

The intensity of rail failure flow

Oleksandr Patlasov, and Yelyzaveta Fedorenko*

Dnipro National University of Railway Transport named after academician V. Lazaryan, Department of Railway track and Track facilities, Ukraine

Abstract. The article reveals the quantitative changes in the intensity of failure accumulations in areas with gradual introduction of high axial loads. To obtain the actual values, the authors received three-dimensional array of intensity of rail failure flow. According to the results of the research, it was discovered that the main cause of failure of the rails are the defects in the main contact-fatigue origin. The main factor that impacts the intensity of the rail failure flow is the number of transmitted tonnage. The size of the axial load and curvature of the line pours weight on this process. The proposed rail failure model is a model that can be used to optimize the track maintenance system. The authors conducted a study on the identification of quantitative changes in the intensity of accumulation of track failures in areas with high axial loads and evaluated their influence on the planning of repair and road works. On the basis of the obtained results it is possible to estimate the effect of the axial load on the intensity of changes in the state of the flow rail failure flows.

Introduction

For rational management of the track facilities and the choice of the most appropriate upper structures of the track, it is necessary to determine the expected service life of the upper structure of the track as a whole and its individual elements. An analysis of the actual state of the rail facilities and repair planning on the actual state of the track is an urgent problem.

The most dangerous failures when operating the track are broken rails. To prevent this, there is a control system to detect cracks in the metal at an early stage of development and to ensure the removal of potentially hazardous rails prior to their destruction.

In order to predict the service life of the rails, it is necessary to evaluate the factors affecting them, to describe the work of rails with the help of a mathematical model, in which it is necessary to take into account the influence of the main factors of the operation of the railway track and determine the quantitative changes in the intensity of the accumulation of rail failures in areas with the gradual introduction of high axial loads.

Existing norms for determining the periodicity of carrying out track repair work depend on the screened tonnage, as well as additional criteria, including a single output of rails, which takes into account the actual state of the track. In turn, the conditions of the tracks depend on gages, radiuses and lengths of curves, their total length, ascents and descents of different lengths.

The intensity of the rail failure flow rates is established on the basis of massive observations of their work in different operating conditions.

Theoretical and experimental researches on intensity of development of defects of rails, influence on them axial loading, low temperatures, plan of the line, volumes of transportations are devoted to work of domestic and foreign scientists: IS. Baulin, S.A. Kolotushkin, E.A. Shur, NI Karpushchenko, VS Lysyuk, VO Pevzner, A. Yu. Abdurashitov, VV Ribkin, VV Kosarchuk, J. V. Ringsberg, V.A. Reichart, M. Taraf, E.H. Zachaf, O. Ususoadi, A. Zegul. [1-16].

In [17] experimental dependences of the intensity of the flow of failures were obtained.

Given that increasing the capacity of cars up to 25 tonnes / axle is considered as one of the priority areas for the development of railways, it is advisable to consider the effect of such cars on the condition of the track, namely on the condition of the rail economy in the conditions of heavy freight trains.

Taking into account that increasing the carrying capacity of carriages up to 25 t/axle is considered as one of the priority directions of development of railways, it is expedient to consider the influence of such carriages on the state of the track.

The main objective of this study is to identify quantitative changes in the intensity of accumulation of failure flows in areas with high axial loads.

Methodology and results

It is estimated that the productivity of carriages with a load of 25 tf/axle is higher by 7-10% due to an increase in inter-repair mileage and a reduction in the cost of traction in calculating the carriage of one ton of cargo. But a heavier carriage more intensively wears a track and leads to malfunctions [18].

* Corresponding author: rapunzeelliza@gmail.com

With the development of tonnage in the process of operation, rails accumulate various damage, deformation, fatigue defects, resulting in a decrease in their reliability, more often failures occur and there is a need to reduce speed or stop the movement of trains.

The main reason for the track failure are mainly defects of contact-fatigue origin. The occurrence of contact-tired defects is a long process. Significantly influences its formation of the load on the axle from the rolling stock.

Defects originate at the stage of smelting, bottling and metal processing, and then appear at the rolling and heat treatment. The inefficiency of control at all stages of production and release of rails leads to the supply of a track complex of rails with defects of production origin.

The main criterion for total rail replacement for new and old ones is the continuous wear of the rails above the standard value or the same number of rails, as with the appointment of the appropriate type of modernization or major repair of the track. In this case, the type of accompanying work, the number of elements of fastenings and sleepers, which must be replaced, is determined by the distance of the track according to the results of commission inspections.

The complete replacement of rails, the replacement in curved sections, as well as the replacement of rails from external threads of the curved parts of the track to the straight ones, are intended provided that the rails are drained to the limits set by the Ukrzaliznytsya [19].

The main types of damages, deformations and defects of the rails are cracks, exfoliation, deflection, erosion, influx, corrosion of the metal, mechanical damage to the rails in the form of bends, screw heads or soles, internal fatigue defects in rail metal, etc.

The intensity of the single output of rails depends on the tonnage (runtime), load intensity, dynamic loads loaded on the rolling stock of the structure of the track and its condition, plan and profile of the track and other factors.

The function of the failure rate depends on the average axial load on the axle, the screened tonnage, the radius of the curve:

$$\lambda = f(P_{av}, T, R) \quad (1)$$

where P_{av} – average axle load in tf/axle;
 T – screened tonnage in million tons gross;
 R – curves radius in meters.

However, the intensity of the rail failure flows depends not only on the magnitude of the axial load, but also on the following other factors:

- type and structure of the upper structure of the track,
- rail steel quality,
- line plan and profile,
- load capacities,
- screened tonnage,
- types and number of repairs,
- speed of movement,
- climatic conditions, etc.

By analyzing the function of the dependence of the intensity of the rail failure flow, we can predict that with increasing axial load, the intensity of the rail failure flow increases, as well as inter-repair terms reduce. This is due to the fact that with the increase of the axial load the life of the track decreases, which is the most expensive element of the upper structure of the rail, shortening the life of the transfer services and increasing labor costs.

To solve these issues, a study was conducted on double tracks of the Pridneprovska railway distillation on Pryshyb station - Burchatsk station running line (1174 km, PC 3). The photo of the experimental site is shown in Fig. 1



Fig. 1. Photo of the experimental site

As input data, a train No. 1762 was considered, which was moving according to the schedule, and consisted of the VL-11 locomotive, five carriages with an axial load of 25 tf/axle and 51 carriages with an axle load of up to 23.5 tf/axle.

The scheme of the experimental train is shown in Fig. 1. The train was moving at a speed of about 75 kmph.

Carriage dead weight and cargo weight are shown in Table 1. The experimental train was moving from the side of the Pryshyb station in the direction of Burchatsk station.

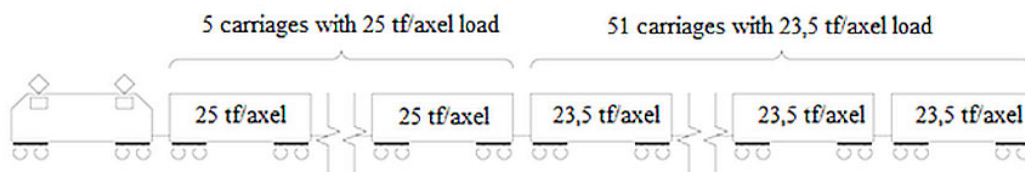


Fig. 2. Experimental train schem

Table 1. Load capacity of train carriages

No.	Carriage No.	Dead weight, tons	Tonnage, tons	Total, tons	Average axle load, tf/axle
0	VL-11	184	0	184	23,000
1	62139845	23,5	76	99,5	24,875
2	62139878	23,5	76	99,5	24,875
3	62139852	23,5	75	98,5	24,625
4	63584981	23,5	76	99,5	24,875
5	62139860	23,5	76	99,5	24,875
average 25 tf/axle		23,5	75,8	99,3	24,825
6	55081020	23,5	70	93,5	23,375
7	62783170	23,5	70	93,5	23,375
8	56732332	23,6	71	94,6	23,65
9	65576373	23,5	70	93,5	23,375
10	52183282	23,5	70	93,5	23,375
11	55210926	23,5	70	93,5	23,375
12	53007878	23,6	71	94,6	23,65
13	55531487	23,6	70	93,6	23,4
14	62073077	23,6	70	93,6	23,4
15	55267934	23,6	70	93,6	23,4
16	56653389	23,6	69	92,6	23,15
17	59787184	23,5	70	93,5	23,375
18	52283546	23,5	71	94,5	23,625
19	52244332	23,5	70	93,5	23,375
20	55732184	23,5	70	93,5	23,375
21	62782917	23,5	70	93,5	23,375
22	54008180	23,5	70	93,5	23,375
23	62783022	23,5	70	93,5	23,375
24	62783063	23,5	70	93,5	23,375
25	56264443	23,5	71	94,5	23,625
26	53148474	23,5	70	93,5	23,375
27	60736675	23,5	70	93,5	23,375
28	56936529	23,5	70	93,5	23,375
29	62073556	23,5	70	93,5	23,375
30	55483846	23,5	71	94,5	23,625
31	60808706	23,5	70	93,5	23,375
32	62649314	23,5	70	93,5	23,375
33	55440044	23,5	71	94,5	23,625
34	55531537	23,5	70	93,5	23,375
35	62783436	23,5	70	93,5	23,375
36	56462955	23,5	69	92,5	23,125
37	55371645	23,5	69	92,5	23,125
38	56843808	23,5	70	93,5	23,375
39	62479860	23,5	70	93,5	23,375
40	56592603	23,5	71	94,5	23,625
41	55459895	23,5	71	94,5	23,625
42	57656985	23,5	70	93,5	23,375
43	63679112	23,5	70	93,5	23,375
44	56367360	23,5	70	93,5	23,375
45	56846421	23,5	70	93,5	23,375
46	56479066	23,5	71	94,5	23,625
47	61236154	23,5	70	93,5	23,375
48	62309620	23,5	70	93,5	23,375
49	58140310	23,5	70	93,5	23,375
50	56002819	23,5	69	92,5	23,125
51	56850043	23,5	70	93,5	23,375
52	53587937	23,5	70	93,5	23,375
53	53586806	23,5	70	93,5	23,375
54	62932181	23,5	70	93,5	23,375
55	56421084	23,5	69	92,5	23,125
56	61102281	23,5	70	93,5	23,375
Average 23,5 tf/axle		23,51	70,08	93,59	23,398

Today, Ukraine already has a rolling stock with an axle load of 25 tf/axle and its implementation is considered, but the actual axle load is 23.5 tf/axel. To calculate, let us compare the value of the intensity of the rail failure flow, depending on the average of the actual and increased axial load.

The actual average axle load for the carriage of cargo shall be the following (2):

$$P_{av \text{ cargo}} = \frac{T_{car}}{n_{axis}} \quad (2)$$

where T_{car} – dead weight of a loaded carriage in tons;

n_{axis} – number of axels in the carriage;

Actual average axle load for empty carriages (3):

$$P_{empty \text{ cargo}} = \frac{T_{car}}{n_{axis}} \quad (3)$$

where T_{car} – dead weight of an empty carriage in tons;

n_{axis} – number of axels in the carriage;

The following initial documentation of the distances and the service of the track was used for obtaining the initial data: longitudinal profiles, rail-sleeper-ballastinc map, record of rails taken from the main tracks (form PU-4), annual reports of the track distance.

For the selected experimental sites and each element of the plan, the following parameters were determined:

- load capacity;
- average axle load;
- description of plan and profile;
- the term of the last major repair;
- screened tonnage after the last upgrade.

From each removed rail from a track, the following aspects were fixed:

- direction;
- track number;
- kilometer and number of the rail;
- day, month, and year of rail removal;
- defective classification number [20].

One of the main indicators that characterize the system reliability of the track is the parameter of the rail failure flow. The rate of failure of the rails is the number of defective rails, which are replaced by 1 km referenced to the unit of the passed tonnage:

$$\lambda_{ijk} = \frac{N_{ijk}}{L_{ijk} \cdot \Delta T_{ijk}} \quad (4)$$

where N_{ijk} – the number of rails replaced on the experimental plot, pcs;

L_{ijk} – length of the experimental plot, km;

ΔT_{ijk} – screened tonnage, million tons gross;

i, j, k – the levels of the axial load test factors, the line plan and the screened tonnage.

To obtain the actual values it is necessary to get three-dimensional array of intensity of rail failure flow. The size of the array is determined by the number of levels of each of the test factors (axial load, plan of the line, screened tonnage) [21].

The algorithm of calculation begins with the sorting of data on each replaced rail in relations with levels of influencing factors. As a result of sorting, the values of the indexes i, j, k are found. Thus, the number of replaced rails is determined at all levels of the analyzed factors.

The next step is to determine the length of the track segment, which corresponds to the characteristics of each element of the three-dimensional array L_{ijk} . Each elementary segment is understood as a segment of the track, where any chosen for the analysis change. Moreover, it was taken into account that one and the same real elementary segment can be entered into a cell of the array, which are different values of the screened tonnage. For example, if the factor "screened tonnage" is divided at the level of 50 million tons gross, then the length of one and the same elementary segment can be entered in the first, second, etc. levels, as the same that through this real segment of the track the tonnage of 0 to 50 million tons gross can be screened, from 50 to 100, etc. It is also taken into account that during a certain period of operation of the section of the track there are no data on the failure of rails in this area. In this case, the length of this section in the corresponding cell of the screened tonnage is not entered. If the level of the screened tonnage is lower than the level of the factor at the site, then the "length" changes in proportion to the actual tonnage missed.

After filling all the cells of the three-measuring array with the number of replaced rails and the "length" of the sections according to the formula (4), the intensity of the rail failure flow is determined.

Taking into account that the levels of all factors being analyzed are intervals, for each value of the intensity of the rail failure flow, the value of the screened tonnage, the axial load and the radius of the curve were determined.

For the implementation of the dispersion analysis, factor 3 was adopted: the line plan (straight and curves with a radius of 600 m) and the screened tonnage of 800 million tons gross, and variants of axial load, namely: 5% of carriages loaded 25 tf/axel, 95% - up to 23.5 tf/axel
10% of carriages loaded 25 tf/axel, 95% - up to 23.5 tf/axel
25% of carriages loaded 25 tf/axel, 95% - up to 23.5 tf/axel
50% of carriages loaded 25 tf/axel, 95% - up to 23.5 tf/axel
75% of carriages loaded 25 tf/axel, 95% - up to 23.5 tf/axel
100% of carriages loaded 25 tf/axel, 95% - up to 23.5 tf/axel

The results of calculating the intensity of the rail failure flow are shown in Table 2.

Table 2. Results of calculating the intensity of the rail failure flow

Average axial load, tf / axel	The curvature of the site.	Missed tonnage, million tons	The parameter of the flow of the rail, pcs
23,46935	0.0143478	800	0,118149899
23,5407	0.0143478	800	0,118160136
23,75475	0.0143478	800	0,118190848
24,1115	0.0143478	800	0,118242033
24,46825	0.0143478	800	0,118293219

Conclusion

According to the results of researches, it has been discovered that the main cause of track failure are mainly defects of contact-fatigue origin. The main factor that impacts the intensity of the rail failure flow is the number of transmitted tonnage. The size of the axial load and curvature of the line pours weight on this process. The track failure model is proposed. Which can be used to optimize the track maintenance system.

Literature

1. Baulin I. S., Dyakov V. N., Uskova O. N. et al. *Investigation of the mechanism of contact-fatigue damage (defect 82 and 64) / Vesnik VNIIZhT. No. 4, 1962. - p.34-39*
2. Kolotyshkin S. A., Dyakov V. N., Poroshin V. L., Baulin I. S. *Detection of internal longitudinal-inclined cracks in the track heads / Vesnik VNIIZhT. Edition 1, 1973, p. 41-43*
3. Tsukanov P. P. *Operational stability of tracks of modern production / Research on heavy type tracks. Collection of VNIIZhT scientific papers. M. : 1961. P. 4-31*
4. Shur E. A., Konyukhov A. D. *Influence of residual stresses in hardened tracks on the emergence and propagation of fatigue cracks in cyclic bending / Residual stresses and strength of railway tracks. VNIIZhT. Edition.491*
5. Shur E. A. *On the choice of permissible stresses under the strength of track calculations / Vesnik VNIIZhT. Edition 8, 1977, pp. 38-41*
6. Shur E. A., Kiselev T. N., Poroshin V. L., Beysarov M. S. *Durability of tracks with cracks / Vesnik VNIIZhT. Edition 5, 1984, p. 48-52*
7. Karpushchenko N. I. *Planning of repairs of the railroad according to its the state // G. K. Shchepotin Improving the reliability and efficiency of the railroad. / Under edition if N. I. Karpushchenko. Collection of scientific papers – Novosibirsk, 1991, - p. 122.*
8. Lysyuk V. S. *Fundamentals of the methodology for calculating failures and inter-repair resources of the railway track for damages of tracks // VNIIZhT. - M., 1983. - 57 p. CNIITEI MPS Dep 25.02.83, № 2120 ZHD-D83 // Railway Transport Magazine abstract, No. 6, 1983.*
9. Pevzner V.O. *To improve planning of track works. // Track and track facilities, 1993, № 9, - P. 10-12.*
10. Abdurashitov A. Yu. *The regularities of the formation of contact-fatigue defects. // Track and track facilities, 2002, No. 11, pp. 16-20.*
11. Rybkin V. V. *Mathematical model of track failure due to fatigue defects // A. M. Patlasov. Aspects of the interaction of the track and the rolling stock. Works of DIIT. - D., 1990. - P. 52-58.*
12. Ringsberg J.W. *Cyclic ratcheting and failure of a pearlitic rail steel // Fatigue & Fract. Engng. Mater.& Struct. – 2000. – 23. – P. 747 – 758*

13. Reichart V.A. *Analysis of rail defects // Path and track economy*. - 2001. - №4. - P. 22 - 25
14. Kosarchuk V.V., Agarkov O.V. *Prediction of durability of rails by the criterion of occurrence of contact fatigue cracks // Proc. Sciences. to wash DUIT. Transport Systems and Technologies Series*. - 2012. - Vip. 20. - P. 77 - 90.
15. Taraf M., Zahaf E.H., Oussouaddi O., Zeghloul A. *Numerical analysis for predicting the rolling contact fatigue crack initiation in a railway wheel steel // Tribology International*. – 2010. – 43. – P. 585 – 593.
16. Kosarchuk V.V., Danilenko E.I., Agarkov O.V., Rafalsky O.Y. *Influence of the profile of car wheels on the level of contact stresses in rails // Coll. Sciences. to wash DUIT. Transport Systems and Technologies Series*. - 2018. - Vip. 31. - P. 3
17. Rybkin V. V., Umanov M. I., Bal O. M. *Individual track output as an important factor for forecasting the period of repair of a track // Bulletin of the Dnipropetrovsk National University of Railway Transport named after academician V. Lazaryan*. - 2007. - Ed. 18. - P. 62-70. - Access mode: http://nbuv.gov.ua/UJRN/vdnuzt_2007_18_16
18. Rybkin, V. V. *Stress-deformed state of the track in the interaction of wagons with increased axial load / V. V. Rybkin, A. M. Patlasov, V. I. Klimov // Problems of mechanics of railway transport. Increase of reliability and perfection of structures of rolling stock: theses. doc. All Union. conf. (Dnipropetrovsk, May 1988)*. - Dnipropetrovsk, 1988. - P. 96.
19. Regulations on conducting scheduled maintenance and repair works on railways of Ukraine: CP-0287: Order of Ukrzaliznytsia dated 11/3/2014 № 470-CZ / A. Babenko, G. Linnik, K. Moiseenko [et al]. - Kyiv, 2015. - 45 p.
20. Classification and catalog of defects and damage of elements of switching transfers and tracks of Ukrainian railways: CP 0060 - 2000.
21. Patlasov A. M. Improvement of the system of planning of repairs of a railway tracks: diss. Cand. of Tech. Sciences: 05.22.06 / Alexander Mikhailovich Patlasov; St. Petersburg Institute of Ing. Railway Transport Engineering - St. Petersburg, 1991. – p. 167.