UDC 629.027; 629.032 DOI: 10.30977/AT.2219-8342.2022.51.0.01

Refined assessment of tire rolling resistance in the starting mode

Karpenko V.[1], Neskreba E.[1]

[1]Kharkiv National Automobile and Highway University, Ukraine

Annotation. Problem. *Rolling resistance is one of the most important operational characteristics of a car tire. First of all, the fuel consumption, durability and service life of the tire depend on the rolling resistance. Of course, the higher the rolling resistance, the faster and more intensively the tire will wear out. Also, car braking parameters, such as deceleration and, accordingly, the braking distance, may indirectly depend on the rolling resistance characteristics. In turn, rolling resistance is influenced by the properties of the tire itself, as well as the condition of the road surface and weather conditions. It is especially important to evaluate the operational characteristics of a car tire in the starting period of movement, because at this time the behaviour of the tire is unpredictable.* ***Goal.*** *The purpose of this work is to improve the methodology for evaluating the rolling resistance of a car tire in the starting period of movement. Knowing how the rolling resistance changes during the starting movement, it is possible to evaluate the operational properties of the car.* ***Methodology****. Refined assessment is carried out with the help of dependencies obtained in previous scientific works. But in order for the result of the rolling resistance assessment to be correct, it is necessary to determine the necessary characteristics of the tire. Namely, we are talking about the characteristics of radial stiffness. In the work, these characteristics are determined both by conducting experimental studies and by using FEM.* ***Results.*** *Thanks to the conducted research, significant results were obtained on the change in rolling resistance during the starting motion. It was established that with an increase in internal pressure from 0.17 MPa to 0.225 MPa, as a result of the starting motion, the rolling resistance decreases by approximately 20-25%.* ***Originality.*** *From the analysis of the literature, it can be concluded that in most of the studied works, the peculiarities of the interaction of automobile tires with the supporting surface in the starting period are not taken into account during various studies. It can be said that the originality of this work, on the one hand, is that the rolling resistance is investigated during the starting motion, and on the other hand, that its assessment is carried out both on the basis of the results of experimental studies and with the help of FEM.* ***Practical value.*** *In this work, it is possible to highlight the obtained results, thanks to which we can estimate the rolling resistance of a car tire with sufficient accuracy. The methods of determining the operational characteristics of a car tire, presented in the work, can be used during its operation and at the design stage.*

Key words: *automobile tire, starting period, rolling resistance, experimental research, finite element method, refined assessment, stabilization, safety.*

Introduction

The condition and behavior of a car tire in the period from the start of driving on "cold" tires to the stabilization of its operational characteristics are unpredictable. The above-mentioned movement period is usually called the "starting period" [1]. At this time, the main characteristics of the tire change, such as the internal pressure of the gas filler (mainly air), the temperature of the tire, etc. [1-2].

After analyzing the scientific publications in which the operational characteristics of car tires are studied, it can be concluded that the starting period is not taken into account when evaluating various properties of tires and the car. That is, in most works, the tire is considered already warmed up (it has constant values of internal pressure, temperature, etc.). Also, quite often the research does not take into account the weather conditions under which the experiments are conducted, namely the ambient temperature. It should be noted that the condition and behavior of the tire significantly depends on the temperature of the surrounding environment.

In the starting period of movement, it is important to know how the operational characteristics of a car tire will change, among which the most important characteristic is rolling resistance. Of course, this characteristic depends on a combination of many factors, such as: the condition of the car tire and bearing surface, environmental conditions, etc. The rolling resistance of a tire directly affects the durability and service life of the tire, as well as fuel economy. In one of the previous works, the methods of indirect assessment of the rolling resistance of a car tire in the starting period have already been given. In the current work, a refined assessment of rolling resistance is carried out. For this assessment, parameters are used, which are determined as a result of conducting experimental studies and due to the application of the finite element method (FEM).

Currently, it can be confidently stated that FEM is the most common in solving many engineering problems of varying complexity [3-4]. This is primarily due to the high accuracy of calculations and relative ease of application of this method. There are a large number of software systems based on FEM, sometimes it is not even necessary to fully understand this method, because all calculations are performed automatically. In this work, FEM will be used to determine the radial deflection, otherwise we can say to evaluate the stiffness of the car tire. But it is also worth noting that when solving the problem, some assumptions will be made that, on the one hand, greatly simplify the problem, and on the other hand, do not entail significant errors. In more detail, the application of FEM to solving the problems of car tire mechanics will be indicated in the corresponding section.

Therefore, it can be said that the question of evaluating the rolling resistance of a car tire when driving in the starting mode is relevant and deserves careful research, especially with the use of modern technologies.

Analysis of publications

As it has already been repeatedly stated, the issues related to the safety of road transport are very important and require detailed research to further ensure traffic safety. Traffic safety directly depends on the condition of car tires [5]. Accordingly, there is a large number of scientific works devoted to the study of these issues.

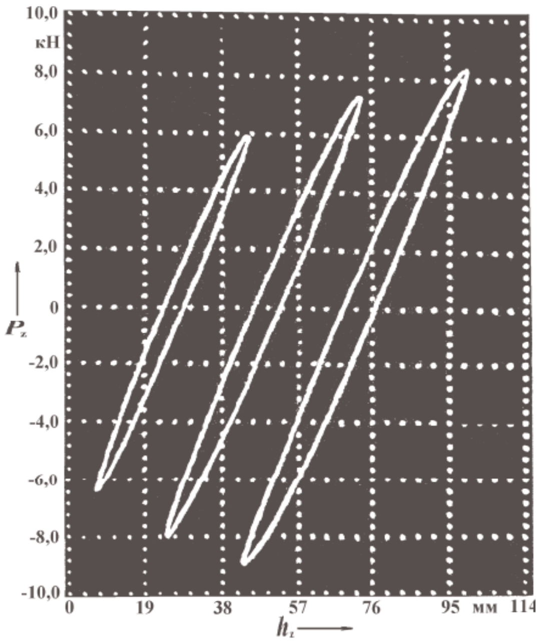
It should be recalled that this work is a continuation of the scientific work [2], which presents the methods of indirect assessment of the rolling resistance of a car tire during the start-up period. The work [2] also presents the results of experimental studies of changes in the internal pressure of the gas filler and the temperature of the tire. The value of the increase in the internal air pressure in the tire was determined and the starting time for the cars under study was approximately determined. It was found that the most intense temperature increase occurs in the shoulder zone of the tires. Also, the starting time of the studied cars was determined. Namely, the internal pressure in the tire, in the mode of starting movement, stabilizes after about 20-30 minutes of uniform movement, the temperature of the surface layers of the tire stabilizes after about 30-40 minutes. The temperature of the surface layer of winter tires increases less than that of summer tires, and accordingly, driving on winter tires is safer at temperatures close to 0^{o}C and below. This confirms the well-known statement that it is necessary to replace summer tires with winter tires in a timely manner (when the ambient temperature can reach $+5^{o}$C and below), thanks to this, road safety can be significantly increased. As a result of an indirect assessment, it was established that the rolling resistance during the starting movement changes by approximately 15% [2]. But still, it is worth noting that during the indirect assessment, not all the physical and mechanical properties of the investigated tires were indicated. In this work, it is planned to carry out a refined assessment of rolling resistance in the starting period, taking into account the properties of the tire material.

Works [6-7] present a method for estimating the rolling resistance coefficient, which is based on the elliptic-degree model of the absorbing property of the tire. This model is built by mathematically describing the experimental characteristics of normal stiffness. As you know, the stiffness characteristic, in the form of the area of a closed loop, reflects the energy spent during deformation due to the action of inelastic resistance forces (hysteresis losses). The stiffness characteristics of the tires obtained in the dynamic loading mode are presented in Fig. 1.

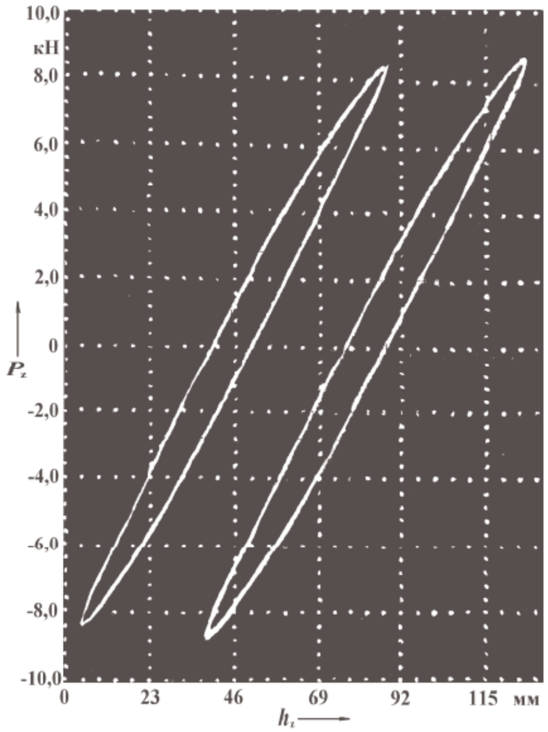
Based on the obtained characteristics and taking into account the functional dependence of the values of the inelastic resistance force on the amplitude values of the radial deformation of the tire, the mathematical description of the elliptic-degree model of the absorbing property of the tire can be determined by equation (1).

$$f_c = \frac{2^{1-n} k_l H_{\text{Ш}} h_{z\max}^{1+n}}{3\pi r_d P_z}, \qquad (1)$$

where k_l – the proportionality factor between the length of the contact zone and the normal deflection of the tire; $H_{\text{Ш}}$ – the proportionality factor between the value of the inelastic resistance force and the normal deflection; $h_{z\max}$ – full deflection of the tire in the radial direction, mm; r_d – dynamic wheel radius, mm; P_z – normal load on the wheel, N; n – exponent (reflects the degree of absorption capacity).



a



b

Fig. 1. Characteristics of radial stiffness of tires [6]: a – tire 245/70HR16, no rotation ($P_z = 9$ kN, $p = 0{,}24$ MPa); b – tire LR70-15 GL, with rotation ($P_z = 9$ kN, $p = 0{,}24$ MPa, $\omega_k = 172$ min^{-1});

The proposed method of determining the rolling resistance coefficient is based on the characteristics of the normal stiffness of the tire. This approach is more reliable than experimental methods of direct measurement of rolling resistance forces. Note that for the correct use of equation (1), it is necessary to determine the necessary tire parameters. To find them, both the results of experimental studies and the results of modeling the interaction of a car wheel with the supporting surface of the FEM will be used. The methodology of experimental research on determining the area of the contact zone is well covered in the work [8].

Problems related to the study of the radial stiffness of tires are quite common. In [9], the radial and tangential stiffness of the tire is determined. Two different load schemes were used to determine the vertical (radial) stiffness. The difference between the schemes lies in the contact area of the outer cylindrical surface of the tread with the load, i.e. in the first case the contact area constantly increases (with increasing load), in the second case the contact area remains constant. As a result of the conducted research, functional dependences for the radial and tangential deformation of the tire from the external load were obtained.

The method of determining the radial rigidity is also presented in works [5,10]. Thus, the work [5] describes the stand that was developed at the KNAHU. This stand allows you to determine the dynamic radial stiffness and damping coefficient of car tires. This stand uses the method of free oscillations of the system, the elastic element of which is a pneumatic.

Purpose and Tasks

The main goal of this work is to evaluate the rolling resistance of a car tire when driving in the starting mode. As has been repeatedly stated, rolling resistance is an extremely important operational characteristic. In order to determine this characteristic with sufficient accuracy, it is necessary to clarify the already existing methods of predicting the amount of rolling resistance.

To apply already known dependencies, it is necessary to know the relevant parameters of the tire, including stiffness characteristics and geometric parameters. That is, to determine the specified parameters, experimental studies should be conducted, and the stiffness of the tires can also be estimated by using the FEM. For its correct application, it is necessary to create a model of the investigated car tire with appropriate (allowable) simplifications.

Experimental studies of car tire stiffness

The purpose of conducting experimental research is to determine the stiffness characteristics of a car tire, namely, the radial deflection. Having obtained the dependence of the radial deflection on the internal pressure of the tire gas filler, it is possible to indirectly predict how the rolling resistance coefficient will change. To determine the rolling resistance, using equation (1), it is necessary to determine the area and length of the contact zone of the tested tire with the support surface at different values of internal air pressure.

In fig. 2 presents the process of obtaining an impression of the contact zone.

Fig. 2. The process of obtaining an impression of the contact zone of the 235/55R18 tire under study

The experiment was conducted on a technically sound Lexus RX300 car equipped with 235/55R18 winter tires. The air temperature in the room where the measurements were taken was +20°C, humidity - 80%. It is also worth noting that the study was carried out on a "flat" support surface to ensure the correct result of measuring the geometric characteristics of the contact zone. In addition to the car, a jack, a sheet of A3 format (preferably Whatman paper) and copy paper are needed to conduct the research. It can be immediately noted that this experiment is quite simple from the point of view of the necessary tools for its implementation.

As a result of the research, a number of impressions of the tire contact zone with the support surface at different values of internal pressure (from 0.16 to 0.225 MPa) were obtained. One of the prints is shown in fig. 3.

Fig. 3. Imprint of the contact zone of the 235/55R18 tire with the supporting surface (value of internal pressure $p = 0{,}225\ \text{MPa}$)

Next, we measure each print and calculate the areas of contact zones. The results of the calculations are summarized in the table. 1. The dependence of the area of the contact zone on the value of the internal pressure is presented in Fig. 4.

Table 1. Results of contact area measurements

Parameters	Internal pressure, MPa					
	0.17	0.18	0.19	0.2	0.21	0.225
Area, m^2	0.0291	0.0267	0.0247	0.0239	0.0235	0.0224
Length, mm	158	153	153	141	135	120
Deflection, mm	6.2	5.8	5.8	5	4.524	3.57

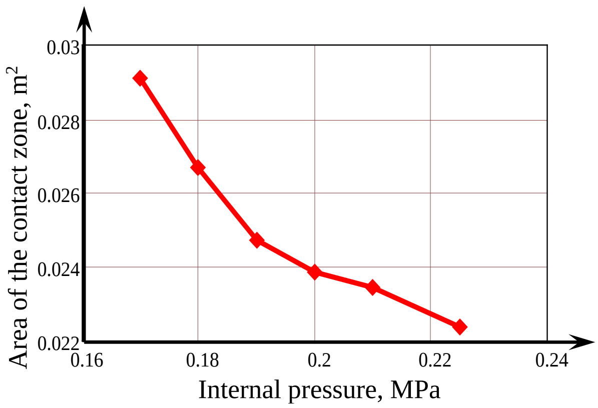


Fig. 4. Dependence of the area of the contact zone on the internal pressure in the tire

The application of the finite element method to solving the problems of the mechanics of a car tire

The finite element method is a progressive tool for solving a wide range of engineering problems. The fundamental principle of FEM consists in dividing the studied area into elementary areas of finite dimensions (finite elements) [11]. In each such element, the unknown function is approximated by a polynomial. Currently, there are many software systems based on FEM for solving various engineering problems. The most developed and well-known is the "Ansys" system. However, it can be said that other, more affordable systems can be used to solve relatively simple problems. In this work, we will solve the problem of evaluating the radial stiffness of the tire using the "Autodesk Inventor" program.

To solve the given problem, it is first necessary to create a model of the tire under study. At first glance, it may seem that a car tire is a fairly simple element of a car wheel. But in fact, it is an extremely complex structure in the form of a shell made of composite material (cord) with a connecting rubber (Fig. 5).

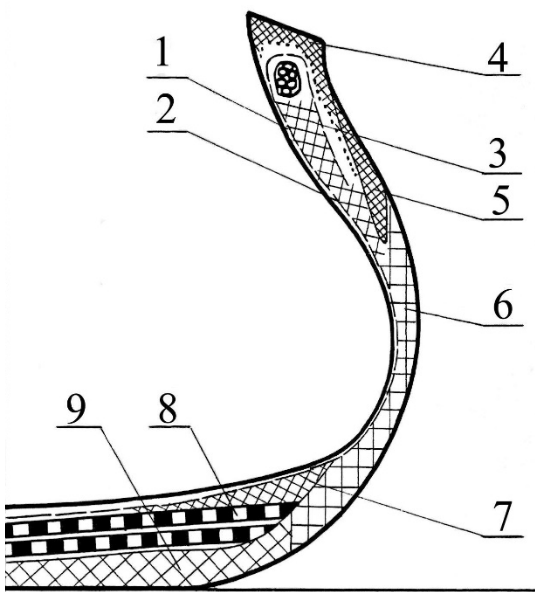


Fig. 5. Meridional section of the tire [12]: 1 – innerliner; 2 – carcass; 3 – bead filler; 4 – chafer; 5 – bead wire wrapping; 6 –sidewall; 7 – under-belt corner; 8 – belt; 9 – tread.

It is clear that each of the elements of the tire has different physical and mechanical properties, about which, by the way, it is not always easy to find information. So, to solve the problem, you need to make certain assumptions about the car tire model. At the first stage of FEM modeling, we can assume that the tire consists of one continuity, isotropic and homogeneous material. Moreover, the specified material will have the physical and mechanical properties of the sidewall. After all, in our case, when it is necessary to determine the radial deflection, the main role is played by the sidewall of the tire.

To apply FEM, it is necessary to know the following properties of the tire material: composite modulus of elasticity, shear modulus, Poisson's ratio, density, yield strength, and strength limit. The definition of the composite modulus of elasticity is considered in detail in [12-13].

But again, in order to determine the composite Young's modulus, it is necessary to know many parameters, for example, the curl angle of the frame cord rope, the density of threads per unit length, etc. Therefore, we finally choose the material properties according to [5].

Before creating a model of a 235/55R18 car tire, it is necessary to determine the geometry of the meridional section. From the marking, the mounting diameter, width and height of the tire profile are known. It is clear that the manufacturers do not provide complete information regarding the geometric parameters of the tire. Therefore, it is necessary to independently create a simplified drawing of the meridional section based on the known dimensions (Fig. 6).

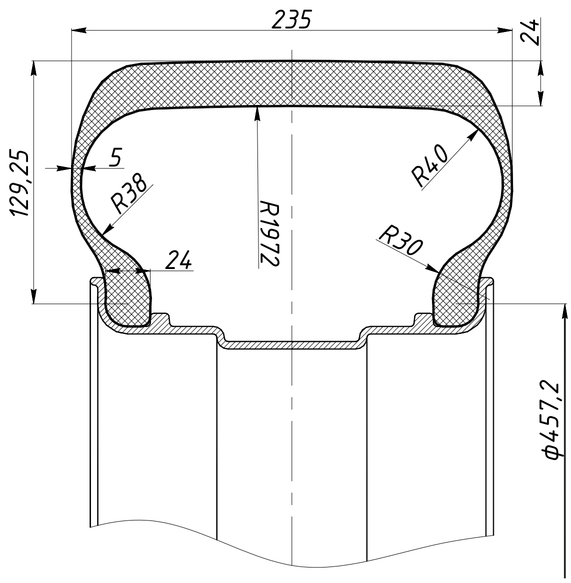


Fig. 6. Geometric parameters of the simplified meridional section of the 235/55R18 car tire

Based on the drawing (Fig. 6), we create a model of a car tire in the Autodesk Inventor environment (Fig. 7), and set the above properties for its material.

Next, we create an approximate model of a car disk and connect it to the tire, and also create an element that will imitate the supporting surface and then position the car wheel relative to the supporting surface. We run the simulation with the same inputs as in the actual experiment detailed in the previous section.

Fig. 7. Car tire model 235/55R18

In fig. 8 shows the result of modeling the interaction of a car wheel with a support surface, at the value of the internal pressure $p = 0{,}225$ MPa and wheel loads $P = 5000$ N. In this case, the radial deflection is – $h = 3{,}85$ mm, which almost coincides with the result of a real experimental study.

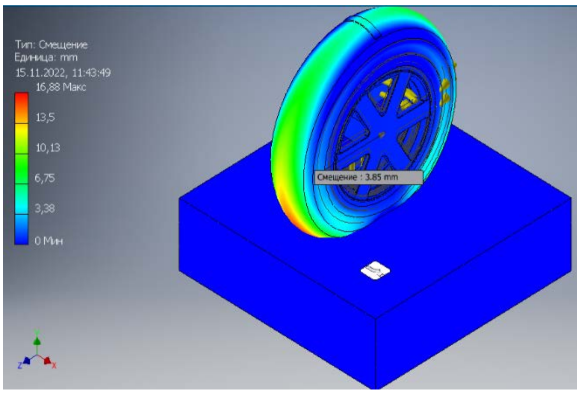


Fig. 8. The result of modeling the interaction of a car tire with a support surface ($p = 0{,}225$ MPa, $P = 5000$ N)

Next, we perform simulations at different values of internal pressure and summarize the results in the table. 2.

The dependence of the area of the contact zone on the value of the internal pressure, according to the results of FEM simulation, will be close to the graph shown in Fig. 4.

Table 2. The results of measurements of the contact zone in the simulation of FEM

Parameters	Internal pressure, MPa					
	0.17	0.18	0.19	0.2	0.21	0.225
Area, m^2	0.031	0.029	0.027	0.026	0.026	0.024
Length, mm	191	170	162	148	143	128
Deflection, mm	6.55	6.25	6.1	5.15	4.7	3.85

Evaluation of the rolling resistance of a car tire

Based on the results of experimental research and simulation of FEM, it is possible to estimate the rolling resistance of a car tire using equation (1). To do this, we calculate the necessary parameters that will change as a result of the change in internal pressure: k_l – the proportionality factor between the length of the contact zone and the normal deflection of the tire; $H_{\text{ш}}$ – the proportionality factor between the value of the inelastic resistance force and the normal deflection; $h_{z\max}$ – full deflection of the tire in the radial direction, mm; r_d – dynamic wheel radius, mm. Recall that the load in each case remains constant $P = 5000$ N.

Based on the results of the calculations, we plot the dependence of the rolling resistance coefficient on the internal pressure. In fig. 9 shows the dependence built on the basis of the results of an experimental study.

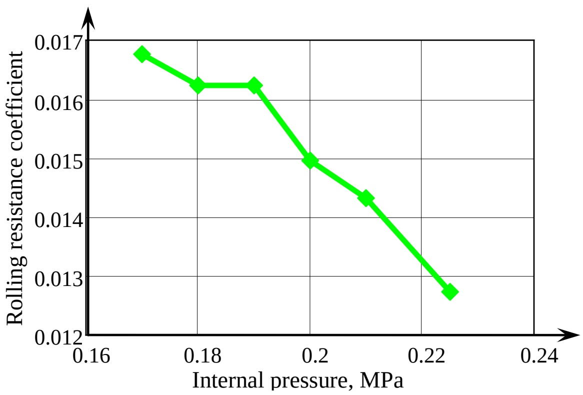


Fig. 9. The dependence of the rolling resistance coefficient on the internal pressure, built on the basis of the results of a real experiment

In fig. 10 shows the dependence, which is built on the basis of the results of FEM simulation.

Comparing the results, it can immediately be noted that higher values of the rolling resistance coefficient are observed in the FEM simulation. It is worth noting that the dependence (Fig. 9) is closer to the results of determining the rolling resistance coefficient obtained in [2]. It can also be said that the general trend of change in rolling resistance is quite obvious (as the internal pressure increases, the rolling resistance coefficient decreases). But the shape of the curves (Figs. 9, 10) differs from those given in [2].

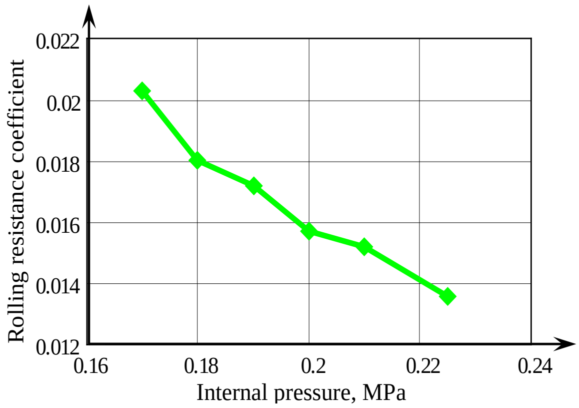


Fig. 10.Dependence of the coefficient of rolling resistance on internal pressure, built on the basis of the results of FEM

Conclusions

In the work, an analysis of the literature is performed, which examines the issue of the interaction of a car tire with a supporting surface. Based on the results of the analysis of the research works, it can be said that most of the works do not cover the peculiarities of the mechanics of the car tire when driving in the starting mode. That is, when studying operational characteristics, it is considered that the tire has already reached optimal parameters (temperature, internal pressure, etc.), that is, in other words, it can be said that the presence of the starting period of movement is not taken into account. In previous works [1-2], it was already proven that in the period from the start of movement (on "cold" tires) to the stabilization of the operational characteristics of the tire, the internal pressure and temperature change quite significantly (by approximately 20-35%), and accordingly other properties of the car tire also change.

In this paper, the dependences of rolling resistance on internal pressure, based on the elliptic-degree model of the absorbing property of the tire, were obtained [6]. To apply this method of determining rolling resistance, it is necessary to evaluate the stiffness characteristics of the car tire and the geometric parameters of the contact zone of the car tire with the supporting surface. Stiffness assessment (determination of radial deflection), as well as determination of geometric parameters of the zone of contact with the support surface, was carried out by conducting a real experiment and using the FEM. It is worth noting that a simplified tire model was used to simulate the interaction of a car wheel with the road surface.

The following conclusions can be drawn on the basis of the research carried out in the work on the assessment of rolling resistance:

– the results of simulation of the interaction of a car tire with the road surface of the MSE almost coincide with the results of experimental studies, which indicates the sufficient accuracy and efficiency of the application of the FEM to solve the problems of the mechanics of the car tire;

– the rolling resistance of a car tire decreases with an increase in the internal pressure of the gas filler, with an increase in the internal pressure in the range from 0.17 to 0.225 MPa, the coefficient of rolling resistance decreased by approximately 20-25%;

– when studying the operational characteristics of automobile tires, it is necessary to take into account the presence of a starting period of movement to ensure safety during this period.

References

1. Karpenko, V., Kaps'kyy, D., Rudenko, N., & Neskreba, E. (2021). Determining the starting time of car movement to stabilize the internal pressure and the temperature in the tires. *Automobile Transport*, 48, 38–44. https://doi.org/10.30977/AT.2219-8342.2021.48.0.38
2. Karpenko, V., Voropay, O., & Neskreba, E. (2022). Indirect assessment of the rolling resistance of a car tire in the starting mode of motion. *Automobile Transport*, 50, 5–13. https://doi.org/10.30977/AT.2019-8342.2022.50.0.01
3. Басов К.А. (2002) *ANSYS в примерах и задачах* / Под общ. ред. Д.Г. Красовского М.: КомпьютерПресс. Basov K.A. (2002) ANSYS v primerakh i zadachakh [ANSYS in examples and problems]. Moscow [In Russian].
4. Wriggers, Peter. Nonlinear finite element methods. (2008) / Springer Science & Business Media.
5. Перегон В.А., Карпенко В.А., Позднякова Е.И., Левченко А.Н., Загородний А.А., Баранник И.М., Коряк А.А. (2017) *Колебания и виброакустика автомобильной шины*. Х.:

Лидер. Peregon V.A., Karpenko V.A., Pozdnyakova E.I., Levchenko A.N., Zagorodnij A.A., Barannik I.M., Koryak A.A. (2017) *Kolebaniya i vibroakustika avtomobil'noj shiny'* [Vibrations and vibroacoustics of a car tire]. Kharkov [in Russian].
6. Рыков С.П., Тарасюк В.Н. (2004) Исследование выходных характеристик пневматических шин. Поглощающая способность. *Системы. Методы. Технологии. Серия: Проблемы механики и машиноведения*, 19-30. Rykov S.P., Tarasyuk V.N. (2004) Issledovaniye vykhodnykh kharakteristik pnevmaticheskikh shin. Pogloshchayushchaya sposobnost' [Investigation of the output characteristics of pneumatic tires. absorption capacity.] *Sistemy. Metody. Tekhnologii. Seriya: Problemy mekhaniki i mashinovedeniya*, 19-30. [in Russian]
7. Рыков С.П., Тарасюк В.Н. (2009) Коэффициент сопротивления качению автомобильного колеса. Новый подход к моделированию и оценке. *Системы. Методы. Технологии. Серия: Проблемы механики и машиноведения*, 30-33. Rykov S.P., Tarasyuk V.N. (2009) Koeffitsiyent soprotivleniya kacheniyu avtomobil'nogo kolesa. Novyy podkhod k modelirovaniyu i otsenke [Rolling resistance coefficient of an automobile wheel. New Approach to Modeling and Estimation.] *Sistemy. Metody. Tekhnologii. Seriya: Problemy mekhaniki i mashinovedeniya*, 30-33. [in Russian]
8. Хольшев Н.В., Лавренченко А.А., Коновалов Д.Н., Минаев П.С. (2020) Обоснование диагностического параметра для определения скрытых повреждений шин автомобилей. *Вестник гражданских инженеров* 3. 191-196. Khol'shev N.V., Lavrenchenko A.A., Konovalov D.N., Minayev P.S. (2020) Obosnovaniye diagnosticheskogo parametra dlya opredeleniya skrytykh povrezhdeniy shin avtomobiley [Substantiation of a diagnostic parameter for determining hidden damage to car tires] *Vestnik grazhdanskikh inzhenerov* (3). 191-196. [in Russian]
9. Козарь Д.М., Крауиньш П.Я. (2013) Определение радиально и тангенциальной жесткости автомобильной покрышки. *Современные проблемы теории машин*, 1, 136-140. Kozar' D.M., Krauin'sh P.YA. (2013) Opredeleniye radial'no i tangentsial'noy zhestkosti avtomobil'noy pokryshki [Determination of the radial and tangential stiffness of an automobile tire] *Sovremennyye problemy teorii mashin*, 1, 136-140. [in Russian]
10. Соколовский С.А., Коханенко В.Б., Яковлев А.Н. (2012) Обзор методов моделирования поглощающей способности шин. *Вісті Автомобільно-дорожнього інституту*. 1, 70-77. Sokolovskiy S.A., Kokhanenko V.B., Yakovlev A.N. (2012) Obzor metodov modelirovaniya pogloshchayushchey sposobnosti shin [Review of tire absorption modeling methods] *Visti Avtomobil'no-dorozhn'oho instytutu*, 1, 70-77. [in Russian]
11. Демидов С.П., (1979) *Теория упругости*. М.: Высшая школа. Demidov S.P. (1979) *Teoriya uprugosti* [Theory of elasticity]. Moscow [in Russian].
12. Эллис Д.Р., (1975) *Управляемость автомобиля*. М.: Машиностроение. Ellis D.R. (1975) *Upravlyayemost' avtomobilya* [Vehicle handling]. Moscow [in Russian].
13. Бидерман В.Л., Володина Т.Л., Пугин В.А. (1967) *Исследование связи между деформациями каркаса и протектора шины и силами в площади её контакта с дорогой*. М.: Химия. Biderman V.L., Volodina T.L., Pugin V.A. (1967) *Issledovaniye svyazi mezhdu deformatsiyami karkasa i protektora shiny i silami v ploshchadi yeyo kontakta s dorogoy*. [Investigation of the relationship between the deformations of the carcass and tread of the tire and the forces in the area of its contact with the road.]. Moscow [in Russian].

Karpenko Volodymyr[1], DSci (Engineering), Professor Department of Machine Components and Theory of Mechanisms and Machines,
e-mail: 56vak56@gmail.com,
Phone.: +38050-938-67-55,
ORCID: http://orcid.org/0000-0001-7376-7585
Neskreba Eduard[1], bachelor, student of the Automobile Faculty, e-mail: eeneskreba12@ukr.net,
Phone.: +38-066-583-70-97

[1]Kharkiv National Automobile and Highway University Yaroslava Mudrogo str., 25, Kharkiv, Ukraine, 61002

Уточнена оцінка опору коченню автомобільної шини в стартовий період руху

Анотація. Проблема. *Опір коченню є однією з найважливіших експлуатаційних характеристик автомобільної шини. В першу чергу від опору коченню залежать витрата палива, довговічність та ресурс шини. Зрозуміло, чим вище опір коченню, тим швидше та інтенсивніше буде зношуватися шина. Також від характеристики опору коченню непрямо можуть залежати параметри гальмування автомобіля, такі як уповільнення та відповідно гальмівний шлях. В свою чергу на опір коченню мають вплив як властивості самої шини, так і стан дорожнього покриття та погодні умови. Особливо важливою є оцінка експлуатаційних характеристик автомобільної шини в стартовий період руху, адже в цей час поведінка шини є непрогнозованою.* ***Мета.*** *Метою даної роботи є вдосконалення методики оцінки опору коченню автомобільної шини в стартовий період руху.*

Знаючи як змінюється в процесі стартового руху опір коченню можна оцінювати й експлуатаційні властивості автомобіля. ***Методологія****. Уточнена оцінка здійснюється за допомогою залежностей, що були отримані в попередніх наукових працях. Але для того щоб результат оцінки опору коченню був коректним, потрібно визначити необхідні характеристики шини. А саме, мова йдеться про характеристики радіальної жорсткості. В роботі дані характеристики визначаються як шляхом проведення експериментальних досліджень, так і за допомогою застосування МСЕ.* ***Результати.*** *Завдяки проведеним дослідженням отримані вагомі результати зміни опору кочення в період стартового руху. Встановлено, що зі збільшенням внутрішнього тиску від 0,17 МПа до 0,225 МПа, внаслідок стартового руху, опір коченню зменшується приблизно на 20-25%.* ***Оригінальність.*** *З аналізу літератури можна зробити висновок, що в більшості з вивчених робіт, особливості взаємодії автомобільних шин з опорною поверхнею в стартовий період не враховуються під час різноманітних досліджень. Можна сказати, що оригінальність даної роботи з одного боку полягає в тому, що опір коченню досліджується в період стартового руху, а з іншого в тому, що його оцінка здійснюється як на основі результатів експериментальних досліджень так і за допомогою МСЕ.* ***Практичне значення****. В даній роботі можна виділити отримані результати, завдяки яким можна з достатньою точністю оцінювати опір коченню автомобільної шини. Методики визначення експлуатаційних характеристик автомобільної шини, що представлені в роботі, можна використовувати при її експлуатації та на стадії проектування.*

Ключові слова: *автомобільна шина, стартовий період, опір коченню, експериментальні дослідження, метод скінченних елементів, уточнена оцінка, стабілізація, безпека.*

Карпенко Володимир Олександрович[1], д.т.н., проф. деталей машин і теорії механізмів і машин, e-mail: 56vak56@gmail.com, тел.: +38050-938-67-55, ORCID: http://orcid.org/0000-0001-7376-7585
Нескреба Едуард Євгенійович[1]**,** бакалавр, студент автомобільного факультету, e-mail: eeneskreba12@ukr.net, тел. +38-066-583-70-97

[1]Харківський національний автомобільно-дорожній університет, вул. Ярослава Мудрого, 25, м. Харків, Україна, 61002