CALCULATION OF TIME OF MOVEMENT AND SPEED OF A CAR ON THE INTERMEDIATE SECTION OF THE HUMP YARD UNDER TAIL WIND

Turanov, Khabibulla T., *Ural State University of Railway Transport (USURT), Yekaterinburg, Russia.*
Gordienko, Andrey A., *Ural State University of Railway Transport (USURT), Yekaterinburg, Russia.*

ABSTRACT

The dynamics of the car rolling from a hump yard at a railway station is studied in its various aspects. The authors have also touched upon this topic repeatedly (see, in particular, World of Transport and Transportation, 2015, Iss. 6). However, earlier reports lacked estimates of time of movement and speed of a car on the intermediate section of the hump yard under the influence of tail wind of low speed. The published article fills this gap, introduces the results of calculations, mathematical and graphical dependencies enabling to make certain generalizations and conclusions.

Keywords: principle of D'Alembert, classical formulas of path and velocity of bodies, railway station, hump yard, intermediate section, tail wind, time and speed of car's rolling.

Background. *The results of analytical studies of the car driving on the slope of the hump yard, when the force of aerodynamic tail wind resistance* $\overline{F}_{rw}$ *depends on the square of velocity, i.e.* $\overline{F}_{rw} = f(\overline{v}_{rw}^2)$ *(where* $\overline{v}_{rw}$ *is relative wind speed in relation to the car) are set forth in [1–5]. In [3–5], there are data of numerical experiments with construction of graphical dependences of car's rolling speed from the slope of the hump yard. However, the analytical formulas for determining car speed when it is moving on the slope are complicated for practical use. That is exactly why in [6–16] cases are studied where the airdynamic resistance force* $\overline{F}_{rw}$ *of tail wind of small value (for example, with tail wind of 2–4 m / s) depends linearly on the windward area of the car with a load* $F_{rw} = f(A_{ww})$. *This approach is widely used in fastening of loads on cars [17], in which it is assumed that the specific pressure per 1* m^2 *of area of the car with load is equal to 0,5 kN /* m^2.

In [6–8] attempts were made to construct a simplified mathematical model of car movement under the influence of tail wind of small value, but in them there are some inaccuracies in the presentation of diagram of tail wind speed and speed of car movement on the slope. These inaccuracies, in fact, did not affect the results of calculation on time of movement and speed of car's rolling, as set out in [9, 10], which is associated with a slight angle of inclination of the hump ψ_0, *since* $\cos\psi_0 \approx 1$ *[11].*

In [12] force relations are shown that arise in the system of «car-track», they are considered separately for the hump section before and after the turnout switch. In [13–15] car movement on the section of the first brake position with braking when exposed to tailwind of small value. In this the problem of determining car speed and braking distance according to braking time, including before the car stops, is solved.

Despite the large number of studies on dynamics of car's rolling from the hump, there are still no examples of calculation of travel time and speed of car's rolling on an intermediate section (hereinafter – INT section) of the hump yard when exposed to tailwind of small value. This article aims to make a real step in this direction.

Objective. *The objective of the authors is to calculate time of movement and speed of a car, when it moves on an intermediate section of the hump yard under tail wind.*

Methods. *The authors use general scientific and engineering methods, graph construction, mathematical calculation.*

Results.

Approaches to task solution

In this case, movement of car on INT section of the hump under tail wind according to [16] is divided into two phases: in the first one a car moves to the turnout switch, in the second – after the switch on the curved section.

It is necessary to receive a sample calculation of time and car speed by the simplified procedure where for the known value of INT section of the hump $l_j = x(t_k)$ *it will be possible to find time* t_k, *during which motion occurs at a predetermined initial speed before and after the turnout switch, and for the time value – car speed* $v_{ek}(t_k)$. *Hereinafter, according to [12], k = 4 corresponds to accounting of only environment resistance* F_{env} *on INT section of the hump to the switch and k = 41 to accounting of impact of environment resistance* F_{env} *and wind projection on a lateral side of the car* F_{rwy}; *k = 4c – to accounting of impact of resistance of any kind (environment, switches, curves, snow and frost)* $F_{r.}$ *on INT section of the hump after the switch, k = 41c – to accounting of impact resistance of any kind* $F_{r.}$ *and wind projection on a lateral side of the car* F_{rwy} *and k = 42 s – to simultaneous accounting of impact of resistance of any kind* F_r, *transverse inertial forces* I_{ey} *and wind projection on a lateral side of the car* F_{rwy} *(impact of different resistances when the car is moving on a curved section of the track). Hereinafter, j = 4corresponds to the case when k = 4, 41, 42, and j = 4s – when k = 4s, 41s, 42s.*

General approaches to task solution [12, 16] are as follows

1. In considering car movement from the hump yard the basic principle of D'Alembert in coordinate form [23] and the classic formula of speed and path from the physics course are used.

2. In the context of the tasks and taken assumptions a case arises where the car along the slope of the hump yard enters INT section with a given initial speed v_{0k}. *When a single car enters, we believe that it will be mainly influenced by external forces in the form of its own weight with load G, projection of aerodynamic drag force of tailwind of small value* F_{rw} *(e.g., south-east or north-east direction) along the longitudinal axis Ox and the transverse axis Oy as* F_{rwx} *and* F_{rwy}, *i.e.* $\overline{F}_{rwx}, \overline{F}_{rwy} \in \overline{F}_{rw}$ *) (Pic. 1), bearing in mind that in its projection of aerodynamic drag forces are taken as dependent only on the area of the windward surface of the car with cargo, as is in the case of dealing with the problem of fastening cargo on cars [7].*

Pic. 1 indicates: $\bar{v}_{rw}$ – absolute speed of tailwind; $\varpi + \xi$ – directional angle of vector of absolute speed of wind $\bar{v}_{rw}$ relative to the horizontal (axis Ox) for south-west direction; $\bar{F}_{rw}$ – force of impact of tail wind; $F_{rw.x}$ and $F_{rw.y}$ – projections of impact force $\bar{F}_{rw}$ of a tail wind on Ox and Oy, i.e. $(\bar{F}_{rw.x}, \bar{F}_{rw.y}) \in \bar{F}_{rw}$. Note that if the wind is of north-east direction, then the force F_{rwy} has an opposite direction.

3. When forming the calculation model of movement of the car on INT section of the hump to the switch an assumption is made that the wheel sets on rail strands move under pure rolling of the wheels relative to the tread surface of rail lines $F_{rol.fr.}$ and sliding friction of wheel flanges on the side surface of the rail line $F_{sl.fr.}$ by taking into account the impact of wind projection on a lateral side of the car F_{rwy}, i.e. $F_{fr.x} = F_{\tau} = F_{rol.fr.} + F_{sl.fr.}$. When the car is moving on a curved section of the track after the switch in addition to resistance of any kind $F_{r.}$ it is necessary also to take into account the impact of transverse inertial force I_{ey} and projections of force F_{rwy} on the direction of the latter force.

In line with this simplified calculation model of movement of the car on INT section of the hump is shown in Pic. 2, where O is origin of the moving coordinate system Ox_1yz, rigidly connected with the car; Ox is axis in horizontal direction; ψ_{04} is angle of slope (descent) of INT section of the hump; v_{rwx} is relative air speed; $v_0 = v_{wx1}$ is initial speed of the car; v_w is the speed of the car; $F_{r.} = F_{env.}$ is force of resistance of environment before the switch and after the switch $F_{r.}$ is force of resistance of any kind; N and $F_{fr.x}$ are normal and tangential components of the reaction of links (of rail lines). And $N = N_1 + N_2 + N_3 + N_4$ and $F_{тr.x} = F_{fr.x1} + F_{fr.x2} + F_{fr.x3} + F_{fr.x4}$ act as parallel forces.

Thus, using the basic principle of D'Alembert and the classic formulas of path and speed of the body with the known value of INT section of the hump $l_k = x(t_k)$ and in accordance with [16] are identified time t_k, in which the car is moving at a given initial speed v_{0k} to the beginning of the switch turnout and lwith the value of time t_k – car speed $v_{ek}(t_k)$. Similarly, time of movement t_{kc} and car speed $v_{ekc}(t_{kc})$ after the switch to the beginning of the second brake position are found.

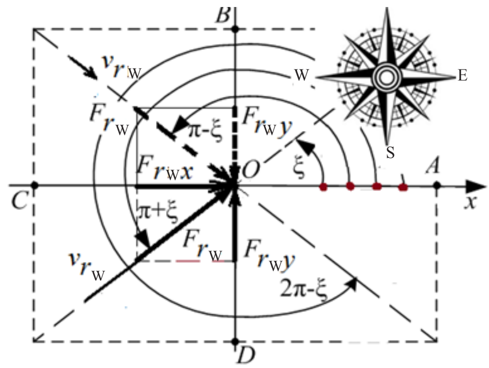
Simplified sequence of actions

Note that the following formulas were determined by us earlier [12]. The original results are calculated values of forces that promote and / or impede car movement on INT section of the hump, as well as the values of acceleration, time, motion and rolling speed of the car. A simplified sequence of calculating the car speed on INT section before and after the switch turnout under tail wind, as in [12, 16] can be represented as follows.

1. Let's consider a case of hump neck designing on track 24. When designing a hump yard the full length of INT section l_k is taken according to the recommendations [24]. For example, the slope of the hump 9 ppm, ψ_{04}= 0,009 rad. (sin(ψ_{04}) = 0,009), the length of the section to the switch l_4 = 20,001 m, and after the switch – l_{4c} = 21,271 m.

2. The projections of the impact force of a tail wind on the car, such as the south-western direction, along the longitudinal Ox and transverse Oy_1 axis (in Pic. 2 Oy_1 axis is not shown) in the form (2) [12], kN:

$$F_{rwx} = 0,5A_{\rm e}; \quad F_{rwl} = 0,5A_{\rm l}, \tag{1}$$



Pic. 1. Diagram of tailwind of south-east and north-east directions.

where 0,5 is specific pressure per 1 m² of the area, kN/m² [17]; A_e is area of end surface of a car with cargo, m²; A_l is area of lateral surface of a car with cargo, m². For example, if A_e = 6,384 and A_l = 27,36 m², then $F_{rw.x}$ = 3,192 and $F_{rw.y}$ = 13,68 kN.

3. The «shearing» force $F_{sh.x1}$ is calculated (i.e., the projection of gravity force of the car with cargo G_{x1} and impact force of a tail wind $F_{rw.x}$ on the direction of car rolling on the axis Ox_1) – see Pic. 2 and (3), [12]:

$$F_{sh.x1} = G\sin(\psi_{0k}) + F_{rwx}\cos(\psi_{0k}), \tag{2}$$

where G is gravity force of a car with cargo, taking into account the inertia of rotating masses, kN.

For example, if G = 908 kN, sin(ψ_{04}) = 0,009, $F_{rw.x}$ = 3,192 kN, cos(ψ_{04}) = 1, then $F_{sh.x1}$ = 11,364 kN.

4. Rolling friction force $F_{fr.rol}$ is determined depending on the projection of gravity force of the car with a cargo G_z and a tail wind resistance force $F_{rw.x}$ on the direction of Oz axis (see Pic. 2) as the tangential component of reaction of connection (of rail lines) F_{τ}, which according to the Coulomb's law is (see (7), [12]):

$$F_{fr.rol.} = f_0\left(G\cos(\psi_{04}) + F_{rwx}\sin(\psi_{04})\right); \tag{3}$$

where f_0 is some resulted rolling friction coefficient, taking into account the number of wheels in bogies, rolling friction (on bearing's rings and wheel on the rail) (usually take f_0 = 0,0001) [1–5].

For example, if f_0 = 0,0001, G = 908 kN – gravity force of a car with cargo taking into account the inertia of rotating masses (wheel sets) (excluding this inertia G = 794 kN at gravity force of cargo G_{cargo} = 650 kN), cos(ψ_{04}) = 1, $F_{rw.x}$ = 3,192 kN, sin(ψ_{04}) = 0,009, then $F_{fr.\,x1} = F_{fr.rol.}$ = 0,094 kN.

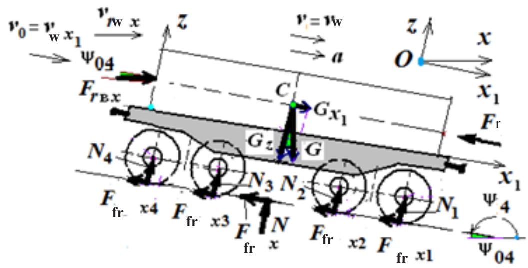
5. Sliding friction force $F_{fr.sl.}$ from the influence of wind projection on a lateral side of the car $F_{rwy} = F_{rw.l}$ with account of this force as a tangential component of reaction of connection (of rail lines) F_{τ}, which according to Coulomb's law is determined by the expression (10b [12]):

$$F_{\rm fr.l.x} = F_{\rm fr.sl.} = f_{\rm sl0}F_{rwy} = f_{\rm sl0}F_{rly}, \tag{4}$$

where f_{sl0} is coefficient of sliding friction of wheel flanges on the lateral surface of a rail line (usually take up to f_{sl0} = 0,25) [12–14]. For example, if f_{sl0} = 0,2, $F_{rw.y} = F_{rly}$ = 13,68 kN, then $F_{fr.l.\,x} = F_{fr.sl}$ = 2,736 kN.

6. Based on (3) and (4) is calculated the frictional force along the car movement as the sum of rolling friction forces $F_{fr.rol}$ and sliding friction forces $F_{fr.sl}$, taking into account the impact of wind projection on the lateral side of the car $F_{rw.y}$ in the form

$$F_{\rm fr.x1} = F_{\tau} = F_{\rm fr.rol} + F_{\rm fr.sl}. \tag{5}$$



Pic. 2. Simplified calculation model of car movement on the profile of INT section of the hump under tail wind.

For example, if $F_{fr.rol.}$ = 0,094, $F_{fr.sl.}$ = 2,736 kN, then $F_{fr.\,x1}$ = 2,954 kN.

7. Determine the Forces of resistance to movement of the car from the environment $F_{env.}$ as (10b) [12]:

$$F_{\text{env.}} = k_{\text{env.}} k_{\text{in.}} G, \qquad (6)$$

where $k_{env.}$ is coefficient, taking into account the share of gravity force G at accounting of environmental resistance (usually within 0,0001–0,0005 at a speed of tail wind from 2 to 4 m/s) [25, p. 182]; $k_{in.}$ is coefficient, taking into account the inaccuracy of calculations $k_{env.}$ (usually taken up to 1). For example, if $k_{env.}$ = 0,0003, $k_{in.}$ = 0,8 and G = 908 kN, then $F_{env.}$ = 0,218 kN.

8. The «holding» forces $F_{shk.x1}$ are calculated resisting the movement of the car on INT section of the hump before and after the switch turnout in the form (see (12), [16]):

$$F_{\text{sh}k.x1} = F_{\text{fr.rol.}} + F_{\text{env.}} + F_{\text{fr.sl.}}; \qquad (7)$$

$$F_{shk.x1} = f_0\left(G\cos(\psi_{04}) + F_{rwx}\sin(\psi_{04})\right) + \\ +(k_{env.} + k_{sw.} + k_{s.f.} + k_{cur.})k_{in.}G + f_{sl0}(I_{ey} + F_{r\text{вwб}}\cos(\alpha_4)). \qquad (8)$$

Here again k = 4 corresponds to the impact of only resistance of environment $F_{env.}$ on INT section of the hump to the switch and k = 41 – to accounting of impact of resistance of environment $F_{env.}$ and wind projection on a lateral side of the car F_{rwy}; k = 4c – to accounting of resistance of any kind $F_{r.}$, k = 41c – to accounting of impact of resistance of any kind $F_{r.}$ and wind projection on a lateral side of the car F_{rwy} and k = 42c – to accounting of impact of different resistances when the car is moving on a curved section of the track, kN. In (8) there are following indications: α_4 is rotation angle of curves on INT section (are usually taken depending on the number of tracks on the hump neck); $k_{sw.}$, $k_{s.f.}$ and $k_{cur.}$ – coefficients, taking into account the share of gravity force G, as well as resistance of the switch, snow and frost, curves (usually are taken $k_{sw.}$ = 0,00015, $k_{s.f.}$ = 0,00015 (according to [25] it comes to 0,00025) and $k_{cur.}$ = 0,00011); I_{ey} – transverse inertial force (often 3 kN and more).

9. Using the value of «shearing» $F_{sh.x1}$ and «holding» $F_{holk.x1}$ forces is calculated force F_k, which facilitates the movement of the car on INT section before and after the switch turnout, kN:

$$F_k = F_{\text{sh}.x1} - F_{\text{hol}.k.x1}. \qquad (9)$$

For example, if $F_{sh.x1}$ = 11,364 kN; $F_{hol4.x1}$ = 0,312 kN, then F_4 = 11,052 kN – force, under which impact the car moves with acceleration on INT section before the switch, taking into account only the resistance of environment $F_{env.}$, and with addition of wind projection on a lateral side of the car $F_{sh41.x1}$ = 3,048 kN, i.e. F_{41} = 8,316 kN.

After the switch turnout the values of these forces with account of influence of only resistance of any kind $F_{r.}$, calculated by (2) and (8), are such: $F_{sh.x1}$ = 11,364 kN, $F_{sh4c.x1}$ = 0,611 kN, F_{4c} = 10,753 kN; taking into account resistance of any kind $F_{r.}$ and wind projection on a lateral side of the car – $F_{sh41c.x1}$ = 3,3 kN, F_{41c} = 8,064 kN; taking into account the influence of various resistances and movement of the car on a curved section of the track – $F_{sh42c.x1}$ = 3,763 kN, F_{42c} = 7,6 kN.

10. According to the value of force F_k and the mass of the car M taking into account the inertia of rotating parts is calculated acceleration of the car a_k when moving on the considered section of the hump with acceleration, m / s² (see (14), [12]):

$$a_k = \frac{F_k 10^3}{M}. \qquad (10)$$

For example, if M = 5,484·10⁴ kg – mass of the car with cargo, taking into account the inertia of rotating parts of the car and F_4 = 11,052 kN, then acceleration of the car, when takes places accelerated movement before the switch in the presence of resistance of environment: a_4 = 0,119 m/s² (if consider the impact of resistance of environment and wind projection on a lateral side of the car, then at F_{41} = 8,316 kN – a_{41} = 0,09 m/s²). When the car moves after the switch on a curved section under the influence of resistance of any kind $F_{r.}$: F_{4c} = 10,753 kN and a_{4c} = 0,116 m/s²; under the influence of resistance of any kind $F_{r.}$ With account of impact of wind projection on lateral side of the car at F_{41c} = 8,064 kN – a_{41c} = 0,087 m/s²; under the influence of resistance of any kind $F_{r.}$ With account of movement of the car on a curved section F_{42c} = 7,6 kN – a_{42c} = 0,082 m/s².

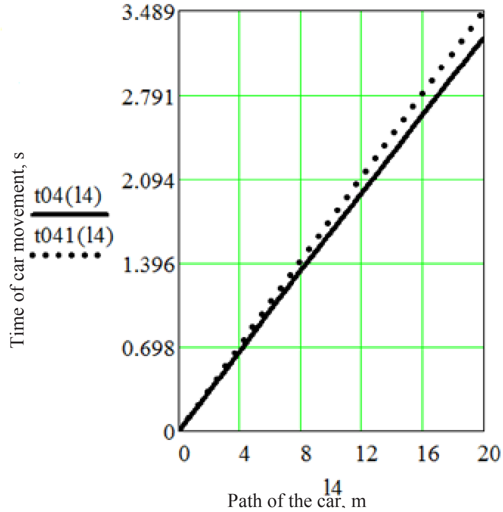
11. Time t_k, during which occurs rectilinear uniformly accelerated motion of the car on INT section with the length of l_k, m (see (16), [12]):

$$t_k = \frac{-v_{0k} + \sqrt{v_{0k}^2 - 2a_k l_j}}{a_k}, \qquad (11)$$

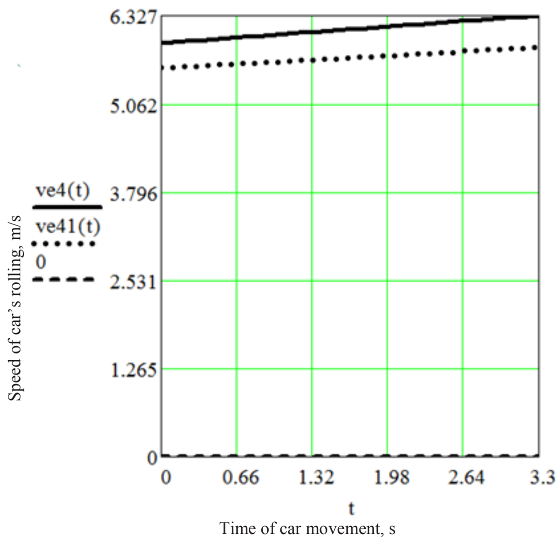
where v_{0k} is initial speed of the car (at the entrance to INT section), m/s.

According to the calculations of the previous sections, according to the design program which we have developed for the entire length of the hump yard, we assume that v_{04} = 5,933 m/s with account of the influence of only resistance of the environment $F_{env.}$ on INT section to the switch, but with account of the influence of resistance of environment and wind projection on lateral side of the car – v_{041} = 5,575 m/s. During movement of the car after the switch v_{04c} = 6,323 m/s with account of influence of only resistance of any kind $F_{r.}$, under the influence of resistance of any kind and wind projection on lateral side of the car v_{041c} = 5,889 m/s, and under the influence of resistance of any kind with account of movement of the car on a curved section v_{042c} = 6,14 m/s.

For example, if v_{04} = 5,993 m/s, a_4 = 0,119 m/s², l_4 = 20,001 m, the time of car's rolling on INT section to the switch under the influence of only resistance of environment – t_4 = 3,264 s and under the impact of resistance of environment and wind projection on



Pic. 3. Graphic dependence of car movement on the intermediate section of the hump to the switch on the distance covered.



Pic. 4. The graphic dependence of speed of car's rolling on INT section of the hump to the switch on time of movement.

lateral side of the car (i.e. v_{041} = 5,575 m/s and a_{41} = 0,09 m/s^2) – t_{41} = 3,489 s. During movement after the switch, if v_{04c} = 6,323 m/s, a_{4c} = 0,116 m/s^2, l_{4c} = 21,271 m, then time of car's rolling under the influence of resistance of any kind – t_{4c} = 3,266 s, under the influence of also wind projection on lateral side of the car (v_{041c} = 5,889 m/s and a_{41c} = 0,087 m/s^2) – t_{41c} = 3,521 s, and under the influence of resistance of any kind with account of movement on a curved section of the hump (v_{042c} = 6,14 m/s and a_{42c} = 0,082 m/s^2) – t_{42c} = 3,388 s.

If necessary, it is possible to construct a graphic dependence $t_k = f(l_k)$.

12. Speed of the car on INT section of the hump before and after the switch v_k is determined according to the classical formula of physics course, m/s (see (13), [12]):

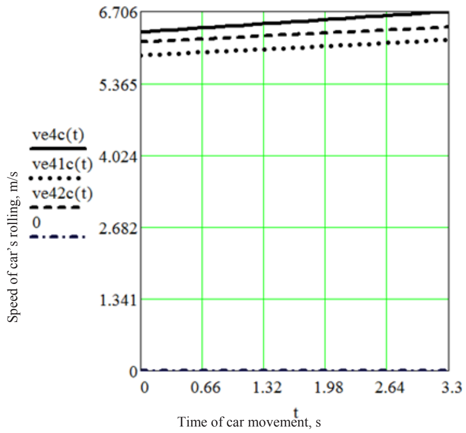
$$v_{ek}(t) = v_{0k} + a_k t. \qquad (12)$$

For example, for set initial data: v_{04} = 5,933 m/s, a_4 = 0,119 m/s^2, t_4 = 3,264 s on INT section to the switch turnout the speed of the car $v(t_4)$ = 6,323 m/s or 22,76 km/h with account of only resistance of environment $F_{env.}$; at v_{041} = 5,575 m/s, a_{41} = 0,09 m/s^2, t_{41} = 3,489 s with account of influence of resistance of environment $F_{env.}$ and wind projection on lateral side of the car $v(t_{41})$ = 5,889 m/s or 21,2 km/h. During movement after the switch turnout the speed of the car (v_{04c} = 6,323 m/s, a_{4c} = 0,116 m/s^2, t_{4c} = 3,266 s) $v(t_{4c})$ = 6,7 m/s or 24,1 km/h with account of only resistance of any kind $F_{r.}$, with account of influence of resistances of any kind $F_{r.}$ and wind projection on lateral side of the car (v_{041c} = 5,899 m/s, a_{41c} = 0,087 m/s^2, t_{41c} = 3,521 s) $v(t_{41c})$ = 6,19 m/s or 22,3 km/h, but under the influence of resistances of any kind $F_{r.}$ with account of movement of the car on a curved section (v_{042c} = 6,14 m/s, a_{42c} = 0,00046 m/s^2, t_{42c} = 2,642 s) $v(t_{42c})$ = 6,42 m/s or 23,1 km/h.

Graphic dependence of time and speed of rolling

We show as an example graphic dependencies of time of motion on the length of distance covered at l4: = 0,2..20 m – and speed of car's rolling on INT section of the hump at any time moment t to the switch at t = 0, 0,1...2,5 s. (Pic. 3 and 4).

Time of car movement $t_k(l_k)$ depending on the length of section of the hump yard l_j with account of only resistance of environment $F_{env.}$, as well as resistance of environment $F_{env.}$ and wind projection on lateral side of the car F_{rwy} (i.e. at j = 4, which



Pic. 5. The graphic dependence of speed of car's rolling on the intermediate section of the hump after the switch on time of movement.

corresponds to k = 4; 41), which follows from (11):

The speed of car's rolling on INT section of the hump at any time moment t of uniformly accelerated movement to the switch is calculated according to (12):

ve4(t) = v04 + a4·t – car speed v(t) with account of only resistance of environment $F_{env.}$, m/s;

ve41(t) = v041 + a41·t – car speed v(t) with account of impact of resistance of environment $F_{env.}$ and wind projection on lateral side of the car F_{rwy}, m/s.

As can be seen, in case of uniformly accelerated movement of the car on INT section to the switch with account of resistance of environment and wind its rolling speed increase linearly.

Rolling speed at any time moment t of car movement uniformly accelerated after the switch is found by the same method (12):

ve4c(t) = v04c + a4c·t – car speed v(t) under the influence of only resistance of any kind (environment, switch, curves, snow, frost) $F_{r.}$, m/s;

ve41c(t) = v041c + a41c·t – speed v(t) under the influence of resistance of any kind $F_{r.}$ and with account of wind projection on lateral side of the car $F_{rwy.}$ m/s;

ve42c(t) = v042c + a4c·t – speed v(t) under the influence of resistance of any kind $F_{r.}$ and with account of car movement on a curved section of the hump $F_{rwy.l'}$, m/s.

The calculation results are shown in Pic. 5.

As follows from Pic. 5, speed of car's rolling after the switch at simultaneous account of resistance of any kind (environment, switches, snow, frost, curves, wind) increase also linearly.

Summarizing the calculation results with account of only resistance of environment $F_{env.}$ and wind, it can be noted, that if time of car movement to the switch, for example, at k = 4 is t_4 = 3,264 s, speed $v(t_4)$ = 6,323 m/s or 22,76 km/h at speed of car entrance to the section v_{04} = 5,933 m/s, and at k = 41: t_{41} = 3,489, $v(t_{41})$ = 5,889 m/s or 21,2 km/h, v_{041} = 5,575 m/s, then similar data after the switch with account of resistance of any kind (environment, switches, snow, frost, curves) $F_{env.}$ and wind at k = 4c will be: t_{4c} = 3,266 c, $v(t_{4c})$ = 6,7 m/s or 24,1 km/h, and at k = 41c: v_{041c} = 5,589 m/s, t_{41c} = 3,521 s, $v(t_{41c})$ = 6,2 m/s or 22,3 km/h.

The calculation results show that regardless of whether a car moves to the switch or after it, under the influence of only resistance of environment $F_{env.}$ or together with wind projection on lateral side of the car $F_{rwy.}$, or resistances of any kind (environment, switch, snow, frost, curves) $F_{r.}$ with account of car passing on the curved section of the hump occurs uniformly accelerated car movement. At the same time time of movement remains practically unchanged: from t_4 = 3,264 s (at k = 4) to t_{4c} = 3,266 s (at k = 4c), and speeds of car rolling increase from v_{04} = 5,933 m/s to $v(t_{4c})$ = 6,7 m/s (at k = 4) and from v_{041c} = 5,575 m/s to $v(t_{41c})$ = 6,2 m/s (at k = 4c).

Conclusions.

1. Power ratios that occur in the system «car-track» on INT section under tail wind of small value with account of different kinds of resistance (environment, switch, snow, frost, curves, wind) to and after the switch, allowed to determine acceleration of the car at its movement on the slope of the hump yard.

2. The proposed simplified sequence of calculation makes it possible using the known value of the length of INT section of the hump to and after the switche l_j to find time of car movement t_k under different conditions (influence of only resistances of any kind, wind projection on lateral side of the car etc.), and then speed of its rolling at the end of the section $v_k(t_k)$.

3. Calculation found that on INT section of the hump under tail wind of small value regardless of accounting of different kinds of resistance (environment, switch, snow and frost, curves, wind) before and after the switch occurs uniformly accelerated motion of the car, which means the increase of speed of its exit from this section compared to the speed of entrance into this section.

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Information about the authors:
Turanov, Khabibulla T. – D.Sc. (Eng.), professor of Ural State University of Railway Transport (USURT), Yekaterinburg, Russia, khturanov@yandex.ru.
Gordienko, Andrey A. – Ph.D. (Eng.), teaching assistant at the department of Stations, junctions and cargo work of Ural State University of Railway Transport (USURT), Yekaterinburg, Russia, gordiii89@yandex.ru.

Article received 31.12.2015, accepted 16.05.2016.