Influence of Service Conditions of Quarry Dump Trucks on the Thermal State Large-size Tires

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Abstract - Operability of tires depends substantially on their thermal state. High operational temperature of tires worsens mechanical properties of tire materials and reduces their durability. The country average level of large-size and over large-size tires service life considerably decreases because of the tires which have failed as a result of thermal destructions. In order to decrease the operational temperature and, consequently, increase the service life of tires taking into account their hypersensibility to various service conditions, quality of production and other factors, complex researches of a thermal state have been made. Dependence of tire temperature on the load factor and speed was received. Such studies conducted to date are still insufficient. They have partial, local character and make it impossible to establish the regularities allowing to ensure the required performance of tires.

Keywords – dump truck for quarry; tire resource; temperature condition of tires; load factor.

I. INTRODUCTION

Open pit mining takes the leading place in the mining industry. In this method of production the main type of technical transport is the quarry motor transport. Costs of motor transport make 50-60% of prime cost of the transported mineral weight in which costs of fuel (more than 50%) and tires (25-30%) account for the most part [1][2] [3].

Currently, more efficient use of large-size tires resource is the reserve of decrease in cost of mineral transportation as shown in Figure 1[4].

Underutilisation of large-size tires resource happens for the following reasons:

- natural wear of a protector (81%);

- thermal and fatigue failures which represent stratification of a cord, peeling of a protector and sidewalls (15%);

- the mechanical damages caused by cuts and punctures of tires (3%);

- production defect (1%);

A number of factors influence the tires resource of dump truck for quarry, the basic of which are [5]:

- load factor;

- average operational speed of the movement, i.e. average speed of a dump truck for its time spent on the route. When calculating this speed, all the time of the car spent for getting the work order and the downtime during loading/unloading was considered;

- longitudinal inclination of the road;

- ambient temperature.

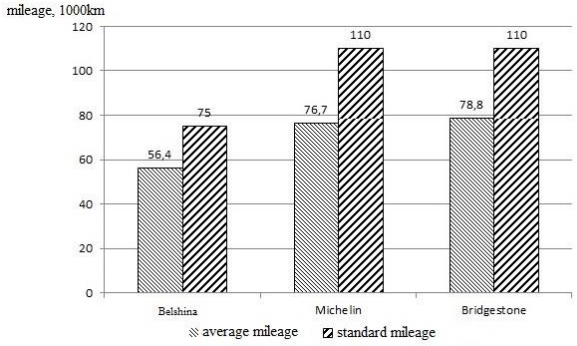

Fig. 1. Large-size tires operation

The above mentioned factors influence the thermal condition of the tire and hence its working capacity and the operation. At temperatures over 110 ^{0}C there is a deterioration in mechanical properties of the tire material that reduces its reliability, reduces wear resistance and durability.

It is impossible to affect all these factors as, for example, change of a longitudinal profile of the road is possible only at the stage of quarry formation, and it is impossible to influence ambient temperature in any way. Therefore, there are only two factors by means of which it is possible to manage tires operation: the average operational speed of a dump truck and its load factor.

The aims and the objectives of the study are as follows: increase of efficiency of quarry dump trucks by means of establishment and practical use of influence regularities of loading

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degree and travelling speed on the thermal condition of tires. For achievement of this purpose the following tasks have to be solved:

- Carry out pilot studies to determine the influence of a thermal condition of tires on productivity of quarry dump trucks;

- Develop models of tires temperature regression from the degree of loading, travelling speed, ambient temperature and the road longitudinal slope.

II. MATERIALS AND METHODS

For determination of rational values of average travelling speed and load factor the researches have been made experimentally in the conditions of branch of JSC "CC "of KQC "Kedrovsky Coal Mine". The object of the study at the same time was tires temperature condition of dump trucks the BelAZ – 75131, – 75136 with a loading capacity of 130 t. Researches were carried out by means of universal system of temperature monitoring which fixed tire temperature during the set time, and then the obtained information was processed on the personal computer.

Change of a temperature condition of tires was fixed by means of special sensors “termokhronDS1921GiButton”. See the sensor in Figure 2.

TermokhronDS1921GiButton is a powerful, independent system which carries out measurements of temperature, also keeps results in the protected memory. Registration of temperature is made with a frequency established by the user in the form of absolute values and in the form of the histogram.

The sensors were installed on the rear right external wheel (Belshina, the model Bel-102, serial number 0509 Bel 1772, the size 33.00R51) and on the right forward wheel (MICHELIN, the model XDTA, serial number VVB074A2A, the size 33.00R51).

Fig. 2. Appearance of "TermokhronDS1921GiButton"

After dismantle of the wheels, the sensors have been fixed in the center of the racetrack and on the tire sidewall. The arrangement of the sensors in the wheel is shown in Figure 3.

For more convenient entering of data into the personal computer, such indications as ambient air temperature, road longitudinal inclination, and load factor were recorded by means of regular sensors of the remote parameter control system.

The experiment was conducted for 4 years, during all seasons of the year with the air temperature from – 43 ^{0}C to + 38 ^{0}C, the longitudinal inclination of the road varying from 0% to 9%. More than 12000 measurements have been taken.

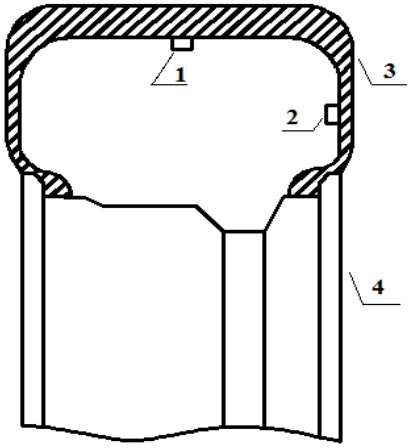

Fig. 3. Arrangement of sensors in a wheel
1 – the sensor located in the center of a racetrack; 2 – the sensor located on a tire sidewall; 3 – tire; 4 – wheel rim.

After the experiment was carried out, the data were processed, and the following equations of regression were received for the front and rear axles of the dump truck:

- Front axle:

$$T_t = 0{,}671 \cdot t_a + 31{,}155 \cdot \gamma_c + 0{,}812 \cdot v_{a.o.s} + 0{,}073 \cdot i + 32{,}976 \quad (1)$$

- Rear axle:

$$T_t = 0{,}743 \cdot t_a + 35{,}135 \cdot \gamma_c + 1{,}547 \cdot v_{a.o.s} + 6{,}541 \cdot i + 27{,}992 \quad (2)$$

where T_t – temperature of tires;

t_a -air temperature;

γ_c – load factor;

$V_{a.o.s}$ – average operational speed;

i – longitudinal inclination of the road.

III. RESULTS

Processing of the experiment data has shown that temperature of tires changing from +24 0C to 105 0C depends on such parameters as the average operational speed of the dump truck movement and load factor. The average operational speed varied from 8 to 18 km/h, and the load factor - from 0.7 to 1.1. Dependence of temperature of the tire (Тш) has the linear dependence presented in Figures 4 and 5.

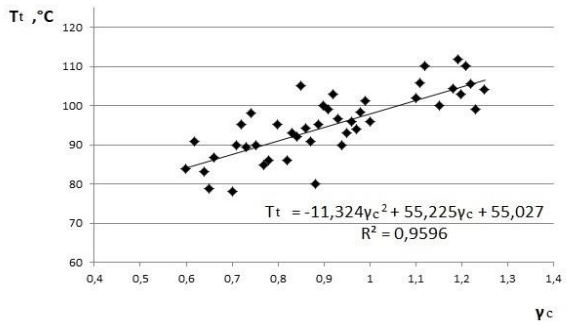

Fig. 4. Dependence of the tire temperature $T_ш$ on load factor $\gamma_{гр}$

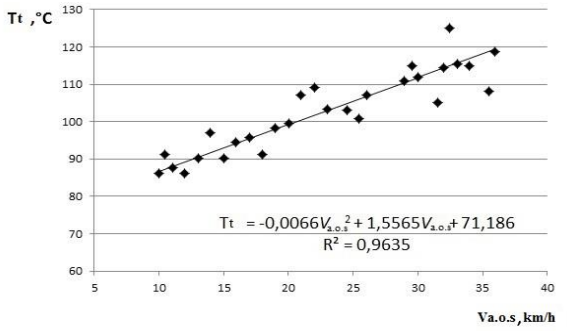

Fig. 5. Dependence of the tire temperature $T_ш$ on the speed of the dump truck movement $V_{сэ}$

IV. Discussion

As a measure of reliability of the equation of correlation dependence, the percentage of a mean square mistake of the equation to the average level of a productive indication ($\bar{y}$=t) is used:

$$\sqrt{\frac{\sum(y-\hat{y}}{n-l}} \div \bar{y} \bullet 100\% < 15\%$$

where y – the actual value of a productive indication;

$\hat{y}$ – value of a productive indication from the regression equation;

n – number of measurements;

l – number of parameters in the regression equation.

If this relation doesn't exceed 15%, then it is necessary to consider that the regression equation rather well displays the studied interrelation.

For both groups of selection the percentage of a mean square mistake of the equation to the average level of a productive indication doesn't exceed 15% that speaks about reliability of the equation of correlation dependence. Therefore, for calculations it is possible to use these formulas which with a big reliability describe tires temperature condition of dump trucks.

TABLE 1. Percentage of a mean square mistake.

Group of selection	Percentage $\frac{s}{\bar{y}} \cdot 100\%$
Front axle	12,4%
Rear axle	14,2%

On the basis of these equations of regression, the computer program "Optimum degree of loading" (The certificate on the state registration of the computer program No. 2016613992) has been developed. By means of this program, it is possible to define optimum loading of a dump truck taking into account the thermal condition of tires in various service conditions.

V. Conclusion

The received dependences allow to define rational load factors that in turn will give the chance to use dump trucks more efficiently, i.e. to lower costs of their operation, to increase tires operation and to reduce cost of mining. It is established that for a dump truck BelAZ - 7531 a decrease in load factor to 0.7 leads to an increase in a life service of tires by 35-40% and a decrease in specific costs of tires by 3,5-4%.

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