METHODS OF EVALUATION OF THE IMPACT OF FREIGHT CARS ON THE TRACK

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ABSTRACT

The author suggests experiment-calculated method to evaluate the impact of freight cars on the rail track. The suggested instruments have own mathematical apparatus, system of rates and equations, set of methods to identify stresses in the main platform of subgrade and in the ballast. Methodical basis of comparison of estimated and experimental data has been proved to be correct (discrepancy does not exceed on average 4–5%) and can be used as an alternative to long-term and high-cost tests.

ENGLISH SUMMARY

Background.

Operational procedures concerning calculation of durability of permanent way [1] presume that vertical dynamic load caused by vertical oscillations of loaded spring body (from wheel to rail) is defined by formulae $P_р = ж\, z_{max}$, where ж – rigidity of suspension brought to the wheel in vertical plane; z_{max} – maximum dynamic deflection of springs, мм.

For instance for four-axle freight car with the bodies of model 18–100: $z_{max} = 10 + 16*10^{-4} V^2$. Those formulas take into consideration the speed of the wagon (km/h) and don't account for resistance to oscillations of the wagon body, caused by friction wedge-type shock absorber, neither for irregularities of the track in vertical plane. Besides those formulas were written 55–50 years ago and don't account significant changes that the railways have undergone: maximum speed of freight trains has attained 90 km/h; average technical speed has attained 45–48 km/h; axle load of freight cars has been augmented to 23,5 t (expecting load is of 25 t); the superstructure has been reinforced; jointless track has appeared; traffic volume has increased et cetera.

Objectives.

The author, taking into account the described changes, suggests to define maximum dynamic load with the help of a new formula $P_{дин.max.} = P_{ст}\,(1 + к_{дн.в})$, where $P_{ст}$ – statics load of the wheel on the rail and $P_{ст} = \frac{Q+T}{m}$ (Q – loading capacity of a wagon, T – tare, m – number of wheels, $к_{дн.в}$ – rate of dynamic addition of vertical forces along mass of bogies without springs). The objective of the article is also to prove the correctness of the formula for practical calculations and to show positive effects of its application.

Methods.

The rate $к_{дн.в}$ can be defined through experiments during dynamic tests of a real car on real rail track as relation of dynamic stresses to static stresses, measured with the help of tensometric sensors at lateral bogie frame or axle of a wheel pair. This rate helps to reveal real dynamic forces of body oscillations (spring mass) of a wagon with spring suspension with friction wedge-type shock absorbers and inertia forces caused by oscillation of not suspended mass.

Preliminary calculations (before dynamic testing) of vertical load $P_{дин.max}$ the rate $к_{дн.в}$ can be defined by [2] formula

$$к_{дн.в} = \lambda_в \left(A + \frac{BV}{f_{ст}}\right),$$

where $\lambda_в$ – a value which depends on the number of bogie axles (for two-axle bogie it is equivalent to 1,0, for three-axle bogie – 0,9, four-axle bogie – 0,8);

A – value which depends on parameters of spring suspension:

for two-, three-, four-axle bogie $A = 8{,}125\,(f_{ст} - 0{,}0463)$;

B – value, which depends on wagon type (for four-, six-, eight axle cars $B \times 10^4 = 5{,}94$);

V – speed of a wagon, км/h;

$f_{ст}$ – static deflection of spring suspension of a car, м.

This formula is achieved on the basis of statistical treatment of experimental data during dynamic tests and of theoretical analysis, that takes into account probability of repeatable dynamic vertical load.

Further calculation of durability of rail track under the impact of the wagons with two-, three-, four-axle bogies and with different base, and accounting for dependence on the rate of dynamic addition of vertical force, distance between adjoining wheels of a bogie and motion speed, is held in conformity to rules of calculation of the durability of superstructure [1]. But the suggested set of methods (contrary to the cited rules) supposes that the maximum impact force produced by wheels on the rails is equal for all the wheels (the rules suppose that maximum force is produced by calculated wheel, while other wheels produce average value forces). In accordance with the rules equivalent loads $P_{экв}$, produced by the wheels on the rails, were defined autonomously for end wheels of all types of bogies, for middle wheel of three-axle bogie and for two middle wheels of four-axle bogie taking into account distance between the centers of adjoining wheels (pic. 1 and a set of formulas). The author introduces basic data, concerning track and wagons, which were taken for calculation of stresses in the elements of track superstructure.

Results.

Maximum values of the rate of additional vertical forces along unsuspended mass of bogie were found by experimental method using the data on tensions in lateral beams of bogie frame during dynamic tests of the wagons on the real track [3, 4]. Maximum values of tension for different wheels (described above) were calculated by formula [1]:

$$\sigma_h = \sigma_h^1 + \sum\sigma_{hc} = \sigma_Б\,[mC_1 + (2 - m)\,C_2] + 0{,}25\,A\sigma_{БС},$$

where σ_h^1 – tensions caused by load of the main calculated sleeper (Pic. 2); $\sum\sigma_{hc}$ – tensions caused by load of the sleepers adjoining the calculated sleeper; $\sigma_Б$ – compression tension in the ballast under calculated and adjoining sleepers.

Then the train (average) tensions on the main platform of subgrade were calculated:

$$\sigma_h^n = \frac{2\sigma_h^{кр} + \sigma_h^{ср}}{3} \text{ – for three-axle bogies,}$$

$$\sigma^{кр} = \frac{2\sigma_h^{кр} + 2\sigma_h^{ср}}{4} \text{ – for four-axle bogies,}$$

where $\sigma_h^{кр}$ – tension under end wheels of a bogie, $\sigma_h^{ср}$ – tension under middle wheels (Pic. 3). The methods used to determine tensions in main platform of subgrade and in the ballast are described in [1].

Pic. 3 shows that (if the distance between adjoining wheels is similar, and the rate of additional vertical force along unsuspended mass of the bogie is also similar) the most negative impact on the stressed state of

main area of the subgrade is produced by the wagons with three- and four-axle bogies which is explained by greater number of wheel pairs.

Some calculations and argumentations show that base of a bogie and the rate of dynamic addition of vertical forces are closely interrelated (longer is the base of a bogie, less is the rate of dynamic addition of vertical forces and vice versa). The article offers some numeric examples of that interrelation. But from the practical point of view it is difficult to achieve «ideal» relations because, friction wedge-type shock absorber is deemed to create more resistance, more friction, and springs of a wagon will work only at high speeds and under the conditions of higher disturbing forces from behalf of the track. And if, on the contrary, the speed is little (lower than resonance speed) and disturbing forces of the track causing wagon oscillations are lower, then springs are not working and almost all the wagon mass is unsuspended, thus causing: a) high impact on the track; b) growth of deflected mode of nods and parts of the wagon itself. The reduction of the rate of dynamic addition of vertical forces can't be achieved by increasing of static deflection of springs, neither by reducing of unsuspended mass of a bogie (deflection should not exceed 50–60 mm according to specifications for auto coupler devices; it is difficult to reduce the mass because it is necessary to ensure strength of lateral part of bogie frame and of a wheel pair, especially taking into account the growing loading capacity of wagons).

That is why in order to reduce stresses and tension in subgrade, it is necessary to increase bogie base, that will result in increase of an unsuspended mass of bogie with central suspension (it is not the case of suspension over axle-boxes) as well as to reinforce superstructure of track (heavier rails, thicker ballast, plate-type under rail construction, more sleepers per km of track et cetera). It will be also necessary to enhance technical maintenance of the track to respond to dynamic impact of the wagons, that will cause more expenses but they could be neutralized by increase in longevity of superstructure and subgrade.

The study has shown that the distance between adjoining wheels of three- and four-axle bogie influences stress state of the rails, but that influence is of inverse character as compared to the influence on the stresses in main area of subgrade. If the distance is less, then the stress in the rails is also less. Also it appears that in the case of six-axle wagons with three-axle bogies and of eight-axle wagons with four-axle bogies the most important stress emerges under the end wheels, while the stress under the middle wheels is less important than under the end wheels, that is explained by relieving effect of end wheels. This relieving effect is bigger when the distance between adjoining wheels is less (the article contains exact figures as example).

Eight-axle wagons with four-axle bogies with 3200 mm base have almost the same impact on the subgrade as four-axle wagons with bogies with 1850 mm base, as the values of rate of dynamic addition of vertical forces are less important due to bigger number of wheel pairs for four-axle bogie. Under some conditions (the article cites some examples) eight-axle wagons have even better effect on the subgrade than four-axle wagons.

Pic.4 shows that if even the rates of dynamic addition of vertical forces are similar, the maximum stress caused by wagons with different types of bogies differs due to different distances between adjoining wheels in the bogies.

Pic.5 shows that if the rates of dynamic addition of vertical forces are similar, the values of maximum stress are less when the distance between the adjoining wheels in the bogies is bigger. Nevertheless, the larger effect on increasing of stress is produced by the rate of dynamic addition and not by the distance between adjoining wheels in the bogie (the article cites some figures proving this result). The practical conclusion is that more attention should be drawn to enhancing of dynamic features of wagons and of technical state of the track in order to reduce disturbing forces, that cause dynamic oscillations of wagons.

The calculations of bearing stress in sleepers and ballast have shown that under other similar conditions they become less important when the distance between adjoining wheels in three-axle and four-axle bogies becomes larger (the article cites numerical examples).

Conclusions.

Correctness and possibility to apply experiment-calculated method of assessment of the impact of wagons on rail track instead of applying of expensive and long-term tests were proved with the help of comparison of the results of calculations and data received by verification tests. Discrepancy in the results has not exceeded on average 4–5%. It is to note that larger values were received via the calculations, that gives place to a certain reserve of durability and longevity of track superstructure and subgrade.

Key words: *rail track, freight car, rails, subgrade, springing, dynamic load, evaluation of impact, experiment-calculated method.*

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