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RAILCON '22

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XX SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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ANALYSIS OF DEFECTS ON RAILWAY TRACKS OF SERBIA ON THE SAMPLE OF TWO DIFFERENT LINES

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Abstract *– This paper discusses the current situation of the railway infrastructure of the Serbian Railways - common defects on the rails, as well as the most common defects and failures at turnouts and tracks generally. A study was also conducted on the classification of top mechanical defects on them, as well a statistical analysis of converging data that was carried out in order to determine the most common defects that occur on the railway track and consider what leads to such defects.*

Keywords – Track, Rail, Defect, Joint, Serbia

1. INTRODUCTION

Railway track is a line that connects two or more places, with equipment that serve to carry out railway traffic. The primary purpose of the track is to provide guidance to the wheels of the train and absorb the dynamic load caused by the movement of the train [1].

Overhaul or major repairs of the railway track are approached, when it is no longer possible to ensure safe rail traffic [2] with current maintenance works, by repairing malfunctions and defects.

A very common place of rail damage is at the ends of the rail when it is connected with another rail by fishplates (joint bars), as well as in the welded joints of the rails welded into a continuous welded rails (CWR). Observing rail defects, through various aspects, has been dealt by various researchers around the world. Popović *et al* [8] point out two basic types of defects on Serbian railways: defects due to contact fatigue of the rail steel when the wheels roll on the rail head, and defects caused by friction, and give closer descriptions. Moreover, Popović *et al* [3] show defects caused by friction, after which the rails must be repaired by machining and then surface welding with electrodes (which some of those they compared in their work), in order to restore the required profile of the rail head.

In this paper, all observed defects on the two lines: Niš – Dimitrovgrad – the state border with Bulgaria and Niš – Preševo – the state border with North Macedonia, which spotted by Serbian Railways staff, are analyzed.

2. DEFECTS DUE TO CONTACT FATIGUE AND FRICTION

The main factors that define rail degradation are wear and fatigue, which influence the rail become unusable due to unacceptable profiles, cracks, peeling and fractures. Despite the improvement in the quality of the steel, higher loads cause more wear and fatigue, and breakages sometimes occur after less than a year (minimum design life of the rail is 7 years).

While rail wear has been significantly reduced by the introduction of suitable steels and lubricants, defects caused by the fatigue of the rail steel when the wheels roll on the rail head, so-called RCF (Rolling-contact fatigue) faults become an increasing problem, especially on highly loaded transport lines. Fatigue fractures of railway rails, are one of the main factors of train derailment nowadays [11].

As a result of higher stresses, the local yield stress can accelerate fatigue crack initiation and growth. It should be mentioned that surface cracks are a

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relatively new problem associated with high speeds and loads. In the past, the rails were exposed to intense wear and tear, so the surface layer was constantly peeling off, and with it new cracks were developed. With the development of modern rail steels that have a much higher wear resistance, the removal of the surface layer has been reduced, so the resulting cracks need more time for further development.

2.1. Defects due to contact fatigue

All over the world, including on the rails in Serbia, there are two basic types of rail defects due to the fatigue of the rail steel when the wheels roll on the rail head (RCF - Rolling Contact Fatigue): squat defects and head checking defects [8]. Both can be repaired by welding.

Defect Head checking – HC

The HC defect is found in the form of fine short oblique surface cracks at a mostly regular distance, which is usually 1-7 mm. If the defect is not removed in time, it progresses leading to separation of smaller or larger parts of the running edge at the rail head. Within the UIC 712 standard, the defect is marked with code 2223.

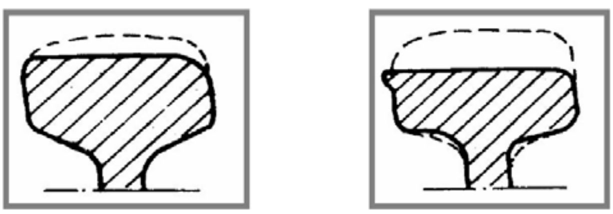
Squat type defect

This type of defect is the most common, characterized by the appearance of microcracks under the track surface. Cracks in the indentation are caused by high dynamic loading of the track from the rolling of the wheel on the rail, which leads to fatigue of the material. At first, these cracks look like a small dark spot. They then increase from the bottom of the point and grow at a shallow angle in the longitudinal direction. The defect is marked with code 227 according to UIC code 712.

2.2. Defects caused by friction

Defects caused by friction on the straights

Figure 1 shows the appearance of a typically damaged rail head away from rail ends and in rail ends of the straight line.



a) away from rail ends *b) in rail ends*

Fig. 2: Sketch of a worn rail in a bend [3]

Defects caused by friction in bends

Figure 2 shows the damage to the inner edge of the head of the outer rail, which is caused by the centrifugal force that tends to push the vehicle towards the outer side of the track, where the outer wheel flange rests on the edge of the outer rail.

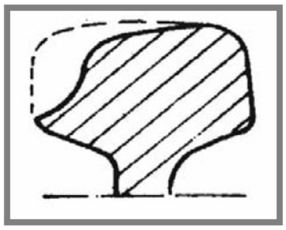


Fig. 2: Sketch of a worn rail in a bend [3]

3. MAINTENANCE OF RAILWAY TRACK

Regular track maintenance is carried out mainly at fixed intervals (periodic / regular maintenance) and consists of inspection and repair / removal of defects [5].

Rail defects can be classified into surface and deep defects.

4. DEFECTS IN RAIL WELDED JOINTS

4.1. Welded rails by the aluminothermic melting process

Aluminothermic welding can be: aluminothermic fusion welding or aluminothermic pressure welding.

Aluminothermic fusion welding is used in the formation of the CWR, which joins the ends of the rails by melting preheated liquid metal from the chemical reaction between finely divided aluminum and iron oxide [9]. Therefore, it is performed at joints, and it is mainly practiced in the field, because the equipment is easily movable. Before welding, a distance is left between the ends of the rails:

$$a = 0.75\sqrt{A},\ \mathrm{mm} \tag{1}$$

where A is the area of the rail profile in mm^2, and then the groove is filled with wax. The cavity filled with wax represents the model around which the box (mould) is placed and the casting sand is packed. After the molding is complete, the gas flame from the soldering lamp is directed through the window, melting the wax model and preheating the edges of the base material.

Aluminothermic pressure welding is used in the plant as well as electro-resistance welding, but electro-resistance welding is much more common.

Fig. 3. Defect 421 (left) and 422 (right) [6]

Defects that can occur are: transverse cracking of the profile 421 (Fig. 3 - left) and horizontal cracking of the web 422 (Fig. 3 - right). They are observed visually or ultrasonically. The defect is eliminated by repair welding if possible.

4.2. Rails welded by flash-butt process

In this case, the ends of the rails are tightly clamped in a welding machine [4]. The electrodes for power supply are 12 - 16 cm apart. The ends of the rails to be welded do not need to be pre-processed, and can also be autogenously cut. They are brought close so that they touch easily, and then a current of 25000 A and a voltage of 5 V is supplied. When the current passes between the ends of the rails, a spark is created and heat develops (Joule effect). The machine successively moves the rails towards each other and away from each other, during which the steel particles burn and the rail ends are brought to the melting temperature. Now the rails are compacted under pressure, resulting in their shortening and the creation of metal filings at the seam. They are cleaned with a cutter and the seam is sanded, so that the rail profiles match perfectly. The execution time of one stitch is 2.5 – 3 minutes. The shortening of the rails is up to 15 mm.

Today, this is the fastest, cheapest and highest quality rail welding process. It is used in workshops because it requires massive, heavy equipment to perform the seams. Electricity consumption is high, although success has been achieved in this field in recent times.

With this welding method, rails with a length of at least 5 m – 6 m can be welded. The capacity of one rail is over 100 quality welds in one shift.

It is possible to perform the same welding procedure by welding in the track.

In Serbia, a PRSM-4 rail welding wagon was used.

Given that multiple rails with a factory length of mostly 30 m are connected in the CWR, by flash or aluminothermic welding, sometimes there are defects caused by welding, either from the formation of the CWR or from the repair of other defects. Defects that can occur are also: transverse cracking of the web 411 (Fig. 4 - left) and horizontal cracking of the web 412 (Fig. 4 - right). They are observed visually or ultrasonically. The defect is also eliminated by repair welding if possible.

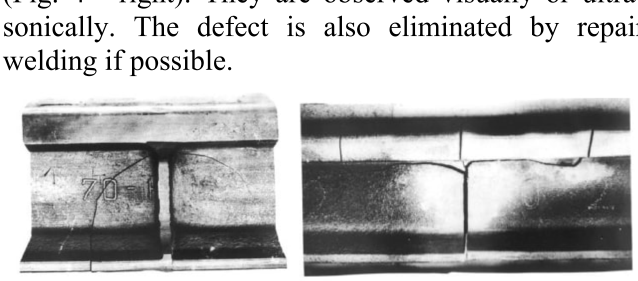


Fig. 4. Defect 411 (left) and 412 (right) [6]

4.3. Arc welded rails

The procedure consists in approaching electrodes that are under voltage and that create an electric arc on the composition of the rails [4]. The molten metal particles from the electrodes move to the rail and the dilatation opening between the two rails is closed. In this way, a layer of metal is applied to the metal, and in addition to welding the rails in the track, this procedure is also used for welding damaged places on the rails and turnouts, such as, for example, rails with skid marks of locomotive wheels or corroded turnout frogs and points.

The electrodes are 4 - 6 mm in diameter, 30 - 45 cm long. Air access to the electric arc can be harmful, so coated electrodes are used. The coating reduces the effect of air and improves the melt. Coated electrodes can be used for DC or AC welding currents. The current voltage is from 5 V to 40 V, and the current strength is from 20 A to 600 A. It is necessary to have a generator on the field if no connection to the existing network has been made.

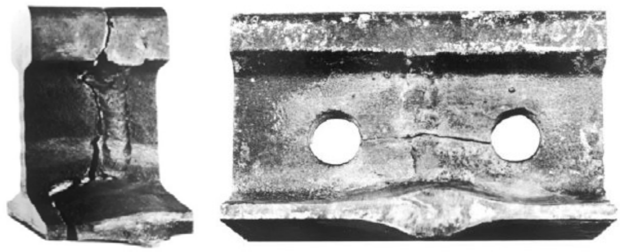


Fig. 5. Defect 431 (left) and 432 (right) [6]

The defects that can occur are the same: transverse cracking of the web 431 (Fig. 5 - left) and horizontal cracking of the web 432 (Fig. 5 - right). They are observed visually or ultrasonically. The defect is also eliminated by repair welding if possible. For the above case in Figure 5 - without hitting the rail foot with a hammer after the surfacing is complete.

4.4. Gas welded rails

This procedure does not require electricity, only a bottle of acetylene and a suitable apparatus. The composition of the rails can be well welded, but the quality depends a lot on the welder (usually two work together).

In the USA, gas compression welding is used. The ends of the rails are heated in the device with an acetylene flame, and then compressed as in the electro-resistant welding process.

5. DEFECT ANALYSIS

In order to analyze the data on all observed defects on the tracks Nis - Dimitrovgrad – Bulgarian border and Nis – Preševo – Macedonian border, a classification of defects was made based on rail parts.

Table 1 shows an overview of all rail defects on the two noted lines.

Tab. 1. Defects per section of rail - the last 56 months

Rail section/place	Defect quantity	Frequency distribution (%)
Rail end - fishplate	20	36,4
Flash-butt joint	4	7,3
Aluminothermic joint	16	29,1
Away from ends	17	30,9
Total	55	100

Many factors contribute to the formation of defects. Since all information included the time of year when the defects occurred, in order to find out how the frequency of defects varies with climate, additional attention was paid to determining the effect of climate on the occurrence of defects (Table 2 and Fig. 6) [10].

Tab. 2. The relationship between the season and the number of defects on the railway track rails - the last 56 months

Season	Defect quantity	Frequency distribution (%)
Spring	10	18,2
Summer	6	10,9
Fall	8	14,5
Winter	31	56,4
Total	55	100

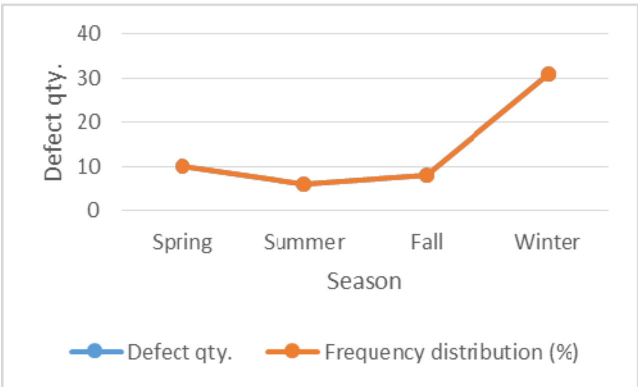


Fig. 6: The relationship between the season and the number of defects on the railway track rails - the last 56 months

The analysis revealed a relationship between seasons and failed components. It is clear that time plays a very significant role in the probability of failure. In Table 2, the seasonal defects represent a better representation of the influence of climate on failure, where a large number of failures occurred in the winter period. This means that cold weather is a problem of great importance to the railway system. Indeed, much attention should be paid to inspection during cold weather.

6. CONCLUSION

This analysis made it possible to identify the most common defects and the most critical parts of the rail along its length. Accordingly, in future works, failure risk assessment based on a wider range of data might support maintenance development by providing precise criteria for deciding how often routine tasks of the periodical maintenance should be performed. This policy could include improved inspection and repair service levels.

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