

АВТОТРАНСПОРТНЫЕ СРЕДСТВА

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REGRESSIVE ANALYSIS OF BRAKING EFFICIENCY OF M1 CATEGORY VEHICLES WITH ANTI-BLOCKING BRAKE SYSTEM

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Abstract. The problematics of assessing the effectiveness of vehicle braking after road accident occurrence is considered. For the first time in relation to the modern models of vehicles equipped with anti-lock brakes there were obtained regression models describing the relationship between the coefficient of traction and a random variable of steady deceleration. This does not contradict the essence of the stochastic physical object, which is the process of vehicle braking, unlike the previously adopted method of formalizing this process, using a deterministic function.

Key words: vehicle, road accident, braking, clutch, deceleration, calculation.

РЕГРЕСІЙНИЙ АНАЛІЗ ЕФЕКТИВНОСТІ ГАЛЬМУВАННЯ АВТОМОБІЛІВ КАТЕГОРІЇ М1 З АНТИБЛОКУВАЛЬНОЮ СИСТЕМОЮ ГАЛЬМ

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Анотація. Розглянуто проблематику оцінки ефективності гальмування автомобіля після дорожньо-транспортної пригоди. Уперше стосовно до сучасних моделей транспортних засобів, обладнаних антиблокувальною системою гальм, отримано регресійні моделі, які описують зв'язок між коефіцієнтом зчеплення коліс із дорогою та випадковою величиною усталеного сповільнення.

Ключові слова: автомобіль, аварія, гальмування, зчеплення, сповільнення, розрахунок.

РЕГРЕССИОННЫЙ АНАЛИЗ ЭФФЕКТИВНОСТИ ТОРМОЖЕНИЯ АВТОМОБИЛЕЙ КАТЕГОРИИ М1 С АНТИБЛОКИРОВОЧНОЙ СИСТЕМОЙ ТОРМОЗОВ

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Аннотация. Рассмотрена проблематика оценки эффективности торможения автомобиля после дорожно-транспортного происшествия. Впервые применительно к современным моделям транспортных средств, оборудованных антиблокировочной системой тормозов, получены регрессионные модели, описывающие связь между коэффициентом сцепления колес с дорогой и случайной величиной установившегося замедления.

Ключевые слова: автомобиль, авария, торможение, сцепление, замедление, расчет.

Introduction

It has been established that the value of the vehicle steady slowdown largely depends on the coefficient of adhesion of the wheels with the road surface. In mathematical statistics event

linkages are studied by the correlation method. In this case it is necessary to establish the degree of influence of the coefficient of wheel adhesion with the road on the steady deceleration value of the vehicle, which is equipped with anti-lock brake system (ABS). This problem is solved by

defining the regression equation and is called regression analysis. Regression analysis is performed on the basis of multifactor experiment, which was conducted in 18 different models of vehicles of such brands as: Audi, BMW, Chevrolet, Ford, Daewoo, Honda, Lexus, Mazda, Mitsubishi, Opel, Porsche, Renault, Skoda, Volkswagen, Volkswagen. These vehicles belong to the category M1 although differ in size and belong to different classes - small, medium and large. They are all equipped with modern ABS and were in good condition. The state of the wheels of these vehicles meets the requirements of traffic rules. In testing there were taken into account and stabilized such influential parameters like pressure in the wheels, brake temperature, the friction coefficient of the wheels with the road, the load and vehicle speed. All measurements were accompanied by record-locking of all influential factors in the process of braking. The experiment was conducted using special equipment that had the mandatory metrological check mark.

Analysis of publications

Actuality of the theme and its feasibility is due to the increasing number of traffic accidents (RTA) and the severity of their consequences, causing the need for objective and qualitative research [1]. Existing guidelines for conducting autotechnical examination of road accidents is based on the data obtained during the test of vehicles of outdated design made in 60–70 s of the last century. They are vehicles with brake system design that allows blocking the wheels. Due to emergency braking there appear the wheel slip on the road surface, with the help of which the expert can estimate the vehicle parameters during the accident [2–4]. In modern practice it is on the contrary very difficult for the expert to

objectively define the parameters of vehicle braking with ABS, which leaves no traces of braking on the road surface. It is specified in various literature sources [5–7]. Besides, modern vehicles with ABS have a lower braking efficiency than the ones without such a system. The problem of evaluating the effectiveness of vehicle braking with ABS was studied in a number of current researches, but there is no still a final decision as well as clear and practical recommendations for specialists in autotechnical examination [7, 8].

Purpose and setting of goals

Purpose – to improve the current method of assessing the effectiveness of the braking car accident in the study through the application of mathematical statistics and regression analysis. Objective: To examine issues determine parameters of braking performance of the car after the accident; establish the correlation coefficient between the wheels grip the road and braking performance of the car with ABS.

Regression analysis of vehicle braking performance

To find the type of function paired regression linking the value of the car steady deceleration with a coefficient of adhesion road wheels, on the basis of statistical data was compiled correlation table (Table 1).

Graphically we'll display statistical relationship between values and steady deceleration rate of adhesion to the road. Number of dots on the chart will depend on the number of groups, which given the average values of both variables. Connecting the dots, we get a broken line regression (Fig. 1).

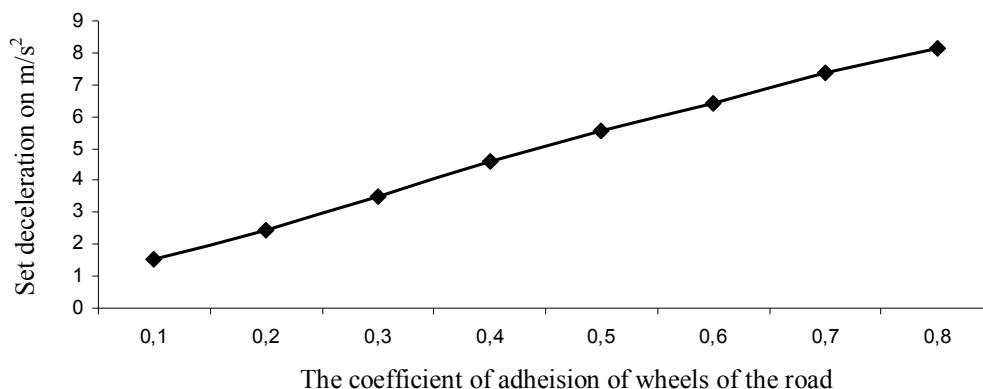


Fig. 1. The statistical dependence of the value of steady slowdown on the tire-to-surface friction coefficient

Table 1 Correlation values of vehicle steady deceleration and the coefficient j_{set} of adhesion to the road φ

φ $j_{set}, m/s^2$	Glaze	Glaze, snow	snow	Wet asphalt			Dry asphalt		N
	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	
0,0–0,5	–	–	–	–	–	–	–	–	–
0,5–1,0	–	–	–	–	–	–	–	–	–
1,0–1,5	9	–	–	–	–	–	–	–	–
1,5–2,0	11	–	–	–	–	–	–	–	10
2,0–2,5	–	14	–	–	–	–	–	–	16
2,5–3,0	–	10	–	–	–	–	–	–	14
3,0–3,5	–	–	10	–	–	–	–	–	23
3,5–4,0	–	–	12	–	–	–	–	–	14
4,0–4,5	–	–	–	9	–	–	–	–	18
4,5–5,0	–	–	–	20	–	–	–	–	20
5,0–5,5	–	–	–	3	4	–	–	–	7
5,5–6,0	–	–	–	–	20	5	–	–	25
6,0–6,5	–	–	–	–	8	16	–	–	24
6,5–7,0	–	–	–	–	–	6	13	–	19
7,0–7,5	–	–	–	–	–	1	13	6	20
7,5–8,0	–	–	–	–	–	–	12	32	43
8,0–8,5	–	–	–	–	–	–	2	37	39
8,5–9,0	–	–	–	–	–	–	–	5	5
N	20	24	22	32	32	28	40	80	278
average value $j_{set}, m/s^2$	1,55	2,45	3,5	4,6	5,55	6,4	7,35	8,14	–

Analyzing the graphic, we can assume that there is a direct statistical relationship between growth and value steady deceleration rate of adhesion to the road. As known, direct connection requires the use of parabolic, exponential or linear regression. In this case, interpretation paired connection using linear regression function will be more clearly and better

Write regression equation in the form of direct

$$\overline{y}_i = a_0 + a_1 x_{ni}, \quad (1)$$

where \overline{y}_i – the estimated value of a random variable steady slowdown in the i-th interval, m/s^2 ; a_0, a_1 – linear regression coefficients; x_{ni} – the average coefficient of adhesion to the road wheels on the i-th interval.

To determine the coefficients of the linear regression should be drawn up and solve a system of equations of the form

$$\begin{cases} ka_0 + a_1 \sum x_{ni} = \sum y_i; \\ a_0 \sum x_{ni} + a_1 \sum x_{ni}^2 = \sum y_i x_{ni}, \end{cases} \quad (2)$$

where y_i – the average steady slowdown in the i-th interval, m/s^2 ; k – number of intervals of the argument, $k = 8$.

We divide ratio range adhesion to the road at 8 intervals, every 0,1. To calculate the equation (2) make a table of variables of the equation (Tab. 2).

Table 2 Values of variables to determine the coefficients of the linear regression

The average value of the coefficient of adhesion of the road and i -ohm range x_{ni}	The average value of the steady deceleration in the i -th interval y_i , m/s ²	x_{ni}^2	y_i^2	$x_{ni}y_i$	Estimated value of the steady deceleration in the i -th interval \bar{y}_i , m/s ²	$(y_i - \bar{y}_i)^2$
0,15	2,0	0,0225	4,0	0,3	2,04	0,0016
0,25	2,98	0,0625	8,88	0,75	3,0	0,0004
0,35	4,05	0,1225	16,40	1,42	3,96	0,0081
0,45	5,08	0,2025	25,80	2,29	4,92	0,0256
0,55	5,98	0,3025	35,76	3,29	5,88	0,01
0,65	6,88	0,4225	47,33	4,47	6,84	0,0016
0,75	7,75	0,5625	60,06	5,81	7,8	0,0025
0,85	8,4	0,7225	70,56	7,14	8,76	0,13
$\sum x_{ni} = 4,0$	$\sum y_i = 43,12$	$\sum x_{ni}^2 = 2,42$	$\sum y_i^2 = 268,79$	$\sum y_i x_{ni} = 25,47$	-	$\sum (y_i - \bar{y}_i)^2 = 0,1798$

Substituting in equation (2) tabular variables to determine the connection between the size and the steady slowdown coefficient of adhesion of the road with the wheels, we get. Msg

$$\begin{cases} 8a_0 + 4a_1 = 43,12; \\ 4a_0 + 2,42a_1 = 25,47. \end{cases} \quad (3)$$

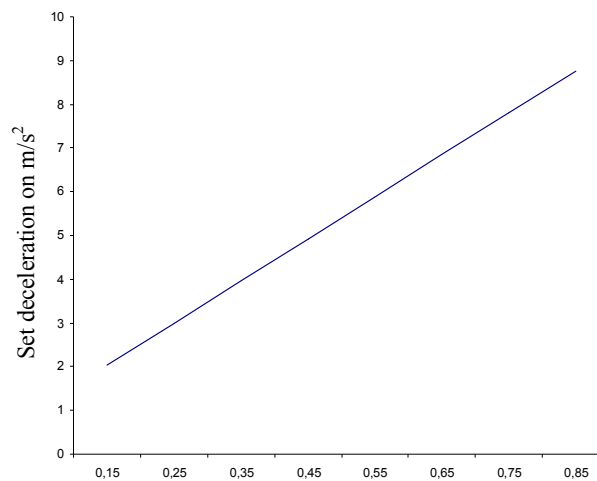
The solution of the equation system (3) gives the coefficients $a_0=0,6$; $a_1=9,6$, taking into account which function regression (1), which establishes the dependence of the steady slowdown car coefficient of adhesion to the road looks

$$\bar{y}_i = 0,6 + 9,6x_{ni}. \quad (4)$$

Calculate the value and the steady slowdown in-ohm range and data in Table 2 is listed. If the calculated value of the random variable deceleration \bar{y}_i and steady friction coefficient road wheels x_{ni} traditionally mark, as j_{set} in φ , respectively, we obtain empirical equations to calculate steady deceleration of M1 category vehicle, which is equipped with ABS

$$j_{set} = 0,6 + 9,6\varphi. \quad (5)$$

The graphic image (Fig. 2) clearly shows that the statistical relationship (broken regression) about playable estimated function (regression).



The coefficient of adhesion of wheels of the road

— the calculated regression function; - - - static regression function

Fig. 2. The dependence of steady deceleration of the vehicle with ABS on the tire-to-surface friction coefficient of adhesion gradient of the road

Mean square error, which in this case is characterized as algebraic proximity empirical-theoretical data is $\sigma = 0,15$ m/s².

Reasonable degree of closeness of the connection between the two variables is linear correlation coefficient

$$r_k = \frac{\overline{xy} - \bar{x} \cdot \bar{y}}{\sigma_x \sigma_y}. \quad (6)$$

To calculate the correlation coefficient, the following formula

$$\bar{xy} = \frac{\sum x_{ni}y_i}{k} = \frac{25,47}{8} = 3,18; \quad (7)$$

$$\bar{x} = \frac{\sum x_{ni}}{k} = \frac{4}{8} = 0,5; \quad (8)$$

$$\bar{y} = \frac{\sum y_i}{k} = \frac{43,12}{8} = 5,39; \quad (9)$$

$$\sigma_x = \sqrt{\frac{\sum x_{ni}^2}{k} - \bar{x}^2} = \sqrt{\frac{2,42}{8} - 0,5^2} = 0,23; \quad (10)$$

$$\sigma_y = \sqrt{\frac{\sum y_i^2}{k} - \bar{y}^2} = \sqrt{\frac{268,79}{8} - 5,39^2} = 2,13. \quad (11)$$

All the necessary data for the calculation of these formulas were defined before (see. Table. 2). According to the formula (6) we obtain the linear correlation coefficient

$$r_k = \frac{\bar{xy} - \bar{x} \cdot \bar{y}}{\sigma_x \sigma_y} = \frac{3,18 - 0,5 \cdot 5,39}{0,23 \cdot 2,13} = 0,98.$$

The correlation coefficient

$$\sigma_r = \frac{1 - r_k^2}{\sqrt{n - 1}} = \frac{1 - 0,98^2}{\sqrt{278 - 1}} = 0,0024. \quad (12)$$

The fact that a very high correlation coefficient $r=0,98$, and the error is very small correlation coefficient $\sigma_r=0,0024$ indicates a close relationship between the coefficient of adhesion road wheels and function steady slowdown of the car with ABS. The coefficient of determination – squared correlation coefficient is too high and is 0,96.

Findings

1. This work is aimed at solving scientific problems related to the lack of expert research practice accident calculation method that would take into account the effect on current vehicle braking systems and brake constructions made based on ABS.

2. The mathematical regression model that establishes dependence of steady slowing of the car with ABS wheel coupling coefficient of the road. The correlation coefficient is 0.98

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