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Analysis of the Relationship between Rail Cant and Track Gauge Based on the Data Obtained by Track Recording Cars

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ABSTRACT

The increase in the service life of track superstructure has always been an important task since this allows reduction in the cost of repairs and current maintenance of the track.

The objective of the work is to determine the mutual influence of the rail cant and the track gauge based on the results of measurements carried out by track recording cars, as well as their impact on the stress-strain state of the rail. The analysis was based on statistical and the finite element methods. Using statistical methods, it was determined that the rail cant and track gauge values do not have a normal distribution and have a weak feedback. The reasons were explained in the conclusions.

To determine with the finite element method contact stresses in the rail head on the track sections available in the sample, with different combinations of rail cant and track gauge, a model with full geometric similarity was developed.

The results obtained from the calculations demonstrate that the deviation of the cant within the range from 1/15 to 1/30 leads to an increase in stresses by more than 20 %, while changing the track gauge has a weak effect on the stress-strain state of the rail head. The maximum increase in contact stresses, at the analysed section, was 97 %, with a cant of 1/990 and a track gauge of 1526 mm.

The growth of contact stresses leads to the formation of fatigue cracks and, as a consequence, to the defects and then to replacement of the rail. To increase the service life of the rails, it is recommended to monitor the condition of fasteners and compliance with the technology of current maintenance works, as well as to reconsider tolerance of the deviation of the cant both upward and downward.

Keywords: railway transport, track gauge, rail cant, wheel-rail contact, contact stresses, finite element method, rail service life.

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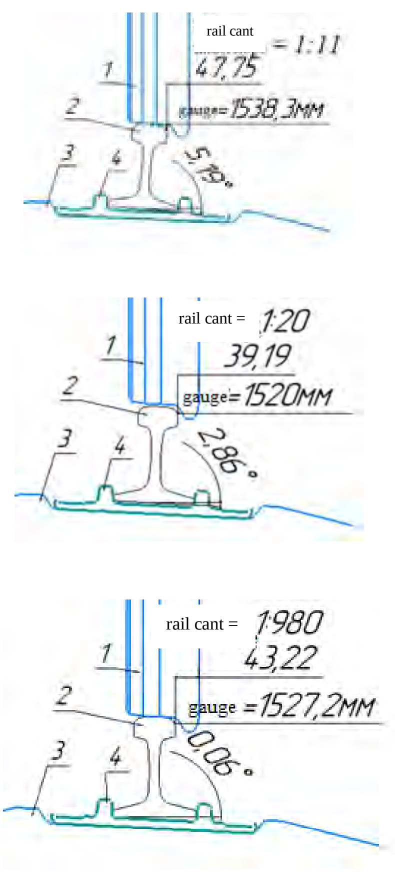
Текст статьи на русском языке публикуется в первой части данного выпуска.

INTRODUCTION

The reduction in costs in track facilities is primarily associated with an increase in the service life of the elements of the track superstructure, which will significantly reduce the costs associated with current maintenance of the track and its repairs.

The most expensive element in the track superstructure is the rail, so increasing its service life is a priority. The analysis of the replacement of rails per types of defects showed that the appearance of a fracture in the rails is preceded by the appearance of defects of contact fatigue origin in the rail head, development of which depends on the level of the stress-strain state caused, among other things, by the processed tonnage [1].

The stress-strain state of the rail head depends on the position of the wheel relative to the rail, as well as on vertical and lateral forces acting on the rail from the rolling stock. The transfer of the load from wheels to rails takes place over a very small site compared to the dimensions of wheels and rails. The material near this site is in a volumetric stress state. The distribution of these stresses, called contact stresses, is very complex and can be studied only by methods of the theory of elasticity [2].



Pic. 1. Influence of track gauge and rail cant on the position of the wheel on the rail. 1 – wheel; 2 – R65 rail; 3 – reinforced concrete sleeper; 4 – tie-plate [performed by the authors].

The position of the wheel relative to the rail primarily depends on the track gauge and rail cant (Pic. 1).

The *objective* of the work is to determine the mutual influence of the track gauge and rail cant, the degree of their distribution and correlation, as well as their influence on the stress-strain state of the rail head.

MATERIALS AND METHODS

To determine the relationship between the track gauge and rail cant, statistical analysis methods were used, namely, frequency histograms and the calculation of the correlation coefficient. The calculation of the stress-strain state of the rail was carried out using the finite element method, for which a three-dimensional model of the interaction of the wheel and the rail was built with full compliance with geometric parameters and physical and mechanical properties of the material.

During the analysis, a section of the track 50 km long was considered. Data on the geometry of the rail track were obtained using ERA diagnostic complex, with a measurement interval of 20 cm. The sample excluded the sections of the track, where, due to the characteristics of the measuring equipment, it was impossible to fix the rail cant but only the track gauge.

The recording of the cant values was carried out along both left and right rails of the track, so, a more detailed geometry values of the contact between the wheel and the rail were obtained.

The sample comprised 255307 values, the general view of the data obtained is presented in Table 1. For a more accurate calculation, the values of the cant are transferred into the angle of inclination of the rail foot, relative to the plane of the sleeper foot.

The initial analysis of the data obtained showed that besides normal geometry of the track gauge (regular track gauge of 1520 mm, standard rail cant of 1/20) there were other situations:

• Broadening or narrowing of the track gauge with standard rail cant (1/20).

• Standard track gauge (1520 mm) with deviation of the rail cant upward (till 1/11) or downward (till 1/990).

Table 1

General View of the Data Used for Analysis [performed by the authors]

Km	M	Cant of the left rail		Cant of the right rail		Track gauge, mm
		Inclination	Degrees	Inclination	Degrees	
1	0	1/28	2,045	1/20	2,862	1522,9
1	0	1/28	2,045	1/20	2,862	1522,8
1	1	1/28	2,045	1/19	3,013	1522,7
1	1	1/28	2,045	1/19	3,013	1522,6
1	1	1/28	2,045	1/19	3,013	1522,6
1	1	1/28	2,045	1/19	3,013	1522,5
1	1	1/28	2,045	1/19	3,013	1522,5
1	2	1/28	2,045	1/19	3,013	1522,4
1	2	1/28	2,045	1/19	3,013	1522,4
1	2	1/28	2,045	1/19	3,013	1522,3

• Broadening of the track gauge (> 1520 mm), deviation of the rail cant downward (till 1/990).

According to flow charts track gauge is adjusted by adjusting rail position in horizontal plain along the tie-plate without changing rail cant. Nevertheless, if there is a considerable lateral wear of the rail, such an adjustment does not allow attaining standard track gauge. If there is a case, the employees adjust the track gauge by changing rail cant. The third type of gauge deformation is caused by wear of the elements of intermediate fasteners, by weakening of the moment of tightening of the fasteners [3].

To test the hypothesis about the normal distribution of the rail cant and track gauge, the arithmetic mean, median, standard deviation (hereinafter SD), minimum and maximum values were determined (Table 2).

To test the hypothesis about the normality of the distribution of a random variable, indirect, graphical and computational methods are used.

Graphical methods include frequency histograms, normal probability plot and box plot. The calculation methods include the Kolmogorov–Smirnov criterion, the Shapiro–Wilk test, Pearson's Chi-squared test, and others [4]. This work used a graphical method of frequency histograms to test the hypothesis of normality of distribution of rail cant.

RESULTS

Comparison of Empirical and Theoretical Data

Frequency histograms were used to test the hypothesis of normality of distribution of rail cant by graphical method.

The construction of the histogram is carried out based on empirical and theoretical frequencies of sample values. The identification of frequencies is carried out at equal intervals of the sampling range. For rail cant, this interval is 0,235 degrees, for track gauge it is of 1 mm. Theoretical frequencies are determined from the density function of the normal law:

$$f(x)=\frac{1}{\sigma\sqrt{2\pi}}\bullet e^{-\frac{(x-\mu)^2}{2\sigma^2}}, \qquad (1)$$

where σ is standard deviation;

μ – mathematical expectation (median).

The results of determining the frequencies are presented in Table 3 and 4.

Based on the obtained data, frequency histograms were constructed (Pics. 2, 3, 4).

Table 2

Calculation of Mean Values, Median, Standard Deviation, Minimum and Maximum Values [performed by the authors]

Parameter	Cant of the left rail		Cant of the right rail		Track gauge, mm
	Inclination	Degrees	Inclination	Degrees	
Arithmetic mean	1/22	2,644	1/21	2,721	1522,53
Median	1/21	2,727	1/21	2,727	1522
SD		0,421		0,427	2,73
Minimum value	1/990	0,058	1/990	0,058	1516,3
Maximum value	1/12	5,194	1/11	5,194	1541,8

Table 3

Frequencies of Rail Cant along Both Rails within Specified Intervals [performed by the authors]

Intervals Empirical frequencies		Left rail		Right rail	
		Theoretical frequencies	Empirical frequencies	Theoretical frequencies	
1/195	1/990	764	0,01	593	0,00
1/108	1/195	714	0,18	621	0,07
1/75	1/108	652	3,10	467	1,07
1/57	1/75	622	37,64	452	12,46
1/46	1/57	864	317,88	705	105,84
1/39	1/46	1950	1868,74	1011	657,77
1/34	1/39	4112	7647,46	1860	2989,95
1/30	1/34	8365	21785,42	3472	9940,73
1/26	1/30	25234	43201,23	8191	24173,48
1/24	1/26	75992	59635,86	29127	42995,84
1/22	1/24	82380	57306,03	51430	55934,58
1/20	1/22	29982	38333,14	80699	53223,19
1/18	1/20	21196	17849,66	39755	37041,45
1/17	1/18	1670	5785,84	25040	18855,66
1/16	1/17	455	1305,52	11146	7020,40
1/15	1/16	193	205,06	508	1911,83
1/14	1/15	117	24,13	168	436,28
1/13	1/14	26	0,09	37	5,91
1/12	1/13	19	0,00	25	0,46

Table 4

Frequencies of Track Gauge within Specified Intervals [performed by the authors]

Intervals	Empirical frequencies	Theoretical frequencies
≤1517	48	8550,19
(1517; 1518)	1046	9678,56
(1518; 1519)	6415	16458,60
(1519; 1520)	20693	24508,99
(1520; 1521)	44701	31960,38
(1521; 1522)	56595	36496,79
(1522; 1523)	45953	36496,79
(1523; 1524)	30108	31960,38
(1524; 1525)	18383	24508,99
(1525; 1526)	12269	16458,60
(1526; 1527)	7073	9678,56
(1527; 1528)	3358	4983,96
(1528; 1529)	1894	2247,39
(1529; 1530)	1648	887,39
(1530; 1531)	1044	306,82
(1531; 1532)	654	92,89
(1532; 1533)	300	24,62
(1533; 1534)	104	5,72
(1534; 1535)	338	1,16
(1535; 1536)	561	0,21
(1536; 1537)	622	0,03
(1537; 1538)	690	0,00
(1538; 1539)	373	0,00
(1539; 1540)	329	0,00
(1540; 1541)	85	0,00
(1541; 1542)	23	0,00

The obtained histograms for rail cant and gauge are asymmetric, do not coincide with theoretical normal curves, therefore, the hypothesis of the normal distribution of these values is rejected.

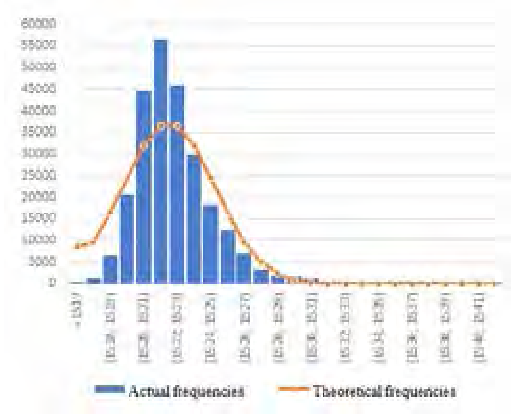
To determine the relationship between the values, the calculation of the correlation coefficient between the left rail cant and the gauge, as well as the right rail cant and the gauge with Pearson's method was performed:

- The correlation coefficient between the left rail cant and the track gauge is –0,20, which indicates a weak feedback.
- The correlation coefficient between the right rail cant and the gauge is –0,41, which indicates a moderate feedback.

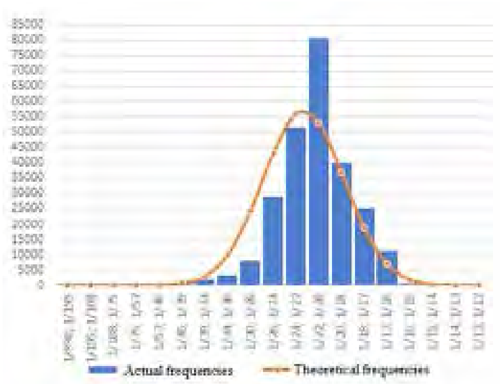
Cant Distribution

With a normal track gauge of 1520 mm and a 1/20 cant of both rails, the contact stresses do not exceed 650 MPa [5], however, with a deviation within the allowable cant from 1/12 to 1/60, they increase by more than 170 % and exceed the ultimate strength of rail steel.

It should also be taken into account that the rail cant on tracks with reinforced concrete sleepers is primarily formed by the inclination of the tie-plates of sleepers with tolerances from



Pic. 2. Frequency histogram of track gauge [performed by the authors].



Pic. 3. Frequency histogram of rail cant for the right rail [performed by the authors].

1/18 to 1/22 for the first grade and from 1/16 to 1/24 for the second grade[1].

The calculation of contact stresses at the analysed section was carried out on track segments with the following parameters: the cant of both rails was the same; cant of both rails was >1/20, <1/20; cant of the right and left rails differed in opposite directions. The rail cant indicated above was considered at the standard value, with broadening and narrowing of the rail gauge. All types of geometry were taken from the sample.

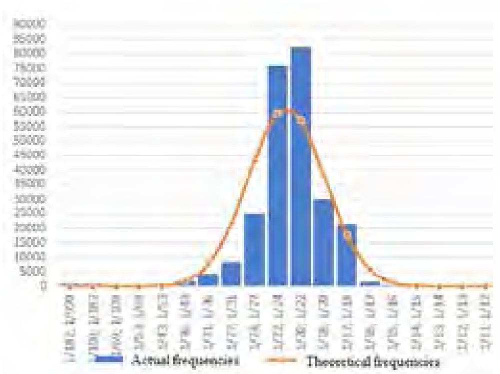
Contact stresses were calculated using the finite element method.

The finite element method (FEM) is a numerical method for solving partial differential equations, as well as of integral equations that arise in solving problems of applied physics. The method is widely used to solve problems of solid mechanics, heat transfer, hydrodynamics, and electrodynamics. Concerning railways, the finite element method is used not only to solve the problems of the track facilities, but also of rolling stock [6–8], systems of train traffic control [9; 10] and in the design of artificial structures [11].

The power of the created model is about 300 thousand nodes and 200 thousand elements (Pic. 5). The model consists of a wheel and a rail. The rail is rigidly fixed along the foot, vertical loads are applied to the wheel, corresponding to the axial load of 23, 25 and 30 tf/axle.

The results of the calculation of contact stresses when changing the gauge and cant are shown in Pics. 6, 7 and in Table 5.

[1] GOST [State standard] 33320–2015 Reinforced concrete sleepers for railways. General specifications. Moscow, Standartinform publ., 2019, 39 p. [Electronic resource]: https://docs.cntd.ru/document/1200124225. Last accessed 28.10.2022.



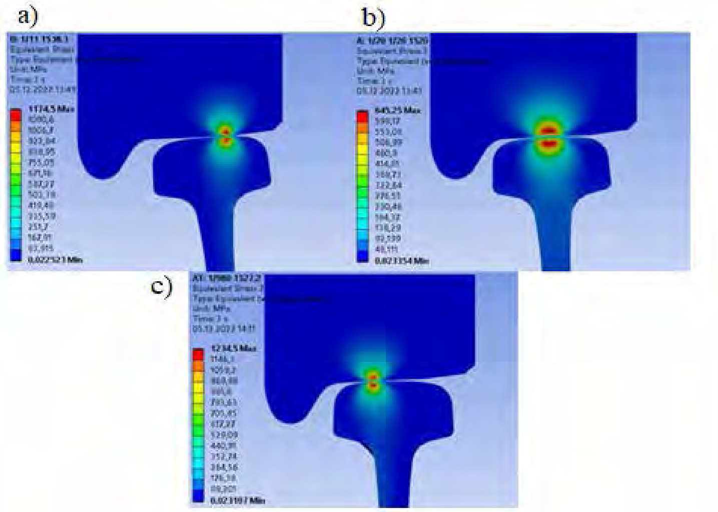
Pic. 4. Frequency histogram of rail cant for the left rail [performed by the authors].

FINDINGS

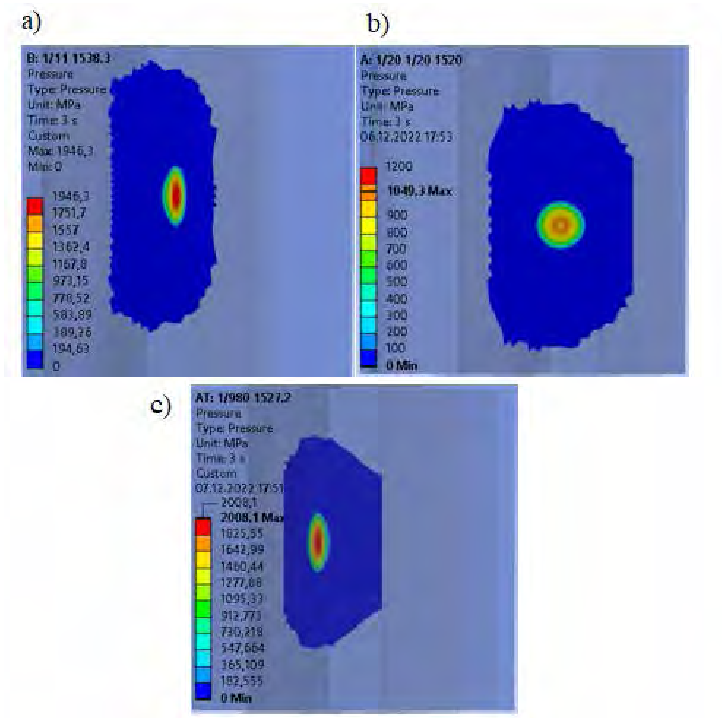
The value of the rail cant is not a normally distributed value, because any deviation of the cant from 1/20, except for the indicated assumption of the inclination of the under-rail area for reinforced concrete sleepers, is a consequence of wear of elements of intermediate fastenings, weakening of the tightening torque of fasteners [3] or the result of a violation of the established procedure for adjusting the track gauge.

Violations when adjusting the track gauge are characterised by a change in the angle of

Pic. 5. Volumetric finite element model of wheel-rail contact [performed by the authors].



Pic. 6. Contact stresses in the rail head when cant and gauge have the values: a) 1/11, 1538,3 mm; b) 1/20, 1520 mm; c) 1/980, 1527,2 mm.



Pic. 7. Contact spots and contact pressures in the rail head when cant and gauge have values: a) 1/11, 1538,3 mm; b) 1/20, 1520 mm; c) 1/980, 1527,2 mm.

inclination of the rail, due to placement of foreign objects under the rail foot. The presence of such violations is clearly demonstrated on sections of the track with a gauge corresponding to the standard, with deviations within the deviation tolerance of the 1st degree (–4 mm; +8 mm), and with different cant of both rails. In table 5 they are presented in lines 2–17.

A change in the track gauge has little effect on the change in contact stresses, which is demonstrated by the example of a 1/20 cant, with a track gauge of 1516, 1520, 1536 and 1540 mm (Table 5, lines 1, 2, 20 and 22, respectively). The growth of contact stresses in these cases is of 2–3 %.

The growth of stresses in the rail head is a negative factor that reduces the contact fatigue properties of rail steel, and ultimately can lead to formation of transverse fatigue cracks in the rail head in the form of a light or dark spot,

Table 5

Geometrical Parameters of the Track Gauge for calculation of Contact Stresses [performed by the authors]

No.	Gauge, mm	Cant		Contact stresses in the rail head, MPa / Change intensity KN, in %					
		Left rail	Right rail	23 tf/axle		25 tf/axle		30 tf/axle	
				Left rail	Right rail	Left rail	Right rail	Left rail	Right rail
1.	1520	1/20	1/20	586,24 0 %	586,24 0 %	603,46 0 %	603,46 0 %	645,25 0 %	645,25 0 %
2.	1516.3	1/19	1/14	602,87 3 %	843,68 44 %	619,73 3 %	863,6 43 %	657,28 2 %	906,83 41 %
3.	1516.9	1/18	1/17	593,97 1 %	604,06 3 %	613,67 2 %	621,07 3 %	657,62 2 %	659,39 2 %
4.	1517.1	1/22	1/15	599,25 2 %	713,36 22 %	615,55 2 %	731,26 21 %	654,35 1 %	769,81 19 %
5.	1518	1/33	1/18	804,66 37 %	599,62 2 %	824,79 37 %	617,57 2 %	871,42 35 %	657,45 2 %
6.	1518.9	1/16	1/249	614,15 5 %	1132,6 93 %	635,47 5 %	1157,3 92 %	685,06 6 %	1212,9 88 %
7.	1519	1/38	1/17	954,73 63 %	600,39 2 %	975,7 62 %	617,64 2 %	1018,9 58 %	656,09 2 %
8.	1519.9	1/64	1/64	1047 79 %	1047 79 %	1072,3 78 %	1072,3 78 %	1128,7 75 %	1128,7 75 %
9.	1521.2	1/13	1/238	921,64 57 %	1115,7 90 %	941,54 56 %	1142,1 89 %	997,53 55 %	1209,6 87 %
10.	1521.5	1/13	1/339	931,45 59 %	1153,8 97 %	952,31 58 %	1179,4 95 %	995,28 54 %	1234,8 91 %
11.	1521.9	1/364	1/980	1127,8 92 %	1140,1 94 %	1153,5 91 %	1174,5 95 %	1209,6 87 %	1251 94 %
12.	1523.7	1/14	1/410	824,35 41 %	1126,7 92 %	841,67 39 %	1161,9 93 %	880,63 36 %	1237,8 92 %
13.	1523.8	1/113	1/12	1077,3 84 %	1035,6 77 %	1107,6 84 %	1059,8 76 %	1174,7 82 %	1113,6 73 %
14.	1523.9	1/83	1/12	1049,9 79 %	1025,6 75 %	1077,4 79 %	1046,4 73 %	1142,7 77 %	1091,7 69 %
15.	1526	1/855	1/990	1125,7 92 %	1134,4 94 %	1157,7 92 %	1169,7 94 %	1234,1 91 %	1247,3 93 %
16.	1527.1	1/535	1/16	1118,6 91 %	615,16 5 %	1150,3 91 %	634,25 5 %	1228,9 90 %	680,16 5 %
17.	1527.2	1/980	1/16	1126,7 92 %	615,66 5 %	1156,1 92 %	637,48 6 %	1234,5 91 %	686,44 6 %
18.	1533.9	1/16	1/46	615,38 5 %	916,23 56 %	634,59 5 %	940,25 56 %	677,09 5 %	997,57 55 %
19.	1534.9	1/27	1/27	622,85 6 %	622,85 6 %	642,14 6 %	642,12 6 %	685,48 6 %	685,48 6 %
20.	1536.3	1/20	1/62	598,2 2 %	1025,8 75 %	614,8 2 %	1044,1 73 %	652,48 1 %	1092,9 69 %
21.	1538.3	1/11	1/28	1078,2 84 %	633,4 8 %	1108,3 84 %	652,84 8 %	1174,5 82 %	696,89 8 %
22.	1540	1/20	1/101	598,2 2 %	1081,8 85 %	614,78 2 %	1102 83 %	654,09 1 %	1162 80 %
23.	1540.3	1/19	1/106	602,24 3 %	1096,7 87 %	618,87 3 %	1124,2 86 %	656,36 2 %	1185 84 %
24.	1540.7	1/15	1/35	740,1 26 %	859,48 47 %	761,66 26 %	879,51 46 %	812,35 26 %	925,94 44 %
25.	1541.7	1/15	1/43	723,37 23 %	954,82 63 %	744,47 23 %	972,94 61 %	791,9 23 %	1012,5 57 %

leading to failure of the rail before the warranty tonnage is processed [12–15].

An increase in contact stresses by 20 % or more begins when the cant leaves the interval from 1/15 to 1/30.

The greatest increase in contact stresses is observed when approaching the horizontal position of the rail foot. When the cant is less than 1/100, the stress increase is of 80–97 %.

When the cant is changed in the direction of increasing the angle of inclination of the rail foot from 1/14 to 1/11, the increase in contact stresses is of 41–84 %.

CONCLUSION

The parameter of the rail cant has a significant general impact on the stress-strain state of the most important element of the track superstructure which is the rail, and ultimately affects durability (life cycle). To increase the service life of the rail, it is necessary to prevent, among other things, deviations of the rail cant due to wear of individual elements of intermediate rail fastenings and violations of the technological process of adjusting the gauge. As an additional measure to increase the life of the rail, it may be worth reconsidering the tolerances for deviation of the cant from 1/20.

REFERENCES

1. Sychev, V. P., Ovchinnikov, D. V., Abdurashito , Sycheva, A. V. Procedure for determining railway track life depending on its operating conditions. *Nauka i tekhnika transporta*, 2021, Iss. 3, pp. 44–50. DOI 10.53883/20749325_2021_03_44.

2. Chernyshev, M. A. Practical methods of track calculation [*Prakticheskie metody rascheta puti*]. Moscow, Transport publ., 1967, 236 p.

3. Ovchinnikov, D., Pokatsky, V., Gallyamov, D. Factors Affecting the Dynamic Rail Canting of the Railway Track. *Transportation Research Procedia*, 2020 International Scientific Siberian Transport Forum, Transsiberia 2020, Novosibirsk, 2021, pp. 544–551. DOI: 10.1016/j.trpro.2021.02.106.

4. Kobzar, A. I. Applied mathematical statistics. For engineers and scientific workers [*Prikladnaya matematicheskaya statistika. Dlya inzhenerov i nauchnykh rabotnikov*]. Moscow, Fizmatlit publ., 2006, 816 p. ISBN 5-9221-0707-0.

5. Pokaski, V. A., Ovchinnikov, D. V., Gallyamov, D. I. Contact voltages at different mutual location of wheels and rails. *Put i putevoe khozyaistvo*, 2020, Iss. 3, pp. 7–10. [Electronic resourceypc]: https://elibrary.ru/item.asp?id=42608180 [limited access].

6. Peng, D., Jones, R., Constable, T. Tools and methods for addressing the durability of rolling stock. *Engineering Failure Analysis*, 2013, Vol. 34, pp. 278–289. DOI: 10.1016/j.engfailanal.2013.08.011 [limited access].

7. Vorobyev, A. A., Fedorov, I. V., Chistyakov, E. Yu., Abduganiyev, T. R., Glukhov, A. E. Calculation of the design life of solid-rolled wheels of railway rolling stock according to the criterion of reliability. *Izvestiya Peterburskogo univesiteta putei soobshcheniya*, 2021, Vol. 18, Iss. 1, pp. 121–131. DOI: 10.20295/1815-588X-2021-1-121-131.

8. Ivanov, P. Yu., Agafonov, V. M., Dulskiy, E. Yu. Mathematical modeling of the process of heating of stator winding insulation of electric locomotives asynchronous auxiliary machine. *Sovremennie tekhnologii. Sistemniy analiz. Modelirovanie*, 2016, Iss. 1 (49), pp. 183–189. [Electronic resource]: https://elibrary.ru/item.asp?id=25815924 [limited access].

9. Song, Yang; Zhang, Mingjie; Øiseth, O., Rønnquist, A. Wind deflection analysis of railway catenary under crosswind based on nonlinear finite element model and wind tunnel test. *Mechanism and Machine Theory*, 2022, Vol. 168, 104608. DOI: https://doi.org/10.1016/j.mechmachtheory.2021.104608.

10. Zalesova, O. V., Yakubovich, M. V. Calculation of the induced voltage on a disconnected power line using the FEMM program [*Raschet navedennogo napryazheniya na otklyuchennoi LEP s pomoshchyu programmy FEMM*]. *Proceedings of Kola Scientific Centre of the Russian Academy of Sciences*, 2011, Iss. 1 (4), pp. 37–42.

11. Zhi-Ping, Zeng; Fu-Shan, Liu; Wei-Dong, Wang. Three-dimensional train–track–bridge coupled dynamics model based on the explicit finite element method. *Soil Dynamics and Earthquake Engineering*, 2022, Vol. 153, 107066. DOI: https://doi.org/10.1016/j.soildyn.2021.107066. [Electronic resource]: https://www.sciencedirect.com/science/article/pii/S0267726121004887. Last accessed 24.11.2022.

12. Daves, W., Kubin, W., Scheriau, S., Pletz, M. A finite element model to simulate the physical mechanisms of wear and crack initiation in wheel/rail contact. *Materials Science, Engineering. Wear,* 2016, pp. 78–83. DOI: 10.1016/j.wear.2016.05.027.

13. Magheri, S., Malvezzi, M., Meli, E., Rindi, A. An innovative wheel–rail contact model for multibody applications. *Materials Science, Engineering. Wear,* 2011, Vol. 271, Iss. 1–2, pp. 462–471. DOI: 10.1016/j.wear.2010.10.038.

14. Wen, J., Marteau, J., Bouvier, S., Risbet, M., Cristofari, F., Secordel, P. Comparison of microstructure changes induced in two pearlitic rail steels subjected to a full-scale wheel/rail contact rig test. *Materials Science, Engineering, Wear,* 2020, 203354, pp. 456–457. DOI: 10.1016/j.wear.2020.203354.

15. Khoa, D. Vo; Tieu, A. Kiet; Hongtao, Zhu T.; Kosasih, Buyung P. A 3D dynamic model to investigate wheel–rail contact under high and low adhesion. *International Journal of Mechanical Sciences*, 2014, Vol. 85, pp. 63–75. DOI: 10.1016/j.ijmecsci.2014.05.007. ●

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