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Dependence of the effect of pressure on the bearing surface on the pressure in a summer tire of size 225/55 R18

Pysartsov O. [1]

[1] Kharkiv National Automobile and Highway University, Ukraine

Annotation. Problem. *During the study of the influence of tire pressure on the bearing surface of* M_1 *category vehicles, it was found that research on modern tire sizes has not been conducted. This can be useful when driving general traffic vehicles on the rough terrain. This served as the motivation for the present study. This article investigates the relationship between internal tire pressure and the pressure exerted by the vehicle on the bearing surface. The issue of optimizing tire pressure is especially relevant for ensuring high passability, reducing stress on road surfaces, and improving handling, especially under operating conditions on soft or uneven terrains such as sand, mud, or snow. Options for influencing the pressure on the supporting surface to increase the cross-country ability of the vehicle and practical solutions for increasing the passability are also considered.* ***The purpose of the study*** *was to determine the relationship between changes in internal tire pressure and the specific pressure exerted on the bearing surface.* ***Originality.*** *An experimental study was carried out according to the algorithm presented in the article on a vehicle of category* M_1 *of general cross-country ability "Opel Grandland 1.5 BHDi" at the level of a concrete surface with Michelin Primacy 3 summer tires of size 225/55 R18 98V installed.* ***Results.*** *It was determined that reducing the tire pressure from 2.1 to 1.6 atmospheres leads to a decrease in bearing surface pressure from 1.37 to 1.08 kg/cm², which potentially improves vehicle passability. The mechanism of influence of car weight and tire contact area with the supporting surface from the pressure value in summer tires of standard size 225/55 R18 is described. An almost inverse proportional relationship between tire pressure and bearing surface pressure was also established. The article presents graphical and analytical dependencies and substantiates the feasibility of reducing tire pressure in the context of vehicle operation under challenging road conditions.* ***Practical value.*** *The results of the study can be applied in the design of wheeled vehicles, as well as in the practical operation of vehicles in off-road conditions.*

Key words: *tire pressure, bearing surface pressure, contact patch area, passability, tires, Opel Grandland.*

Introduction

The passability of a vehicle largely depends on the force of interaction between the wheels and the bearing surface. One of the key parameters that determines this interaction is the pressure on the bearing surface—a physical quantity that reflects how the vehicle's weight is distributed over the contact area between the tires and the road or ground. Under operating conditions on soft or unstable surfaces (such as sand, snow, or mud), excessively high surface pressure leads to wheel sinkage, loss of traction, and reduced overall mobility efficiency.

Reducing tire pressure is one of the most accessible ways to lower surface pressure without altering the vehicle's design. As the tire pressure decreases, the contact patch area increases, allowing the load to be distributed over a larger surface. This is particularly important for vehicles operating in off-road conditions, as well as for special-purpose and agricultural machinery.

Analysis of publications

In the field of research on the influence of tire pressure on vehicle surface pressure and related issues, significant contributions have been made by scientists and research institutions. The problem of the relationship between tire pressure, contact area, and pressure on the bearing surface is actively studied in both domestic and international scientific literature [1–16]. Most authors emphasize that reducing internal tire pressure leads to an increase in the contact patch area, which in turn reduces the pressure on the bearing surface and improves vehicle passability.

Studies [3, 7] indicate that there is an almost linear relationship between wheel load, internal tire pressure, and contact area size. The authors of [15] and [16] examined the pressure distribution within the contact zone and found that tire shape and stiffness also significantly affect the effectiveness of contact with the supporting surface.

An analysis of recent experimental and numerical research suggests that regulating tire pressure is not only a method of improving passability, but also an important tool for reducing the harmful impact on road surfaces, increasing energy efficiency, and optimizing vehicle handling. Nevertheless, most studies highlight the need to adapt the obtained results to specific vehicle models and operating conditions.

Purpose and Tasks

The aim of this study is to establish a quantitative relationship between internal tire pressure and the pressure exerted on the bearing surface by the vehicle, as well as to assess the impact of tire pressure variation on the potential passability of the vehicle under flat road surface conditions.

The method of determining the relationship between the pressure in the tire and the pressure on the supporting surface

The pressure exerted on the bearing surface by a vehicle is an integral parameter that defines the magnitude of the normal load per unit area of contact between the supporting elements (wheels or tracks) and the ground or road surface. This pressure is determined as the ratio of the vehicle's mass (or the mass of its loaded part) to the total contact area of support.

There are several ways to influence surface pressure in order to improve vehicle passability. One approach is reducing the surface pressure by lowering the weight of the vehicle or tractor, which helps prevent wheels or tracks from sinking deeply into soft ground, thereby reducing the risk of getting stuck. Another method involves increasing the diameter and width of the wheels, which expands the contact area and distributes the vehicle's weight more evenly. Tire pressure regulation is also effective–lowering tire pressure increases the contact area between the tire and the ground, enhancing grip and off-road performance.

Practical solutions for improving vehicle passability include:

- Increasing contact area: using low-pressure tires or track systems.
- Reducing vehicle weight: through lightweight design or decreasing the payload.
- Tire pressure regulation systems: implementing automatic tire pressure control systems allows for decreasing tire pressure while driving on soft terrain and increasing it on hard surfaces.

These methods enhance vehicle passability in challenging terrain or on soft ground by reducing pressure on the supporting surface.

Minimizing surface pressure is one of the fundamental design criteria for off-road vehicles, tracked vehicles, and heavy mobile machinery intended for operation on weak bearing surfaces (e.g., loose sand, swampy areas, snow). In such environments, excessive point loads can cause deep penetration of the supporting elements into the soil, resulting in loss of traction due to a reduction in the coefficient of grip. This underscores the necessity of optimizing the design of the running gear to ensure maximum contact area while maintaining an acceptable vehicle mass.

$$P = \frac{F}{A} \qquad (1)$$

where P is the pressure; F is the force (weight) acting on the bearing surface, and A is the contact patch area through which the load is transmitted to the bearing surface.

From the analytical expression for surface pressure–where the vehicle's weight (mass multiplied by gravitational acceleration) acts on the bearing surface, and A is the effective contact area – it follows that two primary factors have a decisive influence on the pressure exerted by the vehicle: the vehicle's mass and the geometric characteristics of the support system.

As the mass of the vehicle increases, the pressure on the bearing surface rises proportionally, whereas an increase in the contact area leads to a reduction in pressure. Therefore, the use of tracked propulsion systems or pneumatic tires with reduced internal pressure (which expand the contact patch) is a reasonable engineering solution for minimizing the load on the bearing surface.

These structural measures significantly improve the passability of vehicles on soft, low-bearing surfaces by preventing excessive sinking of support elements and maintaining traction performance.

Fig. 1. Pressure on the bearing surface of an M_1 category vehicle

Thus, regulation of the pressure on the bearing surface can be achieved either by reducing the vehicle's mass or by increasing the contact patch area between the wheels and the surface.

All of the above approaches to reducing pressure on the bearing surface have led to the necessity of this research – namely, exploring how to increase the off-road capability of an M_1 category vehicle when required.

The study was conducted on a flat concrete surface using an Opel Grandland 1.5 BHDi vehicle. At the time of the experiment, the total vehicle mass was 1553 kg.

The tires installed on this M_1 category vehicle were Michelin Primacy 3 225/55 R18 98V, with the following specifications:

- Brand: Michelin;
- Season: Summer;
- Vehicle type: SUV;
- Width: 225 mm;
- Aspect ratio: 55;
- Diameter: R18;
- Speed index: V – up to 240 km/h;
- Load index: 98 – up to 750 kg;
- Model: Primacy 3;
- Tread type: Asymmetric;
- Fuel efficiency: C;
- Wet grip rating: A;
- Noise level: 69 dB;
- Tire size: 225/55 R18.

The study was conducted according to the following procedure:

1. The tire was dirtied to make the tread pattern visible.
2. Clean sheets of paper were placed under the front and rear wheels.
3. The vehicle was driven onto the sheets.
4. Using a ruler, the boundaries of the tire's contact with the sheet were marked, and control lines were drawn at the front and rear contact points.
5. The vehicle was driven off the sheets.
6. The tires were inflated to the next pressure value.
7. The procedure was repeated.

During the study, the tire contact patch imprints on the paper sheets were recorded. After obtaining the imprints, photographs were taken. Using graphic editing software, the images were scaled to correspond to the actual dimensions.

Subsequently, the actual geometric parameters of the contact patch were applied to the images, allowing for accurate measurement of the contact area for further calculations of the vehicle's pressure on the bearing surface.

Fig. 2. Conducting the study on the rear wheel of the vehicle

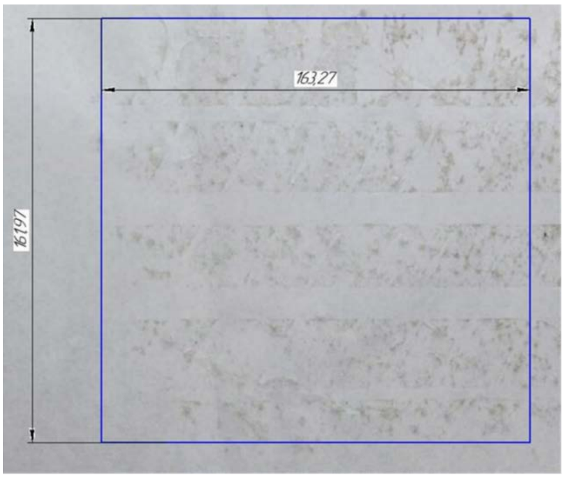

Fig. 3. Example of a tire contact patch imprint

Such measurements were taken for the wheels on both the front and rear axles of the vehicle, since the center of gravity is not located in the middle, and therefore the front and rear wheels have different contact patch areas. The next step involved calculating the contact patch areas of the wheels, summing them, and then multiplying by two to obtain the total contact area of the wheels on both axles of the entire vehicle.

The final step in our study was to determine the vehicle's pressure on the bearing surface for each tested tire pressure value in the summer tires, using the formula presented above. All obtained results were recorded in the table.

Table 1. Test and calculation results

Tire pressure	$P_ш$, atm	1.60	1.70	1.80
Contact area of the front wheel	A_1, cm^2	364.00	354.75	345.24
Contact area of the rear wheel	A_2, cm^2	354.02	329.08	309.11
Contact area of all four wheels of the vehicle	ΣA, cm^2	1436.04	1367.67	1308.69
Pressure on the vehicle's bearing surface	P, кg / cm^2	1.08	1.14	1.19
Tire pressure	$P_ш$, atm	1.90	2.00	2.10
Contact area of the front wheel	A_1, cm^2	336.86	323.62	319.26
Contact area of the rear wheel	A_2, cm^2	286.27	264.45	246.75
Contact area of all four wheels of the vehicle	ΣA, cm^2	1246.27	1176.15	1132.02
Pressure on the vehicle's bearing surface	P, кg / cm^2	1.25	1.32	1.37

As a result of the study, a graph was obtained showing the relationship between the pressure in summer tires and the pressure on the bearing surface of an M_1 category vehicle.

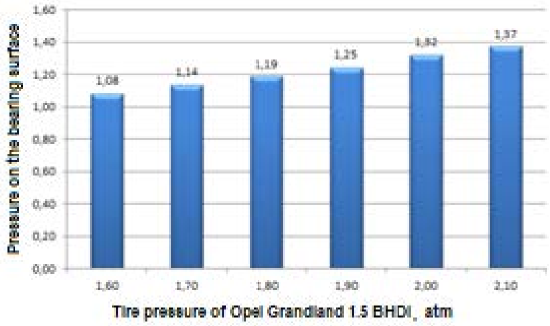

Fig. 4. Pressure of an M_1 category vehicle on the bearing surface at different tire pressures

Conclusion

According to the chart shown in the figure, a clear trend is observed: reducing the tire pressure from 2.1 atmospheres (which corresponds to the recommended value for an M_1 category vehicle – Opel Grandland 1.5 BHDi) to 1.6 atmospheres leads to a decrease in pressure on the bearing surface from 1.37 kg/cm² to 1.08 kg/cm². This change contributes to improved vehicle mobility, especially on soft or uneven terrain. An almost inversely proportional relationship between tire pressure and pressure on the bearing surface was also established. The study results can be applied when adapting vehicles for operation on surfaces with reduced load-bearing capacity.

Prospects for further research: It is advisable to continue studying the influence of different tire types, their diameters, road surfaces, temperature conditions, and dynamic characteristics on changes in the contact area and pressure on the vehicle's bearing surface.

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Pysartsov Oleksandr[1], PhD, Senior Lecturer Departament of Automobiles named after A. B. Gredeskul,
e-mail: alex.pisartsov@gmail.com
Phone: +38 (093) 846-73-68
ORCID: https://orcid.org/0000-0003-4661-5441

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

Анотація. Проблема. *Під час вивчення питання по впливу тиску у шинах на транспортних засобах категорії M_1 на опорну поверхню, було встановлено, що дослідження сучасних типорозмірів шин не проводився, а це може стати у нагоді під час руху автомобілів загальної прохідності по пересічній місцевості. Цим і було обумовлено дане дослідження. У цій статті досліджено взаємозв'язок між внутрішнім тиском у шинах і тиском, який транспортний засіб чинить на опорну поверхню. Питання оптимізації тиску в шинах є особливо актуальним для забезпечення високої прохідності автомобіля, зменшення навантаження на дорожнє покриття та покращення керованості, особливо в умовах експлуатації по м'яких або нерівних поверхнях (пісок, болото, сніг тощо). Також розглянуті варіанти впливу на тиск на опорну поверхню, для підвищення прохідності транспортного засобу і практичні рішення для підвищення прохідності.* ***Метою дослідження*** *було встановлення залежності між зміною внутрішнього тиску в шинах і величиною питомого тиску на опорну поверхню.* ***Оригінальність.*** *Проведено експериментальні дослідження за наведеним у статті алгоритмом на автомобілі категорії M1 загальної прохідності «Opel Grandland 1.5 BHDi» на рівній бетонній поверхні при встановлених літніх шинах Michelin Primacy 3 розміру 225/55 R18 98V.* ***Результати.*** *Визначено, що зменшення тиску в шинах з 2,1 до 1,6 атмосфери призводить до зниження тиску на опорну поверхню з 1,37 до 1,08 кг/см², що потенційно підвищує прохідність. Описано механізм впливу ваги транспортного засобу та площі контакту шин з опорною поверхнею відносно величини тиску у літніх шинах типорозміру 225/55 R18. Також була установлена наявність майже обернено пропорційної залежності між тиском у шинах і тиском на опорну поверхню. У статті наведено графічні та аналітичні залежності, а також обґрунтовано доцільність зниження тиску шин у контексті експлуатації транспортних засобів у складних дорожніх умовах.* ***Практична цінність.*** *Результати дослідження можуть бути використані в проектуванні колісних транспортних засобів, а також у практиці експлуатації автомобілів в умовах бездоріжжя.*

Key words: *тиск у шині, тиск на опорну поверхню, площа плями контакту, прохідність, шини, Opel Grandland.*

Писарцов Олександр Сергійович[1], к.т.н., старший викладач кафедри автомобілів ім. А. Б. Гредескула,
e-mail: alex.pisartsov@gmail.com
тел.: +38 (093) 846-73-68
ORCID: https://orcid.org/0000-0003-4661-5441

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