UDC 629.3.014.7+629.3.022.4
DOI https://doi.org/10.32782/2663-5941/2022.5/47

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DISCOVERY OF THE UNACCOUNTED INFLUENCE OF A COMPRESSED TIRE ON CHANGES IN TIRE GRIP COEFFICIENT WHEEL DRIVE WITH ROAD AND WHEEL ACCELERATION MOVEMENT

The working process of the car is accompanied by the coupling of the wheel drive with the road, which is regulated by the coefficient of adhesion, which leads to the movement of the compressed part of the tire (stretching of the tire and its compression, which leads to the dynamic movement of the rolling arm of the wheel drive of the car. The article deals with the study of the movement of the deformed part of the wheel tire engine of a car using the theorem on the change of kinetic energy of this system, the general equation of dynamics.

The purpose of the research is to improve the theory of the technological scheme of the wheel drive load with the detection of the movement of the deformed part of the movement of the car wheel drive and the connection of this movement with the movement of the rolling arm of the car wheel drive and the influence of the output parameters on this connection.

The scientific and practical direction of the work consists in the fact that for the first time a technology was considered in which, during the rotation of the wheel drive, the points of the deformed part of the tire of the wheel drive of the car are displaced and the Coriolis force appears, which significantly affects the coefficient of adhesion of the wheel drive to the road.

The methodology of the study was to establish a mathematical relationship between the coefficient of traction of the wheel drive tire and the road.

As a result of the study, it was established: the influence of the initial parameters and the surrounding environment on the deformed part of the tire of the car's wheel drive is reflected in graphic dependencies; a change in the speed of the deformed part of the tire of the wheel drive causes the appearance of Coriolis acceleration, and for the appearance of Coriolis acceleration, the authors proposed a formula for calculating the acceleration of the deformed part of the car tire; the degree of dependence of the size of the deformed part of the tire on the size of the shoulder of the wheel of the wheel drive was established, and this degree is negative.

Key words: *Coriolis forces, Coriolis acceleration, rolling shoulder, deformed tire part, wheel drive.*

Formulation of the problem

Qualitatively prepared road surface is of great importance in the operation of cars in order to realize their traction and traction properties. An increased average speed, even with good traction and traction properties and an unsatisfactory path, can lead to an emergency situation with negative consequences.

To ensure accident-free operation of the car on an unsatisfactory [3,p.1-8] road, the driver needs to prepare in advance for the possible behavior of the wheel drives of his car, which may inadequately implement traction and traction properties. Figures 1...8 show possible road "trouble" and the driver's behavior when encountering such a road.

Fig. 1-8 provides an overview of typical obstacles on highways.

To reduce the shock load on the wheels and suspension from driving through large potholes, car operation specialists offer two methods. Before passing through a pothole, it is suggested to change the direction of the car: make a short and quick turn and turn the steering wheel back. This simulation of bypassing an obstacle can reduce damage to the car's suspension, and the shock load on the wheel will decrease. This is explained by the fact that the forces of inertia at this moment will redistribute part of the car's mass to the wheels on the other side.

Fig. 1. Pits [3]

Fig. 2. "Washing board" [3]

Also, specialists in automobile transport introduce the concept of "washboard", which is dangerous when braking a car, with worn out shock absorbers, this path will be much longer. This is explained by the fact that the shock absorbers in such a situation are not able to press the wheels to the road. The "washboard" path leads to the fact that the unloaded wheels will lock, and the anti-lock system in this case automatically reduces the braking force in the brake pad drive mechanisms. Cars that do not have an ABS system in this situation, the braking distance has less impact on the stopping distance.

Fig. 3. Cobblestone [3]

Experienced drivers on road barriers "cobblestones" increase the distance to the car moving in front, so as not to create an emergency situation, and in some cases take to the side, where there is less undulation and a greater probability of extinguishing the activity of the ABS with the handbrake.

Fig. 4. Borders [3]

Curbs are an unwanted barrier that can cause "injuries" to the wheel. The most dangerous are low curbs (or medium height) stone curbs with a sharp right angle. To reduce the risk of injury to the tires, it is advisable to pull into the curb smoothly and at a greater angle (closer to 90 degrees).

Fig. 5. Rails [3]

Tram and railway tracks projecting above the road are very dangerous for both cars and motorcyclists and cyclists. Tram tracks are the most dangerous because they have sharper edges, such an obstacle can be more than 4-5 cm. Such an obstacle can easily cut tires and deform the disc. Crossing metal rails that are polished by car wheels, so tires can slide. Light vehicles (motorcycles and bicycles) are particularly dangerous, as driving over polished metal causes these vehicles to fall.

Fig. 6. Puddles [3]

Water obstacles hide two dangers. First, potholes can be hidden under them, which will lead to damage to tires and car suspension units. Secondly, deep pits filled with water cause water to enter the air intake of the engine, which will lead to water hammer. Therefore, if you saw an unfamiliar puddle on your way, it is better to reduce the speed as much as possible. With a thin film of water on the road, aquaplaning cannot be avoided, when a layer of water appears between the tire tread and the road, which turns the car into an object of motion by inertia.

Fig. 7. Stone-brick [3]

Large stones and bricks that have fallen from the bodies of trucks, when hitting them, can cause damage to tires and wheels, as well as plastic elements of the lower part of the car body.

Fig. 8. Crushed stone-sand-soil [3]

Driving on roads that are made by spreading and tamping with crushed stone, sand or soil is dangerous, as the wheel drives of cars falling into the spot of contact between the tire tread and the road causes an increase in the braking distance and a significant deterioration of controllability.

Analysis of recent research and publications

We performed an analysis of the interaction of the wheel's adhesion coefficient with the road. The tangential reaction of the road R_x is limited and cannot exceed a certain value, determined by the nature of the interaction between the wheel and the road (the adhesion of the wheels to the road) and the magnitude of the normal reaction. Specialists in the theory of motion of cars [1, p.40-45] came to a single conclusion that the longitudinal coefficient of adhesion φ_x is the ratio of the maximum possible the coupling of the tangential reaction R to the normal reaction Rz and the formula takes the form:

$$\varphi_{x} = \frac{R_{Xmax}}{R_Z} \qquad (1)$$

The coupling coefficient φ_x depends on many operational and design factors [2, p.89-95]. The main ones are the type and condition of the road, the speed of the car, the air pressure in the tires, the size of the wheels, the weight of the wheel, and the design features of the tire. The highest value of the coefficient of adhesion is achieved on dry and clean roads with a concrete or asphalt concrete surface. On such roads, on average, the coefficient of adhesion can be considered equal to φ_x = 0.7 ... 0.8. For some types of tires, in this case, the coupling coefficient can be equal to φ_x< = 1.0 ... 1.1.

The lowest value of the adhesion coefficient occurs on icy and snowy roads at temperatures close to zero (φ_x> = 0.05 ... 0.15). When the temperature drops, the adhesion coefficient on these roads increases and can reach 0.3 ... 0.35.

On wet and dirty roads with a hard surface, the coefficient of adhesion is one and a half to two times lower than on dry and clean ones. A particularly large decrease occurs at high speeds of rolling or sliding of the wheel. A decrease in road surface roughness leads to a decrease in φ_x. As the vehicle speed increases, φ_x decreases, especially on wet and dirty roads. For example, on wet asphalt concrete when driving speed increases from 25 to 80 km/h. φ_x decreases almost twice.

The air pressure in the tires has different effects on the value of the coefficient of adhesion on roads with different surfaces. On dry, clean roads with a hard surface, increasing the air pressure in the tires reduces φ_x. On wet and dirty roads with a hard surface, increasing the air pressure in the tires to certain limits increases φ_x due to the fact that, as a result of the increase in specific pressures, the conditions for squeezing out the film of moisture and dirt from the contact are improved.

On deformable roads (snow, sand, wet dirt roads), a decrease in air pressure, as a rule, leads to an increase in the coefficient of adhesion. The exception is deformable road surfaces with a hard sub-layer. On such roads, when the air pressure in the tires increases, the wheel pushes through the upper soft layer, as a result of which φ_x increases. In fig. 9. tire protectors are presented, which are capable of increasing the traction coefficient in certain road conditions.

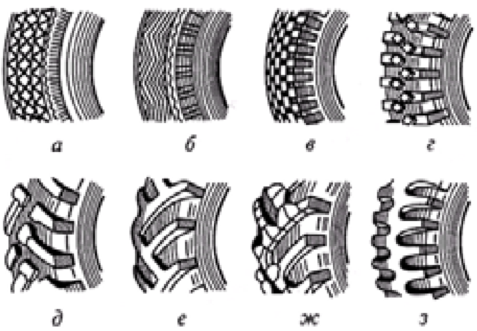

Fig. 9. Tire protectors: a, b – road; c, d – universal; d-z – increased patency

According to the results of numerous tests, the average values of the coefficient of adhesion for different types of road surface were obtained

Table 1

Average values of the coefficient of adhesion for different types of road surface

Type of road surface	Surface condition (adhesion coefficient value)	
	dry surface	wet surface
asphalt	0,7 ... 0,8	0,3 ... 0,4
dirt road	0,5 ... 0,6	0,3 ... 0,4
clay	0,5 ... 0,6	0,3 ... 0,4
sand	0,5 ... 0,6	0,4 ... 0,5
frozen road	0,2 ... 0,3	
Road covered with snow	0,2 ... 0,4	

Highlighting previously unresolved parts of the overall problem

The movement of the military vehicle is carried out with the help of wheeled drives with a flexible tread, which on the roads in violation of the norms of the DSTU do not fully satisfy the performance of military tasks in the zone close to the combat ones, since there is a discrepancy between the coefficient of adhesion and the load of the military vehicle. The main drawback is the imperfect study of the influence of a deformed tire on increasing the traction capabilities of a wheeled vehicle [2,3 p.89-95].

To increase the reliability of the technology of moving a car in off-road conditions, the development of world-class specialists is aimed at improving the theory of motion and the design of the tire of the wheel drive and the technology of its movement [1, p. 40-45].

Presentation of the main research material

In order to establish the law of influence of the deformed part of the tire of the wheel drive on the coefficient of adhesion with the road, we applied the law of conservation of energy when the wheel drive collides with an obstacle, the kinetic energy of the car will be transformed into heat due to the deformation of the tire when it hits the obstacle. Accordingly, we suggest using the following formula:

$$E_K = A = \frac{mv^2}{2}\varphi(R_Z + R_д)S_{дш} \qquad (2)$$

where v is the initial speed of the car hitting the obstacle;

$S_{дш}$ – tire deformation path

$$Рзч = \varphi(R_Z + R_д)S_{дш} \qquad (3)$$

where G_{ek} is the vertical load on the wheel. Therefore, the coefficient of adhesion of the wheels to the road can be calculated:

$$\varphi_x = \frac{v^2}{2gSдш} \qquad (4)$$

We proposed artificial deformation of the car's wheel drive tire using the devices shown in Fig. 10, 11. In Fig. 10, a tire deformation device of a wheel drive based on an elastic battery, in Fig. 11 shows a device that is controlled by a pneumatic system from the driver's cabin

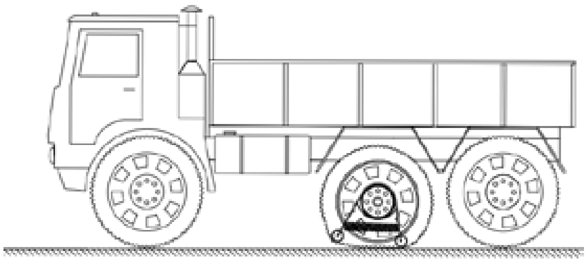

Fig. 10. Device for deformation of a tire of a wheel drive based on an elastic battery

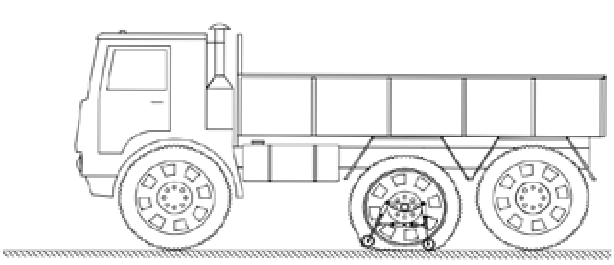

Fig. 11. A device controlled by a pneumatic system from the driver's cabin

Table 2 shows the results of studies of the influence of the initial parameters and the surrounding environment on the adhesion coefficient of the deformed part of the wheel drive tire of the car

In fig. 12, 13 shows the influence of the speed of the car and the longitudinal deformation of the compressed part of the tire on the coupling coefficient of the wheel drive with the road.

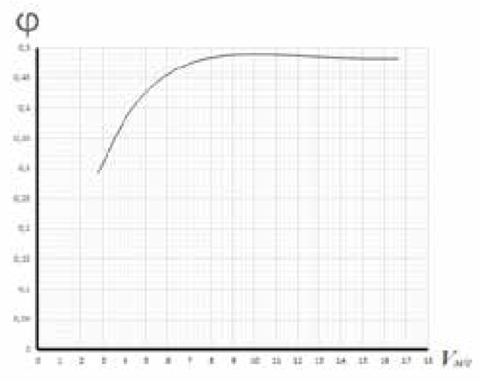

Fig. 12. Dependence of the coefficient of traction of the wheel drive with the road on the speed of the car

Table 2

Results of studies of the influence of the initial parameters and the surrounding environment on the adhesion coefficient of the deformed part of the wheel drive tire of the car

v	ϕ	S*дш*	*αш*	n
2,777778	0,291469419	1,349283	0,05	-0,1
4,166667	0,389719844	2,270523	0,065	-0,3
5,555556	0,444939518	3,535534	0,08	-0,5
6,944444	0,473132233	5,195095	0,095	-0,7
8,333333	0,485503004	7,29032	0,11	-0,9
9,722222	0,489139909	9,849155	0,125	-1,1
11,11111	0,488407613	12,88349	0,14	-1,3
12,5	0,485980194	16,38711	0,155	-1,5
13,88889	0,483502997	20,33466	0,17	-1,7
15,27778	0,482000688	24,68162	0,185	-1,9
16,66667	0,482127037	29,36547	0,2	-2,1

During the time interval D

$$a_c = 2\omega_e v_r sin < \left(\overrightarrow{\omega_e}, \overrightarrow{V_r}\right) \qquad (5)$$

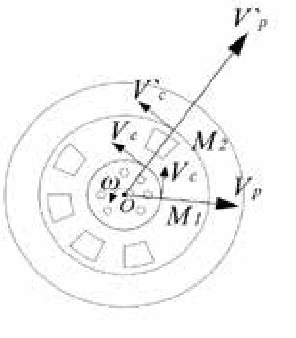

Fig. 14. Model of the change in the positions of the points of application of force on the wheel drive and the emergence of the Coriolis force

Table 3 shows the results of changing the accelerations of the deformed part of the tire from the initial parameters of the wheel drive.

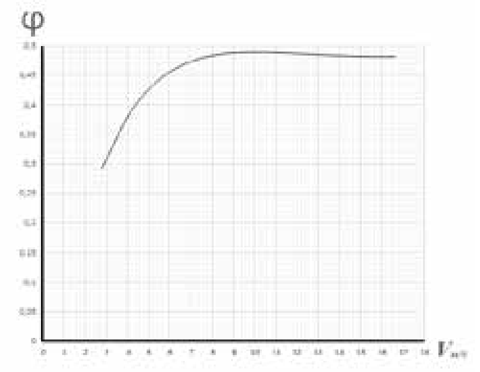

Fig. 13. Dependence of the coupling coefficient on the length of the longitudinal deformation of the compressed part of the tire

Table 3

Results of changing the accelerations of the deformed part of the tire from the initial parameters of the wheel drive

v	*αc*	ω	Кут
8,333333	2,15682538	0,5	15
9,722222	4,20606465	0,7	18
11,11111	7,16735899	0,9	21
12,5	11,1852577	1,1	24
13,88889	16,3941014	1,3	27
15,27778	22,9166667	1,5	30
16,66667	30,8628787	1,7	33
18,05556	40,3285993	1,9	36
19,44444	51,3944986	2,1	39
20,83333	64,1250164	2,3	42
22,22222	78,5674201	2,5	45

In fig. 15, 16, 17 show the results of the influence of the output parameters of the wheel drive on the acceleration of the deformed part of the tire.

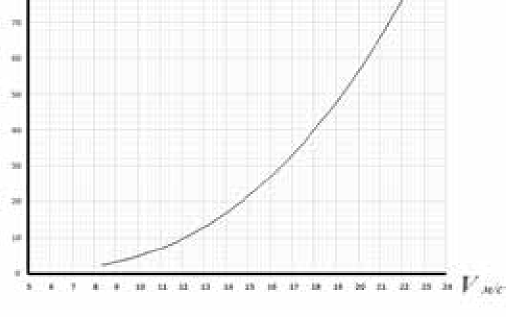

Fig. 15. Dependence of the acceleration of the deformed part of the tire on the speed of the wheel drive

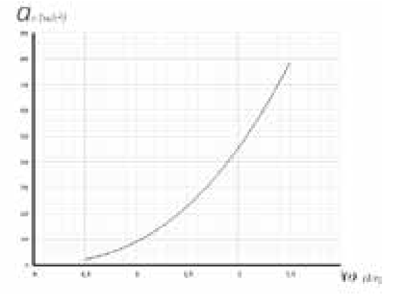

Fig. 16. Dependence of the acceleration of the deformed part of the tire on the angular velocity of the wheel drive

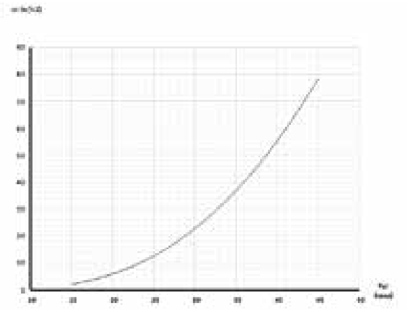

Fig. 17. Dependence of the acceleration of the deformed part of the tire on the angle between the vectors of the angular speed and the linear speed of the wheel drive

Conclusions

1. When examining the article "Identification of the unaccounted influence of a compressed tire on the change in the coefficient of traction of a wheel drive tire with the road and the acceleration of the wheel drive", the influence of the initial parameters and the surrounding environment of the deformed part of the tire of the wheel drive car on the coefficient of traction of the tire with the road was revealed.
2. The influence of the initial parameters and the surrounding environment on the deformed part of the wheel drive car tire is displayed in graphic dependencies.
3. A change in the speed of the deformed part of the tire of the wheel drive causes the appearance of Coriolis acceleration. For such changes in speed, the authors proposed a formula for calculating the acceleration of the deformed part of the car tire.
4. The degree of dependence of the size of the deformed part of the tire on the size of the shoulder of the wheel of the wheel drive was established, and this degree is negative.

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Петров Л.М., Кішянус І.В., Петрик Ю.М. ВИЯВЛЕННЯ НЕВРАХОВАННОГО ВПЛИВУ СТИСНУТОЇ ШИНИ НА ЗМІНЕННЯ ЗНАЧЕННЯ КОЕФІЦІЄНТА ЗЧЕПЛЕННЯ ШИНИ КОЛІСНОГО РУШІЯ З ДОРОГОЮ ТА ПРИСКОРЕННЯ КОЛІСНОГО РУШІЯ

Робочий процес автомобіля супроводжується зчепленням колісного рушія із дорогою, що регламентується коефіцієнтом зчеплення, що приводить до руху стиснутої частини шини (розтягування шини та її стиснення, що приводить к динамічному руху плеча кочення колісного рушія автомобіля. В статті розглянуті питання дослідження руху деформованої частини шини колісного рушія автомобіля з застосуванням теореми про зміну кінетичної енергії цієї системи, загального рівняння динаміки.

Метою дослідження є удосконалення теорії технологічної схеми навантаження колісного рушія з виявленням руху деформованої частини руху колісного рушія автомобіля та зв'язок цього руху з рухом плеча кочення колісного рушія автомобіля та вплив вихідних параметрів на цей зв'язок.

Науковий та практичний напрям роботи полягає в тому, що вперше розглянута технологія в якій при обертанні колісного рушія відбувається зміщення точок деформованої частини шини колісного рушія автомобіля та поява сили Коріоліса, яка істотно впливає на коефіцієнт зчеплення колісного рушія з дорогою. Методологією дослідження являлося встановити математичний зв'язок між коефіцієнтом зчеплення шини колісного рушія з дорогою, виявлено вплив вихідних параметрів та оточуючого середовища деформованої частини шини колісного рушія автомобіля на коефіцієнт зчеплення шини із дорогою.

Результатом дослідження встановлено: вплив вихідних параметрів та оточуючого середовища деформованої частини шини колісного рушія автомобіля відображено в графічних залежностях; зміна швидкостей деформованої частини шини колісного рушія викликає появу прискорення Коріоліса *і на появу прискорення Коріоліса авторами запропонована формула для обчислення прискорення деформованої частини шини автомобіля; встановлено степенева залежність величини деформованої частини шини від величини плеча колеса колісного рушія і ця степінь від'ємна.*

Ключові слова: *сили Коріоліса, прискорення Коріоліса, плече кочення, деформована частина шини, колісний рушій.*