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RAILWAY TRACK DEFORMATION RESULTING FROM A CURVE NEAR ONE LEVEL CROSSING

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Abstract *– Numerous deformations and failures occur to the railway superstructure within a period of its projected life of use. The rails are the most exposed part of the superstructure for wear. In addition to transferring the vertical load from the vehicle to other elements of the superstructure and substructure, the rail, being in direct contact with the wheel of the vehicle, is subject to several other static and dynamic effects during traffic. In the case of a predicted impact, some procedures can be implemented to minimize rail wear and extend their service life. However, unfavorable circumstances arise, quickly reducing the service life of rails and might contribute to more serious accidents. The investigation focuses on the specific phenomenon of rail's head deformation and track lateral movement at the point of the curvature, when the curvature was placed next to one level crossing. A collection of field data has been studied for a variety of curves. The findings of this study revealed assumption that position of the curvatures in respect to the one-level crossing disrupts the geometry of the track, resulting in rail deformation, is not entirely valid.*

Keywords – railway track deformation, rail in curvature, railway crossings.

1. INTRODUCTION

The friction between the wheels of the railway vehicles and the rails is what causes train to move onto the tracks. In this circumstance, the contact surfaces gradually and inevitably degrade. Railway vehicles have a characteristic shape of the wheel with a section that lies vertically on the rail (middle circle of wheeling) and an inside edge that guides the vehicle and ensures its lateral stability. The appearance of the characteristic wheel of the vehicle and the rail in the direction is presented in the Figure 1 [1]. Clearly, there is a gap between the inner surfaces of the rails and the edge (δ1+δ2) allowing fluid movement of the train. This gap varies during the train movement.

When the train passes through a curvature, the vehicle's position in relation to the rails changes. The weight is no longer uniformly transferred over both rails. Due to the appearance of centrifugal force in the curvature, the outer rail is elevated. The superelevation is determined using the design speed [1, 2]. If, for any reason, the train goes slower than the calculated speed the inner rail carries the majority of the train's weight and is heavily loaded on the side of the rail's head. In that case, the entire gap (δ1+δ2) is on the outer rail, while the wheel is pressed against the inner rail.

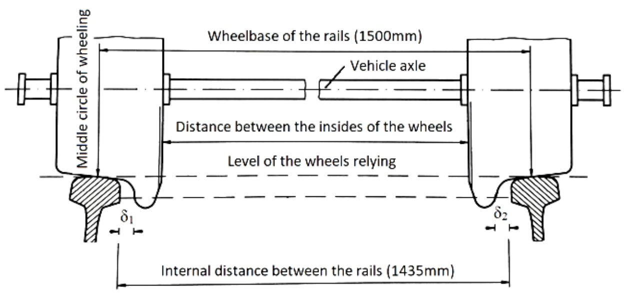

Fig.1. The appearance of vehicle and rail positions when the train is moving on a straight line [1]

If the train moves at the proper speed, the load is better distributed over both rails. It is troublesome when the train speed decreases, which frequently occurs when freight trains pass. It becomes much more challenging when there is a level crossing along the railway track in a curve and the train is obliged to stop or slow down for some reason.

The study gives data analysis on the deformation of track in a curvature caused by freight trains moving slowly. After two and a half years of operation, five one-level crossings were investigated for differences

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in outer rail superelevation in curvatures and internal distance between the rails.

2. MATERIALS AND METHODS

2.1. Study area

Research was carried out on the railway line number 219, Red Cross-Zaječar-Prahovo (km 0+000.00 ÷ 94+931.45), on the Matejevac-Knjaževac railway section from km 12+085,00 to km 69+000,00. The railway was designed for mixed traffic, but it is primarily freight traffic. This section of the railway underwent reconstruction between april 2019. year and december 2021. year.

Along with the deteriorating infrastructure, there was significant track deformation prior to reconstruction, including lateral movements toward the curve's center and crushing head of the rail on the inner rail. Frequent one level road crossings cause freight trains to run slower and sometimes even stop moving, which imposes a significant pressure on the inner rail and causes a part of the steel to be pushed out of the inner rail. This is a plastic deformation of rail, which is in jargon called a "nail" (Figure 2).

Fig. 2. Deformation of the rail’s head (condition before reconstruction of superstructure)

In the long term, this type of plastic deformation can significantly reduce the profile of head of the rail which is crucial information in terms of maintenance [3]. One of the causes of train derailment is the rail's profile reducing.

2.2. Techniques and procedures for track’s condition monitoring

Visual inspection and reporting of visual observations precedes instrumental assessment of the condition and position of superstructure elements. The internal distance between the rails and the superelevation of the outer rail were verified using the "Geismar" track management gauge (Figure 3).

Fig. 3. "Geismar" track management gauge

3. TRACK’S CONDITION AND CONSTRUCTION ELEMENTS AFTER RECONSTRUCTION

Railway reconstruction was finished in december 2021. The railway's renovation involved the replacement of superstructure elements such as ballast, sleepers, fasteners and rails. All elements match the applicable criteria [2]. Concrete sleepers B-70 and rail UIC 49 have been installed. The rails were attached to the sleepers with the skl-14 fasteners. It was foreseen to install devices to prevent lateral movement of rails [1] (Figure 4). The frequency of devices used to restrict lateral movement of the track is determined by the radius of curvature. According to the Regulations [2], devices are installed on every other sleeper within a curvature with radius of 250 to 400 m. In the case of curvature with a radius of less than 250 m, devices have been fixed on each sleeper.

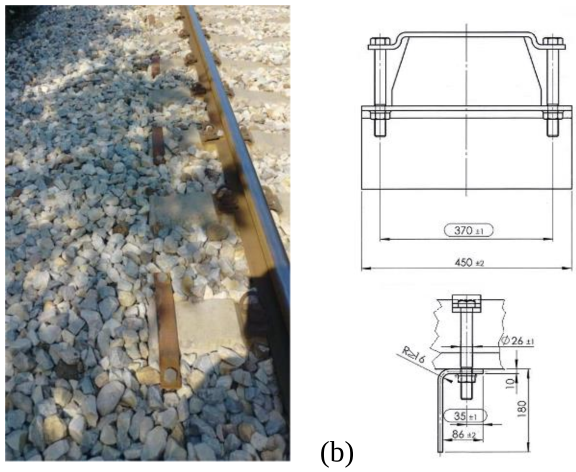
(a)  (b)

Fig. 4. Concrete sleeper's devices against lateral movement of the tracks: (a)-appearance of the devices on the track, (b)-device’s workshop detail (DIV-Svrljig)

Taking into account all of the factors that contribute to the disruption of the railway's stability and designed condition, as well as the experiences prior to the reconstruction, the section from Matejevac railway station (12+085) to Gramada station (30+000) was especially processed. This section of the railway has a slope of 8 ÷ 12 ‰, which not only decreases train speed but also negatively affects freight train traction.

This section's estimated speed is 65 km/h. Table 1 lists the basic geometrical characteristics of the major curvature points (transition curve beginning, curvature beginning, curvature ending, and transition curve ending) for curvatures 30, 32, 43 and 45, on the Matejevac-Gramada section. The situation after the reconstruction is indicated in these statistics. One level crossings are positioned at 19+393.37 (Crossing 1), 19+862.38 (Crossing 2), 20+043.18 (Crossing 3), 24+762.66 (Crossing 4) and 26+263.08 (Crossing 5).

Tab. 1. Position of curvatures numbered 30, 32, 43 and 45 on the railway line Red Cross-Zaječar-Prahovo

No	30	32	43	45
TCB	19+342.26	19+802.82	24+552.45	25+732.22
CB	19+412.26	19+882.82	24+632.45	25+792.22
CE	19+530.08	20+022.41	25+220.64	26+354.06
TCE	19+600.08	20+102.41	25+220.64	26+414.06
R	250	250	252	250
L	70	80	80/0	59
h	120	120	120	120

No- number of curvature on the railway line Red Cross-Zaječar-Prahovo
TCB- transition curve beginning
CB- curvature beginning
CE- curvature ending
TCE- transition curve ending
R- radius of the curvature
L- length of the transition curve
h- outer rail elevation (superelevation)

According to the data from Table 1, road crossings 1, 2 and 3 are located at the transition curves. Crossings 4 and 5 are situated on circular part of the curvature. Based on the given superelevations and the lengths of transition curves, the projected superelevations (h [mm]) of road crossings for crossings 1, 2 and 3 were determined. At crossings 4 and 5, the superelevations at the road crossings are the same as the maximum superelevation at the point of the curvatures number 43 and number 45 (Table 2).

Tab. 2. Outer rail's elevation for one-level crossings

Number of road-crossing	1	2	3	4	5
h [mm]	88	89	89	120	120

4. RESULTS AND DISCUSSION

The control was carried out after two and a half years of the exploitation period. Initially, the tracks in the observed segment were visually inspected.

The typical wear and tear of the driving surface at the curvatures was readily apparent. With the rails on the inside of the curvature, it was clear that the vehicle's wheel goes across practically the whole upper surface of the rail's head. In the case of outer rail, the vehicle's wheel also made a mark but only halfway to the railhead. A typical example of this phenomena is shown in the Figure 5.

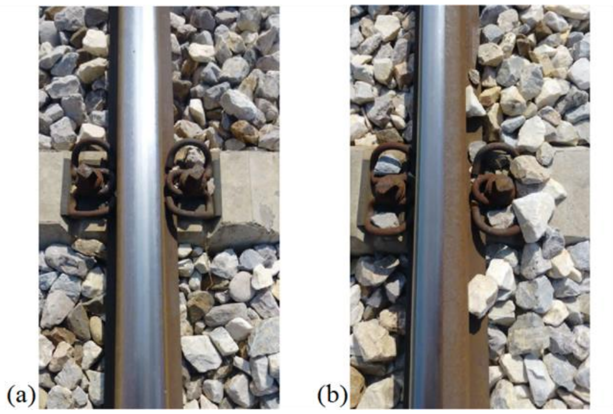


Fig. 5. Appearance of the rail's rolling surface following 2,6 years of exploitation: (a)-left inner rail, (b)-right outer rail

Another sort of deformation on the rails was identified as a wavy imprint on the rail. Given that the deformation occurs in the direction rather than the curvatures, it was determined that the trains have difficult traction. In this aspect, the locomotive's inadequate traction qualities for the specified slope of the track might cause the train to move at lower speeds than intended.

Fig. 5. Rail distortion caused by struggling train traction.

Aside from visual inspection, the internal distance between the rails and the outer rail elevation were verified using the "Geismar" track management gauge. During the inspection of the rail's internal distance, a continuous expansion of 4 mm was detected at the locations of all curvatures. The measurements also included one-level crossings.

The examination's findings reveal that the elevation of the outer rail at one-level crossings has increased significantly. Table 3 shows the precise results of the testing. In addition to examinations at crossings, superelevations were measured at random position in curvatures. The elevation differences between estimated and measured values were determined to be 15-20mm.

Tab. 2. Elevation of outer rail at the point of one level crossings

No	Position of the crossing	Year	Outer rail elevation h [mm]
1	19+393.37	2021	88
		2024	100
2	19+862.38	2021	89
		2024	110
3	20+043.18	2021	89
		2024	110
4	24+762.66	2021	120
		2024	140
5	26+263.08	2021	120
		2024	135

In the zone of one-level crossings, 2 m before and after it, a movement of the tracks in the direction towards the inner side of the curvature was observed. By measuring, it was confirmed that the elevation at those positions is non-linearly increased in relation to the track on very beginning or end of the one-level crossing, regarding the track at the transition curve. In the case of one-level crossing, in a position of circle curve, comparing the superelevation just before and after the crossing with the superelevation at the crossing, it is observed that the superelevations outside the crossing are greater. This leads to the conclusion that the level crossing improves the lateral stability of the track to a certain extent.

5. CONCLUSION

The condition of the track reconstructed two and a half years ago was examined. The research focuses on one-level crossings, specifically the internal rail gap and the rail's superelevation. A visual check and measurement revealed that, despite the recent repair, there was an obvious increase in track overhang of 15-20mm. Measured values exceed the desinged by 13.5-23.5%. In addition to the mechanism for lateral movement of the tracks, the internal distance increased by 4 mm along all curvatures. Another sort of rail distortion was discovered, indicating that the trains had problematic traction.

This invalidates a belief that the presence of railroad crossings is only responsible for the increase in overhang. It is evident that the train is not operating at the intended speed because of traction characteristics, not just one-level crossings. The measured data are concerning given the brief time of exploitation. If the replacement of traction vehicles is not addressed, maintenance costs might be substantial, making rail transportation unprofitable.

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