ANALYSIS OF TIRE TYPES AND TREAD DEPTH IN VEHICLES OF M1 AND N1 CATEGORIES OPERATED IN THE SUMMERTIME IN ŠIAULIAI

Darius Astrauskas
Šiauliai State University of Applied Sciences
Lithuania

Annotation

From the point of view of traffic safety, tires are one of the most important parts of cars. Their wear or choosing the wrong tires quite often becomes the cause of an unfortunate traffic accident. It is especially important to pay attention to the use of the right tires for truck and passenger car drivers, because the car has contact with the road surface only on four surfaces of the human palm. Road traffic safety depends on activities in various areas: education of drivers and other road users, road quality and technical condition of cars. Tires are one of the components of a car. This paper examines grip coefficient characteristics, tire tread patterns and types to determine the condition and types of tires in use.

Key words: *tire types, tread depth, braking efficiency, adhesion coefficient.*

Introduction

In order to improve road traffic safety, it is necessary to undertake activities in various areas: educating drivers and other road users, improving the quality of roads and ensuring good technical condition of cars. Tires are one of the components of a car. More than a century after the creation of the first pneumatic (air-filled) tire, it is time to appreciate the benefits of this discovery. After a closer analysis of the development of the tire, we notice that there have been no very significant external structural changes, only the production technology itself and the properties of the materials used have changed. Despite this, the performance characteristics of the tires in terms of adhesion coefficient, driving speed and noise have changed radically. Not only the tires were changed, but also the vehicle. In order to ensure traffic safety, cars are equipped with various systems that help the driver in emergency situations: anti-lock brake system, traction control system, electronic stability system. However, none of the mentioned systems will be able to function properly when cars are operated with improperly selected or worn tires. The interaction of car tires with the road surface has a significant impact on traffic safety, which encourages the improvement of both car tires and the operational parameters of car roads.

Wheels with tires are of decisive importance for the car, because they are an elastic support that provides the car with engine traction and braking power, enables the car to change its direction of travel, and prevents the car from sliding under the influence of centrifugal forces. In case of adverse weather conditions, i.e. with a large amount of water on the road surface, insufficient depth of the tire tread pattern significantly reduces the adhesion of the car tires to the road surface. A wedge of water intervenes between the car tire and the road surface. This phenomenon is called aquaplaning. Therefore, the purpose of determining the minimum tread depth is to prevent accidents that occur in conditions that reduce road grip. The depth of the tread pattern must be such that it guarantees sufficient grip on the road, even in the worst conditions. Since 1989 June 1 EU approved requirement that minimum tread depth be 1,6 mm.

The performance of the tire is also greatly influenced by the parameters of the road. The surface structure of the potash coating determines driving comfort, rolling resistance, braking properties, and the noise produced by car tires. The road is an inseparable second part of the system (tire - road surface), on which all the properties of the system depend, so it must be considered in a complex manner.

It is very important to ensure that the cars are operated with tires whose grip properties match the weather conditions, i.e. summer tires would be used in summer and winter tires in winter. In order to find out what kind of tires are used by the drivers of cars operating in Šiauliai, a study was conducted evaluating the use of different types of tires during the summer period.

The aim of the research:

To study the types of car tires used in the summer and the depth of the tread pattern.

Research tasks:

1. Determine what types of tires are used on cars in the summer period;
2. Determine the depth of the tread pattern of are used car tires.

Methodology of investigation

After the mandatory use of winter tires was introduced in Lithuania from November 10. until April 1, some drivers drive cars with winter tires even in the warm season. It is known that a car with winter tires does not brake as effectively as a car with summer tires in the warm season. The task of the study was to investigate how many cars drive with winter tires in the warm season. To implement the task, three parking lots near shopping centers in Šiauliai were chosen, where cars are not left for longer periods of time. This assumes that the cars analysed are in continuous operation. The check of the condition and types of car tires was carried out near the shopping centers "Bruklinas", "Tilžė" and the store "Maxima" located at Rudės street 14. The map of places for checking the condition of tires is shown in Figure 1.

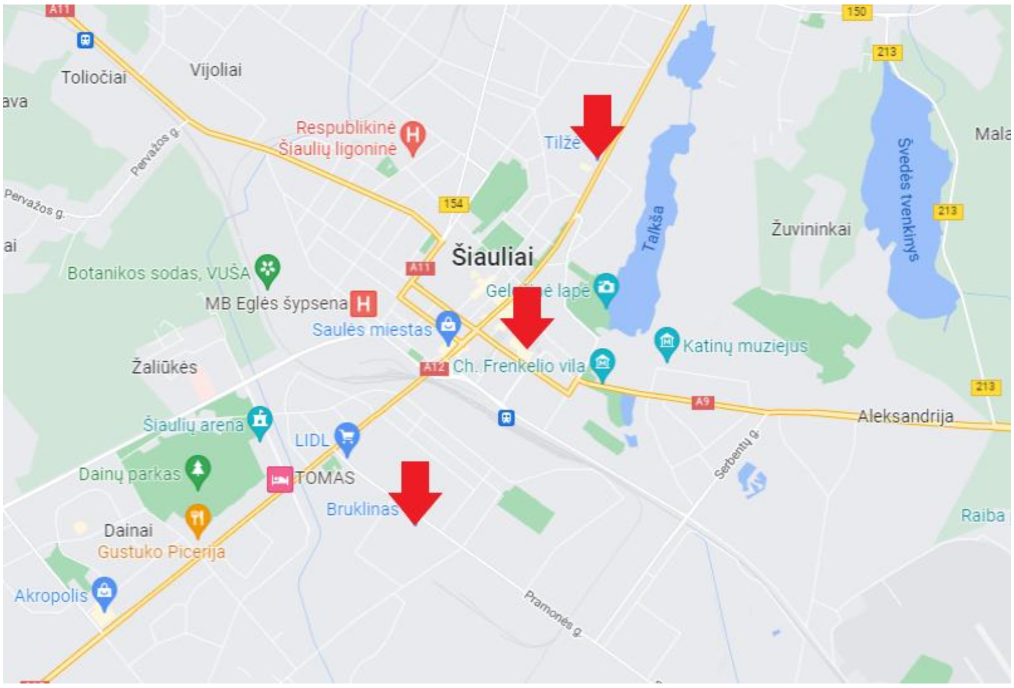

Fig. 1. Tire condition inspection locations in Šiauliai

During the investigation, car tires were inspected and their type was determined based on the tread pattern and markings. In the tread pattern, tire manufacturers insert a tire wear indicator (Figure 2). The tread wear indicator is a narrow raised mark located across the longitudinal grooves of the tire's tread pattern.

Fig. 2. Tire tread depth wear indicators

To make it easier to find tread depth indicators, tire manufacturers print the letters TWI (Tread Wear Indicator) on the side of the tire. If the tread depth is reduced to 1,6 mm, the height of the tread and its wear mark are at the same level. Such a tire is considered no longer suitable for use (unsafe). During the winter period, from November 10 to April 1, cars must be operated with winter or universal tires, the tread depth of which cannot be less than 3,0 mm. The tread depth of the tested tires is measured in three places: in the middle of the tire and on both sides (Figure 3).

Fig. 3. Tire tread depth measurement

The research to determine the types of tires used and the depth of the tread was carried out in August 2022. In Lithuania, it is the summer period.

Analysis of theoretical aspects of tire adhesion to the road surface

A tire is one of the car's elements, on which traffic safety, fuel consumption, and passenger comfort depend. The adhesion coefficient is the main parameter for predicting the car's behaviour during braking and other emergency situations and for designing active safety systems. The contact properties of the road surface and tires determine the driver's behaviour in an emergency situation and the consequences [1].

Longitudinal traction is the ability of a car tire to transmit longitudinal traction or braking force in the area of the contact patch to the rolling surface. When the driving wheel tire transmits a longitudinal force to the contact surface during rolling, a shift occurs between the tire and the road contact, i.e. kinematic distances. The linear speed of the outer part of the driving wheel at the point of contact with the road during traction is higher than the speed of the center of gravity of the car itself. This phenomenon is called relative slip and is denoted by *s*. Slip in the longitudinal direction s_L (%) is calculated [5]:

$$s_L = [(V_R – V_o)/ V_o] \cdot 100\ \%; \quad (1)$$

here: V_R - speed of the outer part of the driving wheel, m/s; V_o - speed of the car, m/s.

or:

$$s_L = [(S_R / S_o) – 1\ ] \cdot 100\ \%; \quad (2)$$

here: S_R – displacement of the wheel periphery, m; S_o – distance, m.

The greater the force exerted by the tire on the road surface, or the lower the sliding friction coefficient of the road surface, the greater the slippage. Although the tire slips relatively, there is friction between it and the road surface, which is characterized by the coefficient of adhesion μ_k:

$$\mu_k = F_L / F_R\ ; \quad (3)$$

here: F_L – longitudinal force, F_R – normal load.

The adhesion coefficient is defined as the ratio of the longitudinal force of wheel traction acting on the road surface and the normal load pressing on the wheel.

The adhesion of a tire to the road surface is one of the main indicators of its efficiency, which affects traffic safety. By improving tire designs, materials that allow improving the main indicators of tire adhesion to the road surface (adhesion and sliding friction coefficients), new tread patterns, special tread rubber compounds have been created. Which significantly improve tire grip on wet and slippery road surfaces, tire elasticity at low ambient temperatures (-8 °C and below) [3]. Improvements in the design of cars (anti-locking and traction control systems, active and semi-active suspension systems, etc.) affect the interaction of the car wheel with the road.

The road surface (materials, texture, technical condition, meteorological conditions - water, snow, ice) has a no less influence than the tire on the optimality and stability of the parameters of the connection road - tire.

One of the main indicators of tire adhesion to the road surface is tread slippage. The values of the adhesion coefficient depend on the longitudinal slip. On a dry road, with a wheel slip of about 14 %, the grip is the highest and its value reaches μ_k = 0,99. On a wet road, the μk value decreases by about 20 %, on a snow-covered road - by about 60 % ($\mu_k \approx$ 0,40) and on an ice-covered road - by about 82 % ($\mu_k \approx$ 0,18). As tire slippage increases, the efficiency of its tread grip with the road surface decreases. When the slip reaches the critical limit, that is 100 %, the longitudinal contact force acting on the area of contact of the tire with the road will become equal to the frictional force between the tread and the road surface. This happens when braking the car with locked wheels or when moving with spinning wheels. In this case, the adhesion coefficient is immediately reduced by 20...35 %. The values of the coefficient of adhesion and the coefficient of sliding friction are equal: $\mu_k = \mu_l$ [4]. Under this condition, the car practically becomes out of control (emergency situation).

The parts of the tire include the distribution of materials in terms of cross-section and the thickness of the tread and grooves. The tire consists of five rubber elements (tread, lower tread, shoulder wedge, sidewall and bead filler) and five reinforcing straps [2]. The distribution of rubber components in half the cross-section is presented in Figure 4. Temperature and load have the greatest influence on rolling resistance, while speed and tire inflation pressure have little influence on rolling resistance.

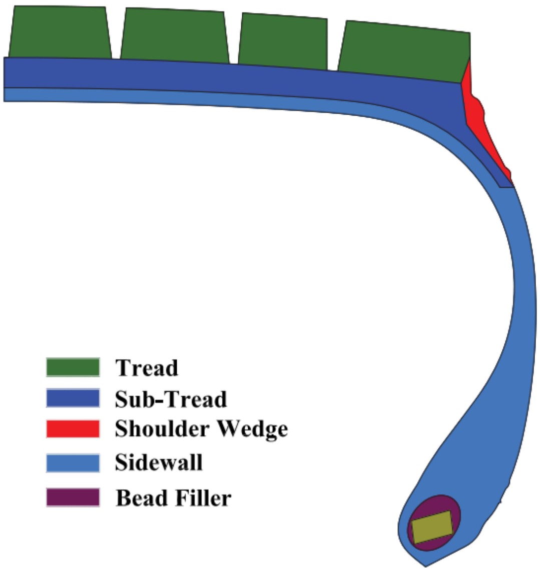

Fig. 4. Distribution of material properties in tire's half cross section. [2]

Tire-wet-road friction depends heavily on tread depth, speed, and water depth. The car owner-operator has control over speed and tire condition, but not on water depth or road surface texture. While wet-road speed conditions are not legislated, minimum tire tread depth generally is codified. The easiest and safest response to wet road conditions is to reduce speed, usually below posted speeds, which are set for dry conditions. Common experience indicates this does not happen routinely, except in very heavy downpours. Speeds should be reduced to below 90 km/h, even for minimally wet roads, to prevent significant loss of friction.

The research also shows that the common legislated value of minimum tread depth (1,6 mm) is not a sufficient depth to prevent a substantial loss of friction on even minimally wet roads at highway speeds. A doubling of this legal minimum, to approximately 3 mm, is recommended and is supported by other researchers. Both the EU and the UK have adopted a minimum legal tread depth standard of 1.6 mm. Recent research has indicated a substantial loss of friction on minimally-wet roadways, at highway speeds, when tire-tread depth falls below 3,0 mm [5].

The European Commission classifies vehicles as part of emission standards and other vehicle regulations. Passenger cars receive an “M” categorization, while commercial vehicles receive an “N” categorization. Two directives of the European Parliament and of the Council serve as sources for these definitions and classifications: 2002/24/EC of 18 March 2002 and 2007/46/EC of 5 September 2007. In addition, the EU legislation on driving licenses (Directive 2006/126/EC of 20 December 2006) provides for a splitting of some categories of vehicles [6].

Category M – Motor vehicles having at least four wheels and for the carriage of passengers. Category M1 – Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat, and having a maximum mass ("technically permissible maximum laden mass") not exceeding 3,5 tons. Category N – Power-driven vehicles having at least four wheels and for the carriage of goods. Category N1 – Vehicles designed and constructed for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat, and having a maximum mass ("technically permissible maximum laden mass") not exceeding 3,5 tons. [7].

Tires are the only part of the car that is in direct contact with the road, therefore, they must be suitable and of good quality. They provide adequate grip with the road surface, thanks to which the car is easy to control, accelerate or brake when necessary. Tires can be of different types (Figure 5), intended for different seasons, with different tread depth and pattern.

Fig. 5. Types of tire treads [8]

Summer tires have a dedicated rubber compound that delivers excellent grip and handling on both dry and wet roads in warmer conditions. They also have reduced rolling resistance and therefore provide greater fuel efficiency and generate less road noise. The tread pattern on a summer tire is more streamlined than a winter tire, with fewer grooves for water clearance, maximizing the contact patch with the road. Consequently, the vehicle has superior traction and braking during dry summer months. However, these same characteristics – the unique rubber compound and simple tread design – make summer tires unsuitable for winter driving conditions. When the temperature drops below 7 degrees Celsius, the compound becomes hard and brittle, and the tread design can't adequately handle snow or ice.

Winter tires provide outstanding grip on road surfaces covered with snow and ice, as well as wet roads in cold conditions. The tread compound of a winter tire contains more natural rubber, so it doesn't harden when the temperature drops below 7 degrees Celsius. Instead, it stays flexible and limber in cold climates to reduce the stopping distance when braking. The tread design has deeper blocks that will dig into snow and ice to provide more grip. The winter tire also has a lot of sipes, which are excellent for clearing water and slush from the path of the car and mitigating the risk of hydroplaning. Winter tires shouldn't be used for the summer season, however. The compound is far too soft for dry asphalt, meaning it will wear out quicker. Moreover, the increased rolling resistance will lead to higher fuel consumption and road buzz [9].

During the summer, winter tires should be changed to summer or universal tires, because: 1. Winter tires are made for a lower temperature range than all-season or summer tires Many drivers think that they can save money by riding their winter wheels all year round. Unfortunately, this is completely wrong. All tires start life with differently engineered rubber compounds, each designed for specific temperature ranges. Compared to summer compound tires, which have a lot of smooth tire blocks for maximum surface area grip, winters have a lot more sipes and softer compound tread blocks. These flexible heavily siped blocks are designed for gripping onto uneven snowy or icy surfaces and not for consistently dry and warm pavement. 2. Your winter tires will wear much faster above 7 degrees Celsius. As the aforementioned sipes and tread blocks come into contact with the dry and warmer spring pavement, heat is created as the rubber blocks are compressed. Because the sipes rapidly open and close as they come into contact with the dry pavement with no snow or ice to cool them down. And too much heat is the worst enemy of a tire. 3. You will not be able to stop your car as quickly By design, compared to a good all-season tire, a winter tire will have 2-3 times as many tread blocks. On dry and warm pavement though, this flexible-by-design construction can make stopping distances significantly longer (Figute 6).

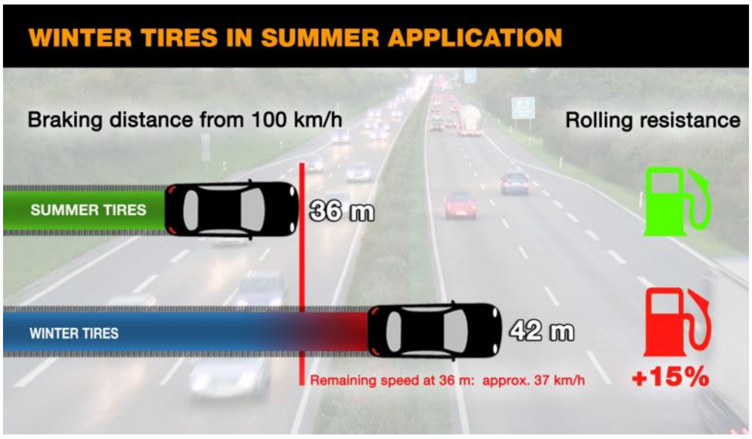

Fig. 6. The difference in stopping distance with winter tires in summer application [10]

At over 30 degrees Celsius, the winter tires' rubber will start to marble. A dangerous situation as little rubber balls are formed and will spin under the wheel. Study's found that winter tire equipped cars (in spring/summer conditions) needed one-and-half to two car lengths more stopping distance. The hotter the ambient temperature, the longer the stopping distance. A potentially dangerous scenario. A winter/summer tire comparison study done by Continental Tires found that there is around 15 per cent less steering precision when using winter tires during warm spring/summer temperatures. The same study found that in summer conditions, winter tires reached their critical limits below 70 km/hr during an avoidance maneuver. By contrast, the same maneuver is unproblematic even at 80 km/hr when equipped with summer tires. Due to the softer and stickier rubber compound, winter tires have a much higher rolling resistance. Rolling resistance is defined as the energy that is lost when the tire is rolling. The main reason for loss of energy is the constant deformation of the tire. The level of wear on winter tires is high at warm times of the year and the rolling resistance is 15% higher than that of summer tires [10].

Research results and their analysis

During the research, car tires were inspected and their type was determined, and their tread depth was measured. Tire inspection took place in 2022. in August in Šiauliai. During the entire investigation, 603 cars were checked. During the research, 352 cars were found operating with the best tires for this season, which is 58,4% of all cars checked. The rest (41,6%) of cars in use are not properly adapted to the operating conditions of the season. Of these, 182 cars were found with winter tires, which is 30,2% of all cars checked. The drivers of 41 tested cars chose to use universal, that is, tires adapted to all seasons. Cars operated with universal tires accounted for 6,8% of all inspected vehicles. During the research, a small part (4,6%) of such cars were also found, which were also operated with different types of tires (Fig. 7).

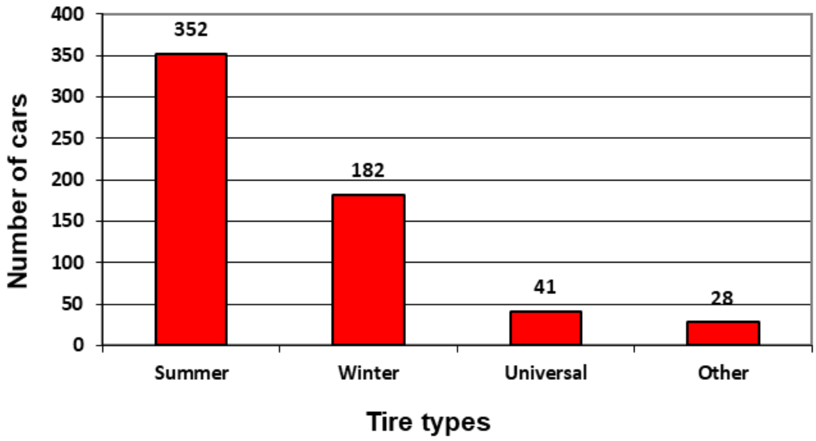

Fig. 7. The results of checking the types of tires of cars in use in Šiauliai

As already mentioned before, during the research, not only the type of tires used was determined, but also the depth of the tread pattern was measured. It was found that only two cars were found to have exceeded the permitted level of tire tread wear by up to 1,6 mm. We know from the traffic rules that it is forbidden to operate cars with a tire tread depth of less than 1,6 mm. During the investigation, 64 cars with summer tires were found, the tread depth of which was less than 3,0 mm but still allowed for operation. There were 18,2% of such cars with insufficient tire tread depth from the point of view of traffic safety. The other cars tested with summer tires were with good tread depth and scored 81,3 percent (Figure 8).

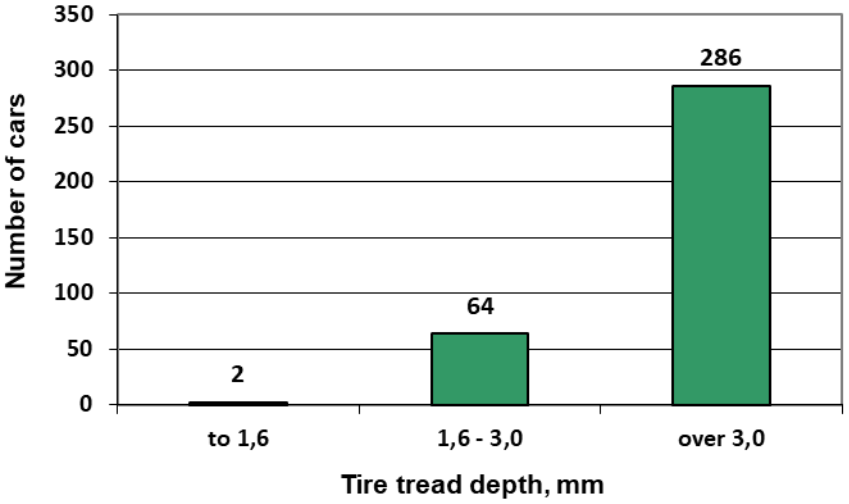

Fig. 8. The results of the study of the tread depth of summer tires

The depth of the tread pattern of cars operated with winter tires was also studied. No tires with a tread pattern depth of less than 1,6 mm were found (Figure 9). Such tires cannot be used in summer. Of the cars operated with winter tires, 68 of them were used with a tire tread depth of less than 3,0 mm. There were 37,4% of such cars. As we know from the traffic rules, it is forbidden to operate cars with a tire tread depth of less than 3,0 mm from November 10 to April 1, i.e. during the winter period. But nothing forbids the use of such tires in the summer. Other cars with winter tires had a tread depth greater than 3,0 mm and these cars can still be operated in the winter period. The question arises why drivers use such tires in the summer time.

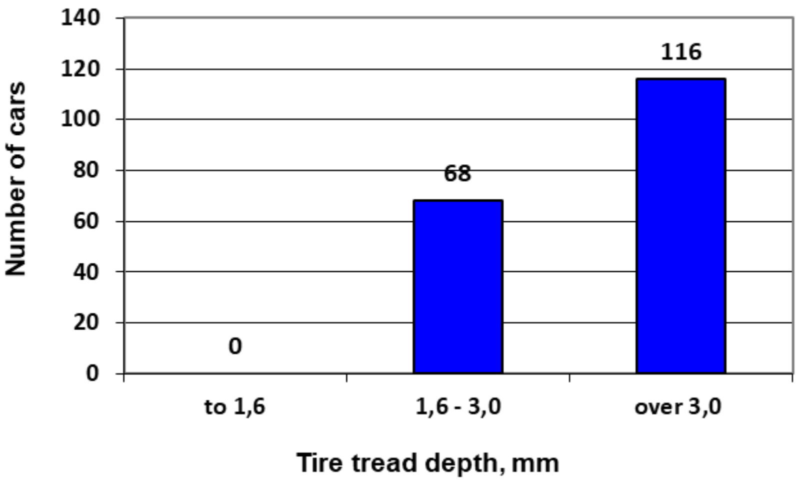

Fig. 9. Results of winter tire tread depth research

When checking the types of tires in use, 41 cars with universal tires were found. Tires with a tread pattern depth of less than 1,6 mm were also not found, as in the case of winter tires (Figure 10). Of the cars operated with universal tires, 22 of them were used with tire tread depth less than 3,0 mm. There were 53,6% of such cars. As we know from the traffic rules, cars with a tire tread depth of less than 3,0 mm are prohibited to operate in the winter period. But nothing forbids the use of such tires in the summer. Other cars (46,4%) with universal tires had a tread pattern depth greater than 3,0 mm and these cars can still be operated in the winter period.

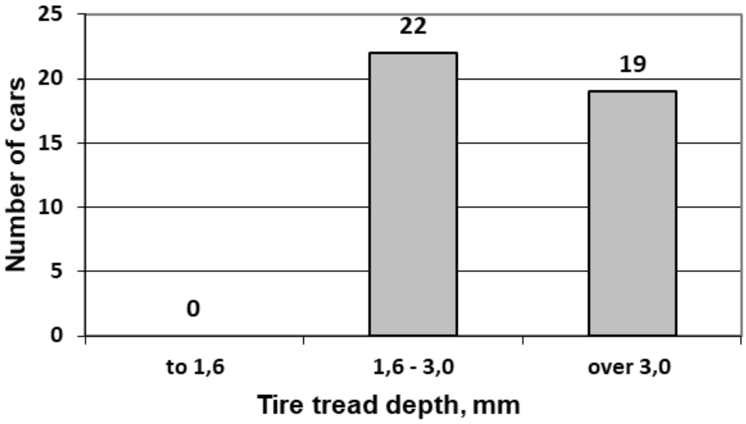

Fig. 10. The results of the study of the tread depth of universal tires

In total, only 0,4% of cars were detected with unsuitable tires during the summer period. 154 types of non-rated tires with a tread depth between 1,6 mm and 3,0 mm were found on cars, which is 25,5% of all cars checked. This tread depth is considered permissible, but not recommended by transport safety specialists. 74,1% of the checked cars have good tires with a tread depth of more than 3,0 mm.

During the study of the types of tires used in the summer period, it was noticed that older cars were mostly recorded with winter tires. It can be assumed that their owners have a lower income and are not always inclined to change tires with the change of seasons. In the case of inflation, the prices of the tires themselves and the prices of service services also rise. More frugal drivers tend to use winter tires whose tread depth will no longer be suitable for the winter season to "drive" in the summer. This is not acceptable from the point of view of driver safety.

During the study of the types of tires used in the summer period, it was noticed that older cars were mostly recorded with winter tires. It can be assumed that their owners have a lower income and are not always inclined to change tires with the change of seasons. In the case of inflation, the prices of the tires themselves and the prices of service services also rise. More frugal drivers tend to "kill" winter tires whose tread depth will no longer be suitable for the winter season in the summer. This is not acceptable from the point of view of driver safety.

Conclusions

The technical condition of car tires operated in Šiauliai is not bad. Only 0,33% of all cars tested were found to be operating with tires with the wrong tread depth (less than 1,6mm). During the investigation, 603 cars were checked. Quite a large part of the cars operated in Šiauliai (25,9%) use tires with a tread depth of less than 3 millimeters. Tires worn to this level are no longer recommended for wet conditions. During the investigation, the behaviour of drivers was found to be unacceptable as a sign of traffic safety. Drivers operate summer cars with winter tires. Cars with winter tires were found in 182 out of 603 checked cars. This is 30,2 percent of all inspected cars. It has been noticed that cars operated with winter tires are usually quite old. Drivers of such cars are likely to have lower incomes and are not always inclined to change tires with the changing seasons. In the case of inflation, the prices of tires and service services also rise. Another possible reason for drivers behaving like this was the reluctance to visit car repair shops during the containment of the COVID-19 pandemic. More frugal drivers prefer winter tires, whose tread depth (less than 3,0 mm) will no longer be suitable for the winter season to "kill" in the summer time.

References

1. Bachmann T. und andere. Der Reibwert zwischen Reifen und Fahrbahn und dessen Inanspruchnahme durch den Fahrer // ATZ Automobiltechnische Zeitschrift. 2005, N 10, 658-667 p.

2. Jaime A. Hernandez, Imad L. Al-Qadi & Hasan Ozer (2017) Baseline rolling resistance for tires' on-road fuel efficiency using finite element modeling, International Journal of Pavement Engineering, 18:5, 424-432

3. Jeschor M.und ander., „Ein neues verfahren zur Bewertung von Pkw-Reifen ein Beitrag auf dem unterschiedlich Weg. Dresden 2005.

4. Reindl L. Über Funk auslesbare passive Sensoren. Institut für Elektrische informationstachnik, Tachnische Universität Clausthal. // ITZ Berichte. 2009.

5. William Blythe & Debra E. Seguin (2006) Commentary: Legal Minimum Tread Depth for Passenger Car Tires in the U.S.A.—A Survey, Traffic Injury Prevention, 7:2, 107-110

6. EU: vehicle definitions. Retrieved from: https://www.transportpolicy.net/standard/eu-vehicle-definitions/

7. DIRECTIVE 2007/46/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.

8. Types of tire treads. Retrieved from: https://www.continental-tires.com/ca/en/b2c/tire-knowledge/summer-or-winter-tires.html

9. Tires tipes. Retrieved from: https://www.continental-tires.com/car/tire-knowledge/tire-basics/tire-types

10. Why treating your winter tires as all-seasons is dangerous? Retrieved from: https://openroadautogroup.com/blog/5-reasons-why-treating-your-winter-tires-all-seasons-dangerous

Received: 10 October 2022.
Accepted: 28 October 2022.