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VISIBILITY OF AN UNTYPICAL OBSTACLE IN LOW BEAM HEADLIGHTS DURING DRIVING AT NIGHT

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Abstract

The article deals with the problems connected with road traffic safety highlighting driver's ability to notice an untypical obstacle in the light of low beam headlights while driving in the night. Visibility of an unlit object during the night is not only related to its motion but also to the necessity of its being lit to up to the required minimum height.

On the basis of a study of a road accident, it was found that the standards accepted in reconstruction of the accident for determination of the light beam height to be used for lighting an obstacle should not be taken for granted. The driver's surprise at the sight of an unlit obstacle is accompanied with the need to direct the light beam higher, which causes shortening of the distance available for a driver to react in an attempt to avoid hitting into an obstacle. An analysis of this case shows that verification of road accidents involving a crash with an untypical, incompatible obstacle that happen during the night needs to be carried out with attention and care.

A simulation program V-SIM4 version and Ratschbacher AutoView database was used for calculation of the possibility to avoid an accident. The results obtained on the basis of the authors own investigations can also be used in information campaigns, education for road safety improvement and development of proper attitudes of the road traffic users.

Keywords: *night driving, obstacle recognition, road traffic safety*

1. Introduction

Presently, there are no available data on road accidents, which occurred in Poland in 2015. However, according to the data from 2014, the value of a demographic rate, which is defined by the number of deaths per 100 thousand inhabitants, has decreased. The year 2014 finished with the rate value at the level of 8.3. This puts Poland in the group of countries with accident rate higher than the average European. This rate in the European Union was 5.1 deaths per 100 thousand inhabitants [15].

Unofficially, the initial data for 2015 does not indicate any substantial change in the value of the above-discussed rate.

It can be seen that Poland is the last but five among the countries of the European Union and only such countries as Bulgaria, Lithuania, Romania with the rate equal to 9 and Latvia where the rate reached a value 10.5 occupy higher positions in terms of the discussed rate.

However, in Croatia and Greece, the rate is at a level similar to Poland and it is, respectively: 7.3 and 7.2. The above presented data indicates that there is a need to address the issues connected with road safety improvement in Poland.

2. Road accidents at night

In this article, there are results of studies carried out to analyse accidents, which occurred during the night focusing on untypical character of road obstacles.

In the real road traffic conditions drivers can encounter untypical obstacles which are likely to cause a surprise and in order to make them visible it is required to use higher light beam than it is set out in standard calculation procedures as for example for accidents with involvement of pedestrians [4].

According to the data of The National Road Safety Council (KRBRD) in 2014, in Poland, there happened 34 970 of road accidents [15].

However, according to Police statistical data, most accidents took place during the day. This is due to the fact that the most intensive road traffic is reported during the day, which involves significantly higher likelihood of accident occurrence. However, it is the night, which poses a risk of occurrence of the most fatal events. This data shows that every fourth person involved in such an accident is killed, whereas every fifth person dies in result of road accidents that happen during the day. Among those classified as running into a stationary object, 365 accidents were reported (1%), in which 41 people died (1%) and 469 sustained injuries [16]. Despite being a time with rather low traffic intensity, night poses significant difficulties in recognition of a stationary object standing on the road. The shorter the distance necessary for identification of an obstacle the smaller chances to avoid running into it and the higher material losses and casualties.

3. Physical possibilities to notice an obstacle at night

Human eyes have limited perception possibilities and have to adapt to variable and difficult perception conditions. Obviously, lighting the road in front of a car with the use of light emitted from the vehicle headlights, significantly improves a driver’s ability to observe the road, its infrastructure, and obstacles.

The most important factors that contribute to better identification of obstacles are [4, 9, 10]:

- eyes of the driver,
- lights of the car,
- road,
- obstacle.

The process of perceiving an image is carried out inside a system, which is divided into an executive and a perceptive part. The optical system plays the executive role and the perceptive function is performed by human nervous system [14].

In front of an eye, there is a pupil, cornea and iris, the last one performs the function of light regulator, and a lens.

The lens projects the image onto the opposite part of an eye. On the wall opposite to the pupil, in vascular membrane, there are receptors called rods and cones, which are responsible for seeing at night – scotopic vision. They are spread over the whole area of the retina though they occur mainly on its edges.

Human vision in the night involves perception of shades of grey and, no sooner than after increasing the amount of light reflected from an obstacle, there appears a distinction of colours, which is the responsibility of cones. Thanks to these receptors – cones, a human can see during the day (photopic vision).

Under the conditions of night, we can talk about mesopic vision, that is, a combination of scotopic and photopic vision [9, 10].

The vehicle headlights are a very important factor, which has a significant influence on noticing an obstacle, depending on their design, condition, quality and cleanliness – this work deals with the problem of noticing an obstacle in low beam of the headlights, which depends on the above-mentioned design of headlights. The design solution of low beam headlights differ from each other in terms of the optical system type and the kind of the light source. The designs of headlights are divided into four groups: parabolic, ellipsoidal DE, multi-surface of FreeForm (FF) type, combined DE and FF [9, 10].

Modern efficient versions of halogen light bulbs of H type are filled with protective gas. Halogen lamps of blue light colour, more similar to daylight, can seem lighter and more contrastive, thanks to which they cause less fatigue to the eye. In Poland, cars are several years old on the average [17], therefore the most commonly used headlights are those from the above-mentioned groups. Vehicles equipped with the so called 'xenon headlights' are not widespread yet.

The condition of the road has also a large influence on noticing an obstacle by a driver. Distinctive features of the road are its shape, course and whether it is a straight section or a curve, uphill o downhill; other factors that determine safety of driving are the colour of its surface-black or white and the condition of its surface – whether it is dry or wet. When the road surface is smooth and wet, it is more difficult for the driver to notice an obstacle and headlights of other vehicles make thigs even worse [4]. On the other hand, an obstacle is characterized by geometric parameters, that is, its size, colour and brightness [9, 10].

4. Simplified model for noticing an obstacle

Noticing an unlit obstacle at night by a driver occurs when it is lit up to the height 25-30 cm. A distance of lighting an obstacle up to this minimum height can be calculated from formula [4, 7, 8]:

$$S_{wr} = S_{wt} \cdot \frac{h_r - h_p}{h_r}, \tag{1}$$

where:

h_r – distance of headlights axis from the road surface,

h_p – minimum height of the obstacle lighting,

S_{wt} – distance from an obstacle when it reaches the borderline of headlights light beam equal to 10 Lx.

5. Case study – own research

Circumstances of the analysed accident

The considered accident happened at night outside a built-up area. An articulated truck tractor stopped upon pulling out from a field in such a way that the trailer was standing diagonally across the road.

A driver of passenger Daewoo Matiz crashed into the right side of the trailer, which was standing on the right traffic lane. Fig. 1 shows the accident.

Fig. 1. The accident

Caused damage and traces on the road

Daewoo had the following damage:

– hood smashed and displaced backward,
– front left mudguard crashed,
– front left post (upper) smashed and its middle part moved backward,
– windshield broken, damage concentrated on the left side,
– damage to the front part of the left front door,
– left side mirror broken off,
– the front left headlight broken,
– the rim of the front left wheel damaged, the tire without compressed air.

Figure 2 shows damaged Daewoo vehicle and the damaged trailer.

Fig. 2. Damaged Daewoo and trailer

The trailer had the following damage:

– damage to the trailer found in its middle part on the left side,
– protection bar (fender) damaged and broken off,
– fastening (basket) of the spare wheel damaged on the left side,
– left foot of the trailer with red varnish pile-ups within the lower part at height of the front left wheel rim of Daewoo.

In the place of accident there were found:

– on the right traffic lane in the distance of 35.6 m after SPO (permanent point of reference) and 3.7 m from the left edge of the road there was the beginning of a braking trace left by a car wheel running straight to be finished at the distance of 37.7 m behind SPO and 3.7 m from the left edge of the road (trace no. 1),
– the second wheel braking trace was found 35.3 m behind SPO and 5.1 m from the left edge of the road to be finished 37.7 m behind SPO and 5.1 m from the left edge of the road (trace no. 2).

Assessment of the vehicles headlights

The analysis of headlights has revealed the following facts:

– lampshades of the side lamps splashed with mud,
– light of the lamps noticeable from a close proximity of the trailer,
– side lamps within the road out of order,
– efficient lamps of the trailer situated within the roadside.

The analysis of Daewoo headlights has revealed the following facts:

– left headlight damaged,
– right headlight broken,
– light switch in the position ‘on’ (low beam),
– light bulbs were not examined, according to authors sources the driver had switched to low beams when he noticed the lights of the truck tractor on the left traffic lane.

6. Sages of the investigations

Technical data of the research objects and traffic conditions

Daewoo:

- Matiz, htb 5d, complete vehicle kerb weight 800 kg (plus weight of the driver and passengers 68 kg each),
- length 3.495 m, width 1.495 m, height 1.485 m, wheel space 2.340 m, front wheel space 1.315 m ear wheel space 1.280 m,
- brakes efficiency 100%, braking system without ABS, tires 155/65 R13,
- engine with spark ignition, capacity 796 cm^3, capacity 38 kW, gear box with 5 gears,
- initial speed of Daewoo equal to 14.14 $m \cdot s^{-2}$ estimated on the basis of the length of braking traces and EES Catalogue [13].

Trailer:

- comparatively Kogel SN 24 P90/1.110, box type, kerb weight 6200 kg,
- length 11.100 m, width 2,550 m, height 3.970 m, number of axes 3, wheel space 2.400 m,
- brake efficiency 100%, braking system without ABS, tires 365/65 R22.5,
- stationary during collision.

Road:

- asphalt dry, clean, smooth, two traffic lanes with a central intermittent line,
- grip coefficient of wheels - adhesive 0.8 and slide 0.75, speed limit 90 $km \cdot h^{-1}$.

Results of calculations and simulation

The vehicle headlights distance from the road surface was estimated to be 0.76 m, on the basis of the vector silhouette of Daewoo Matiz with the use of Ratschbacher AutoView data [11]. The necessary height of the trailer headlights or rather its undercarriage with a spare wheel, mounted to the frame and the trailer foot, was estimated on the basis of images calibrated in V-SIM4 and was approximately 0.5 m [18], which is presented in Fig. 3. Whereas, the distance necessary to see the obstacle in the beam of 10 Lx illuminance headlights was assumed to be 50 m, that is equal to a typical low beam of a vehicle equipped with conventional headlights of older generation.

On the basis of formula (1), the distance covered until the trailer was lit up to the minimum height, which simultaneously corresponds to the distance available for the driver of Daewoo Matiz to take emergency actions, was, calculated [4, 7, 8]:

$$S_{wr} = S_{wt} \cdot \frac{h_r - h_p}{h_r} \approx 17.1m.$$

The calculated distance provided for the driver of Daewoo Matiz to be able to notice an unlit stationary articulated trailer standing on his traffic lane across the road is approximately 17 m.

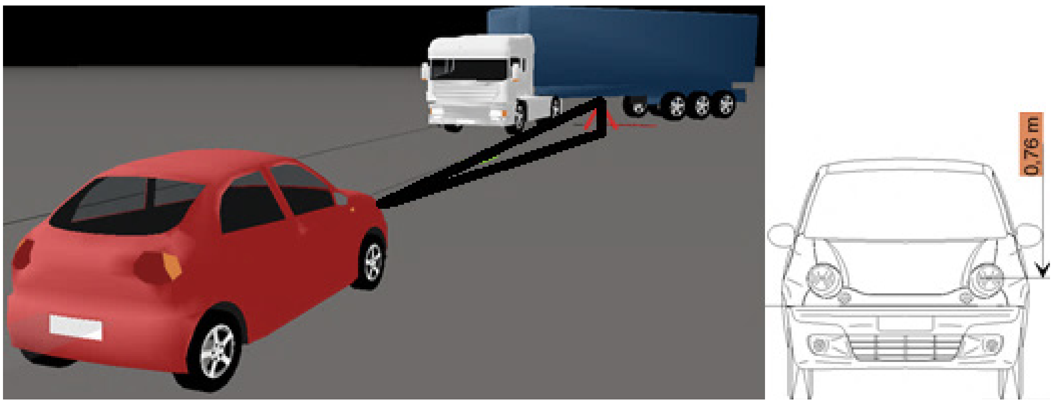

Fig. 3. Scheme of h_r and h_p estimation

The possibility to avoid the collision was analysed with the use of simulation program V-SIM4 and database for vehicles Ratschbacher AutoView [11, 18].

Figure 4 presents a simulation of Daewoo vehicle braking after its driver made the decision to push on the brakes, at the distance of 17 m before the obstacle, with the assumption of mean statistical reaction time considered to be adequate [6]. Fig. 5 shows the collision of Daewoo with the trailer set in 3D environment offered by the applied program.

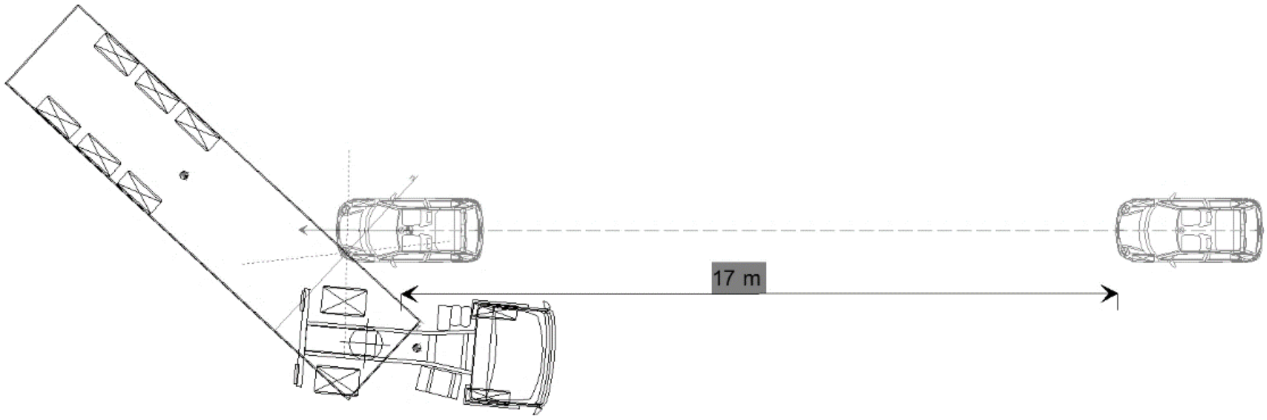

Fig. 4. Simulation of Daewoo braking

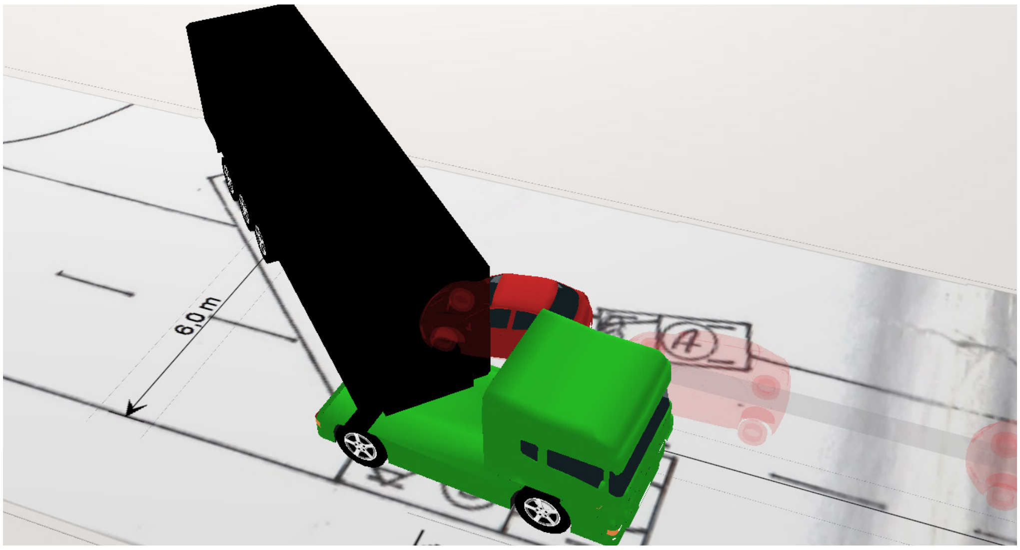

Fig. 5. Collision of Daewoo with the trailer

Further calculations were also performed with the use computer tool V-SIM4 [18]. The speed of the collision of Daewoo Matiz with the trailer was ~ 10 $m{\cdot}s^{-1}$. It should be noticed that it was the trailer frame, which was hit by Daewoo. The impact took place above the zone of Daewoo designed for absorption of crash impacts. If the crash had not been a head type with its impact to the basket and spare tire of the trailer its consequences could have been incomparably more serious as the car could have run under the trailer.

The calculations show that the impact caused a large change in inertia delay, in a very short time, affecting the persons inside the vehicle, which can cause additional injuries [2, 3]. The maximum delay reached value of almost 200 $m{\cdot}s^{-2}$ within only 0.1 s – a vehicle suddenly braking on dry asphalt gains delay equal to app. 7-8 $m{\cdot}s^{-2}$.

Below, in Fig. 6 there are time histories of speed, distance and kinetic energy changes of Daewoo, and in Fig. 7, additionally, delay changes of this vehicle during braking and collision in the function of time.

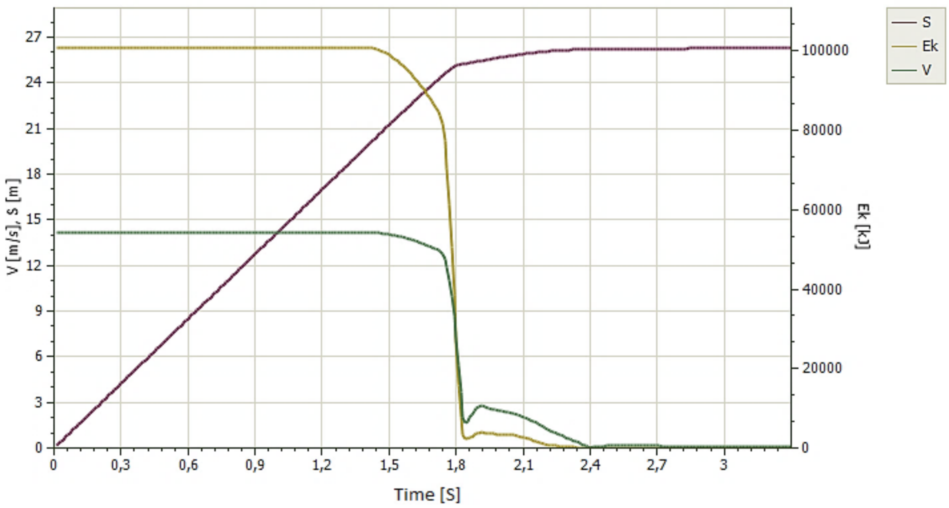

Fig. 6. Changes of S, V and E_k in time

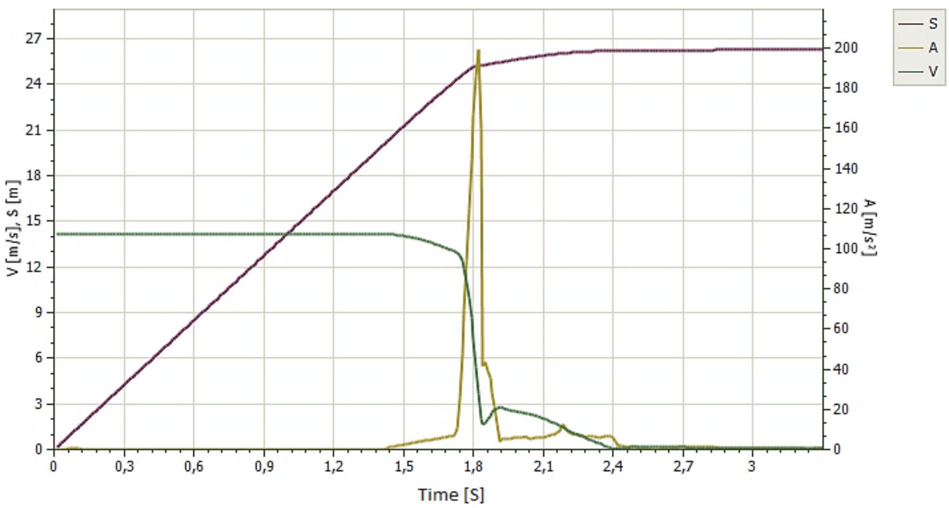

Fig. 7. Changes of S, V and A in time

7. Conclusions

An analysis of this case shows that verification of road accidents involving a crash with an untypical, incompatible obstacle that happen during the night needs to be carried out with attention and care. Determination of adequate height of lighting poses a big problem. In this specific case, it turned out that this height needed to be twice higher than the one accepted for a collision with a pedestrian. Therefore, it is necessary to measure the object or to use pre scaled pictures in order to make the assessment accurate enough to be used for further analyses [1]. Moreover, as the calculation results show, when a driver runs into an unlit obstacle during night driving, there occurs an element of surprise, which makes things even worse as it is usually perceived in close proximity. This leads to a collision with only slightly lower speed than the initial one.

At the same time, a crash into an obstacle, which is destructive to areas without reinforcement and zones designed for shock energy absorption, poses a risk of more serious injuries and material losses [2, 3].

The above presented case study proves a necessity of shaping proper attitudes of drivers, which have a large influence on road traffic safety in relation to leaving unlit vehicles on the roadside or even partly on the traffic lane. Simulation programs allow presentation of consequences of such irresponsible behaviours, and animations of the course of an event, which can be used in, educational and information campaigns organized for improving road traffic safety [5].

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