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DEVELOPMENT OF A WINTER ALL-WEATHER SAFETY TIRE MODEL

In the conditions of a constant increase in the speed and intensity of motor transport, it is of particular importance to ensure its active safety on roads of different categories, including those with a layer of snow and ice mass on the surface, which significantly reduces the coupling properties of the car – the main factor in guaranteeing its stable controlled movement.

In this regard, carrying out works aimed at improving the reliability of the wheel's grip with the road is of great importance, and taking into account the change in the temperature regime and the condition of the road surface, it often requires an extraordinary approach to solving this problem.

In this regard, a conceptual model of a winter all-weather safe car tire has been developed to ensure the safety of driving a car in extreme winter conditions, increase the reliability of the tire and anti-skid spikes, improve the resource saving of the road network.

Keywords: traffic safety, car tire, road surface, traffic accident.

Introduction

The safety of road transport will always remain an urgent task, as it is associated with the death and injury of people, estimated in the tens of thousands killed and hundreds of thousands injured and disabled. Thus, in 2018, 18,214 people were killed and 214,853 injured in road accidents in our country, and in the first four months of 2019, 4,000 people were killed and 54,847 people were injured [1].

According to statistics, slippery surfaces and poor road maintenance in winter are among the top three causes of road accidents related to road conditions [2]. As traffic increases, this problem becomes more acute, becoming particularly important in extreme winter operating conditions, characterized by the presence of frozen precipitation on the road surface and limited visibility, and requiring increased vigilance from drivers and strictly controlled speed limits.

In these conditions, the wheel's grip on the road becomes of paramount importance among other traffic safety factors [3], since it determines the implementation of traction capabilities, stability, handling and, most importantly, the braking dynamics of the car as the most common cause of accidents.

When developing design measures aimed at ensuring traffic safety, one of the fundamental factors is the reliable grip of the wheel on the road, at least minimizing the risk of loss of control of traffic in high-speed traffic, especially on urban roads. The study of the coupling properties of tires with support surfaces is devoted to a lot of work, in particular.

When developing the concept of a winter tire, the main requirement that others should be subject to is safety, especially in conditions where the road, covered with a layer of melting ice, has almost zero coefficient of traction. The most reliable means of eliminating the sliding of the tire are anti-skid spikes (SHP), the lack of an alternative to which is confirmed by the practice of operation and the results of the experiments listed below.

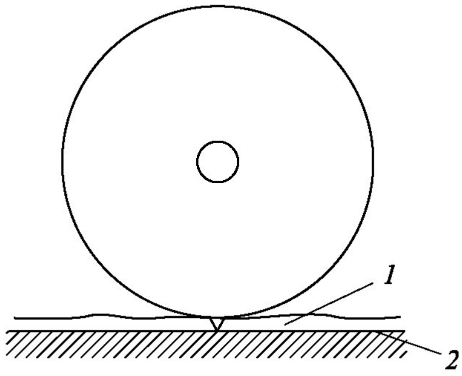
In order to determine the effectiveness of studded tires on snow-covered, icy and clean asphalt roads, we conducted tests on Autopoligon by US. To do this, on the dynamometer road (straight in plan, horizontal), sections were prepared that were covered with rolled snow, a layer of ice and free of snow-ice layer (clean). The tests involved winter tires and non-studded tires.

On a road covered with an ice layer, studded tires provided qualitatively better results in all driving modes, including acceleration, uniform movement and braking with different intensity. On the section with rolled snow, studded and non-studded tires showed almost the same results, since the nature of the grip determined the tread pattern, the presence of spikes did not manifest itself in any way. In the clean section, the performance of non-studded tires was better than that of studded tires, since the coefficient of adhesion of hard-alloy spikes is slightly less than that of rubber.

These tests allowed us to conclude that studded tires are absolutely effective on an icy surface, that spikes are useless on areas covered with rolled snow, and that they perform slightly worse on a clean road.

If we consider the interaction of the tire with the road surface covered with a layer of melting ice, schematically shown in Figure 1, it becomes clear that almost all measures, including the tread pattern, the composition of its rubber compound and the so-called sticky tread, are powerless if a water film has formed between the tire and the ice surface.

In order to ensure the wheel's grip on the road under these conditions, it is necessary to overcome the water layer and introduce a rigid body into the road surface, which is achieved by using the SHP. An attempt to get by with the "stickiness" of the tread without spikes is doomed to bad luck in advance. This is clear to every specialist, and is designed for amateurs as a promotional move.



1 – water film; 2 – ice
Figure 1 – Interaction of the tire with the road surface covered with a layer of melting ice

However, as effective as they are on an icy surface, they are also useless and even harmful on a clear road. This is due to several reasons, including the damage that is caused to the tire itself in terms of intense wear, loosening and falling out of the spikes and, as a result, loss of their performance. But no less damage is caused to the road [4–10]: its surface experiences concentric impacts of carbide spikes and becomes unusable.

In some European countries with a milder climate than in Russia, the use of SHP is prohibited in order to save resources on the road network. At the same time, in the Scandinavian countries – the birthplace of such spikes, as in Russia, SHP is recommended for winter operation. Currently, in order to minimize the damage caused by spikes on the road network, work is being carried out to determine the minimum number of spikes allowed under safety conditions. In our opinion, this activity has no prospects, since the expected gain in resource-saving roads cannot be sacrificed for safety.

Thus, when developing the concept of a safe tire, the studded tire should be the basis, which effectively solves the problem of safety on icy roads. As for the period when the road is free of ice cover, the spikes should be turned off from interaction with its surface. Therefore, the problem consists of two opposite conditions, which at first glance excludes the traditional solution.

Materials and methods

To successfully solve this problem, it is necessary to find a mechanism for adapting the tire to road conditions. This mechanism was suggested by the tire itself, which is an elastic pneumatic shell. When interacting with a rigid reference plane, this shell changes the position of the resultant force, redistributing its position between the center when the stiffness increases and the periphery when this parameter decreases, while increasing the contact area.

This position, which is widely known to specialists, is used for variable pressure tires. In particular, when overcoming difficult sections, the internal pressure in the tire decreases, as a result of which its support area becomes larger, the stiffness of the central part of the treadmill decreases, and the stiffness of the extreme contact zones of the tire increases, where the resultant contact force shifts. At the same time, the softer central part of the tire deforms the track to a lesser extent, and the harder contacting part at the edges prevents the dirt from being squeezed out from under the wheels, which contributes to increased cross-country ability.

Therefore, by adjusting the internal air pressure in the tire and thus varying its stiffness, it is possible to concentrate the resultant contact forces either in the center with a slight increase in this pressure, or on the periphery of the treadmill with a decrease in this parameter.

It is this property that was the basis for the creation of a conceptual model of a winter all-weather safe car wheel tire. Then, placing the SPS where they are most effective, you can create a mechanism for adapting the tire to road conditions. The spikes will either be turned on when there is an ice layer on the road, lowering the air pressure in the tire by 0.01...0.02 MPa, or they will be turned off if the road is dry, by increasing this pressure by the specified value.

Tires of the radial design 205/55R16 were carried out at the Yaroslavl Tire Plant under the leadership of Yu.V. Kremlev with the help of a special laboratory installation of XSENSOR Technology Corporation. The experiments were performed in the range of internal pressure in the tire rvn = 50...300 kPa in increments of 50 kPa with a load of P = 6.7 and 5.0 kN, which corresponds to the full and curb weight of the car per wheel. The obtained pressure distributions in the contact of the 205/55R16 tire with the support base.

The analysis of the obtained results showed that the variation of the load P does not significantly affect the nature of the change in the contact area, which, as expected, increases slightly with increasing load. At the same time, the influence of the internal air pressure in the tire increases significantly due to changes in the length of the contact area, increasing for every 50 kPa, the air pressure decreases by about 15.20 %.

The use of the XSENSOR system for tire testing, based on the principle of color identification of the measured pressure in the tire contact, did not allow us to obtain an accurate quantitative value of this parameter. Nevertheless, the results of the experiment make it possible to fairly accurately assess the qualitative picture of the pressure distribution in the contact, as well as to confirm the fact of the redistribution of contact forces depending on the internal air pressure in the tire, concentrating their resultant either in the central part of the contact area when the air pressure increases, or on the periphery when it decreases.

The decrease in air pressure in the tire is accompanied by an increase in the contact area, which should be considered as a positive factor contributing to an increase in the coupling area of the tire, the number of spikes engaged with the road, and therefore the total coupling force of the wheel. According to the results of the experiment, these patterns appear both at maximum load and at partial load, asserting the invariance of the properties of the tire to redistribute the specific forces in the contact of the tire between the central and peripheral sections of the treadmill, regardless of the load on the wheel.

In addition, the data obtained allow us to recommend reducing the internal air pressure in tires when operating on slippery winter roads, thereby increasing their traction capabilities and driving safety.

The results of computer studies of the tire of the radial design 175/70R13, conducted under the guidance of Professor S. L. Sokolov. Here is the distribution of the contact pressure over the width of the tire footprint 175/70R13 at an internal pressure rvn = 0.25 and 0.40 MPa and the load on the wheel corresponding to the total weight of the car.

As shown by the analysis of curve 1, at an internal pressure of rvn =0.25 MPa, the distribution of contact pressure over the width of the tire footprint is more or less uniform, including in the extreme zones of the tread that carry the SHP. With an increase in the internal air pressure in the tire, there is an increase in the contact pressure in the middle part of the treadmill and its significant decrease (almost to zero) in the extreme zones, completely freeing them from contact with the support surface.

The analysis of the research results clearly confirmed the inherent property of all elastic pneumatic shells of tires to distribute the contact pressure along the reference plane, depending on the stiffness. By adjusting the stiffness by changing the internal pressure, you can purposefully focus the interaction forces either in the center of the treadmill (at high pressure), or in its extreme zones (at low pressure), which opens up the possibility of developing the concept of an all-weather winter tire adaptable to road conditions.

Results and discussion

The conducted research cycle allows us to form a conceptual model of an all-weather safe tire that can adapt to various road conditions, ensuring the implementation of optimal driving characteristics of a mobile car. This tire will have advantages over its analogues both on roads covered with a snow-ice layer (due to spikes) and on clean roads (due to the ability to interact with the road surface with the part of the treadmill on which there are no SPS).

The tool for adapting the tire to the condition of the road surface allows you to either use the spikes or disable them from engaging by adjusting the internal air pressure in the tire. In this regard, the question arises, how can the change in the internal environment be reflected.

An increase in the internal air pressure in the tire, which is recommended to be resorted to to remove the SHP from operation, leads to an increase in the stiffness of the tire and a reduction in the area of the treadmill, which should negatively affect the intensity of tire wear and reduce its resource. It can be assumed that this will also not have a significant negative impact according to the reasoning outlined earlier. At the same time, it is expected that as a result of a decrease in the intensity of the deformation mode, at least, the rolling resistance value will not change.

When assessing the effect of increased tire stiffness on the vibration-acoustic mode of a mobile car, it is also necessary to take into account the quantitative aspect. As is known, at high vehicle speed, it is recommended to increase the internal air pressure in the tires to reduce the intensity of heating of ordinary summer tires, and, accordingly, the intensity of deformations from the increased dynamic background.

Conclusions

All the above considerations are based on a logical premise and are justified by the accumulated experience of operation, as well as the laws of mechanics. In order to get an accurate idea of the working process of the proposed winter all-weather safe pneumatic tire, it is necessary to carry out the next stage of development of this project, experimenting on real models. This will allow you to clarify some of the provisions and create design and technological documentation for the mass production of such a product.

The proposed promising solution has no foreign analogues and guarantees commercial success in the international market. This solution will help to improve the safety of operation in extreme winter and provide financial preference for users, increasing the resource of winter studded tires.

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ҚЫСҚЫ АУА-РАЙЫНЫҢ ҚАУІПСІЗ ШИНАСЫНЫҢ МОДЕЛІН ЖАСАУ

Автомобиль көлігі қозғалысының жылдамдығы мен қарқындылығының тұрақты өсуі жағдайында оның әр түрлі санаттағы жолдарда, оның ішінде бетінде қар мен мұз массасының қабаты бар, бұл машинаның ілінісу қасиеттерін едәуір төмендетеді. Бұл оның тұрақты қозғалыс кепілдігінің негізгі факторы.

Осыған байланысты доңғалақтың жолға адгезиясының сенімділігін арттыруға бағытталған жұмыстардың маңызы зор, ал температура мен жол бетінің жай-күйінің өзгеруін ескере отырып, көбінесе бұл мәселені шешудің ерекше тәсілін қажет етеді.

Осыған байланысты қыс мезгіліндегі автомобиль қозғалысының қауіпсіздігін қамтамасыз ету, шиналар мен сырғанауға қарсы шыбықтардың сенімділігін арттыру, жол желісінің ресурс үнемдеуін жақсарту үшін қысқы ауа-райының қауіпсіз автомобиль шинасының тұжырымдамалық моделі жасалды.

Кілтті сөздер: қозғалыс қауіпсіздігі, автомобиль шинасы, жол жамылғысы, жол-көлік оқиғасы.

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РАЗРАБОТКА МОДЕЛИ ЗИМНЕЙ ВСЕПОГОДНОЙ БЕЗОПАСНОЙ ШИНЫ

В условиях постоянного возрастания скорости и интенсивности движения автомобильного транспорта особую важность приобретает обеспечение его активной безопасности на дорогах разных категорий, в том числе имеющих на поверхности слой снежно-ледяной массы, существенно снижающей сцепные свойства машины – главного фактора гарантии ее устойчивого управляемого движения.

В связи с этим проведение работ, направленных на повышение надежности сцепления колеса с дорогой, имеет большую значимость, а с учетом смены температурного режима и состояния дорожной поверхности зачастую требует неординарного подхода к решению данной проблемы.

В связи с этим разработано концептуальная модель зимней всепогодной безопасной автомобильной шины для обеспечения безопасности движения автомобиля в экстремальных зимних условиях, повышения надежности работы шины и шипов противоскольжения, улучшения ресурсосбережения дорожной сети.

Ключевые слова: безопасность движения, автомобильная шина, дорожное покрытие, дорожно-транспортное происшествие.

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