DEFECT ANALYSIS ON LATVIAN RAILWAY, RESEARCH ON DEFECTIVE RAIL

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Abstract. The article is focused on the study of the defective rails on the Latvian railway. The analysis of defects on the Latvian railway by eight sections of the division during 2013, 2014, and 2015 has been performed in the paper. Statistical data about defective rails have been collected and processed. The main classification of defects was considered, the interpretation of each type of defect was analyzed separately. The graphs analyzing quantitative classification of defective rails in each division were built. The aim of this paper is the study of the isolated defective rail. The study process consisted of three stages. The first stage is a determination of hardness of the metal on the Brinell scale with a modern instrument "Krautkramer". The analysis of the results obtained should be performed and compared with the data of the manufacturer. The second stage is a determination of the chemical composition of rail steel with the "ARC-MET 8000 Mobile Lab" optical-emission analyzer. The data obtained should be compared with the data of the manufacturer as well as with the standard data. The main conclusions of the work that was done should be performed in the third stage of the study.

Keywords: defective rails, defect code, chemical composition, rail steel, standard, metallographic analysis, rail elements.

Introduction

The main consequence of the insufficient reliability of the modern design of the rail joint is the failure of the rails on the joint defect 53.1, as well as the intensive easing of the tightening of the track bolts on the defect code 53 – classified as cracks in the pin of pinhole or other holes in rails. It should be noted that this defect is very difficult to identify. There are cases when this defect led to the removal of wheel sets from the rails [1].

Since 2013, the defect detection in the rails has been noticeably increased on the Latvian railway. As it is known, any defect in the rails can lead to the collapse of the rolling stock. In this regard, it was decided to analyse the defects of the rail joints on the Latvian railway and identify the most frequently repeated defect. As it turned out, on the Latvian railway - this is a defective rail under the code 53.1.

It turned out that this problem is also relevant in other countries. In particular, on the Russian railways, the case of defective rails also prevails. According to the information, the number of breaks of rails on the Russian railways has been at a very low level in recent years (no more than 60 breaks per year), in turn, one of the main sources of risk to train safety is the sudden breaks in rails due to the development of defects in them [2]. According to the latest statistics of the Central Directorate of Infrastructure of "Russian Railways" OJSC, the most problematic are the cases of rails breaks:

- in the area of welded joints of rails (more than 35 %);
- because of transverse cracks in the head (25 %);
- because of cracks of corrosive origin in the rail base under the code 69 (20 %).

Analysing the problem of defective rails on the railways, the question arises, what are the causes of these defects? It was decided to investigate one defective rail (defective rail under code 53.1) in order to analyse the state of the metal for hardness and chemical composition and compare the obtained data with the manufacturer's factory.

Data on defective rails on the Latvian railway

Safety of train movement is determined by many factors. In recent years, on the Latvian railway, one can observe an increasing number of defective rails (Fig. 1). To define the reasons of development of defective rails, an analysis was performed.

The Latvian railway is divided into eight railway sections, which are: CDN-1 Sorting section, CDN-2 Čiekurkalns section, CDN-3 Daugavpils section, CDN-9 Riga section, CDN-5 Rēzekne section, CDN-6 Ventspils section, CDN-7 Liepāja section, CDN-8 Jelgava section (Fig. 1).

Classification of the main defective rails for 2015 is presented in the diagram (Fig. 2), where we can see that the main part of defective rails are defects 21 and 30H [3].

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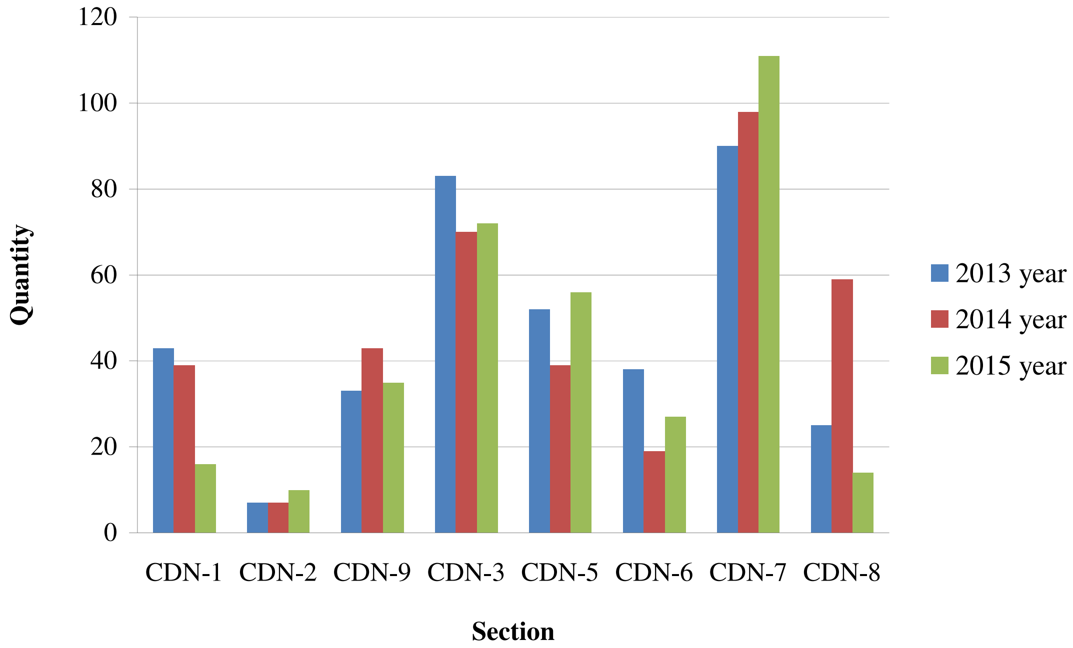

Fig. 1. **Diagram of defective rails in the period 2013 to 2015**

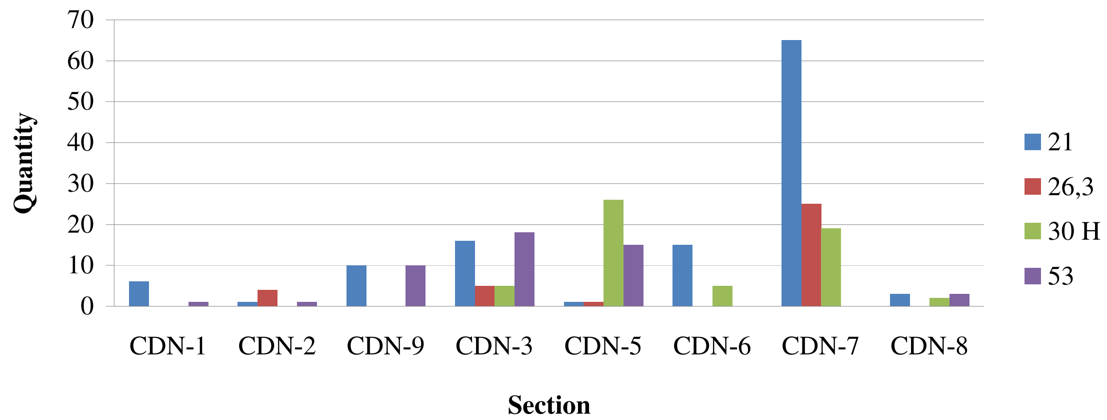

Fig. 2. **Quantitative classification of defective rails for 2015**

The defect code 21 (Fig. 2) – transverse cracks in the head in a form of light and dark spots, and fractures because of transverse cracks due to insufficient contact endurance of the metal. Respectively, defect code 21 is divided into defect code 21.1. and 21.2., which means 21.1 defect in conjunction, and 21.2 – defect out of conjunction [4].

The number of defective rails of this group for 2015 on the Latvian railway was 17 cases of defects, of which 65 defects on CDN-7 Liepāja section.

30 H. (Fig. 2) – horizontal layering of the head due to the presence of non-metal inclusions [5]. There were found 57 cases of defects of this group, of which – 26 cases in CDN-5 Rēzekne section.

Defect code 53 (Fig. 2) – classified as cracks in the pin of pinhole or other holes in rails. 48 cases of defective rails were found for the year 2015, of which 18 cases were found in CDN-3 – Daugavpils section.

Defect code 26.3. (Fig. 2) – defect of contact junction welding. This type of defect is deciphered as transverse cracks in a head due to breach of the rail welding procedure.

There were found 35 cases of defective rails of this group on the Latvian railway. Of them, 25 cases are found on CDN-7 – Liepāja section.

In this work, the object of the research was to cut a defective 53.1 isolated rail MC metal composite, type of the rail UIC 60, issued by Tagil iron and steel plant in 2014 [6]. This rail is cut from the section Vecumnieki-Lāčplēsis 231. kilometer of 7 station distance.

In the first stage of the research in the laboratory of the Riga Technical University testing of rail steel for hardness according to the Brinell scale was performed with the help of the modern device Krautkramer. The results of the research are shown in Fig. 3.

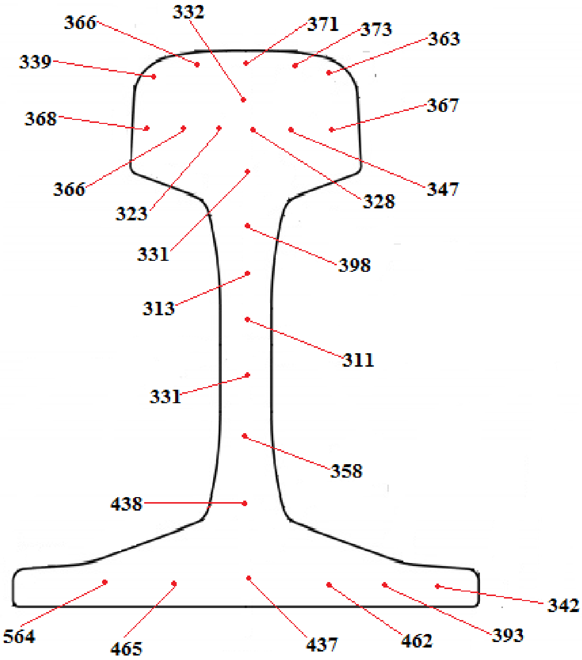

Fig. 3. **Definition of isolated rail MK with the type of rail UIC 60 T 04. 2004, determination of hardness in HB:** in the rail head (366, 371, 373, 339, 332, 363, 368, 366, 323, 331, 328, 347, 367); in the rail web (398, 313, 311, 331, 358, 438); in the rail base (342, 393, 462, 437, 465, 564)

On the basis of the received data, the table is created and comparison with the passport data of the manufacturing is performed. The results of the comparison are summarized in Table 1.

Table 1

Table of hardness of the rail 60 E1 T with steel grade R350 HT

Place of hardness test	Rail steel grade R350 HT	
	Manufacturing plant hardness (HB)	Specified hardness (HB)
On the head tread surface HB	352-405	370
10 mm deep of the head tread surface on the rail vertical axis not less than	341	336
10 mm deep of the circular surface not less than		
22 mm deep of the head tread surface on the rail vertical axis not less than	321	349
In a pin, not more than	388	318
In a foot, not more than	388	342
Note: * – the value of the difference of hardness on the tread surface in the same rail cannot exceed 30 HB.		

Hardness on the rail head trade surface is in the allowable range from 352-405 HB, specified hardness is equal to 370 HB. According to the standard requirements, 10 mm deep of the head tread surface on the rail vertical axis hardness must be not less than 341 HB. In the course of the research, it was found that hardness in this section was 336 HB, which is 5 HB less. 22 mm deep of the head tread surface on the rail vertical axis hardness must be not less than 321 HB. In the course of the experiment, hardness in this section was 349 HB. Norms of hardness in a pin and foot are not more than 388 HB. The results showed that hardness in a pin is 318 HB, in a foot is 342 HB.

At the first stage, analysis of the chemical composition of metal was performed. With the help of a band-saw blade, a sample of the defective rail was cut subject to the research. With the help of a grinding machine, this sample was grinded to mirrored surface (Fig. 4).

Fig. 4. **Coupon for the research**

To determine the chemical composition of metal, the optical and emissive analyzer MET 8000 MobileLab was used, which operates according to the principle of burning off of the surface of the sample with subsequent determination of the chemical composition and extraction of the obtained data to the printing device. Measurements were performed in three different locations. Average results of the analysis of the chemical composition of the samples are given in Tables 2 and 3.

Table 2

Chemical composition of the researched isolated MK with the type of rail 60 E1 04004

	Fe	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**Ni**
Min	-	0.570	0.0000	0.600	0.0000	0.0000	0.0000	0.0000	0.0000
Max	-	0.650	0.400	0.900	0.0450	0.0450	0.200	0.100	0.200
1	97.9	0.626	0.360	0.864	0.0050	0.0050	0.0315	0.0030	0.0362
2	979	0.630	0.387	0.846	0.0050	0.0050	0.0365	0.0030	0.0400
3	98.0	0.619	0.356	0.855	0.0050	0.0050	0.0352	0.0030	0.0432
Average	97.9	0.625	0.368	0.855	0.0050	0.0050	0.0344	0.0030	0.0398
	Al	**Co**	**Cu**	**Nb**	**Ti**	**V**	**W**	**Pb**	**Zr**
Min	-	-	-	-	-	-	-	-	-
Max	-	-	-	-	-	-	-	-	-
1	0.0020	0.0362	0.0083	0.0030	0.0020	0.0339	0.0250	0.0100	0.0030
2	0.0123	0.0378	0.0091	0.0030	0.0020	0.0350	0.0250	0.0100	0.0030
3	0.0061	0.0362	0.0076	0.0030	0.0020	0.0335	0.0250	0.0100	0.0030
Average	0.0061	0.0367	0.0084	0.0030	0.0020	0.0341	0.0250	0.0100	0.0030

Table 3

Table of the chemical composition of Tagil manufacturing plant with the type of rail 60 E1

	C	**Mn**	**Si**	**P**	**S**	**Cr**	**Ni**	**Cu**	**Al**
Min	0.570	0.600	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-
Max	0.650	0.900	0.400	0.0450	0.0450	0.200	0.200	0.400	-
1	0.770	0.960	0.380	0.010	0.010	0.0410	0.0490	0.0060	0.0030
2	0.770	0.990	0.350	0.014	0.010	0.0350	0.0480	0.0080	0.0025
3	0.760	0.940	0.350	0.010	0.011	0.0340	0.0480	0.0110	0.0024
Average	0.766	0.963	0.360	0.011	0.010	0.0367	0.0483	0.0083	0.0026
	V	**N**	**H (ppm)**	**O_2**					
Min	0.0000	-	-	-					
Max	0.100	-	-	-					
1	0.0390	0.00550	1.4	0.0012					
2	0.0360	0.00370	1.4	0.0012					
3	0.0430	0.00450	1.2	0.0012					
Average	0.0393	0.00457	1.3	0.0012					

In Table 4, the main allowable values of the composition of rail steel in % correlation are summarized.

Table 4

Table of allowable deviations on the rail chemical composition not more than, per cent %

C carbon	**Mn** manganese	**Si** silicon	**V** vanadium	**Cr** chrome	**N** nitrogen	**P** phosphorus	**S** sulfur	**Al** aluminum
± 0.02	± 0.05	± 0.02	+ 0.02	± 0.02	± 0.005	+ 0.005	+0.005	+ 0.001

Let us analyze the results of the chemical composition analysis of the coupon of the defective rail (Fig. 4) and compare with the data of the standard of the researched steel grade (see Table 3). For it to be done, let us construct a graph (Fig. 5) and compare the data.

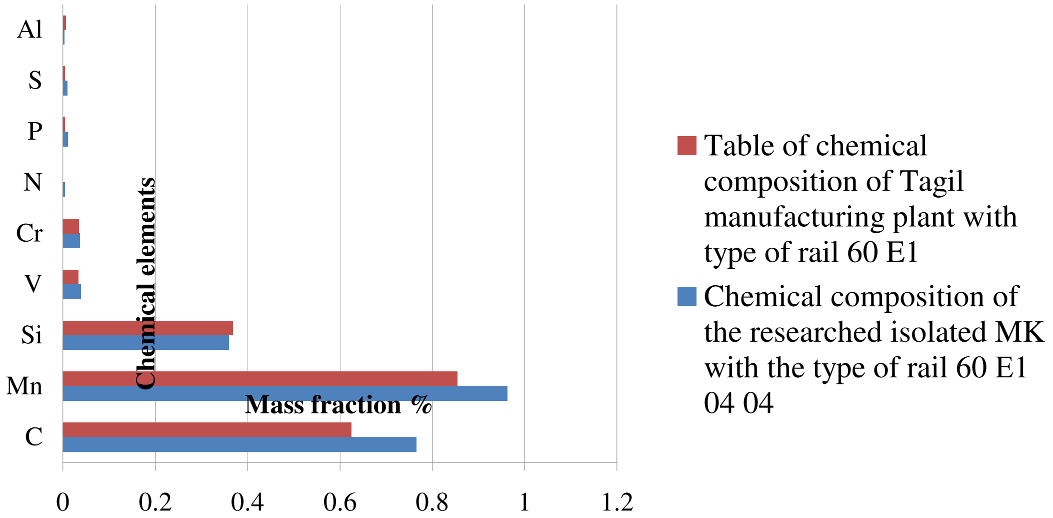

Fig. 5. **Graphical display of the results of the chemical analysis of the sample and by passport data of the manufacturing plant**

In the course of determination of the chemical composition of rail steel in the laboratory of the Riga Technical University, the following discrepancies were found. In the passport data of the manufacturing plant, the following chemical elements were not given: (Mo) molybdenum, (Co) cobalt, (Nb) niobium, (Ti) titanium, (W) wolfram, (Pb) plumbum, (Zr) zirconium.

Further, let us compare the main allowable values of the chemical elements of the composition of rail steel (Fig. 5). Content of (C) carbon, based on the graph, is less 0.121 % than is offered by the manufacturing plant. The results of the researche show that the content of (Mn) manganese is also less than is offered by the manufacturing plant. The value of (Mn) is 0.058 %.

The chemical elements (Si) silicon and (Cr) chrome are within the range of the allowable values. Based on the obtained data, the content of (V) vanadium in the exploited sample is less by 0.052 % than specified in the passport of the manufacturing plant. Percent composition of such chemical elements as P (phosphorus) and S (sulfur) is also within the allowable values. Percent composition of P (phosphorus) is less by 0.006 % than in the manufacturing plant, and the percent composition of (S) sulfur 0.005 %.

Percent composition of the value of such chemical element as (N) nitrogen was not found in the course of the research. Composition of (Al) aluminudm grew by 0.0025 %.

The research performed enables to determine hardness of rail steel, the chemical composition of steel, establish the weight ratio of metal elements, which can answer the questions, for example, in case of rail fracture [7].

Results and discussion

An isolated defective rail of the UIC 60 T 04.2004 type was investigated in the paper. In the course of the research, the rail metal was checked for hardness according to the HB scale. Analysing the results obtained, we can draw the following conclusions: the hardness of the metal on the rolling surface of the rail head is within the permissible range from 352 to 405 HB, which corresponds to the passport data.

However, the metal hardness at a depth of 10 mm from the rolling surface of the head along the vertical axis was 336 HB, which is 5 HB less than the manufacturer's factory norm. At a depth of 22 mm from the rolling surface of the head along the vertical axis of the rail, the hardness was 349 HB. It should be noted that the hardness in the rail web was 318 HB, in the rail base it was 342 HB, which is much less than the manufacturer's factory (388 HB).

Comparing the obtained results of the chemical composition of rail steel with the manufacturer's passport data, discrepancies also prevail.

It can be assumed that the insufficient strength of the metal, as well as the non-conformity of the chemical composition of the metal cause the generation of defects and the formation of cracks.

Conclusions

1. In the course of work performance, the main aim was achieved – research in the hardness and chemical composition of defective rail and comparison of data of the values with the manufacturing plant.
2. A check was made for the steel rail on the Brinell hardness (HB) with the Krautkramer modern device. The data obtained were compared with the manufacturer's factory data. The studies show that the hardness of the investigated rail steel object (60E1T) from the rail steel grade (R350HT) does not match in the rail web and rail base with the manufacturer's passport data.
3. The chemical composition of rail steel is determined and its comparison with the data of the standard is performed.
4. The research has shown that chemical elements of silicon (Si) and chrome (Cr) are within the allowable range, except for the values of composition of carbon (C), manganese (Mn) and vanadium (V), in which there was insignificant decrease of the weight ratio in %: (C) by 0.121 %, (Mn) by 0.058 %, (V) by 0.052 %.
5. Carbon (C) which determines hardness and endurance of the metal is the main and principal among the enumerated chemical elements. Decrease of the percent composition of carbon (C) can cause formation of cracks and fractures in steel.
6. The results of the researches have shown that the composition of such harmful chemical elements as phosphorus (P) and sulfur (S) are within the allowable values and do not affect the quality of rail steel.

References

1. Лысюк В.С. Управления надежностью бесстыкового пути (Reliability control of the continuous welded railway track.), Moscow, Trasport, 1999, 115 p. (in Russian).
2. Евразия Вести, Новые технологии, Актуальные проблемы дефектоскопии рельсов и пути их решения VII 2015 (Eurasia News, New technologies, Actual problems of rail defect detection and ways to solve them VII 2015) (in Russian).
3. GOST R 51685-2013 Rails. General technical specifications (as amended N1). National standard of Russian Federation Rails general technical specifications. 2014.
4. НТД/ЦП-3-93 «Признаки дефектных и остродефектных рельсов». Утверждено министерством путей сообщения РФ 22.03.1993 г. (NTD/TSP-3-93 Signs of defective rails. Approved by the Ministry of Railways of the Russian Federation dated 22.03.1993.) (in Russian).
5. Latvian railway SJSC Service of railway equipment. Confirmed Latvian railway SJSC First deputy of CEO Baiko S. Norms and specifications for defective rails NTD-S-97. Riga 1997, pp. 51 -76.
6. НТД/ЦП-2-93 «Каталог дефектов рельсов». Утверждено министерством путей сообщения РФ 22.03.1993 г. (NTD/TSP-2-93 Rails defects catalogue. Approved by the Ministry of Railways of the Russian Federation dated 22.03.1993) (in Russian).
7. Гуляев А.П. Металловедение. Учебник для вузов. (Metal science. Textbook for high schools). "Metallurgy", Moscow, 1986, 544 p. (in Russian).