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METHODOLOGY FOR STATISTICAL ANALYSIS OF SQUAT RAIL DEFECTS

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Abstract *– This paper proposes a methodology for statistical analysis of data obtained by visual inspection of squat defects on the rail head. Rail inspection by visual observation, including measurement of the squat defect position and depth was performed in Pančevo Varoš railway station in 2017. The obtained data about the squat rail defect (defect type 227 according to the UIC 712) on the main tracks was analysed in this paper. The rail defect position was determined regarding the position of the nearest sleeper in the track. Statistical analysis of the occurrence of squat rail defect was conducted according to the performed visual inspection in the field. Statistical data processing was performed for tracks zones according to the vertical stiffness of rail support. Furthermore, the impact of traffic load, the type and the arrangement of sleepers on the appearance of the squat rail defect was considered.*

Keywords – railway, rolling contact fatigue, squat, visual inspection, statistics.

1. INTRODUCTION

During May, June and July 2017, detailed visual inspection of squat rail defects (rail defect due to rolling contact fatigue type 227 according to [1]) was performed on main tracks in Pančevo Varoš railway station (track number 2 and 3 as shown in Figure 1). In order to point out the importance of an effective methodology for inspection, classification and treatment of squat rail defects occurring during exploitation, the set of relevant data was collected. The main purpose of this research is to improve the rail maintenance, thus reducing the risk of fracture due to rolling contact fatigue (RCF). The research results are expected to be applied in the technical regulations for railway infrastructure maintenance in the Republic of Serbia.

On modern railways, rail defects due to RCF are the dominant problem in the wheel - rail system and they are subjected to the intense research. RCF rail defects require an adequate maintenance strategy to avoid the risk of sudden rail breaks. Unfortunately, these defects are largely visible on the track rails in Serbia, without proper maintenance strategy.

There is a common occurrence of squat rail defects on straight tracks or in large radius curves $R \geq 3000$ m (Figure 2). Since the squat defect occurs in the areas with braking and acceleration of the railway vehicles, the visual inspection of rail defects was performed on the tracks in station and straight railway sections in the front of pre-signal and signal. Furthermore, it was necessary to inspect the zones around the sleepers with the change of vertical track stiffness, zones with corrugated rail head and welded rail joints [2, 3, 4].

Fig.1. Pančevo Varoš railway station

Before the visual inspection in Pančevo Varoš station was performed, main tracks were divided into the zones:

- zone I - from switch No. 1 to switch No. 5 (km 17+854.61 - km 18+027.89),
- zone II - from switch No. 5 to station building (km 18+027.89 – km 18+210.00),
- zone III – from station building to switch No. 14 (km 18+210.00 – km 18+719.06),
- zone IV – from switch No. 14 to switch No. 16

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(km 18+719.06 – km 18+774.26).

The track No. 2 was divided into I, II, III and IV zones, and the third track into II and III zones.

Fig.2. Successive occurrence of squats (left rail, track No. 2, Pančevo Varoš station, 2017)

The squat rail defects observed by visual inspection are separated from other existing defects, photographed, measured, positioned and systematically arranged. Afterwards, statistical processing of the obtained data was performed using the created squat defect database for the main tracks No. 2 and No. 3.

2. SQUATS IN PANČEVO VAROŠ STATION - RESULTS OF THE STATISTICAL ANALYSIS

Database was created for the left and right rail of main tracks No. 2 and No. 3 (extension of the Belgrade-Vršac railway line through the Pančevo Varoš station) in accordance with the above-mentioned track zones for visual inspection. Squat rail defects observed by visual inspections were classified according to the position along the track. The distribution of defects according to their location (above the sleeper or between two sleepers) was analysed for both rails. The average depth was measured for each defect. The distance between the sleepers was measured at each position of squat defect occurrence. Each squat defect was photographed and assigned with the appropriate symbol ($SQ_1,\ldots,SQ_n$) in the database. Furthermore, zones with wooden and concrete sleepers were marked in the database.

Table 1 shows the statistics of the total number of squat defects observed on the tracks No. 2 and No. 3. Accordingly, 87% of detected defects occur on the track No. 2 and 13 % on the track No. 3. Since the inspected length of track No. 2 is 270 m greater than the inspected length of track No. 3, and considering that traffic load on track No. 2 is two times higher than load on the track No. 3, one could conclude the severity of number of squat rail defects observed on the track No. 2. The traffic load was estimated according to available official data.

Tab. 1. Statistics of squat defects

Information about track and squat defects	Track No. 2	Track No. 3
Inspected track length [m]	920	650
Average sleeper distance [cm]	55	54
Number of electric-powered vehicles [number / year]	6570	0
Number of diesel-powered vehicles [number / year]	9855	6205
Estimated total traffic load per track [MT / year]	6.25	3.16
Total number of squats	155	23
Percentage [%]	87	13

Figure 4 shows the distribution of squat rail defects in zones I-IV. The greatest number of squats was observed in zones II and III on both tracks, in the area where trains break and accelerate (in front of the station building).

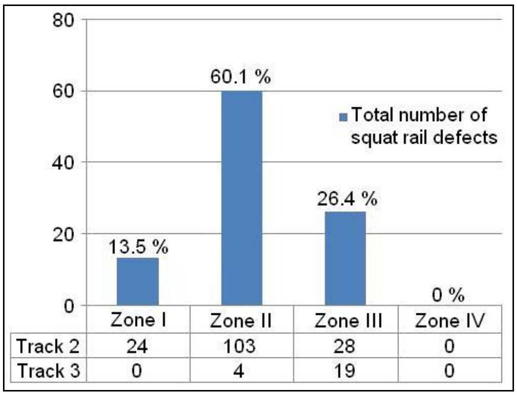

Fig.4. Distribution of squat rail defects per zones

The total number of squat rail defects on the left and right rails in the second and third tracks is shown in Figure 5. It was observed that the left rail of the second track is significantly more damaged than the right rail.

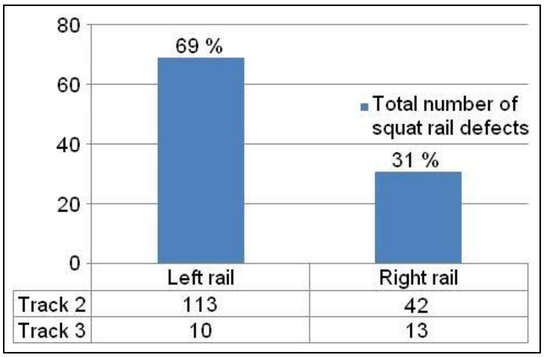

Fig.5. Distribution of squats on rails

The following statistics refers to the total number of squats that occur above the sleeper and between two sleepers (Figure 6). The zones above and between sleepers are defined in accordance with [3] (Figure 7).

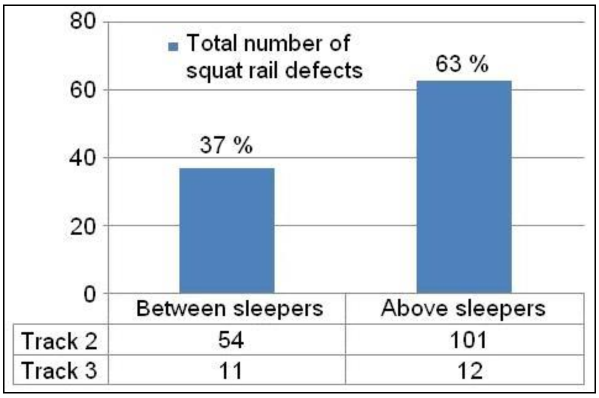

Fig.6. Distribution of squats between and above sleepers

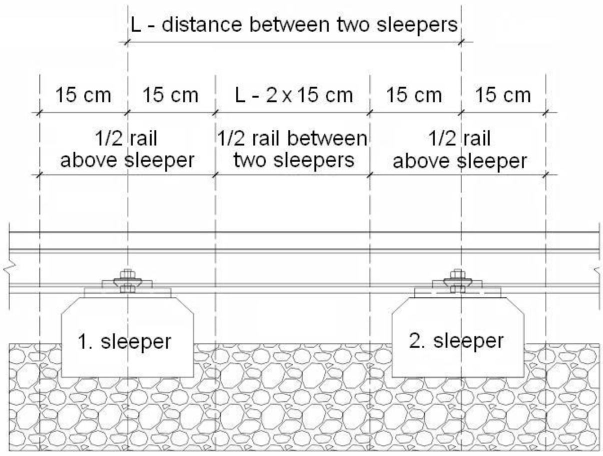

Fig.7. Zones of squat occurrence above and between sleepers

Furthermore, two cases were considered: one with the sleeper distance less than 60 cm and another with distance greater than 60 cm (Figure 8).

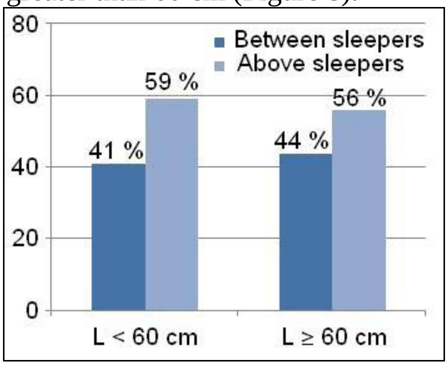

Fig.8. Distribution of squats depending on the sleeper distance

Figure 9 shows statistical data on the total number of squats observed on the tracks No. 2 and No. 3 in zones with wooden and concrete sleepers (zones II and III). According to the total number of detected defects, a significantly greater number of squat defects was observed in zones with concrete sleepers.

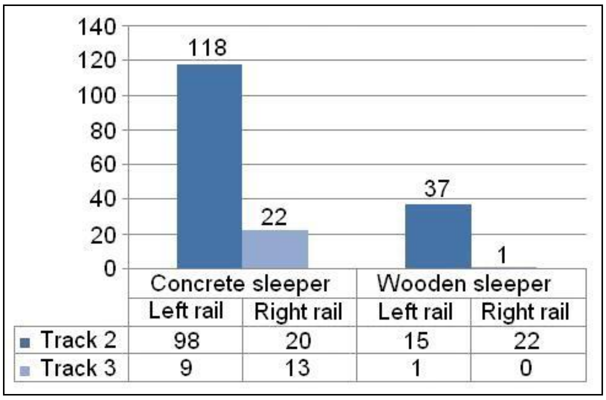

Fig.9. Distribution of squat rail defects in zones with concrete and wooden sleepers

The visual inspection showed a higher percentage of squat occurrences in the zones above the concrete sleepers for both tracks (Figure 10).

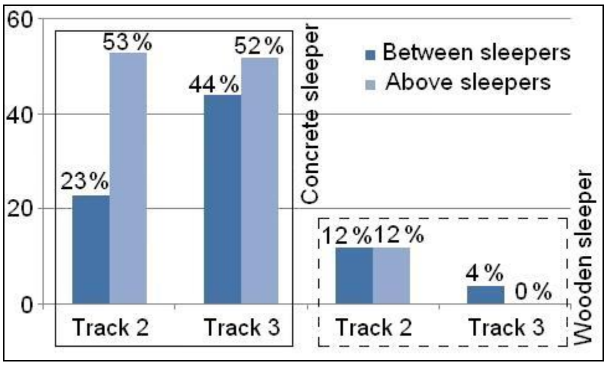

Fig.10. Distribution of squat rail defects occurring between and above concrete and wooden sleepers

The depth of squat rail defects is divided into three classes: 0.5 mm, 1 mm and 2 mm. Figure 11 shows the average depth of squat defects per tracks in zones with concrete and wooden sleepers.

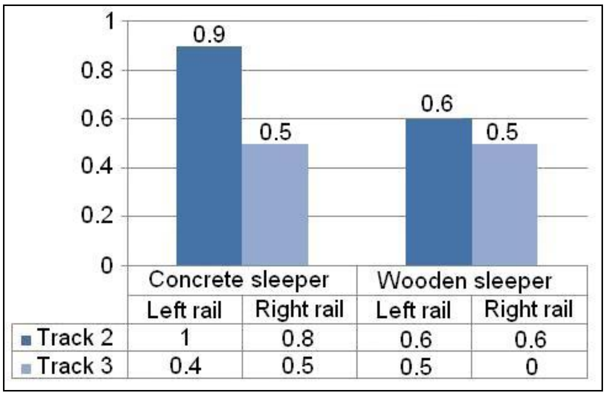

Fig.11. Average depth of squat rail defects [mm]

3. DISCUSSION AND CONCLUSION

Rail defects due to rolling contact fatigue (RCF) in the areas of high wheel/rail contact stresses are a serious danger for railway traffic worldwide [2, 5]. RCF rail defects are coded, described and illustrated in the Handbook of Rail Defects according to UIC Code 712 [1]. Furthermore, UIC Code 725 [6] provides recommendations of methods for inspection, monitoring and processing of these defects. After conducting a detailed visual inspection of the rails, information about squat rail defects is entered in the form in accordance with [1] and saved into the database. Photos of defects and other necessary details are attached to the main form according to [3].

Significant difference in traffic loads on inspected main tracks in Pančevo Varoš station confirmed that the occurrence of squat rail defects is directly related to the traffic load. This was proved by the obtained results, which showed that the appearance of squat rail defects is more frequent on the rails in track with higher traffic load.

Due to inadequate railway infrastructure maintenance in Pančevo Varoš station, especially in the inspected zones II and III, where the trains break and accelerate, a successive squat occurrence was observed. Therefore, the statistics of squat rail defects in the station proved that these defects occur in places with higher friction, i.e. on the track sections where greater traction and greater braking are required.

It is interesting to note that the left rail is significantly more damaged than the right rail on both tracks. Wooden sleepers are located in the zones of switches at the beginning and at the end of railway station, while the zones II and III contain concrete sleepers. By comparing zones with wooden and concrete sleepers, it can be concluded that the percentage of squat rail defects is significantly higher (more than 3 times) on the rails above the concrete sleepers. This is closely related to the rail support stiffness.

Based on the defined zones of defect occurrence (Figure 7), around 63% of all squat rail defects were detected in the zone above the sleeper, while 37% of squat defects were detected in the zone between two sleepers. Thus, the correlation of the defect location and the rail support stiffness was confirmed. In addition, larger number of defects above the sleepers was detected in the case of decreased distance between sleepers (L<60 cm). Therefore, it could be concluded that the distance between sleepers affects the occurrence of squat rail defects. The continuous occurrence of squat rail defects is observed in the zones with smallest sleeper distance (higher vertical stiffness of rail support).

The results of the squat depth analysis for the second track show a greater average depth value in the zones with concrete sleepers (0.9 mm) comparing to the zones with wooden sleepers (0.6 mm). However, the maximum measured depth of squat rail defect was 2 mm (the rails were laid in the track in Pančevo Varoš station in 1992). This could be considered as an alarming situation, since squat depth between 3 and 5 mm leads to the crack propagation downward and transversely, thus causing the rail break [3].

The data collected in the field investigation that is presented in this paper will be considered in future research, which is aimed at monitoring the development of observed squat rail defects, detecting new defects, as well as their mutual comparison.

Visual inspection represents a significant and reliable inspection method for detecting rail surface defects. However, such type of inspection is slow and subjective. Nowadays, different automatic visual inspection systems are developed. Therefore, certain phases of visual inspection should be replaced with automatic visual inspection whenever possible, and only disputable track sections should be inspected visually. In order to make the rail inspection faster and more accurate, visual and automatic visual inspection should be combined.

ACKNOWLEDGEMENT

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