long and heavy trains; fuel and power resources; mode diagrams; haulage mode; mode of coasting; mode of pneumatic and rheostat braking; longitudinal dynamic efforts

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RESEARCH ON SELECTION OF MODES OF DRIVING HEAVY TRAINS ON MAIN IXB AND IXD CORRIDORS OF JSC "LIETUVOS GELEŽINKELIAI"

Summary. Optimum haul times of running for a train schedule and mode diagrams corresponding thereto calculated using the program system passed operational check with the purpose to obtain reliable statistical estimation of their impact on reduction of the fuel consumption on haulage of trains and level of longitudinal dynamic efforts. The optimal speed of the train is chosen (defined) taking into account the given travel time and the longitudinal track profile, when the Diesel locomotive fuel consumption are minimum. Results of experimental research with long trains, weight up to 8000 tons, are presented herein. Experimental operational trips confirmed the correctness of theoretical preconditions and techniques of selection of optimum modes of driving of long trains, demonstrated potential for decrease of level of longitudinal dynamic efforts by 1.5–2 times and achievement of fuel economy on haulage up to 5–8 % when such trains move on a site with the undulating way profile.

ИССЛЕДОВАНИЯ ПО ВЫБОРУ РЕЖИМОВ ВОЖДЕНИЯ ТЯЖЕЛОВЕСНЫХ ПОЕЗДОВ НА ГЛАВНЫХ КОРИДОРАХ IXB И IXD АО «ЛЕТУВОС ГЯЛЯЖИНКЯЛЯЙ»

Резюме. Оптимальные перегонные времена хода к графику движения и соответствующие им режимные карты, рассчитанные с помощью программного комплекса, прошли эксплуатационную проверку с целью получения достоверной статистической оценки их влияния на уменьшение расхода топлива на тягу поездов и уровень продольных динамических усилий. По заданому временив пути, в зависимости от продольного профиля, подбирается оптимальная скорость движения поезда с наименьшим расходом топлива. Приведены результаты экспериментальных исследований с длинносоставными поездами массой до 8000 т. Опытные эксплуатационные поездки подтвердили корректность теоретических предпосылок и методики выбора оптимальных режимов вождения длинносоставных поездов, показали возможность уменьшения уровня продольных динамических усилий в 1,5–2 раза и достижения экономии топлива на тягу до 5–8 % при движении таких поездов по участку с перевалистым профилем пути.

1. INTRODUCTION

Increase in weight and length of cargo trains is one of the important and effective areas of technical policy in the railway transport of Lithuania. The increase in carrying capacity of railways can be achieved by organization of regular trips of long trains. When such trains move through changes of gradient on the longitudinal way profile, the longitudinal dynamic efforts can reach dangerous (in aspect of durability and stability of carriages in a track) values.

Therefore the mode of driving a train should be selected in view of dynamic burden of a rolling stock on each specific site [1–8].

Optimum haul times of running for a train schedule and mode diagrams corresponding thereto calculated using the developed technique [9] passed operational check with the purpose to obtain reliable statistical estimation of their impact on decrease of the fuel consumption on haulage of trains and level of longitudinal dynamic efforts.

2. FULL-SCALE STUDIES

Field investigations with long trains, weight up to 8000 tons, (double-headed) with two locomotives and contjoint trains to two locomotives located in the head and middle of a train which in the long term could be operated on main corridors IXB (Kena–Vilnius–Kaišiadorys–Radviliškis–Šiauliai–Klaipėda) and IXD (Kaišiadorys–Kybartai) of the Lithuanian railways.

The research was aimed for development of rational and safe modes of driving the long and conjoint trains by studying the longitudinal dynamic efforts arising in such trains in the course of running on sites of intricate profile of the long mileage way according to calculated mode diagrams obtained using the high-speed personal computers.

Experimental research allowed making final updating of calculated mode diagrams, to present recommendation on rational and safe ways of operating the traction and braking tools of locomotives, as well as to recommend a number of organizational and technical measures.

In service conditions impact was investigated of uncoordinated actions of drivers of a head (HL) and auxiliary (additional) locomotives (AL) on the level of longitudinal dynamic efforts in various modes of the train running.

Before taking the experimental trips, the gasoline locomotives and cars were equipped by gauges for measurement and recording of longitudinal efforts, traction and brake currents of traction electric motors (TEM), fluctuations of air pressure in the brake highway and brake cylinders, and other parameters. After weighing and connecting of measuring cables, pickup calibration of gauges of all measured parameters was performed.

Since a great number of technical devices were required, the experimental trips were performed on the basis of a rake in Ukraine. Figure 1 presents the scheme of making up of an experimental long train with indication of sections where values of investigated parameters [2] were recorded. Figure 2 presents the scheme of making up of a test conjoint train with indications of sections where values of investigated parameters [2] were recorded.

For recording of measured values, the strain-gauge instrumentation (SGI) in the track test car was applied. Figure 3 presents the block diagram of measurements and records of the investigated parameters taken in the track test car during the experimental trips.

Recorded parameters were processed in test trains in both train and laboratory conditions in order to determine the maximum values of longitudinal forces, as well as to perform the qualitative analysis of wave processes proceeding in a train caused by unsteady modes of the train running in the course of haulage and braking.

Analysis of longitudinal dynamic efforts in long and conjoint trains, weight up to 8000 tons, in transitive and permanent modes of running on real sites Mironovka–Piatichatki and Verhovcevo–Nizhnedneprovsk Station is presented herein.

As an example, Fig. 4–5 present oscillograph charts recorded on starting of a conjoint train from a point (Fig. 4) and on its coasting through changes of gradient on the longitudinal way profile.

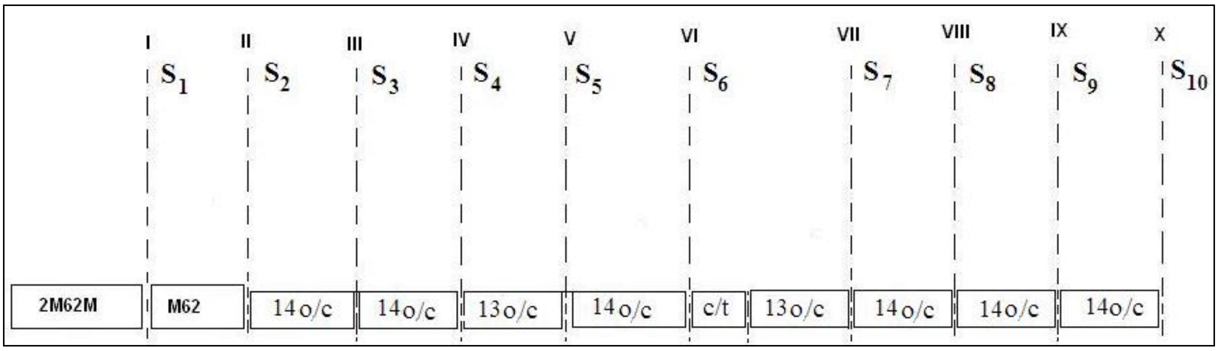

Fig. 1. Scheme of a long train and recorded parameters on the basis of a rake: M62 – locomotive; $S_1 \div S_{10}$ – longitudinal efforts in corresponding sections of the experimental train (S_{10} – between last and penultimate cars); c/t – track test car; o/c – open car

Рис. 1. Схема длинносоставного поезда и регистрируемых параметров на базе постоянного состава: М62 – локомотив; $S_1 \div S_{10}$ – продольные усилия в соответствующих сечениях опытного поезда (S_{10} – между последним и предпоследним вагонам); c/t – вагон-лаборатория; o/c – полувагоны

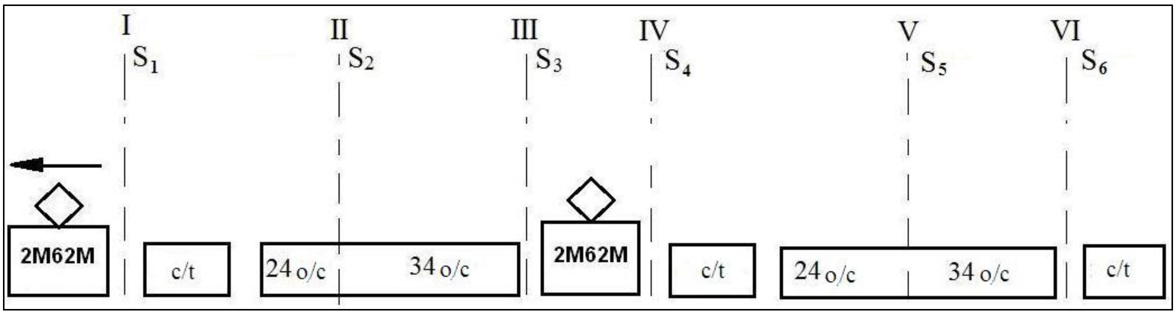

Fig. 2. Scheme of a conjoint train and recorded parameters on the basis of a rake: $S_1 \div S_6$ – longitudinal efforts in corresponding sections of the experimental train; c/t – track test car; o/c – open car

Рис. 2. Схема соединённого поезда и регистрируемых параметров на базе постоянного состава: $S_1 \div S_6$ – продольные усилия в соответствующих сечениях опытного поезда; c/t – вагон-лаборатория; o/c – полувагоны

Designation of lines on oscillograph charts are as follows: I_{B1}, I_{G1} – brake current and current of generator of the HL locomotive, I_{B6}, I_{G6} – brake current and current of generator of the AL locomotive; $S_1 \div S_{10}$ – longitudinal efforts in automatic couplings.

When processing oscillograph charts, during all trips the maximum values of stretching and compressing longitudinal efforts were recorded in sections of the train on starting from a point, at each kilometre of the train running in haulage mode and on coasting through changes of gradient on the longitudinal profile. Such processing of oscillograph charts was resulted in tables of maximum (S_{max}) and the most of maximum (maxS) values of longitudinal efforts on length of the conjoint train for all abovementioned modes of running. These results are presented in Table 1 (starting from a point), Table 2 (haulage mode), Table 3 (mode of coasting through changes of gradient on the longitudinal way profile).

In tables stretching efforts are presented with a "+" sign and compressing efforts – with a "- " sign. Table 4 executed on the basis of Tables 1–3 presents the most (maxS) longitudinal efforts in a train received during all eight trips in abovementioned transitive modes of railway traffic.

As follows from tables, on starting of a conjoint train from a point, the most stretching efforts in sections of a train have made from 0.50 up to 0.94 MN.

In haulage mode, on increasing and decreasing haulage, the maxS stretching effort has made 0.96, and compressing effort – 0.92 MN.

In coasting mode caused by running through changes of gradient on the longitudinal way profile, the most stretching efforts have not exceeded 0.97, and compressing efforts – 0.95 MN.

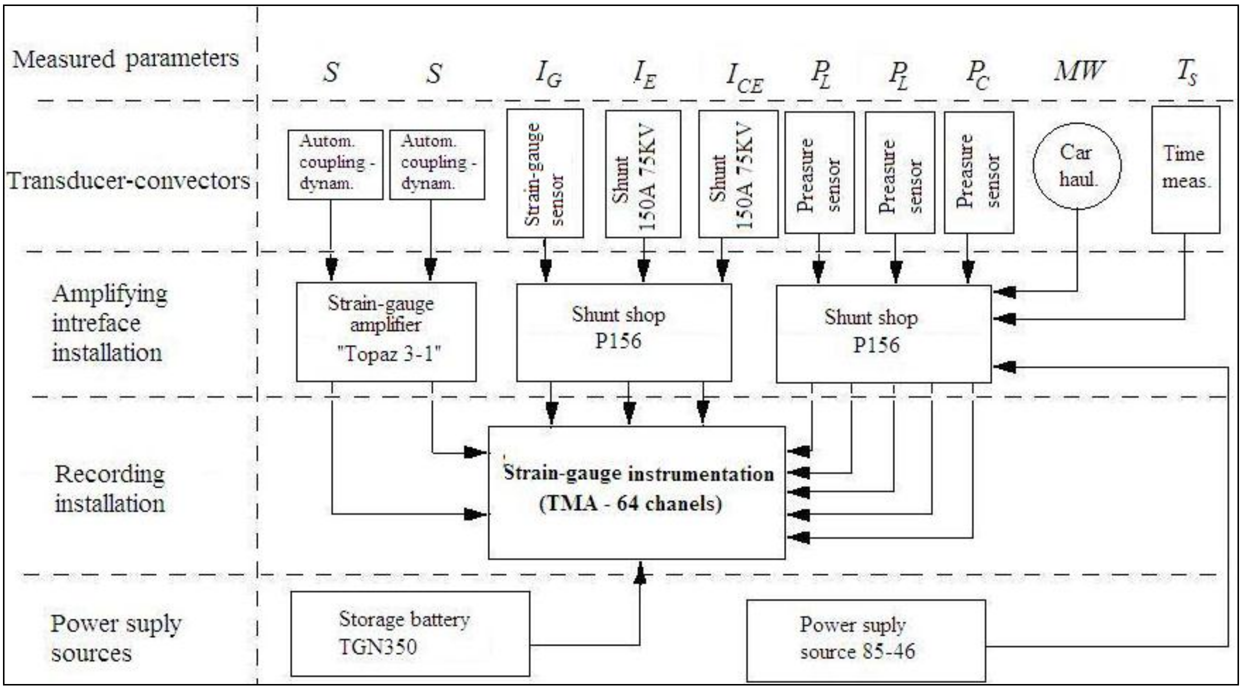

Fig. 3. Block diagram of measurements and records of investigated parameters taken in a track test car: S – longitudinal force; I_G – armature current; I_E – excitation current; I_{CE} – control excitation current; P_L – line pressure; P_C – pressure in the cylinder; MW – momentum wheel; T_s – time stamp

Рис. 3. Блок-схема измерений и регистраций исследуемых параметров, проводимых в вагоне-лаборатории: S – продльная сила; I_G – ток якоря; I_E – ток возбуждения; I_{CE} – ток управления возбуждения; P_L – давление в магистрале; P_C – давление в цилиндре; MW – обороты колеса; T_s – отметка времени

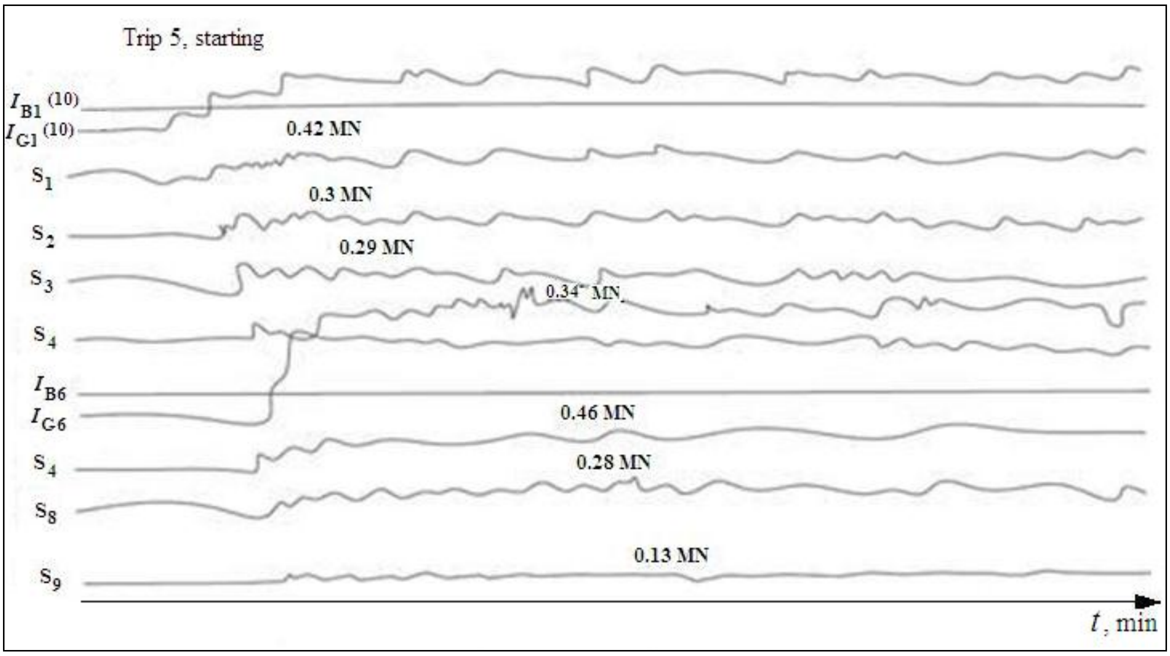

Fig. 4. Oscillograph chart for a conjoint train in mode of starting

Рис. 4. Осциллограмма режима трогания соединённого поезда

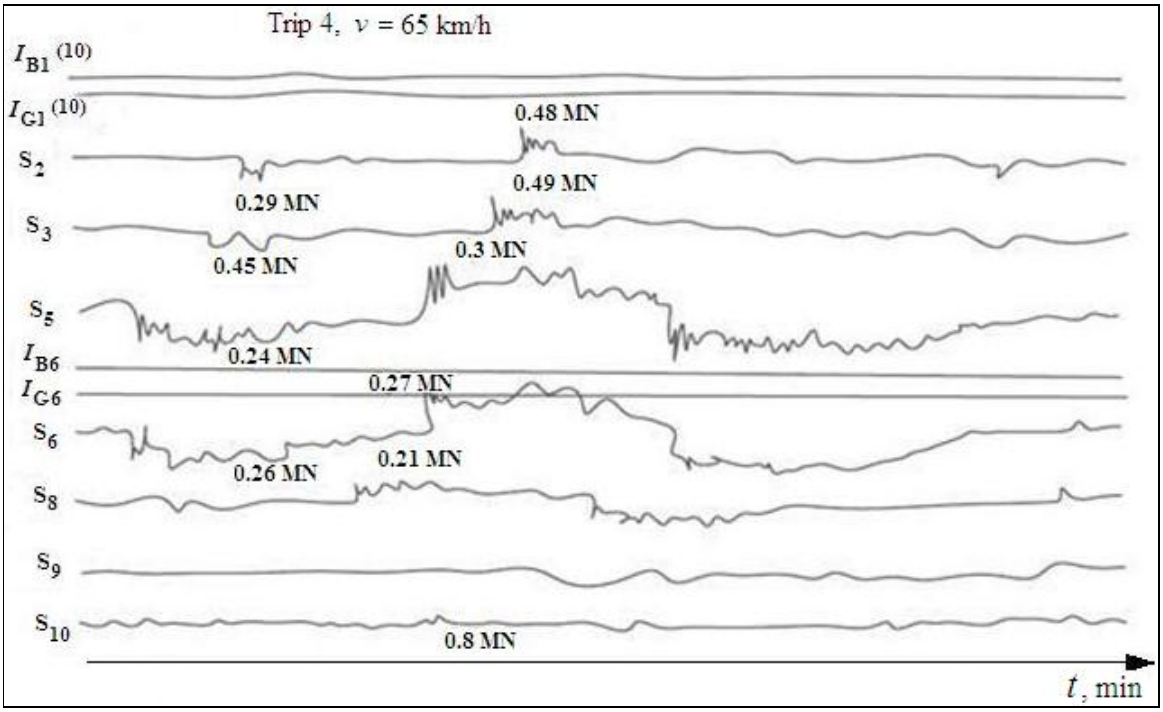

Fig. 5. Oscillograph chart for a conjoint train in mode of coasting through the change of gradient on the longitudinal way profile, v = 65 km/h

Рис. 5. Осциллограмма режима выбега при движении соединенного поезда по перелому продольного профиля пути, v = 65 км/ч

Thus, for all haulage modes of the maxS of both stretching and compressing efforts have not exceeded 1.0 MN.

Table 1

Maximal (S_{max}) and the most (maxS) longitudinal forces in a train on starting on Mironovka–Piatihatki Site

Trip No.	Number of tests	S_{max} in sections of a train, MN							maxS, MN
		1	2	3	5	6	8	9	
2	2	+0,48	+0,52	+0,56	+0,94	+0,84	+0,54	+0,36	+0,94
4	2	+0,36	+0,29	+0,43	+0,40	+0,50	+0,35	+0,48	+0,50
8	3	+0,92	+0,69	+0,48	+0,55	+0,76	+0,50	+0,60	+0,94
For all trips	7	+0,94	+0,69	+0,56	+0,94	+0,84	+0,54	+0,60	+0,94

All experiments on pneumatic adjusting (PB) and stopping (SB) braking were performed by a discharge step of brake highway 0.7–0.8 MPa. Thus under command from the head locomotive (HL) the pressure was, as a rule, simultaneously, reduced in the brake highway of the additional (AD) locomotive.

It should be noted, that all cars of the train were equipped with automatic brake control valves conv. No. 483 and composite brake hobs. Brake highways of both components of the train were connected making a through highway.

Table 2

Maximal (S_{max}) and the most (maxS) longitudinal forces in a train running in haulage mode on Mironovka–Piatihatki Site

Trip No.	Number of tests	S_{max} in sections of a train, MN							maxS, MN
		1	2	3	5	6	8	9	
1	38	+0,73	+0,60	+0,64	+0,77	+0,88	+0,95	+0,48	+0,95
		-0,2	-0,46	-0,40	-0,85	-0,92	-0,46	-0,35	-0,92
3	74	+0,93	+0,67	+0,72	+0,80	+0,96	+0,69	+0,75	+0,92
		-0,29	-0,32	-0,54	-0,68	-0,64	-0,73	-0,64	-0,73
5	86	+0,75	+0,70	+0,60	+0,76	+0,84	+0,61	+0,57	+0,84
		-0,10	-0,25	-0,42	-0,56	-0,50	-0,62	-0,78	-0,78
7	28	+0,67	+0,60	+0,67	+0,60	+0,87	+0,57	+0,64	+0,87
		-0,55	-0,34	-0,43	-0,53	-0,52	-0,44	-0,69	-0,69
For all trips	224	+0,93	+0,7	+0,72	+0,80	+0,96	+0,95	+0,75	+0,96
		-0,55	-0,46	-0,54	-0,85	-0,92	-0,73	-0,78	-0,92

Table 3

Maximal (S_{max}) and the most (maxS) longitudinal forces in a train, caused by change of gradient on the longitudinal way profile on coasting on Mironovka–Piatihatki Site

Trip No.	Number of tests	S_{max} in sections of a train, MN							maxS, MN
		1	2	3	5	6	8	9	
2	63	+0,2	+0,50	+0,37	+0,67	+0,83	+0,62	+0,60	+0,83
		-0,10	-0,62	-0,42	-0,52	-0,62	-0,63	-0,70	-0,70
4	36	+0,31	+0,64	+0,40	+0,51	+0,57	+0,48	+0,60	+0,64
		-0,25	-0,50	-0,57	-0,66	-0,62	-0,68	-0,72	-0,72
6	58	+0,56	+0,71	+0,87	+0,67	+0,97	+0,58	+0,74	+0,97
		-0,40	-0,57	-0,50	-0,75	-0,73	-0,54	-0,60	-0,75
7	18	+0,21	+0,21	+0,26	+0,32	+0,52	+0,61	+0,63	+0,63
		-0,21	-0,63	-0,58	-0,69	-0,63	-0,79	-0,95	-0,95
8	14	+0,17	+0,27	+0,22	+0,24	+0,27	+0,19	+0,17	+0,27
		-0,33	-0,48	-0,65	-0,70	-0,81	-0,41	-0,60	-0,81
For all trips	189	+0,56	+0,71	+0,87	+0,67	+0,97	+0,62	+0,74	+0,97
		-0,40	-0,63	-0,65	-0,75	-0,81	-0,79	-0,95	-0,95

Based on processing of oscillograph charts obtained in the course of all trips, the maximal (Smax) longitudinal forces given in recorded sections of the train for all mentioned types of braking were determined. Tables 5–9 present the said data.

The same Tables present values of the most (maxS) longitudinal forces given in the each trip.

Table 5 presents the longitudinal forces arising on adjusting pneumatic braking (PB) by a step 0.8 MPa on sites of the route of even and odd directions of running. Apparently, the longitudinal compressing and stretching forces irrespective of sections and directions of running do not, as a rule, exceed 1.00 MN.

However in some cases values of the longitudinal forces exceeding 1.0 MN were determined: S_6 (trip 2); S_1 (trip 8). In these experiments the longitudinal efforts reached +1.12 MN (stretching) and -1.04 MN (compressing).

Table 4

The most (maxS) longitudinal efforts in a train caused by starting from a point, increase and decrease of haulage and changes of gradient on the longitudinal way profile on coasting for all trips

Transitional mode	maxS in sections of a train, MN							For a train
	1	2	3	5	6	8	9	
Starting from a point	+0,94	+0,69	+0,56	+0,94	+0,84	+0,57	+0,60	+0,94
Traction mode	+0,94	+0,79	+0,97	+0,80	+0,96	+0,95	+0,83	+0,97
	-0,55	-0,46	-0,54	-0,85	-0,92	-0,93	-0,78	-0,93
Coasting (impact of longitudinal profile)	+0,56	+0,71	+0,88	+0,80	+0,97	+0,78	+0,78	+0,97
	-0,40	-0,63	-0,66	-0,75	-0,81	-0,84	-0,95	-0,95
For all traction modes	+0,94	+0,79	+0,97	+0,94	+0,97	+0,95	+0,83	+0,97
	-0,56	-0,63	-0,88	-0,85	-0,92	-0,93	-0,95	-0,95

Table 5

Maximal (S_{max}) and the most (maxS) longitudinal forces in a train on pneumatic adjusting braking (PB) on Mironovka–Piatihatki Site

Trip No.	Number of tests	S_{max} in sections of a train, MN							maxS, MN
		1	2	3	5	6	8	9	
2	2	+0,24	+0,40	+0,36	+0,89	+0,84	+0,46	+0,42	+0,89
		-0,15	-0,46	-0,83	-0,82	-1,04	-0,37	-0,42	-1,04
4	1	+0,30	+0,50	+0,55	+0,67	+0,73	+0,70	+0,67	+0,73
		-0,70	-0,17	-0,20	-0,17	-0,19	-0,13	-0,29	-0,70
6	10	+0,57	+0,69	+0,70	+0,78	+0,90	+0,58	+0,46	+0,90
		-0,51	-0,76	-0,63	-0,75	-0,73	-0,63	-0,46	-0,76
8	4	+1,12	+0,87	+1,00	+1,07	+0,78	+0,75	+0,55	+1,12
		-0,80	-0,80	-0,65	-0,63	-0,65	-0,72	-0,50	-0,80
For all trips	17	+0,12	+0,87	+1,00	+1,07	+0,90	+0,75	+0,67	+1,07
		-0,80	-0,80	-0,65	-0,82	-1,04	-0,72	-0,50	-1,04

Table 6

Maximal (Smax) and the most (maxS) longitudinal forces in a train on rheostat (R) braking on Mironovka–Piatihatki Site

Trip No.	Number of tests	S_{max} in sections of a train, MN							maxS, MN
		1	2	3	5	6	8	9	
2	17	+0,21	+0,15	+0,14	+0,67	+0,61	+0,50	+0,55	+0,67
		-0,21	-0,49	-0,61	-0,42	-0,44	-0,42	-0,37	-0,61
4	21	+0,10	+0,20	+0,23	+0,25	+0,20	+0,26	+0,55	+0,55
		-0,25	-0,33	-0,46	-0,42	-0,52	-0,48	-0,48	-0,52
6	6	+0,23	+0,29	+0,33	+0,41	+0,26	+0,25	+0,23	+0,33
		-0,23	-0,29	-0,46	-0,48	-0,88	-0,46	-0,37	-0,88
8	5	+0,34	+0,53	+0,62	+0,70	+0,74	+0,90	+0,88	+0,90
		-0,46	-0,38	-0,54	-0,52	-0,39	-0,37	-0,33	-0,54
For all trips	52	+0,34	+0,51	+0,62	+0,70	+0,74	+0,90	+0,88	+0,90
		-0,46	-0,38	-0,54	-0,52	-0,88	-0,48	-0,48	-0,88

Table 7

Maximal (Smax) and the most (maxS) longitudinal forces
in a train on mixed (R + PB) braking on Mironovka–Piatihatki Site

Trip No.	Number of tests	S_{max} in sections of a train, MN							maxS, MN
		1	2	3	5	6	8	9	
3	6	+0,55	+0,60	+0,54	+0,76	+0,57	+0,80	+0,75	+0,80
		-0,28	-0,42	-0,33	-0,54	-0,43	-0,34	-0,50	-0,54
5	1	+0,53	+0,55	+0,71	+0,98	+0,89	+0,74	+0,83	+0,98
		-0,21	-0,25	-0,33	-0,74	-0,23	-0,40	-0,26	-0,74
7	3	+0,10	+0,12	+0,10	+0,14	+0,19	+0,17	+0,21	+0,21
		-0,26	-0,21	-0,24	-0,17	-0,38	-0,18	-0,16	-0,38
For all trips	10	+0,55	+0,60	+0,71	+0,98	+0,89	+0,80	+0,83	+0,98
		-0,28	-0,42	-0,33	-0,54	-0,38	-0,40	-0,50	-0,54

Table 8

Maximal (Smax) and the most (maxS) longitudinal forces in
a train on stopping (SB) braking on Mironovka–Piatihatki Site

Trip No.	Number of tests	S_{max} in sections of a train, MN							maxS, MN
		1	2	3	5	6	8	9	
2	5	+0,32	+0,32	+0,60	+0,12	+0,92	+0,83	+0,92	+0,92
		-0,34	-0,56	-0,68	-1,55	-1,50	-0,66	-0,28	-1,55
4	3	+0,29	+0,32	+0,47	+0,35	+0,21	+0,20	+0,19	+0,47
		-0,17	-0,10	-0,10	-0,13	-0,14	-0,13	-0,14	-0,17
6	2	+0,10	+0,10	+0,10	+0,30	+0,33	+0,25	+0,37	+0,37
		-0,15	-0,37	-0,54	-0,41	-0,23	-0,10	-0,10	-0,54
8	3	+0,61	+0,69	+0,57	+0,86	+0,88	+0,60	+0,60	+0,88
		-0,11	-0,16	-0,30	-0,48	-0,50	-0,29	-0,57	-0,57
For all trips	13	+,61	+,69	+,60	+,86	+,92	+,83	+,92	+,92
		-0,34	-0,56	-0,68	-1,55	-1,50	-0,66	-0,57	1,55

Table 9

The most (maxS) values of longitudinal efforts in
a train for all experimental trips in various braking modes

Braking mode	maxS in sections of a train, MN							For a train
	1	2	3	5	6	8	9	
PB	+1,12	+0,87	+1,00	+1,07	+0,90	+0,83	+1,06	+1,12
	-0,80	-0,80	-0,65	-0,82	-1,04	-0,81	-0,57	-0,82
R + PB	+0,55	+0,60	+0,58	+0,98	+0,89	+0,92	+0,83	+0,98
	-0,28	-0,42	-0,41	-0,72	-0,46	-0,74	-0,50	-0,74
R	+0,34	+0,53	+0,62	+0,83	+0,83	+0,98	+0,88	+0,98
	-0,55	-0,50	-0,54	-0,72	-0,88	-0,73	-0,77	-0,88
SB	+0,61	+0,69	+0,60	+0,86	+0,92	+0,83	+0,92	+0,92
	-0,34	-0,56	-0,68	-1,55	-1,50	-0,66	-0,57	-1,55
For all types of braking	+1,12	+0,87	+1,00	+1,07	+0,92	+0,92	+1,06	+1,12
	-0,80	-0,80	-0,68	-1,55	-1,50	-0,98	-0,77	-1,55

Arising of stretching forces of such range is explained by ‘pull-offs’ occurring because of absence of preliminary compression of a rake and uncoordinated actions of train drivers.

3. CONCLUSIONS

1. As experiment demonstrated, rheostat braking (R) applied with the purpose of maintaining the constant speed of running on long descents (in this case – up to 8–9‰) does not result in arising of longitudinal forces which values are dangerous to durability and stability when squeezing the loaded cars off a track since their level does not exceed ± 1.0 MN (Table 6).
2. As rather effective type of adjusting braking, 'mixed' braking (pneumatic braking with preliminary switch-on of a rheostat) can be applied since even significant decrease in speed of running does not result in arising of longitudinal forces exceeding 1.0 MN. Furthermore, when applying rheostat braking (for compression of a rake) followed by adjusting pneumatic braking, the mean value of longitudinal compressing forces on so long descents (up to 8–9‰) is 0.5 MN that is less than for 'just' pneumatic braking (Table 7).
3. When applying stopping (SB) braking (Table 8) during trip No. 2 in sections S_5 and S_6, there were two cases recorded with values of compressing efforts within 1.50–1.55 MN. The reason was that at the moment of brake application the rake was in the stretched condition and moved with low speed (25 km/h). In other 11 experiments with SB braking (Table 8) the compressing forces did not exceed 0.68 MN, and stretching forces – 0.92 MN.
4. Data in Table 9 allow stating that even considering the given single cases of deviations from recommendations on application of brake tools of locomotives in long and the conjoint trains, the longitudinal efforts do not reach dangerous values.

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