Analysis of the Movement of an Empty Car on the Longitudinal Profile of the Hill

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ANALYSIS OF THE MOVEMENT OF AN EMPTY CAR ON THE LONGITUDINAL PROFILE OF THE HILL

Abstract*: At present, in the existing methods for determining the height of a hump, the height is calculated based on the most difficult conditions - winter temperature and head wind, and a four-axle empty covered wagon is selected for a poor runner. Based on the basic law of dynamics (D'Alembert's principle) as applied to weak links and the use of analytical formulas in the article, the calculation of the kinematic parameters of the movement of cars in the braking zone of the section of the first braking position of the hump is carried out. A sorting hump 3.08 m high is considered, for a four-axle empty covered wagon the winter temperature is -100, the headwind speed is 5 m/s m. When calculating the height of the marshalling yard, it is necessary to take the technical characteristics of a four-axle empty gondola car as a poor runner, since the headwind also acts inside the gondola car and prevents the car from rolling down the hill. It is recommended to study the effect of a headwind on a four-axle empty gondola car.*

Key words*: railway, station, marshalling yard, wagon, rational mode, railroad switch, combination of capacities of brake positions.*

Analyzing the content of the published discussions devoted to the problem of designing sorting slides [1-10], it can be concluded that until now the dynamics of the car moving along the profile of the sorting slide has not been studied enough. For this reason, it is worth noting the ideas about the importance of controlling, coordinating the speed of a moving car along the profile of a sorting slide. This requires the study of two states: the movement of a 4-axle empty covered car and a gondola car along the profile of a sorting slide [5,7,9,11,13,15,17].

Currently, in the existing methods of V.N. Obrazov, I.P. Starshov, V.M. Rudanovsky, H.T. Turanov and other recognized scientists to determine the height of the sorting slide, it is calculated based on the most difficult conditions - winter temperature and headwind, and for a bad runner, a four-axle empty covered wagon is selected. The reason for choosing this car was that the cross-sectional area of the closed car is larger than that of other cars (Table 1) [4,6,8,10,12,14,16,18].

Table 1

The values of the resistivity coefficients S_x and S_{xxj} from the environment

Type of car	Number of axles	S, m^2	Angle between the final vector and the relative velocity of the direction of descent of the uncoupling, deg.						
			0	10	20	30	50	70	90
Values of coefficients S_x / S_{xxj}									
Covered wagon	4	9,7	1.12 0,22	1,46 0,38	1,64 0,56	1,58 0,67	0,92 0,85	0,29 0,29	0,10 0,10
Gondola car	4	8,5	1,36 0,50	1,68 0,69	1,83 0,82	1,76 0,88	1.11 0,80	0,43 0,43	0,10 0,10
the same	8	10,7	1,56 0,75	1,95 0,97	2.09 1.13	2.03 1,16	1,15 0,88	0,40 0,40	0,15 0,15
C_x coefficient value									
Platform	4	4.1	1,51	2.02	2.30	2,23	1.30	0,40	0,10
Tank car	4	9,8	0,59	0,82	0,96	0,96	0,56	0,19	0,05
the same	8	10.3	0,81	1,08	1,22	1.10	0,65	0,19	0,05
Hopper car	4	9,9	0,92	1,18	1,38	1,46	1,21	0,68	0,25

The following forces act on a car moving along an inclined plane (Fig. 1):

Q — gravity;

W — resistance forces;

F — main driving force;

P — force exerting normal pressure on the inclined plane.

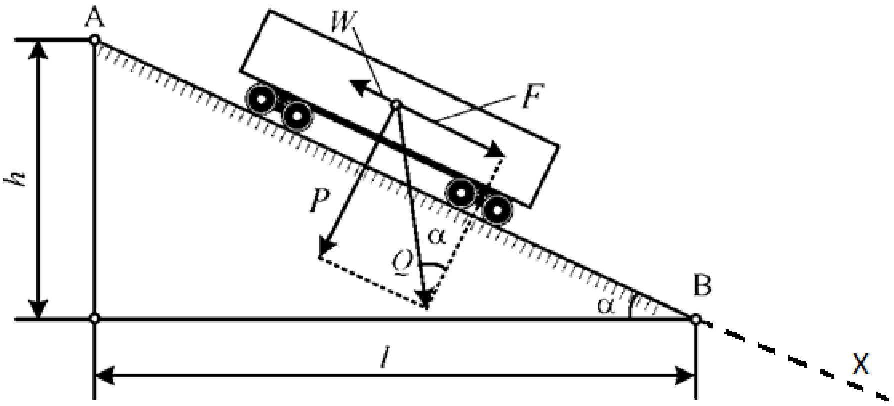

Figure 1. Forces acting on a car descending from a hill

As can be seen from Figure 1,

$$P = Q\, cos \propto; \tag{1}$$

$$F = Q \sin \propto. \tag{2}$$

on the slides, the slope a in practice does not exceed 5 ° and can be considered equal

$$\sin \propto \approx tg \propto = \frac{h}{l} = i \cdot 10^{-3}, \tag{3}$$

Here i — slope value, ‰.

The resistance force W is proportional to the weight of the car.

$$W = Q\omega 10^{-3}, \tag{4}$$

where, $\omega = \omega_{o}$ – total resistivity of the movement of the car, kgfpts (N/kN) or ‰.

Resistance forces:

- continuous (basic ω_o, resistance from the environment and wind ω_{osh}, resistance arising from snow and dew ω_{qsh});
- periodic (resistances arising along the switches ω_{sw}, curves ω_{cur}, for example, at the braking positions ω_{bp} in working condition).

Hence the total resistance force can be calculated using the following formula

$$W = \omega_o + \omega_{osh} + \omega_{qsh} + \omega_{sw} + \omega_{cur} + \omega_{bp} \tag{5}$$

Resistivity from the environment (air temperature and wind) ω_{osh} or, kgfpts, is determined by the following formulas:

for one car (single uncoupling)

$$\pm\omega_{osh} = \frac{17.8 \cdot S_x \cdot S}{(273 + t^0)q} \cdot V_{nt}^2, \tag{6}$$

for multigroup uncoupling

$$\pm\omega_{osh} = 17{,}8 \cdot \frac{S_x \cdot S + \sum_2^n S_{xxj} \cdot S_j}{(273 + t^0)\sum_{j=1}^n q_j} \cdot V_{nt}^2, \tag{7}$$

here S_x - relative coefficient of resistance from the environment for a single car or the first car of uncoupling;

S_{xxj} – coefficient of relative resistance from the environment for uncoupling wagons, except for the first wagon;

S, S_j – the cross-sectional area (midsection) of a separate car or the first car of the uncoupling and the other cars of the uncoupling, respectively, m^2;

$\sum_{j=1}^n q_j$- the mass of a car or a decoupling consisting of n cars, t;

t^0 - air temperature, °C ;

V_{nt} - relative (final) speed of the car (uncoupling) taking into account the wind direction, mps.

S_x and S_{xxj} are accepted according to Table 1 based on the parameters of the car.

The relative speed of the V_{nt} and the angle a is determined by the following formulas:

$$V_{nt}^2 = V^2 + V_{sh}^2 \pm 2V \cdot V_{sh} \cos\beta; \tag{8}$$

$$\propto = arc\sin\frac{V_{sh}\sin\beta}{V_{nt}}, \tag{9}$$

where, V - average speed of the car on the considered section, mps;

V_{sh} - wind speed (in case of a headwind, the sign "+" is taken, and in case of a headwind, the sign "-"), mps;

β - angle between the direction of the wind and the direction of movement of the car (fracture), deg.

If the angle β does not exceed 30^0,

$$V_{nt} = V \pm V_{sh}, \tag{10}$$

can be taken equal to

$$\propto = \frac{\beta}{2} \tag{11}$$

If the oncoming wind speed is greater than the descent speed V, then the sign V_{nt} is negative, and in this case the value of wsh is taken with the sign "-" [1 – 5, 7 – 13] .

The height of the sorting slide is 3.08 m, for a four-axle empty covered wagon, the winter temperature is -10^0, the headwind speed is 5 mps m. It is from this calculated height of the slide that the descent of a four-axle empty gondola car on a difficult path is determined.

A headwind on a four-axle empty gondola moving along the profile of the sorting slide has the following effect (Fig. 2).

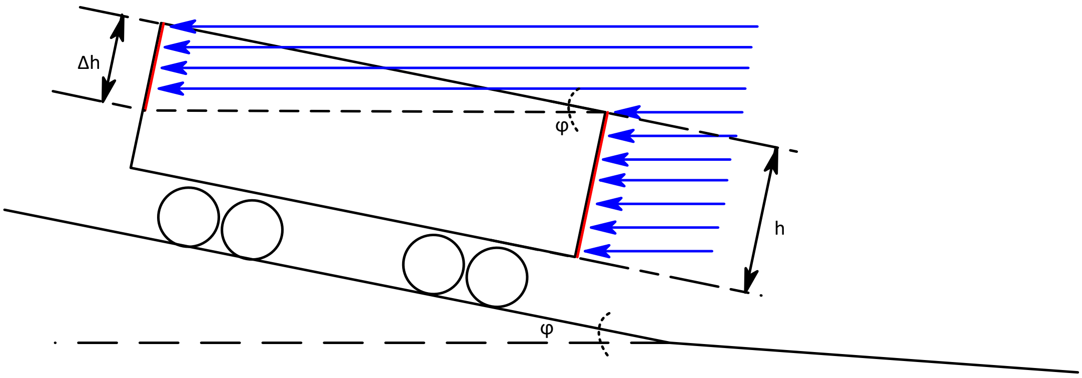

Figure 2. The effect of headwind on a four-axle empty gondola car

Moving on the profile of the sorting slide (see Fig. 2) for a four-axle empty gondola car, the headwind affects not only the end transverse surface of the car, but also the inner rear partition of the empty gondola car.

ΔS - cross-sectional area of the rear bulkhead of the gondola affected by the wind, m^2

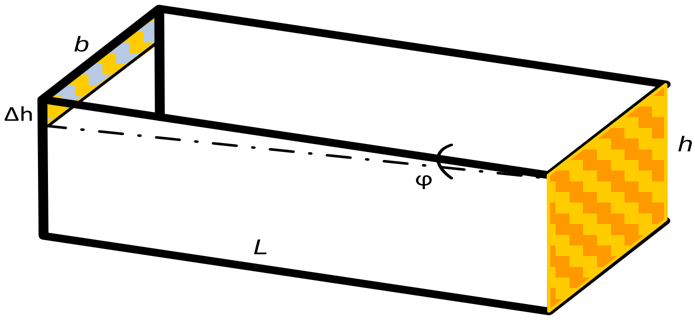

Figure 3. Transverse areas of an empty gondola car, which is affected by a headwind.

From Fig.3, we conclude that the headwind on the surface of an empty gondola car acts as follows:

The transverse area of the end of the gondola car is taken from Table 1:

$$\Delta S = L \cdot \mathrm{b} \cdot sin_{\varphi} \approx \mathrm{L} \cdot \mathrm{b} \cdot {}_{\varphi} \quad (14)$$

Further, through a 3.08 m high slide defined for a four-axle empty covered wagon, we determine and analyze the kinetic energy heights of a four-axle empty gondola car. The results are shown in Figure 4.

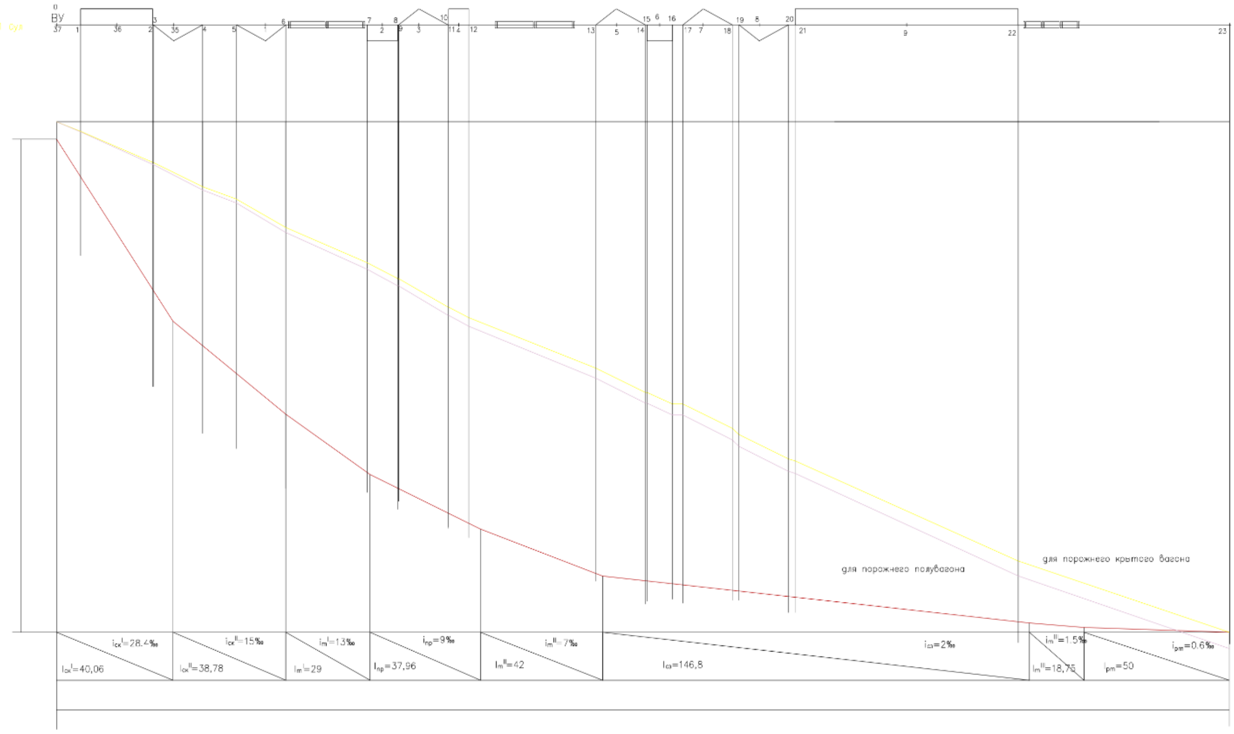

Figure 4. Construction of kinetic energy heights for four-axle empty covered and gondola cars

As can be seen from Fig.4, the height of the sorting slide, determined based on the parameters of an empty covered wagon, is low and the empty gondola car does not reach the calculated point of the difficult path, since the kinetic energy height of the empty gondola car graphically crosses the longitudinal profile of the slide.

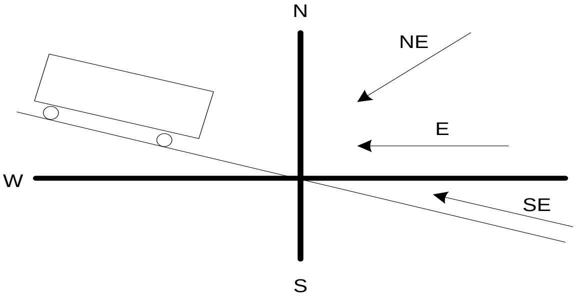

Figure 5. The effect of the headwind on the moving gondola cars on the hill

From Fig. 5 it can be seen that a single four-axle empty gondola moving along the sorting hill is affected by a south-easterly (SE), easterly (E), north-easterly (NE) headwind.

Conclusion

When calculating the height of the sorting slide, it is necessary to take as a bad runner the technical characteristics of a four-axle empty gondola car, because the headwind also acts inside the empty gondola car and prevents the normal descent of the car down the hill. It is recommended to study the impact of headwind on a four-axle empty gondola car.

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