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Improving the Methodology for Calculating the Parameters of Hump Yards

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ABSTRACT

The paper presents a new approach to selection of design standards in design of hump yards, which are among the most important elements of railway stations. The height of gravity hump is a key parameter to ensure succesful and safe operations of separating railway cars at stations. Estimations of the gravity hump's height are influenced mostly by the path length and the value of the main specific resistance to movement of the estimated free axles.

Following currently changing structure of the processed car flow at stations, it is necessary to update the current methods. The objective of the study is to update the existing method of choosing of estimated free axle and estimated point while calculating the estimated height of marshalling gravity humps.

Following the results of the study that used statistical and mathematical analysis the weight of the estimated free axle is proposed to be determined by the average value of the total car flow processed at the hump yard, and that calculations of estimated path length and estimated point should take into account the useful length and slopes of the sorting tracks.

The application of the proposed changes in the methodology for determining the required height of gravity humps will help to increase the efficiency and safety of their operation. The methodology of the study, while its conclusions in the form of calculated values are intended for Russian railways, can be applied for conducting similar analysis at any railway.

Keywords: transport, railway transport, station, marshalling yard, gravity hump, car, estimated free axle, parameters of hump yards, calculation procedure.

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Background. Hump yards are among the most important elements of railway stations for separating and formation of car flows on the railway network. The decisive parameter in ensuring successful and safe operation of separating of trains at stations is the required height of humps, which depends on many factors: characteristics of a processed car flow, running properties of cars, track characteristics, and meteorological conditions. The experience and the results of statistical and mathematical analysis show that the estimated path length of cars and the value of the main specific resistance to movement of the estimated sample free axles have the greatest influence on the design of the humps' height.

Objective. The objective of the authors is to consider methods for improving the methodology for calculating the parameters of hump yards.

Methods. The authors use general scientific and engineering methods, mathematical calculations, statistical and mathematical analysis.

Results. The scientific papers and Russian current regulatory documents on design of sorting devices [1–5] suppose that the estimated height of humps (H_e) is determined by the conditions of how an estimated sample free axle (a type of wagon considered together with its mass) rolls to the estimated point (EP), taking into account its running properties, characteristics of a track, curves and switches, meteorological data corresponding to the considered month:

$$H_e = 1{,}75 \bullet [L_e w_o + \sum_{i=1}^{K} (l_i w_{rc.i} + 0{,}56 v_i^2 n_{ci} + 0{,}23 v_i^2 \acute{a}_{ci}^{o})] \bullet 10^{-3} + L_{sn} w_{sn} 10^{-3} - \frac{v_o^2}{2g'}, \text{ m}, \quad (1)$$

where 1,75 is coefficient of deviation of estimated values of specific resistance to movement from their average values;

L_e – estimated path length of a car from the top of the hump to EP, m;

w_0 – main specific resistance to movement of cars, kgf/tf;

w_{rc} – specific resistance to movement of a car caused by air and wind, kgf/tf;

$0{,}56 v_i^2 10^{-3}$ – average specific work of forces of resistance to movement of a car caused by impacts against points, a frog and counter-rails of a switch, m en. h. (meters of energy height);

v_i – average speed of a car on the estimated *i*-th section, m/s;

n_{ti} – number of turnouts along the cars' path along the *i*-th considered section;

$0{,}23 v_i^2 10^{-3}$ – average specific work (in meters of energy height) of forces of resistance to movement of a car on roller bearings in curved sections of a track per each degree of rotation angle;

α_{ci}^{o} – sum of rotation angles in (degrees) in curves, including curved turnouts of switches, for the considered *i*-th section;

L_{sn} – distance from beginning of the head turnout of the sorting tracks set to the estimated point, m;

w_{sn} – average specific resistance to movement of a car caused by snow and hoarfrost;

$\frac{v_o^2}{2g'} = h_o$ – energy height (specific kinetic energy) corresponding to the estimated speed of separating of the wagons of a train m en.h.;

v_o – estimated speed of separating of wagons of a train, m/s;

g' = g/(1+ g) – value of acceleration of gravity of a car, taking into account influence of inertia of its rotating masses, m/s^2;

g = 0,42 n_0/q – coefficient taking into account influence of inertia of rotating masses of a car;

n_0, q – accordingly, the number of axles and the gross weight of the estimated sample free axle, tf.

The estimated point (EP) is assumed to be located on an estimated «difficult» track (with regard to the conditions of movement of cars along slopes, curves and switch sections) of a sorting track at a distance of 50 meters from the output end of the yard brake position, while the useful length of the yard tracks is not taken into account.

The weight of the estimated free axle is calculated [5] on the basis of the analysis of the structure of the car flow processed at the hump yard during the most intense and unfavorable period of the year. If the processed wagon flow is of the mixed type (the share of lightweight cars is more than 10 %), then the weight of the estimated free

Table 1

Numerical characteristics of distribution w_0, (kgf/tf) for different weight categories of wagons

Weight range of wagons, q, tf	Weight category of wagons		Numerical characteristics of distribution w_0, kgf/tf	
	Name	Designation	Average value w_0	Standard deviation
Up to 28	Light	L	1,75	0,67
28–44	Light-medium	LM	1,54	0,59
44–60	Medium	M	1,40	0,50
60–72	Medium-heavy	MH	1,25	0,38
Свыше 72	Heavy	H	1,23	0,35

Table 2

Change in the structure of processed wagon flows (in %) at hump yards during different years of their operation

Weight category, tf	1970	1990	2016
Light (up to 28)	17 %	7,3 %	61 %
Light-medium (28–44)	15 %	2,7 %	4 %
Medium (44–60)	18 %	25 %	8 %
Heavy (above 72)	50 %	65 %	27 %

axle is taken as the weighted average weight of a car in the selected group of lightweight cars. If the processed wagon flow belongs to the loaded type (the share of lightweight cars is less than 10 %), then the weight of the estimated free axle is taken as the weighted average value of the car weight in the selected group (about 10 % of the car flow), consisting of light and medium weight cars.

The main specific resistance to movement of cars rolling down the hump is considered as a random variable, the distribution of which can be approximated by the gamma distribution [5, p. 20; 6, p. 127]. The numerical values of w_0 are considered regardless of the outdoor temperature and are applied to the weight categories of single cars according to Table 1.

When performing hump design and technological verification calculations, the values of the main specific resistance w_0 to movement of the estimated free axles are usually taken as follows:

– a very bad free axle (VB) – 4,5 kgf/tf; bad free axle (B) – 4,0 kgf/tf;

– a good free axle (G) – 0,8 kgf/tf; a very good free axle (VG) – 0,5 kgf/tf, that is, the total spread of resistance to movement is quite large.

To more accurately take into account the influence of weight of cars, the main specific resistance to movement of cars and the standard deviation can be calculated by the formulas:

$$w_0 = 188/q+80, \quad (2)$$

$$\sigma_\omega = 67/q+80. \quad (3)$$

Practice shows that the greatest impact (60–65 %) on the height of humps is exerted by the estimated path length and the value of the main specific resistance to movement, so the choice and justification of these values is an important factor in determining the optimal parameters of the hump.

The impact of changing conditions

Currently, the operating conditions of the Russian railways have changed significantly [7, p. 12; 8, p. 34], so the choice of only 10 % of the car flow when determining the estimated value of w_0 does not reflect the current real conditions of hump yards. In 2004–2012 Russian railways were developing operations with private wagon fleet, and the multiplicity of rolling stock operators has led to an increase to 41 % of the rate of empty run of cars. At the same time, the structure of the processed wagon flow at stations has significantly changed (Table 2).

Today, it is not uncommon for lightweight railcars to make up more than half of the total volume of wagons arriving at hump yards, whereas earlier this indicator was 2–3 times less. Under those circumstances, the current estimated height of most humps is insufficient. As a result, a significant portion of empty cars stops at the middle of sorting tracks. For their further marshalling it is necessary to perform additional shunting work at the hump yard. Based on the foregoing, it can be concluded that the existing methodology for choosing the estimated sample free axle and estimated point in determining the design height of humps requires revision.

Proposed methodology

It is proposed to determine the weight of the estimated sample free axle by the average value of the total wagon flow (n) processed at the hump yard during the most intense and unfavorable period of the year, and not by the specified group of cars, that is by formula:

$$q_e^{av} = \sum_{k=1}^{n} \frac{q_к}{n}, \quad (4)$$

and then, according to Table 1 or formula (2), determine the average estimated value w_o^{av}.

It is proposed to take the estimated path length (l_{epl}) and the estimated point taking into account the entire useful length (l_{st}) of the sorting tracks from the yard brake position to the opposite elevation (inverse slope). In this case, the total estimated path length taking into account the distance from the top of the hump to the yard brake position l_{th} will be equal to:

$$l_{epl} = l_{th} + l_{st}. \quad (5)$$

The estimated height of humps should be determined by the formula:

$$H_e = [L_e\ w_o + \sum_{i=1}^{K}(l_i w_{rc.i} + 0{,}56 v_i^2 n_{ci} + 0{,}23 v_i^2 á^o_{ci})] \bullet$$
$$\bullet 10^{-3} + L_{sn} w_{sn} 10^{-3} - \frac{v_o^2}{2g'},\ m, \quad (6)$$

where $L_e = l_{epl} = l_{th} + l_{st}$ is full estimated path length of the car from the peak of the hump to the estimated point at the end of the sorting tracks;

$w_o = w_o^{av}$ – average value of the main specific resistance to movement of cars, corresponding to the average value (q_e^{av}) of the total car flow during the calculated month.

Preliminary estimates show that the change in the height of humps using formula (6) can be of ±10–20 % compared with the values calculated by formula (1). Moreover, the calculations according to formula (6), in our opinion, are more accurate, because that formula takes into account the full real car flows and the useful length of sorting tracks.

Conclusions.

1. The practices of designing of hump yards showed that their main parameters (height and longitudinal profile) are most influenced by the estimated path length and the value of the main specific resistance to movement of estimated sample free axles.

2. Currently, as Russian Railways work with a private car fleet, there is an increase in empty mileage of cars (up to 41 %) and, accordingly, a significant change in the structure of car flows at stations, requiring a modification of the calculation method and of the regulatory document [5] regarding design of hump yards.

3. Following the change in the structure of car flows at the stations of Russian Railways, the weight of the estimated sample free axle at the hump yard is proposed to be determined by the average value of the total car flow processed at the hump yard during the most stressful and unfavorable period of the year, and the estimated path length and the estimated point should be considered with account of the useful length of sorting tracks.

The application of the proposed changes in the calculation method will help optimize the operation of hump yards, reduce operating costs and increase safety of separating the wagons of the trains.

The suggested methodology, while values in the research have been calculated at the example of Russian railways, can be applied for similar analysis for any other railways.

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