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FUNCTIONAL PERFORMANCE OF THE MAIN LIGHTING SYSTEM OF MOTOR VEHICLES

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Abstract. Visual perception plays a crucial role in the safety of road users. However, certain conditions such as twilight, the impact of bad weather, dirty windshields, etc. have a negative impact, which in turn increase the likelihood of traffic accidents (TAs) [1]. The ever increasing number of vehicles on the road is an additional potential danger. In response to these factors work is constantly being done to modernize existing and develop new lighting devices.

Vehicular headlights are firstly assigned to optimally illuminate the roadbed in order to ensure safety [2]. For this reason headlights, including their light source, are important safety elements for vehicles, and their application requires official permission. The type and location of vehicular lighting, as well as their design, light source, color and light settings are regulated by law [3].

Automakers pay sufficient attention to the fuel economy and safety of their vehicles. So for this reason automotive light sources, such as incandescent and gas-discharge (HID) bulbs, are increasingly being replaced by LED and laser diode bulbs as they provide superior lighting with lower power consumption. This in turn leads to increased vehicle safety and economy [3].

Keywords: vehicle; lighting system; headlights; lamp; low beam; illumination; power supply; diffuser; blinding oncoming drivers.

Introduction and Problem Statement

Nowadays, in the market, there is a large number of incandescent lamps, as well as LED and gas-discharge lamps, which choosing is performed by the customers independently taking into account different criteria (for example, a price or a brand). Someone pays greater attention to the power and the light output of the lamp, others prefer such criteria as colour of light, efficiency and shape of the lamp.

The problem of the correct choosing a lamp for a modern car, both for the purpose of energy efficiency and traffic safety, is not enough analysed by researches of scientists. In particular, the features of driving at night time and the functioning of new light sources in the headlights of modern cars are considered in [4], the problems of improving the automotive lighting system, both for the designation and ensuring visibility of a car on the road are analysed in [5].

At the same time, a large number of scientists consider the peculiarities of evaluating the operation of the lighting systems of modern cars. In particular, the paper [6] considers the main requirements for the illumination, and the technique of its determination, and defines the dependence of the variation of illumination for headlight of the main lighting system in the modes of low beam (passing light) and high beam (driving light). In papers [7] and [8], there is developed a technique of road studies of determination the headlights illumination of the road sections and the perception of the road conditions by the driver. None of the researchers considered the issue of efficient and safe operation of the main lighting system of the car depending on its state and the use of different types of light sources.

The question then is how to improve the effectiveness of lighting in used vehicles, such as those using halogen incandescent bulbs. There is not enough attention paid to the correct selection of light sources and the impact main performance factors have on the effectiveness of lighting systems. Drivers use halogen lamps with improved characteristics that often do not meet regulatory requirements, or make unacceptable changes to the design of the headlights by installing gas-discharge light sources. For this reason we decided to investigate the influence of key operational factors on the effectiveness of the main vehicular lighting system.

Objectives and Problems of Research

The aim of this paper is to study the influence of key vehicular operational factors on how well the roadway is illuminated. To achieve this goal we analyzed the structure and principle actions of existing vehicular lighting systems; developed research methods and created an experimental setup; and determined the effect of supply voltage, condition of lens surface, and the effectiveness of the light source in the lighting system.

Main Material Presentation

The most common and cheapest vehicular headlights are reflective types indicated for use with halogen incandescent bulbs. The main element of such headlights are free form (FF) reflectors divided into separate sections (vertical and radial) which have a particular focal length and are optimized for a specific type of light reflection to provide a highly uniform illumination. The light beams from FF-headlights are formed freely within the space of the surface reflector. They can be calibrated and optimized only with the help of computer simulation. The deviation of light beams and scattering light is directly controlled by the surface reflector. The extent to which the light beam illuminates the right side of the road depends on how the horizontal segments of the reflector are adjusted. Additionally a diffuser with a smooth surface is used, instead of one fitted with optical elements for light diffusion, made of plastic materials [9].

Halogen incandescent bulbs are used as the light source for such headlights; they emit heat, in much the same was as conventional incandescent bulbs. However, in contrast to conventional incandescent bulbs, halogen bulbs do not darken because of the halogen cycle; they also reach a higher temperature and a higher level of illumination (22–32 lumens per watt (lm/W). When adding a halogen (iodine or bromine) to a bulb the temperature of the filament increases almost to the melting point of tungsten (~3400 °C). Before the evaporated particles of tungsten fall on the inner surface of the bulb, the tungsten binds to the halogen molecules to form light-permeable gas - halide. Halide does not leave a coating on the glass. Instead, thermal convection causes the Halide to move freely in the bulb until it again falls onto the spiral filament. Due to the high temperature of the filament, when halide reaches the filament it is again split into tungsten and halogen. Particles of tungsten again get deposited on the colder parts of the spiral, for example, on the based on a spiral. This prevents the tungsten atoms from settling on the inside of the bulb and hence prevents blackening of the bulb. For this reason, even the smallest amount of halogen will allow a bulb to always remain transparent. The result is that the inevitable reduction in light, as is the case with conventional incandescent lamps, can be completely avoided throughout the life of the bulb.

The composition of the gas in the bulb is also largely responsible for the luminous efficacy. The gas which fills the bulb takes on a considerable amount of heat from the filament. Using xenon instead of a noble gas such as argon, reduces heat loss. The larger the atoms of gas, the lower the gas's thermal conductivity and, consequently, the less the heat loss. Heavy xenon atoms also slow down the evaporation of tungsten from the filament; this reduces the loss of material from the filament increasing the life of the bulb. Xenon, however, is very rare and therefore expensive [9], [10].

In order to be used on vehicles, each headlight is certified together with its intended light source, in accordance with the requirements of ECE Regulations. Headlights are tested to determine their level of illumination on low beam and high beam by measuring the magnitude of illumination at specified points on a special screen which represents a distance of 25 meters from the headlights on a two way road. These results are then compare with acceptable values [11].

In order to conduct research in the laboratory, the screen is printed on a 1: 3.4 scale and located 7.355 meters from the headlight. The level of illuminance at all points is noted according to the screen size and distance from the headlights using the inverse square law: as the distance from the light to the illuminated surface increases the level of illuminance decreases in an inverse proportional way to the square of the distance. A used car headlight from a Chevrolet Aveo is designed for a double filament halogen bulb (H4), 5 halogen bulbs with different characteristics and 1 category H4 HID bulb (Fig. 1).

a *b* *c*

d *e* *f*

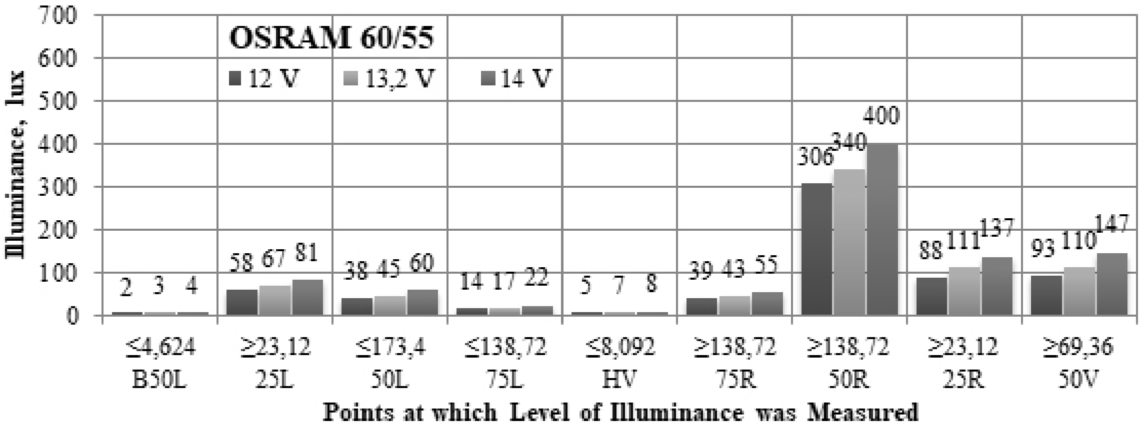
***Fig. 1.** Lamps used in research: a – halogen Osram 60/55; b – Osram +30% 60/55; c – Valeo 60/55; d – Narva 100/90; e – Pulso 60/55; f – gas-discharge*

When a standard Osram bulb's power supply increases by 1 watt, the level of illuminance on low beam increases by 10–50 %, and on high beam by 7–34 %; the level of illuminance with Osram +30 % bulbs increases by 18–100 % on low beam and by 6–33 % on high beam (Fig. 2). If the Osram +30 % bulb is used the allowable level of illuminance is exceeded, blinding oncoming drivers 1.7–2.4 times more than acceptable and drivers being followed by 1.9–2.6 times.

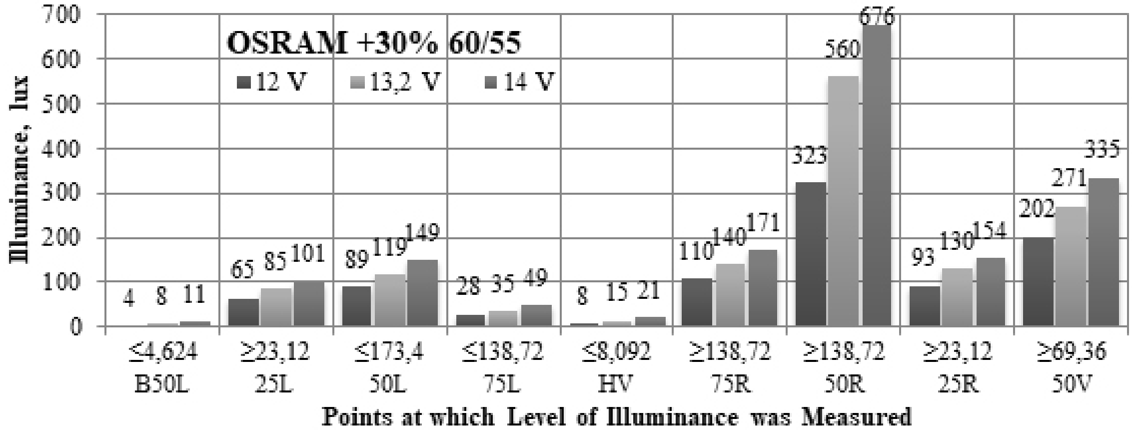
On low beam a wet and dirty lens will reduce the clarity of the light beam and make it more diffuse, while increasing the level of illuminance of the light beam (Fig. 3). A wet diffuser increases the level of illuminance by up to 10 times and reduces low beam illuminance by up to 34 % on low beam and 38 % on high beam when compared to a dry diffuser; a dirty diffuser increases the level of illuminance by up to 5.67 times and reduces it by up to 59 % on low beam, and 57 % on high beam. Additionally, a wet lens exceedes the allowable level of blinding oncoming drivers and drivers being followed by 6.5 and 5.4 times respectively; a dirty lens by 3.7 and 2.6 times respectively.

Using the Osram +30 % bulbs provides a higher level of illumination compared with conventional bulbs because of increased luminous flux: up to 2.7 times more on low beam and up to 20 % more on high beam (Figs. 4–5). This exceeded the permissible level of glare by 1.7–1.9 times.

A halogen bulb coated with Valeo provides a higher level of illumination on low beam (2.7 times) and at high beam (up to 20 %) exceeding the permissible level of glare by 2.2–2.4 times.

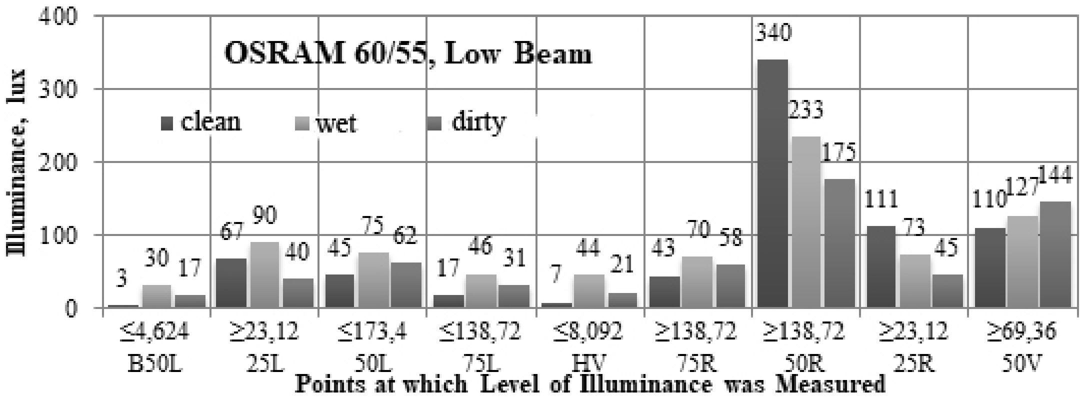


a

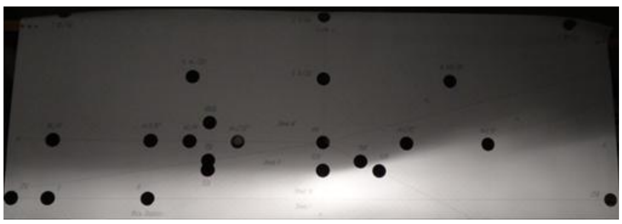


b

Fig. 2. *The influence of the supply voltage on the level of road illuminance on low beam: a – lamp OSRAM 60/55, b – lamp OSRAM +30% 60/55*



a



b *c*

Fig. 3. *The influence of lens condition on the level of road illumination on low beam (a); light distribution with a clean lens surface (b); light distribution with a wet diffuser (c)*

The Narva 100/90 bulb provides the highest level of illumination thanks to increased voltage: up to 17.1 times on low beam, up to 1.5 times on high beam, thus exceeding the permissible level of glare by 3.2–3.8 times. This bulb is not intended for use on public roads.

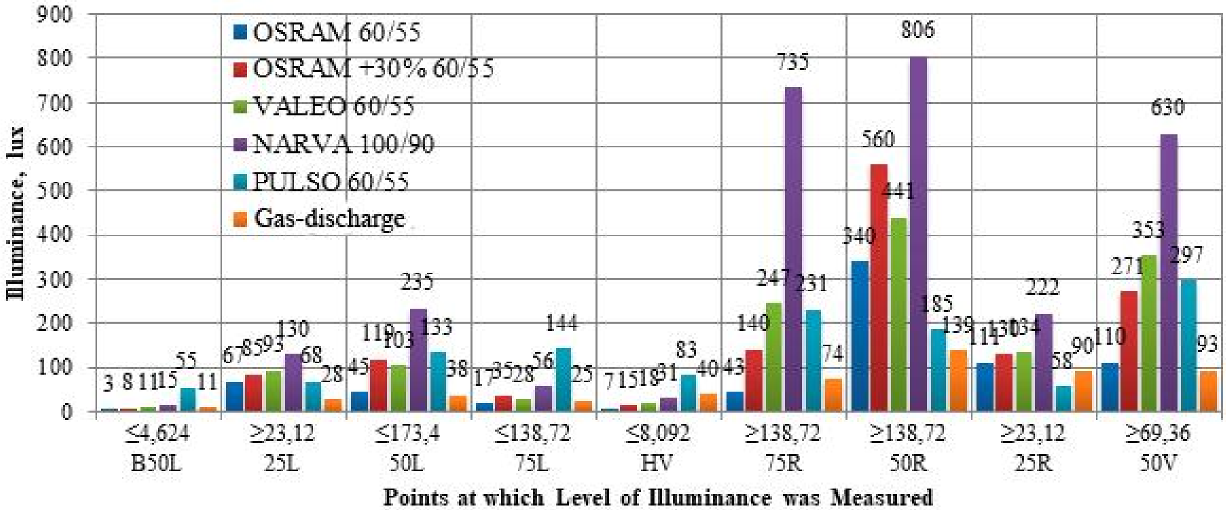
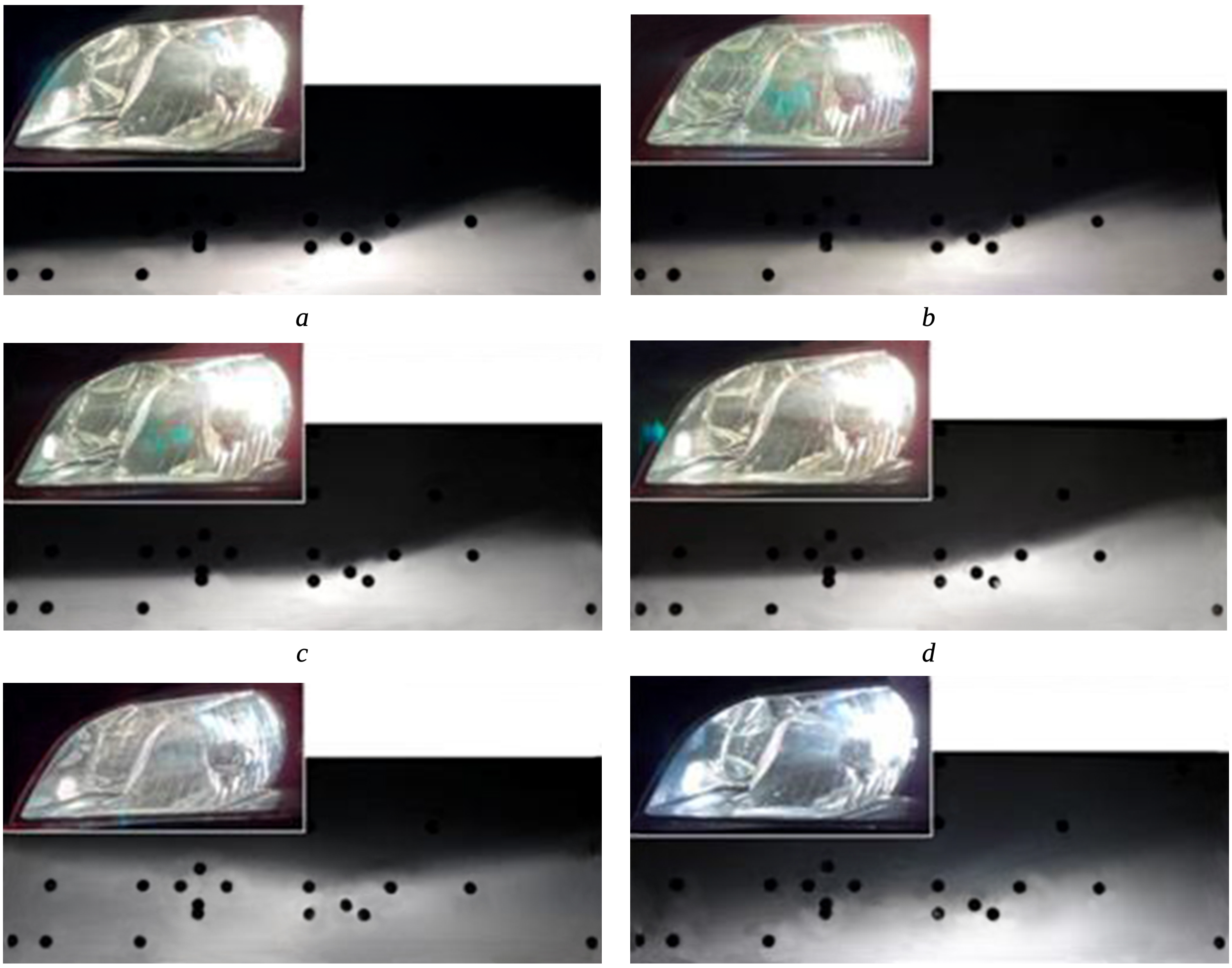


Fig. 4. *Correlation between the light source and the efficiency of the road illumination on low beam*



a *b*

c *d*

e *f*

Fig. 5. *Light distribution on low beam of halogen incandescent lamps: a – Osram 60/55; b – Osram +30% 60/55; c – Valeo 60/55; d – Narva 100/90; e – Pulso 60/55; f – xenon gas discharge lamp*

Halogen lamp filled with xenon Pulso does not provide the correct light distribution on low beam, causing more blinding of other drivers than any other tested bulb at 10.3–11.9 times the acceptable level. This bulb has not undergone official testing and therefore can not be used in vehicles.

Using gas discharge bulbs in headlight assemblies intended for halogen bulbs doesn't provide a clear light beam, leads to excessive scattering of light and a decrease in the level of illuminance: by up to 60 % on low beam and up to 80 % on high beam when compared to halogen bulbs. They also exceeded the permissible level of glare by 2.4–4.9 times and insufficiently illuminate (1.9 times less than required) the right edge of the road (75R).

Conclusions

Increasing the voltage of halogen incandescent bulbs leads to an increase in the overall illumination of the road while exceeding the acceptable level of blinding other drivers and shortening the life of the bulb. Water droplets on the surface of the headlight lens act as additional lenses, and dirt, in addition to being a barrier to the spread of the light beam, reduces the clarity of the light beam and increases the diffusion of the luminous flux, leading to a more than acceptable level of blinding other drivers, while reducing the illumination of the road.

Using lamps with improved characteristics or those not indicated for use by the manufacturer is not recommended, because in addition to increasing the overall level of illumination of the road, it also increases glare on other drivers, distortion of the light beam, and in some cases reduces the level of road illumination and is a violation of regulations. Therefore, to ensure the effective and safe operation of the main lighting system it is necessary to maintain the vehicle lighting equipment in good and clean condition, to use officially approved bulbs that are intended for the type of headlamp light sources.

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