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Assessment of technical condition of gearbox-motor-wheels and tires according to heating wear criterion when transporting building materials

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Abstract. The article analyzes the dynamics of tire heating depending on the operating time and the speed of a dump truck, as well as the effect of high temperature values during transportation on tire mileage. The dynamics of heating of hydraulic equipment, gearbox and hydraulic motors at different time intervals and in different working conditions is also analyzed. The task is to determine the dependence of changes in tire tread hardness on changes in tread temperature using experimental studies in laboratory conditions and to determine the direct relation to emerging loads in gearbox on the quality condition of tires. The analysis of the results of the influence of tire temperature on its properties and on early wear of hydraulic unit (gearbox) is carried out.

1. Introduction

Daily in the life of every city, subject, autonomy, the irreversible processes-changes in the environment take place due to the secondary processes of the industrial sector.

The share of pollutant emissions into the air from automobile transport is predominant compared to pollutant emissions from industrial enterprises. In metropolitan and large cities the share of pollutants can reach up to 95% of all emissions. In this way, extremely high air pollution is generated by substances released from the exhaust gases of automobiles.

Environment pollution in the area of heavy automobile traffic also occurs with suspended solids due to operational wear of tire treads, braking mechanisms and road surface.

According to the results of studies conducted by Moscow Ecomonitoring Service, the main pollutant of urban air in Moscow is the following: more than 60% of pollutants and hazardous substances to health are tires of car worn into fine dust [1].

With the increase in the need for constituent components of building materials that are part of the roadbed, foundation and other construction objects, there is the increase in demand and the increase in productivity in highway. It leads to the increase in the productivity of machines, and, consequently, of their dimensions.

Nowadays the main type of transportation of bulk materials is dump trucks. The cost of dump trucks is 50-60% of the cost of transported material, the main part of it is spent on fuel (more than 50%) and large tires (LT) (25-30%) [2].

In the age of modern technology, it is necessary to follow the inherent vector of technical development and environmental safety. It is impossible to separate these concepts.

The wear of tires of highway dump trucks is influenced by many factors, but from the a priori ranking [3] of the factors affecting the tire mileage, the most influential factors are as follows: tire pressure and operating temperature in tire.

The effect of internal tire pressure will not be considered in these experimental studies, and its quantitative assessment can be controlled using a tire pressure monitoring system.

The wear of large tires depending on their thermal state is significant, since the basic materials and adhesives used for the production of tires are sensitive to high temperatures. Often, the generation of temperatures in large tires used in highway dump trucks reaches its maximum value, due to the fact that they have a low cooling rate. It is dictated by the design feature of tires, which have a large thickness. This is especially relevant in summer, when the average mileage of large tires is noticeably reduced due to tires that fail as a result of thermal damage (up to 70% of all destructions) (Figure 1).

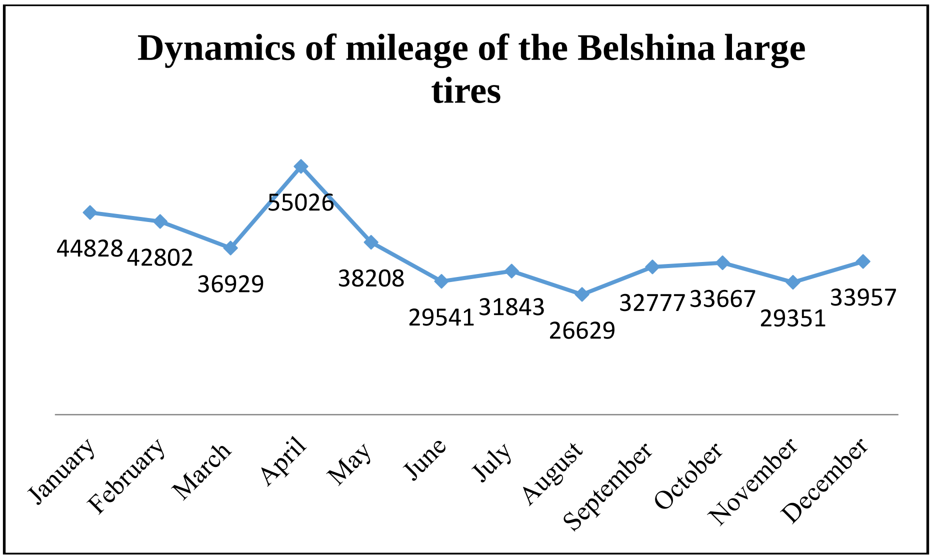

Figure 1. Dynamics of mileage of the Belshina large tires for BelAZ75306 dump trucks for 2014, according to the data of Razrez Berezovsky LLC

As a result of thermal damage, a break in the cord or ignition of generator fire can occur.

For modern tubeless tires, the temperature of 120 ° C is critical. At higher temperatures, tires will collapse due to a decrease in the strength of cord and its bond with rubber, the development of defects such as separation, bloating of tread and ply separation [4].

Table 1. The quantitative assessment of destruction rate of the elements and nodes of dump trucks

Reason	*Saint-Petersburg*		*Moscow*		*Germany*	
	m/h	%	m/h	%	m/h	%
Engine	19265	24,9	1623	12,6	7986	11,3
Electric equipment	10032,4	14,2	0	0	8698	18,1
Operating system	856,1	1,22	356,6	2,7	2489	3,22
Braking system	2165	3,08	523,1	4,07	2389	3,09
Large tires	**15798**	**22,51**	**1165**	**9,08**	**13998**	**18,1**
Welding work	7234	10,3	800	6,24	4111	5,31
Rotator gearbox	**18286**	**26,05**	**5855**	**45,6**	**23100**	**29,86**
Other	7837	11,1	2509	19,5	3300	4,27
Total:	70196	100	12833	100	77352	100

In addition to the wear of large tires, tire temperature has an effect on technical condition of gearbox-motor-wheel (GMW). These two nodes are inextricably linked by the severity of losses due to their interrelation. The technical condition of gearbox directly depends on the state of central heating generator. Uneven tire wear can cause a critical load transmitted to planetary gearbox [11].

By analyzing the quantitative assessment of destruction rate of the elements and nodes of dump trucks (Table 1), it is possible to conclude that almost half of destructions occur in a combination of GMW and LT.

The significant influence of temperature on tire fatigue destruction is confirmed in many studies [3, 5–8]. In most of the studies, it is reasoned by the fact that when a tire is in operation, in the array of which a high temperature is maintained for a long time, there is a sharp decrease in both the strength of rubber itself and its adhesion to a cord. At the same time, in the places of the greatest decrease in adhesion, mechanical friction occurs between a cord and rubber, which additionally causes a sharp increase in temperature and, ultimately, rapid destruction of tire. In this regard, tire fatigue damage caused by high temperature exposure is often called tire heat destruction.

The study [10] (with the speed of the dump truck of V_{av} = 17 km / h and the average temperature of t_{av} = 20) shows the dynamics of heating "cold" tires, depending on the operating time (Figure 2). During the first 10 hours of operation, the tires heat up to the maximum temperature, during loading and unloading of a dump truck, the large tires do not have time to cool down, operation in such conditions leads to thermal destruction of the tire, which significantly affects the economy of mining enterprises.

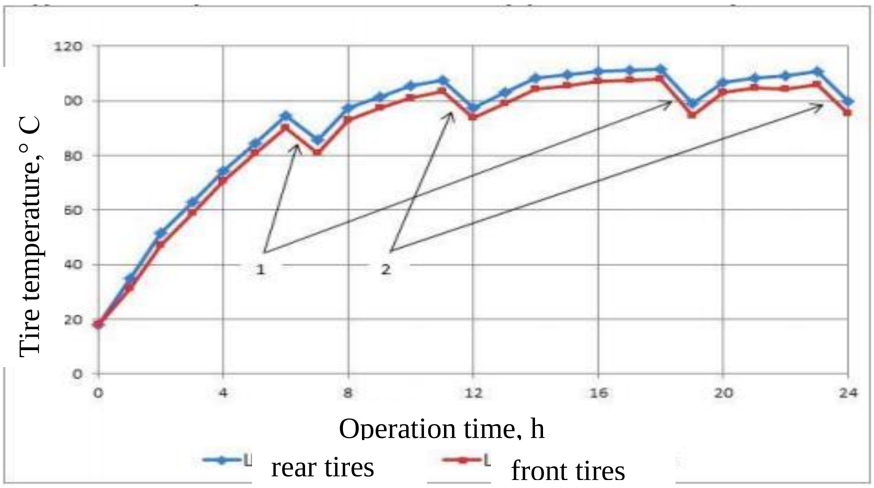

Figure 2. Heating dynamics as a function of operating time: 1 – dinner break; 2 – shift change

2. Results

In order to determine the dependence of the influence of tire temperature on its properties, it was necessary to conduct experimental studies in which the temperature values of heating of the test sample and the hardness index of the tire tread correlated to these values were measured.

Due to the difficulty of obtaining samples of materials of large tires, it was decided to conduct experimental studies on passenger car rubber, and after analyzing the data of the Avtostat analytical agency on tire manufacturers, the 3 most popular brands in Russia were selected: Yokohama, Continental and Kama. Temperature measurements were carried out using a FLUKE VT04A thermal thermovisor (Figure 3a), with each selected sample being heated to a certain temperature using an electric oven (Figure 3b). The hardness of the already heated tread was measured. The hardness of the rubber was determined using a needle hardness tester (Figure 3c), by the value of immersion of a blunt needle in it under the action of a device spring.

a) b) c)

Figure 3: a) – thermovisor; b) – electric oven; c) – hardness tester

In order to reduce the measurement error associated with uneven tread wear of the selected samples for experimental studies, 4 samples were obtained from each tire, and temperature measurements were carried out in eight intervals with hardness measurements for each sample from three manufacturers. The experimentally obtained values are presented in Table 2.

Table 2. Hardness indicators at different temperatures

№	1			2			3			4			5			6			7			8		
	Hardness 20-25°c			Hardness 50-55°c			Hardness 70-75°c			Hardness 85-90°c			Hardness 100-105°c			Hardness 115-120°c			Hardness 125-130°c			Hardness 135-140°c		
	Kama	Yokohama	Continental	Kama	Yokohama	Continental	Kama	Yokohama	Continental	Kama	Yokohama	Continental	Kama	Yokohama	Continental	Kama	Yokohama	Continental	Kama	Yokohama	Continental	Kama	Yokohama	Continental
1	73	67	70	64	65	68	64	64	66	64	63	65	63	63	65	61	63	64	60	63	63	59	62	62
2	73	65	71	64	64	66	64	64	65	63	64	65	63	63	65	62	63	64	61	63	63	57	62	62
3	73	64	71	64	64	65	64	64	65	63	64	64	62	63	64	62	63	62	61	62	62	58	61	61
4	74	66	72	64	65	66	63	64	64	62	64	64	62	63	63	62	63	62	61	63	60	59	62	60

Based on the obtained experimental data, the dependences of the influence of tire temperature on the hardness for each test sample were determined (Figures 4-7).

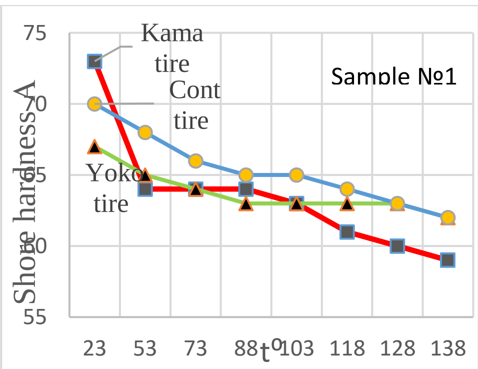

Figure 4 – Dependence of hardness of sample №1 on t°

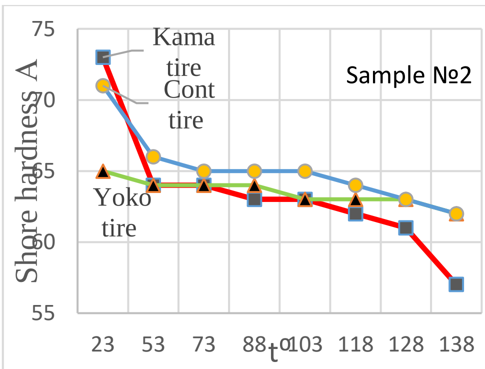

Figure 5 – Dependence of hardness of sample №2 on t°

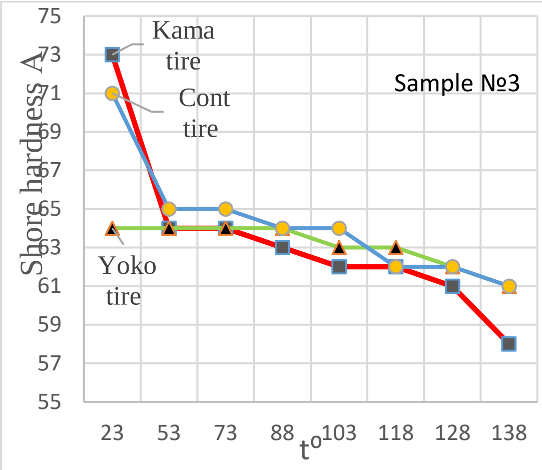

Figure 6 – Dependence of hardness of sample №3 on t°

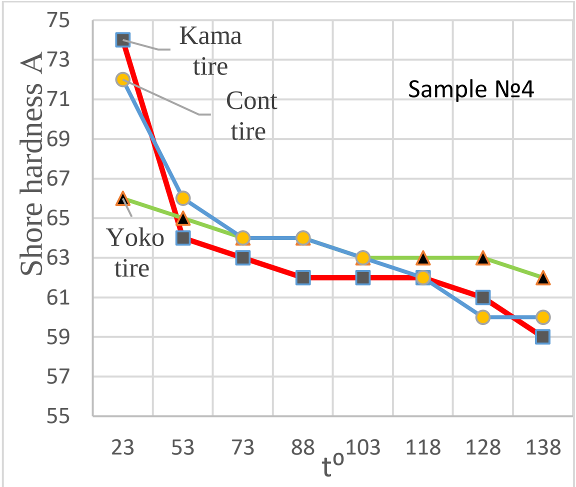

Figure 7 – Dependence of hardness of sample №1 on t°

3. Conclusion

The analysis of the obtained dependences demonstrates the similarity of the general vector of decrease in material hardness with the increase in temperature. It is necessary to note that the samples of two producers have a strongly pronounced vector of hardness reduction in the primary heating range from 20-25 to 50-55 ° C. Less pronounced, but above average, a similar result occurs in the temperature corridor from 125-130 to 135-140 ° C. The confirmation of the effect of temperature on hardness and further analysis of the obtained dependences is necessary in order to study the influence of the factor of tire temperature change on tread properties, and therefore the mileage and operation of tires. The determination of the operating temperature range for large tires, as one of the most influential factors on their mileage, is an actual operation and research task.

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