The research of operational temperatures of dump trucks tires

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Abstract. Oversized tires play a significant role in the mining process for ensuring continuous and safe operation of open cast mining equipment. The article presents the influence of large tires operating temperatures tolong life operation. The results of studies of the tire heating nature during the operation arealso presented. The regression models of studied multifactor processes of heating tires are obtained by methods of computational experiment and mathematical planning. The influence of the tread height at tire heating is evaluated.

1 Introduction

In Russia an open cast mining has a dominant role in mining industry, as it is safer and more economical [1-2].

High productivity and uninterrupted operation of the rock mass transportation is an important part of mining enterprise functioning. It is ensured by the increase in the technical readiness of the vehicle fleet while maintaining acceptable levels of safe operation. So, the significant role of large tires in ensuring continuous and safe operation of open cast mining equipment becomes apparent. It is also important that, the large tires have the significant role in the structure of the rock mass transporting cost (the cost of large tires varies from 10 to 40 thousand dollars per unit).The consumers of these products are interested in the most efficient management of the tire resource during operation.

The analysis of statistical data, for the typical reasons of large tires failure, showed that about 12% of failures are associated with fatigue and thermal damage caused by excess temperature of large tires during operation for various reasons, and a temperature of 120 ° C is critical for them. If the temperature exceeds the critical temperature, the tire will collapse due to a decrease in the strength of the cord and its connection with rubber, the development of the following defects, such as delamination, bloating of the tread and delamination of the carcass [3]. There were also situations where the cord broke and the tire self-ignited. The significant temperature effect in tire fatigue failure has been confirmed by many researchers. In most performed studies, this fact is explained, so that, when a tire

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is used a high temperature is maintained for a long time in it, there is a sharp decrease in both the strength of the rubber itself and its adhesion to the cord. At the same time, in places of the greatest decrease in adhesion, mechanical friction occurs between the cord and rubber, which additionally causes a sharp increase in temperature and, ultimately, rapid destruction of the tire. In this regard, the fatigue damage of car tires due to the influence of high temperature is often called the thermal damage of tires [4-5].

It should be noted that, during fatigue and temperature failures, we practically cannot extend the life of large tires by restoring the tread, since with these damages, the tires are subject to decommissioning, which leads to significant material losses of the enterprise.

The taking into account and temperature control of large tires at mining enterprises is usually not carried out. As a rule, the mining company is guided only by the operational performance parameter when choosing large TKPH tires (ton-kilometer per hour), which represents the maximum allowable tire load according to the heat generation. The main focus is on factors that influence tire longevity primarily in terms of tread wear, such as tire pressure and average operating speed. All of these factors are controllable and it is possible to influence them. They are monitored at the mining enterprises through the use of navigation and the tire pressure monitoring system “Pressure Pro”, or periodic measurements [6-8].

Today, mining enterprises, in connection with plans to increase productivity and reduce fixed costs in the structure of transportation costs, are making changes to the design of mining dump trucks by increasing the height of the side sides of the cargo platform (Fig. 1).

Fig. 1. BelAZ-7513 dump truck with extended side sides of the cargo platform.

Since loading a dump truck is performed with a “cap”, this leads to exceeding the rated load capacity of a mining dump truck. Based on the data obtained by weight control at the mining enterprises of Kuzbass, the utilization rate of the carrying capacity of mining dump trucks with extended sides varies from 0.9 to 1.15. Exceeding the permissible load on the tire causes increased heat generation. It is possible to level this out by changing the average operational speed of a mining dump truck.

All mentioned above indicates the relevance of the study of operating temperatures of large-sized tires of mining dump trucks and factors influencing heat generation.

2 Experimental research

The heating of large tires is associated with the following reasons: hysteresis losses, external friction of the tire on the surface of the road surface, as well as the effect of solar radiation on the surface of the tire [9-12].

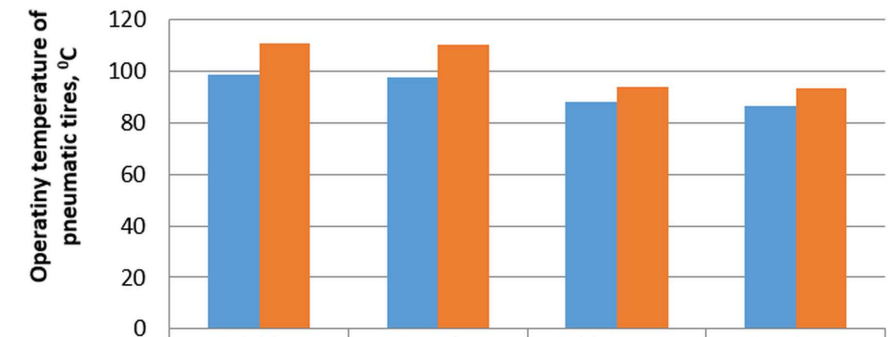
For the most operating modes, the heat generation is about 85-95 % because of the deformation and internal friction, from 5 to 15%is from external friction. The exceptions are skidding, slipping and applying to the wheel moments exceeding the maximum traction moment significantly. In these cases, the main cause of heat generation in the tire is the external friction on the road surface. However, such modes are implemented quite rarely in the actual operation of dump truck, mainly during the season of sluts and uphillmovement. Solar radiation affects tire heating only in the hottest time of the year. In this case, the temperature of individual sections of the tire illuminated by the sun can increase by 10-15 ° C compared with the surface of the tire in the shade.

Part of the heat generated in the rolling tire array is continuously discharged into the environment. Moreover, if at the beginning of the movement the tire temperature is equal to the ambient temperature and the heat generation is much greater than the heat transfer, then after a certain time the total heat generation and heat transfer are equalized, and the temperature in the tire stabilizes (stationary mode) [13-14].

In the production process of open cast mining enterprises in Kuzbass, mining dump trucks of various capacities from 45 to 220 tons are operated. The dump trucks BelAZ-7555 and BelAZ-7513, with a loading capacity of 55 and 130 tons have the greatest efficiency [15].

Investigation of large-sized tires thermal state of open cast mining dump trucks was carried out in a combination of a computational experiment with methods of mathematical planning, that reduces the number of calculations and facilitates the analysis of the results. Measurement of tire operating temperatures was carried out, using a Raytek-MT6 pyrometer. The main heat generation in the tire occurs in the area of its contact with the supporting surface. In such a zone, the maximum strain rate and the rate of deformation: normal, circumferential and lateralto the tire element act. It has been established that, the largest amount of the heat per unit volume is generated in the middle of the tire's tire layer and at its edges, and the total heat generation in the tire is distributed on its main elements on average as follows: tread (including the undercut) - about 50%, carcass from 12 to 33%, the breaker layer - from 7 to 15%, the sidewalls and the adjoining side from 5 to 25%.

The results of processing experimental studies of pneumatic tires operational temperatures are shown in Fig. 2 and 3. Figure 2 shows the steady-state operating temperatures of the rear axle pneumatic tires, with an average ambient temperature t*av* = 20-23 °C and equal operating conditions.



	Belshina	Eurotire	Bridgestone	Goodyear
BelAZ-7555V	98,8	97,7	88,1	86,5
BelAZ-7513	111,1	110,5	94	93,4

Fig. 2. Steady operating temperatures of large tires.

As it can be seen from the graph, the steady-state operating temperatures of pneumatic tires, are significantly different according to the manufacturer. This is primarily due to the design of the tire and its elasticity. It should be noted, that the operating temperatures of pneumatic tires of Bridgestone and Goodyear, Belshina and Eurotire are practically comparable. During the study, it was revealed that the pneumatic tires of the BelAZ-7513 dump truck are additionally heated by the motor-wheel gearbox.

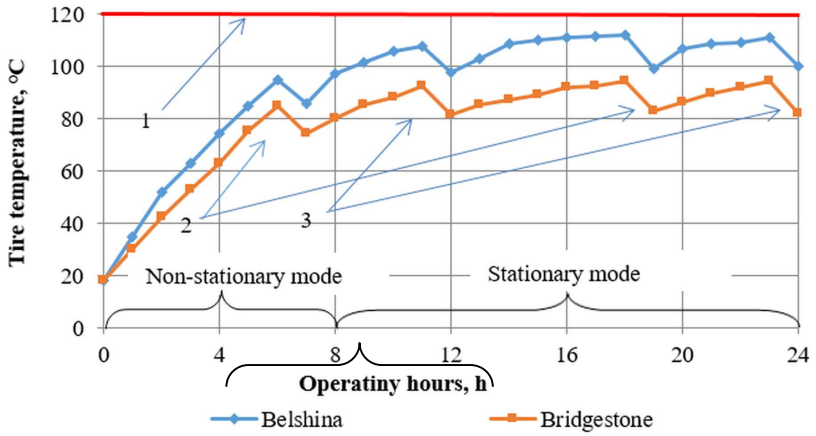


Fig. 3. Dynamics of heating of rear axle large-sized tires of the BelAZ-7513 dump truck (1 - critical temperature, 2 - lunch break, 3 - shift shift).

Based on the analysis of the data obtained, the most intense temperature increase occurs in the first 8operating hours of the truck, that is, unsteady mode. Subsequently, the increase in tire temperature is approximately 1 ... 5 °C/h. During the operation of dump trucks, the tires warm up and cool down in connection with the operating conditions of the dump truck itself.

It has been established that a large tire at an ambient temperature of 20 ... 25 °C is cooled on average 10 hours after shutdown. At the same time, in the first 4 hours of the dump truck sludge, the tire cooling rate is 10 ... 12 °C/h, and later it drops to 5.0 ... 6.7 °C/h. The dynamics of heating the pneumatic tires of the BelAZ-7555V dump truck is similar.

The task of determining the root that causes thermal failures is one of the most important problems to be solved when organizing large-scale tires and dump trucks at the modern level of operation. There are different ways to solve these problem, but in any case, it is necessary to obtain correlation relationships of temperature depending on specific operating conditions, taking into account the wear degree of the tire tread. Without this knowledge, optimization of the modes of movement of dump trucks is impossible.

We define the most determining factors of large tire heat generation [3]:

- the average for the transport cycle radial load on the tire;
- operational speed of a dump truck;
- ambient temperature.

These factors are completely controllable, and we can influence them during the operation of large tires. We'll not consider the internal pressure in a large tire, since it is a completely controllable factor and is currently controlled quite well. Although, special attention must be paid to the work of the rear axle twin wheels. When the pressure

difference in the tires of a double wheel is 10%, the temperature of the tire with the highest pressure can exceed 16%.

Experimental studies found that, with a maximum load of 392000 N on a tire of 33.00R51 dimension of the Bel-162 model with an increase in speed from 10 to 15 km / h, the tire temperature increases by 32.9% with a slight increase in air pressure in it by 6%. Exceeding the permissible operating speeds of dump trucks leads to thermal tire failures due to operational reasons. When subject to recommended operating conditions, these types of failures will be determined by production reasons, i.e. insufficient level of workmanship. This confirms the significant influence of the truck speed to the heating of its tires.

The experimental data on the weight per tire on the axis of the BelAZ mining dump truck in operation was determined by weight control, and the average speed of its movement was determined by timing the dump trucks with a fixed speed and comparing it with the GLONASS readings. Information about the air pressure in every tire of mining truck was delivered to the control room of the enterprise through the GLONASS global navigation satellite system.

Technological vehicles at Kuzbasscoal enterprises use pneumatic tires from such manufacturers as: Belshina and Bridgestone. Using the Statistica 6.0 program and the Gauss method with an accuracy of ± 3.9%, the correlation dependences of the maximum steady-state temperature of the rear and front tires were obtained:

BelAZ-7513 -(Belshina)

$$t_{r.ax.t} = 31.7 + 0.6\, t_{av.n.} + 0.101 Q_{r.ax.t.} V_{av.s.} \quad (1)$$

$$t_{f.ax.t} = 26.5 + 0.6\, t_{av.n.} + 0.096\, Q_{f.ax.t.} V_{av.s.} \quad (2)$$

BelAZ-7513 (Bridgestone)

$$t_{r.ax.t} = 30.1 + 0.6\, t_{av.n.} + 0.078\, Q_{r.ax.t.} V_{av.s.} \quad (3)$$

$$t_{f.ax.t} = 25.8 + 0.6\, t_{av.n.} + 0.076\, Q_{f.ax.t.} V_{av.s.} \quad (4)$$

BelAZ-7555V (Belshina)

$$t_{r.ax.t} = 37.2 + 0.6\, t_{av.n.} + 0.097 Q_{r.ax.t.} V_{av.s.} \quad (5)$$

$$t_{f.ax.t} = 22.5 + 0.6\, t_{av.n.} + 0.074\, Q_{f.ax.t.} V_{av.s.} \quad (6)$$

BelAZ- 7555V (Bridgestone)

$$t_{r.ax.t} = 35.4 + 0.6\, t_{av.n.} + 0.081\, Q_{r.ax.t.} V_{av.s.} \quad (7)$$

$$t_{f.ax.t} = 20.3 + 0.6\, t_{av.n.} + 0.064\, Q_{f.ax.t.} V_{av.s.} \quad (8)$$

Where $t_{r.ax.t.}$,$t_{f.ax.t.}$ - tire temperature, respectively, of the front and rear axles of the truck, °C; $t_{av.n.}$ – average ambient temperature, °C; $Q_{r.ax.t.}$, $Q_{f.ax.t.}$ -average operating weight per tire of the front and rear axles of the truck, respectively, t; $V_{av.s.}$ - average operating speed of the dump truck, km/h.

A comparison of the results of experimental studies with the results of calculations based on the obtained regression dependences showed that the error does not exceed 6.5% for BelAZ-7513 dump trucks, and for BelAZ-7555V dump trucks they obtained comparable results and the error is about 5.2%. Consequently, the obtained regression dependences can be used to estimate the maximum steady-state temperatures for heating pneumatic tires during operation and to determine average operating speeds.

To assess the influence of the tread height of a large tire on its heating in operation, experimental studies were conducted, the results of which are shown in Fig.4.

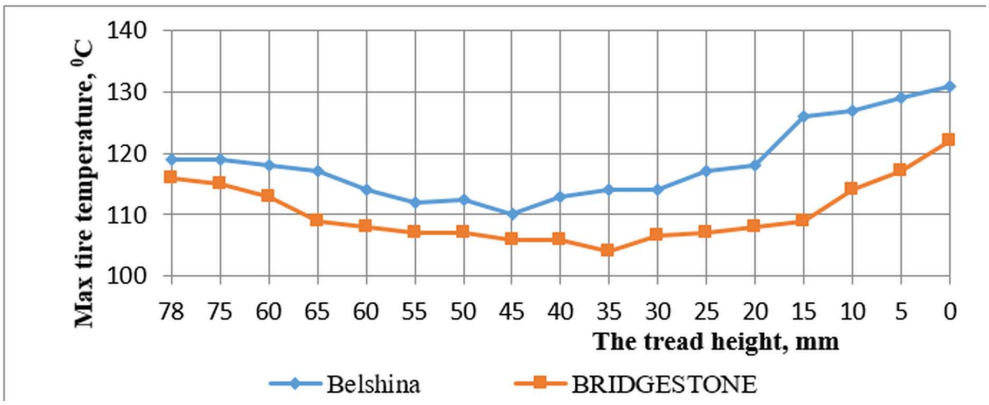


Fig. 4. Effect of tread height on the maximum temperature of tires of the BelAZ-7513 dump truck.

It has been established that during operation of tires of the open cast mining truck, the temperature of heating of the tires changes depending on the amount of wear. In the process of tire wear, their heating temperature decreases to a certain value first, and then increases. Worn out (bald) tires are subject to higher heat. Moreover, Bridgestone tires undergo less heat compared to similar tires of the Bel-162 model of Belshina OJSC. Obviously, this is due to lower hysteresis losses in Bridgestone tires.

3 Conclusions

In general, the studies conducted allow us to assess the main factors that affect the operating temperatures of large tires, and to manage them to realize the most complete tire life. In the course of the study, the influence of the tread height on the heat generation in the tire was established, thatmust be taken into account during the operation. The use of research results in the organization of production processes for mining will reduce the cost of rock mass transporting.

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