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Allowable Speeds Along Railroad Switches Upon Their Various Layouts

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Abstract*: *This article presents data on experimental verifications of predicted speeds along combination of railroad switches. Criteria of motion kinematics, strength, stress–strain behavior, wheel stability on rail, impact on passengers within the limits of switches used for speed determination are given including their values obtained by direct tests on route. Recommendations are given with regard to experimental predictions of speeds along combinations of railroad switches in railroad yard necks.

Index Terms*: *railroad switches, motion speeds, combination of railroad switches, criteria of speed determination, test results.

I. INTRODUCTION

Railroad yard necks constitute about 15% of sites limiting working capacity of Russian railroads. The limiting factor is motion speed across railroad switches and their combinations. Taking into consideration distances between railroad stations characteristic for European Russia, low speeds in railroad yard necks also prevent implementation of traction capabilities of locomotives in running lines, thus increasing travelling time of trains, reducing effect of increase in their weight and length.

Motion speeds along combinations of railroad switches are generally determined lower than designed values. This is related with peculiar features of motion of wagons and locomotives along combinations of short curves without transition segments. This work is aimed at revealing reserves of increase in motion speeds along combinations of railroad switches upon maximum approximation to designed speeds along the railroad switches.

The design motion speeds along newly created railroad switches are verified by dynamic and strength tests. The allowable motion speed along railroad switches as well as for new types of rolling stock are also determined on the basis of dynamic and strength tests. In order to determine motion speeds along combinations of railroad switches, it would be reasonable to test such approach.

II. METHODS

A. General description

The researchers in [1–3] carried out kinematic analysis of motion of various underframes along combinations of railroad switches and studied possibilities to increase the speed upon passing these combinations. This work is aimed at verification of theoretical predictions of motion speeds for combinations of railroad switches on the basis of dynamic and strength tests.

B. Algorithm

Criteria of determination of train speed along railroad switches and their combinations can be subdivided into groups.

Dynamic and kinematic criteria. This group of criteria was studied in [1–2].

Criteria of strength and stress–strain behavior. While testing compliance of railroad switches to safety regulations, it is necessary to examine strength properties of elements of railroad switches. Such criteria are comprised of allowable strains measured in bases of foundations of the most loaded sections.

The allowable strains should not exceed for rail elements: 240 MPa; for switch rails and frog tongues with continuous wheel treads: 275 MPa; for profiled counter-rails: 330 MPa; for tongues made of high manganese steel: 110 MPa.

While determining speeds along combinations of railroad switches, the strength properties should also be satisfied.

Deformations of rail elements (elastic and residual vertical and horizontal bending, elastic and residual variations of rail track, variations of trough dimensions, variations in dynamics of mutual position of switch rail and stock rail, and others) for railroad switches are not specified by safety regulations. While testing railroad switches, they are applied as additional variables characterizing operation.

Criterion of safety against derailing. Vertical and horizontal transversal (lateral) forces transferred by wheels of rolling stock to rail elements of railroad switch make it possible to judge about stability against wheel derailing and possibility of wheeling into switch rail in the case of switch counter course. These variables were determined using the Schlumpf method or by strain gauge wheel pair. Regarding railroad switches, due to sharp variation of their variables, application of these procedures is restricted. Thus, in order to determine vertical and lateral forces of wheels of rolling stock acting on elements of railroad switch, the sensor systems are used similar to Schlumpf method but localized for certain sections where the wheel action is maximum.

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Criterion of displacement of assembled rails and sleepers. While determining allowable speeds of rolling stock, the criteria preventing displacement of assembled rails and sleepers are considered.

Railroad switches and impacts of rolling stock on railroad switches are tested in VNIIZhT for more than 40 years. New designs of railroad switches are tested at speeds up to 10–15% higher than designed values. Herewith, no data were obtained evidencing displacement of assembled rails and sleepers at railroad switches, type R65.

Since the planned analysis of possible increase in motion speed along the combinations of railroad switches will be performed in the limits of designed speed for railroad switches in the combinations, this criterion is not considered in this work.

Criterion of impact on passengers and freights. Such criterion is presented by accelerations in bodies of passenger and freight wagons. According to experimental results obtained by experts of VNIIZhG and VNIIZhT in Russian railroads, the accelerations in wagon body impacting on a passenger should not exceed 2.0 m/s^2 [4].

The tests were performed using two characteristic combinations of railroad switches: railroad switches on crossover with intertrack spacing of 4.3 m; combination of railroad switches using connection of front stock rail of one railroad switch to front stock rail of another railroad switch without straight plug, with turnouts in all directions. The tests were performed in Moscow railroads.

The speeds of testing train were 25 km/h, 40 km/h, 50 km/h, and up to 60 km/h, which was by 10 km/h higher than the designed speed.

Strain–stress state of railroad switch elements was estimated by the following properties:

Strains in switch elements (in switch rails and stock rails), frog (counter-rails and tongue), rails of connecting and adjacent tracks, as well as rails of turnout curve (Fig. 1);

Deformation properties: vertical and horizontal bending of rail elements, variation of track width, deformation and displacement of switch elements, frog, rails of adjacent tracks and turnout curve were determined along overall length of considered segment (Fig. 2);

Wheel stability on rails was determined by vertical and horizontal forces acting on rail elements of railroad switches in the front offset of stock rail, in the switch, in turnout curves (Fig. 3).

The impacts on passengers and freights were estimated by body accelerations at the points of bogie pivots and middle point of freight and passenger wagons.

The variables were detected by electronic method. The obtained values of body accelerations, vertical and horizontal transversal dynamic forces of wheel impact on rail elements of railroad switches, vertical and horizontal displacement of rail elements, as well as other recorded variables match well with similar variables determined previously by VNIIZhT laboratory "Railroad switches" [5].

C. Flowchart

Tables 1–4 summarize maximum experimental values of horizontal transversal accelerations in the body of passenger all-steel wagon and freight open wagons: loaded and empty, vertical and horizontal transversal forces transferred by wheels of these wagons onto rail elements of railroad switches, vertical bendings and displacements of rail heads in railroad switches.

The data are subdivided by areas of railroad switches: switch (including front offset), turnout curve, and frog. The given values are the highest obtained in both railroad switches of each combination.

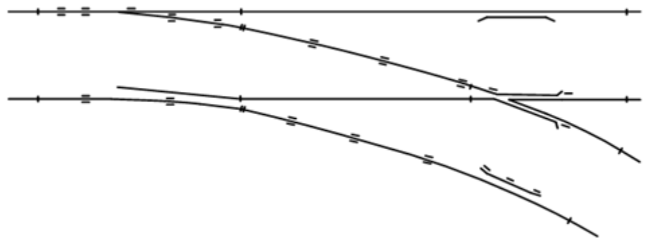

Fig. 1. Measurements of strains in rail elements of railroad switch, type R65, model 1/11.

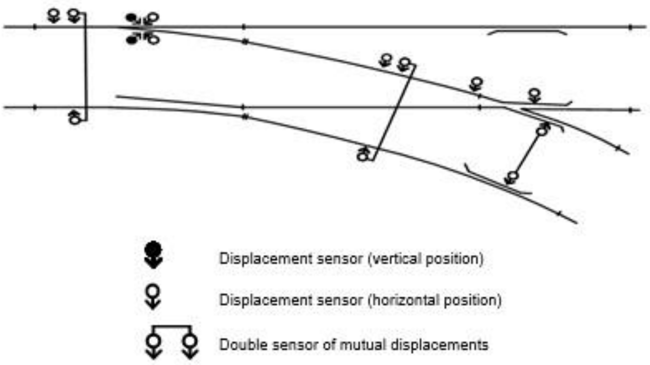

Fig. 2. Measurements of deformations on railroad switch, type R65, model 1/11.

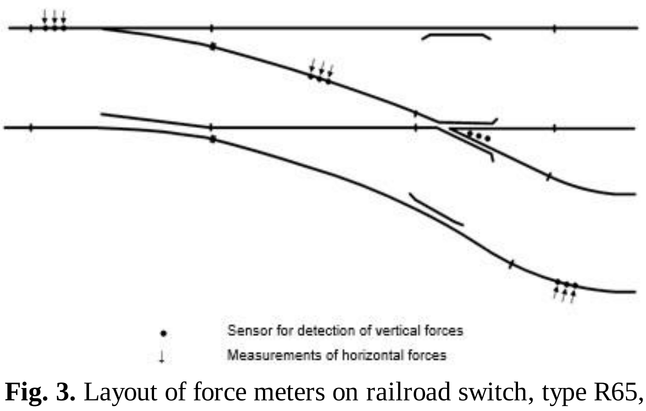

Fig. 3. Layout of force meters on railroad switch, type R65, model 1/11.

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Table 1. Impact of freight open wagons on railroad switches. Variant: crossover with intertrack spacing of 4.3 m. The highest detected impacts (numerator of loaded 230 kN/axle, denominator of empty 60 kN/axle open wagon)

Measured parameter	Units	Railroad switch (including front offset of stock rail)				Frog			
		Speed, km/h							
		25	40	50	60	25	40	50	60
1	2	3	4	5	6	7	8	9	10
Horizontal transversal accelerations	m/s^2	1.2	1.8	2.4	2.9	0.8	1.3	2.0	2.4
		0.9	2.4	3.0	3.9	0.9	1.8	2.2	2.6
Vertical forces (Schlumpf method)	kN	128.5	149.8	168.6	189.6	118.8	163.5	176.1	188.9
		39.7	52.5	59.8	67.6	38.2	53.2	58.3	60.3
Horizontal transversal forces (Schlumpf method)	kN	70.9	81.5	89.7	98.7	-	-	-	-
		26.5	36.5	42.1	49.0				
Vertical bending	mm	3.7	4.3	4.7	5.1	3.6	4.1	4.8	5.1
		2.9	3.9	4.5	4.7	2.7	3.1	3.7	3.9
Displacement of rail head	mm	35	41	4.2	4.6	2.5	31	3.4	36
		2.6	2.9	3.1	3.4	2.1	2.5	2.6	2.9

Table 2. Impact of passenger wagon on railroad switches. Variant: crossover with intertrack spacing of 4.3 m. The highest detected impacts

Measured parameter	Units	Railroad switch (including front offset of stock rail)				Frog			
		Speed, km/h							
		25	40	50	60	25	40	50	60
1	2	3	4	5	6	7	8	9	10
Horizontal transversal accelerations	m/s^2	0.4	1.5	2.0	2.2	0.6	1.2	1.5	1.7
Vertical forces (Schlumpf method)	kN	74.5	83.8	106.4	118.9	78.2	88.0	111.0	120.0
Horizontal transversal forces (Schlumpf method)	kN	43.8	50.0	56.3	70.4	-	-	-	-
Vertical bending	mm	2.9	3.3	3.7	4.1	2.4	2.9	3.1	3.5
Displacement of rail head	mm	2.3	2.9	3.2	3.7	1.9	2.3	2.7	2.9

Table 3. Impacts of loaded freight open wagons on railroad switches. Variant: opposite layout of railroad switches, without straight rail plug, turnouts in all directions. The highest detected impacts (numerator of loaded 230 kN/axle, denominator of empty 60 kN/axle open wagon)

Measured parameter	Units	Railroad switch (including front offset of stock rail)				Frog			
		Speed, km/h							
		25	40	50	60	25	40	50	60
Horizontal transversal accelerations	m/s^2	0.9	20	27	38	13	17	20	25
		1.0	2.2	2.8	4.2	1.0	2.0	3.0	3.2
Vertical forces (Schlumpf method)	kN	131.2	152.2	171.5	184.5	124.3	167.4	178.6	188.6
		42.5	56.8	61.2	66.5	45.8	65.3	67.3	71.3
Horizontal transversal forces (Schlumpf method)	kN	80.5	111.6	125.5	128.8	-	-	-	-
		28.3	41.2	41.7	42.2				
Vertical bending	mm	39	4.1	4.5	4.8	35	39	4.7	52
		2.8	3.9	3.8	5.1	2.5	2.9	3.7	4.1
Displacement of rail head	mm	31	3.9	4.1	4.5	2.6	31	35	38
		2.3	2.9	3.1	3.5	2.3	2.9	3.2	3.4

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Table 4. Impacts of passenger wagon on railroad switches. Variant: opposite layout of railroad switches, without straight rail plug, turnouts in all directions. The highest detected impacts

Measured parameter	Units	Railroad switch (including front offset of stock rail)				Frog			
		Speed, km/h							
		25	40	50	60	25	40	50	60
Horizontal transversal accelerations	m/s^2	0.7	1.3	1.9	2.4	0.5	0.9	1.5	1.3
Vertical forces (Schlumpf method)	kN	78.7	86.5	90.0	91.2	77.2	97.7	109.0	113.0
Horizontal transversal forces (Schlumpf method)	kN	44.8	47.1	50.9	51.3	-	-	-	-
Vertical bending	mm	3.1	3.9	4.2	4.9	2.3	2.7	3.3	3.8
Displacement of rail head	mm	2.1	2.9	3.7	3.9	1.6	2.1	2.8	3.1

III. RESULTS AND DISCUSSION

On the basis of the experimental results, it is possible to directly estimate possible increase in motion speeds along the combinations of railroad switches where the tests were performed.

For crossover from railroad switches, type R65, model 1/11, project 2750 with intertrack spacing of 4.3 m:

Passenger all-steel wagon on KVZ bogies:

- according to requirements to strength of railroad switch elements, there are no limitations in the range of 25–60 km/h: the strains in the elements do not exceed 65% of allowable;

- according to motion safety requirements (in terms of stability against wheel derailing), there are no restrictions: minimum coefficient of stability reserve is 1.72 (in turnout curve);

- according to conditions of impact on passengers and freights, the speed should be limited to 50 km/h, since horizontal transversal accelerations in wagon body at high speeds exceed 2.0 m/s^2 (the value fixed upon tests confirming designed speeds along railroad switches). At 60 km/h the accelerations of 2.2 m/s^2 were obtained.

Loaded freight open wagon with load on axle of 235 kN:

– according to requirements to strength of railroad switch elements, the limiting speed is 50 km/h. At 60 km/h in the front offset of stock rail and external line of turnout curve, overstrains up to 15% can occur (276 MPa).

– according to motion safety requirements (in terms of stability against wheel derailing), there are no restrictions: minimum coefficient of stability reserve is 1.87 (in the front offset of stock rail at 40 km/h);

– according to conditions of impact on freights in wagon, the speed should be limited to 50 km/h, since accelerations in wagon body at high speeds exceed 2.5 m/s^2 (the value fixed upon tests confirming designed speeds along railroad switches).

Empty freight open wagon:

– according to requirements to strength of railroad switch elements, in the range of 25–60 km/h there are no restrictions: the strains in the elements do not exceed 70% of allowable;

– according to motion safety requirements (in terms of stability against wheel derailing), there are no restrictions: minimum coefficient of stability reserve is 1.39 (in turnout curve at 60 km/h);

– according to conditions of impact on freights in wagon, the speed should be limited to 50 km/h, since accelerations in wagon body at high speeds exceed 3.0 m/s^2 (the value fixed upon tests confirming designed speeds along railroad switches). During testing the value of 3.9 m/s^2 was obtained in the switch area.

For combinations of counter-wise positioned railroad switches, type R65, model 1/11, project 2750, without straight rail plug with turnouts in all directions:

Passenger all-steel wagon on KVZ bogies:

– according to requirements to strength of railroad switch elements, in the range of 25–60 km/h there are no restrictions: the strains in the elements do not exceed 55% of allowable;

– according to motion safety requirements (in terms of stability against wheel derailing) there are no restrictions: minimum coefficient of stability reserve is 1.76 (in turnout curve);

– according to conditions of impact on passengers and freights, the speed should be limited to 50 km/h, since accelerations in wagon body at high speeds exceed 2.0 m/s^2 (the value fixed upon tests confirming designed speeds along railroad switches). At 60 km/h the accelerations of 2.8 m/s^2 were obtained.

Loaded freight open wagon with load on axle of 235 kN:

– according to requirements to strength of railroad switch elements, the limiting speed is 50 km/h. At 60 km/h overstrains of 18% (283 MPa) can occur in external line of turnout curve; and higher than 5% (290 MPa) in switch rails.

– according to motion safety requirements (in terms of stability against wheel derailing), there are no restrictions: minimum coefficient of stability reserve is 1.40 (at railroad switch at 40 km/h);

– according to conditions of impact on freights in wagon, the speed should be

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limited to 40 km/h, since accelerations in wagon body at high speeds exceed 2.5 m/s^2 (the value fixed upon tests confirming designed speeds along railroad switches). While testing, the value of 3.8 m/s^2 was obtained during motion along the railroad switch.

Empty freight open wagon:

– according to requirements to strength of railroad switch element, in the range of 25–60 km/h there are no restrictions: the strains in the elements do not exceed 70% of allowable;

– according to motion safety requirements (in terms of stability against wheel derailing), there are no restrictions: minimum coefficient of stability reserve is 1.39 (in turnout curve at 60 km/h);

– according to conditions of impact on freights in wagon, the speed should be limited to 50 km/h, since accelerations in wagon body at high speeds exceed 3.0 m/s^2 (the value fixed upon tests confirming designed speeds along railroad switches). While testing, the value of 4.2 m/s^2 was obtained in the switch area.

IV. CONCLUSION

1. For the considered underframes at crossovers with intertrack spacing of at least 4.3 m comprised of railroad, type R65, model 1/11, it is possible to recommend motion speed equaling to design motion speed along railroad switch turnout: 50 km/h.

2. For passenger wagons and empty open wagons in the case of opposite layout of railroad switches, type R65, model 1/11, without straight rail plug with turnouts in all directions, it is possible to recommend motion speed equaling to design motion speed along railroad switch turnout: 50 km/h, for loaded open wagons the motion speed along such combinations: 40 km/h.

3. Generally, the obtained results correspond to predicted motion kinematics of rolling stock along various combinations of railroad switches, however, kinematic predictions do not permit to consider completely all peculiarities of underframe passing along railroad switches. Thus, in order to determine motion speeds along railroad yard necks, it would be reasonable to apply experimental predictions.

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