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Analysis of Factors Influencing the Friction Coefficient Between Wheels and Rails of Main Train Locomotives

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Abstract. *This article presents an analysis of the factors that influence the friction coefficient between the wheel pair and the rail, which are crucial components of the wheel motor unit of main locomotives. The research results indicate that the coupling coefficient between the rail and the wheel pair is influenced by factors such as the tire diameter of the wheel pair, the radius of the rail head, the materials of the tires and rails, the contact surfaces, the wear of the road components, the road surface wear, curved sections of the track, vertical load on the rails from the wheels, vibrations on the traction track during locomotive movement, differences in traction force conditions among moving axles, and weather conditions including air humidity, temperature, chemical composition of contaminants on contact surfaces, among others.*

Keywords: *wheel pair, rail, sliding, speed, coupling coefficient, main locomotive.*

Introduction. This article emphasizes the significance of the wheel-rail friction coefficient in facilitating the efficient movement of rolling stock. It delves into the factors influencing the wheel-rail interaction, starting with the rail. The presence of contact spots formed due to vertical force on the wheel and rail surfaces is identified. It is observed that these contact spots and fibers shift under the influence of torque. The intermolecular forces of attraction within the fibers impede this movement, leading to tensile stresses. These stresses collectively generate the contact force and opposing forces exerted on the wheel contact patch.

Addressing the challenges faced by the railways of the Republic of Uzbekistan involves the successful development of transportation infrastructure, comprehensive modernization of railway systems, reconstruction of tracks, electrification of key railway segments, and the upgrade of rolling stock with advanced locomotives, freight, and passenger cars.

The issue of torsional vibrations in the traction transmission of mainline locomotives is closely connected to the wheel-rail interaction. Efforts have been consistently made to enhance the traction force within the wheel-rail connection.

The research team at the Department of Materials Science and Mechanical Engineering at Tashkent State Transport University is actively studying and analyzing torsional forces and structural parameters of moving components in relation to the aforementioned critical issues.

Materials and factors affecting wheel-rail coupling coefficient. Coefficient of adhesion, which is one of the factors affecting the force of contact of the wheel with the rail, depends on many factors, including locomotive construction, track construction, weather conditions, and contamination characteristics of the contact surfaces. can be divided into related groups. In this case, the factors that directly affect the possibility of reaching the maximum torque of the locomotive are the following:

- geometric dimensions - the tire diameter of the wheel pairs and the rounding radius of the rail head;
- material of bandages and rails;
- the amount of wear of the contacting surfaces, as well as the remaining nodes of the walking part;
- erosion of the upper part of the road, as well as curved sections of the road;
- vertical load from the wheel pair to the rails;
- vibrations on the track during the movement of the locomotive;
- the difference in the conditions under which the traction force is realized by some of its moving axes;
- weather conditions - air humidity and temperature, chemical composition of contamination on contact surfaces, etc.

Two contact surfaces or contact spots are formed where the wheel rests on the rail. As can be seen from Figure 1, the contact spot of the wheel is convex, and the spot of the rail is concave.

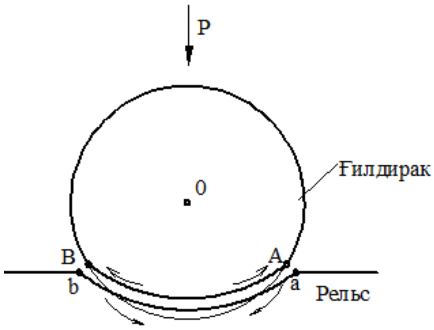


Figure -1. Movement directions of the contact patch and fibers under the influence of the vertical force load of the wheel.

The arrows indicate the fiber movement directions at the contact points between the wheel and rail, influenced by the vertical force R exerted by the wheel's load. The appearance of the contact points' lines is intricate, varying with the shape of the wheel and rail surfaces, which alter based on corrosion levels. Thus, in the theoretical analysis of wheel rolling phenomena on rails, the contact patch can be simplified as a flat strip with a width denoted by h, with the load transmitted from the wheel pair to the rails equating to $P_0 = 18 \div 23m$, $h = 26мм$ [3].

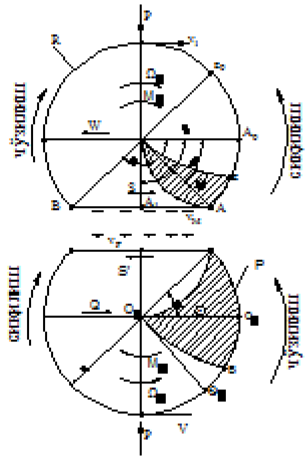
In the flat diagram depicted in Figure 2, the contact points are represented as straight line sections:

AB for the wheel and $ав$ for the rail. When visualizing the contact patch as a strip with a perfectly smooth surface, the vertical load P induces normal relative loads with an elliptical semi-cylindrical shape on the spot. However, in reality, the contacting surfaces are not entirely flat or smooth, with the actual contact area being only a small fraction (about 10%) of the contoured contact spot surface. Consequently, the resulting normal pressures lead to elastic-plastic deformations with a relatively complex stress distribution, and intermolecular forces of attraction come into play between the actual contact elements.

Under the influence of the torque $M_к$ applied to the wheel pair, the contact spots move relative to each other. In this case, the forces of intermolecular attraction resist the displacement, resulting in tensile stresses.

These stresses, combined, form the contact force S on the wheel contact patch and an equal and opposite force.

According to its physical essence, the adhesion force is one of the manifestations of the dry friction force, which appears during the rolling of the wheel along the rail. Recently, local scientists [1-3], as well as foreign studies [4] make it possible to understand the physical essence of the processes that occur during dry friction, as well as to explain the laws of changes in the force of the wheel's contact with the rail.



Picture-2. A physical model showing the initial angular displacement of the fixed wheel relative to the rail due to torque

It's understood that there exists a distinction between inertial friction and sliding friction. Sliding friction typically denotes its maximum value, beyond which objects in contact slide. At lower values, it's termed as the pseudo-friction force of the static state. In a stationary state, incomplete frictional force leads to initial displacement of the contacting bodies. Holding other conditions constant, the magnitude of this displacement increases with static friction force.

The coefficient of friction at rest increases approximately exponentially with the contact duration, as the actual contact area enlarges due to belt and plastic deformations. Modern friction theory suggests that when bodies slide, molecular self-oscillations occur in their contact, alternating between stationary and moving states. The static friction force in stationary contact is much greater than in moving contact. Sliding friction force is approximated as its average value during self-oscillations, so longer stationary contact results in greater sliding friction force.

With increased mutual movement speed, fixed contact duration decreases and contact temperature rises, leading to surface erosion and changes in real contact surface. Wheel sliding along a rail can be complete or uneven, with sliding and rolling occurring simultaneously. Imperfect sliding involves adhesion forces akin to incomplete static friction forces, resulting in continuous appearance and disappearance of frictional forces.

In complete sliding, all contact fibers are affected, and studying especially incorrect sliding is crucial.

Lawrence's theory is relevant in explaining this process, where the rolling region length equals one fiber width, represented by a point in a flat scheme. The coefficient of friction remains constant across the contact patch, ranging from 0 to the static friction coefficient, determined by external torque and relative normal load.

$$\tau = \mu \cdot q$$

Thus, according to this theory, the flat contour of the comparative effort load remains elliptical in all modes [5].

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