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ON THE MOVEMENT OF A WAGON ALONG THE ENTIRE LENGTH OF A MARSHALLING HUMP UNDER TAILWIND CONDITIONS

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Abstract

The article presents the results of studies varying the slopes of speed sections and the power of brake positions of the marshalling hump under the influence of tailwind force. In the brake position sections, the loaded wagon performs translational motion. Unlike existing hump calculation methods, the mass of the loaded wagon in the brake position sections should be determined without accounting for the inertia of rotating masses. A significant discrepancy is established in the values of the average time of wagon movement along the entire track profile, determined according to the Technical Operation Rules, compared to the wagon movement time calculated by the elementary physics formula. For the accepted initial data, the rational approach is maximum braking on all brake position sections, ensuring compliance with the permissible collision speeds established by the Technical Operation Rules.

Keywords

Railway, station, marshalling hump, wagon movement, tailwind, brake position power, analysis of research results.

Relevance of the problem

This article, as well as [1], is a continuation of the series of works [2–9], dedicated to the analysis of the results of studies on wagon movement down the descent part of the marshalling hump under various movement modes, obtained based on a specially developed calculation programme (for example, see [10]).

It is well known [11] that the technological process of the marshalling hump operation is based on reducing the speed of moving wagons through sequential braking at brake positions to the established collision speeds [1]. As noted in [1], the technology of marshalling humps provides for cases of disbanding wagons (cuts) "on passage" (without braking by wagon retarders) or using the powers of park brake positions (non-mechanised or mechanised), usually used, as a rule, for "poor runners" and "very poor runners".

Based on this, it is relevant to determine the optimal disbanding mode with a rational combination of brake position powers and the application of the "on passage" variant, ensuring compliance with the permissible collision speeds established by the Technical Operation Rules.

Aim of the Present Article

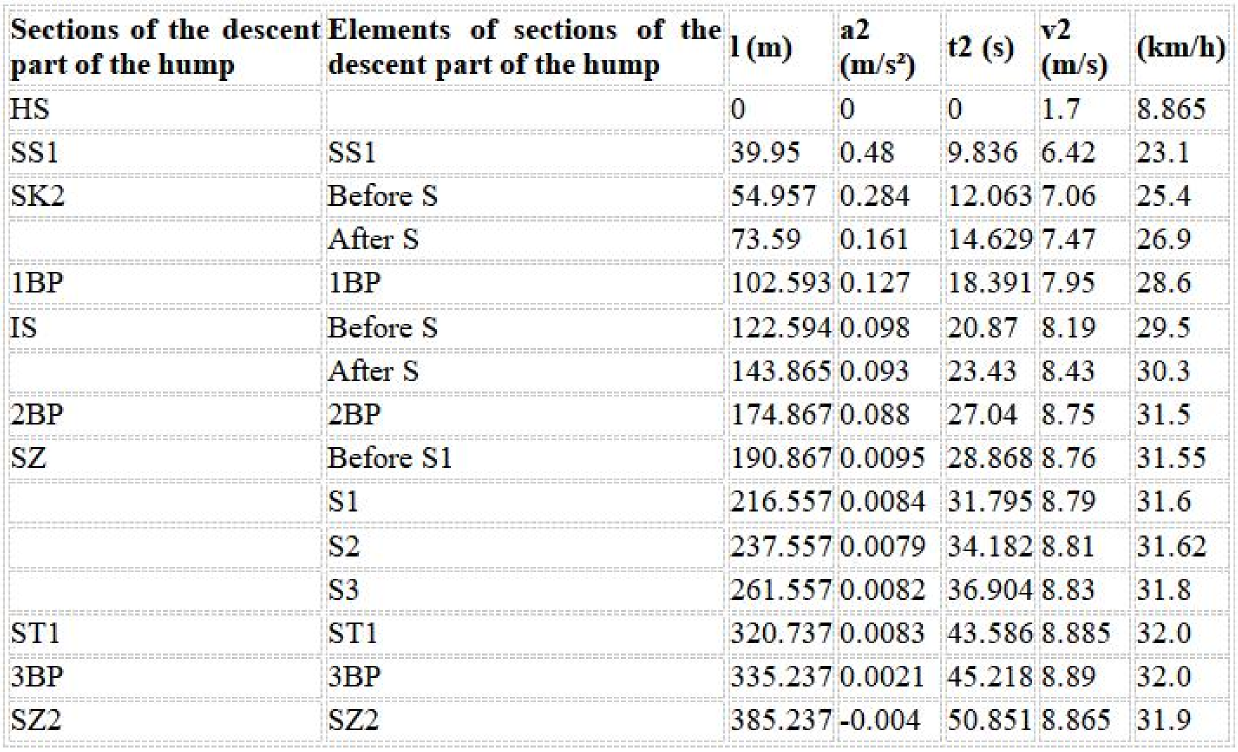
Using the developed calculation programme (for example, see [10]), to analyse various disbanding variants of a "very poor runner" under given characteristics and climatic conditions and to identify the optimal disbanding mode for the "very poor runner".

Formulation of the Task

Similar to [1–5], it is required to compare the results of studies on the movement of a "very poor runner" down the descent part of the marshalling hump using the powers of the hump brake positions and without applying braking.

Results of Studies in Tabular and Graphical Forms

Below, in Table 1, we present the results of studies on the movement of a "very poor runner" "on passage" down the descent part of the marshalling hump under the influence of the projection of the tailwind force from the South-West direction both on the end face Fгвх and on the side of the wagon Fгв.у, while simultaneously accounting for resistances of all kinds (environment Fср., switches Fстр., curves Fкр., snow and frost Fси.) Fс.



Sections of the descent part of the hump	Elements of sections of the descent part of the hump	l (m)	a2 (m/s²)	t2 (s)	v2 (m/s)	(km/h)
HS		0	0	0	1.7	8.865
SS1	SS1	39.95	0.48	9.836	6.42	23.1
SK2	Before S	54.957	0.284	12.063	7.06	25.4
	After S	73.59	0.161	14.629	7.47	26.9
1BP	1BP	102.593	0.127	18.391	7.95	28.6
IS	Before S	122.594	0.098	20.87	8.19	29.5
	After S	143.865	0.093	23.43	8.43	30.3
2BP	2BP	174.867	0.088	27.04	8.75	31.5
SZ	Before S1	190.867	0.0095	28.868	8.76	31.55
	S1	216.557	0.0084	31.795	8.79	31.6
	S2	237.557	0.0079	34.182	8.81	31.62
	S3	261.557	0.0082	36.904	8.83	31.8
ST1	ST1	320.737	0.0083	43.586	8.885	32.0
3BP	3BP	335.237	0.0021	45.218	8.89	32.0
SZ2	SZ2	385.237	-0.004	50.851	8.865	31.9

Similar to [1–5], in Table 1: HS – hump summit; SS1 and SS2 — first and second speed sections of the hump; 1BP, 2BP and 3BP — first, second and third brake positions of the hump, through which the wagon moves "on passage" (i.e., without braking by wagon retarders); IS –

intermediate section of the hump; SZ – switch zone of the hump; SP1 and SP2 – first and second sections of the sorting track; S – dividing switch (switch), S1, S2 and S3 – first, second and third switches; l – length of each section of the descent part of the hump, starting from the hump summit; a2 – wagon acceleration on each separate section of the hump; t2 and v2 – movement time and rolling speed of the wagon, starting from the hump summit. Here, l = 0 corresponds to the marshalling hump summit (HS), and v01 = 1.7 m/s or 8.87 km/h – the pushing speed of the wagon onto HS (or initial wagon speed) in the case of designing the hump throat for 24 tracks. Considered are humps of increased and high capacity (HIC and HC), as in [1–5].

The data in Table 1, as in [1–3], correspond to the following initial data: G = 538 – gravitational force of the "very poor runner" with load, accounting for inertia of rotating masses, kN (with gravitational force of the "very poor runner" Ggr = 280 kN); M = 5.484×10^4 – mass of the "very poor runner" with load, accounting for inertia of rotating masses, kg; Frв.x = 3.192 and Frв.y = 13.68 – forces of small tailwind impact on the wagon, both along and across the wagon, kN.

Explanations of the acceleration values a2, movement time t2, and wagon rolling speed v2 without braking by wagon retarders, obtained for each section of the descent part of the marshalling hump, given in Table 1, for the case of the projection of the South-West direction wind force on both the end face Frвx and the side Frв.y of the wagon, accounting for simultaneous impact of resistances of all kinds (environment, switches, curves, snow and frost) Fc, are similar to those given in [1–5].

Using the data from the third and fourth columns of Table 1, we construct graphs of wagon acceleration ak on sections lj of the descent part of the marshalling hump under the influence of the projection of the tailwind force from the South-West direction Frв, accounting for simultaneous impact of resistances of all kinds (environment, switches, curves, snow and frost) Fc and the projection of the tailwind on the wagon side Frвy (Fig. 1).

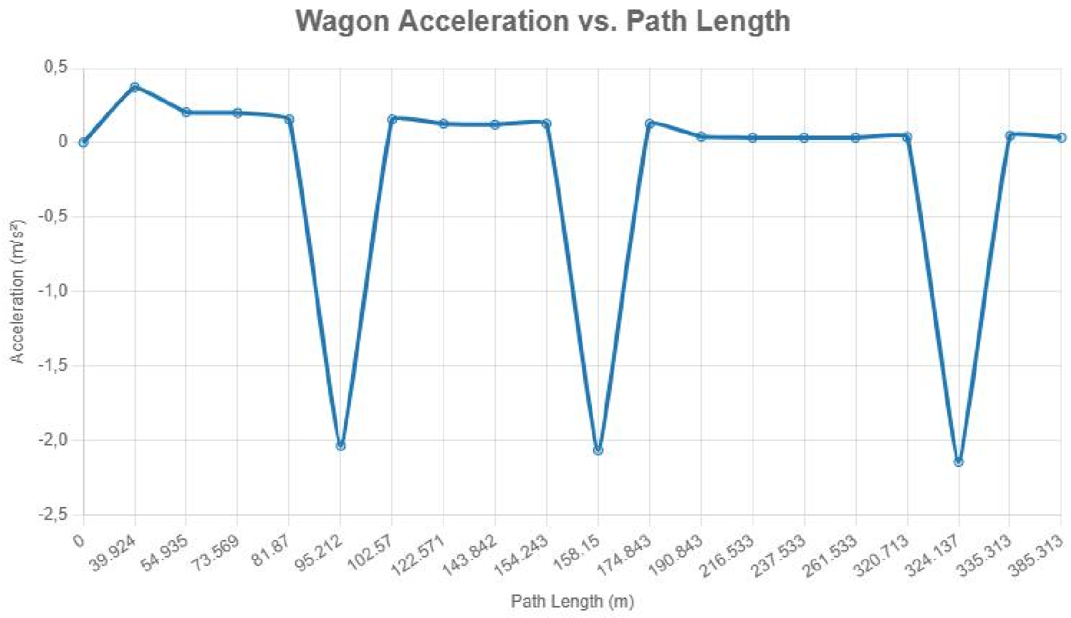


Fig. 1. Graphical changes ak = f(lj) accounting for forces Fc and Frвy.

The designations in Fig. 1 are the same as in Table 1.

In Fig. 1, for example, on the second section of the sorting track (SZ2) with length l9 = 50.0 m (in Table 1: 385.237 m) and slope ψ09 = 0.0006 rad (0.6 per mille) at the wagon entry speed to this section v09 = 8.888 m/s and accounting for the projection of the tailwind from the South-West direction Fгв on the wagon side Fгв.y on the second sorting track section (SP2), the linear acceleration, unlike [1], is uniformly decelerated (has a negative value, for example, for the given initial data a9 = -0.0042 m/s^2), and on all brake position sections (1BP, 2BP and 3BP), as in [1], – uniformly accelerated.

Note that according to the theoretical premises of works [7, 11–13], it is impossible to calculate the wagon accelerations on the hump brake positions because they take the linear acceleration as the acceleration of free fall of the body accounting for inertia of rotating masses (wheel pairs), which is fundamentally erroneous [6, 8, 9].

Similar to ak = f(lj), using data from the third and fifth, as well as third, sixth and seventh columns of Table 1, one can construct graphical dependencies tk = f(lj) (Fig. 2) and vk = f(lj) (Fig. 3).

Fig. 2. Graphical changes tk = f(lj) accounting for forces Fc and Fгвy

As seen, similar to [1–5], the graphs of wagon movement time from the hump summit (HS) to the calculation point (CP) are practically linearly increasing.

Fig. 3. Graphical changes vk = f(lj) accounting for forces Fc and Frвy

The designations in Fig. 3 are the same as in Fig. 1.

From Fig. 3, it is also clear that in the hump braking zones, for example, on sections 1BP, 2BP and 3BP, as in [1], there is an increase in wagon movement speed, and on the second section of the sorting track (SZ2) accounting for the projection of the tailwind from the South-West direction on the wagon side Frв.y, unlike [1], there is a slight decrease in the speed of the "very poor runner" (for example, from 8.888 m/s or 32.9 km/h to v9 = 8.865 m/s or 31.9 km/h.

It is particularly noted that according to the theoretical premises of works [7, 9, 11–13], as follows from the research results [8], it is impossible to calculate the wagon sliding speed even on the first hump brake position because it equals an imaginary number, since it is calculated by the formula v = sqrt(al^2), where a – wagon linear acceleration value [8], or by v = sqrt(2g'h), where g' – free fall acceleration of bodies accounting for inertia of rotating parts (wheel pairs), although on brake positions, inertia of rotating masses should not be accounted for in principle, and hт – brake position power.

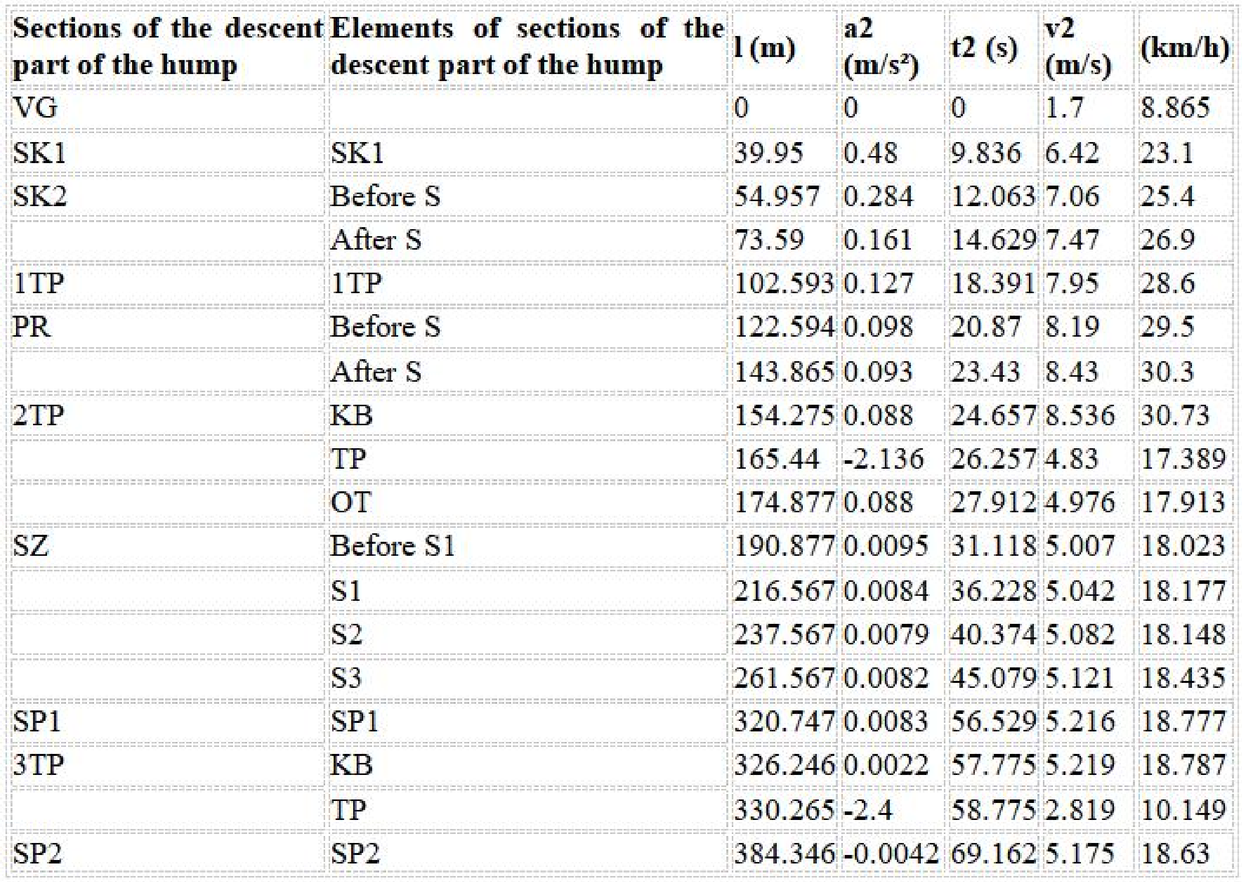
Thus, in the case of disbanding the wagon down the descent part of the marshalling hump (from its summit to the calculation point "on passage" on all brake position sections under the influence of the South-West direction tailwind force Frв accounting for resistances of all kinds Fc, the collision speed of the "very poor runner" "with a group of standing wagons" (31.9 km/h) exceeds the permissible 5 km/h more than 6 times [11].

Hence, it is clear that under the given climatic conditions, it is not possible to apply disbanding without using brake position powers ("on passage") for the "very poor runner".

To determine the optimal disbanding mode, let us consider the case of braking the "very poor runner" on several marshalling hump brake positions using the calculation programme [10].

In Table 2, we present the results of studies on wagon speed changes when passing "on passage" only on the first brake position (1TP) and braking on the second and third brake positions (2TP and 3TP), taking the braking time тзат2 = 1.6 and тзат3 = 1.0 s respectively.

Table 2



Sections of the descent part of the hump	Elements of sections of the descent part of the hump	l (m)	a2 (m/s^2)	t2 (s)	v2 (m/s)	(km/h)
VG		0	0	0	1.7	8.865
SK1	SK1	39.95	0.48	9.836	6.42	23.1
SK2	Before S	54.957	0.284	12.063	7.06	25.4
	After S	73.59	0.161	14.629	7.47	26.9
1TP	1TP	102.593	0.127	18.391	7.95	28.6
PR	Before S	122.594	0.098	20.87	8.19	29.5
	After S	143.865	0.093	23.43	8.43	30.3
2TP	KB	154.275	0.088	24.657	8.536	30.73
	TP	165.44	-2.136	26.257	4.83	17.389
	OT	174.877	0.088	27.912	4.976	17.913
SZ	Before S1	190.877	0.0095	31.118	5.007	18.023
	S1	216.567	0.0084	36.228	5.042	18.177
	S2	237.567	0.0079	40.374	5.082	18.148
	S3	261.567	0.0082	45.079	5.121	18.435
SP1	SP1	320.747	0.0083	56.529	5.216	18.777
3TP	KB	326.246	0.0022	57.775	5.219	18.787
	TP	330.265	-2.4	58.775	2.819	10.149
SP2	SP2	384.346	-0.0042	69.162	5.175	18.63

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