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The efficiency of the supplementary light sources applied in the signaling systems of car vehicles

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Summary. The analysis of the light effectiveness of the chosen LED type electric sources used in motorization was shown in the article. The test stand and the test methodology were described. The evaluation of the influence of LED type bulb and the way of its fixing on the efficiency of generating the luminous flux was made on the basis of carried out measurements.
Key words: car lighting, LED bulbs, light effectiveness.

INTRODUCTION

Certifying a car vehicle fit for use needs meeting many technical requirements [9]. One of the basic ones is the efficiency of lighting elements, both the lighting of road (road lights, passing lights, fog lights, reverse lights) and signalling (indicators, stop lights, parking lights). The use of LED type light sources in new constructions of vehicles encourages the owners of older vehicles to search for this type of new light sources and their use in their vehicles. Therefore the range of LED construction were launched on the market [6, 10, 14, 15, 16]. They were recommended as the replacements for traditional bulbs. Unfortunately LED type light devices are fixed in lighting fittings which were certified for incandescent lighting, thus the vehicles which lighting doesn't meet standards can be often met on roads (e.g. the inequality of lighting of the observed surface). It made the authors carry out test allowing to determine the basic parameters of the lighting of the chosen sources of the incandescent light and LED type lighting which can be used in car vehicles.

CAR LIGHT SOURCES

Electric lights sources used in car vehicles can be divided on the basis of the working principle into incandescent lamps and discharge lamps [8]. The construction of these lamps is shown in Fig. 1.

Fig. 1 Car light sources [2]: a. incandescent lamp; b. discharge lamp

In the first group the working principle is based on the flow of current through a conductor. The second group uses the electric discharge in gases. The incandescent lamp emits the light as the result of the heating of the heating element (filament) [12]. The quantity of the emitted light stream and its colour depend on the temperature of the filament. It is proportional to the intensity of the flowing current. Supply voltage and the resistance of the filament influence the value of intensity [1].

The discharge lamp emits the light in the result of the electric discharge in the arc tube. The change of the spectrum of light radiation is obtained by changing the gas which arc tube is filled with [17]. Xenon is popular gas at present. Unfortunately these sources of the light require the additional converter raising the supply voltage. The LED light-emitting diode – the new kind of the light source does not have this inconvenience. The visible radiation comes into being in the result of the recombination of electric charges coming through the p-n joint [4]. The schematic principle of the operation of LED was shown in Fig. 2.

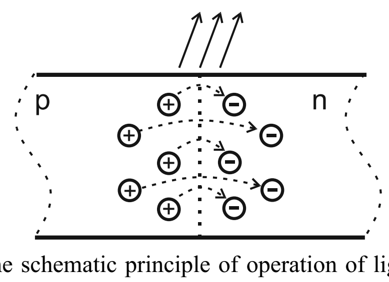

Fig. 2. The schematic principle of operation of light-emitting diode [own study]

In the result of the connection of the electron with "the hole" there is the excess of energy in the p-n joint which is emitted as the electromagnetic radiation [5]. The frequency of the wave, that is the colour of the light, depend on the composition of the base material of the semi-conductive element [13]. The intensity of radiation however depends on the intensity of the electric current coming through the p-n joint [7].

THE TEST STAND

Measurements were carried out with the use of the test stand made in the Department of Technology Fundamentals in Lublin (Fig. 3). The darkroom (1) was used for the test and the investigated sources of light (2) were placed inside. Light source were connected to the controllable feeder of direct current (3). The source of light lit up the measuring screen (4), on the surface of which the illumination was measured with the luxmeter.

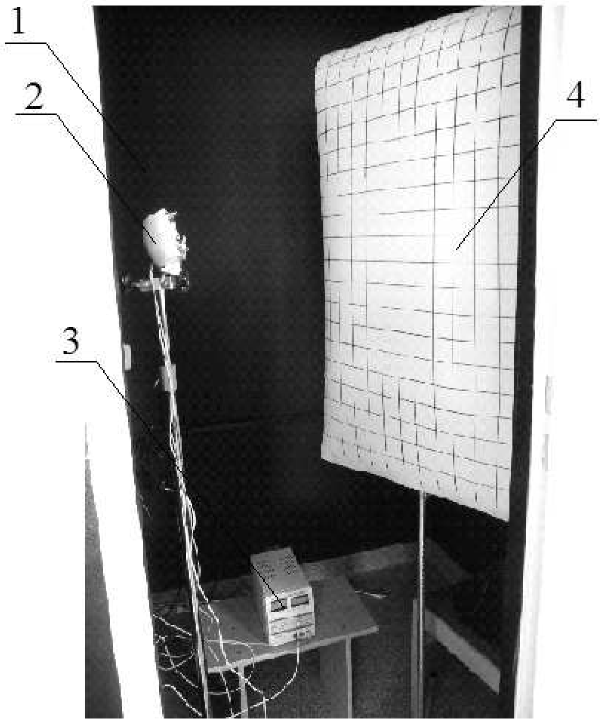

Fig. 3. The test stand for the investigation of the car light sources [own study]: 1- the darkroom; 2 – the lighting fitting of the light source ; 3 – DC feeder; 4 – the measuring screen

The light sources with the type P21W fixing handle were used for the tests. The bulbs of this type are used e.g. in fog lights . R21W bulb, R5W bulb and LED lighting with 5, 9, 12 and 19 light-emitting diodes were used to the test (Fig.4).

The light sources mentioned above were installed in the lighting fitting of rear fog lights (Fig. 5) with the central fixing and side fixing of the light source.

The light bulbs were added to the controllable feeder of the direct current, enabling the control and the measurement of the voltage and the measurement of the intensity of the supply current.

Fig. 4. Light sources used in tests [L11]: BA15s – R21; b. BA15d – R5; c. BA15s – 5LED; d. BA15s – 9LED; e. BA15s – 12LED; f. BA15s – 19LED

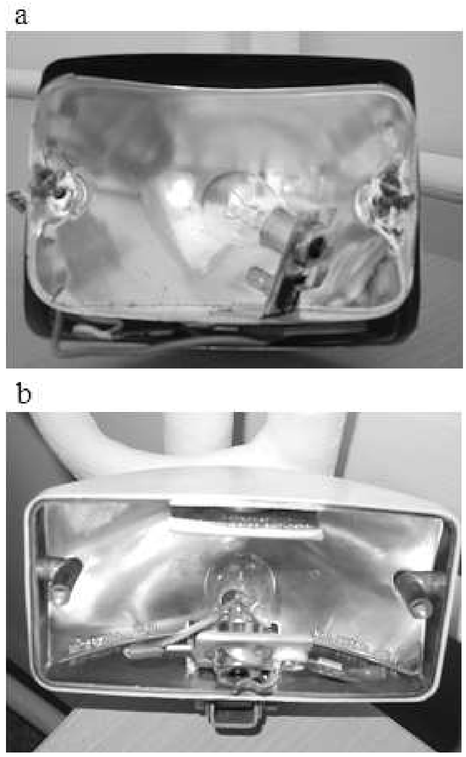

Fig. 5. The lighting fittings used in the test [own study]: a. the central fixing of the light source; b. the side fixing of the light source

THE TEST METHODOLOGY

In order to avoid the influence from outside the test stand was placed in the darkened room. Lighting fittings were fixed to the tripod allowing the control of the fixing height. Light sources were connected to DC feeder. They were supplied with two voltages 12 V and 14,6 V. It corresponds respectively to the voltage of the charged battery and the charging voltage developing when the vehicle engine is running. The feeder makes it possible to read the supply voltage ***U*** as well as the consumed current ***I***. The lighting of the surface was observed on the measuring screen placed in the distance of 1.5 m from the light source. The surface of the screen was divided into 50mm x 50mm squares.

Each square had attributed coordinates, in order to obtain the explicitness and the repeatability of the position of the measuring points. 80 readings of the value of the lighting intensity were made in every measuring series, placing the sensor of the Elbro ELX2111 Light Meter illuminometer on the marked areas of the screen. The results of measurements were shown in the tables of the spreadsheet (table No. 1). The obtained results of the measurements of the lighting intensity ***E*** were converted into the light stream ***f*** on the basis of the dependence:

$$\phi = \sum_{i=1}^{80} E_i \; S\,[lm], \qquad (1)$$

where:
E_i – lighting intensity in measuring point ***i***, lx,
S – the surface of the unitary measuring area, m^2.

The measured value of the supply voltage U and the value of the current intensity I make it possible to calculate the power of the light source:

$$P = U \cdot I\,[\mathrm{W}]. \qquad (2)$$

The parameters calculated on the basis of the dependence (1) and (2) enable the calculation of the light effectiveness of the tested light source [8]:

$$\eta = \frac{\phi}{P}\;[lm/W]. \qquad (3)$$

THE TEST RESULTS

The measurements were carried out to determine the illumination in given points of the measuring screen. The results of measurements for R5W bulb supplied with the voltage of 14.6 V being the reference to further tests were shown in Table 1.

On the basis of carried out tests the value of the power of the lighting source, the light stream and the light effectiveness were calculated. The overall results of calculations were shown in Table 2.

Table 1. The distribution of the illumination of the measuring screen lighted with the R5W bulb supplied with the voltage of 14.6V centrally installed in the lighting fitting

143	65	38	20	17	20	41	57	74	30
118	62	46	25	17	23	42	60	95	38
77	37	24	20	18	22	30	64	73	59
89	52	21	19	18	20	24	42	72	43
84	36	22	18	17	20	27	50	81	46
34	35	33	27	23	26	33	36	98	38
20	24	28	28	26	28	28	26	43	26
9	11	13	17	17	18	17	16	15	10

Table 2. The electric power, the light stream and the light effectiveness of studied light sources.

The type of lighting	Bulb fixing	Power, W	The light stream ϕ, lm	The light effectiveness E, lm/W
R5W	central	5.8	7.6	1.3
	side	5.7	13.2	2.3
R21W	central	28.3	97.3	3.4
	side	28.2	199.5	7.1
5LED	central	0.4	4.6	10.5
	side	0.4	6.5	14.8
9LED	central	0.6	4.5	7.8
	side	0.6	7.1	12.1
12LED	central	0.8	6.8	8.5
	side	0.9	15.0	17.1
19LED	central	1.8	5.4	3.1
	side	1.8	12.0	6.9

The preliminary analysis of the received test results showed that LED type light source can replace only the bulb of R5W type as far as the light stream is concerned. Thus the further lists do not contain calculations for the R21W bulb.

The basic parameter enabling the exchange of light elements is the light stream emitted by them. The list of values of light streams emitted by various light sources with the voltage supply of 14.6 V and for two ways of fixing the bulb in the lighting fitting (central and side) was shown Fig. 6.

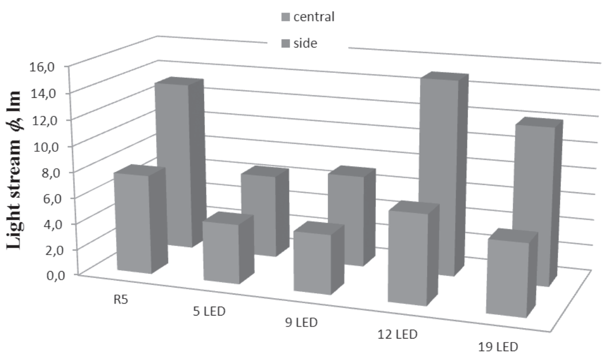

Fig. 6. The comparison of light streams emitted by studied light sources

The comparison of light streams reaching the measuring screen lets us state that 12LED can be the equivalent of the R5W bulb. It has the comparable value with the central fixing in the lighting fitting (7.6 lm and 6.8 lm, i.e. approximately 10% less) and higher with the side fixing (13.2 lm and 15.0 lm, i.e. approximately 13.6% more). The remaining diode light sources however generate the smaller light stream. 19LED has the stream lower by approximately 30% with the central fixing and by approximately 9% with the side fixing. In 9LED the fall of the stream is approximately as much as 41% with the central fixing and approximately 46% with the side fixing. 5LED however is characterized by respectively approximately 39% and 51% lower value of the stream.

The basic advantage of LED type light sources is their high light effectiveness, that is the quantity of the light stream received from 1 watt of the electric power. Thus it was the next parameter which was the subject of the analysis. The comparison of light effectiveness of the studied light sources was shown in Fig. 7.

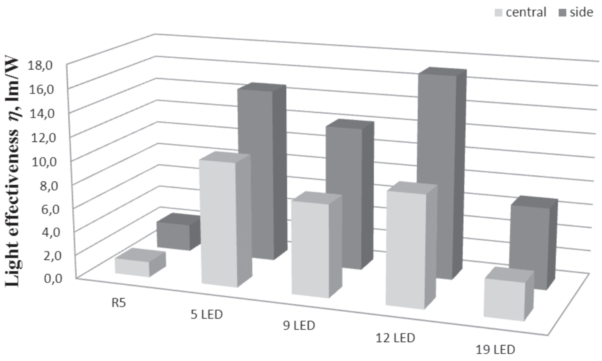

Fig. 7. The comparison of light effectiveness of the studied light sources.

On the basis of the analysis of the of calculations it can be concluded that light effectiveness was higher for every studied light source with side fixing. The diode with 12 light elements (12LED) had the highest light effectiveness. It equalled 17.1 lm/W. The diode with 5 elements (5 LED) had the effectiveness lower by 14 % (14.8 lm/W), the diode with 9 elements (9 LED) had the effectiveness lower by 30% (12.1 lm/W) and the one with 19 elements (19 LED) had the effectiveness lower by 60% (6,9 lm/W). The R5W bulb had the lowest efficiency. Its light effectiveness equalled 2.3 lm/W which was approximately 13% of the maximum effectiveness.

With the central fixing the values of light effectiveness were ranked in the same way as in the side fixing. Their values however were lower by approximately 50% for 12 LED, 30% for 5 LED, 35% for 9 LED and 55% for 19 LED.

CONCLUSIONS

Lighting fittings of car lights used nowadays are designed to use heat or discharge light sources. The use of LED sources in these fittings makes it impossible to use the produced light fully, because of different ways of radiation distribution. The light sources of the LED type emit the directed radiation while the heat sources send the light in all directions.

Large light effectiveness is characteristic of the LED type sources so they becoming more and more popular substitutes of traditional bulbs.

The tests show that these substitutes can only be used in the fittings for fixing light sources used for lighting the elements of the vehicle e.g. the lighting of registration boards or the lighting of the interior. Because the requirements for signalling light such as positional lights or rear fog lights are higher LED with larger number of light elements should be chosen. In our tests it was possible to replace the R5W bulb with 12LED or 19LED diode. The smaller number of elements did not fulfil the condition of the equivalence of the light stream.

However, the large efficiency of the lights of the LED type should lead to development of the new constructional solutions of the lighting fittings adapted to the use of this new light source.

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EFEKTYWNOŚĆ ZASTĘPCZYCH ŹRÓDEŁ ŚWIATŁA STOSOWANYCH W UKŁADACH SYGNALIZACJI POJAZDÓW SAMOCHODOWYCH

Streszczenie. W artykule przedstawiono analizę skuteczności świetlnej wybranych elektrycznych źródeł światła typu LED stosowanych w motoryzacji. Opisano stanowisko badawcze i metodykę badań. Na podstawie przeprowadzonych pomiarów dokonano oceny wpływu typu żarówki LED oraz sposobu jej mocowania na efektywność wytwarzania strumienia świetlnego.

Słowa kluczowe: oświetlenie samochodowe, żarówki LED, skuteczność świetlna.