EXAMINATION OF THE VEHICLE LIGHT INTENSITY IN TERMS OF ROAD TRAFFIC SAFETY: A CASE STUDY

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Summary

Road transport is an essential part of modern life. It brings with itself, besides the desired effects, negative aspects as well. Negative aspect is not only the emissions production but also the traffic accidents occurrence even with tragic consequences. In proportion to traffic intensity, accidents during decreased visibility represent a significant share. A driver has a limited source of information at this time, since only vehicle headlights illuminate the runway and its surroundings. However, these do not only illuminate the roadway ahead of the vehicle, but part of the emitted light also falls into the drivers' eyes of vehicles in the opposite direction. Thus, the eyes of such glared drivers worse recognize details, or lose the ability to see at all, i.e. vision ability. The level of vision loss depends on the light intensity that falls into the drivers' eyes in the opposite direction. This light intensity is related not only to the correct headlights alignment (setting) but also to their design. In this paper, three generations of headlights in terms of the light intensity falling into the driver's eyes of the vehicle in the opposite direction are compared. The headlights alignment of the examined vehicles was checked prior to measurements in accordance with the manufacturer's requirements. Given the fact that intensity of the emitted light is also related to the age of the used source, they have been replaced by the new ones. For the reason of objectivity, examination was performed at night at the New Moon phase, thus it did not light up. The starlight also did not affect the measurement results because it was cloudy, but it did not rain. There were no artificial sources of light near the measuring point.

Keywords: halogen headlights, LED headlights, light intensity, road traffic safety, xenon headlights.

1. Introduction

To see and be seen is considered a basic prerequisite for safe driving in road transport [6]. In order for a person to recognize the obstacle, the approaching vehicle or the roadside failure, they must be sufficiently illuminated [6]. This requirement is particularly important in terms of reduced visibility. At that time, vehicle's headlights are the source of the light. Their light can meet the requirement of lighting the surroundings [3]. The problem arises

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once another vehicle is approaching the opposite direction [6]. Vehicle's headlights transmit beams to illuminate the roadway, while some of which diverge and fall into the field of the driver's field of view [6]. In his eye, they dissipate (disperse) and a glare process occurs [6]. This causes the driver to have a brighter and stronger illumination to detect obstacles [6].

If the driver's eye catches too high light (luminous) intensity, the driver's ability to detect an obstacle will be reduced [6]. He may detect the potential obstacle in the roadway for a very short distance, or he cannot see it at all [15]25]. The degree of glare is different depending on the lighting intensity, and usually, increases during approaching the opposite vehicle [6]. The maximum limitation due to glare is at a distance of approximately 25 m in the moment just before the vehicles encounter (passing each other [24].

If the roadway is wet, glazed or snowy, light emitted by the headlights is reflected from the surface and, together with the dispersed light from the headlights, increases the intensity of the light falling into the driver's field of view [6]. A significantly greater glare of the driver occurs. Glare causes problems to perceive the object on the roadway and causes a load affecting the driver's vision [6]. This situation also concerns the vehicle's headlights located behind the assessed vehicle. In that moment, light emitted by the headlights is being reflected in rear-view mirrors and falling into the driver's eyes in the vehicle ahead [6,21].

The vehicle driver must be able to recognize and detect an obstacle at a sufficient distance [4]. Glare of the driver by the opposite vehicle during night-time travel shortens this distance and is one of the most important factors that can cause a traffic accident [11,22]. In the case that the driver is glared by the headlights of a vehicle moving in the opposite direction, the driver's visual acuity is impaired and his vision may be interrupted [14]. The reason for a glare can be, for example, a situation where the driver of the opposite vehicle forbids to switch the long-distance (long-range beam; high beam activation) headlights into dipped-beam headlights mode, headlights inclination is incorrectly aligned, poor technical condition of headlights, or headlights geometry is incorrectly aligned [13,5]. A very frequent glare case occurs at a rapid vehicle pass through a roadway slope from an ascending to a descending inclination. Since a change in the whole vehicle (also with the headlights) longitudinal tilt occurs, the glare cannot be avoided [1].

In the case of installing the halogen lights, the prescribed headlight inclination is specified by the manufacturer [12]. Xenon headlights and headlights using LED technology utilize automatic headlight range control (automatic tilt adjustment; adaptive headlights). This should reduce the risk of glare generation, especially due to the incorrect headlights inclination [17]. The technology used by the Matrix LED headlights utilizes the dynamic headlight range control (dynamic light beam setting) using diodes which change the geometry of lighting depending on the ambient light conditions and driving speed. Thus, they prevent the generation of glare of the vehicle driver in the opposite [10].

The hypothesis is: LED headlights achieve the highest light intensity, and halogen headlights achieve the lowest light intensity of the types of headlamps used during the measurement described in this article.

2. Materials and Methods

By performing the examination, authors wanted to detect the value of the light intensity falling into the driver's eyes of the opposite moving vehicle using different light sources and the various modes of their operating settings.

Measurement itself was carried out on February 27, at Dolný Hričov Airport (Slovak Republic), 2017 in the evening. The examined roadway section corresponded to the necessary measurement conditions [3,20]. There were no light sources that would affect the measured light intensity values in the vicinity of the examined section. Measurement took place at the New Moon phase and the sky was cloudy. These circumstances guaranteed that the examination was not influenced by the light emitted by the stars and the Moon neither [16]. The examined section was without the longitudinal and transverse roadway slope. When examining, the vehicle in which we measured the light intensity falling into the driver's eyes and the vehicle in the opposite direction were located at a distance of 100 m. Vehicles axle distance was determined in order to correspond to the drive on a common road with two-way traffic [25,29]. The light intensity falling into the driver's eyes was detected using the digital Lux meter LX – 1102, see Figure 1.

Its technical parameters are as follows:

- 5 measuring ranges: 0 - 40/400/4,000/40,000/400,000 lx,
- possible lx/foot/candela display units,
- resolution of 0.01 lx for a range of up to 40 lx, to 100 lx for a range of up to 400,000 lx.

Figure 1. Lux meter LX – 1102. (author)

To determine the falling light intensity, the sensor was positioned at the driver's eyes level. After measuring the light intensity, the simulating vehicle moved 10 meters closer, and again, measuring the falling light intensity in the driver's eyes was performed.

To bring the situation as close as possible to real traffic conditions, both vehicles simulating the situation had set dipped-beam headlights mode and their engine was running at the increased engine speed (higher revolutions per minute). Thus, it was ensured that the headlights were powered from an alternator and their luminous flux corresponded to the operating state.

3. Results

The first measurement was aimed at the glare intensity detection of the examined vehicle Opel Astra with LED headlights. These headlights can operate in three possible headlights in automatic mode. As for this mode, the control unit adjusts the position (inclination) of the headlights, depending on the position of the opposite vehicle, without the driver intervention [6,10,22,24].

- headlights switched to the dipped-beam headlights mode, without the control electronics intervention.
- long-range beam headlights, without the control electronics intervention.

Table 1. Measured values of the light intensity falling into the driver´s eyes emitted by the LED headlights. Source: authors

Headlights LED Matrix	Light intensity in the area of the driver's eye (lx)		
	Headlights mode		
Distance between vehicles	Automatic	Dipped-beam headlights	Long-distance headlights
10 m	1.6	1.55	50.5
20 m	0.83	0.8	37.62
30 m	0.52	0.5	25. 21
40 m	0.63	0.36	15.19
50 m	0.51	0.33	12.10
60 m	0.3	0.26	8.21
70 m	0.27	0.25	10.23
80 m	0.25	0.36	5.16
90 m	0.14	0.13	6.80
100 m	0.12	0.9	5.94

From the measured data, it is clear that the light intensity in the eyes area during the dipped-beam mode even during automatic mode was low and the driver subjectively did not feel the deterioration of the ability to recognize (detect) obstacles on the roadway. Another situation occurred in the case of long-range beam headlights, where the driver felt the deterioration of the ability to detect obstacles on the roadway already at vehicles mutual distance of 70 meters, and at a shorter distance of vehicles, the complete loss of visibility ability [16,24].

Figure 2 provides a graphical comparison of the light intensity falling into the eyes of the opposite vehicle driver using LED headlights. In real traffic conditions, this would mean that the driver would have to stop the vehicle or travel the distance of 50 meters without information on the traffic situation.

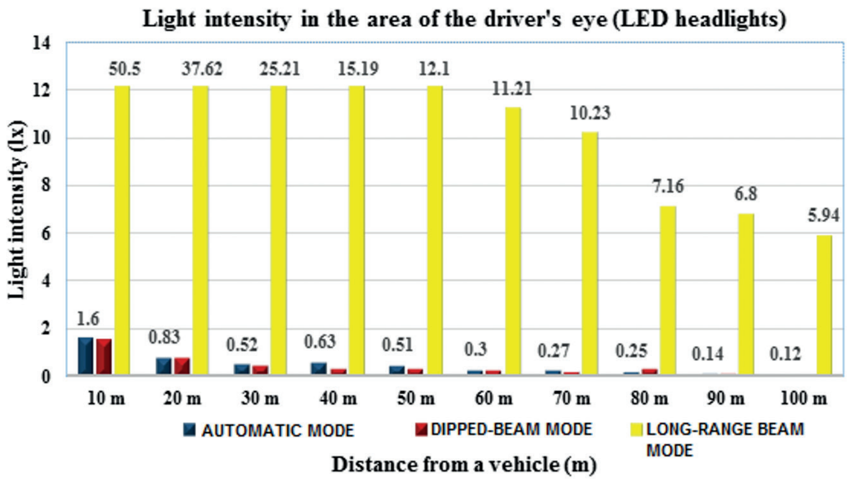

Figure 2. Measured values of the light intensity in the area of the driver's eye (LED headlights). Source: authors

As for the second measurement, the vehicle Hyundai i 40, equipped with xenon headlights, was used. For this vehicle, the long-distance headlights mode is ensured by the H7 halogen bulb and the dipped-beam mode is ensured by the DS1 xenon discharge lamp. When measuring the light intensity in the eyes area, the same measurement procedure as in the previous case (vehicle with LED headlights) was repeated. Xenon headlights are not equipped with automatic mode, thus, measurement was carried out in only two modes. Table 2 lists the measured values.

Table 2. Measured values of the light intensity falling into the driver´s eyes emitted by the xenon/halogen headlights. Source: authors

Xenon/halogen headlights	Glare in the eyes area (lx)	
	Headlights mode	
Distance between vehicles	Dipped-beam headlights	Long-distance headlights
10 m	1.15	2.89
20 m	0.42	12.69
30 m	0.12	6.23
40 m	0.02	6.36
50 m	0	6
60 m	0	5.36
70 m	0	5.34
80 m	0	2.56
90 m	0	2.13
100 m	0	2

In the dipped-beam mode, measurable light intensity values were obtained only in a distance of 40 m from the vehicle. Measured values throughout the distance from the vehicle are of values less than 1.5 lux, i.e. no glare of the vehicle driver in the opposite direction is occurred. In the long-range beam mode, the driver indicated the distance of 50 meters from the vehicle as a vision (visibility) influencing distance. With a subsequent approaching the vehicle in the opposite direction, the light intensity emitted by the halogen headlights significantly affected even inhibit the driver's vision. Figure 3 graphically shows the measured values.

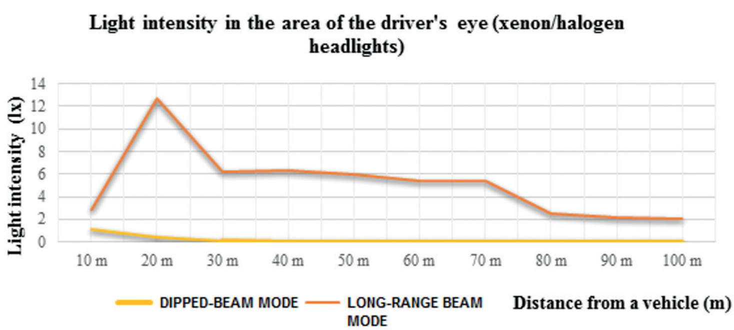

Figure 3. Measured values of the light intensity in the area of the driver's eye (xenon/halogen headlights). Source: authors

Third measurement was made with the vehicle Škoda Fabia equipped with halogen lights. The dipped-beam headlights mode and long-distance headlights mode are provided by the H7 halogen bulb. Following table 3 summarized the measured values.

Table 3. Measured values of the light intensity falling into the driver´s eyes emitted by the halogen headlights. Source: authors

Halogen headlights	Glare in the eyes area (lx)	
	Headlights mode	
Distance between vehicles	Dipped-beam headlights	Long-distance headlights
10 m	0.16	1.72
20 m	0.03	1.27
30 m	0	0.98
40 m	0	0.87
50 m	0	0.86
60 m	0	0.37
70 m	0	0.29
80 m	0	0.28
90 m	0	0.8
100 m	0	0.5

In the dipped-beam mode, the light intensity values in the eyes area were measured at only two distances, specifically of 10 m and 20 m in front of the vehicle, where the value detected in the distance of 20 m being negligible. This means that in this mode, no glare of the vehicle driver in the opposite direction is occurred.

In the case of the long-range beam mode, values of the overall examined distance were measured. However, they also reached only minimum values and did not cause the driver glare. The glared driver did not indicate the possible influence of his vision throughout the examination in both modes. The measured values are graphically evaluated in the following Figure 4.

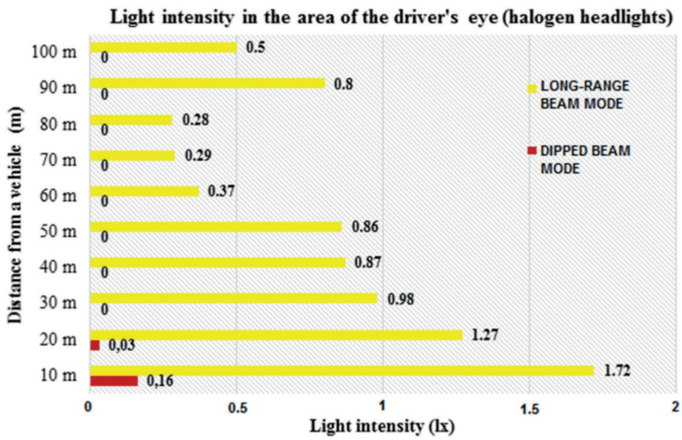

Figure 4. Measured values of the light intensity in the area of the driver's eye (halogen headlights). Source: authors

4. Conclusion

All three headlights systems in the dipped-beam headlights mode show acceptable light intensities falling into the driver´s eyes of the vehicle in the opposite direction. Another situation occurred when the long-distance headlights mode. This mistake, to forget to switch from long-range beam into dipped-beam headlights mode, is made by beginner-drivers or drivers tired of long ride without breaks [13,16,23]. A similarly unpleasant situation occurs even if the driver switches into the dipped-beam mode too late. When switching from the long-range beam mode into the dipped-beam mode to early, the driver loses a part of information, which generates a precondition of pedestrians neglect or other obstacles [1,27,29]. Figure 5 provides a comparison of the measured light intensity values in the long-distance headlights mode of all three measured headlamp types.

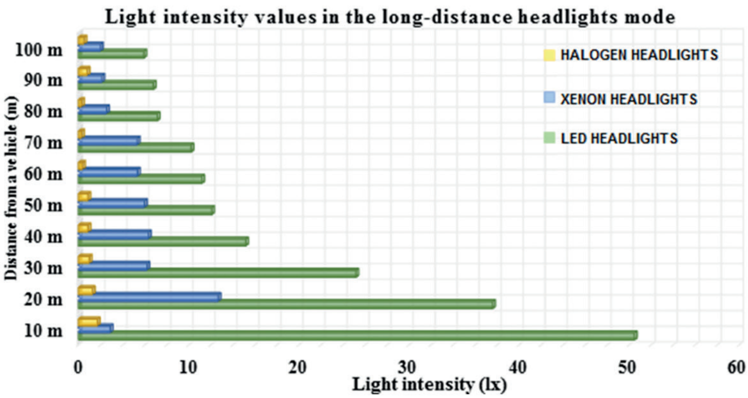

Figure 5. Comparison of the measured light intensity values in the long-distance headlights mode. Source: authors

As for the obtained results, halogen headlights emit the lowest light intensity. Within all three measurement examinations, the vehicle driver identified xenon headlights in long-distance mode and LED headlights also in long-distance mode as the most glaring headlights. The driver mistake, when he does not switch off the headlights into the dipped-beam mode, may cause a dangerous and risky situation. LED headlights allow this mistake only when disabled automatic headlight range control mode [6,9,19,27].

Following the results evaluation, it is possible to identify that the greatest light intensity is emitted by headlights using LED technology. While driving at night, they illuminate the roadway in the vehicle motion corridor with the greatest light intensity compared to other light sources. Xenon headlights are on the second place in terms of illuminating the road. In the case that headlights are not switched into the dipped-beam mode in time, a significant driver glare driving in the opposite direction may occur. This situation may cause so-called driver short blindness.

Emitted light intensity is characteristic by high values which cause considerable glare despite the distance of vehicles. During the experimental measurements, indicated the distance of 70 meters from the vehicle as a significantly glaring distance (vision influencing distance) in case of xenon headlights as well as LED lights.

As the most suitable for practice, Matrix LED headlights in automatic mode appear to be the best. They are able to switch from the daylight mode into the dipped-beam mode without a need of driver intervention and can register the tunnel travel. They are able to switch the headlights from the long-range beam mode into the dipped-beam mode without the driver intervention as well. These functions effectively eliminate possibilities of beginner mistakes and mistakes of inattention.

These headlights can also change the shape of the light cone also with regard to the vehicle speed, switch headlights depending on vehicle detection in the opposite direction as well as vehicle activities behind another vehicle. These headlights are able to recognize the traffic sign and, if there is no danger of glare by other road traffic users, they illuminate the traffic sign to make it easier for the driver to detect it.

The hypothesis has been confirmed.

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