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EXPERIMENTAL INVESTIGATIONS SLIPPING IN A FRICTION PAIR OF STEEL MATERIALS

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Abstract
Effects of examinations on agency of slippage on a modification of performances of a friction are presented. It is installed that the slippage extent essentially changes coefficient of resistance to rolling and coming together of axes in pair of a friction without lubricant. At a modification of extent of slippage in a broad band from 0 to

80 % the maximum meaning of coefficient of resistance to rolling (0,85) is observed at extent of slippage of the order of 15 %, and then reduced to two times (0,44), and coming together of axes has the maximum meaning at the maximum slippage and a time on a stage at fixed slippage (200 microns). At a friction with lubricant agency of slippage and a time on stages at fixed slippage on a modification of coefficient of resistance to rolling and coming together of axes is not detected.

Keywords: contact interaction systems, friction, lubricants, machine SI-03, drip method.

1. Introduction

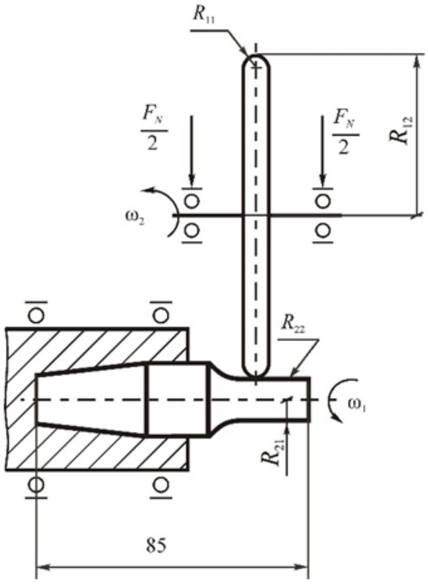
The most critical systems of contact interaction, such as the wheel/rail system, rolling bearings, gears, and some others, operate during rolling with slippage. There are a large number of works [1 – 5], in which, to one degree or another, the issues of the influence of slippage on changes in the resistance of contact fatigue, wear, etc. are discussed. These studies were carried out in relation to various standard sizes and states of the material in friction pairs. However, studies are usually carried out with a limited range of slip change. This is usually a change from 0 to 5%, or sometimes from 0 to 40%.

In this regard, the purpose of this work was to study the effect of slip, which varies in a wide range (from 0 to 80%), on the friction characteristics. This makes it possible to essentially study the processes of friction, starting from pure rolling and ending with practically sliding.

The study of the effect of slip in a friction pair was carried out without lubrication and in the presence of a lubricant.

2. Experimental Technique

Tests to study the regularities of the influence of slippage on the change in the friction characteristics during rolling were carried out according to the scheme shown in Figure 1.



contact geometry	
R_{11}, мм	3; 5
R_{12}, мм	50
R_{21}, мм	5
R_{22}, мм	∞

Figure 1. Test scheme for contact fatigue: friction pair steel 25KhGT/stal25KhGT

During testing, the shaft fixed in the spindle of the testing machine rotates with an angular velocity ω_1. A counter-sample (roller) is pressed against the working area of the shaft by the contact load F_N, which rotates with an angular velocity ω_2. For a correct comparison of the results of studies during tests for contact and contact-mechanical fatigue, the test objects have the same standard sizes. On figure 2 shows the tested model.

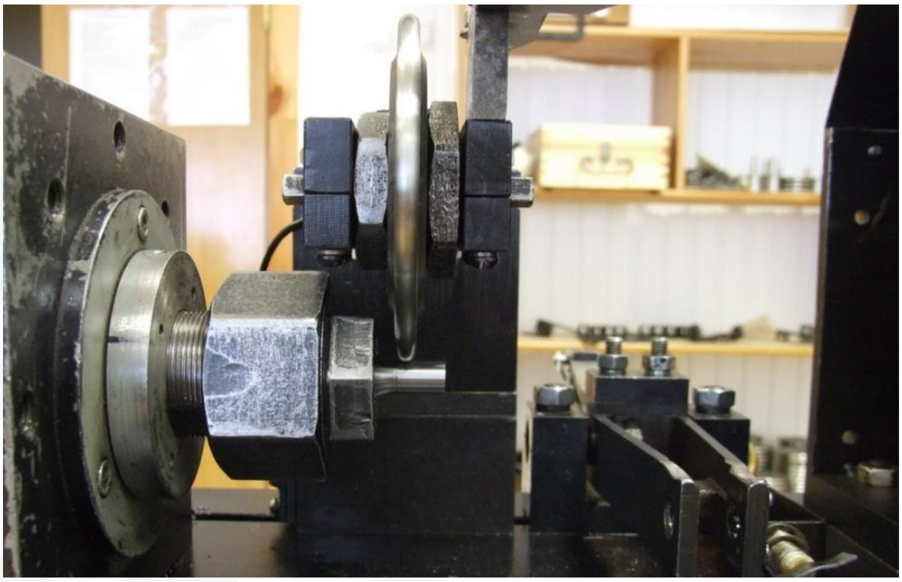


Figure 2. Testing a friction pair steel 25HGT/steel25HGT on the machine SI-03M

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The test objects of the friction pair were made of steel 25KhGT. The main characteristics of this material are given in table 1.

Tab. 1 - Characteristics of the tested materials

Material	Heat treatment	Surface hardness	Bending endurance limit with rotation σ_{-1}, MPa	Tensile yield strength σ_T, MPa	Tensile Strength σ_b, MPa
Steel 25KhGT	Superficial hardening	700 HV	760	900	1700

The tests were carried out on a wear-fatigue testing machine SI-03M at a frequency of 3000 min-1 and normal ambient temperature and humidity in accordance with GOST 15150-69. The parameters of the testing machine met all the requirements of the GOST 30755-2001 standard. The tests were carried out without lubricant and with drip lubrication with TAD-17 I oil.

A precision and high-precision T10F sensor from Hottingen Baldwin Messtechnik was used as a torque meter. The T10F sensor is designed to measure dynamic torques on rotating shafts and does not contain bearings or slip rings. As a result, frictional and thermal effects on the bearings are eliminated. The measurement error of the friction torque is 0.1%. The general scheme of testing and measuring the friction moment is shown in figure 3.

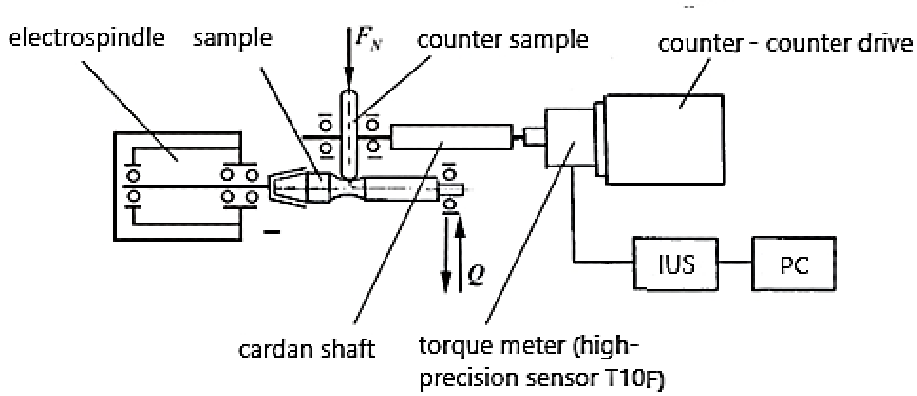

Figure 3. Measuring the friction moment on the testing machine SI-03M

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The rolling resistance coefficient during testing is calculated by the formula:

$$f_r = \frac{M_ò}{F_N \cdot R_{12}}, \quad (1)$$

where $M_ò$ – measured friction moment, N·m;

F_N – contact load, N;

R_{12} = 50 mm = 0.05 m - the radius of the counter-sample (roller).

When testing on the SI-03 machine, full automation of the measurement and registration of the studied parameters is ensured. During the test, the measured values of the test mode are displayed. These are the rotation speeds of the sample and the counter-sample, as well as the calculated value of the slip coefficient (see formula 2).

$$k_S = \left(1 - \frac{\omega_2 \cdot R_{12}}{\omega_1 \cdot R_{21}}\right) \cdot 100\%, \quad (2)$$

where

ω_1, ω_2 – frequency of rotation, respectively, of the sample and counter-sample of the friction pair, rpm;

R_{21}, R_{12} – radii, respectively, of the sample and counter-sample, mm.

The values of the contact and bending loads, the time of testing, the number of loading cycles of the sample, the amount of convergence of the axes of the friction pair and the vibration level are recorded.

The runout of the seat for the sample is checked using the indicator head model 05101, which is installed on the bench frame using the ShM-PN-8 tripod while manually rotating the shaft. The runout of the bore diameter of the spindle shaft should not exceed 0.05 mm.

Determining the error of the system for setting the slip coefficient is carried out by programmatically changing its value and by corresponding measurement of the sample and counter sample rotation frequencies. The error is determined at the points: 0; 25%; fifty%; 75% at a given sample drive speed of 3000 rpm and be no more than 2% of the measured value.

The determination of the error of the system for measuring the moment of friction is carried out using exemplary weights of the 4th category GOST 1328-82.

In the work, the test method for multi-stage loading was applied, in accordance with STB 1233-2000.

Test Results and Discussion

Tests to study the effect of slip on the change in friction characteristics were carried out at a constant contact load (Figure 4). F_N = 124 N (contact stress p_0 = 2800 MPa). During the experiment, an automatic stepwise (14 steps) change in the value of the slip coefficient of 0 experiments was carried out: a) the time on the step with constant slip was 1 min; b) 5 min; c) 10 min (Figure 4). These tests were carried out without lubricant and using TAD-17 I oil lubrication, which was supplied to the contact zone by a drop method.

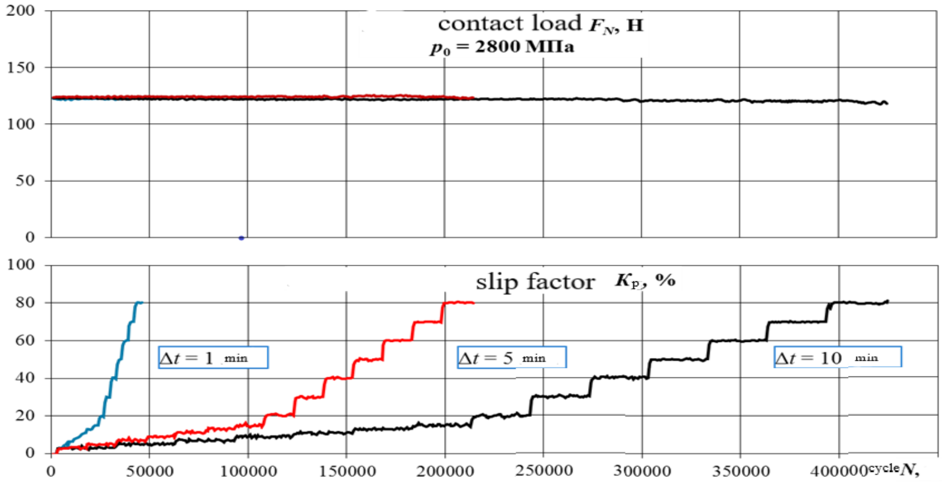

Figure 4. Test report on the study of the effect of slippage on friction characteristics

During the tests, the magnitude of the torque, the convergence of the axes and the overall vibration in the system, depending on the number of cycles, was measured. On fig. Figures 5 and 6 show the test reports for friction, respectively, without lubrication and with lubricant.

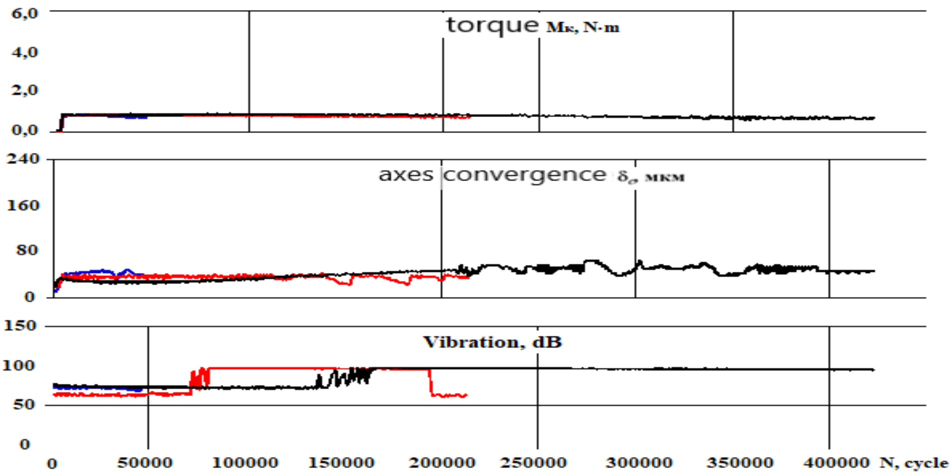

Figure 5. Protocol for measuring torque, axle alignment and vibration (friction without lubrication)

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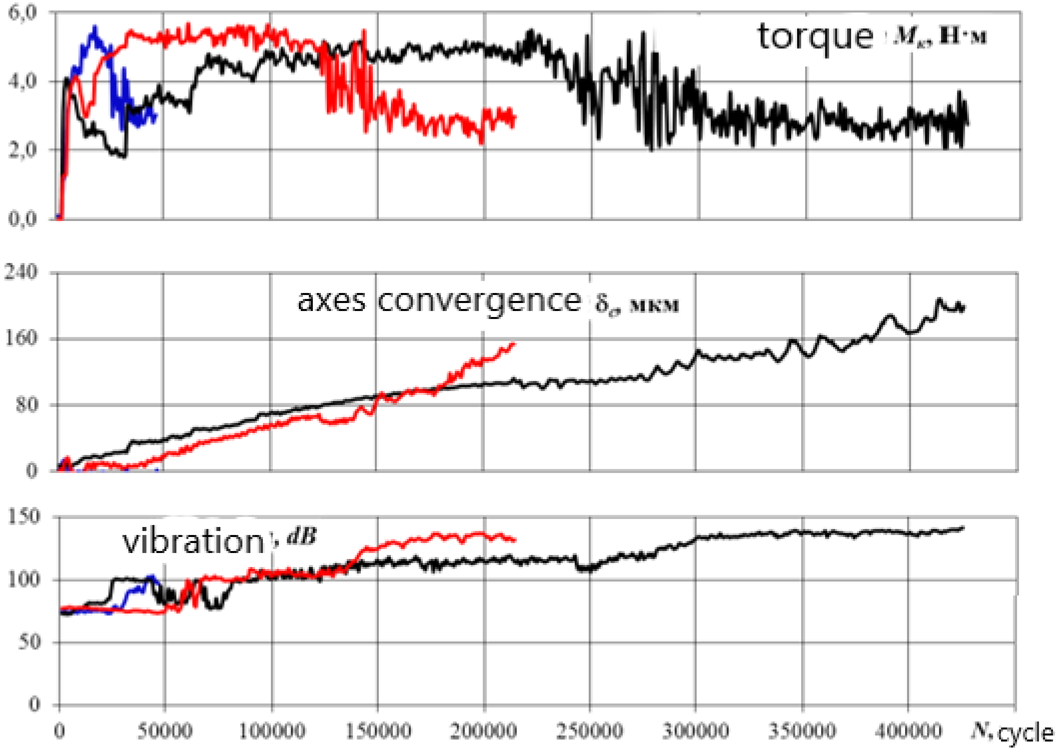

Figure 6. Protocol for measuring torque, axle alignment and vibration (friction with lubrication)

Analysis of the data shows that during friction without lubrication, the torque depends on the number of cycles as follows: first it increases, and then it decreases. The maximum value of the torque (~5.6 N·m) is observed, as a rule, at the seventh step of the slip change (15%) (with an average value of the number of cycles). In this case, the maximum value of the friction torque and the magnitude of its further decrease do not depend on the time on the stage at constant slip. At the same time, under these conditions, with an increase in the number of cycles, there is a constant increase in the convergence of the axes and vibration. Another feature is already observed here: the longer the time per step with constant slip, the greater the values of these quantities. So, Δt=1 min. the convergence of the axes increases from 0 to 20 µm, Δt=5 min. the convergence of the axes increases from 0 to 160 µm, and Δt=10 min. – from 0 to 200 microns.

Data analysis in figure 6 shows that in lubricated friction, the torque does not depend on the number of cycles and time per stage at constant slip - its value always remains almost constant and equal to 0.9 N·m. Comparison fig. 5 and 6 also shows that the pattern of changes in the convergence of the axes and vibration during friction with lubrication is lost. In this case, regardless of the number of cycles and time per step, with constant slippage, the convergence of the axes is at the level of 20-60 microns, and the vibration in the system increases to only 100 dB.

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In order to study the effect of slip on friction processes, we plotted the dependences of the average values of the rolling resistance coefficient (1), the convergence of the axles and vibration on the slip coefficient on the stage (see Fig. 7 and 8).

Depending on the time on the step at constant slip (1, 5 or 10 min.), averaging was carried out over 6-60 points.

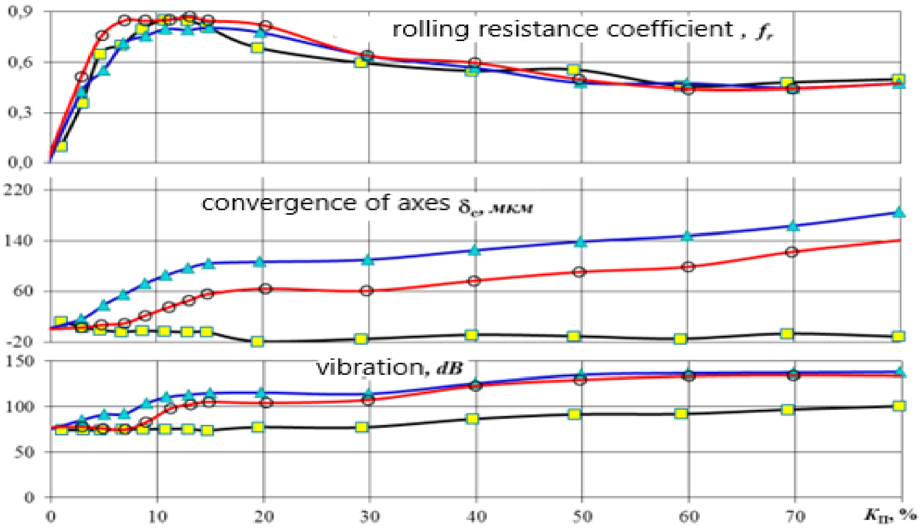

Figure 7. Dependence of rolling resistance coefficient, vibration and convergence of axes from the degree of slippage (friction without lubrication)

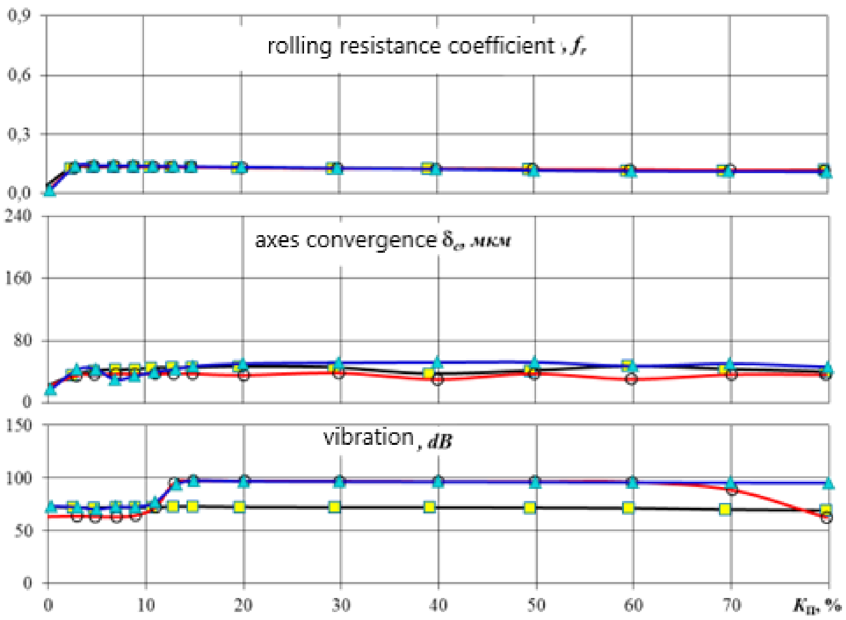

Figure 8. Dependence of rolling resistance coefficient, vibration and convergence of axes from the degree of slippage (friction with lubrication)

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It can be seen that during friction without lubricant, with an increase in the slip coefficient, the coefficient of rolling resistance first increases from 0 to 0.8-0.85, and then its value decreases to 0.44-0.48. At the same time, its maximum value is observed at a slip coefficient of the order of 10-15%, and the minimum value falls on the value of the slip coefficient equal to 60-70%. In this case, the effect of the step duration at constant slip on the value of the rolling resistance coefficient has practically no effect - in all cases, the pattern described above is observed, with the only difference that Δt=1 min. the maximum value of the rolling resistance coefficient is 0.8, and Δt=5 and 10 minutes, this value is 0.85.

The change in the convergence of the axes and the general vibration depending on the slip coefficient during friction without lubrication is of the same nature and has the same patterns as on the number of cycles (see above).

In lubricated friction, the main characteristics of friction do not depend on the slip coefficient. Only a few features can be noted: with an increase in the slip coefficient, the rolling resistance coefficient first increases to a value of ~ 0.14 (at ks =7%), and then decreases to a value of ~ 0.11 (at ks =80%).

Conclusion

The paper developed a test procedure for the effect of slippage on the change in friction characteristics and presented the results obtained by this method for a friction pair steel 25KhGT/steel 25KhGT. It has been established that the degree of slip significantly changes the coefficient of rolling resistance in a friction pair without lubricant. When changing the degree of slip in a wide range from 0 to 80%, the maximum value of the rolling resistance coefficient (0.85) is observed at a slip degree of about 15%, and then decreases to two times (0.44). When friction with a lubricant, the effect of slippage on the change in the coefficient of rolling resistance is not detected. Also, the rolling resistance coefficient is not affected by the step time at constant slip.

The pattern of change in the convergence of the axes of a friction pair during friction without lubrication due to the influence of slip is as follows: the greater the slip, the greater the convergence of the axes. In this case, the change in the convergence of the axes is the greater, the longer the time on the stage with constant slip. So, Δt=1 min. the convergence of the axes increases from 0 to 20 μm, Δt=5 min. - from 0 to 160 microns, and Δt=10 min. – from 0 to 200 microns.

The influence of slippage and time on the steps at constant slippage on the approach of the axes during friction with lubrication under the conditions of the experiment was not found.

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