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RESEARCH OF TIRE WEAR ON PORT CONTAINER SEMI-TRAILERS

Abstract. Seaports play a crucial role in supporting global trade and logistics. They act as key hubs connecting various nations and regions. As integral components of the global supply chain, ports function as entry and exit points for goods, facilitating seamless transitions between different modes of transportation.

In the rapidly evolving landscape of international trade, port semi-trailers hold a central position in facilitating the smooth flow of goods. These specialized vehicles are designed to efficiently transport containers between ports, terminals, and inland logistics centers. They combine a durable design, high load capacity, and advanced technology, ensuring reliability and safety in the most challenging operating conditions.

The purpose of the study was to assess the degree of damage and to study the patterns of intensity and nature of tread wear on the tires of port semi-trailers carrying containers.

24 identical container semi-trailers were inspected, which are operated in 4 Black Sea ports. The mileage of the trailers varies slightly, and they are used to transport 40-pound containers.

In the course of research, the residual depth of the tire tread was measured and compared with previous values, which allowed to establish the dynamics of wear under operating conditions. An analysis of vehicle inspections and logs has shown that the main causes of failure are tire tread wear, local destruction of tread pattern elements, damage to the breaker and frame due to external influences. A special tire depth gauge was used to measure tread wear. Tire wear is not proportional to mileage, but has a more complex nonlinear relationship. This often poses a direct threat to road safety. A detailed analysis showed that the wear on the trailer's tire treads was caused by the following factors: incorrect tire pressure, regular overloading, and improper wheel balancing.

Optimizing the tire wear of a container truck trailer requires a comprehensive program that includes the following elements: selecting high-performance tires, performing regular maintenance, monitoring tire pressure, ensuring even load distribution, and improving driver training.

Keywords: wear, container semi-trailers, port, tire, resource.

Introduction. Ports are indispensable for enabling global commerce and logistical operations. They act as critical junctions, linking nations and regions together. As integral parts of the international supply chain, ports function as entry and exit points for goods, ensuring smooth transitions between different transportation methods [1,2].

Choosing a port container semi-trailer is a strategic decision that can significantly impact the efficiency of logistics operations. It is important to consider factors such as payload capacity, chassis type, additional features, and safety requirements. Investing in a modern and reliable container semi-trailer can lead to reduced operating costs, increased productivity, and improved cargo security.

In the dynamic world of global trade, port semi-trailers play a crucial role in ensuring the smooth flow of goods. These specialized vehicles are designed to efficiently transport containers between ports, terminals, and inland logistics centers. They combine robust construction, high payload capacity, and advanced technology, ensuring reliability and safety in the most challenging operating environments [1-2].

Modern port container semi-trailers are equipped with a range of innovative features that enhance their efficiency and safety. Container Locking Systems (CLS) provide secure locking of containers during transportation, preventing them from shifting or getting damaged. Air suspension and electronic brake control systems (EBS) ensure smooth driving and optimal braking, enhancing road safety. Additionally, they are equipped with monitoring and control systems that allow for tracking the location of cargo, monitoring its condition, and maximizing the efficiency of logistics operations.

The main advantage of the port container semi-trailer is its maneuverability. The shorter base and improved steering system make it easy to move between container yards, storage areas, and berths. This significantly reduces cargo handling time and increases the overall capacity of the port. [3-8].

Literature Review. Tires are the link between the vehicle and the road. During operation, tires gradually wear out, which is inevitable due to various factors such as the type of road surface (asphalt or dirt), the vehicle's technical condition, and driving style [3-9].

The difficulty in assessing the degree of wear on truck tires is due to the specific composition of the rubber used to create a wear-resistant coating. Manufacturers use durable, thick, and dense rubber in the tread, which makes it difficult to visually identify wear and reduce the tread height. Failure to detect wear in a timely manner can lead to damage to the vehicle's chassis, reduced control, increased fuel consumption, and loss of vehicle stability [3-9].

Semi-trailer tires are subjected to severe testing due to constantly changing road and weather conditions. Therefore, it is crucial to understand why they wear out and take effective measures to extend their lifespan and ensure safe operation.

The purpose of the study was to assess the degree of damage and to study the patterns of intensity and nature of tread wear on the tires of port semi-trailers carrying containers. Research methodology and results**.**

24 identical container semi-trailers were inspected, which are operated in 4 Black Sea ports. The mileage of the trailers varies slightly, and they are used to transport 40-pound containers.

The condition of the lateral surface, shoulder, and front part of the tire tread was carefully examined. The test report provides detailed information and visual representations

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of the existing operational defects. The focus is on significant damage that may prevent the tire from being used further.

In the course of research, the residual depth of the tire tread was measured and compared with previous values, which allowed to establish the dynamics of wear under operating conditions. It should be noted that this method does not require complex equipment, preliminary impact on the tire, allows to determine the unevenness of tire wear, both in the width of the tread coating and in the length of its circumference. A special tire depth gauge was used to measure tread wear. The wear degree of the tread was measured at the points indicated in Figure 1. The accuracy of the measurements was 0.01 millimeters (Fig.2).

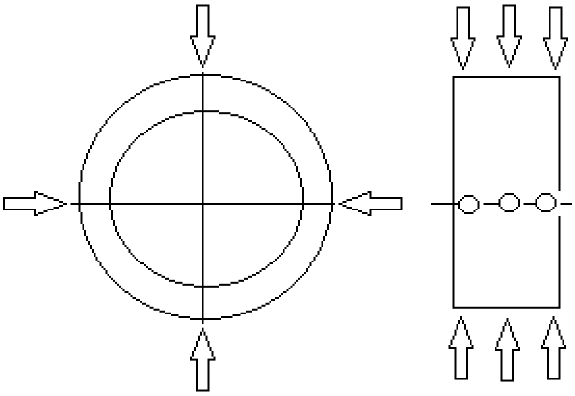

Figure 1 - Tire tread height measurement scheme

Figure 2 - Digital tread depth sensor

Each tread depth measurement was accompanied by the inclusion of the vehicle's technical and registration data in the test report, as well as a detailed description of the shape of the tire damage.

An analysis of vehicle inspections and logs has shown that the main causes of failure are tire tread wear, local destruction of tread pattern elements, damage to the breaker and frame due to external influences. The latter is caused by hitting a road obstacle at high speed (a rail, an open manhole, etc.) and a violation of tire manufacturing technology.

Uneven tire wear on a truck is characterized by different degrees of tread wear in different areas of the same tire. This should be distinguished from uneven wear, where the tread wears evenly across the surface but with different intensity depending on the position of the tire on the axle. Tire wear is caused by the friction between the tread and the road surface as the wheel rolls.

Tire wear is not proportional to mileage, but has a more complex nonlinear relationship. Taking into account the changing intensity of wear, the operating period of a tire is conventionally divided into three sections: initial wear (1), stable wear (2), and the critical wear stage (3), which requires separate consideration (Fig.3).

Accordingly, the break-in and intensive wear stages are smooth functional dependencies of the residual tread pattern height on the tire's service life. This means that they allow for changes in wear intensity as the tire's service life increases. At the same time, in the constant phase, wear follows a linear relationship, and the tangent of the slope of the straight line, ψ, represents the average wear intensity (Fig.3). [6-9].

In practice, it is more convenient to assess the percentage of tread wear, which serves as an indicator of the tire's condition, and it is important for drivers to monitor this. Premature tire failure can lead to significant losses for fleet operators, far exceeding the costs associated with damage. As the condition of the tires directly affects the safety, handling, speed, and longevity of the vehicle, it is the driver's responsibility to prevent tire wear.

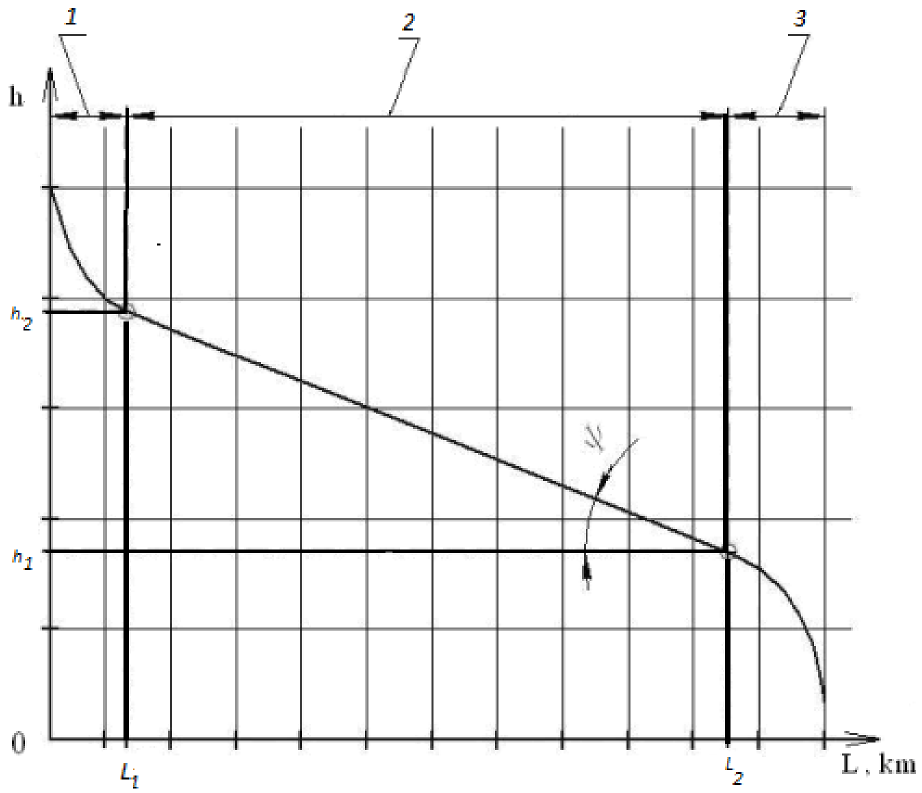

Figure 3 - Dependence of tread wear *h* on tire mileage *L*

The service life of tires is significantly reduced due to aggressive driving styles characterized by slippage at start-up, sharp braking and high-speed maneuvers. Damage can also be caused by obstacles and contact with curbs. An equally important factor is wheel imbalance, which causes periodic impact loads, leading to overstrain of the tire carcass and, consequently, to rapid wear of the tread.

In the course of research, it was found that the tire pressure of some trailers is lower than the recommended value, which leads to an increase in the contact patch with the road and

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a decrease in the specific tire pressure on the surface. However, due to the deformation of the tire inward, the so-called "bending effect" occurs, which causes the average load on the tread to decrease, while the load on its edges increases significantly, resulting in increased material stress.

As a result of the uneven distribution of pressure in the contact area, the tread wears unevenly. The tread edges are subjected to heavy damage, and wear often takes the form of notches or waves. This has a negative impact on the tire's lifespan and vehicle handling.

The detected comb-like wear on the tire is caused by the deformation of the tread in the area of contact with the road surface. The cyclic compression and straightening of the tread blocks as the wheel rotates leads to preferential wear on the front edge. Multiple wear spots around the tire's perimeter are typically indicative of wheel imbalance, which can negatively impact ride quality and cause vibrations. Localized wear in the form of a flat spot is a result of wheel lockup during emergency braking.

Deformation of the trailer shaft housing and the axle bushing under load, combined with gaps in the wheel hub assemblies and uneven road surfaces, can lead to the phenomenon of "twisting" of the wheel. This effect is exacerbated when driving on curved sections of the road. The non-perpendicularity of the wheel to the road surface causes an uneven distribution of pressure in the tire contact patch, resulting in lateral sliding and, consequently, intense wear on the inner side of the trailer axle tire tread.

A decrease in tire diameter implies a decrease in the distance traveled per wheel rotation, which creates the prerequisites for an increase in cyclic load. As a result, during the operation, the number of working cycles for the tire increases, which, in turn, leads to more intensive wear of the tread. Thus, a reduced tire diameter accelerates the process of abrasion.

Two trailers were also found to have delamination starting after the transition from the bead ring to the sidewall. Oblong delamination without irregularities or breaks in the cords. In this case, only the outer layer of the rubber was damaged due to the formation of a joint under the rubber wall.

Exceeding the permissible load weight by commercial vehicles has a negative impact on the durability of tires. This occurs when the weight of the cargo exceeds the established limits, or due to improper weight distribution.

The dragging or dragging that was detected can be explained by the differences in diameter, pressure, and residual tread depth in the wheelset. If the tires have different diameters, the smaller tire will constantly drag, acting as a brake. Additionally, the differences in tire pressure can cause uneven distribution of stress, leading to localized wear.

Intense acceleration and braking create excessive stress on the tires, leading to the formation of microcracks and reducing their durability.

When installing new tires, you should balance the wheels.

It should be noted that half of the samples studied used cheaper tires. The results are presented in Fig.4.

Since rubber is a thermoplastic, heating it from 0 to 100 °C weakens the intermolecular bonds, resulting in a 2-3-fold decrease in strength.

Normal wear of a rebuilt tire is considered to be wear when it has reached its intended mileage, even if it cannot be rebuilt again.

The maximum tread height is h_{min}=1 mm.

An increase in the tire's service life leads to a greater variation in the residual tread depth (Figure 4), which is a result of the inconsistent wear rates in different areas of the tire.

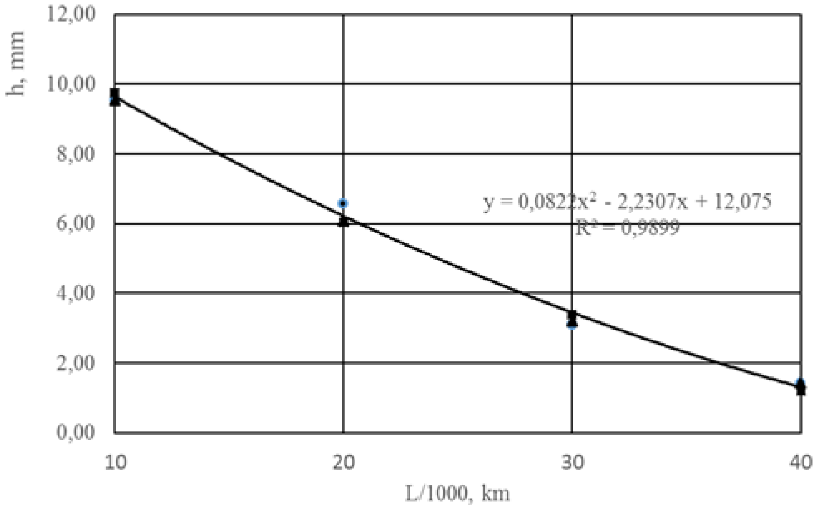
In the critical wear phase, tire wear accelerates significantly, becomes more susceptible to external conditions and internal parameters, and approaches the limit state (see Figure 4).

It should be noted that half of the samples studied used cheaper tires.

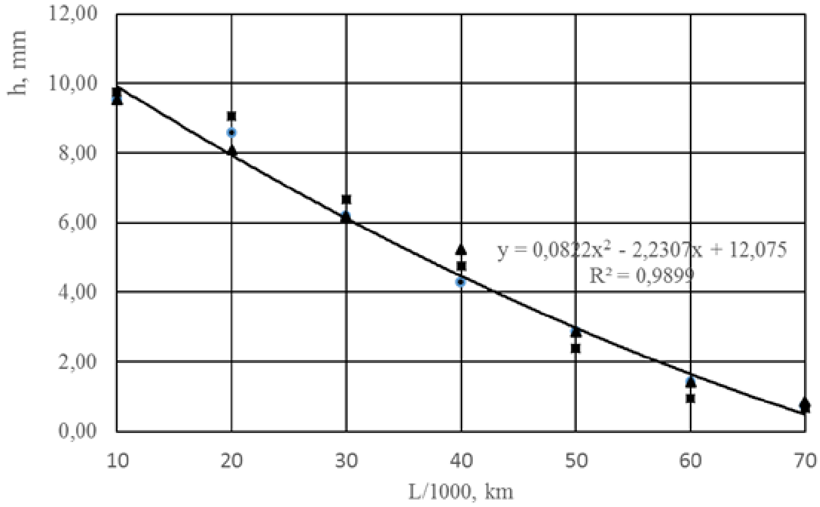
As a result, they failed twice as fast.

Sea water that gets on the tires contains a high concentration of salt. As the salt penetrates the microcracks in the rubber, it crystallizes and expands, gradually destroying the material's structure. This process is accelerated by the fluctuations in temperature and humidity that are common in coastal areas.

High humidity in the marine environment contributes to the corrosion of metal elements in tires, such as the cord and rims.



a)



b)

Figure 4 - Dependence of wear *h* on tire run *L* for regular (a) and special port-specific tires (b)

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Abrasive materials such as sand and small stones carried by wind and water act like sandpaper, wearing down the tread and damaging the tire sidewalls. This is especially relevant in ports, where trailers often move over uneven surfaces and come into contact with various contaminants.

From an economic point of view, the most disadvantageous moment in using a tire is when it reaches the state of extreme wear. Experience shows that more than 80% of tread failures and tire frame damage that cannot be repaired occur when the tires have already reached the end of their useful life.

The most important task of a transport company is to reduce operating costs and ensure the proper functioning of its fleet. To achieve this goal, approaches have been developed to determine the resource of truck tires, taking into account the individual statistics of their actual service life. Additionally, the remaining service life of the tires is predicted through regular monitoring of the tread depth. The most reliable method of predicting the service life of tires is by calculating the actual wear rate, which is based on systematic measurements of the residual tread depth.

It is advisable to determine the residual depth of the tread pattern under conditions that are close to the actual operation of the vehicle. This will allow you to create a reliable data set that can be used for various analytical purposes. In particular, this information can be used to predict the individual life of the tires, to assess the wear on different axles, and to plan the optimal timing for replacing the entire set or individual tires that are most worn out, including the use of spare wheels.

As a result of this complex impact, port trailer tires wear out much faster than tires used in normal conditions. This leads to increased maintenance and repair costs, as well as potential safety risks.

Taking into account that wear usually stops by the time of the first measurement of the residual tread depth, and considering the variability of the pattern depth on new tires, the initial stage of wear (break-in) can be excluded from the calculations. Thus, the calculation of the wear rate should be performed only for the linear section of the dependence, determining the average rate after each measurement.

In addition, it is worth considering modern technologies that help to monitor the condition of tires in real-time. Tire Pressure Monitoring Systems (TPMS) allow you to track the pressure and temperature in each tire, providing warnings about potential issues. This enables you to take timely action and prevent serious damage.

There are also special training programs for drivers, which teach them the correct driving style, allowing to reduce tire wear and increase road safety. Trained drivers are more attentive to the condition of the equipment, observe the speed limit and avoid sharp maneuvers.

Ultimately, effective management of container truck trailer tire wear requires a comprehensive approach that includes the selection of high-quality tires, regular maintenance, pressure monitoring, proper load distribution, and driver training. By doing so, it is possible to ensure the safety of transportation, reduce operating costs, and extend the lifespan of the tires.

Additionally, it is crucial to keep track of the mileage and condition of each tire, which can help in more accurate replacement planning and cost optimization.

Conclusions. Tire wear on container truck trailers is an inevitable process that directly affects the safety, cost-effectiveness, and efficiency of transportation. Understanding the causes, signs, and methods of dealing with tire wear is crucial for fleet owners and drivers.

It is important to remember that saving on tires can lead to much higher costs in the future. Poor-quality or worn-out tires increase the risk of accidents, lead to increased fuel consumption, and require more frequent suspension repairs. You should also pay attention to tire pressure monitoring systems (TPMS), which allow you to monitor the pressure and temperature in each tire, providing warnings about potential issues. Therefore, investing in high-quality tires and regular maintenance is an investment in the safety and efficiency of business.

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Дослідження зносу шин портових контейнерних напівпричепів

Морські порти відіграють вирішальну роль у підтримці світової торгівлі та логістики. Вони виступають ключовими вузлами, що з'єднують різні країни та регіони. Як невід'ємні компоненти глобального ланцюга поставок, порти функціонують як точки входу та виходу товарів, сприяючи безперешкодному переходу між різними видами транспорту.

У швидкозмінному ландшафті міжнародної торгівлі портові напівпричепи займають центральне місце у сприянні безперебійному потоку товарів. Ці спеціалізовані

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транспортні засоби призначені для ефективного перевезення контейнерів між портами, терміналами та внутрішніми логістичними центрами. Вони поєднують міцну конструкцію, високу вантажопідйомність та передові технології, забезпечуючи надійність та безпеку в найскладніших умовах експлуатації.

Метою дослідження було оцінити ступінь пошкодження та вивчити закономірності інтенсивності та характеру зносу протектора шин портових напівпричепів, що перевозять контейнери.

Було перевірено 24 однакові контейнерні напівпричепи, які експлуатуються в 4 портах Чорного моря. Пробіг причепів дещо відрізняється, і вони використовуються для перевезення 40-фунтових контейнерів.

У процесі дослідження було виміряно залишкову глибину протектора шин та порівняно з попередніми значеннями, що дозволило встановити динаміку зносу в умовах експлуатації. Аналіз оглядів транспортних засобів та журналів показав, що основними причинами відмов є знос протектора шин, локальне руйнування елементів малюнка протектора, пошкодження брекера та рами внаслідок зовнішніх впливів. Для вимірювання зносу протектора використовувався спеціальний вимірювач глибини протектора шин. Знос шин не пропорційний пробігу, а має більш складну нелінійну залежність. Це часто створює пряму загрозу безпеці дорожнього руху. Детальний аналіз показав, що знос протектора шин причепа був спричинений такими факторами: неправильний тиск у шинах, регулярне перевантаження та неправильне балансування коліс.

Оптимізація зносу шин контейнеровоза вимагає комплексної програми, яка включає такі елементи: вибір високопродуктивних шин, проведення регулярного технічного обслуговування, контроль тиску в шинах, забезпечення рівномірного розподілу навантаження та покращення навчання водіїв.

Ключові слова: знос, контейнерні напівпричепи, порт, шина, ресурс.

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