ON THE PROBLEM OF DYNAMIC RESPONSE OF THE LONG TRAINS INCLUDING JOINT ONES WITH THE LIQUID CARGO

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The results of long trains with liquid cargo dynamic response at braking obtained by the mathematical simulations are given in the article. Different approaches of the lead and helping locomotives control are considered for the various schemes of the train make-up. Numerical experiments were carried out for the various types of braking on the horizontal track segment and for different regimes of air diffusers work – middle or loaded. The initial motion speeds were equal to 20 and 80 km/h. For the higher speeds the braking distances were estimated. Recommendations on the longitudinal dynamic response reduction in the long trains with liquid cargo are given on the basis of the carried out numerical calculations.

Key words: Longitudinal dynamic response, long joint trains, braking, mathematical simulations, movable liquid

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Under the estimation of the trains longitudinal dynamic response at braking it was assumed that the cars are equipped by air diffusers with the conditional number 483 switched on for the middle or loaded working regime and by composite brake shoes, and the intercar connections are equipped by the elastic-friction draft gears SH-1-TM [1]. The study of tension trains braking allowed to obtain the highest impact forces, and the study of compressed trains – to estimate the forces of quasi-static character.

Numerical values of parameters describing the work of braking systems, intercar connections and thrust control systems were taken in accordance with the long-time tests carried out for trains in natural conditions of the test ring at the station Shcherbinka of the Moscow railways by scientists from DIIT, VNIIZhT sometimes together with the scientists of other institutions.

At the modeling of trains transient motion regimes when tank-cars included in the train are not filled fully, the liquid was modeled by one mass movable in relation to the tank-car tank and by one mass of the unmovable part of liquid [2]. It was assumed that the movable masses are "connected" with the tank by "springs" at the height higher than the upper "edge" of the unmovable mass. Masses and "spring" stiffnesses were determined by the approach given in paper [4]. Only the longitudinal displacements of the liquid movable part was taken into account in our paper.

Let's first determine the length and the mass of the train which consists of the same on type and mass tank-cars, for which the level of the highest forces is less than the permissible value on conditions of strength and cars stability from forcing away (2.5MN).

To solve this problem, the trains made-up from four-axle tank-cars with the 89 tonne masses and two locomotives VL-80t situated in the train head were considered. It was assumed at modeling that the liquid with the density of ρ=0.81 t/m^3 is inside the tank with the liquid free surface situated on the distance of 0.35 m from the upper internal surface of the tank-car tank. The emergency braking with initial speed of 20 km/h on the track horizontal segment was considered.

The highest values of the tension (+) and compressing (-) longitudinal forces are shown in Fig. 1 for the trains of various length.

From the plots given in Fig.1, it is seen that in the train of 10000 t mass consisting of 109 tank-cars the forces at the emergency braking are higher than the permissible values.

As it is known, one of the ways of the longitudinal forces reduction for trains with the increased length is setting the helping locomotive in the middle or at the end of the train.

To solve this problem, the connected trains with 1390 meters length, consisted of 110 four-axle tank-cars of 90 t mass and two locomotives VL-80t were considered. It was assumed at mathematical modeling that the carbamide-ammoniacal mixture is in tank-cars with the density of ρ=1.31 t/m^3 with the level of the liquid free surface in 1.35 m distance from the upper inner surface of the tank-car tank.

Two schemes of the joint train make-up were considered. For the first scheme, it was assumed that the helping locomotive is situated in the middle part of the train, for the second scheme the helping locomotive was situated in the one third part distance from the train end. At the braking modeling it was assumed that the helping locomotive is controlled synchronously with the lead one or it is controlled by the braking line discharge wave, when the lead locomotive is acting as usually and the helping one is realizing the emergency braking after the wave of the pressure reduction in the braking line has come. Two ways of the braking line connection were considered under the study of the joint trains dynamic response: the through braking pipe and the separated (autonomous) ones. The cases of braking only by the lead locomotive and only by the helping locomotive were also considered for the through braking pipe.

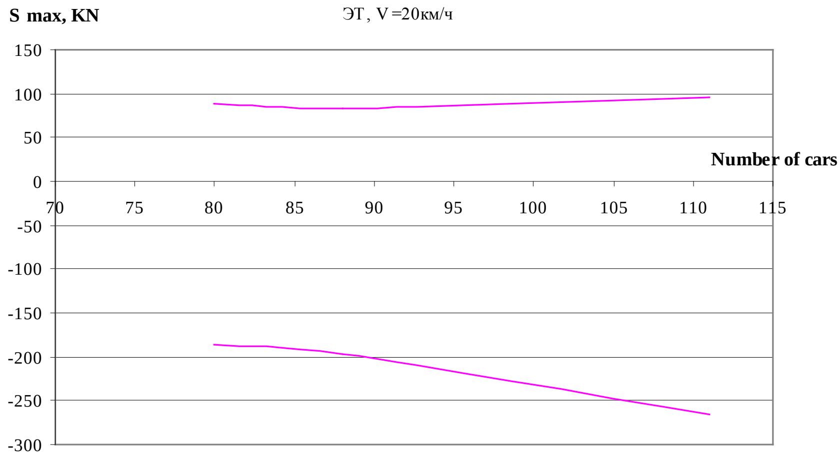

Fig.1. Dependence of the highest longitudinal forces in the train on the number of tank-cars at the emergency braking by the lead locomotive.

To estimate the highest impact longitudinal forces, braking of the tension trains was modeled, at this the clearances in intercar connections were equal to 65 mm.

Numerical tests have been done for the different types of braking on the horizontal track segment (the emergency braking (EB) and the full service brake application (FSBA) and for various regimes of the air distributors work (the middle one and the loaded one). The initial speeds were equal to 20 and 80 km/h.

For each case diagrams of the maximum longitudinal forces distribution along the train, time histories of forces for given cross-sections, values of maximum longitudinal forces in a train for the given time with the cross-section number notation where the force occurred were determined by the results of calculations. At the emergency braking modeling from the speed of 80 km/h the braking distances have been estimated. Values of the maximum expected longitudinal forces in the train are determined by maximum calculated values as it was done in paper [3].

As an example, plots of the highest longitudinal forces distribution along the train made-up from 110 tank-cars at the emergency braking from the speed of 20 km/h when the second locomotive is situated in the middle of the train are given in Fig. 2. The results shown in Fig. 2 correspond to the air distributor loaded work regime and to the braking means control by the discharge wave of the braking line. Curves marked by number 1 give the dependences obtained for the through braking pipe and curves marked by number 2 give the dependences for the separate braking pipes. Solid curves correspond to the longitudinal forces values obtained at the emergency braking of the preliminary tension trains and dot curves correspond to the results for the preliminary buffed trains.

As one can see from the given Figure, the separation of the braking pipes of the first and the second trains at the considered way of control leads to the reduction of the highest longitudinal impact forces up to 13%, and the highest forces of the quasi-static character up to 24%. We consider forces in the intercar connections to have quasi-static character when they are acting longer than 2 seconds [5]. But if the air distributors are switched on to the loaded work regime, the values of the highest longitudinal impact forces reach the dangerous values for the both cases of braking pipes connection.

At the braking of the preliminary buffed trains the separation of the braking pipes allows to obtain forces in intercar connections, which do not exceed the value of 1000 kN dangerous from the point of view of the car forcing away.

The plots of the highest longitudinal forces distribution along the train made-up from 110 tank-cars at the emergency braking by only the second locomotive situated in the middle of the train are given in Fig. 3 for the case of the preliminary tension (solid curves) and buffed (dot curves) trains. The results obtained correspond to the motion of the trains with the through braking pipe and air distributors switched on to the loaded work regime.

From Fig. 3 it is followed that at the emergency braking by only the second locomotive situated in the middle of the train the level of the maximum impact and quasi-static forces is under the permissible value. It is necessary to note that at the braking of the preliminary buffed trains the level of the tension forces in the first half of the train is much higher than in the case of the preliminary tension trains. It is connected with features of the braking for trains carrying liquid cargo, where the movable liquid part gives the more sharp work of clearances

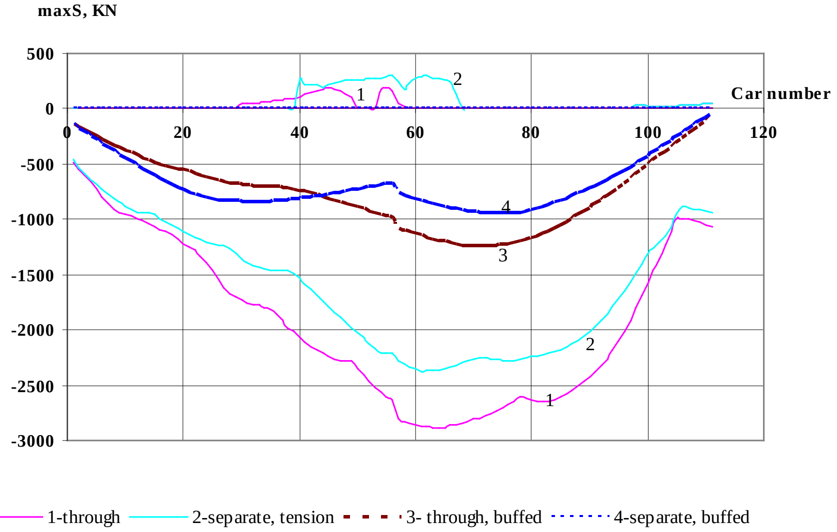

Fig.2. Distribution of the maximum longitudinal forces along the train composed from the tank-cars at the emergency braking by the lead locomotive when the second locomotive is situated in the middle of the train and is braking by the discharge wave of the braking line for the preliminary tension (solid curves) and buffed (dot curves) trains.

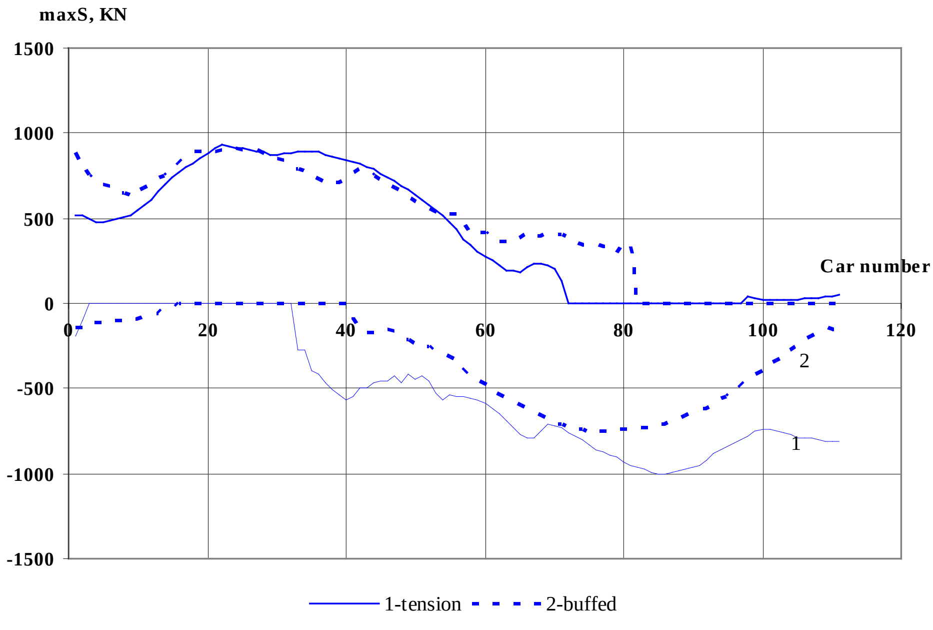

Fig. 3 Distribution of longitudinal forces maximum values along the preliminary tension and buffed trains consisted of tank-cars at the emergency braking from the speed of 20 km/h by only the second locomotive (through braking pipe).

Dependences of the maximum longitudinal forces on the car number for the emergency braking from the speed of 20 km/h for the preliminary buffed train made-up from 110 tank-cars when the helping locomotive is situated in the middle of the train for different ways of braking means control are shown in Fig. 4. Curve 1 corresponds to the situation when the lead locomotive carries out the emergency braking, and the helping one does the same only when the wave of braking pipe pressure reduction has come; curve 2 corresponds to the synchronous control of brakes by the lead and helping locomotives; curve 3 corresponds to the emergency braking by the second locomotive only. At the braking modeling it was assumed that the air distributors are switched on to the loaded regime of the through braking pipe.

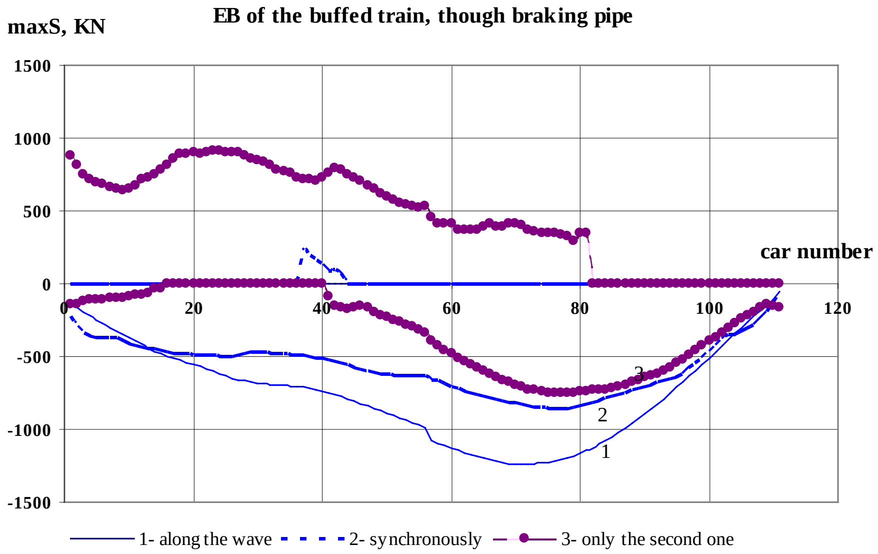

Fig. 4 Distribution of the longitudinal forces maximum values along the train at the emergency braking of the preliminary buffed trains made-up from tank-cars for various ways of brakes control.

Values of the maximum compressed and tension forces in kN for the EB and FSBA from the speed of 20 km/h and the brake distances for the EB from the speed of 80 km/h for the considered trains are given in Table 1.

The lowest level of the longitudinal forces in the train takes place when the second locomotive is situated in the 1/3 distance from the train end and at the synchronous way of braking control. This case may be recommended for the operation both for the middle and loaded regimes of the air distributors work.

When the locomotive is placed in the middle of the train, the lowest longitudinal forces are in the case when the separate braking pipes and synchronous way of control are used. In the case of the through braking pipe, the highest longitudinal forces are much higher than for the case with the separate pipes. If the brakes are controlled only by the second locomotive situated in the middle of the train, the compressed forces are the same as for the synchronous braking from the both locomotives, but with the separate braking pipes. However, the sufficient tension forces have place at the situation.

The highest force level in the train is obtained at the emergency braking for both preliminary tension and buffed trains under the control of braking on the braking line discharge wave. When the helping locomotive is situated in the middle of the train, the force level is higher than in the case when only the lead locomotive is braking. The compressing longitudinal forces occurred at the emergency braking of the preliminary tension trains may be dangerous from the point of view of the car forcing away, as they have quasi-static character (they act for 1.5 -2 seconds) and are above the permissible level of 1000 kN for completely loaded cars. The separation of the braking pipes for the case when the helping locomotive carries out the emergency braking with the braking pipe pressure reduction wave coming allows to reduce the level of maximum forces.

When the second locomotive is situated in the 1/3 distance from the train end, both for the through and separate braking pipes the level of the maximum longitudinal forces are reduced for all the considered braking regimes and air distributors work regimes.

The result obtained show that if it is necessary to use trains with liquid cargo with the mass up to 10 thousand tones, their make-up should be made with the locomotives positioning in the train head and in the 1/3 distance from the train end.

The trains should be equipped by the system of synchronous braking with the helping system working on the braking wave.

In the case when under the service conditions the helping locomotive is situated in the middle of the train, the control of brakes should be made from the helping locomotive by the radio communication of the driver from the lead locomotive.

Table 1.

Maximum values of tension and compressing longitudinal forces in kN in trains made-up from the tank-cars at various braking regimes and various regimes of air distributors work

Helping locomotives positioning				½			1/3 from the end		
Braiking line type	Way of braking control	Train state	Air distributor work regime	EB, V_0=20km/h max S, kN	EB, V_0=80 km/h Braking distance	FSBA, V_0=20 km/h max S, kN	EB, V_0=20 km/h max S, kN	EB, V_0=80 km/h Braking distance	FSBA, V_0=20 km/h max S, kN
Through pipe	I and II synchronously	buffed	load	-820		-800	$\frac{+490}{-470}$		$\frac{+520}{-460}$
			mdl	$\frac{+100}{-660}$		-640	$\frac{+370}{-360}$		$\frac{+440}{-380}$
		tension	load	$\frac{+530}{-1970}$	593	$\frac{+390}{-1630}$	$\frac{+750}{-640}$	538	$\frac{+490}{-640}$
			mdl	$\frac{+430}{-1670}$	675	$\frac{+340}{-1500}$	$\frac{+600}{-575}$	665	$\frac{+400}{-630}$
	only II	buffed	load	$\frac{+940}{-790}$		$\frac{+900}{-600}$	$\frac{+1900}{-450}$		$\frac{+1800}{-350}$
			mdl	$\frac{+720}{-620}$		$\frac{+635}{-450}$	$\frac{+1580}{-360}$		$\frac{+1450}{-270}$
		tension	load	$\frac{+970}{-1030}$	618	$\frac{+740}{-980}$	$\frac{+1380}{-530}$	592	$\frac{+1670}{-450}$
			mdl	$\frac{+720}{-870}$	696	$\frac{+630}{-900}$	$\frac{+980}{-580}$	720	$\frac{+1350}{-500}$
	only I	buffed	load	-1280		-1180	-1245		-1150
			mdl	-970		-890	-940		-870
		tension	load	$\frac{+480}{-2890}$	700	$\frac{+750}{-2300}$	$\frac{+530}{-2850}$	700	$\frac{+850}{-2315}$
			mdl	$\frac{+850}{-2375}$	830	$\frac{+730}{-2025}$	$\frac{+840}{-2325}$		$\frac{+570}{-1990}$
	I, then II along the wave	buffed	load	-1240		-930	-760		$\frac{+250}{-605}$
			mdl	-980		-710	-560		$\frac{+270}{-460}$
		tension	load	$\frac{+190}{-2900}$	627	$\frac{+300}{-2325}$	$\frac{+340}{-1790}$	575	$\frac{+425}{-1440}$
			mdl	$\frac{+300}{-2280}$	710	$\frac{+430}{-1950}$	$\frac{+390}{-1550}$	700	$\frac{+830}{-1275}$
Separate papes	I and II synchronously	buffed	load	$\frac{+240}{-620}$		$\frac{+250}{-540}$	$\frac{+890}{-670}$	590	$\frac{+1010}{-520}$
			mdl	$\frac{+240}{-480}$	557	$\frac{+200}{-400}$	$\frac{+650}{-540}$		$\frac{+800}{-410}$
		tension	load	$\frac{+630}{-1670}$	684	$\frac{+440}{-1440}$	$\frac{+725}{-1075}$		$\frac{+660}{-820}$
			mdl	$\frac{+450}{-1375}$		$\frac{+370}{-1270}$	$\frac{+600}{-900}$	722	$\frac{+650}{-650}$
	I, then II along the wave	buffed	load	-950		-725	$\frac{+520}{-980}$		$\frac{+650}{-660}$
			mdl	$\frac{+120}{-740}$		-575	$\frac{+450}{-740}$		$\frac{+620}{-550}$
		tension	load	$\frac{+330}{-2375}$	588	$\frac{+240}{-2210}$	$\frac{+640}{-1920}$	613	$\frac{+950}{-1270}$
			mdl	$\frac{+425}{-2025}$	714	$\frac{+360}{-1875}$	$\frac{+850}{-1530}$	740	$\frac{+920}{-1130}$

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