Influence of the structural design of rail fastenings on ensuring the stability of track gauge in operating conditions

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Abstract. As the rolling stock speed increases, the requirements for stability parameters increase accordingly. One of these parameters is the track gauge. The stability of this parameter depends on many of the structural elements of the upper track structure and on the environmental conditions. In the research work, the authors have considered the influence of such a structural element as an intermediate rail fastening on its ability to provide a stable track gauge. The most common intermediate rail fastenings on the Ukrainian Railways have been accepted to be compared, including the KB-65 type fastening, the KPP-1 type fastening and the KPP-5 type fastening. In order to determine exactly the influence of each structural element, the other gauge parameters for all three types of fastenings have been taken equivalent. The data have been obtained from the track measuring car. With the obtained data, a statistical analysis has been conducted, which enables to draw conclusions about the ability of the intermediate rail fastenings under consideration to ensure the track gauge stability. The conclusions have been made on the applicability of each of the fastenings under consideration.

1. Introduction

Increased speeds of rolling stock, increased level of force interaction in the wheel-rail system, on the one hand, leads to an increase in geometric deviations during the track infrastructure operation, and on the other, the requirements for the limit levels of deviations of the upper track structure become more stringent.

These factors complicate the maintenance of the track and lead to an increase in the volume of work to ensure its efficiency.

In this case, the correct selection of the design of the upper track structure, which could provide the maximum period of its operation with minimal external interference, becomes of great importance.

One of the main constantly monitored parameters is the track gauge. This is due to the fact that exceeding the permissible track gauge can cause the vehicle to derail, and reducing the width of the track below the permissible value causes the wheels pair to jam and the wheel flange to slide over the rail.
On Ukrainian railways, in accordance with [1], the track gauge in straight and curved sections on reinforced concrete sleepers with a radius of more than 300 m at speeds of 50-140 km/h is set at 1520 mm. The tolerance for deviation by extension is +8 mm, narrowing -4 mm.

Increasing the speed of movement requires tightening tolerances for deviations of track gauge from the normative value [2].

The main structural elements affecting the track gauge stability and its longitudinal stability are intermediate fastenings [3]. Paper [4] show that in the process of operation, fastening clamp of the type KPP are worse pressed to the rail, which can affecting on the track gauge stability and its longitudinal stability too. Therefore, the influence of the rail fastening design on the stability of the track gauge parameters has been investigated in the research work.

2. Methods and course of the study

It is known that the research can be carried out both by the mathematical simulation technique [5-9], and by the methods of laboratory [10, 11] and operational testing [9, 12-13].

In the research the designs of rail fastenings operated on the railway having been investigated, the authors have analyzed the data obtained during the track operation.

The studies have been conducted on a straight track with a load capacity of 60 million gross tons per year with mixed freight-passenger traffic. The considered section uses three types of intermediate rail fastenings: KB-65, KPP-1 and KPP-5.

KB type fastenings, most common on track with reinforced concrete sleepers, have a plate clip-bolt (bolt-and-nut terminal) design. Fastenings of KPP type have a non-plate design with elastic rod clips.

The data on the control measurements received by the track recording car during three years have been accepted for consideration. Since such control measurements are held once every 3 months, twelve measurements have been taken over a three-year period.

The analysis has been performed using standard methods of mathematical statistics. The following parameters of the upper track structure have been obtained: maximum width, minimum width, mode, median, root-mean-square deviation, sample variance.

The sample variance is called the deviation of a random variable from its mean value [14]:

\[ D[X] = \sum_{i=1}^{n} (x_i - m_x)^2 p_i \]  

where \( m_x \) – random distribution centre; \( p_i \) – probability of occurrence of a random variable; \( x_i \) – value of a discrete random variable.

The standard deviation that characterizes the scattering of a random variable from its mean value is determined by the formula [1]:

\[ \sigma[X] = (D[X])^{1/2} \]  

Mode is called the value \( x_i \), for which the probability \( p_i \) of occurrence is the maximum. The median is called the value \( x_i \), for which the probability of occurrence of a random variable of less or greater value is the same.

3. Research results

Figure 1 shows a graph of the change in the minimum track gauge width value at the track section where measurements were taken.

As can be seen in the figure, the maximum deviation of the narrowing of the track gauge is characteristic of the fastenings type KPP-1 and KPP-5. In most cases, KB fastenings exceed the minimum track gauge width value in comparison with the established one. However, all three types of fastenings allow the track to operate within tolerances.
Figure 1. Change in the minimum track gauge width value (based on observations over 3 years).

Figure 2 shows a graph of the variation of the maximum track gauge width value at the track section where measurements were taken.

As can be seen in the figure, the maximum deviation toward the extension has been fixed for the fastenings type KPP-1 and KPP-5. KB type fastenings have shown the smallest amplitude of change in parameter over the observation period. The KPP-5 and KB fastenings have kept the track running within tolerance values. For fastening of KPP-1 cases where the width of a track gauge exceeded admissible limits have been recorded, though it should be noted that this is not a systemic phenomenon.

Figure 2. Change in the maximum track gauge width value (based on observations over 3 years).
Figure 3 shows a graph of the change in mode of track gauge measurements at the track section under consideration.

The minimum amplitude of the change in the measurement mode is fixed for KB type fastening. The maximum is for KPP-5 type fastening.

Figure 4 shows the sample variance of track gauge widths at the track section.

The minimum variance value is fixed for KB type fastenings, maximum for KPP-1 type fastenings. The highest average value of variance is characteristic for the KPP-5 fastenings.

**Figure 3.** Change in the mode values of measured parameters of track gauge (based on observations over 3 years).

**Figure 4.** Change in the variance of values of measured parameters of track gauge (based on observations over 3 years).
Figure 5 shows the change in the median value of the track gauge width at the track section during observations. The largest is the median value of the track gauge width for KB type fastenings, with the minimum amplitude of change for this fastening type at the same time. The minimum median value of track gauge width is characteristic for the KPP-1 fastening. The maximum amplitude of change of median width value of a track is characteristic for fastening of type KPP-5.

![Median of results of track gauge measurements](image)

**Figure 5.** Change in the median value of measured parameter of track gauge (based on observations over 3 years).

4. Conclusions
Thus, considering the main statistics of track gauge changes during operation, we note that all three types of fastenings are capable of providing track gauge stability within tolerances. For fastening type KPP-1 there have occurred single events when the width of the track gauge slightly exceeded the deviations tolerances established by the instruction.

It should also be noted that KB-type fastenings have demonstrated the highest track gauge stability by most statistics parameters.

According to the authors of the presented work, such results may be related to the fact that the track section, where the research has been conducted, has a rather high load capacity, and the freight rolling stock exerts a higher dynamic effect on the track compared to the passenger one.

In order to reach a clear conclusion, additional research is needed on the track sections with high-intensity of passenger service and low-intensity of freight transportation. The authors plan to carry out such studies in the next work, which will allow drawing more definite conclusions.

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