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Theoretical assessment of the distribution of dynamic interaction forces of the "rolling stock-track" system along the length of subway railway switches

Abstract. *One of the peculiarities for switch operation is the increased level of force interaction between the bearing elements of the switch and the rolling stock chassis, which causes increased requirements for strength, stability, reliability and durability of switches. Accordingly, to assess the strength of structures, it is necessary to know the magnitude of the forces acting on them, which can be determined experimentally or by theoretical calculations. In the case of tunnel sections of subways, experimental studies are extremely difficult to organize and conduct, so only theoretical methods are an alternative. This study presents the results of theoretical calculations of the elastic-dynamic characteristics for railway switches used in tunnel sections of subways. Practical calculations of the stiffness of rail threads and the modulus of elasticity of the sub-rail base were performed, and dependencies of the distribution of elastic-dynamic parameters along the length of railway switches were obtained. On their basis, the forces of interaction with the subway rolling stock were determined and their distribution along the length of the railway switch was analyzed. The obtained data can serve as a prerequisite for checking the strength of structural elements.*

Keywords: *railway switches, sub-rail base, stiffness, elastic modulus, elastic-dynamic track parameters, dynamic forces, dynamic deflections, stresses.*

Introduction. Scientific studies of the operation of railway switches in interaction with rolling stock are always relevant, as they provide information on the stress-strain state of the railway switches structure and the permissible speeds of trains, both on the main and side tracks. Compared to a conventional track, the operating conditions of railway switches structures under rolling stock wheels are much more complicated.

The design of railway switches and their operating conditions differ significantly from conventional track, so a number of issues arise during their design, modernization, and operation that require engineering solutions [1]. In particular, it is necessary to take into account the relevant design features of railway switches that cause a variety of dynamic effects on its elements [2-6].

In subways, the operation of railway switches differs from that of mainline railways as the intensity of train traffic is much higher with lower axial loads. Also, in the tunnel sections of subways, the operation of railway switches differs from that of mainline railways due to the peculiarities of the tunnel structure design. Therefore, it is very difficult and, in some cases, almost impossible to take into account the whole variety of force actions on the railway switch elements and the peculiarities of their support on the sub- railway switch base. Such circumstances require that all the features of the interaction between rolling stock and railway switches on subway tracks are taken into account in the calculations and an adequate calculation methodology is applied that would sufficiently reflect the actual operation of the railway switches structure in interaction with rolling stock and at the same time would be brought to engineering application [7].

Analysis of the latest research and problem statement. The long-term and safe operation of railway switches depends, on the one hand, on the magnitude of the forces exerted by the wheels of the rolling stock on the track, and, on the other hand, on the strength of the structure [3-5]. However, most studies on this problem consider only individual parts of railway switches, such as a crosspiece or an arrow [4, 5], and a comprehensive assessment of the dynamic impact along the entire length of the switch structure has not yet been performed. And in the few works [3] that consider the variability of the switch structure along its length and evaluate the force interaction between the rolling stock and railway switch, the adopted mathematical model is not sufficiently demonstrated and does not give sufficiently complete results, and the same emphasis is placed on the study of the stress-strain state of the railway swith sleepers. In other words, the distribution problem of dynamic forces along the length of railway switch has not been completely solved and remains relevant.

Meanwhile, the forces of interaction between track elements and rolling stock largely depend on the stiffness of the so-called elastic-rigid track parameters, which include: the masses of track structures involved in the interaction process, as well as viscous (dissipative) and elastic interconnections between individual interacting masses. When calculating the forces of interaction between track elements and rolling stock using modern computational methods and system modeling consisting of a series of sequential masses connected by elastic and dissipative links, one of the most critical aspects is determining the elastic-stiffness parameters of the track. These parameters, also known as the calculated mechanical parameters of the track, play a crucial role in computational schemes.

In general, research on the stiffness of track structures has been conducted by numerous researchers in various countries around the world, including the United Kingdom [8], France [9], Germany [10], Sweden [11], Spain [12], Slovakia [13], China [14-17], and others.

According to the results of various studies, the vertical stiffness of the track for railway switches on wooden beams ranges from 30,000 kN/m to 11,000 kN/m, and for switches on reinforced concrete beams it ranges from 60,000 kN/m to 13,000 kN/m. In the paper [13], the author notes that with very stiff supports, the vertical stiffness can reach 480000 kN/m. In general, the analysis of the review of sources shows that in various studies, information on the design characteristics of the track within railway switches obtained by experimental methods is difficult to use in practical calculations for specific structures due to a rather large difference in results. This situation arises due to the fact that the results were obtained for specific structures that were operated under specific operating conditions. Therefore, such data cannot be applied to other different structures, for example, of another modification or with other geometric parameters. In this case, it is more correct to determine the track characteristics by calculation methods, if such methods are sufficiently reliable and close to the actual results.

Research conducted by national scientists [1, 18], which was carried out at different times for track structures on wooden and concrete sleepers with various rails and fastenings, can be shown in the form of table 1.

Table 1. **Stiffness of rail thread on cap $\beta^{head}_{y(midd)}$ and sole $\beta^{base}_{y(midd)}$ and the horizontal cross-sectional modulus of elasticity of the sub-rail base U_y for different track constructions**

Sleepers	Type of rail	Type of fastenings	Horizontal cross-sectional stiffness of rail thread, kN/mm		the horizontal cross-sectional modulus of elasticity of the sub-rail base U_y, MPa if only H (P=0)
			$\beta^{head}_{y(midd)}$	$\beta^{base}_{y(midd)}$	
Concrete	R65	KB	from 17 to 23	from 37 to 64,9	10,9
		ZHB	from 8 to 12	from 19,5 to 40	19,7
Wooden	R65	D0	from 16 to 22	from 32 to 48	from 22 to 24,0
	R50	D0	from 12,6 to 13,1	from 25,2 to 27,6	from 19 to 24,0
	R43	D0	from 10,9 to 12,1	from 21,8 to 24,2	from 18 to 24,0

The methodology for determining the stiffness parameters of rail tracks using theoretical methods [1] was developed by Dr. Eng. Prof. E. I. Danilenko in the mid-1990s. Subsequently, from 1995 to 2000, during experimental studies of railroad railway switches on wooden and concrete sleepers, it demonstrated fairly reliable convergence with experimental data. The obtained results were reflected in regulatory and technical documents [18].

Despite the extensive research on the elastic-deformation parameters of railway tracks, there are very few works dedicated to railroad railway switches, and even fewer to switches installed in subways. A similar situation is observed regarding the assessment of the force impact on railroad railway switches.

Thus, this study aims to investigate the interaction forces within the area of a railroad railway switch, depending on changes in the elastic-dynamic parameters of the sub rail base along the length of the railway switch. This is the first time that scientific research in this setting has been performed for switches laid in subway tracks.

The purpose and objectives of the research. The main objective of this study is to assess the power load of railway switches for subway operating conditions.

To be able to theoretically solve this problem, in accordance with the existing methodology for calculating track strength [18], it is necessary to know the track structure, stiffness parameters of the sub rail base and characteristics of the rolling stock. While the stiffness parameters are well studied for conventional track construction, there is no experimental data on these characteristics for subway railway switches. It is quite difficult to organize experimental studies in subway conditions. Therefore, we propose theoretical approaches to solve the following problems.

Thus, the first task of this study, performed for a switch laid in a tunnel section of the subway, is to theoretically determine the elastic and dynamic parameters, taking into account the fact that at a relatively short length of the switch track, its structure and characteristics of the subgrade base undergo significant changes. And the second task, which is solved on the basis of the previous one, is to establish the nature of the distribution of dynamic forces and stresses in the rails and dynamic deflections along the length of the switch, which will further serve as the basis for assessing the strength of individual structural elements, taking into account the specifics of subway conditions.

Research materials and methods. The strength characteristics of railway switches affect the safety of train traffic and the permissible speed level. Strength assessment for a known structure is possible if the forces acting on it are known.

For the theoretical determination of dynamic interaction forces, we can use well-known rules [18], which can be adapted to solve the problem at hand. In this case, we assume the following starting points:

1. Each of the two rails of the track is considered as a beam of infinite length with a constant cross-section, freely resting on a solid equiaxed base or on separate point equiaxed supports.

2. The main calculation of the rail is performed for the action of vertical forces; vertical forces are assumed to be applied in the plane of symmetry of the rail, and the rails of both strands are assumed to be equally loaded.

3. Horizontal longitudinal forces are taken into account by appropriate selection of permissible stresses. The permissible physical stresses are the permissible bending stresses in the rails during endurance service.

4. The static calculation of a rail as a beam on an elastic base is based on the hypothesis of a linear relationship between the pressure per unit area of the base (p) and the elastic settlement of the base (Z), which is defined by the equation:

$$p = C_{ball.} \cdot Z, \tag{1}$$

where p – pressure per unit area of the base (equal to the reactive resistance of the elastic foundation settling);
Z – elastic beam settling;
$C_{ball.}$ – the elasticity characteristic of the base, which is called the ballast's elastic compression ratio, or "bed ratio".

5. In practical engineering calculations, the track structure is designed to withstand dynamic wheel loads.

The elastic bending line of a beam under dynamic vertical load is taken as the elastic bending line of a beam under static load, which is numerically equal to the value of the dynamic force at a given time.

6. The influence of oscillations in the wheel-gauge system and the influence of irregularities on the track and wheel are taken into account by the inertial forces arising from the interaction of the specified system, which arise in the system in addition to the action of static forces.

The resultant of all vertical force components transmitted by the design wheel to the rail is taken at its maximum probable value $P_{calc} = P_{dyn}^{max}$ as a statistical set of random components with a probability level F=0,994 (with a normalizing factor λ=2,5).

7. The effect on the rail thread of all other wheels of the carriage is taken into account by loading the lines of influence of moments M and lateral forces Q with the wheel load system P_{dyn_i} and determining the equivalent loads P_{eq}^{I} i P_{eq}^{II}.

8. In practical engineering calculations, it is noted that the maximum probable dynamic wheel load acts in the design cross-section of the rail (i.e., the section where the stressed state is determined) $P_{calc.} = P_{dyn}^{max}$, and the influence of neighboring wheels is taken in the form of their average dynamic loads $\bar{P}_{dyn_i}$, taking into account that the maximum dynamic pressure of the design wheel does not coincide with the maximum pressure of adjacent wheels.

9. It is considered that the railway track and rolling stock are in a serviceable condition, which corresponds to maintenance standards.

The greatest difficulty for theoretical calculation methods is the determination of variable values of track stiffness and elastic modulus of the sub rail grade within the length of the railway switch. The theoretical solution of this problem in the vertical direction is carried out in stages: first of all, considering the track structure as a beam resting on separate elastic supports, and the work of each support (sleeper or beam) under the influence of loads transmitted from the rails should be considered as the work of a beam of limited length resting on a continuous equiaxed "Winkler" base (Fig. 1).

The solution approach for the mentioned problem for railway switches undoubtedly depends on the considered arrangement scheme of rail threads on elastic supports of the base. However, in general, the algorithm for solving the problem under consideration will be common for all arrangement schemes of rail threads and can be presented as a generalized sequence of calculating the stiffness parameters of the track within the railway switches:

1. Determination of the elastic deflections of the sub-rail supports under the influence of unit forces applied at the sub-rail cross-sections. In cases where multi-threaded rail schemes are considered, the calculation is performed taking into account the influence of loaded and unloaded rail threads.

2. Determination of the total point stiffness of the sub-rail base as a multi-layered structure, taking into account the design features of the sub-rail base;

3. Determination of the vertical modulus of elasticity of the sub-rail base, considering the distribution diagram of ties (sleepers);

4. Determination of the total stiffness of the rail threads working together with the sub-rail base; for multi-threaded constructions, the calculation is performed considering the influence of unloaded threads and the specific structural arrangement (i.e., the stiffness of each thread).

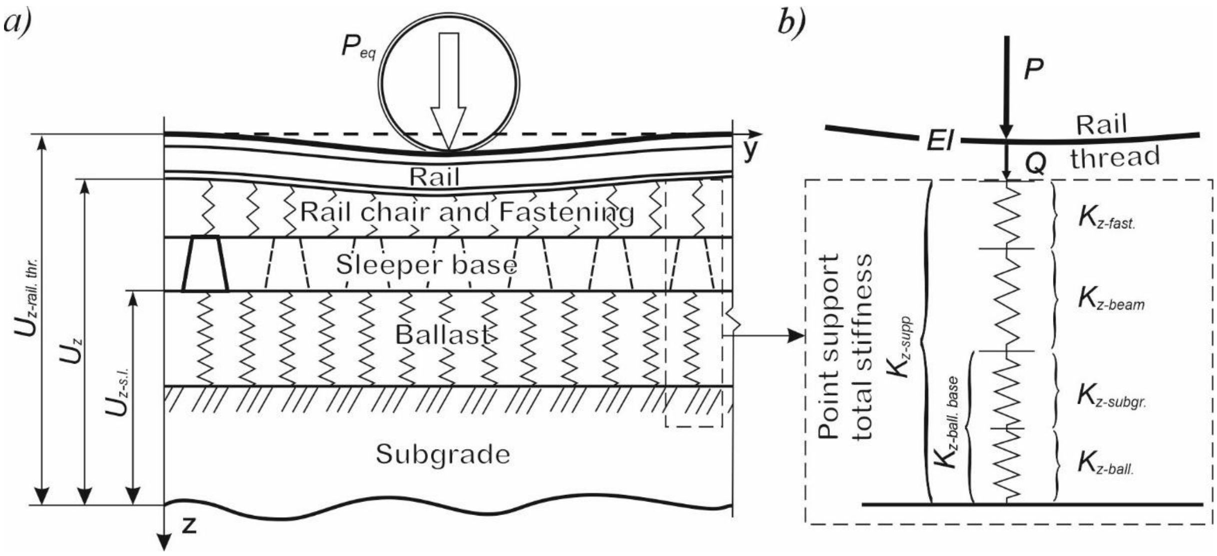

Fig. 1. **Mechanical model of elastic track operation: *a* - as a multilayer structure; *b* - as a single point support under the rail**

According to the research [19], the sequence for determining the elastic-dynamic characteristics of railway switches can be presented as the following algorithm, which can be conveniently implemented as a computer program:

1) Input of initial data for a particular cross-section of the railway switch: length L, height h, width b of the beam; points of load application Q relative to the beginning of the beam a_i; elastic moduli E_i and moments of inertia I_i of the beam and rails; beam bedding factor $C_{ball.}$ and distance between beam axes l_i; area of the substrates ω and modulus of elasticity at compression of the beam E_{st}; stiffness of fasteners K_{fast}; values of vertical dynamic interaction forces P^{dyn};

2) Calculation of elastic deflections of sub-rail supports under the action of unit forces applied in sub-rail sections as beams lying on a continuous equally elastic base by the method of initial parameters from solving a differential equation:

$$EI\frac{d^4Z}{dx^4} + C_{ball.}bZ = \sum_1^n Q_i\eta_i(x - a_i). \qquad (2)$$

The deflections in the characteristic cross-sections Z_i and the bending coefficient α of the beam are determined;

3) Determination of the total point stiffness of the sub-rail base as a multilayer structure:

- the stiffness component is determined, which takes into account the bending of the beam and depends on the elastic subsidence of the ballast layer and subgrade under the beam:

$$K_{z-ball.base} = \frac{C_{ball.}\cdot\alpha\cdot l\cdot b}{2}; \qquad (3)$$

- the stiffness component is determined, which depends on the compression performance of the beam in the sub-rail section:

$$\frac{1}{K_{z-beam}^{compr}} = \frac{h\left(\frac{1}{\omega_i}+\frac{2}{\alpha\cdot l\cdot b}\right)}{2\cdot E_{ball.}^{compr}}; \qquad (4)$$

- the value of point stiffness (pliability) is determined:

$$\frac{1}{K_{z-supp.}} = \frac{1}{K_{z-ball.base}} + \frac{1}{K_{z-beam}} + \frac{1}{K_{z-fast.}}; \qquad (5)$$

4) Determination of the vertical modulus of elasticity of the sub-rail base, taking into account the layout of the beams:

$$U_z = \frac{K_{z-supp.}}{l_i}. \qquad (6)$$

5) Calculation of the equivalent moment of inertia of the design rail thread $I_{in(red.)}$, operating in bending in the vertical plane, taking into account the influence when operating in bending both the loaded thread and the unloaded other threads.

$$I_{in(red.)} = I_{in(calc)} + \sum_{n=1}^{n=m} k_{n(infl.)} \cdot I_{n(unload.)}. \qquad (7)$$

6) Determination of the total stiffness of rail threads working together with a sub-rail base:

$$K_{z(rail.thr.)} = \sqrt[4]{64 \cdot E_{st} \cdot I_{in(red.)}} \cdot \sqrt[4]{U_{zi}^3}. \qquad (8)$$

7) Calculation of vertical dynamic interaction forces $P^{дин}$;
8) Determination of dynamic deflections in a specific cross-section for a given rail thread:

$$Z_{rail.}^{dyn} = \frac{P_i^{dyn}}{K_{z(rail.thr.)}}. \qquad (9)$$

9) Printing out the calculation results: U_z, $K_{z(rail.\ thr.)}$, $Z_{rail.}^{dyn.}$.
In this way, the task is structured and becomes practical. For each stage, more detailed block diagrams were developed and calculation programs were compiled.

According to the above algorithm, we calculated the stiffness parameters of the track using 1/9 grade steel for the P50 railway switch on wooden beams and crushed stone ballast laid in the tunnel section of the subway.

The peculiarity of solving this problem is that the length of the railway switches varies along the length of the beams, the number of rail threads, and the parameters of the cross-sections of the bearing elements. Therefore, the calculation was based on beams of all standard sizes, which are sequentially placed from the railway switch to the cross section.

The results of the calculations of the stiffness characteristics are summarized in Table 2, and a graphical representation of the results is shown in Fig. 2.

For railway switches with wooden sleepers, there are practically no analogs for theoretical determination of stiffness characteristics along the entire length, so the obtained results are of scientific and practical interest.

Overall, the following patterns of stiffness distribution along the length of the railway switch are observed:

- the stiffness characteristics of the inner rail thread have higher values along almost the entire length than those of the outer rail thread;

- there is a significant increase in stiffness within the cross section;
- there are stiffness increase in places of change in the standard sizes of switch beams, and they have higher values for the outer rail thread compared to the inner one;
- there is a local increase in stiffness at the root of the point, which is explained by the peculiarities of their design, while it should be noted that the calculations did not consider the beams placed along the length of the points, so the graphs do not show stiffness increase within the length of the points;

Table 2. **Stiffness characteristics of railway switches type P50 grade 1/9 for subway conditions**

№ beam	U_z, MPa ixternal	U_z, MPa internal	K_z, kg/cm ixternal	K_z, kg/cm internal	$K_{ball.\ base}$, kg/cm ixternal	$K_{ball.\ base}$, kg/cm internal	$K_{rail.\ thr.}$, kg/cm ixternal	$K_{rail.\ thr.}$, kg/cm internal
0	38,57	38,57	20058	20071	44114	44169	62812	62844
1	35,05	35,05	21032	21032	48282	48282	58463	58463
19	37,94	38,4	20866	21121	47546	48679	73668	74283
20	38,94	39,54	20831	21156	47391	48839	72518	73785
26	39,39	41,1	20362	21234	45378	49191	70512	74537
27	47,48	48,25	20889	21231	47649	49181	81196	84115
33	37,24	39,23	20295	21379	45098	49855	64525	71356
34	38,24	39,28	20841	21405	47437	49974	65790	71700
38	37,33	39,49	20342	21521	45292	50514	62627	72662
39	38,26	39,5	20850	21523	47474	50526	64441	71993
41	37,84	39,58	20624	21571	46492	50751	62435	74000
42	38,46	39,56	20963	21562	47973	50707	63134	74363
45	39,59	44,44	22965	25773	47742	50776	73286	104624
46	39,91	44,42	23146	25764	48409	50748	73597	105356
50	47,12	58,94	20733	25932	46965	51023	74967	111262
51	37,55	46,21	21029	25876	48268	50839	63214	92688
63	38,69	39,60	21086	21582	48524	50800	63577	72804

The obtained distribution of the stiffness characteristics of railway switches along its length allows us to conclude that it is necessary to conditionally divide the railway switch into separate zones within which the stiffness parameters include similar components, in particular:
- the front overhang of the frame rails, where the railway switch design differs little from the conventional track;
- the point area, where the overall stiffness includes the effects of the frame rails, points, switch pads and shoes;
- connecting part, is essentially a four-threaded track structure with two loaded and two unloaded rail threads.
- the cross section, which in turn has sections with four rail threads, where counter rails are mounted near the outer threads, and in the middle part the inner threads cross the cross section, which has a variable cross-section and corresponding bending stiffness;
- the cross section, within which the four-threaded railway switch structure gradually transitions to two directions of the conventional track.

The obtained calculation results indicate that for such a multi-threaded construction as a railway switch, the distribution of stiffness characteristics along the length depends on many factors, but the greatest impact comes from the stiffness of the rail threads and the density of the beams. Thus, the presence of counter rails, a strong cross section and carriages result in significant increases in overall stiffness and elastic modulus. Slightly smaller increases in stiffness are caused by densely stacked beams.

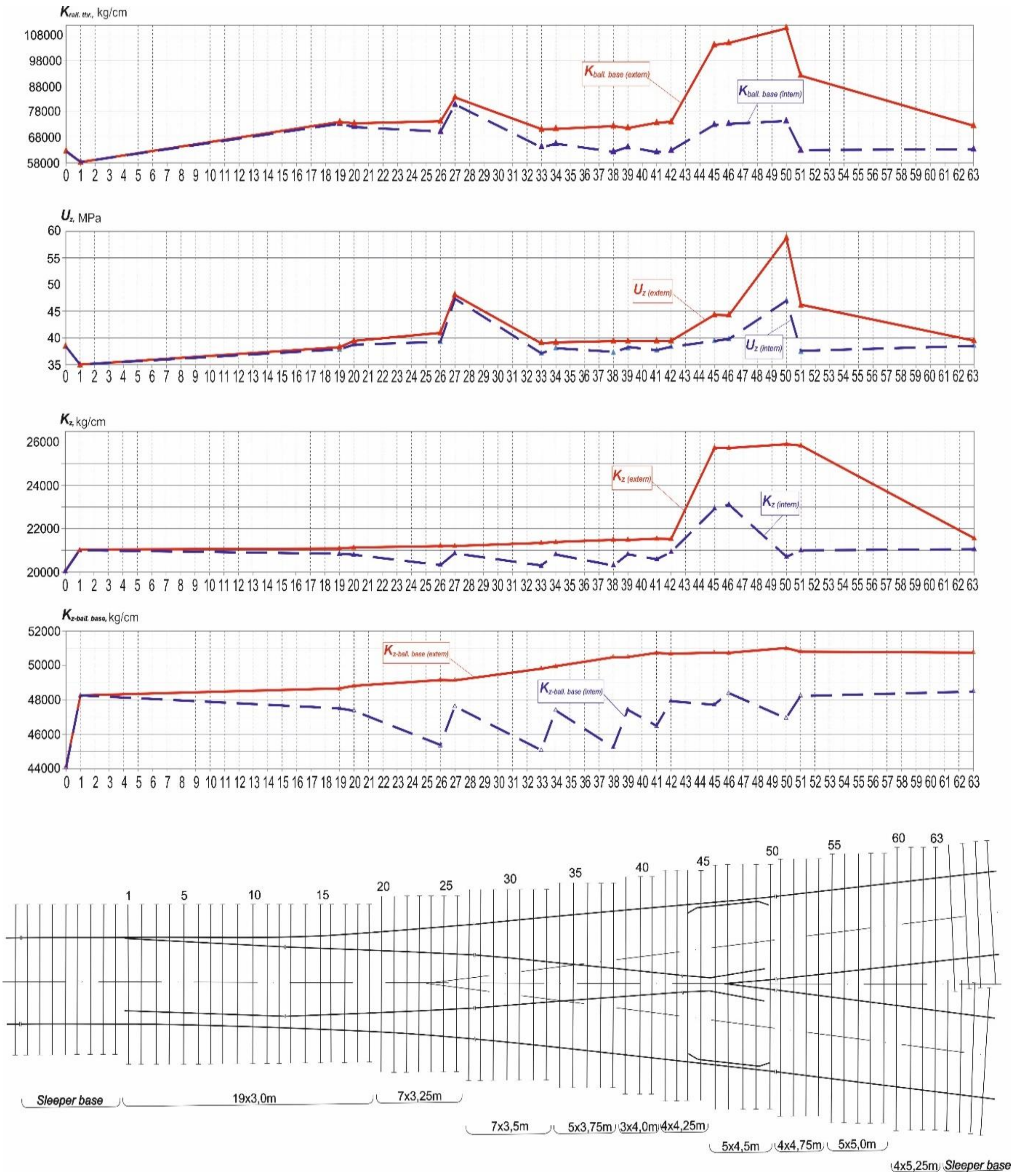

Fig. 2. **Distribution of the stiffness characteristics of a railway switch type P50, grade 1/9, on wooden beams along the length**

Due to the change in the position of vertical loads along the length of the switch beams and the influence of unloaded rail threads, the nature of the change in stiffness parameters along the outer and inner rail threads differs.

The results obtained are a prerequisite for further determining the dynamic forces transmitted from the wheel to the rail elements of the railway switch.

The calculated dynamic load is taken as the maximum probable value from the combination of the effects of constant static and variable dynamic forces in accordance with [18].

The algorithm for determining dynamic interaction forces can be presented in the form of a flowchart shown in Fig. 3.

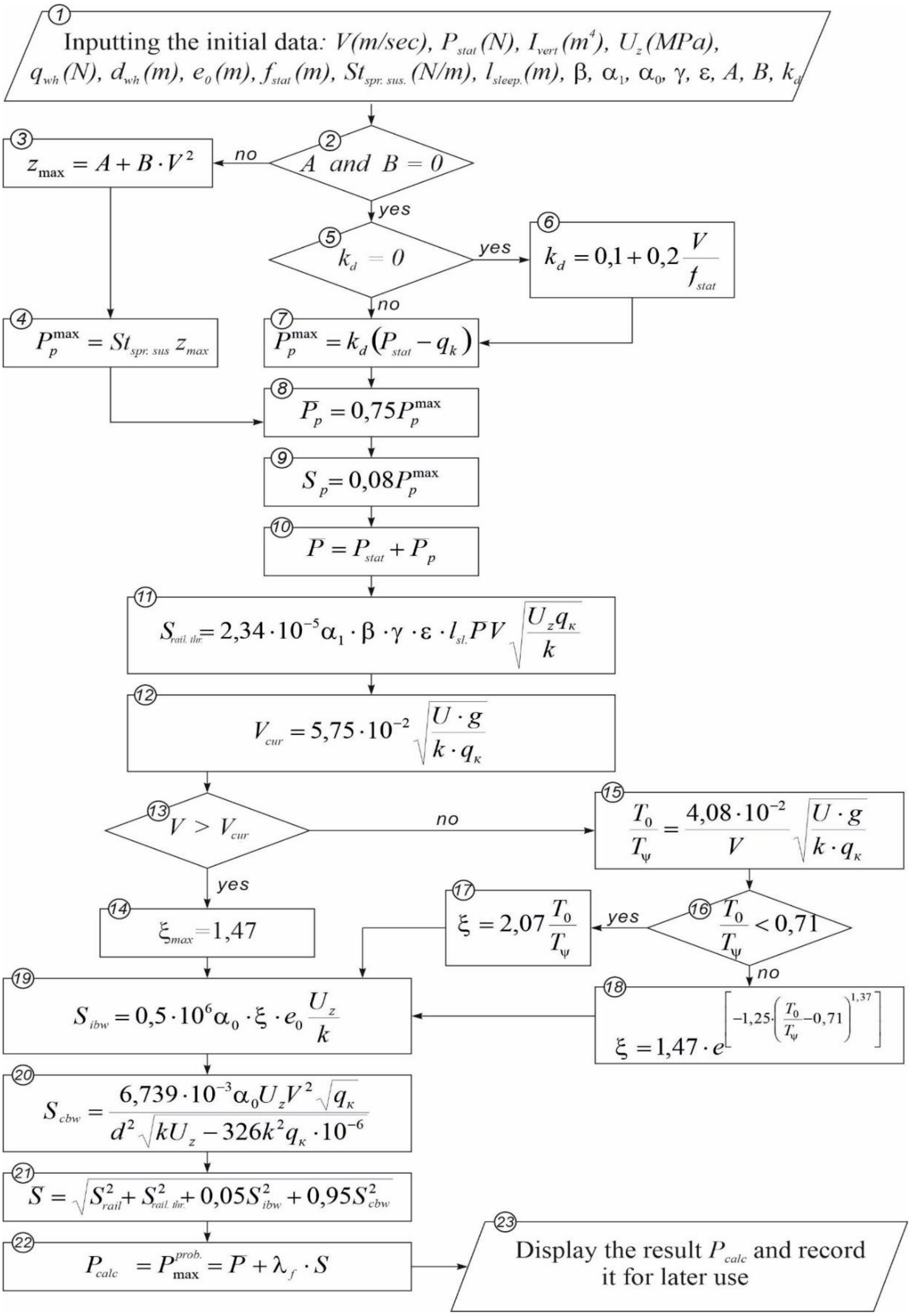

Fig. 3. **Algorithm for calculating dynamic forces**

The above algorithm was implemented in the form of a computer program, and the results of calculations of vertical dynamic forces, stresses in rails and dynamic deflections of rail threads when moving along a subway railway switch are summarized in Table 3 and graphically displayed in Fig. 4.

Table 3. **Vertical dynamic forces and dynamic deflections for a railway switch of type P50, grade 1/9, for subway conditions**

№ бруса	$Z_{dyn,}$ mm ixternal	$Z_{dyn,}$ mm internal	$P_{dyn,}$ кN ixternal	$P_{dyn,}$ кN internal	$\sigma_{head-edge,}$ MPa ixternal	$\sigma_{head-edge,}$ MPa internal	$\sigma_{base-edge,}$ MPa ixternal	$\sigma_{base-edge,}$ MPa internal
0	1,77	1,77	110,55	110,55	97,53	97,53	89,69	89,69
1	1,958	1,958	113,46	113,46	102,14	102,14	93,93	93,93
19	1,815	1,8	111,87	112,0	99,09	98,99	91,13	91,03
20	1,77	1,752	111,39	111,56	98,15	98,02	90,27	90,14
26	1,742	1,692	110,61	111,05	97,2	96,82	89,39	89,04
27	1,477	1,461	108,43	108,59	91,84	91,69	84,46	84,33
33	1,834	1,77	111,43	111,98	99,02	98,56	91,07	90,64
34	1,801	1,768	111,71	111,99	98,79	98,55	90,85	90,63
38	1,831	1,762	111,46	112,05	99,0	98,51	91,05	90,59
39	1,8	1,761	111,71	112,05	98,78	98,5	90,85	90,59
41	1,814	1,759	111,59	112,07	98,88	98,49	90,93	90,57
42	1,795	1,76	111,77	112,07	98,74	98,49	90,8	90,58
45	1,787	1,653	113,84	115,18	100,15	99,17	92,09	91,2
46	1,777	1,654	113,94	115,18	100,08	99,18	92,04	91,21
50	1,484	1,276	108,36	110,54	91,91	89,90	84,5	82,68
51	1,836	1,596	112,26	114,68	99,66	97,88	91,65	90,01
63	1,786	1,758	111,83	112,08	98,68	98,48	90,75	90,57

The obtained calculation results reveal the following patterns in the distribution of dynamic force levels along the length of the railway switch:

- stiffness significantly influences the level of dynamic forces. Increased stiffness leads to a reduction in dynamic forces, stresses, and deflections of the rail threads;
- for the inner and outer rail threads, the forces along almost the entire length have insignificant differences, except for the cross section (for which a different calculation method is used. Within the cross section, the level of dynamic forces should additionally be taken into account due to the presence of vertical irregularities);
- in places of stiffness increases, the forces are higher along the outer rail thread than along the inner rail thread;

Conclusions. The structural peculiarities of a railway switch demand a differentiated approach to assessing the force dynamics depending on the position of the moving load along the length of the railway switch.

The specific design features of railway switches necessitate a differentiated approach to evaluating their force loading and deformability. Therefore, it is advisable to introduce a conditional division of the railway switch into sections, within which the force dynamics exhibit similar characteristics.

For certain parts of the railway switch in the front overhang of the frame rails, on the connecting tracks and in the crossover zone, i.e. in those areas of the railway switch where there are no structural irregularities on the rolling surface, the dynamic forces of interaction between the wheel and rail can be determined using a standard methodology for calculating track strength. However, in the areas of irregularities on the switch and cross section, other approaches, including mathematical modelling methods, should be used to determine the vertical dynamic forces.

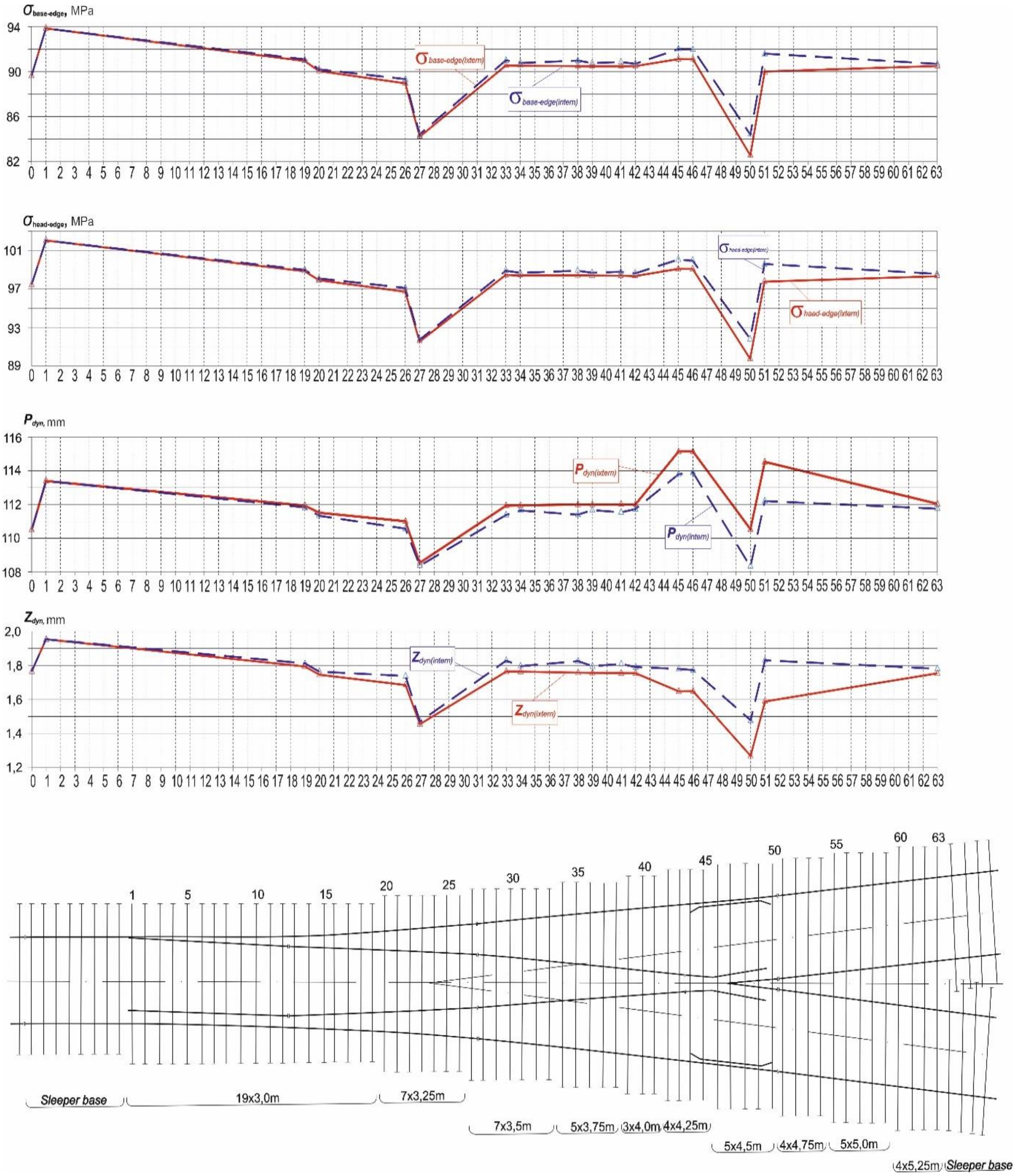

Fig. 4. **Distribution of dynamic forces, stresses in the rails and dynamic deflections of the railway switch of the P50 grade 1/9 on wooden beams along its length**

It is proposed to establish the basic stages of assessing the power load of a railway switch along its length.

1. The railway switch is divided along the length into sections: pre-point, point, connecting, crossing, and post-crossing.

2. For each part, taking into account the design parameters, geometric, inertial, elastic and other design data are determined.

3. Stiffness parameters of the track within each selected part of the railway switch are calculated.

4. On the parts of the railway switch where its design is similar to a conventional track, vertical dynamic forces are calculated according to the algorithm shown in Fig. 3 algorithm.

5. Within the point and cross parts, with known forms of irregularities on the rolling surface, mathematical models of interaction between the rolling stock and track system in the vertical plane are developed and the corresponding dynamic forces are determined based on their implementation.

6. On the basis of the obtained results of power loading, the stress state of the corresponding elements of the railway switch is determined.

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Теоретична оцінка розподілу динамічних сил взаємодії системи «рухомий клад-колія» по довжині стрілочних переводів метрополітенів

Анотація. *Однією з особливостей роботи стрілочних переводів є підвищений рівень силової взаємодії несучих елементів переводу з ходовими частинами рухомого складу, що викликає підвищені вимоги до міцності, стійкості, надійності та довговічності стрілочних переводів. Відповідно для оцінки міцності конструкцій потрібно знати величину діючих на них сил, які можна визначати експериментально або теоретичними розрахунками. У випадку тунельних ділянок метрополітенів експериментальні дослідження вкрай складно організувати та провести, тому альтернативою є лиш теоретичні методи. У даному дослідженні представлені результати теоретичного розрахунку пружнодинамічних характеристик для стрілочних переводів, що експлуатуються в тунельних ділянках метрополітенів. Виконано практичні розрахунки жорсткості рейкових ниток та модуля пружності підрейкової основи й отримано залежності розподілу пружнодинамічних параметрів по довжині стрілочних переводів. На їхній основі визначені сили взаємодії з рухомим складом метрополітену та проаналізовано їх розподіл по довжині стрілочного переводу. Отримані дані можуть служити передумовою для перевірки міцності конструктивних елементів.*

Ключові слова: *стрілочні переводи, підрейкова основа, жорсткість, модуль пружності, пружно-динамічні параметри колії, динамічні сили, динамічні прогини, напруження*.