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WEAR OF TYRE AND RAILS IN CURVES AND METHODS OF ITS REDUCTION

Development of railway transport provides for a further increase of train speed, carrying and crossing capacity of railways. That is why transport mechanics faces vital tasks in the field of train operation, interoperation of a rolling stock and a track, strength of components and nodes of a rolling stock, proper use of railway equipment turned out to operate in extreme conditions.

Keywords: *wear of tires, interoperation of wheel and rail, movement in curves.*

Sliding of a wheel flange relating to the inside surface of a rail head under the influence of a directing force F_d makes a nucleus of surface friction, which is inevitably followed by a wear of contacting surfaces. A wear rate ("worn sharp") of a wheel flange depends on the energy spent for the friction force in contact.

For different types of wagons energy of friction of a wheel flange on the rail is defined by the value which is called a flange wear factor:

$$\Phi = \frac{X}{R} \cdot У_{н} \cdot \mu_{TP}, \qquad (1)$$

where X is a polar distance;

R is a curve radius;

F_d is a directing force;

M_{FR} is a factor of friction in the contact point of a wheel flange and a rail;

$\frac{X}{R} = \alpha$ – striking angle,

And as a directing force in a curve depends on a striking angle of the set of wheels, i.e. $У_{н} \cong \alpha$, we can consider a friction factor to be approximately proportional to the square of a striking angle α. This angle has the most value under the movement in a curve, and therefore, a flange worn sharp is generally defined by this movement mode and greatly depends on a curving.

Wear factor is a relative index, it reflects only dominant physical phenomena, occurring when a wheel flange is sliding on a rail side edge. This index is good to compare wagons under the estimation of wear rates of wheels and rails in case they move in curves of different radiuses.

Wear of flanges of set of wheels and rails has a great impact on the safety of movement in a curve, as the contours of the wheel and rail are changed. Moreover, a strong friction of a wheel flange on a rail side edge increases a train rolling resistance.

A wear factor could be reduced if it was possible to reduce a friction factor μ_{FR} in the contact point of a wheel flange and a rail.

To reduce a friction factor it is necessary to introduce lubricants into a contact area. There are various lubricating devices, (lubricators), distinguished by a position of installation (track or rolling stock) and by the object a lubricant is applied to (rail or flange).

In native conditions, when driving of a train in curves often comes with large amounts of sand (to increase adherence), the efficiency of this effective method of wheel and rail protection is reduced due to adhesion of sand pieces to a lubricated rail surface. The works acre carried out to create lubricants which after being applied shall make a coating, unable to hold sand pieces. There are also other problems.

A bogie, when curving in, can hold two extreme positions: maximum slope and chord placement (setting of high speeds, as well as intermediate position called a loose placement.

A pole distance for a maximum slope is defined by the following formula:

$$X = \frac{l}{2} + \frac{R \cdot \delta}{l},$$

where δ is a total backlash between a flange and a rail in curves;

l is a bogie wheelbase;

R is a curve radius.

At a dynamic negotiation there is a determination of directing forces, side forces and и frame forces, as well as displacement of rails depending on the speeds in the curves radiuses.

A side force, overturning a rail is defined by the following formula:

$$У'_{иi} = У_i \pm H,$$

where F'_i is a side pressure of the *i*-th axis wheel;

F_{di} is a directing force of the *i*-th axis;

H_i is a transverse component of the force of wheel friction on the *i*-th axis wheel.

For the axis which is in front of a turning center, H_i is taken with a minus, and for the axle, which is behind a turning center – with a plus.

Frame forces shall be found by the values of directing forces with consideration of a centrifugal force of a wheel set:

$$У_{pi} = У_{иi} \mp 2H_i - C_{КП},$$

where S_{SW} is a centrifugal force of a wheel set.

Displacement of rails from the guide wheels is defined by the formula of professor K.P. Korolev:

$$\bar{У} = K_Г (\alpha_к \cdot У' + \frac{У' - f \cdot P_Н}{\beta_к}),$$

where $C_Н$ is a coefficient of horizontal dynamics, depending on the speed, for the front guide of a bogie's axis and lack of cross deflection in the system of wheel set – bogie frame $C_Н = 1 + 0{,}006 \cdot V$, and in case of cross deflection $C_Н = 1 + 0{,}002 \cdot V$;

f is a factor of friction of a wheel on a rail;

$\alpha_c \cdot У'$ is a value of the a rail displacement due to a restraint of a sleeper by a covering plate;

$\frac{У' - f \cdot P_Н}{\beta_к}$ is value of the a rail displacement due to its deflection;

F' is a side force of a wheel to a rail, H;

V is a rolling speed, km/h;

α_c and β_c are the coefficients depending on the form of track bed structure, they are shown in

Table 1

Type of rail	Amount of sleepers per 1 km of track	Type of ballast	$\alpha_к \cdot 10^{-4}$	$\beta_к \cdot 10^3$
R 75	1800	gravel	0,07	17,0
R 65	1800	- " -	0,08	15,0
R 50	1800	- " -	0,10	12,0
R 43	1500	Sand or gravel	0,24	10,5
R 38	1500	- " -	0,28	10,0

Movement in a curve is considered to be acceptable under the following rail displacements (see Table 2).

Table 2

Type of rails	R 75	R 65	R 50	R 43	R 38
Displacement, $\bar{У}$, mm (not more than)	5,0	6,0	6,5	7,5	8,0

Safety of movement in curves by the term of track pointing is estimated by a displacement of a high rail.

The most impact to a track is usually made by striking wheel sets of a wagon.

To reduce another widespread type of wear – roll of a wheel rolling – it is necessary to match the contours of its crossing profile guided by the following: a new standard profile with a constant taper angles 1:20 when striking to a rail, makes contact with it in two points: one of them is on the rolling surface, the other one is on the side edge of the rail.

In the place of contact of the side edge of the rail with a wheel flange there is a more heavy wear of a flange, than of rolling surface of the wheel due to high resultant sliding velocities and substantial pressures.

After a small run (10-20 thousand km) a character of contact of a wheel with a rail could change: it shall become single-point instead of two-point contact, and effect of directing force F_d is reduced and as the result s flange wear as well.

During a contacting of worn wheels and a rail there is a fir of profiles over a larger surface, and the intensity of wear is reduced.

Forms of wear of wheels and rails considerably depend on initial profiles and on strength of the materials of the pair in contact.

On this basis professor G. Heymann offered to change initial form of the profile of a taping line, shaping it with contours close to the worn ones.

Under the movement in curved track sections a wheel flange strikes a high rail. Directing forces of the striking wheel are applied between a flange and a rail head.

At large force values a wheel could rise over a rail head and contact with it only in one point, and a flange could roll onto a rolling surface of a rail. Apparently, it shall be followed by a running of a wheel set off the rails, and probably, by a train accident.

During a rolling a wheel passes a certain distance which is called a rolling path. Rolling onto a rail head can be done only by striking wheels in a curve – these are high wheels which roll over a high rail.

Main active factor that causes a crawling of a wheel flange on a rail head, is a side force in the point of strike. This force depends on characteristics of a strike and the effects occurring in the point of contact of a flange with a rail head.

One of such characteristics is an angle of striking of the flange, which depends not only on track geometrics, but also on running gears of a rolling stock, as well as on tough release of e rail head in the striking point.

To prevent from the crawling of a wheel flange on a rail head, the congruence $\frac{Y'}{P_H}$ must comply with inequation:

$$\frac{Y'}{P_H} \le \frac{tg\gamma - f}{f \cdot tg\gamma - 1},$$

where f is a factor of a wheel friction on a rail;

γ is an angle of slope of a wheel flange relating to horizon;

F' is a side force of a wheel to a rail;

P_R is a vertical loading of a striking wheel to a high rail.

Table 3 provides safety criteria in the function of a friction factor f and a flange slope angle γ.

Table 3

angle γ / **friction factor *f***	**80°**	**70°**	**60°**
0,20	2,67	1,54	1,13
0,25	2,24	1,48	1,03
0,30	2,00	1,34	0,95

For a RF rolling stock with a flange slope angle **γ** = 70° and f = 0,25 the safety criterion corresponds to the following formula:

$$\frac{Y'}{P_H} \le 1,48.$$

Due to the development of high-speed operation based on the number of experimental research works carried out by VNIIZHT, there has been proposed a so called matching profile, having different taper angles on three sections 1:7; 1:20; 1:100. Such profile shall provide a 30% increase of the factor of safety against rolling of a wheel flange to a rail, it will help to increase a length of a wabbling wave of under a nosing motion of a wheel set, to reduce the intensity of clearance development.

Issues of dynamics in curves remain topical: there is a large side wear of rails and wheel flanges, contact damages of rails and track deterioration, supply of rails with higher hardness, increase of sections with speed limits (excessive rise of a high rail at low speeds, when a wagon is forced against a low rail), maintenance and improper state of ease curves, long contact of flange with a side edge of a rail head due to an excessive slope of wheel axis. It is facilitated by a number of factors specifying the state of wagon equipment:

Slope of a long direct axis of a bogie frame relating to a wheel axis ;

Non-optimality of structure schemes of bogies, which means links in excess which correspond to a number of dimensions required to be maintained.

Special attention should be paid to a choice of a reasonable value of a friction moment in the structure of the frame of a body or a bogie.

Much research have found that a considerable dynamic addition to side forces could be made in case of increase of a friction moment under a bogie rotation relating to the body in curved sections of track.

References

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