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Increase Durability of the System "Wheel-Rail"

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Annotation- Severe working conditions of friction units in the machine-building field lead to rapid wear, and, as a result, reduced performance. The main reason for reducing the reliability of machine components and mechanisms is the lack of a systematic supply of lubricant throughout the entire overhaul cycle, as a result of which the unit works most of the time in conditions of a lack or even complete absence of lubricant.

One of the solutions to the above problem is the development and implementation of adaptive mechanics in friction units without a fundamental design change. This approach will increase the reliability and safety of operation of machine components and mechanisms, as well as simplify the industrial implementation of such systems.

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Increase Durability of the System "Wheel-Rail"

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I. Introduction

In railway transport, wheel flange lubricators of various designs are used, which provide the supply of lubricant to the contact area of the side surface of the rail head with the wheel pair flange, which is a resource and energy-saving technology. The application of the above-described method of lubricating the wheel-rail system on rolling stock reduces the following indicators:

– Wear of the crests of the wheel sets by 2-5 times;
– Wear of the side surface of the rail head by 2-6 times;
– Consumption of diesel fuel and electric power of traction rolling stock up to 15%;
– The probability of the descent of railway rolling stock in the curved sections of the track;
– Level of generated noise.

The wear problem in the wheel-rail system is currently being addressed in two ways:

– Application of wheel sets to flanges, using nozzles or solid lubricant pencils, lubricants;
– Applying grease to the side surface of the rail head.

A study of the systems used and their working conditions showed that due to the complex design of the unit (tank, pump, nozzles, hoses), the comb lubricator is highly likely to fail during operation and there is a risk of lubricant getting onto the raceway (Figure 1).

II. Decision

The most promising solution to the problem of improving reliability is the use of adaptive self-organizing systems. The use of these systems will increase one of the main indicators of reliability - durability, which in turn will extend the service life and resource of heavily loaded systems such as wheel-rail [1,2].

The successful solution of the wear problem in the wheel-rail system using adaptive self-organizing systems is confirmed by patented designs [3,4]. For example, (Figure 2), a recess is provided in the flange of the wheel set along its entire perimeter, into which solid lubricant is introduced. During operation, the lubricant will enter the friction zone, covering both the working surface of the flange and the side surface of the rail head and thereby reducing the wear rate [5,6,7].

Let us consider the operation of a wheel using an example of an overhead crane (Figure 3), which implements an adaptive lubricant supply principle, which consists of wheel 1 itself, having blind holes 2 filled with solid lubricant 3, while the diameter of the working surfaces of the wheel is equal to the diameter and depth of the blind holes under the lubricant, respectively.

The depressions formed by the roughness of the working surfaces are filled with lubricant and have a depth R_a. In addition, the working surfaces are separated by a layer of lubricant h, the value of which has a maximum value $h_{\max}$ characteristic of this type of lubricant, the design of the assembly and the operating mode. Thus, we are talking about the best mode of operation of the unit, in which the friction processes will occur in the lubricating layer, which will ensure the minimum value of the coefficient of friction f and the intensity of wear J. According to the principle of operation of the proposed wheel design, it is obvious that the formation of a separation lubricating layer, ceteris paribus, is possible only when the volume of lubricant entering the friction zone is greater than the volume formed by the separation lubricating layer and the volume distributed over the microroughness troughs condition:

$$V_1 = V_2 + V_3 . \tag{1}$$

The volume V_2 will be determined by the height of the separation lubricating layer h and the contact surface area:

$$V_2 = \frac{\pi \cdot D^2}{4} \cdot h . \tag{2}$$

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In determining the volume V_3, we will proceed from the following considerations. The total volume V_R formed by the microroughness of the working surfaces will be greater than the volume V_3 of the depressions by a certain amount $S<1$, i.e.

$$V_3 = S \cdot V_R . \quad (3)$$

Given the height of the roughness of both surfaces $R_a + R_a = 2 \cdot R_a$, the total volume will be equal to:

$$V_R = \frac{\pi \cdot D^2}{4} \cdot 2 \cdot R_a = \frac{1}{2} \cdot \pi \cdot D^2 \cdot R_a . \quad (4)$$

As a result, the volume of the lubricant layer distributed over the troughs of the microroughness will be:

$$V_3 = \frac{1}{2} \cdot \pi \cdot D^2 \cdot R_a \cdot S . \quad (5)$$

The amount of released lubricant V_1 will be determined by the total area A_1 of the holes and the depth of wear U for a given period of time t, determined by a certain value:

$$\frac{dU}{dt} = J . \quad (6)$$

J - where is the wear rate.

The total area of the holes on the contact surface, if n_1 - the total number of holes:

$$A_1 = \frac{\pi \cdot d}{4} \cdot n . \quad (7)$$

As a result, the volume of lubricant delivered to the friction zone will be:

$$V_1 = A_1 \cdot n_1 \cdot U = \frac{\pi \cdot d^2}{4} \cdot n \cdot U . \quad (8)$$

We compose (1) taking into account (2), (5), (8):

$$\frac{\pi \cdot d^2}{4} \cdot n \cdot U \geq \frac{\pi \cdot D^2}{4} \cdot h + \frac{1}{2} \cdot \pi \cdot D^2 \cdot R_a \cdot S \quad (9)$$

If simplify and transform the expression:

$$\frac{d^2}{2} \cdot n \cdot U \geq D^2 \cdot (\frac{1}{2} \cdot h + R_a \cdot S) . \quad (10)$$

As follows from the description of the system's principle of operation, the beginning and end of the release of lubricant is determined by the thickness of the intermediate layer, therefore, for further study of the work cycles, it is necessary to determine its theoretical value depending on other parameters. To do this, we transform expression (10) relatively h, considering the case of equality:

$$h = \frac{d^2}{D^2} \cdot n \cdot U - 2 \cdot R_a \cdot S > 0 \quad (11)$$

In the appendix to the case considered, when $h = h_{\max}$, wear U is U_o equal to some initial value $U = U_o$, then:

$$h_{max} = \frac{d^2}{D^2} \cdot n \cdot U_o - 2 \cdot R_a \cdot S \quad (12)$$

Since at this stage $\omega = 0$, then and $J = 0$.

The second stage (Figure 4). At the beginning of the wheel's movement $\omega \neq 0$, but $h = h_{\max}$, consequently $J = 0$, $f = f_{\min}$, $U = U_o$ and the form of equation (11) will not change accordingly.

The third stage (Figure 5). In the process, part of the lubricant is removed from the friction zone and the thickness of the lubricant layer h is equal to a certain working value $h = h_i$. In this case, contact of the surfaces is possible and, consequently, wear U_i, the intensity of which $J_{\min}$ has a minimum value $J = J_{\min}$, the coefficient of friction f_i characteristic for this mode $f = f_i$, and equation (11) will look like this:

$$h_i = \frac{d^2}{D^2} \cdot n \cdot U_i - 2 \cdot R_a \cdot S . \quad (13)$$

The fourth stage (Figure 6). Let the part of the lubricant layer be removed from the friction zone during operation. In this case h, it will fluctuate between zero and minimum values $0 \leq h \leq h_{\min}$, the wear rate will reach maximum values $J = J_{\max}$, as a result of which the wear will spasmodically reach the maximum value $U = U_{\max}$ and equation (11) will take the form:

Global Journal of Science Frontier Research (A) Volume XX Issue IV Version I Year 2020
2

$$h_{min} = \frac{d^2}{D^2} \cdot n \cdot U_{max} - 2 \cdot R_a \cdot S. \tag{14}$$

The "excess" of lubricant will fall into the friction zone and normal operation will be established. As a result, equation (14) takes the form of equation (12) and the system reaches the level of the first stage.

III. Conclusion

Thus, the lubricant consumption occurs only when there is contact between the flange of the wheel pair and the side surface of the rail head, and the thickness of the intermediate layer is a parameter that determines the supply of lubricant to the friction zone.

This approach was implemented on bridge cranes of the railway industry enterprise, JSC Zheldorremmash. According to the results of operation, the average resource of the wheels of the bridge crane increased by 1.5 ... 2 times [8].

The proposed approach to solving the problem of wear in the wheel-rail system is relevant for any rail systems.

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