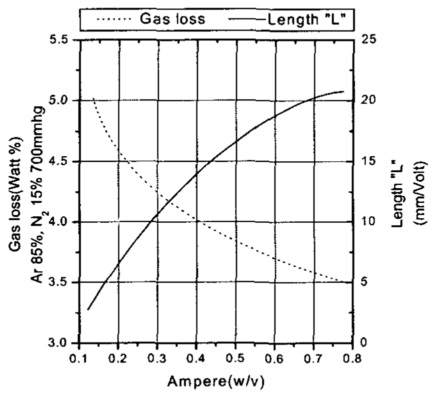

Fig. 5 Coiled coils gas-filled 0.15~0.8[A] gas loss & length

Efficiency [lm/W] Lamp should be 12.1[lm/W], wire weight G should be 3[mg/200mm], length L should be 4[mm/volt] and is 220[V] therefore whole length is 220×4=880[mm], and the heat convection g of gas should be 12.5[%][see Fig. 5].

3.2 Determination of mandrel wire and pitch

Coiled filament is made by wrapping a tungsten wire around mandrel wire than dissolving the mandrel wire through chemical means. In case of double coiled filament, by cutting the filament wire in a certain length, the length of the wire is shortened if the mandrel is slightly thick or thin, which affects the characteristics significantly. Also, if the pitch becomes tighter or broader, the number of times wrapped around the pitch is increased or decreased, affecting the characteristics drastically. The data on mandrel wire and pitch is shown in [Table 1].

Table 1. Depending on coil

Description	Fill gas	
	Coiled coil	
	First coil	Second coil
Wire diameter G[mg/200mm]	Fig. 5	
Wire length L[mm/volt]	Fig. 6	
Diameter of mandrel wire	1.8~2.2	1.8~2.2
Material of mandrel wire	Molybdenum	Molybdenum or steel wire
Coil pitch	1.5~1.9	1.5~1.9

3.3 Production of filament

Molybdenum is used as supplementary material for dissolving after the structure is complete by using tungsten as the primary material. By wrapping the original tungsten material around a small mandrel wire frame, then wrap the tungsten on top of molybdenum in form of a coil. In this process, if the wrapping is done once, it is a single coil, twice a coiled coil, and three times a triple coil. In case of a single coil, where the length of the completed filament may be long, it is usually used in incandescent lights while coiled coil and triple coil are usually used for smaller places with fluorescent lamps. To preserve perfect structure, it is heat processed twice repeatedly, cut into appropriate size, then molybdenum is dissolved in a place with mixture of water, nitric acid and sulfuric acid to complete pure filament.

3.4 Krypton gas density

The light emitting amount and the life cycle of an incandescent bulb is inversely proportional. Coil has electric resistance according to the laws of Ohm, in case of a MG with constant coil, if the length is shortened 1[%] the currency is increased 1[%], along with temperature rise. The evaporation ratio of tungsten at 2,500[℃] is 7×10-8[g/㎠ · sec] and at 3,000[℃] 2.4×10-5[g/㎠ · sec], meaning that with 500[℃] rise in temperature of the filament, the evaporation rate is increased by 343 times. Therefore, the operation temperature of incandescent bulb is 2,500[℃], where gas bulb evaporates faster than vacuum bulb in same conditions.

4. Result of the experiment

The gas used in this research was krypton, with more than 25[%] inserted, the filament would short circuit upon lighting, causing spontaneous explosion. The reason for use of the krypton gas was that it is a heavy gas among non flammable gases, and with the evaporated tungsten particle bouncing off the heavy krypton and returning to its origin, the efficiency and life cycle of the lamp may be increased as well as reducing the size of the lamp itself. As seen in [Fig. 6] the wave of neodymium lamp shows little brown area. [Figure 7] shows color metric properties where measured chromaticity coordinate is x=0.4382, y=0.4055 and color rendering index at 99.

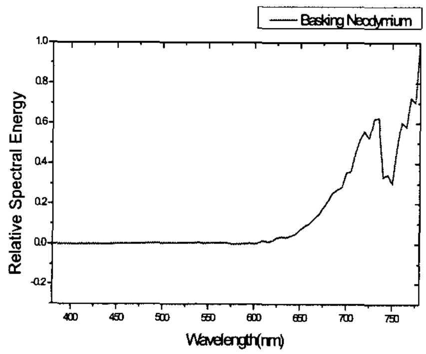

Fig. 6 Wavelength

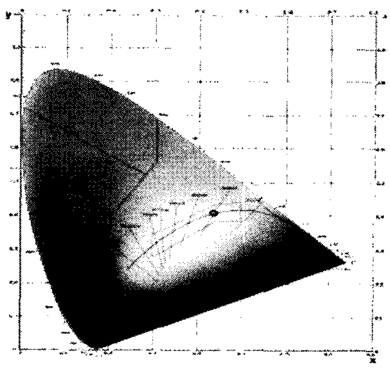

Fig. 7 Color metric properties

Results of candela measurements, [Figure 8] and [Figure 9] shows candela distribution x-y plot plan.

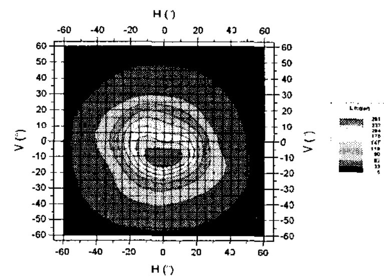

Fig. 8 Candela distribution x-y plot(plan view)

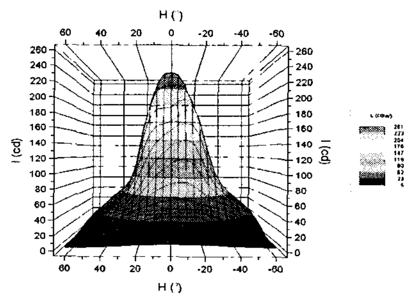

Fig. 9 Candela distribution x-y plot(front view)

5. Conclusion

The rhenium filament showed much difference in life expectancy and luminance without mixing an appropriate amount in very dense and high-melting structure with tungsten. According to the results of the experiment, stronger red and blue with weaker yellow showed typical characteristics of neodymium, showing a strong white color. The life expectancy was measured at 7,200 hours while enhanced protection showed stability which did not short-circuit from exterior pressure such as light vibrations. The color temperature was 2,990[°K] and color rendering index at 99, showing superior illumination characteristics. However, the increase in costs of rhenium filament and gas makes the lamp unsuitable economy-wise. Also due to the active solid state light a response to a specific place with considerations to the purpose is required.

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