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INVESTIGATION OF AUTOMOBILE WHEEL IMPACT ON THE ROAD BORDER

Edgar Sokolovskij[1], Olegas Prentkovskis[2], Robertas Pečeliūnas[3], Jurgita Kinderytė-Poškienė[4]

[1, 3, 4] Dept of Automobile Transport, Vilnius Gediminas Technical University, J. Basanavičiaus g. 28, LT-03224 Vilnius, Lithuania. E-mail: Edgar.Sokolovskij@ti.vgtu.lt
[2] Dept of Transport Technological Equipment, Vilnius Gediminas Technical University, Plytinės g. 27, LT-10105 Vilnius, Lithuania. E-mail: olegas@ti.vgtu.lt

Abstract. Impact of the automobile wheels on the road border, as a result of which the wheel tire gets dismantled, is considered in the article. The required force and the minimal speed of driving, which is equivalent to the expenditures of the kinetic energy, necessary for dismantling the tire from the wheel rim after impact on the road border, are ascertained. The values of this force and speed, typical of the automobiles, attributed to different classes, their dependence upon the height of the road border and the angle of impact with the border are fixed. The more precise methods for calculating the automobile speed prior to the traffic accident, by taking into consideration the expenditures of the kinetic energy, necessary for dismantling the wheel after occurrence of its impact on the road border, is suggested.

Keywords: impact, wheel, automobile, road border, tire, dismantling, equivalent speed.

1. Introduction

The automobile movement, when the side of its wheel impacts on the road border, is little investigated [1–4]. Seeking for a more practical application of the results of these investigations (for example, while carrying out the examination of traffic accidents and while fixing the speed of the automobile movement prior to the traffic accident more precisely), it is necessary to fix the speed of the automobile movement, which is equivalent to expenditures of the automobile's kinetic energy at the moment of impact of the automobile wheel side on the road border.

The investigation of damages of automobile wheels proves that one of the most often damage of the wheels, ie the tire mounting sides, displaced from the edges of the rim, usually occurs in the course of a traffic accident, after the wheel has collided with hard objects, for example, the road border [5, 6]. The automobile losses a part of its kinetic energy and speed at the moment of collision. Up to now, while rating the speed of the automobiles before the traffic accidents, usually the expenditures of the automobile kinetic energy and loss of its speed have not been taken into consideration [7, 8]. Thus sometimes the reduced values of the automobile speed have been obtained. Seeking to rate the automobile speed before the occurrence of the traffic accident more precisely, it's necessary to evaluate the amount of kinetic energy of the automobile or the automobile speed, which is equivalent to the expenditures of its kinetic energy, which have been present and caused the above-mentioned damage of the wheel at the moment of its impact on the obstacle, for example, the road border.

2. Theoretical investigation

When the automobile slides sideways and the side components of its wheels impact on the road border, the area of the contact of the wheel with this border makes the segment (Fig 1).

Thus to dismantle the tire, the outside force $F_{iš}$, which produces an impact on it, should be larger than the force F_d, which is composed out of two constituents, ie the force, which is necessary to cope with the inside pressure of the tire, and the force, which is necessary to cope with friction of the mounting side and the rim.

Having carried out the theoretical investigation [5, 9], the condition of dismantling of the tire from the rim was obtained:

$$F_{iš} > F_d = \frac{R^2}{2}\left(\frac{\pi\alpha}{180} - \sin\alpha\right)\cdot \frac{p\left(\pi R^2 - \pi r^2\right)b}{\left(\pi R^2 - \pi r^2\right)b - \frac{R^2}{2}\left(\frac{\pi\alpha}{180} - \sin\alpha\right)l_d} + mgf,$$

$$F_{iš} > F_d = \frac{1}{2}\left(lR - a\left(R-h\right)\right)\cdot \frac{p\left(\pi R^2 - \pi r^2\right)b}{\left(\pi R^2 - \pi r^2\right)b - \frac{1}{2}\left(lR - a\left(R-h\right)\right)l_d} + mgf, \quad (1)$$

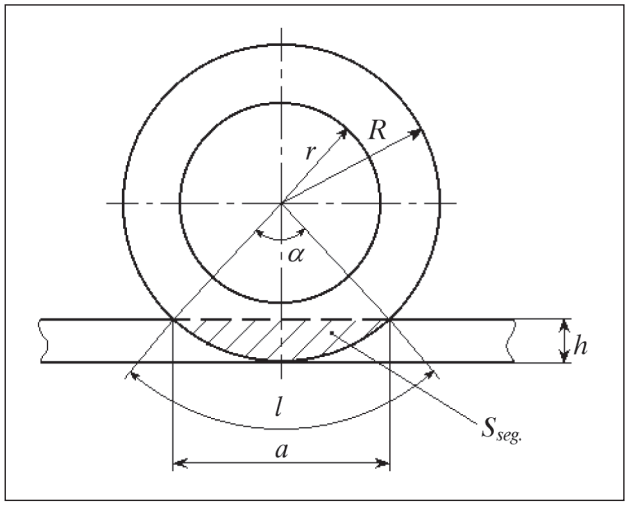

Fig 1. The contact of the side component of the automobile wheel with the road border

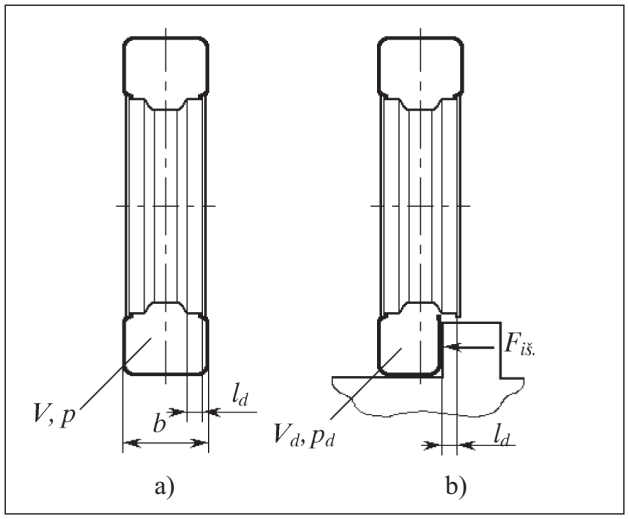

Fig 2. The automobile wheel: a – before the impact on the road border; b – at the moment of impact, just before the tire dismantling

where R – the external radial of the wheel, m; α – the angle of the sector, obtained by connecting the edge dots of the segment of the contact area with the centre of the wheel, deg (Fig 1); p – pressure of the undamaged tire, Pa; r – the internal radial of the tire (the external radial of the wheel rim), m; b – width of the tire, m; l_d – the distance, which is necessary to remove the tire from the edge of the wheel rim to be dismantled, m (Fig 2); m – weight of the automobile, kg; g – acceleration of gravity, m/s^2; f – the conventional coefficient of friction of the mounting side of the tire and the wheel rim; l – a part of the rim, located in between the edge dots of the segment of the contact area by measuring the external perimeter of the wheel, m (Fig 1); a – length of the straight line, which connects the edge dots of the segment of the contact area, m (Fig 1); h – height of the road border, m.

However, while carrying out the job practically (for example, while carrying out the examination of traffic accidents), not the force, which is necessary for dismantling the tire should be known, but the speed of the automobile movement v_E, which is equivalent to the expenditures of its kinetic energy, used for dismantling the tire from the wheel rim (m/s):

$$v_E = \sqrt{\frac{2}{m}A_d} = \sqrt{\frac{2l_d}{m}\left(\frac{R^2}{2}\left(\frac{\pi\alpha}{180} - \sin\alpha\right)\cdot \frac{p\left(\pi R^2 - \pi r^2\right)b}{\left(\pi R^2 - \pi r^2\right)b - \frac{R^2}{2}\left(\frac{\pi\alpha}{180} - \sin\alpha\right)l_d} + mgf\right)},$$

or

$$v_E = \sqrt{\frac{2l_d}{m}\left(\frac{1}{2}\left(lR - a\left(R-h\right)\right)\cdot \frac{p\left(\pi R^2 - \pi r^2\right)b}{\left(\pi R^2 - \pi r^2\right)b - \frac{1}{2}\left(lR - a\left(R-h\right)\right)l_d} + mgf\right)}, \quad (2)$$

where A_d – the job on dismantling the tire from the wheel rim, J.

It's a usual case when the values of the angle α, as well as the distance a and the length of the rim l are not known. Thus they can be expressed by other known values (Fig 1):

$$\alpha = 2\arccos\left(\frac{R-h}{R}\right);$$

$$a = 2\sqrt{R^2 - (R - h)^2} = 2\sqrt{2Rh - h^2};$$

$$l = \frac{\pi R}{180} 2 \arccos\left(\frac{R - h}{R}\right).$$

Knowing the minimal speed v_E, which is equivalent to the expenditures of the automobile kinetic energy, necessary for dismantling the tire from the rim, in cases, when the automobile, sliding to the side, impacts on the road border and the automobile wheel becomes depressurised through the displaced mounting side of the tire, it is possible to calculate more precisely the automobile speed before occurrence of the traffic accident (km/h) by evaluating the expenditures of kinetic energy, necessary for dismantling the tires:

$$v_a = \sqrt{26\left(S_1 j_1 + ... + S_i j_i\right) + v_s^2 + v_E^2 z}, \qquad (3)$$

where $S_{1...i}$ – the distance, which was covered by the automobile, which has been sliding along a certain road-cover, m; $j_{1...i}$ – the deceleration of the automobile, which has been sliding along a certain road-cover, m/s^2; v_s – the automobile speed, equivalent to the expenditures of its kinetic energy at the moment of its collision with the other object, for example, the automobile, km/h; v_E – the automobile speed, equivalent to the expenditures of its kinetic energy, necessary for dismantling the tire from the rim, km/h; z – the number of the dismantled wheels.

3. Results of investigation

The minimal force, necessary for dismantling the tire from the rim, and the minimal speed of the automobile, equivalent to the expenditures of its kinetic energy, after the automobile straightforwardly impacts on the road border, when the tire is dismantled, have been calculated for the definite automobiles of different types, ie HONDA CIVIC, MAZDA 626 and VW TRANSPORTER. The results are presented in Figs 3, 4.

As we see, the above-mentioned force and speed increase with the increase of the obstacle height; the larger values are typical of the automobiles with a larger mass.

The dependence of the force, necessary for dismantling the tire from the rim, and of the automobile speed, equivalent to the expenditures of kinetic energy at the moment of impact on the road border, when the tire is dismantled, upon the angle of impact has been ascertained (for the border height, equal to 6, 8 and 10 cm). The results are in Figs 5–10.

It should be stated that the force, necessary for dismantling the tire from the rim, and the speed, equivalent to the expenditures of the automobile kinetic energy, necessary for dismantling the tire, which have been calculated, are minimal as, while calculating, the amount of kinetic energy, which is consumed in the course of distortion of

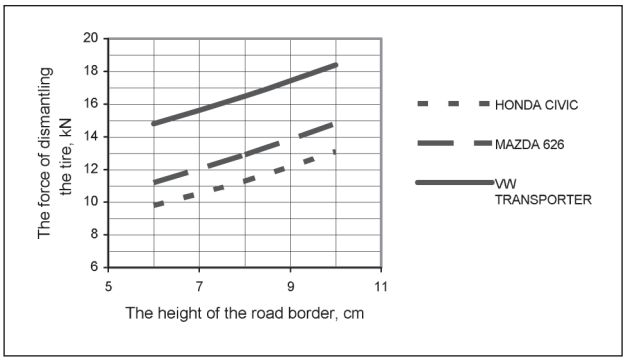

Fig 3. The minimal force, necessary for dismantling the tire from the rim

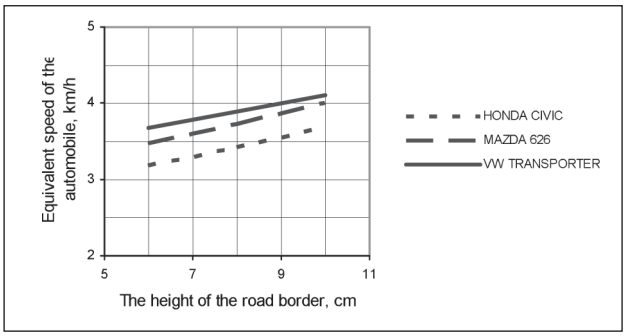

Fig 4. The automobile minimal speed, equivalent to the expenditures of its kinetic energy at the moment of its impact on the road border, when the tire becomes dismantled

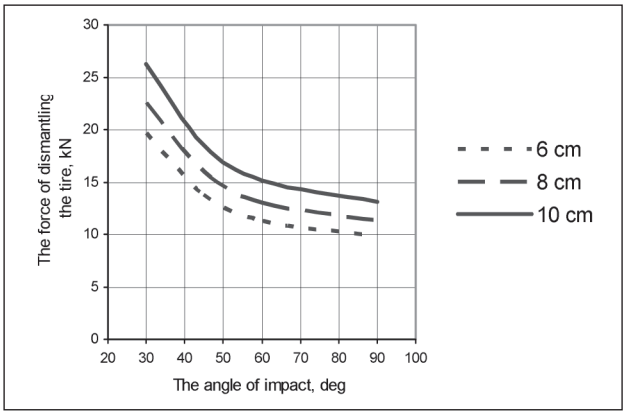

Fig 5. Dependence of the force, necessary for dismantling the tire from the rim, on the angle of impact for HONDA CIVIC

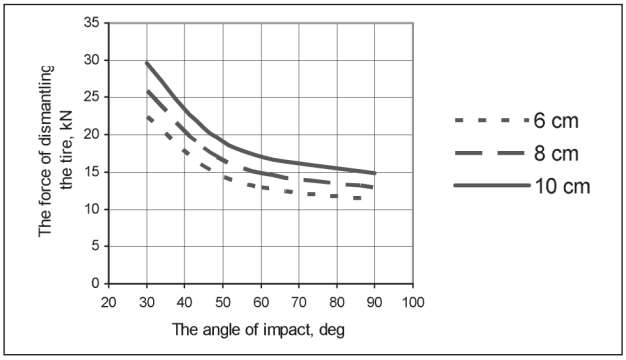

Fig 6. Dependence of the force, necessary for dismantling the tire from the rim, on the angle of impact for MAZDA 626

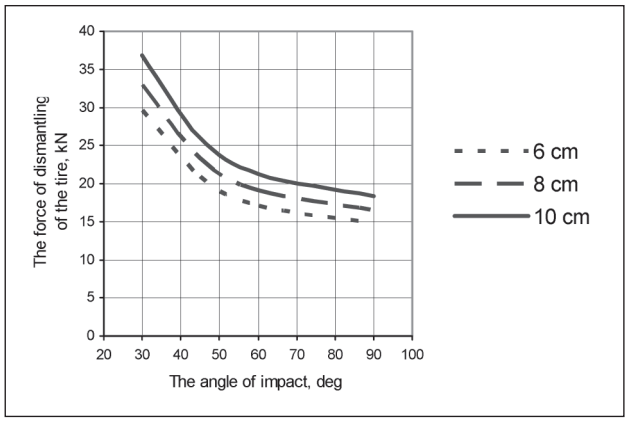

Fig 7. Dependence of the force, necessary for dismantling the tire from the rim, on the angle of impact for VW TRANSPORTER

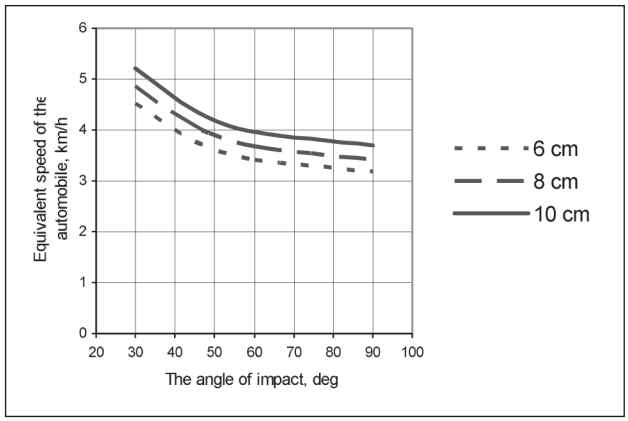

Fig 8. Dependence of the minimal automobile speed, equivalent to the expenditures of its kinetic energy at the moment of impact on the road border, when the tire becomes dismantled, on the angle of impact for HONDA CIVIC

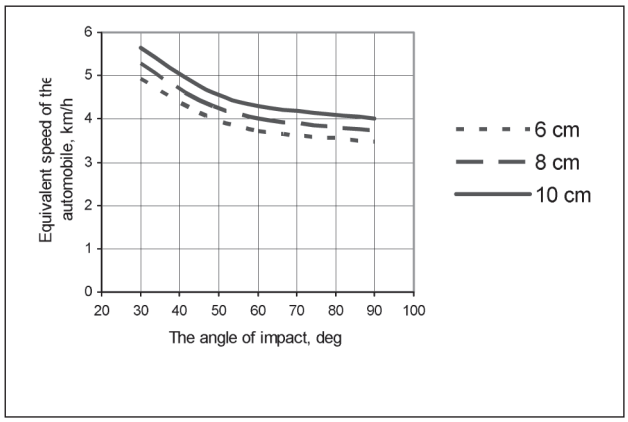

Fig 9. Dependence of the minimal automobile speed, equivalent to the expenditures of its kinetic energy at the moment of impact on the road border, when the tire becomes dismantled, on the angle of impact for MAZDA 626

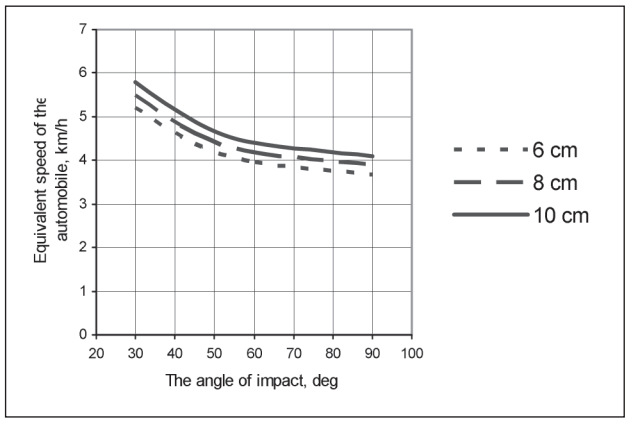

Fig 10. Dependence of the minimal automobile speed, equivalent to the expenditures of its kinetic energy at the moment of impact on the road border, when the tire becomes dismantled, on the angle of impact for VW TRANSPORTER

the tire carcass as well as in cases, when the rim contacts the road border and causes the damage, has not been evaluated.

4. Conclusions

1. After having created the methods of calculating the minimal force, necessary for dismantling the tire from the rim, and the automobile speed, which is equivalent to the expenditures of its kinetic energy, necessary for dismantling the tire after the wheel has collided with the road border, the dependence of this force and speed upon the height of the road border (Figs 3, 4) and the angle of impact of the automobile on the road border (Figs 5–10) for the automobiles of different classes (HONDA CIVIC, MAZDA 626 and VW TRANSPORTER) has been ascertained.

2. The values of the force, which is necessary for dismantling the tire from the wheel rim, and of the speed, which is equivalent to the expenditures of the automobile's kinetic energy, necessary for dismantling the tire from the wheel rim, which are calculated according to the offered methods, can serve as the minimal possible values as, while calculating, the amount of kinetic energy, which is consumed in the course of distortion of the tire carcass as well as in cases, when the rim contacts the road border and causes the damage, has not been evaluated.

3. The offered methods provide the possibility to calculate more precisely the speed of the automobile movement prior to the traffic accident by evaluating the expenditures of the kinetic energy, used for dismantling the tires when the automobile slides in the transversal direction and impacts on the road border and the automobile wheel becomes hermetically unsealed through displacement of the tire mounting side. However, application of the offered methods in practice is quite complicated, as, in the course of examining traffic accidents, the expert is not very often aware of many values, which are necessary for calculation.

References

1. DANNER, M.; HALM, J. *Technical analysis of road accidents* (Technische Analyse von Verkehrsunfällen). Eurotax (International) AG CH-8808 Pfäffikon, 1994. 570 p. (in German).
2. LANZENDOERFER, J.; SZCZEPANIAK, C.; SZOSLAND, A. *Theory of automobile move* (Teoria ruchu samochodu). Łódź: Wydawnictwo politechniki łódzkiej, 1988. 340 p. (in Polish).
3. BOGDEVIČIUS, M.; PRENTKOVSKIS, O.; VLADIMIROV, O. Engineering solutions of traffic safety problems of road transport. *Transport*, Vol XIX, No 1, 2004, p. 43–50.
4. PRENTKOVSKIS, O. *Interaction between the vehicle and obstacles:* Doctoral diss., Technological Sciences, Transport Engineering (Automobilio sąveika su kliūtimis: Daktaro disertacija, Technologijos mokslai, Transporto inžinerija). Vilnius: VGTU, 2000. 117 p. (in Lithuanian).
5. SOKOLOVSKIJ, E. *Investigation of interaction of the wheel with the road and its elements in the context of examination of traffic accident*s. Doctoral diss. (Rato sąveikos su keliu ir jo elementais tyrimai eismo įvykių ekspertizės kontekste. Daktaro disertacija). Vilnius: VGTU, 2004. 147 p. (in Lithuanian).
6. SOKOLOVSKIJ, E. The analysis and statistical research of damages of cars wheels appearing just before and during an accident. *Transportas* (*Transport Engineering)*, 2000, Vol XV, No 3, p. 118–122 (in Lithuanian).
7. ILARIONOV, V. A. *Examination of road traffic accidents* (Экспертиза дорожно-транспортных происшествий). Moscow: Transport, 1989. 254 p. (in Russian).
8. LUKOŠEVIČIENĖ, O. *The accident analysis and simulation.* Monograph (Autoįvykių analizė ir modeliavimas. Monografija). Vilnius: Technika, 2001. 244 p. (in Lithuanian).
9. KORN, G.; KORN, T. *Reference book on mathematics for scientific workers and engineers* (Справочник по математике для научных работников и инженеров). Moscow: Nauka, 1968. 720 p. (in Russian).

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