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DEFINITION OF REQUIREMENTS TO THE ACCOUNTING OF ROTARY MOVEMENT IN THE ANALYSIS OF VEHICLES COLLISIONS

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Abstract:

In work the analysis of the road accidents main types (RA) in the Russian Federation for the last five years, for the purpose of determining change dynamics of the main accident rate indexes is made. Main types of road accident, common to the considered subject – the Belgorod region — are defined. It is established that the main type of road accident is vehicles collision (V), the analysis of the main directions used in expert practice in researching this type of incident is carried out. The key parameters used by the expert-autotechnician in the analysis of specific type of incident are received, the approaches used for their definition are analyzed. On the basis of the obtained data the experimental analysis of various methods use to determine fundamental values of the obtained data is carried out, the procedure of collision analysis for the CU and use of various methods depending on parameters of the cars participating in road accident are analyzed. Instructions and recommendations to use of the received results are developed, the technique of the rotary movement accounting depending on car category is offered.

Keywords: Road accident, vehicles collision, rotational movements, traveling speed, expert assessment.

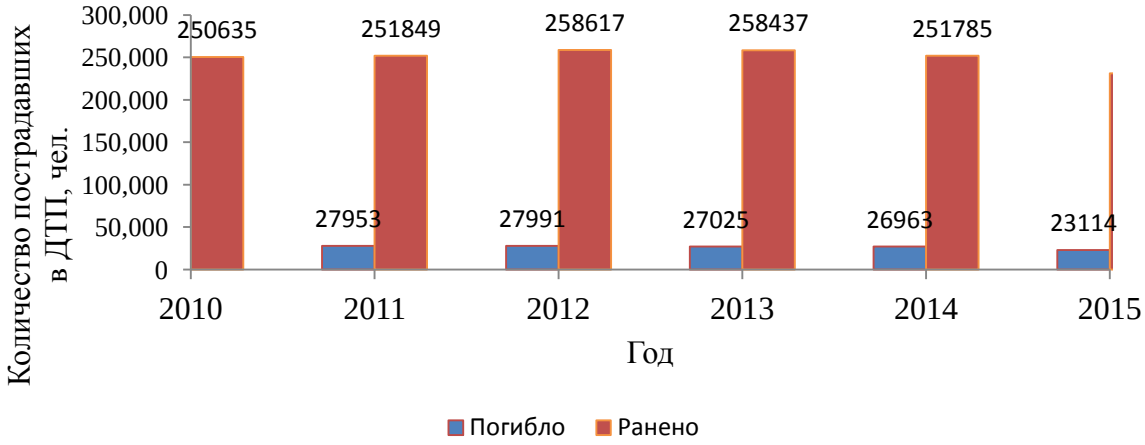
Introduction

The systematic analysis and structuring statistical data of the road accidents (RA) allows to answer a number of questions, to take measures concerning efficiency taken for decrease in accident rate and increase in traffic safety. Also the analysis allows to reveal some undercounting and weaknesses of similar actions and to actually create final re-

quirements for traffic safety (TSR). Qualifying standards exert impact on a set of departments work: executive authorities and medical and educational institutions graduees. Therefore the analysis of road accident, though can take a lot of time (especially in the detailed analysis of single road accidents, with various types of cars in the most various conditions), is an important stage of future actions rational planning.

According to data of the state traffic safety inspection (STSI), in the Russian Federation in 6 years (2010-2015) the total of the dead in road accident makes 159613 people of them 5269 children aged under 16 years [1]. The general view of dynamics of the dead is presented in Fig. 1.

Figure 1 — the Dead and wounded on roads of the Russian Federation during 2010-2015.



1. Количество пострадавших в ДТП, чел.	1. The number of victims in road accident, persons.
2. Погибло	2. Died
3. Ранено	3. Wounded
4. Год	4. Year

As we can see from the chart, during the period from 2010 to 2012 growth of fatal cases in road accident is observed [3]. From 2012 to 2014 small recession took place, and already by the end of 2015 the number of the road accident victims was sharply reduced by 4977 people relatively 2012. Year 2012 is peak on a death toll and in 2013-2020 it is stated in the Federal Target Program (FTP) for "Increase in traffic safety" as basic concern to plan and form improvements of accident rate indicators [2]. According to the FTP, by 2020 the death toll is planned to reduce by 8 thousand people. Thus, by 2020 this indicator should not exceed 20000. For 3 years of the program it was succeeded to reduce mortality by 4877 people. Considering that before the termination of the 5 years program there are good

chances to exceed the plan. It is also worth noting that in 15 years of the 21st century a mark of 23 thousand people can be called minimum. But, despite such positive dynamics, weight of consequences in Russia is steady and remains at the level of 9-10 people. It means that 9-10 people from 100 victims die in road accident.

The most widespread type of incident is collision of two cars [4]. In Russia 41% of all road accidents in 2014 and 2015 are the share of them. Character of this type of road accident can be most various and not less various are options of its configuration. There is a large number of the software products allowing to make the analysis and calculations of parameters in researching the mechanism of cars colliding [5]. Mathematical models which allow to define necessary data are their cornerstone. The research of these methods and their improvement will allow to determine these parameters more precisely.

Methods

Fundamental parameter at examination of road accident is the speed of the car movement before applying the emergency brake [6-9]. In expert practice the greatest distribution was gained by the following equation:

$$v_a = 1{,}8 \cdot j_{\text{уст}} \cdot t_3 + \sqrt{26 \cdot j_{\text{уст}} \cdot S_{ю}} \qquad (1)$$

where t_3 – delay increase time, s; j_{ycm} – the established delay TC, m/s^2; $S_{ю}$ – length of break track, m.

At cars colliding there is a need to determine the speed of the vehicle (V) at the time of blow v'_1, and for this purpose in turn it is necessary to determine the speed of both CU after collision (v''_1 и v''_2). This calculation takes place on formulas:

$$v_1' = v_1'' \cdot \frac{\sin(\alpha - \delta_1)}{\sin\alpha} - \frac{G_2}{G_1} \cdot v_2'' \cdot \frac{\sin\delta_2}{\sin\alpha} \qquad (2)$$

$$v_1'' = \sqrt{26 \cdot j_1 \cdot S''_{m1}} \qquad (3)$$

$$v_2'' = \sqrt{26 \cdot j_2 \cdot S''_{m2}} \qquad (4)$$

where v_1' – TC1 speed at the time of collision, km/h; v_1'' and v_2'' – speeds of the movement TC1 and TC2 respectively after blow, km/h; S''_{m1} and S''_{m2} – the size of movement of the mass center for TC1 and TC2 respectively after blow, m; j_1 – delay of TC1 in the course of rejection m/s^2; j_2 – the minimum delay of TC2 after collision, m/s^2; $\delta_1$andδ_2 – corners of deviation for TC1 and TC2 after blow, deg.; α – corner between longitudinal axes of the CU at the time of collision, deg.; G_1 - mass of TC1, kg.; G_2 - mass of TC2, kg. Expression (2) is received proceeding from conservation law of number of the movement. The equations (3) and (4) consider expenses of kinetic energy at forward movement of the CU after blow, but do not take into consideration a car turn around the gravity center. Depend-

ing on a point of the first contact of cars, there can be a moment of force which leads to complex rotary motion of the CU. In this case formulas (3) and (4) will take a form:

$$v_1" = \sqrt{26 \cdot j_1 \cdot \left(S"_{m1} + \frac{2a_1 b_1 \varepsilon_1}{L_1}\right)} \quad (5)$$

$$v_2" = \sqrt{26 \cdot j_2 \cdot \left(S"_{m2} + \frac{2a_2 b_2 \varepsilon_2}{L_2}\right)} \quad (6)$$

where a_1 and a_2 – distance from the forward bridge to the gravity center for TC1 and TC2 respectively, m; b_1 and b_2 – distances from the back bridge to the gravity center, m; ε_1 and ε_2– angles of rotation of a longitudinal axis around the gravity center after collision, I am glad. Knowing residual speeds of the CU after collision, on conservation law of number of the movement it is possible to find their speeds at the time of collision:

$$v'_1 = v_1"\cos\varphi_1 + \frac{G_2}{G_1} v_2"\cos\varphi_2 \quad (7)$$

$$v'_2 = \frac{G_1}{G_2} v_1"\sin\varphi_1 + v_2"\sin\varphi_2 \quad (8)$$

where v'_2 – TC2 speed at the time of collision, km/h; φ_1 – corner of deviation from the gravity center of TC1 at the time of travel after blow, deg.; φ2 – corner of deviation from the gravity center of TC2 at the time of travel after blow, a hail. Important value renders rotary motion on speed, but in expert practice this parameter generally is accepted as constant, within the research we will make the analysis of angles of rotation of the CU and we will develop the criteria data allowing to make the accounting of rotary motion.

Main Part

According to the scientific state-of-the-art review, the influence analysis of a turn of an axis of the car around the gravity center is made and we will define sensitivity of speed calculation result for the car before application of braking from this factor for this road accident. We will for this purpose be set by various values of a corner of a turn axis from 0 ° to 360 °C at a slow pace 30 ° and we will observe as TC1 speed before braking application changes. First, we will transform system from the equations (1), (5), (6) and (7). Then TC1 speed before braking:

$$\sqrt{26 \cdot j_1 \cdot \left(S"_{m1} + \frac{2a_1 b_1 \varepsilon_1}{L_1}\right)} \cdot \cos\phi_1 + \frac{G_2}{G_1} \cdot \sqrt{26 \cdot j_2 \cdot \left(S"_{m1} + \frac{2a_2 b_2 \varepsilon_2}{L_2}\right)} \cdot \cos\phi_2 \quad ^2$$
$$26 \cdot j_{\text{уст}} \cdot S_{ю} +$$
$$v_a = 1{,}8 \cdot j_{\text{уст}} \cdot t_3 + \sqrt{\quad} \quad (9)$$

When calculating all parameters, except ε_1 and ε_2 are accepted as constants. Taking it into account the expression (9) will take a form:

$$v_a = 2{,}7 + \sqrt{3260{,}4 + \sqrt{156 \cdot (6{,}84 + 1{,}33 \cdot \varepsilon_1)} \cdot 0{,}97 + 1{,}36 \cdot \sqrt{31{,}2 \cdot (3{,}9 + 1{,}33 \cdot \varepsilon_2)}}^{\,2} \quad (10)$$

Thus, the equation (9) is reduced to two variables ε_1 and ε_2. Let us carry out calculations in the Excel software. We bring a formula (10) in a cell of the table and by means of the massif formula we will receive a data set which represent various speed values at various combinations of an axis turn corners (tab. 1):

Table 1 – Data array of speeds.

ε2	*0*	*30*	*60*	*90*	*120*	*150*	*180*	*210*	*240*	*270*	*300*	*330*	*360*
0	*76,46*	*77,28*	*78,05*	*78,78*	*79,48*	*80,15*	*80,79*	*81,42*	*82,02*	*82,61*	*83,19*	*83,74*	*84,29*
30	*77,46*	*78,30*	*79,08*	*79,83*	*80,54*	*81,22*	*81,88*	*82,51*	*83,13*	*83,72*	*84,30*	*84,87*	*85,42*
60	*78,44*	*79,29*	*80,09*	*80,85*	*81,57*	*82,26*	*82,93*	*83,57*	*84,19*	*84,80*	*85,38*	*85,96*	*86,52*
90	*79,40*	*80,26*	*81,07*	*81,84*	*82,57*	*83,27*	*83,94*	*84,59*	*85,22*	*85,84*	*86,43*	*87,01*	*87,58*
120	*80,33*	*81,20*	*82,03*	*82,80*	*83,54*	*84,25*	*84,93*	*85,59*	*86,23*	*86,85*	*87,45*	*88,03*	*88,61*
150	*81,24*	*82,13*	*82,96*	*83,75*	*84,49*	*85,21*	*85,90*	*86,57*	*87,21*	*87,83*	*88,44*	*89,03*	*89,61*
180	*82,13*	*83,03*	*83,87*	*84,67*	*85,42*	*86,15*	*86,85*	*87,52*	*88,17*	*88,80*	*89,41*	*90,01*	*90,59*
210	*83,01*	*83,91*	*84,77*	*85,57*	*86,33*	*87,07*	*87,77*	*88,45*	*89,10*	*89,74*	*90,35*	*90,96*	*91,54*
240	*83,87*	*84,78*	*85,64*	*86,45*	*87,23*	*87,96*	*88,67*	*89,36*	*90,02*	*90,66*	*91,28*	*91,89*	*92,48*
270	*84,71*	*85,64*	*86,50*	*87,32*	*88,10*	*88,84*	*89,56*	*90,25*	*90,91*	*91,56*	*92,19*	*92,80*	*93,39*
300	*85,54*	*86,47*	*87,35*	*88,17*	*88,96*	*89,71*	*90,43*	*91,12*	*91,79*	*92,44*	*93,07*	*93,69*	*94,29*
330	*86,35*	*87,30*	*88,18*	*89,01*	*89,80*	*90,56*	*91,28*	*91,98*	*92,66*	*93,31*	*93,95*	*94,56*	*95,17*
360	*87,16*	*88,11*	*89,00*	*89,84*	*90,63*	*91,39*	*92,12*	*92,83*	*93,51*	*94,16*	*94,80*	*95,42*	*96,03*

In a cell No. 1 at values ε_1 and ε_2 equal to zero there is speed values for TC1 equal to 76,46 km/h which we calculated in the previous section without rotary motion of the car. We accept this value as settlement concerning which percentage deviations for other values will be counted. Having processed data array, presented in table 1, we receive:

Table 2 – Percentage deviations of speed values from settlement.

ε_2	0	30	60	90	120	150	180	210	240	270	300	330	360
0	0	1,07	2,05	2,97	3,83	4,64	5,4	6,1	6,8	7,5	8,1	8,8	9,4
30	1,30	2,37	3,34	4,25	5,1	5,9	6,7	7,4	8,1	8,7	9,4	10,0	10,6
60	2,54	3,59	4,56	5,5	6,3	7,1	7,8	8,6	9,2	9,9	10,5	11,1	11,7
90	3,71	4,76	5,7	6,6	7,4	8,2	9,0	9,7	10,3	11,0	11,6	12,2	12,8
120	4,83	5,9	6,8	7,7	8,5	9,3	10,0	10,7	11,4	12,0	12,6	13,2	13,8
150	5,9	6,9	7,9	8,7	9,6	10,3	11,0	11,7	12,4	13,0	13,6	14,2	14,7
180	6,9	7,9	8,9	9,7	10,5	11,3	12,0	12,7	13,3	14,0	14,6	15,1	15,7
210	7,9	8,9	9,8	10,7	11,5	12,2	12,9	13,6	14,3	14,9	15,4	16,0	16,5
240	8,9	9,8	10,8	11,6	12,4	13,1	13,8	14,5	15,1	15,7	16,3	16,9	17,4
270	9,8	10,7	11,6	12,5	13,3	14,0	14,7	15,3	16,0	16,6	17,1	17,7	18,2
300	10,6	11,6	12,5	13,3	14,1	14,8	15,5	16,2	16,8	17,4	17,9	18,5	19,0
330	11,5	12,4	13,3	14,1	14,9	15,6	16,3	16,9	17,5	18,1	18,7	19,2	19,7
360	12,3	13,3	14,1	14,9	15,7	16,4	17,1	17,7	18,3	18,9	19,4	19,9	20,5

Percentage deviations of speeds which exceed the admissible error of ±5% accepted in engineering practice are noted by bald italics. Analyzing the table, it is possible to notice a tendency – in cases when the total corner of a turn of both cars, exceeds or is equal 150 °, underestimation of rotary motion of cars leads to an error which is more than admissible. This condition has an appearance:

$$\varepsilon_1 + \varepsilon_2 \geq 150° \qquad (11)$$

Thus, if this inequality is carried out, then in formulas (5) and (6) it is recommended to consider a turn of a longitudinal axis of the car around the gravity center.

The received condition is fair for a case of cars colliding of category M1, but often these collisions happen also to cars of other categories, we will make the analysis what tendency in case of collision of the car of category N2 and M1, under the same conditions [10].

Table 3 – A percentage deviation at collision of M1 with N2.

ε_2	0	30	60	90	120	150	180	210	240	270	300	330	360
0	0,0	2,9	5,4	7,7	9,8	11,7	13,4	15,0	16,5	17,9	19,2	20,5	21,6
30	1,3	4,1	6,6	8,9	10,9	12,8	14,5	16,1	17,5	18,9	20,2	21,4	22,6
60	2,5	5,3	7,8	10,0	12,0	13,8	15,5	17,0	18,5	19,8	21,1	22,3	23,4

90	*3,7*	***6,5***	***8,9***	***11,0***	***13,0***	***14,8***	***16,4***	***18,0***	***19,4***	***20,7***	***21,9***	***23,1***	***24,2***
120	*4,8*	***7,5***	***9,9***	***12,0***	***13,9***	***15,7***	***17,3***	***18,8***	***20,2***	***21,5***	***22,7***	***23,9***	***25,0***
150	***5,9***	***8,5***	***10,9***	***13,0***	***14,8***	***16,6***	***18,2***	***19,6***	***21,0***	***22,3***	***23,5***	***24,6***	***25,7***
180	***6,9***	***9,5***	***11,8***	***13,8***	***15,7***	***17,4***	***19,0***	***20,4***	***21,8***	***23,0***	***24,2***	***25,3***	***26,4***
210	***7,8***	***10,4***	***12,7***	***14,7***	***16,5***	***18,2***	***19,7***	***21,2***	***22,5***	***23,8***	***24,9***	***26,0***	***27,1***
240	***8,7***	***11,3***	***13,5***	***15,5***	***17,3***	***19,0***	***20,5***	***21,9***	***23,2***	***24,4***	***25,6***	***26,7***	***27,7***
270	***9,6***	***12,1***	***14,3***	***16,3***	***18,1***	***19,7***	***21,2***	***22,6***	***23,9***	***25,1***	***26,2***	***27,3***	***28,3***
300	***10,4***	***12,9***	***15,1***	***17,0***	***18,8***	***20,4***	***21,9***	***23,2***	***24,5***	***25,7***	***26,8***	***27,9***	***28,9***
330	***11,2***	***13,7***	***15,8***	***17,7***	***19,5***	***21,1***	***22,5***	***23,9***	***25,1***	***26,3***	***27,4***	***28,4***	***29,4***
360	***12,0***	***14,4***	***16,5***	***18,4***	***20,1***	***21,7***	***23,1***	***24,5***	***25,7***	***26,9***	***28,0***	***29,0***	***30,0***

Apparently from table 3, at such option underestimation even of rather small angles of rotation for TC1 and TC2 leads to errors, exceeding admissible. Sensitivity of results of calculation it is possible will explain with the fact that the car needs a significant amount of kinetic energy to force the truck, bigger on weight, to turn the axis on a certain corner. Thus, if the car 1 collided the car 2 which considerably exceeds it on weight, then it is recommended to consider an axis turn:

$$G_1 << G_2 \qquad (12)$$

On the basis of the executed researches it is possible to formulate the conclusion that at existence of difficult rotary motion of cars it is expedient to enter into the equations of speeds composed, considering this nature of the car movement as even at rather small corners of a turn of an axis, value of speed of TC1 approached border of an admissible error.

Conclusion

Cars colliding is difficult multiple-factor process. The mathematical models used at investigation by road accident represent theoretically reasonable equations providing sufficient accuracy despite simplifications which are used in them.

The most important initial parameters which influence the size of initial speed are the established delay and coefficient of coupling. Experimental determining these sizes by means of special means is a desirable action. Especially it concerns delay as the tabular data used at the moment become irrelevant against the background of continuous development of brake systems.

At existence of difficult rotary motion of cars it is expedient to enter into the equations of speeds composed, considering this nature of the car movement as even at rather small corners of a turn of an axis, value of speed of TC1 approached border of an admissible error.

Summary: High level of accident rate in the Russian Federation at rather low level of auto-mobilization is a symptom of a serious disease of motor transportation system. The analysis of statistics of road accident does not allow to doubt that in Russia it is required to hold still a set of organizational and technical events before the situation changes to the best.

The difficult situation in the sphere of traffic safety, demands from specialists of this area of decisive steps in advance of the last achievements of science and technology for the most effective studying of the road accidents. In particular, in the future broad application in the field of investigation and examination of road accident will be received by the software of the fourth generation capable to use difficult mathematical models which did not find broad application in the classical approved techniques in a type of their labor input. Besides, it is necessary to accumulate statistical data on the most different activities of traffic safety. Much important aspect is improvement of the legislation.

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References

1. Indicators of security status of traffic. Date of access 20.09.2016 http://www.giTSR.ru/stat/.
2. The federal target program for increase in traffic safety in 2013-2020. Date of access 08.08.2016 http://www.fcp-pTSR.ru/.
3. Novikov, I.A., A. G. Shevtsova and G. A. Bakharev, 2015. Assessment of dynamics of accident rate on roads of the Russian Federation and a measure for its decrease. Equipment magazine and technologies of construction, 4 (4): 5-10.
4. Semikopenko, Y.V., A. G. Shevtsov, D. V. Dmitriyev and G. A. Bakharev, 2016. Main types of the road accidents in the Russian Federation. Magazine Progress of modern science and education, 5 (7): 76-79.
5. Shutov, A.I., E. A. Novopisny, 2012. Examination of cars colliding and opportunity for improvement. Magazine Bulletin of the Belgorod state technological university of V. G. Shukhov, 1:177-181.

6. Balakin, V.D., 2005. Examination of the road accidents. Omsk Publishing house of SIBADI, with: 136.
7. Ilarionov, V.A., 1980. Judicial autotechnical expertize. Moscow VNIISE Publishing house, p: 152.
8. Shevtsov, C.O., K.B. Grosbeak, 2003. Investigation of circumstances of the road accidents. Kharkiv 2nd prod., additional, p: 93.
9. Sarev, A.V., E. A. Novopisny, S. V. Dorokhin and I. A. Novikov, 2015. General questions of examination of the road accidents. Belgorod BGTU publishing house, p: 85.
10. Ostretsov, A.V., B. N. Belousov, P. A. Krasavin, V. V. Voronin, 2011. Classification of vehicles. Moscow MSTU of "MAMI", p: 92.