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DETERMINATION OF INTERDEPENDENCES BETWEEN LOADS AND TECHNICAL STATE OF THE MOTOR VEHICLE DURING TRANSPORTATION

Load on the transport vehicle is one of the most important parameters, to be taken into account in the process of its operation, as it influences the controllability, stability, operation characteristics and safety of the transport vehicle. Determination of the regressive interdependences between the load and the intensity of the weight wear of the transport vehicle tires in the process of transportation is the relevant scientific-engineering problem. The objective of the research is the construction by means of regression analysis the regressive interdependences between the load and intensity of the weight wear of the transport vehicle tires during transportation which can be used for the improvement of the safety level and reduction of the risks for the workers, involved in the process of loads transportation. In the process of investigation, method of regressive analysis of the results of single-factor experiments and other paired dependences with the selection of the rational type of function among the most widely spread variants by the criterion of maximum value of the correlation coefficient was used. Regressions were carried out on the base of the linearized transformations. Enabling to reduce the non-linear dependence to linear one. Determination of the coefficients of the regression equations was performed, applying the method of the least squares by means of the developed computer program "RegAnaliz", protected by the Certificate of the state registration of the rights to the copyright object. Adequate regression interdependences between the loads and technical state of the transport vehicle in the process of transportation have been obtained, they can be used for the improvement of the security level and risks reduction for the workers, involved in the process of cargoes transportation. Graphic interdependences between the loads and the intensity of the weight wear of the transport vehicles tires have been constructed, they enable to illustrate these dependences and show the sufficient convergence of the theoretical results with actual. It is established that with the increase of the longitudinal and transversal forces in the area of the tires contact with the road surface the intensity of the tires wear increases by power dependences. In this case the increase of the intensity of weight wear of the tires as a result of transversal force increase is more intensive than as a result of longitudinal force increase.

Key words: *load, technical state, tires wear, intensity of weight wear, transportation, transport vehicle, regression analysis, regression dependence.*

Introduction

Relevance of the given study lies in the need to improve the approaches for determination of the transport vehicle loading in the process of transportation, taking into account its technical state, that is stipulated by a number of reasons. First, in Ukraine, there are many transport vehicles, technical state of which is not satisfactory. This may cause the overloading of the transport vehicles and have a negative impact of the safety and operation characteristics. Secondly, available approaches to the determination of the transport vehicle loading do not take into account its technical state. As a result, transport vehicles can be overloaded even their technical state is satisfactory.

Problem set- up

Loading on the transport vehicle is one of the most important parameters to be taken into account in the process of transport vehicle operation. Loading influences the controllability, stability, operation characteristics and safety of the transport vehicle. That is why, determination of the regression interdependences between loading and technical state of the vehicle in the process of transportation, which can be used for the enhancement of the security level and decrease of risks for the employees, dealing with goods transportation, is relevant scientific-engineering problem.

Analysis of the recent research and publications

The selected subject matter is presented in the papers of V. M. Gumeniuk, V. I. Kornienko, N. Trushkinoyi, M. V. Pushkarenko, O. V. Shevchuk and other authors [1 – 8]. In spite of active study of the given subject matter the most efficient method of transport vehicle loading has not been found, that is why there exist prerequisites for carrying out the investigations in the chosen field.

A number of methods are used for the determination of the loading on transport vehicles. Weight method of loading determination is the most accurate since it is based on the direct load measurement. This method is applied for all the types of transport vehicles, irrespectively of their configuration and operation conditions. Weight method can be used in various conditions, including the roads with different surface and under different weather conditions. Method of loading determination on the base of volume is created on measurement of load volume. Load volume can be measured by means of special equipment, for instance, load meter or ultrasonic sensors. In all the countries the weight method is the most accurate method of load determination on transport vehicles and is obligatory for application in certain cases, for example, for the control of the following the admissible load on the axle. Method on the base of volume is also used in certain countries for the determination of loading on transport vehicles, transporting liquid or bulk cargoes [1].

Technical maintenance is an important factor, influencing the technical state of the transport vehicle. Technical maintenance enables to keep the transport vehicle in good working condition and avoid preliminary wear. There exist several types of technical maintenance [2]:

- daily maintenance – work, performed by the driver of the transport vehicle before each trip;
- periodic technical maintenance – work, performed in certain time interval or after certain mileage of the transport vehicle;
- seasonal technical maintenance – work, performed before and after the season of the transport vehicle operation.

Repair is a last resort, performed if the transport vehicle cannot be recovered by means of technical maintenance. Repair enables to restore functionality but it is more expensive and labor consuming than technical maintenance. Technical state of the transport vehicle has a great impact on its efficiency. Satisfactory technical state of the transport vehicle allows [2]:

- increase functionality of the transport vehicle;
- reduce cost of fuel and operating materials;
- decrease the accident risk.

Unsatisfactory technical state of the transport vehicle may reduce the level of the transport vehicle functionality, increase cost of fuel and operating materials and increase the accident risk. It is important to perform technical maintenance regularly and eliminate all the revealed faults to provide the functionality and security level of the transport vehicle. For the determination of the technical state of transport vehicle various devices are used, in particular [3]:

- stethoscope is used to detect faults in the engine undercarriage and other elements of the transport vehicle;
- ultrasonic tester is used for the detection of the irregularities and cracks on the surface of the parts of the transport vehicle;
- tachometer is used for measuring the rotation frequency of the crankshaft of the engine;
- pressure sensors are used for measuring pressure in the tires, brake circuits and other systems of the transport vehicle;
- temperature sensors are used for measuring temperature in different parts and units of the transport vehicle.

One of the possible approaches to the development of the technique is usage of the machine learning methods [4]. Machine learning methods can be used for the forecasting of load distribution on the transport vehicle, based on the data, regarding the technical state of the transport vehicle.

When the model of the machine learning has been introduced, it will be able to be used for the forecasting of the load distribution on the transport vehicle [5]. For this purpose, it is necessary to introduce in the model the data, concerning the technical state of the transport vehicle. Forecast of load distribution allows to enhance the efficiency of load management. For instance, forecast of load distribution can be used for:

- wear forecast of transport vehicle construction elements;
- forecast of the accident rate of the transport vehicle;
- planning of the transport vehicle repair.

Paper [6] considers the example of using the technique for load determination. In this case, it is necessary to obtain data, regarding technical state of the motor vehicle. The data can be obtained by means of the sensors, installed in the motor vehicle. Sensors will help to measure the following parameters:

- tires wear degree;
- suspension elements wear degree;
- body elements wear degree.

If uneven load distribution on the motor vehicle axles is detected, it is necessary to perform diagnostics of the transport vehicle to detect and remove the faults [7].

Besides exercising the impact on the operation characteristics of the transport vehicles, introduction of new techniques may have a positive impact on the system of labor protection in the process of cargo transportation [8].

Paper [9] substantiates the usage of the simulation modeling at the real motor transport enterprise for the determination of its development strategy. Among the variants of motor transport enterprise development the creation of the station for the control of technical state of transport vehicles is noted.

In the materials of the article [10] the dependences of the impact of the volume of technical maintenance and repair of the motor vehicles, taking into account the work of the staff, loading of technological equipment, usage of the production space on the cost of the executed work are obtained.

Research [11] contains the suggested model of the control system of technical operation of tires and units of the motor vehicle on the base of the information regarding the intensity and character of tire tread wear and determination of the tire resource normative, this model enables to change the structure of the complex of actions, flexibly be used along with other systems of technical state control, reduce the cost and term of the technical maintenance.

Paper [12] is devoted to the establishment of regularities of dustcarts tires wear in the process of solid municipal waste transportation. Using the method of experiment planning of the first order with the interaction effects of the first order by means of Box-Wilson method adequate regularities of dustcart tires wear on the front and rear axles on the transported mass of solid municipal waste and mileage of the dustcart. Regularities of the number of the dustcart trips to maximum permissible tires wear on the front and rear axles are obtained.

The study [13] contains data, regarding the intensity of the tires weight wear of the transport vehicle during transportation for different values of loading (longitudinal and transversal forces). However, as a result of the analysis of the known publications the authors did not reveal specific mathematical interdependences between the loading and the intensity of the weight wear of the transport vehicle tires during transportation.

Objective and task of the paper

Objective of the paper is construction by means of the regressive analysis the regressive interdependences between the loading and intensity of the weight wear of tires of the transport vehicle during transportation which can be used for the improvement of the security level and decrease of risks for the staff, working with cargoes transportation.

Methods and materials

The following methods were used for the determination of the regression interdependences between loading and intensity of weighting wear of the transport vehicle during transportation: regression analysis of the results of single-factor experiments and other paired dependences, computer modeling.

Results of the research

Table 1 contains data regarding the intensity of weight wear of transport vehicle tires during transportation for different values of loading (longitudinal and transversal forces) [12]. On the base of the Table 1 data it was planned to obtain paired regressive interdependences between loading and intensity of weight wear of transport vehicles tires during transportation.

Regressions were carried out on the base of the linearized transformations, which enable to reduce the non-linear dependences to linear ones. Determination of the coefficients of the regression equations was performed by the method of the least squares, with the help of the developed computer program "RegAnaliz" [14], protected by the Certificate of the State Registration of the rights to the copyright object and described in the work [15, 16].

Table 1

Intensity of the weight wear of the transport vehicle tires in the process of transportation for different values of loads [13]

Longitudinal force, N	20	250	500	750	1000	1100	
Intensity of the weight wear of tires, mg/km	25.3	26.8	30.6	36.6	48.3	60.0	
Transversal force, N	20	250	500	750	1000	1100	1250
Intensity of the weight wear of tires, mg/km	19.7	24.6	41.9	93.7	248.9	365.8	700.0

Program "RegAnaliz" enables to perform regression analysis of the results of single factor experiments and other paired dependences with the selection of the rational type of function from the most widely used variants by the criterion of maximum correlation coefficient, saving the results in MS Excel and Bitmap format.

The results of the regression analysis are presented in Table 2, cells with maximum values of correlation coefficient *R* for each function are in grey color.

Table 2

Results of the regression analysis of the interaction between loads and intensity of weight wear of the transport vehicle tires in the process of transportation

№	Type of regression	Correlation coefficient R		№	Type of regression	Correlation coefficient R	
		$I_м = f(P_x)$	$I_м = f(P_y)$			$I_м = f(P_x)$	$I_м = f(P_y)$
1	y = a + bx	0.92865	0.84644	9	$y = ax^b$	0.75658	0.79014
2	y = 1 / (a + bx)	0.98601	0.97749	10	y = a + b·lg x	0.70131	0.58997
3	y = a + b / x	0.49225	0.37679	11	y = a + b·ln x	0.70131	0.58997
4	y = x / (a + bx)	0.89441	0.31132	12	y = a / (b + x)	0.98601	0.97749
5	$y = ab^x$	0.96296	0.98357	13	y = ax / (b + x)	0.60385	0.74256
6	$y = ae^{bx}$	0.96296	0.98357	14	$y = ae^{b / x}$	0.54818	0.56620
7	$y = a \cdot 10^{bx}$	0.96296	0.98357	15	$y = a \cdot 10^{b / x}$	0.54818	0.56620
8	$y = 1 / (a + be^{-x})$	0.56262	0.70138	16	$y = a + bx^n$	0.99479	0.99927

Thus according to the results of regression analysis on the base of the data of Table 1 the following regression interdependences are taken as the most adequate:

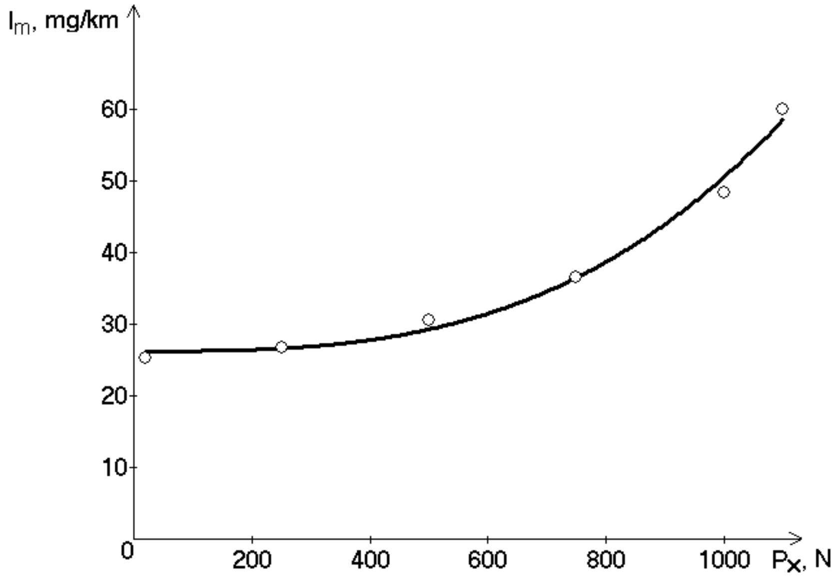
$$I_m = 26.24 + 2.426 \cdot 10^{-8} P_x^3 \text{ [mg/km]}; \quad (1)$$

$$I_m = 28.69 + 2.181 \cdot 10^{-13} P_y^5 \text{ [mg/km]}, \quad (2)$$

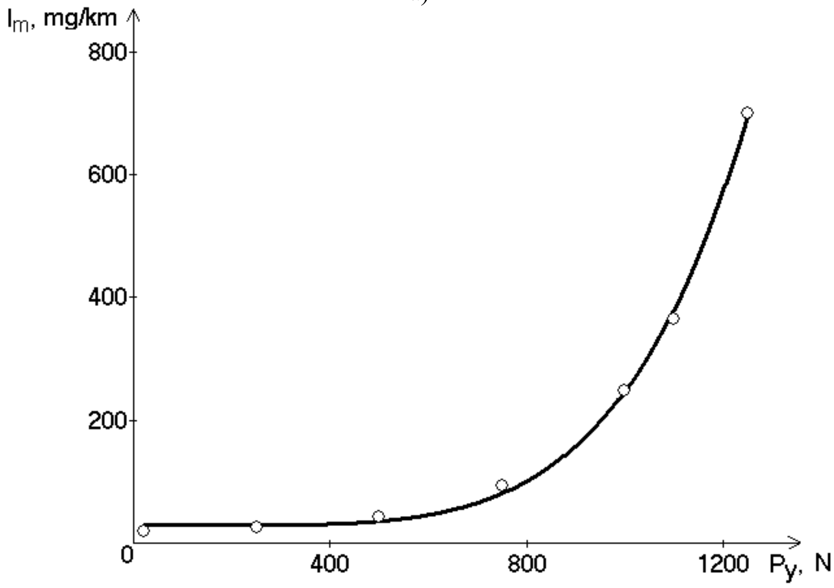
where I_m – is the intensity of weight wear of tires, mg/km; P_x, P_y – are longitudinal and transversal forces in the area of tires contact with road surface, correspondingly, N.

Fig. 1 shows actual and theoretical graphic interdependences between loads and intensity of weight wear of the transport vehicle tires during transportation.

Comparison of actual and theoretical data showed that theoretical intensities of weight wear of transport vehicle tires in the process of transportation, calculated by means of regression equations (1) and (2), do not differ greatly from the data, presented in the research [13], that proves the sufficient coincidence of the theoretical results with actual data.



a)



b)

Fig. 1. Interdependences between loads and intensity of the weight wear of the transport vehicle tires in the process of transportation: a) $I_m = f(P_x)$; б) $I_m = f(P_y)$; actual ○, theoretical —

As it is seen from Fig. 1 growth of the intensity of tires weight wear on the increase of the transversal force is more intensive than on the increase of the longitudinal force.

Conclusions

1. Regressive interdependences between the loads and technical state of the transport vehicle during transportation are determined, they can be used for the improvement of the security level and reduction of the risks for the staff, involved in cargoes transportation.
2. Graphic interdependences between loads and intensity of weight wear of transport vehicle tires during transportation are constructed, they enable to illustrate these dependences and show sufficient coincidence of the theoretical and actual results.

3. By means of regression analysis it has been established that with the increase of the longitudinal and transversal forces in the area of tires contact with road surface the intensity of weight wear of tires increases by power dependences. Increase of weight wear intensity of tires as a result of transversal force is more intensive than as a result of longitudinal force increase, it is expedient to take into account this fact in the process of technical maintenance and repair of transport vehicles.

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