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FEATURES OF TIRE TREAD WEAR BY ROLLING

Maksym Balaka, *Assoc. Prof., Cand. Sc. (Engineering),* balaka.mm@knuba.edu.ua
Dmytro Palamarchuk, *Assoc. Prof., Cand. Sc. (Engineering),*
Dmytro Mishchuk, *Assoc. Prof., Cand. Sc. (Engineering),*
Kyiv National University of Construction and Architecture

The durability improvement of the wheeled mover for transport and technological vehicles is the actual problem, since the tire set cost can reach 30 % of the wheeled machine cost, and the operating costs of tires are 10…15 % of the total costs on the operation of machines. At the same time, tire durability is characterized by the ability to maintain performance until the onset of the limit state during the performance of established maintenance and repair work. It is determined either by the lifetime until unacceptable wear of the tire tread, or before the tire fails [1] due to the side rupture, delamination of the tread or cord, the appearance of tread cracks, dynamic rupture or another defect during the operation of wheeled transport and technological vehicles.

One of the most important purposes for the tire is to ensure the specified traction forces and high traffic safety. Moreover, the main functions of the tire to ensure the transfer of traction and braking forces are performed by the tread, which in ordinary tube tires is made together with the sidewalls. The tire tread according to its functional purpose must provide the traction coefficient necessary for driving safety, which is stable during operation. To do this the tire tread must have, on the one hand, properties to ensure the conditions of its interaction with the supporting surface of the movement remain constant, and on the other hand, maintain its working characteristics during the time specified by the technical standards.

The operation experience of pneumatic tires, which are used on self-propelled scrapers of various designs and work in extremely difficult and diverse operation conditions on road and reclamation construction objects, has shown sufficiently high traction-clutch and speed properties, but insufficient actual lifetime [1–3]. In 65…75 % of cases, unacceptable wear of the tire tread was obtained as a result of intensive sliding motion relative to the supporting surface (ground, soil, snow) on the traction mode of operation. The tread of a pneumatic tire wears out under the influence of effort and sliding motion, which occur in the contact band with the road [4]. Mechanical energy is dissipated in the case of sliding motion in contact. Its certain part goes to the detachment of rubber particles from the tread massif. Sliding motion and loss of mechanical energy, and therefore the wear intensity, depend significantly both on the operation mode of the wheeled mover with pneumatic tires and on the properties of the supporting surface.

In its essence, wear is a more complex process than external friction and is the result of the combined effect of physicochemical and mechanical processes that occur in the surface layer of the tire in contact with the supporting surface of the movement. The prevention task of premature wear and tear of tires is complex and involves the ability to determine their types, as well as unmistakably define the cause of each tire tear.

Tire tread wear can occur by different mechanisms depending on the operation conditions: abrasive, fatigue, by rolling [5, 6]. At the same time, the total intensity of wear is determined by the ratio of individual types. Wear indices can change significantly when operating conditions change.

A specific abrasion mechanism for highly elastic rubber materials was established – wear by rolling, when studying the characteristics of rubber abrasion during friction on relatively smooth surfaces. This wear mechanism is realized at a relatively high value of the friction coefficient between the rubber and the worn surface. Rolling wear occurs at a high friction coefficient but on relatively smooth surfaces. Bands perpendicular to the direction of sliding motion appear on the rubber surface with such wear.

To identify the features of the wear mechanism by rolling, it is advisable to consider the interaction of some protrusion on the rubber surface with the surface of a smooth opposite element, which is pressed against the protrusion with a normal force N and moves parallel to the rubber surface with speed v (Figure 1) [6]. If the friction between the rubber protrusion and the worn surface is large enough, then at the first stage, the movement of the opposite element does not lead to sliding motion in contact but causes a protrusion complex deformation. The development of protrusion deformations may be the reason for the growth of elastic forces that prevent this deformation with further movement.

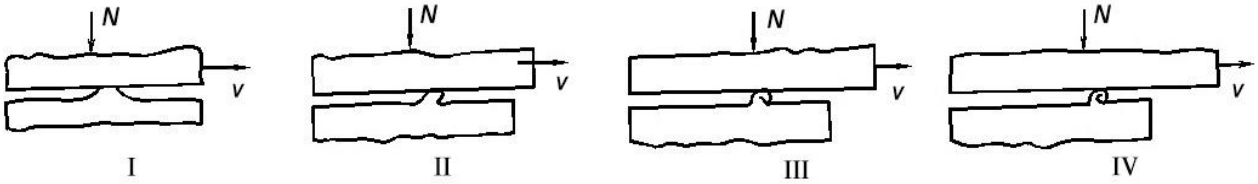

Figure 1 – Serial stages I–IV of the roll formations when rubber friction at the smooth opposite element

Sliding motion begins when the tangential component of elastic forces in contact is equal to the friction force. But if the rubber does not have the necessary strength, and the frictional force is large enough, then the destruction in the largest deformations band may occur earlier than the sliding motion begins in the contact band [1, 4]. The probable nature of this destruction can be imagined, based on the fact that when rubber is under complex stress, the destruction usually begins where the surface layers of the rubber material are more stretched.

It is also known that failure begins with the appearance of a crack perpendicular to the action of the tensile force. If a crack has already appeared, its further growth occurs under the influence of a relatively small force. The crack direction of growth depends in a complex way on the nature of the stress state and on factors related to the presence of micro inhomogeneities in the material structure [7]. The non-uniform temperature distribution near the contact band also has a significant impact. The growth of cracks will lead to the immediate separation of rubber particles from the surface layer. Immediate separation, which is unlikely, rather the rubber gradual tearing, in which there is a relative movement in the contact band without sliding motion. Such a movement is possible if the rubber layer rolls down, separated during tearing (Figure 1, IV). The further movement of the opposite element takes place already under the conditions of rolling friction, which is accompanied by continuous tearing of the rubber and the folding of the piece on the resulting roll surface. The rolled piece is in the tense state. The force that causes its stretching depends on the resistance provided by the rubber to tearing at the place of the piece separation. The piece stretches in the band, where its stretches is critical, leads to the separation of the ridge formed. Thus, completes the considered stage of frictional wear.

The rolling wear mechanism can only occur under a certain combination of external conditions and properties of the rubber being worn. Obviously, this abrasion type is most likely for rubber with low tear resistance. The surface layer heat due to friction in sliding contact can affect the wear process, since the strength properties of rubber depend significantly on temperature [1, 2]. Heat leads to the tarnishing of the rubber surface layer and the sticky appearance, which sharply increases the effective friction.

The rolling wear pattern can be explored in more detail on the basis of an approximate quantitative analysis for an idealized case. If that, all contacts between the rubber and the opposite element (solid and smooth) are made through the roll, and wear occurs only by rolling.

Wear resistance will be characterized by an indicator β, which is the ratio of the friction power N_{fr} to the abrasion intensity J.

We will define the friction power as:

$$N_{fr} = N_{tear} + N_{str} + N_{roll}, \tag{1}$$

where N_{tear} – power spent on tearing the piece from the rubber surface layer; N_{str} – power spent on stretching the piece; N_{roll} – power spent on hysteresis losses accompanying the pitch rolling.

The main condition that determines the formation possibility of slopes and the realization of the considered wear mechanism can be presented in the form:

$$N_{fr} \le \mu \cdot N \cdot v_L, \tag{2}$$

where v_L – motion speed of the opposite element.

We write down the expression for determining wear resistance, using the idea of the characteristic rupture energy and the results of studies on the work evaluation dissipated when tires roll on the solid support surface [6, 7]:

$$\beta = \frac{N_{fr}}{J} = \frac{H}{a} + \omega + 0,9 \cdot \frac{N^{4/3} \cdot (1-\xi) \cdot (\varepsilon + 1)}{ab \cdot (E \cdot r_{roll} \cdot b)^{1/3}}, \quad (3)$$

where H – characteristic rupture energy; ω – average value of the specific stretching energy; ξ – rubber elasticity; ε – relative elongation; r_{roll} – pitch radius; a, b – thickness and width of the separated piece of rubber.

Despite the fact that a number of assumptions were made when deriving dependence (3), it shows the existence of a relationship between the wear intensity by rolling and the elastic-relaxation and strength properties of rubber. The critical conditions for the wear realization in the form of rolling have been established, using this dependence. Ideas about the tire wear mechanism by rolling were experimentally confirmed with the device help in which rubber friction was carried out with smooth plexiglass, and the phenomena occurring in the contact band were observed under a microscope [7]. The formation of characteristic transverse folds and furrows transitioning into ridges during wear was clearly identified.

Rolling wear is of particular interest, since this mechanism is realized for highly elastic materials and, in principle, cannot be observed in the friction of solid elements or solid rubbers. The wear mechanism by rolling is the highly intensive type. The pneumatic tire turns out to be short-lived if such a wear mechanism is realized.

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