The Ability of Airless Tires to Self-Purify

V V Mazur¹, S P Rykov¹

¹Bratsk state university, 40 Makarenko St, Bratsk, 665709, Russian Federation

E-mail: mazurvv@yandex.ru, rsp7-8-48@rambler.ru

Abstract. A well-known disadvantage of pneumatic tires is the cessation of the ability to work with mechanical damage through and determines the need to search for fundamentally new design solutions for wheels and tires to increase the safety and the survivability of wheeled vehicles. One such solution is the use of airless tires made of elastic polymeric materials. The Department of Mechanical Engineering and Transport of the Bratsk State University has developed full-scale models of wheels with airless tires made of elastic polyurethanes of Russian production and was done experimental studies of their ability to self-purify in the process of rolling on a moist soil surface. Research results may be claimed by manufacturers of automobiles and tractors, construction and road vehicles, special motor vehicles and wheeled planetary rovers

1. Introduction
As a rule, exploitation in off-road conditions and on roads without a hard surface leads to contamination of the external surfaces of the machine and its components, and the ingress of dirt into open mechanisms. The most intense accumulation of dirt occurs when the machine moves on wet clay and loamy soil surfaces [1]. Wet clay and loamy soils have high adhesive properties and this causes them to adhere to the elements of the undercarriage of the wheeled machine, primarily on wheels and tires interacting with the supporting surface. Modern pneumatic tires for cross-country wheeled vehicles have the ability to self-purify when working on viscous soils. This ability is provided by a more discharged tread pattern. However, the treadmill grooves and lamellas are quickly contaminated with wet clay. This affects the traction and coupling properties of a wheeled vehicle, course stability and controllability, may result in partial or complete loss of patency.

2. Relevance
Dirt on the surface of wheels and tires can lead to their imbalance and vibration which also affects the controllability and smooth running of the machine, especially at high speeds. In addition, clay and loamy contaminants make daily maintenance difficult, especially at low ambient temperatures.

In severe off-road conditions, the speed of cars does not exceed 10-15 km/h. When driving from a dirty dirt road to an asphalt road for reasons of road safety, it is also undesirable for the car to travel at high speed until traces of dirt are cleared on the treads of its pneumatic tires.

Pneumatic tires have a significant drawback associated with the loss of excess air pressure, which leads to a loss of workability, stability and controllability of vehicles. One solution to the problem is wheels with airless tires made of elastic polymer materials.

Airless tires of elastic polymeric materials were first applied in 1991 to wheeled armored machinery by South African company Allthane Technologies International SA (Pty) Ltd. A significant
contribution to creation and improvement of non-pneumatic tires was made by such companies as Uniroyal [2], Michelin [3-5], Resilient Technologies [6] in common with the University of Wisconsin-Madison's Polymer Engineering Center, Polaris [7], Yokohama [8], Bridgestone [9], Hankook [10], Toyo [11], Boeing [12], Amerityre [13], Sumitomo [14], Britek [15] and others. Russia’s research on non-pneumatic tires are conducted by Vescom Research Centre for Tire Industry LLC [16], Bauman Moscow State Technical University [17] and others.

Airless tires, like pneumatic ones, can be made with any tread pattern depending on the expected exploitation conditions, including exploitation on unpaved roads and in heavy off-road conditions. In this case, the ability of the tread to self-purify from dirt can be provided by known design solutions.

However, there is an opinion that the holes between the flexible spokes of the airless tires will be filled with dirt in the first place, which will cause imbalance and vibration of the wheels. There is a similar opinion that in winter the space between the flexible spokes will be filled with snow, which will melt upon contact with the heated tire during rolling, and when the wheeled vehicle stops the snow turns to ice at a low ambient temperature and this also causes imbalance and vibration.

3. Experimental research

An experimental test of the ability of airless tires with flexible spokes to self-purify from dirt during rolling was carried out during bench and road tests of full-scale models.

Figure 1 shows one of the full-scale models of wheels with an airless tire, created at Bratsk State University [18-20].

![Figure 1. Wheel with airless tire of elastic polymeric materials: (1) flexible spokes; (2) standard JX13H2 disk wheel with a deep edge-free band; (3) supporting ring; (4) protector; (5) fitting ring; (6) mounting ring.]

During bench tests, full-scale wheel models with airless tires were mounted on the rear axle of an automobile. In this case, one of the wheels was fixed from longitudinal movements by large wheel chocks, and the airless tire of the other wheel rested on a roller platform. The open spaces between the spokes of the airless tire were filled with moist greasy quarry clay or wet snow completely when the wheel hung over the platform of the roller.

Figure 2 (a) shows a general view of an airless tire, the cavities of which are filled with clay, and in Figure 2 (b) the cavities of which are filled with wet snow.
Figure 2. General view of the airless tire with cavities, filled with: (a) clay; (b) wet spring snow.

Wheel rolling with an airless tire on the platform rollers was carried out in the leading mode. The test process was recorded on a digital video camera, which allowed us to observe and analyze physical processes in slow motion. The mass of the wheel with an airless tire, the cavities of which were filled with wet clay, was 27.5 kg.

When increasing rotation of the test wheel to a speed of 40 km/h (20 km/h according to the vehicle’s speedometer) for 3-4 seconds, the airless tire cleared from 80-85% clay. Further rolling of the wheel at a speed of 40 km/h for 10-12 seconds provided a degree of purification of 90-95%. An increase in speed to 50 and 60 km/h did not lead to an increase in the degree of purification due to the high adhesive properties of wet clay, which allow the thin mud layer to remain not only in the cavities, but also on the side surfaces of the airless tire. Full self-purification of the airless tire during the rolling process was observed when separating a thin mud layer after drying of the clay.

Compared to wet clay, wet snow does not have fluidity and its adhesive properties to the polyurethane surfaces of an airless tire are manifested to a much lesser extent. However, the adhesion between the grains of wet snow is high enough and under the action of centrifugal forces arising from the rolling of the wheel, the snow is compacted, which increases its shear strength and makes it difficult to remove parts of the airless tires from the cavities. For this reason, the wheel rolling along the platform rollers at a speed of 60 km/h provided a lesser degree of wet tire cleaning from wet snow (80-85%). Full self-purification of the airless tire during the rolling process was observed after freezing of the snow remaining in its cavities with a decrease in ambient temperature, at which the ice formed was destroyed when the support ring was deformed under the influence of a weight load.

Figure 3 (a) shows a general view of an airless tire with a degree of purification from wet clay of 90-95%, and Figure 3 (b) with a degree of purification from wet snow of 80-85%.

During road tests, full-scale wheel models with airless tires were mounted on the front axle of the car. Open cavities between the spokes of airless tires were also filled with wet quarry clay or wet snow with the wheels raised.

Road tests were carried out on asphalt concrete pavement and showed similar results [21]. In addition, in real conditions of dirt roads and off-road it was found that filling the entire volume of cavities between flexible spokes of airless tires with moist cohesive soils that is periodically changing as the vehicle moves is extremely difficult. On the contrary, open cavities are easily filled with waterlogged soil, which has increased fluidity in combination with poor adhesive properties, which leads to low requirements for self-purification modes of airless tires.
4. Conclusions
Ultimately, according to the results of bench and road tests of full-scale models, carried out in comparison with the real ones under more extreme conditions, it was found that the ability of airless tires with flexible spokes made of elastic polyurethanes to self-purification from dirt is not inferior to pneumatic tires of traditional designs. Self-purification occurs during the rolling of the wheel even at low speeds under the influence of centrifugal forces and normal load in the contact zone of the airless tire with the supporting surface. Increasing the speed of the car and the roughness of the road surface accelerate the process of self-purification of airless tires from dirt.

The open spaces between the flexible spokes are not a factor limiting the use of airless tires on wheeled off-road vehicles. In addition, open flexible knitting needles not only improve the heat release process, but can also increase the crossability of a wheeled vehicle on wet soils and when overcoming water barriers.

5. Proposition
The tests made it possible to propose a new technical solution [22], which consists in the fact that for faster and more efficient removal of soil from the cavities of an airless tire under the action of centrifugal forces, the surfaces of its support ring are made inclined.

The essence of the new technical solution is illustrated by the diagram shown in Figure 4, which shows the profile of a wheel with an airless tire of increased self-purification from dirt during the rolling process.

![Figure 3. General view of the airless tire: (a) degree of purification from wet clay 90-95%; (b) degree of purification from wet snow 80-85%.](image)

![Figure 4. Wheel profile with an airless tire of increased self-purification from dirt during rolling: (1) wheel rim; (2) landing ring; (3) flexible knitting needles; (4) basic ring with a protector.](image)
6. References

[1] Gorshkov Yu G and Chetyrkin Yu B 2012 Substantiation of the mathematical model of the pneumatic tire selfpurification *Bulletin of the Krasnoyarsk State Agrarian University* pp 192-196

[2] Gajewski V J 1993 Polyurethane elastomer and non-pneumatic tire fabricated therefrom US Patent 522359

[3] Dehasse B 1991 Deformable nonpneumatic tire with recesses extending crosswise over the entire axial width of the tire US Patent 5042544

[4] Rhyne T B et al 2007 Non-pneumatic tire US Patent 7201194

[5] Dotson M E et al 2013 Non-pneumatic tire with reinforcement band spacer and method of manufacturing same US Patent 20130278044

[6] Manesh A et al 2011 Tension-based non-pneumatic tire US Patent 20110079335

[7] Gass D B et al 2017 Non-pneumatic tire US Patent 9573422

[8] Hanada R et al 2012 Non-pneumatic tire US Patent 8276628

[9] Abe A et al 2014 Non-pneumatic tire US Patent 20140251518

[10] Choi S J et al 2016 Non-pneumatic tire with reinforcing member having plate wire structure US Patent 9333799

[11] Iwase M et al 2010 Non-pneumatic tire US Patent 20100132865

[12] Chadwick D R et al 2014 Non-pneumatic survivable tire, cover and fabrication processes US Patent 20140034219

[13] Steinke R A et al 2007 Airless spare tire US Patent 20070119531

[14] Iwamura W et al 2014 Airless tire EP Patent 2801485

[15] Russell B A 2015 Wheel system US Patent 9004120

[16] Veselov I V et al 2016 Calculation and computer optimization of an airless tire *Rubber industry: raw, materials, technology* pp 151-154

[17] Kartashov A B 2010 Development of large wheeled propulsions from composite materials based on fiberglass (Bauman Moscow State Technical University) p 149

[18] Mazur V V 2017 Development and testing of automobile airless tires *Bulletin of Machine Building* vol 3 pp 86-88

[19] Mazur V V 2014 The wheeled propulsor of military motor vehicles with elevated antitank defense *Military thought* vol 2 pp 55-58

[20] Mazur V V 2014 The wheeled propulsor of planet rovers *Astronautics and rocketry* vol 5 (78) pp 86-90

[21] Mazur V V and Mazur M A 2014 Experimental evaluation of the ability of automobile airless tires self-cleaning of dirt *Systems. Methods. Technology* vol 3 (23) pp 78-82

[22] Mazur V V 2014 *Female die for making wheels* RU Patent 2506169