TESTING OF RAILWAY EQUIPMENT FOR THE IMPACT ON THE TRACK AND TURNOUTS

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Resume

The indicators of dynamic qualities that ensure the traffic safety, as well as the permissible impact on the railway track, with the obligatory fulfillment of which the railway rolling stock can be used in the transportation process, are presented in this article. The purpose of this work was to carry out the complex dynamic (running), and the impact on the railway track, tests of the rolling stock, during which simultaneous registration of dynamic processes on the railway rolling stock, and in the elements of the superstructure of the track, is carried out, as well as in elements of turnouts. Dynamic tests were carried out on the track switches from the minimum speed to the maximum possible speed of 50 km/h by the TE33A diesel locomotive during the freight traffic. Meeting the requirement of reproducibility of test conditions and having a typical design of the track structure on wooden or reinforced concrete sleepers.

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1 Introduction

To ensure the growing volumes of traffic with traction resources, urgent measures are needed to modernize the existing and purchase new rolling stock. In addition, at present, changes have been made to the track maintenance standards, the requirements for certification of locomotives, which require the determination of permissible levels of dynamic qualities that evaluate the vibration-protective properties of the mechanical part of locomotives, the strength and reliability of the railway track, while ensuring the unconditional traffic safety indicators [1].

In the Republic of Kazakhstan, locomotives of the TE33A series were put into operation (Figure 1). When creating a new rolling stock of railways, the greatest importance is attached to the study of its dynamic and running properties, as well as the assessment of traffic safety conditions.

Test object - Diesel locomotive TE33A (Evolution ES44ACi) - a freight locomotive with asynchronous traction motors and electric drive, developed by General Electric (USA) and manufactured by the "Locomotive Kurastyru Zauyty" locomotive plant in Astana in 2010 [2].

The connection of the bogie frame with the wheel pairs is carried out through the jaw boxes. The locomotive uses wheel-to-wheel braking using one brake cylinder per wheel with shoe brakes [3-4].

The tests were carried out to establish the compliance of the locomotive performance with the safety standards NB ZhT TsT 02-98. The list of indicators determined during the tests and their allowable values are given in Table 1.

2 Methods

To measure the dynamic performance, the diesel locomotive was equipped with displacement sensors to

Figure 1 *General view of the TE33A diesel locomotive*

Table 1 *Defined indicators*

The name of the indicator, characteristics	Item number NB ZhT TsT 02-98	The value of the indicator to regulatory documents	Method for determining the indicator
1	2	3	4
Deviation of the actual value of the mass of the diesel locomotive from the designed one, %, no more than	7.1	2	tests
Deviation of the actual value of the load from each wheel pair on the rails from the value specified in the terms of reference, %, no more than	-	3	tests
The difference in loads on the wheels of the wheel pair, %, no more than	7.2	4	tests
Difference of loads along the axes of one bogie, %, no more than	7.3	3	tests
Difference of loads on the sides of the locomotive, %, no more than	7.4	3	tests
Frame forces in straight, curved track sections and turnouts, kN, no more than	2.1, 8.4	91.1	experimental-computational
Coefficient of vertical dynamics of the first stage of suspension, no more than	2.2, 8.5	0.4 0.25	tests
Stresses in the outer and inner edges of the rail sole, MPa, no more than	2.3	240	tests
Stresses in the outer edge of the blades in standardized sections, MPa, no more than	2.4	275	tests
The ratio of the maximum horizontal load to the average vertical load of the rail on the sleeper, no more than	2.5	1.4	tests
Stability factor against derailment, not less than	8.2	1.4	tests
Margin for relative movements of crew members	9	Lack of touch	Visual control
Braking distance, m	14	At V_{nom} = 100 km/h, no more than 800	tests

record the movements of the bogie frame relative to the wheel set in the vertical direction and the movements of the body relative to the bogie in the vertical direction. The signals from the sensors were transmitted via cables to the input of the measuring and computing complex "MIC-036" and recorded on the hard disk of a portable computer. Before the testing, all the measuring circuits were calibrated [5-6].

The dynamic performance of the diesel locomotive and the level of its impact on the superstructure of the track and turnouts were measured on the operating main tracks of the Kazakhstan Temir Zholy company. Prior to the start of testing, the locomotive was operated in TCEU-28. In Almaty, by the beginning of the tests, the mileage of the diesel locomotive was 11107 km (Figure 2) [4].

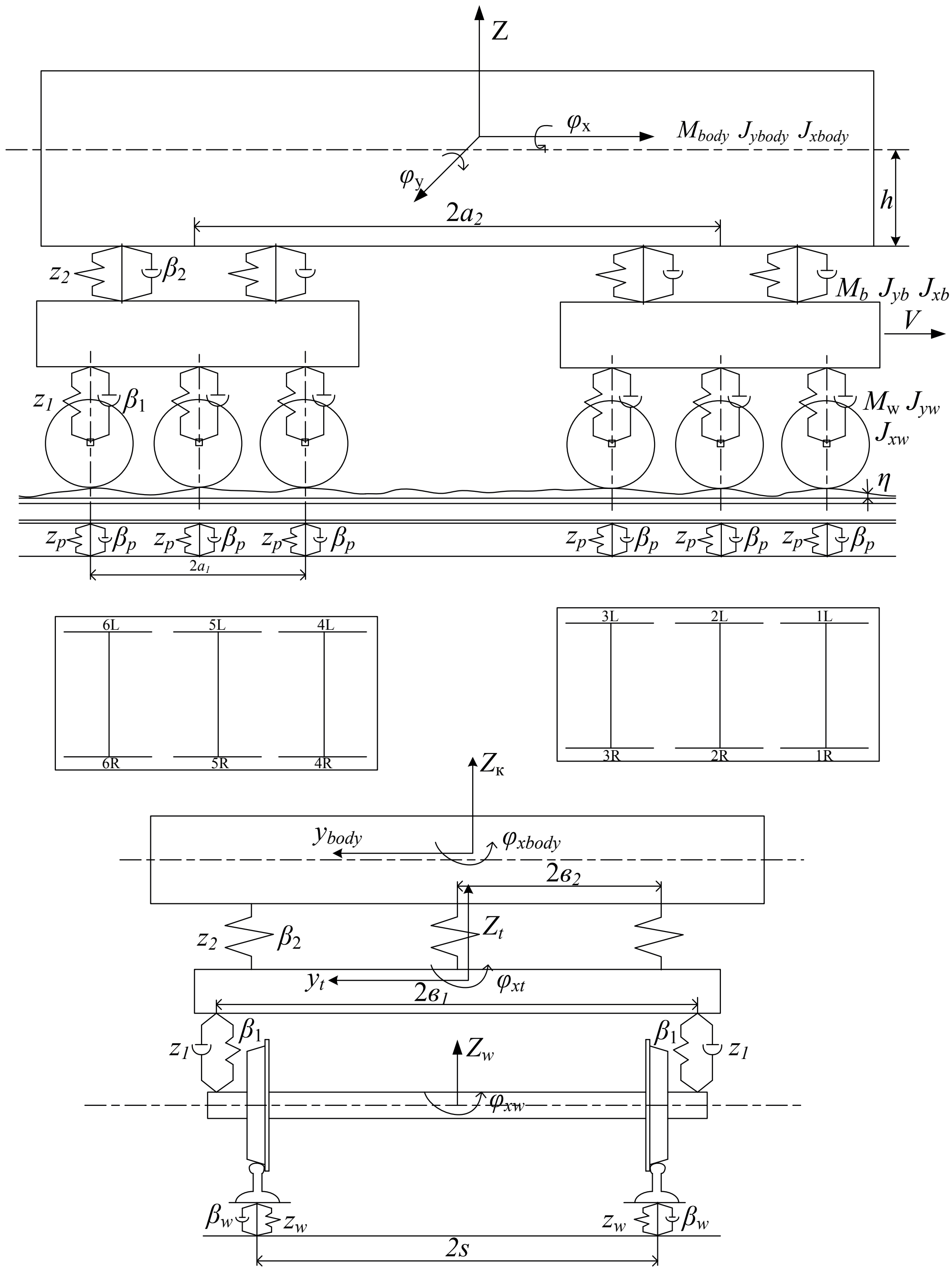

Figure 2 *Kinematic diagram of the TE33A diesel locomotive model*

On the calculated kinematic scheme, the following designations are accepted [4]:

M_{body}, M_t - mass of the body and track, respectively;

M_b - sprung mass of bogies;

M_w - masses of wheelsets;

J_{ybody}, J_{xbody} - moments of inertia of the body relative to the y and x axes, respectively;

J_{yb}, J_{xb} - moments of inertia of bogie frames relative to the y and x axes, respectively;

J_{yw1}, J_{xw2} - moments of inertia of the wheel pairs of the first and second bogies relative to the x axis, respectively;

β_1 - is the damping factor in the box stage of the spring suspension;

z_1 - rigidity of the box stage of the spring suspension;

z_2 - is the damping coefficient in the central stage of the spring suspension;

z_2 - rigidity of the central stage of the spring suspension;

β_w - attenuation coefficient in the way;

z_p - rigidity of the path;

$2a_2$ and $2a_1$ - the base of the body and bogies, respectively;

$2b_2$ and $2b_1$ - the distance between the elastic and dissipative elements of the central and pedestal stages of the spring suspension across the track axis;

$2s$ - is the distance between the points of contact with the rails of the wheels of one wheel pair;

η_r and η_l - equivalent geometrical irregularities on the right and left rails, taken as a disturbance, respectively.

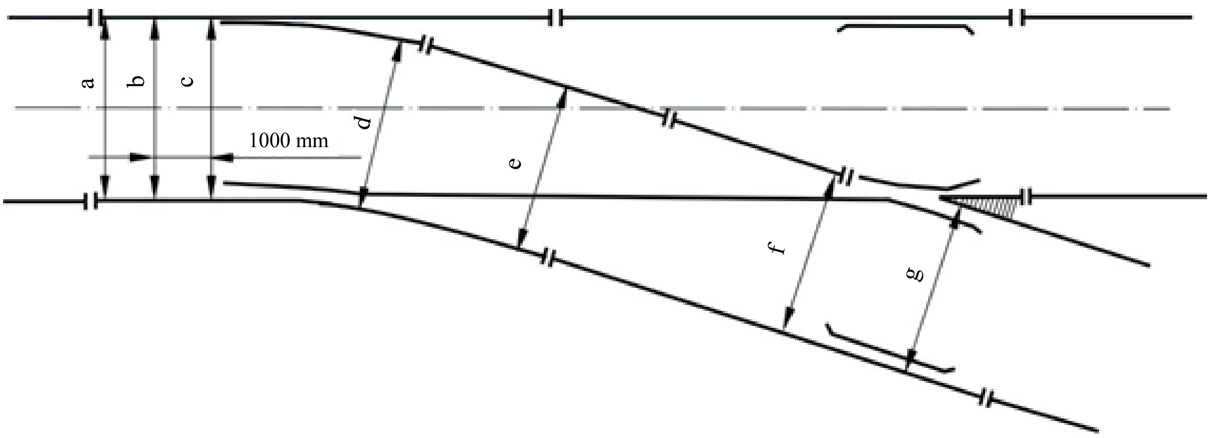

Figure 3 *Places of control measurements on the turnout*

Table 2 *Geometric dimensions of the turnout switch No. 2 Sary-Oba station*

Place of measurement	The designation of the measurement location in Figure 3	Switch R65 1/11 before testing
At the junction of the frame rail	a	1526/5
At a distance of 1000 mm from the point of the wit	b	1520/6
At the sharp edge	c	1522/4
At the root of the wit on the side path	d	1517/2
In the middle of the conversion curve	e	1524/6
At the end of the conversion curve	f	1525/0
In the cross on the lateral path (core section 40 mm)	g	1520/4

Table 3 *Dimensions of the conversion curve, mm*

Number sleepers	22	25	28	31	34	37	40	44	47	50	53
Width	1517	1517	1520	1522	1524	1524	1525	1525	1526	1524	1525
Elevation	2	0	0	4	5	4	3	2	2	2	0

3 Results

Tests of the diesel locomotive on turnouts were carried out when the diesel locomotive was passing turnout No. 2 Sary-Oba station from the odd main path to a side path. The ambient temperature is from 6 to 17 °C, the wind force is not more than 6 m/s.

Turnout switch No. 2 of type R65, grade 1/11, is installed on wooden beams. Before the testing, using a manual template, the geometric dimensions of the turnout were measured according to [7]. Measurement locations are shown in Figure 3.

Measurement data are shown in Table 2.

In addition, the track width and elevation of the outer rail in the transfer curve were measured every two sleepers. The data obtained are shown in Table 3.

During the tests, all the indicated dimensions during the transition from one speed to another were controlled by measurements using the TsUP3 template. In this case, the change in the geometry of the turnout was within 1 mm, which is comparable with the measurement error.

The experimental train consisted of a diesel locomotive TE33A. The direction was considered to be a straight line when the locomotive was ahead in the direction of travel and passed the turnout in the direction of wool. In this case, the first wheel pair of the locomotive was the guide [8].

Registration of dynamic processes in all r the aces began and ended on the straight sections of the track.

The processing of dynamic processes was carried out as follows. In each race, one maximum value of the frame forces was determined, taking into account the quasi-static component. The obtained data were grouped by directions and velocities.

The maximum probable values were calculated with a confidence level of 0.994 using the formula [4]:

$$X_{mp} = X_{res} + 2.5 \cdot \sigma, \quad (1)$$

where X_{res}, σ - respectively, the arithmetic mean and standard deviation of the measured maximum frame forces at a given speed in the selected direction of travel.

The maximum observed value of the frame forces

***Table 4** Frame forces during the movement of the diesel locomotive TE33A along the turnout R65 brand 1/11, kN*

Speed, km/h	Maximum probable value						Maximum observed value					
	Forward run			Reverse run			Forward run			Reverse run		
	Wheel set number											
	1	2	3	1	2	3	1	2	3	1	2	3
15	64.2	65.3	48.5	49.7	58.2	50.4	57.2	59.2	42.1	43.3	51.7	43.6
25	80.2	71.0	64.9	63.3	64.8	64.0	75.8	68.9	60.2	61.4	63.3	54.4
40	85.1	83.0	81.8	80.8	77.3	64.6	78.6	74.8	73.4	71.8	69.3	59.7
50	96.4	87.6	86.6	85.3	84.5	67.4	88.7	80.7	78.5	77.7	77.2	54.8

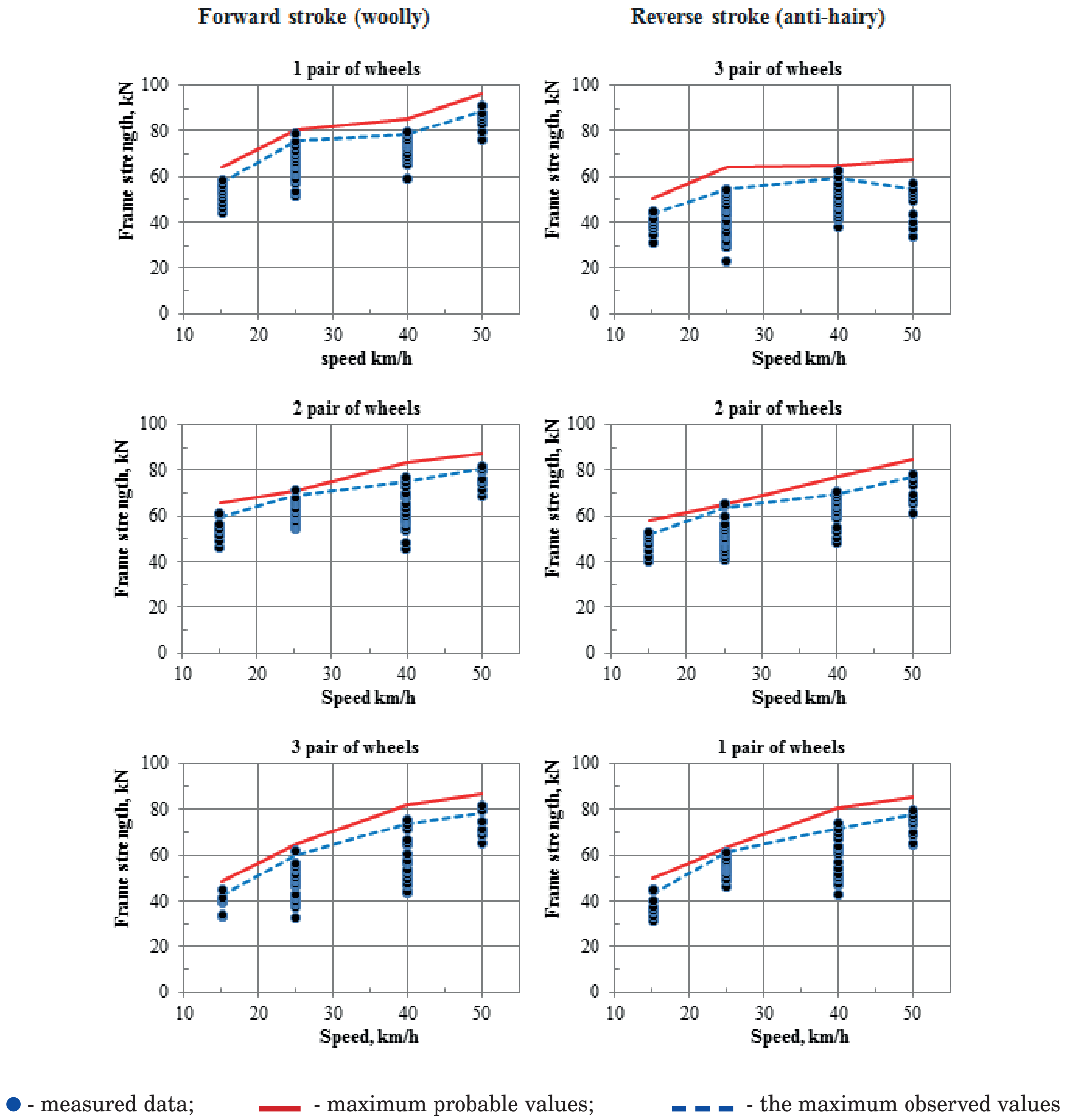

***Figure 4** Frame forces during the movement of the diesel locomotive TE33A-0023 on turnout R65 brand 1/11*

was determined as the arithmetic mean of the three largest values in each group.

The dependence of the frame forces, measured during the passage of the diesel locomotive on the turnout R65 brand 1/11, on the speed is shown in Figure 4.

The allowable value of frame forces for a diesel locomotive of the TE33A type is 23.23 · 9.8 · 0.4 = 91.1 kN. According to Table 4 and Figure 4, it can be seen that at a speed of 50 km/h, the level of frame forces exceeds the permissible value by 5.8 %. Up to a speed of 40 km/h, the maximum probable value of frame forces

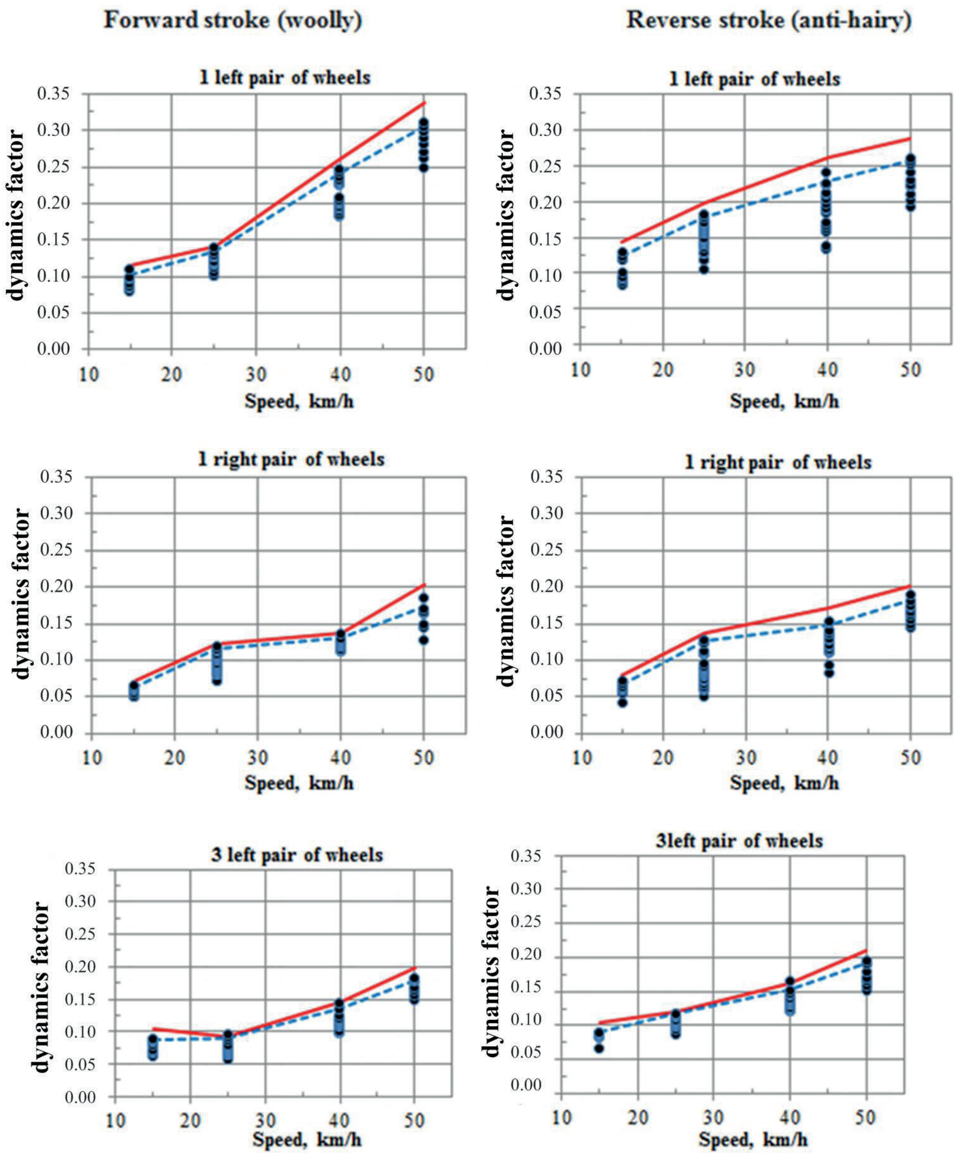

***Figure 5** Coefficient of vertical dynamics of the first suspension stage when the diesel locomotive TE33A moves along the turnout R65 of brand 1/11*

during the cross-country passage of the turnout does not reach the allowable value by 6.6 % does not exceed the permissible limits up to a speed of 50 km/h.

The coefficient of vertical dynamics of the first suspension stage was determined as the ratio of the dynamic vertical displacements of the wheel pair box relative to the bogie frame in the vertical direction to the static deflection of the first suspension stage. According to the data provided by the manufacturer, the static deflection of the locomotive's first suspension stage is 131.5 mm.

The vertical displacements of the box relative to the bogie frame were measured for the first wheel set on the left and right, and for the third wheel set on the left [9].

Dynamic vertical displacements of the box relative to the bogie frame were processed without taking into account the quasi-static component. All measurements were divided into speeds and directions of movement. In each race, one maximum amplitude value of the dynamic process was selected.

Based on the results of data processing at a given speed, separate arrays were formed for each sensor. Based on these arrays, the maximum probable and maximum observed values of the vertical dynamics coefficient of the first suspension stage were found. In the calculations, the same methodology was used as in the calculations of the maximum probable and maximum observed values of the frame forces.

The results of the data processing to determine the coefficient of vertical dynamics of the first suspension stage are shown in Figure 4.

The highest value of the coefficient of vertical dynamics of the first stage was registered on the guide wheel sets of the bogie. At the same time, at the speed

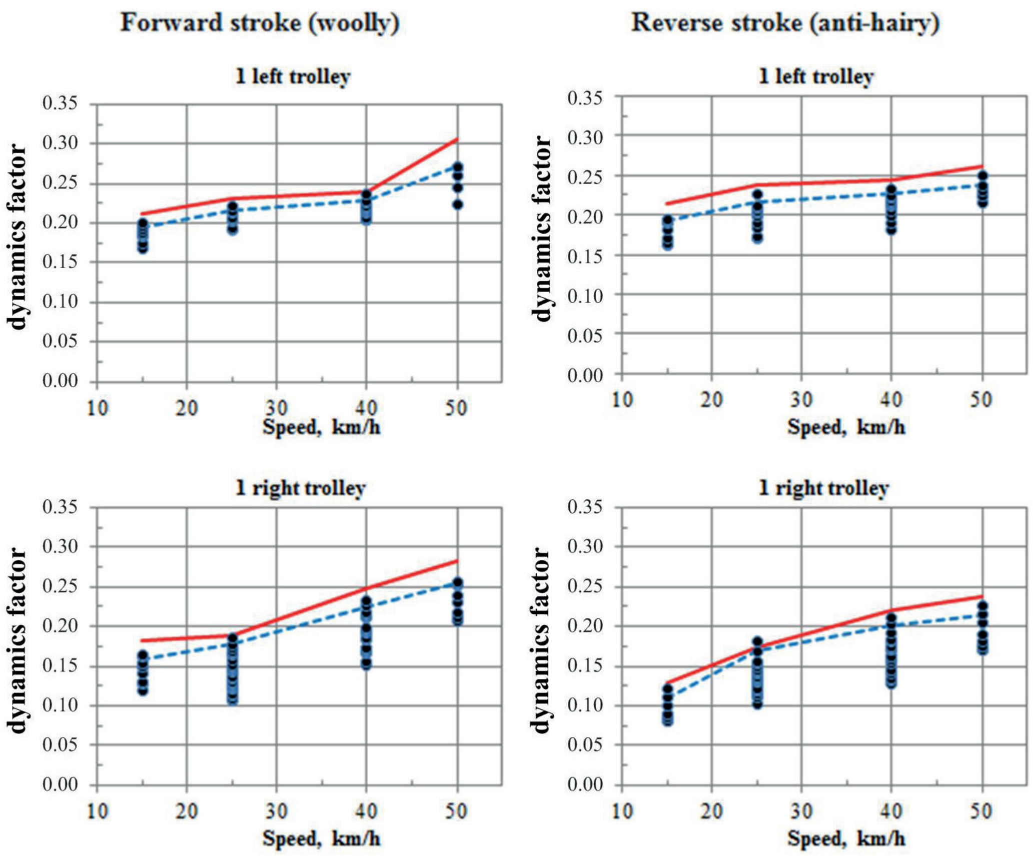

Figure 6 *Coefficient of vertical dynamics of the second suspension stage when the diesel locomotive TE33A moves along the turnout R65 of grade 1/11*

Table 5 *Coefficient of vertical dynamics of the first suspension stage when moving along a turnout type R65, grade 1/11*

Value	Speed, km/h	Forward run				Reverse run	
		Wheel set number					
		1		3		1	3
		left	right	left	right	left	right
maximum probable	15	0.11	0.07	0.10	0.14	0.08	0.10
	25	0.14	0.12	0.09	0.20	0.14	0.12
	40	0.26	0.14	0.14	0.26	0.17	0.16
	50	0.34	0.20	0.20	0.29	0.20	0.21
maximum observed	15	0.10	0.06	0.09	0.12	0.07	0.09
	25	0.14	0.12	0.09	0.18	0.13	0.12
	40	0.24	0.13	0.14	0.23	0.15	0.15
	50	0.31	0.17	0.18	0.26	0.18	0.19

Table 6 *Coefficient of vertical dynamics of the second suspension stage when moving on a turnout type P65 of grade 1/11*

Speed, km/h	Maximum probable value				Maximum observed value			
	Forward run		Reverse run		Forward run		Reverse run	
	left	right	left	right	left	right	left	right
15	0.21	0.18	0.21	0.13	0.20	0.16	0.19	0.11
25	0.23	0.19	0.24	0.17	0.22	0.18	0.22	0.17
40	0.24	0.25	0.24	0.22	0.23	0.23	0.23	0.20
50	0.31	0.28	0.26	0.24	0.27	0.25	0.24	0.22

of 50 km/h, on the first wheel pair of the locomotive, the vertical dynamics coefficient increases significantly and reaches a value of 0.34, without exceeding the permissible norms [2, 10].

Similarly, the coefficient of vertical dynamics of the second stage of suspension is determined, based on the fact that the static deflection of the second stage of suspension of the diesel locomotive is 10.3 mm (side supports). The results obtained are shown in Figure 5.

The coefficient of vertical dynamics of the second suspension stage during the rough movement at a speed of 50 km/h exceeds the permissible norms by 24 %, and up to a speed of 40 km/h it is within the permissible limits.

Based on the data of Figures 5 and 6, Tables 5 and 6 are compiled, which show the maximum probable and maximum observed values of the vertical dynamics coefficient of the first and second stages of the locomotive suspension when moving along the R65 turnout of grade 1/11 [11].

The obtained results show that the dynamic performance of the diesel locomotive (frame forces, coefficients of vertical dynamics of the first and second stages of suspension) when moving along a turnout type R65 brand 1/11 up to speeds of 40 km/h are within acceptable limits. At a speed of 50 km/h, the vertical dynamics coefficient of the first stage is also within acceptable limits, and the frame forces and the vertical dynamics coefficient of the second stage exceed the permissible norm [12-13].

4 Conclusions

In connection with this research goals, the following main tasks were solved:

- determination of the main dynamic indicators of a diesel locomotive;
- determination of the level of diesel locomotive impact on the track and turnouts;
- To achieve the set goals, the following work has been carried out:
- a kinematic diagram of the TE33A diesel locomotive has been compiled with the main values of the main parameters of the mechanical part;
- it was found that for the TE33A diesel locomotive, the permissible value of the frame forces reaches when passing the track switch at a speed of 40 km/h with a margin of 6.6%. This, in turn, makes it possible to determine the critical speed of the TE33A diesel locomotive by the switch.
- graphs of the dependence of the coefficients of the vertical dynamics of the first and second suspension stages of suspension when moving a TE33A diesel locomotive at a speed of up to 50 km/h are constructed. It is determined that, when moving at a speed of 50 km/h, the coefficient of vertical dynamics of the first stage is within acceptable limits, and the coefficient of vertical dynamics of the first second stage exceeds the permissible norm.

Thus, as a result of the experimental study carried out, it should be concluded that the maximum and safe speed for the TE33A diesel locomotive along the track switch with R65 rails is 40 km/h.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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