Double-sided summer-winter vehicle tire: advantages and prospects of industrial production

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Abstract. Improvement of the tire design is considered as the main scenario of innovative development of the tire industry. The results of the research work of the employees of the FSBEI of Higher Education “Pskov State University”, who developed a utility model “Double-sided summer-winter pneumatic tire” (Patent for utility model No. 182679), is presented. The design features of the double-sided summer-winter vehicle tire and the distinctive features that determine its scientific novelty is revealed. Providing the possibility of year-round use of pneumatic tires is highlighted as the main technical problem solved by the proposed utility model. The prospects for the production of the double-sided summer-winter pneumatic tire associates with the possibility of its multiple and periodic overturning. The article specifies the design features of automotive pneumatic tires, which in a particular state are the obstacles for overturning of the tires. The conclusion is made, that the design features determine the possibility and speed of overturning, and the knowledge of the deformation limit values specifies the requirements for the production of this innovative product.

1. Introduction

After the invention of rubber pneumatic tires in 1888, the rapid development of the automotive industry, including tire industry, began [1]. The introduction of synthetic rubber tires in the first half of the 20th century accelerated this process.

Modern high-tech tires have quite a number of advantages such as environmental friendliness and efficiency [1].

The need to the further improvement of competitiveness forces tire manufacturers not only to expand the model range, but also to improve the design of tires [2].

At the beginning of 2013, Global Industry Analysts, Inc. (GIA) published a forecast for the world tire industry, noting the unflagging desire of tire manufacturers for innovations. Despite all the difficulties, enterprises of the tire industry are trying to introduce environmental innovations and develop new products. Now, manufacturers need to focus on tires that are designed to meet environmental standards and reduce costs [1].

In accordance with the Temporary Standards of operational kilometrage of vehicle tires RD 3112199-1085-02 approved by the Ministry of Transport of the Russian Federation in 2002, which operate at the present time, the average kilometrage of light vehicle tires of foreign production and the production of CIS countries is 40...60 thousand kilometers until the tread wear [3].

The increase in the average kilometrage of automobile tires, including their all-season operation, can become one of the directions for the development of innovations in the tire industry.
2. Materials and methods

“Double-sided summer-winter pneumatic tire” (Patent for utility model No. 182679) is developed by the employees of the FSBEI of Higher Education “Pskov State University”. The proposed device contains an overturned tread part with a pattern on two opposing similar surfaces connected by layer of adhesive material, one of which contains anti-slipping spikes and is made of a winter composition of a rubber compound that retains elasticity at a negative temperature, the other is made of a summer composition of a rubber compound that retains elasticity at high positive temperatures [4]. The frequency of overturning of a pneumatic tire is determined primarily by the time of a year, and not by the wear of the outer tread part to the wear limit.

Cross-sections cut of the tire in summer (A) and in winter (B) operation, shown in figure 1, explains the technical essence of the double-sided summer-winter tire [4].

![Figure 1. Cross-sections cut of the tire in summer (A) and in winter (B) operation.](image)

Conceptually, the tire structure consists of the first tread surface 1, which made of a summer composition of a rubber compound, the second tread surface 2, which made of a winter composition of a rubber compound and equipped with anti-slipping spikes 3. The first and the second tread surfaces are connected by layer of the adhesive material 4 [4].

3. Advantages of the innovative solution

The utility model has the following distinctive features that determine scientific novelty: the inner part of the tire is a mirror image of the outer part; one part of the tire is equipped with spikes; if necessary, the tire can be overturned [5].

In the summer season, the outer tread surface is suppose to be in operation. For the winter season, an overturning of the developed tire is performed. In this case, the inner tread surface has become the outer or the working surface. The following change of seasons is accompanied by a repeated overturning of the tire. The operation time of each tread part can be determined by the wear degree.

Therefore, the developed model provides the possibility of year-round use of one set of tires. This feature is designed to reduce the costs for production and operation of pneumatic tires. In addition, features of the structure reduces the chances of a puncture of the tire tread.

4. Prospects for the production of the double-sided summer-winter tire

Prospects for the production of the double-sided summer-winter tire are predetermined by the possibility of its multiple and periodic overturning. Overturning is a complex process of deformation of the tread, carcass, breaker, sidewalls and bead rings of the pneumatic tire.

The main obstacle to the multiple overturning of the pneumatic tire, and, consequently, the technical problem to solve are the design features of automobile pneumatic tires produced in
accordance with GOST 4754-97 (State standard) “Pneumatic tires for light vehicles, trailers to them, light trucks and buses of particularly small capacity” [6].

Modern vehicle tires are a rubber-cord casing filled with compressed air, which has all-direction elasticity (Figure 2) [7].

The design features, studied in the course of research, include [8]:

1. The carcass structure. In contrast to the diagonal arrangement of the threads, radial arrangement is less rigid, complicating the process of overturning the tire [9]. Fiberglass threads, characterized by increased resistance to decay and stretching, also complicate the process of overturning of the pneumatic tire.

2. The structure of the breaker. The ability of an air-filled tire to change its size and shape is directly proportional to the number of rubber-coated layers of fabric or metal cord which envelope the tire carcass on its outer part.

3. The condition of the bead ring. The beads of the pneumatic tire must not be stretched (Figure 3). Therefore, the bead ring consists of a practically non-stretchable wire core.

Figure 2. Components of a vehicle tire [7].

Figure 3. Simulation of stretching of the sidewall of the pneumatic tire when overturn it.
4. The bead ring, which consists of a practically non-stretchable wire core that provides a tight fit on the disc rim, prevents the possibility of slipping off of the pneumatic tire while driving. Stretching or breaking of the bead ring, other forms of deformation accompanying the process of overturning will not allow to ensure secure fastening of the tire on the disk.

5. The tire profile configuration. The degree of complexity of overturning of the tire is directly proportional to the height-to-width ratio of the tire profile. Ultra-low profile of the tire (the ratio of the profile height to its width) provides a high speed of overturning without damaging the bead ring.

6. The features of the tread structure. Execution of the outer part of the tread in the form of a clear symmetrical non-directional pattern facilitates the process of overturning of the pneumatic tire without deformation of the tread. Other versions of the tread (symmetrical directional, asymmetrical directional and asymmetrical non-directional) complicate the process of overturning.

7. The height of the relief pattern and the undertread layer. The thickness of the undertread layer, which determines the strength of the carcass under the influence of concentrated load, as well as the height of the relief pattern, which determines the value of the moment of inertia of the wheel and its rolling resistance, is directly proportional to the speed of overturning of the pneumatic tire.

8. The need to ensure high adhesive strength in the system “metal cord – rubber”. The introduction of special ingredients, so-called adhesion promoters, into the rubber compound formula used in the production of automobile tires allows to solve this problem. For example, silica, modified with cobaltic chloride (II), allows not only to reduce the cost of elastomeric compositions, but also to improve their adhesive properties. Conditional stress at 300% elongation, conditional tensile strength, elongation at break and tear resistance at 23°C and after thermal aging are also practically unchanged [10].

The design features of these basic elements determine the possibility and speed of overturning, the point of application and direction of the force. The study of the limit values of deformation will justify the parameters of the overturn technology of the utility model. Knowledge of the deformation limit values specifies the requirements for the production of innovative product “Double-sided summer-winter pneumatic tire”.

5. Conclusions
The need to the further improvement of competitiveness forces tire manufacturers not only to expand the model range, but also to improve the design of tires. The increase in the average kilometrage of automobile tires, including their all-season operation, can become one of the directions for the development of innovations in the tire industry.

“Double-sided summer-winter pneumatic tire” (Patent for utility model No. 182679) is developed by the employees of the FSBEI of Higher Education “Pskov State University”. The proposed device contains an overturned tread part with a pattern on two opposing similar surfaces connected by layer of adhesive material, one of which contains anti-slipping spikes and is made of a winter composition of a rubber compound that retains elasticity at a negative temperature, the other is made of a summer composition of a rubber compound that retains elasticity at high positive temperatures.

In the summer season, the outer tread surface is suppose to be in operation. For the winter season, an overturning of the developed tire is performed. In this case, the inner tread surface has become the outer or the working surface. The developed model provides the possibility of year-round use of one set of tires.

The prospects for the production of the double-sided summer-winter tire are predetermined by the possibility of its multiple and periodic overturning. The main obstacle to the overturning are the design features of automobile pneumatic tires:
1. The carcass structure;
2. The structure of the breaker;
3. The condition of the bead ring;
4. The tire profile configuration;
5. The features of the tread structure;
6. The height of the relief pattern and the undertread layer;
7. The need to ensure high adhesive strength in the system “metal cord – rubber”.

The design features determine the possibility and speed of overturning, the point of application and direction of the force. The study of the limit values of deformation will justify the parameters of the overturn technology of the utility model. Knowledge of the deformation limit values specifies the requirements for the production of innovative product “Double-sided summer-winter pneumatic tire”.

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