SIMPLIFIED METHOD OF LED LAMP USEFUL LIFE PROJECTION

Vytautas Dumbrava, Irmantas Kupčiūnas, Darijus Pagodinas, Vytautas Knyva, Gedeiminas Činčikas

Department of Electronics Engineering, Studentu str. 50-340, Kaunas, Lithuania, LT-51368
E-mail: vytautas.dumbrava@ktu.lt

Abstract

LED lamps have experienced growth of usage in artificial lightning because of high luminous efficiency, long life and resistance to mechanical stress. A lot of new manufacturers are starting to make such lamps and a part of them does not have experience in this particular field. This leads to cheap products, which does not meet product specific requirements. Due to this reason a case study was started in order to analyze standards governing LED lamps and do simplified evaluation of specific LED lamps.

1. INTRODUCTION

The area of artificial lighting has gone through a lot of important changes in last decades. At first, light emitting diodes (LED) were used only for identification purposes, but now using advanced technologies it is possible to fully replace 60W bulb with a LED lamp [1]. LED lamps are getting more and more popular because they have high luminous efficiency, long life (up to 50 000 hours) and low power consumption compared to conventional incandescent lamps. Such advantage allows reducing electricity bills. Production of LED lamps is growing and more manufacturers are starting make them. Most of the LED lamps in Europe are imported from China and these lamps are relatively cheap. However stability of LED lamps parameters and reliability becomes complicated. With increasing manufacture rates emerges production that does not meet claimed technical parameters and has low repeatability of characteristics. Because of these reasons buyer or importer may be harmed. To reduce chance of this harm and choose reliable suppliers, need for extensive testing of imported LED lamps arises.

The aim of this work is to evaluate possibilities of measuring LED lamps parameters, level of standardization, measure parameters of provided LED lamps and present the results of measurements.

2. OBJECT OF THE RESEARCH

The object of this research is integrated LED lamp. This type of lamp has integrated light source – matrix of light emitting diodes, LEDs driver and base compatible with ANSI standard. Lamp is suitable to be powered directly from mains. LED lamps for research was provided by Lithuanian importer UAB "SIRIJUS". Since lamps were very cheap there was almost no characteristics provided. All data provided is listed in table 1.

Table 1. Initial data of examined LED lamps

Model	Angle of illumination	Luminous flux, lm
GU10-5050-F24	120	320
GU10-3*1W-B	45	240
GU10-4*1W	45	320
B45-E14	160	180
G50-5050-WC12	120	180
JDR E14	120	340
C30-5050-WC12	120	180
C30L-5050-WC12	120	180
JDR E14 60LED	120	180

Also there were lamps with no characteristics provided, so they are not included in table 1. Lamps differentiate by shape, used case materials, light emitting diodes, reflectors. One of the lamps used in research is depicted in figure 1.

Figure 1. GU10 3*1W-AC-L warm-white LED lamp

3. OVERVIEW OF LED LAMP CHARACTERISTICS AND MEASUREMENT TOOLS

We think that the most important characteristics of LED lamp are emitted luminous flux and its degradation over time. Measurement of emitted luminous is defined by Illuminating Engineering society (IES) in documents LM-79, LM-80 [2, 3]. For measuring total emitted luminous flux it is recommended to use an integrating sphere system or a goniophotometer. We shall cover only integrating sphere system.

There is simplified method proposed for relative measurement of emitted luminous flux in article [4]. The idea is to use wooden box to simulate black room. We used mentioned approach and built black box by ourselves, it is depicted in figure 2. The internal dimensions are: 56 cm height, 17 cm depth and 35 cm width. Section with holder is approximately 18 cm height. In figure 3: 1 – lamp holder, 2 – holder for lux meters probe, 3 – lux meter. The interior of box was coated with black mat paint to give closer approximation of dark room.

Although this way of measuring only evaluates forward emission of light, so results cannot be used to compare different models lamps. However it is possible to compare LED lamps of the same model or compare it to itself in order to evaluate its degradation over time.

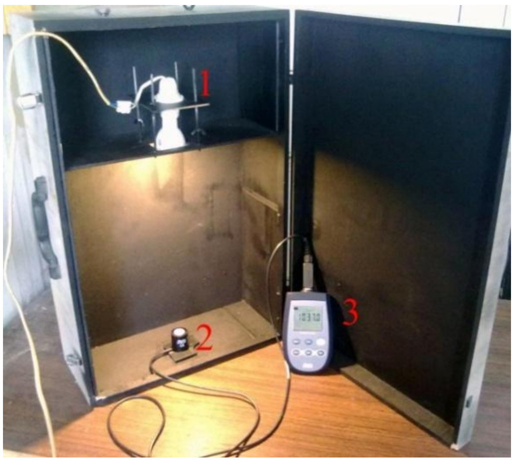

Figure 2. Black box, that we built

4. EVALUATION OF EMITTED LUMINOUS FLUX DEGRADATION

One of the drawbacks of light emitting diodes is luminous flux degradation over time. Normally there are two degradation levels defined – 50% (L50) and 70% (L70) of initial LED lamps luminous flux. However depending on application, L50 or L70 luminous flux degradation may by unacceptable. For example if LED lamp is used to illuminate writing desk it will become unsuitable for usage before reaching its luminous flux degrades to 50% of the initial flux.

There have been solid attempts to approximate light emitting diode luminous flux degradation over time as a function of time [5, 6]. Degradation may be approximated as exponential function [5]:

$$y = e^{\alpha t}. \tag{1}$$

In formula: y - relative luminous flux; t – time, h; α - degradation constant. Value of α is found from experimental results. According to [5] degradation constant depends on LEDs forward current I:

$$\alpha = 5 \cdot 10^{-5} \cdot e^{(0{,}0375)I}. \tag{2}$$

In accordance with formula 2 it should be possible to accelerate luminous flux degradation process by increasing LED forward current. By using data gathered when operating LEDs with increased current it is possible to predict degradation constant in normal conditions. But there is one major drawback – degradation constant must be estimated for every type of LED and this technique is not directly applicable to LED lamps, because they usually have built in current source.

In order to estimate LED lamps useful time until it reaches 70% degradation we adapted method proposed in TM – 21 – 11 published by IES.

5. LED LAMP USEFUL LIFE PROJECTION

TM – 21 – 11 [7] recommends curve – fitting experimentally collected data in order to extrapolate the luminous flux degradation to defined critical value – L70 or L50. Method is applied to each different type of LED lamp.

All experimentally collected data is normalized to 100% at 0 hours for each lamp. Next an exponential least squares curve – fit is performed for each tested type of lamps. The following equitation is used:

$$\Phi(t) = B \cdot \exp(-\alpha t), \tag{3}$$

here: t – operating time in hours; $\Phi(t)$ – normalized luminous flux output at time t; B – initial constant calculated using least squares curve fit; α –

degradation rate constant calculated using least squares curve fit. The following equation from TM – 21 -11 is used to project LED lamps useful life:

$$L_p = \frac{\ln\left(100 \cdot \frac{B}{p}\right)}{\alpha}, \quad (4)$$

here L_p – useful life expressed in hours where p is the percentage of initial luminous flux output maintained.

Coefficients B and α are derived from least squares formula (5, 6):

$$B = \exp(b) \quad (5)$$

$$\alpha = -m \quad (6)$$

Slope (m) and intercept (b) are calculated using formulas (7) and (8):

$$m = \frac{n \cdot \sum x \cdot y - \sum x \cdot \sum y}{n \cdot \sum x^2 - \left(\sum x\right)^2}, \quad (7)$$

$$b = \frac{\sum y - m \cdot \sum x}{n}, \quad (8)$$

here: x, y – experimental data points (x_1, y_1), … (x_n, y_n); n – total number of data points.

6. TEMPERATURE DISTRIBUTION IN LED LAMP

According to some sources [8, 9] LED temperature effect luminous flux output and may affect speed of emitted luminous flux degradation. Distribution of temperature was observed using "MikroSHOT" thermal imaging camera. Temperature of LED mounting plate was measured (Figure 3, 4).

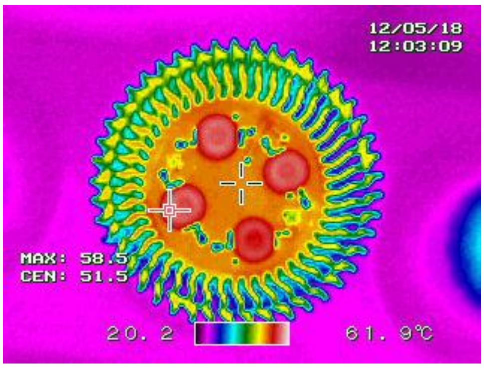

Figure 3. Thermal image of GU10 4X2W-WW

However not all lamps could be disassembled without damaging them, so their case temperature is reported later on (marked with * in table 2).

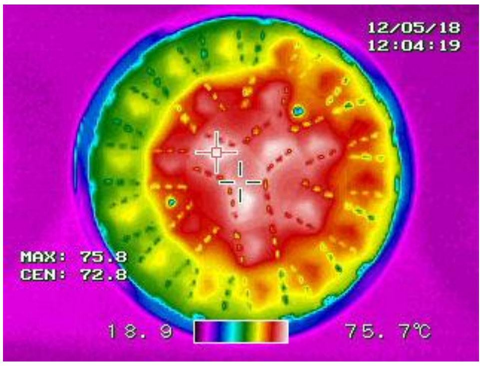

Figure 4. Thermal image of GU10 5050-F24 #1

7. EXPERIMENTAL RESULTS

We have done 2250 hours long test of supplied LED lamps. Measurement intervals were a lot smaller than 1000h suggested by TM – 21 -11 in order to compensate for noisy results due to loose lamp holding point. For each LED lamp model calculations as described earlier were done to calculate its useful time. Results are presented in table 2. The results were very different for each type of lamp – GU10 4X2W (CW) lamp shoved no degradation during test (Fig. 6) while GU10 – 5050 – F24 reached 72% of initial luminous flux output at the end of this test (Fig. 7). For GU10 – 5050 – F24 projected time is 2280 hours.

Table 2. Experimental results

Model	L70,h	α	B	LED temperature, °C
GU10 4X2W (WW)	27442	1.34E-05	1.012248	58.5
GU10 3X1W-AC-L WW	21977	1.66E-05	1.008834	51.8*
GU10-5050-F24 #1	2013	1.77E-04	0.999152	75
GU10-5050-F24 #2	2283	1.58E-04	1.003594	75
B45-14 SMD5050 12 LED	44101	7.54E-06	0.976058	42.1*
C30-5050-WC12	4795	7.42E-05	0.999057	37.6*
C30L-5050-WC12	7731	4.56E-05	0.996129	35.9*
G50-5050-WC12	6547	5.34E-05	0.992665	35.9 *
JDR E14 60LED	10514	3.03E-05	0.962255	65.5
JDR E14 SMD5050 24 LED #1	56162	5.91E-06	0.975720	60.1
JDR E14 SMD5050 24 LED #2	23615	1.40E-05	0.973800	65.5

*Case temperature is reported

The coefficient of determination (R^2) for a linear regression model with one independent variable is:

$$R^2 = \frac{1}{N} \cdot \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sigma_x^2 \cdot \sigma_y^2}, \qquad (9)$$

where N is the number of observations used to fit the model; x_i is the x value for observation i; $\bar{x}$ is the mean value, y_i is the y value for observation i, $\bar{y}$ is the mean y value, σ_x is the standard deviation of x and σ_y is the standard deviation of y.

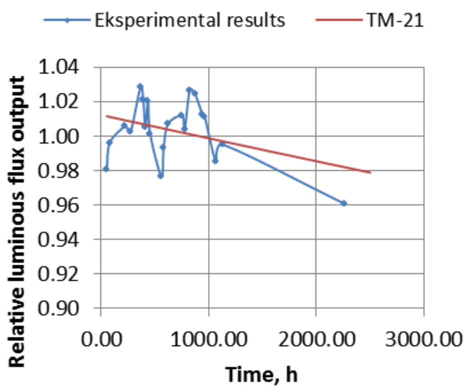

Figure 5. GU10 4X2W (WW) degradation curve

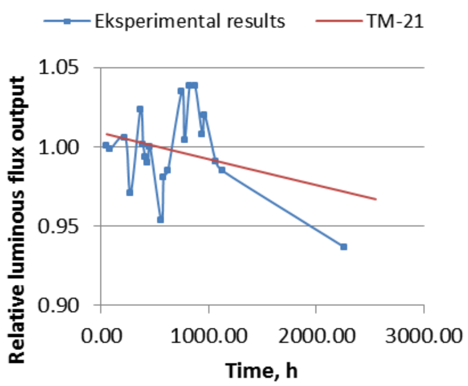

Figure 6. GU10 3X1W-AC-L WW degradation curve

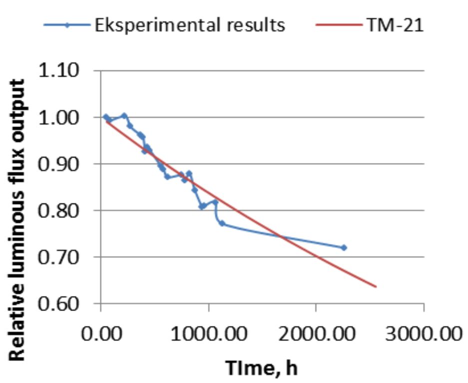

Figure 7. GU10-5050-F24 #1 degradation curve

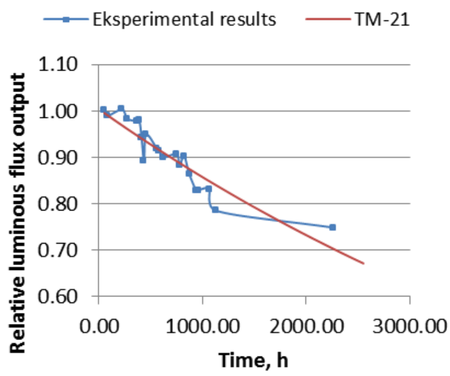

Figure 8. GU10-5050-F24 #2 degradation curve

8. CONCLUSION

Initial LED lamp testing using black box was done. One model of lamp reached 72% initial luminous flux output during this test and projected L70 time is 2280 hours. However in order to confirm this method further work must be done. We plan to significantly increase number of tested lamps and test duration. Also we aim to compare useful life projection results using out black box and integrating sphere.

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