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ANALYSIS OF THE FUNDAMENTALS OF MATHEMATICAL MODELING OF WHEEL MOVEMENT ON THE ROAD SURFACE OF CARS EQUIPPED WITH ABS

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ABSTRACT This article shows the directions of various parameters that affect the wheels of cars equipped with ABS and the dependence of the changes that occur during the braking process as a result of their influence on the braking path, as well as the mathematical models of the wheel. The four stages of the study are given and the stages of developing a model of wheel rotation during braking of a car equipped with ABS in the study of the kinematic model of elastic wheel rotation with a solid tire are correct. concepts are given.

Key words: Wheel, parameters, model, braking torque, angular speed, linear speed

INTRODUCTION A mathematical model is an approximate description of a phenomenon using mathematical symbols. Mathematical modeling is a powerful forecasting method. The process of mathematical modeling, that is, the study of an event using a mathematical model, can be divided into four stages.

The first stage is the formation of laws connecting the main objects of the model. This stage ends with the mathematical recording of ideas about the connections between the objects of the model.

The second stage includes the main question - solving the problem directly, that is, obtaining theoretical results from the analysis of the model to compare them with the results of observation.

The third stage is to determine whether the accepted hypothetical model meets the criteria of practice. The third stage is the main stage in solving the problem of the adequacy of the use of mathematical programs in the description of the real problem, and the resulting data can be compared with the results of observing the studied phenomena within the limits of accuracy.

If the mathematical model is such that the choice of characteristics cannot satisfy these conditions, then the model is not suitable for studying the phenomena under consideration. The fourth stage is the further analysis of the model in connection with the collection of data on the studied phenomena. The application of practical criteria in the evaluation of the mathematical model allows to draw a conclusion about the correctness of the hypothetical model.

RESEARCH METHODOLOGY Studying the kinematic model of wheel rotation with a solid tire is the first step in developing a model of wheel rotation during braking of a car equipped with ABS. Hard wheel braking can be observed in only two cases: a locked wheel moves in a rotating skid, and a situation where the torque of the brake mechanism is not enough to block the wheel and it continues to rotate on the surface.

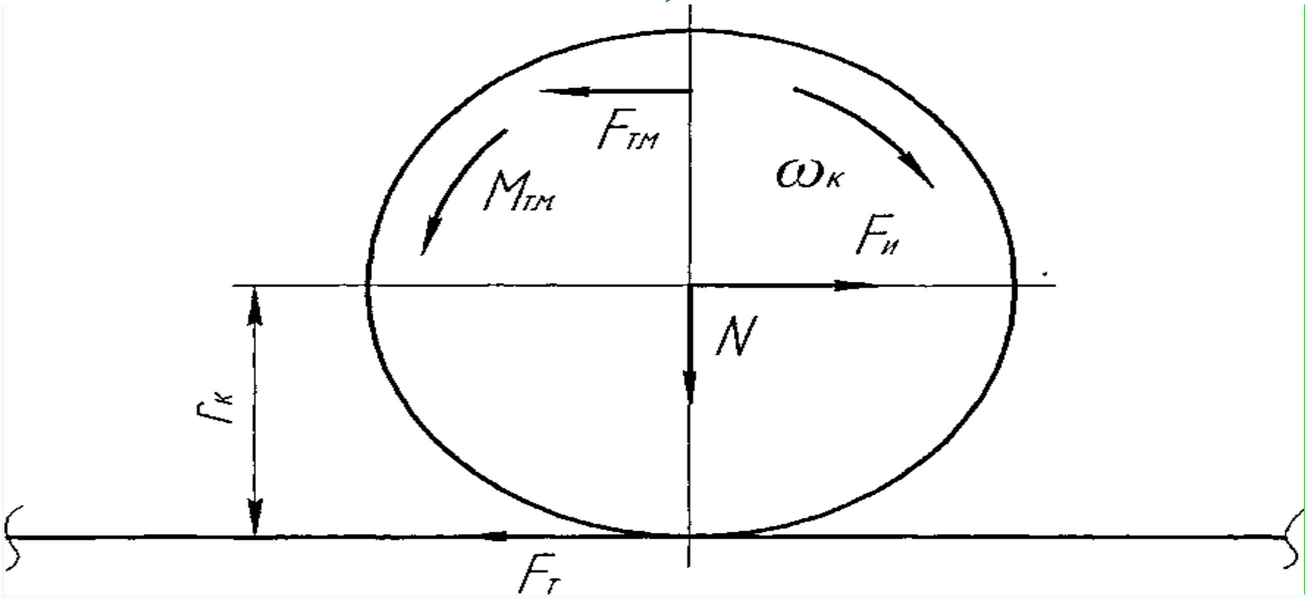

Figure 1.1. A wheel movement diagram is shown.

Here: r_k-is the radius of the wheel; ω_k-is the angular speed of the wheel; F_t-braking force; F_i - inertia force; M_{IM}-is the torque of the brake mechanism.

For this process, we consider both modes of wheel movement from a physical point of view.

- First mode: The moment created by the braking mechanism is greater than the moment created by the frictional force, the wheel slides, the angular velocity of the wheel is zero, and the linear velocity is minimal due to the full use of the wheel.

$$M_{TM} > M_{FT}$$
$$\omega_k = 0; \qquad (1)$$
$$v_k = \min.$$

- Second mode: The moment of the brake mechanism is less than the moment created by the frictional force; The angular speed of the wheel is equal to the ratio of the linear speed to the wheel radius:

$$M_{TM} < M_{FT}$$
$$\omega = \frac{v_k}{r_k} \qquad (2)$$

Real wheels have tires with a certain stiffness in the transverse and longitudinal directions, the effect of the stiffness on the tire performance is beyond the scope of this work. Therefore, we consider the effect of the elastic deformation stiffness on the performance of the car wheel. when the moment produced by the brake mechanism is applied to the wheel, compression deformation of the tire occurs, and the tire itself significantly affects this phenomenon. It makes up the longitudinal speed of the car and the speed of rotation of the wheel. For this model, the two governing equations for the movements of the degrees of freedom for the car model are as follows:

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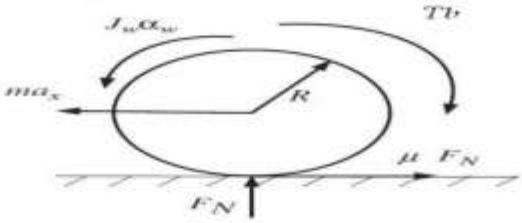

Figure 1.2. Parameters affecting the braking force in the longitudinal direction of the car wheel.

$$ma_x = -\mu F_n \rightarrow m\frac{dv_x}{dt} = -\mu F_n \qquad (3)$$

Moment of assembly at the center of the wheel

$$J_\omega a_\omega = \mu R F_n - T_b \rightarrow J_\omega \omega = \mu R F_n - T_b \qquad (4)$$

For convenience, the slip ratio is determined according to:

$$\lambda = \frac{v_x - \omega R}{v_x} \qquad (5)$$

Differentiating both sides with respect to time (t), we get the following result.

$$\lambda = \frac{v_x(1-\lambda) - R\omega}{v_x} \qquad (6)$$

From the parameters in the above equations:

V_x = linear velocity of the vehicle
a_x = linear acceleration of the car
J_ω = speed of rotation of the wheel
ω = angular acceleration of the wheel
T_b = brake torque
m = coefficient of friction
R = radius of the tire
m=wheel mass

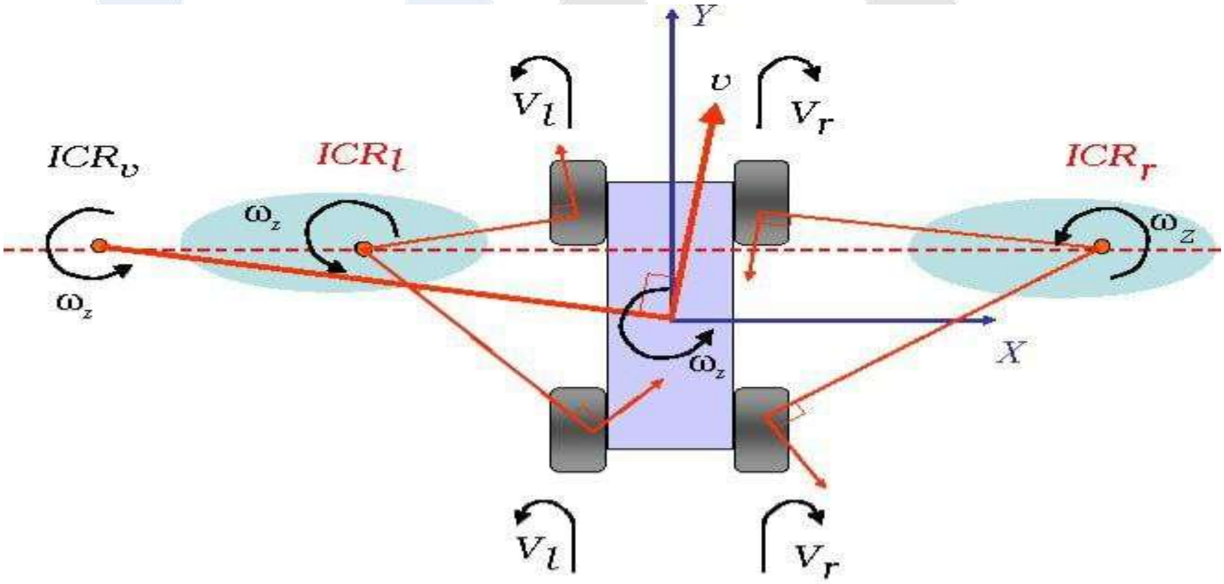

Figure 1.3. Angular direction of angular and linear velocities on a car wheel

When braking a car, the amount of torque created by the braking mechanism is an adjustable value, it can vary from 0 to a certain maximum value, which is enough to move the tire along the road surface.Wheel when approaching blocking, the ABS electronic unit gives a command to reduce the pressure in the brake line and, accordingly, to reduce the braking torque. The problem of analyzing the wheel rotation during braking of a car equipped with ABS arose after receiving experimental data. According to the results of the experimental data, the distance traveled by the wheel is about 5% of the distance traveled by the car. it was found to be less, that is, if the car's braking distance is 8 m, the wheel braking distance calculated by the wheel angular velocity sensor is about 7.6 m. All logical ABS regulates the slip,so the distance traveled by the wheel is less than the distance traveled by the car:

$$\lambda=\frac{S_a-S_k}{S_a} \quad (7)$$

where: ƛ-friction path; S_a-the road traveled by the car; s_k-road is the distance traveled by the wheel.

There should be no dark wheel marks on the road surface, otherwise, their presence is a sign of ABS failure according to technical regulations.When the braking distance of the car is calculated with respect to static elements, an error was made in calculating the braking distance of the wheel.

ANALYSIS AND DISCUSSION OF RESULTS The distance traveled by the wheel was determined using the following formula**:**

$$S_k=2n\pi r \quad (8)$$

Here: n -is the number of wheel revolutions

r- is the radius of the wheel.

During braking, at the point of contact of the tire with the road, it is deformed stretched. Then the distance traveled by the car is equal to the distance traveled by the tire, and it does not have any to does not leave traces. In the calculation, as the effective perimeter of the wheel increases, we get fewer revolutions. Therefore, the distance traveled by the wheel is the same as the distance traveled by the car. What was described above was the reason for creating a model of deformation sliding of a wheel on a hard road surface.There are several concepts in the deformation sliding model of a wheel with an elastic tire on a hard road surface: When the road surface is smooth, flat homogeneous horizontal the deformed state is equal to return to its original state, and the tire elongation is linear happens regularly.

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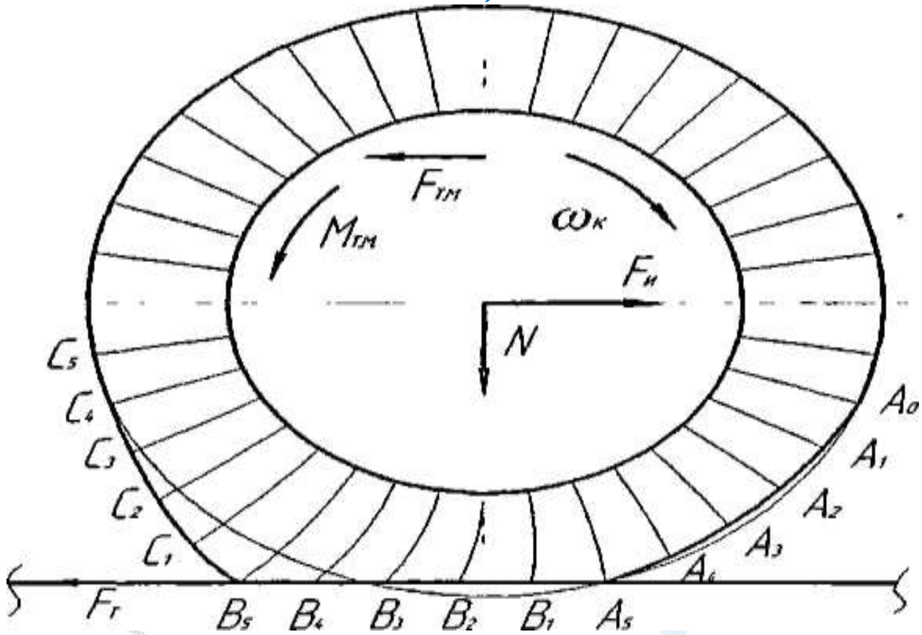

Figure 1.4. Deformation sliding diagram of a wheel with elastic tires on a hard road surface In this case, the processes that occur in the car**:**

- In zone A(G-A5), tire material is stretched due to multi-directional inertia and braking forces.

- In the zone A5-B5, the tire material remains deformed due to the pressure of the normal force on the road surface.

- In the zone B5 - C5, the tire loosens and at point C5 the tire material returns to its original state.

- In the section A2 - B5, the elongation of the tire material remains constant, it is firmly pressed against the road surface with a normal force:

- The tire loosens in the B5 - C5 section. According to the relaxation equation (9), the elongation time coefficient is determined as follows.

$$1 = 10e\text{-}2p'; \qquad (9)$$

$$L_1 = 1_0(1\text{-}e^{-2p'}). \qquad (10)$$

Here: L is the elongation time coefficient e-deformation attenuation coefficient;

The model described above is consistent with the fact that the tire does not slip on the road surface when there is deformation slip during the braking process of the car. In real-world conditions, this means that the vehicle maintains control and stability at any moment of braking.

CONCLUSIONS AND SUGGESTIONS In this article, the directions of the parameters that affect the tires of cars equipped with ABS and how they affect the braking efficiency have been studied, as well as the effective perimeter of the car wheel (radius, angular speed, as the linear velocity) increases, we get fewer revolutions. Therefore, it is shown that we can conclude that the distance traveled by the wheel is the same as the distance traveled by the car, and that the wheel It is explained that the elongation time coefficient is determined in return.

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