Analysis of the Concept ”Spatial Curve on the Railway” with Modelling Elements

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Abstract: Current trends in the design and growth of the railway network in the Russian Federation and in the world should take into account the development of technology both in the design and in the current maintenance of the railway track. The article explores the movement of rolling stock on the existing curves on a section of the Sverdlovsk railway where, during operation, the transition curve was superimposed in terms of the vertical curve in the profile, which does not meet the requirements of the norms. Thus the «spatial» curve was formed. Its influence on the rolling stock is analyzed, forces are studied both in the contact «wheel-rail», and in the intercarriage space. The study argues for the removal of restrictions on the design of combined transition and vertical curves.

1 INTRODUCTION

The need to review legislative norms and regulations and the widespread introduction of modern technologies, including in the design of railways, is one of the most important tasks of Russia in the twenty-first century. Therefore, the Government of the Russian Federation in 2020 adopted the Federal Law (Federal Law of the Russian Federation, 2020. 247-FZ) on the «Regulatory Guillotine», which provides for a total revision of the mandatory requirements according to which the regulatory acts and the mandatory requirements contained in them should be reviewed.

The rules to be reviewed should also include the prohibition to combine transition curves with vertical curves in the profile when designing railways (SR 238.1326000.2015. Railway track; Han, 2014). Initially, it was not possible to contain such a «spatial» curve (Turbin, 2017.) at the beginning of the formation of regulations and development of track equipment, but with the development of pathways this requirement has become obsolete and needs to be reviewed, as it is redundant and costly.

So far, spatial design (following the example of foreign countries) has been based mainly on empirical tracing rules and the use of sketch geometry techniques. This is related to the drawing of forward-looking images to check and improve the road's spatial smoothness. This requires additional labour, specialized training and design skills, so the widespread adoption of spatial design principles has been delayed (Dzenis, 1968).

2 MATERIALS AND METHODS

In order to develop the hypothesis of combining the transition curve with the vertical curve in the profile under conditions of passenger and freight traffic, it is necessary to identify the operation of these sections. In January 2018, the track-measuring car-aboratory KWL-P2 1:075 was allowed to pass through the area under investigation in order to check the state of the rail track on the main geometric parameters (level, template, panel, subsidy). The main performance characteristics of the existing rail section are presented in Table 1.

At the moment, there are sections on the Sverdlovsk Railway where two curves converge — a transition curve in terms of plan and a vertical curve in a profile formed by intensive loads in difficult sections of the railway. The so- called «spatial» curve was formed. This is not a mass phenomenon and

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represents not more than 3% of the entire Sverdlovsk railway network. However, a study of the interaction of the wheel and the rail proves the possibility of such a combination.

Table 1: Main performance characteristics of an existing rail section.

Name	Characteristics
	1 2 section section
Route number	I
Year of laying	2009
Last repair (year)	Average repair (2017)
Rail category	DT350
Fastening type	KB-65
Radius of curvature in plan, m	1507 1500
Length of transition curve PK1/PK2, m	30/90 30/50
Radius of curve in profile, m	10000 5000
Speed permitted on pass/g, km/h	80/60 80/60
Number of defects of degree I, screw	0 0
Number of defects of degree II, screw	4 1
Number of defects of degree III, screw	0 3

It is worth mentioning that on this section in 2017 a continuous change of rails was carried out in the volume of the average repair of track (PS), however, in 2018 defects were detected: subsidence, distortions, widening of track.

For this site, the average number of curves per kilometre, both in plan and profile, is about 95%, while for the distance as a whole it does not exceed 40%.

The resulting «spatial» curves are noticed at «close» contact of transition and vertical curves. Due to the influence of passing trains «lining» of vertical and transition curves occurred. And these derogations were modeled, in the program complex (Universal Mechanism, www.universalmechanism.com).

3 RESULTS AND DISCUSSION

The purpose of the work: is to prove the possibility of combining the transition curves in a plan with the vertical curves in a profile by comparing forces in an existing section of railways with forces on railways in the design position (i.e. an area with and without a «spatial» curve). The following variants were modelled (Akkerman, 2020; Akkerman, 2020a):

— railroad track without defects;
— railroad track with 2 degree derogations at:
— on the transition curve;
— on a vertical curve;
— on the «spatial» curve.

The processing of the simulation results revealed the maximum, minimum and average total forces obtained by the formula 1 (Lyapushkin, 2008):

$$F = \sqrt{F_b^2 + F_h^2 + F_p^2}, \text{H} \quad (1)$$

where *Fb*, Fh, *Fp* are vertical, transverse, and longitudinal forces, respectively.

The difference between the total forces on the existing path section with the resulting «spatial» curve and without combining the curves is insignificant (the difference is not more than 4.5%). The maximum values of the total forces increase by

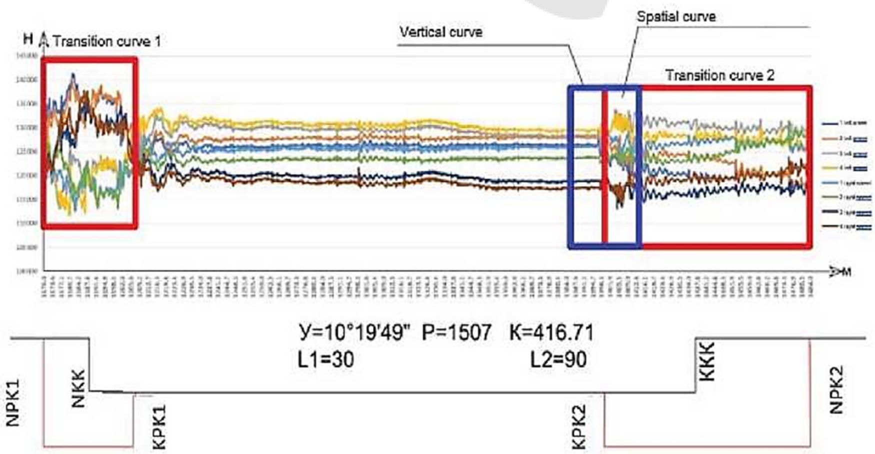

Figure 1: Graphical representation of total forces between wheel and rail on the existing section of track.

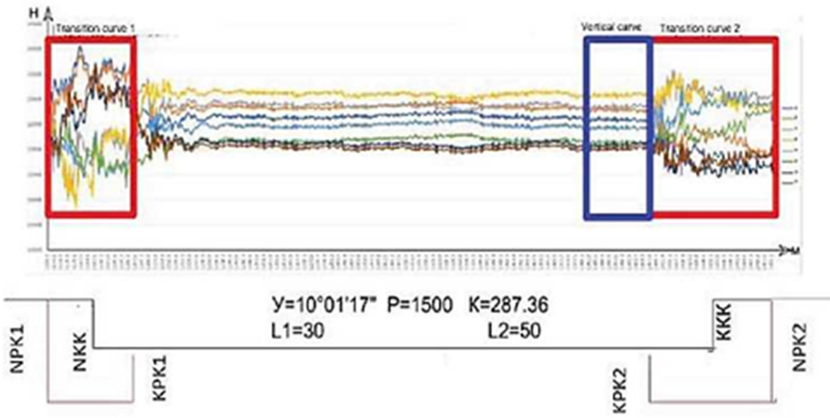

Figure 2: Graphical representation of total forces of interaction between the wheel and the rail on the investigated section of railway track according to the project data.

not more than 2.0 % relative to the section of railway in the design position.

Figures 1 and 2 show graphic images of total forces in contact with «wheel-rail», obtained as a result of modeling in the software complex «Universal mechanism^). The differences in model results between rolling stock on the existing track (combined transition and vertical curves) are almost identical.

The influence of the defect railway on the forces between the wheel and the rail was investigated. If there is a defect, the force values do not exceed the maximum values for the whole driving section.

According to the results of repeated investigations, the change of forces between the wheel and the rail on the «pure» transition curve and on the combined curve are identical at the same speeds of movement of the crew. Thus, it can be concluded that the «spatial» curve does not have a significant influence on the process of interaction of the system “wheel-rail”.

In the processing of the data maximum values, the forces generated by the transition curve were used.

Table 2: Results of the measurement of forces between the wheel and the rail.

Parameter	Value of total forces, kN
Transition curve without	134.5
Vertical curve without	132.0
Resulting spatial curve	135.0

Figure 3 shows a diagram of maximum forces on the existing section of the Sverdlovsk railway line

The diagram shows a slight difference in the value of forces in the investigated sections of the

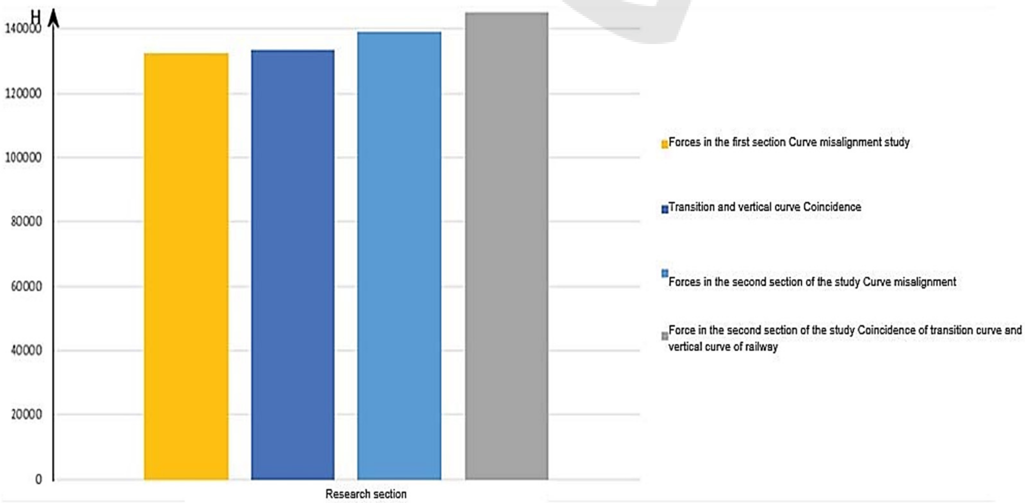

Figure 3: Force interaction diagram for the existing section of the Sverdlovsk railway

Sverdlovsk railway. From 130 kN the total forces reach 132 kN at most in the first study site and from 139 kN to 142 kN in the second study site, respectively. The percentage of the force variance shall not exceed 2%.

4 CONCLUSION

In the course of work, it has been established that the values of maximum forces on the combined and unconvented sections of the railway do not differ significantly. When considering vertical forces in detail, it is determined that forces in contact with the «wheel-rail» reach their maximum on the transition curve sections, and the presence of a vertical curve at that moment does not have a significant influence on the contact of the «wheel-rail». Such a conclusion could lead to a revision of the requirements to prohibit the combination of the transition curves in the plan with the vertical curves in the profile, which would lead to a reduction in the amount of excavation work, the cost of construction, without reducing the level of safety in the operation of such section of the railway.

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