# DECREAZE OF ROLLING RESISTANCE OF A RAILWAY WHEEL BY PERFECTION OF TRIBOLOGICAL PROPERTIES OF WHEEL AND RAIL CONTACT ZONE

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**Abstract**
*Improvement of tribological properties of the wheels and rails interacting surfaces, decrease of rolling resistance of a railway wheels, the train energy consumption, and wear rate is reached by their separation with the third body having due tribological properties. The ecological friction modifiers for tread and steering surfaces are developed. Presence of the third body in the contact zone is determined experimentally by the change of the friction moment and noise. The reasons of the negative, neutral and positive friction, mild, severe and catastrophic wear and types of damage of corresponding surfaces at various relative sliding velocities are revealed.*

**Keywords:** *rolling resistance, third body, tribological properties, wheel, rail.*

## 1. INTRODUCTION

Usually, the surfaces are covered with various types of natural and artificial coatings, which represent the components of the third body in the contact zone of the interacting surfaces and are subjected to heavy power and thermal loads. This causes deformations of these coatings, their destruction, activation of the physical and chemical processes proceeding between the coatings and surfaces, generation of new coatings. According to observations by Godet [1], dry friction is largely determined not by the properties of friction materials of the contacting pair, but by the characteristics of the structure and composition of the thin film that is formed on the surfaces of both bodies. During the interaction of surfaces, the processes of the third body destruction and restoration takes place in the contact zone continuously. When the intensity of destruction of the third body is greater than the intensity of their restoration, the amount of the micro-asperities coming into direct interaction that leads to the seizure, wear rate and types of surfaces damage increase. The power dissipated in the wheel–rail contact accounts for 13.5% [2]. Despite the important role the multidisciplinary approach plays in the reveal of parameters of the third body, there is no comprehensive model of the boundary friction that considers them.[3-6]. It is found in the works [7-9]that the properties of the tribo-film layers also depend on the working conditions and can be in some extent adapted to working conditions.

The adhesive approach to the friction means invasion of micro-asperities into each other in the contact zone, their close contact without the third body, and seizure of micro-asperities.

The thermal effects accompanying the displacement of the seized places relative to each other causes sharp increase of the shear stresses and corresponding deformations, value and instability of the friction forces and rupture of the coupled places.

The experimental researches have shown that at low total and relative sliding velocities of the surfaces, stability of the third body and its resistance to scuffing, are high and a main type of damage is fatigue wear [13, 14]. With increase of the total and relative sliding velocities of surfaces, thermal load of the actual contact zone, destruction intensity of the third body and rolling resistance of wheels increase. Variation of tribological properties of the surfaces is a result of various mechanical, physical and chemical processes proceeding simultaneously in the contact zone whose essence and mechanism of action are not properly studied [11–14].

For revealing the factors influencing tribological properties of the interacting surfaces, the experimental researches were carried out on the twin-disk machine.

## 1.THE EXPERIMENTAL RESEACHES INTO VARIATION OF TRIBOLOGICAL PROPERTIES OF THE INTERACTING SURFACES

For some heavy loaded interacting surfaces of machines are typical unpredictable change of tribological properties and sharp increase of the friction coefficient and wear intensity, so called catastrophic wear. As a main cause of the latter is considered the heaviest form of the adhesive wear – scuffing [14,15] that is not properly studied yet and whose signs are appearance of pits and scratches on the surfaces and transfer of the material from one surface on the other.

For more detailed study of the properties and state of the third body in the contact zone we performed the experimental researches on the twin disk machine MT-1 (Fig. 1) with the use of existing lubricants and ecologically friendly friction modifiers, developed by us.

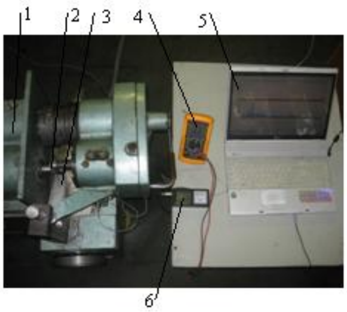



Fig. 1. The twin disk machine MT1 and measuring means:
1 - twin disk machine; 2 - tribo-elements; 3 - the wear products; 4 - tester;
5 - personal computer; 6 – vibrometer

The experimental researches were performed at rolling of discs with up to 20% of sliding. The rollers had diameters of 40 mm and widths of 10 and 12 mm. The tests were performed at single application of the friction modifier on the rolling surfaces of the rollers. After certain number of revolutions, a thin layer of the friction modifier was destroyed that was revealed by appearance the initial impulses of friction moment and initial signs of scuffing on the surfaces. The rollers with various degree of damage are shown in Fig. 2: a) with initial signs of damage; b) damage in the form of a narrow strip; c) damage on the whole contacting area.

a b c

Fig. 2. The stages of damage of the interacting surfaces:
a) damage in the separate points; b) damage in the form of the narrow strip;
c) damage on the whole area of the contacting surfaces

The graphs of dependences of the friction coefficient and number of revolutions of rollers until appearance of the first signs of scuffing on the contact stress for initial linear contact of disks are shown in Fig. 3. It is seen from these graphs that for the initial linear contact, when the contact stress is in the range of 0.65 - 0.77 GPa, increase of the contact stress leads to decrease of the friction coefficient. It can also be seen that increase of the contact stress leads to decrease of number of revolutions untill destruction of the third body and onset of scuffing.

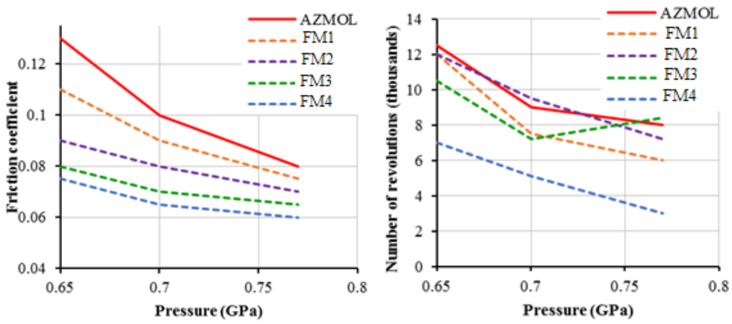



Fig. 3. Dependences of friction coefficients and numbers of revolutions until appearance of the first signs of scuffing on the contact stress for initial linear contact of disks and different anti-frictional friction modifiers

It was revealed experimentally that to negative friction corresponds the continuous or discontinuous but restorable third body; to neutral friction – multiple seizures of the interacting surfaces and to positive friction – increasing scuffing process that is spread on the whole surface. In Fig. 4 is shown variation of the tractive (friction) force with creep [16].

As it was shown by our experimental researches, at presence of the continuous third body increase of the relative sliding velocity leads to increase of the friction power and contact temperature; decrease of the lubricant viscosity, film thickness and friction force (Fig. 4, “negative friction”), stable (or smoothly variable) friction torque and low destruction rate of the surfaces. Worsening of the working conditions caused by the partial, non-progressive damage of the third body in the separate unit places corresponds to the separate small impulses of the friction moment. Destruction of the third body in the multiple places leads to the multiple damage of the third body, multiple adhesive junctions of micro-asperities, disruption of these junctions, and a bit little increased impulse of the friction torque and "neutral friction."

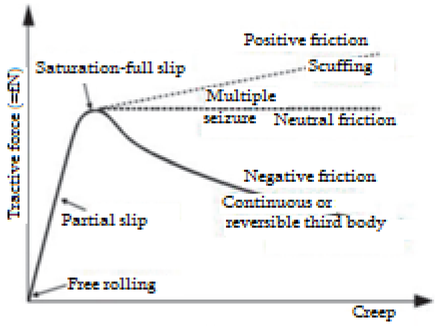
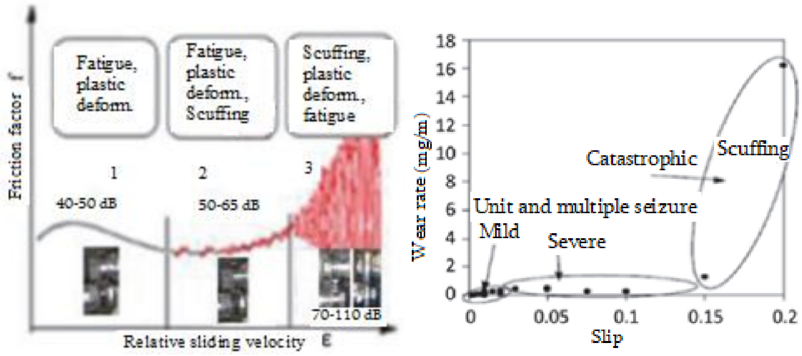



Fig. 4. Friction/creep relationship

At progressive damage of the third body, the friction torque increases and corresponds to positive friction. Our experimental researches have shown that in other equal conditions the variation of the friction coefficient mainly depends on degree of destruction of the third body. Therefore, preservation of the third body between interacting surfaces and avoidance the scuffing, has a crucial importance for decrease of the friction coefficient, wear rate, etc.

In Fig. 5 are shown dependences of the friction factor and various damage types onrelative sliding velocity (a) and of the wear rate (types) on slip (b) [13].




a b

Fig. 5. Dependences of the friction factor and various damage types on relative sliding velocity (a) and of the wear rate (types) on slip (b)

Three zones can be distinguished in Fig. 6a. The low relative sliding velocity, full separation of the interacting surfaces and continuous third body provide high wear resistance of the interacting surfaces and relatively stable friction coefficient (zone 1, Figure 6a) that corresponds to "mild" wear rate (Fig. 6b). In such conditions, the main damage types are the fatigue and plastic deformations.

Small increase of the sliding velocity leads to appearance of small damage sources in multiple places and emergence of small surges of the friction torque (zone two, Fig. 5a). The rise of the third body destruction, as well as the magnitude of the friction coefficient and its instability, are clearly reflected in the oscillogram of the friction torque and may be predicted on the base of results of the experimental researches. The typical damage types of this zone are fatigue, plastic deformation, adhesive wear and limited rate of scuffing and correspond to "severe" wear rate (Fig. 6b).

At further increase of the relative sliding velocity, destruction of the third body becomes irreversible and extending and multiple seizures become uninterrupted (causing scuffing) and they propagate on the whole width of the interacting surfaces. The typical damage types of this zone are scuffing, plastic deformation and fatigue (zone 3, Fig. 6,a, and "catastrophic" wear rate Fig. 6,b). In this case, the scuffing can be avalanche in nature that quickly disables the machine.

## 5. Conclusions

• Tribological properties of the interacting surfaces mainly depend on tribological properties of the third body, degree of its destruction, disposition of the surfaces to seizure etc. The researches have shown that the continuous or discontinuous but restorable third body at the initial stage of destruction and progressively destructing third body have quite different properties. In the first case the said properties are stable and depend on the properties of the third body and in the second case, these properties are instable and worsened that are characterized by increasing friction coefficient, catastrophic wear and typical noise.

• Prediction of destruction of the third body is possible in the laboratory conditions by estimation of the friction torque variation.

• The friction coefficient (negative, neutral and positive), wear rate of the interacting surfaces (mild, severe and catastrophic), damage types (scuffing, fatigue, plastic deformation, adhesive wear) and vibrations and noise generated in the contact zone depend on tribological properties of the third body, its degree of destruction and area of the factual contact zone of the seized places;

• For improvement of tribological properties of the interacting surfaces, it is necessary to provide the contact zone with continuous or restorable third body having due tribological properties at the initial stage of destruction.

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