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Research on widening construction clearance on the transition curve of existing railway lines based on SIMPACK

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Abstract. This paper selects appropriate vehicle as the standard vehicle and designs its shape. Secondly, it chooses some control point on the vehicle according to the current standard. Thirdly, the essay sets four difficult operating conditions with different curve radius and superelevation, simulates on the SIMPACK software and compares the value of control points offset the centre of railway line to the current construction clearance. According to the result of comparison, this paper divides transition curve into three parts to widen construction clearance and proposes the definition of correction coefficient. At last, the paper compares construction clearance that has been corrected with existing construction clearance to check whether the new one is right or not. The study shows that if curve part is divided into three parts to widen construction clearance, it would be more reasonable and satisfactory.

1 Introduction

Nowadays, the out of gauge goods relay on railway to transport, and it has put forward higher requirements for railway construction clearance. Current widened calculation value can not meet the actual operation needs, so it is urgent to study the widening of railway structure gauge. This paper focus on how to refine the widening range and widening value of the current widening standard so that it can fully meet the requirements of modern railway transportation.

When a train is running on the curve line, the bogie of the vehicle can rotate around the centre of the vehicle, but the body cannot be bent along with it. Therefore, both ends of the vehicle will be offset from the outer line of the curve away from the line centreline, and the centre of the vehicle will also deviate from the centreline of the line to the inside of the curve. In addition, the superelevation on curve line causes the entire vehicle tilt toward the inside of the curve, which also has an impact on the clearance. Therefore, on the curve line, the distance between the centreline of two adjacent lines and the safety distance between the centreline of the line and the buildings on the roadside should be calculated in accordance with the widening.

2 Simulation model

2.1 Simulation software

SIMPACK software is a multi-body dynamics software introduced by the German Internet company. Compared with other modelling software, SIMPACK has two advantages over this study:

- Professional track modelling module. SIMPACK has a large number of track modelling bodies, which can be used for intelligent and parameterized substructure modelling quickly and conveniently.The definition of the track line parameters is more convenient.Based on the above advantages, this paper uses SIMPACK9.3.1 as the simulation platform.

2.2 Vehicle model

2.2.1Topology analysis

As shown in Figure 1, the topological structure of the vehicle is represented by four parts: the body, the bolster, the side frame, and the wheelset. The body includes the empty car and the cargo loaded on the vehicle (hinge with the zero-freedom of the vehicle body). And the interaction of the components is realized through various forces in the motion equation.

2.2.2Vehicle virtual model

According to the topology shown in Fig. 1, the vehicle system is modeled in SIMPACK, and the vehicle model is obtained by processing the vehicle's external dimensions and the articulation relationship among the components. The external dimensions of components such as bodywork, cargo, and sideframes are simplified, but the mass, relative position, and center of gravity of each component must be set according to actual values.

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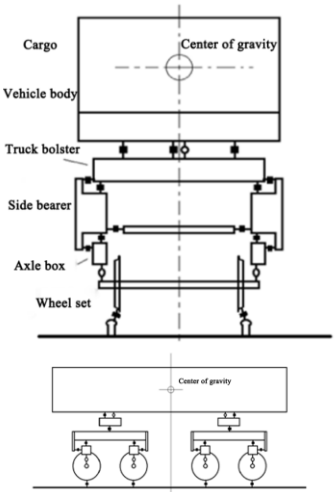


(a) (b)

Fig.1 Topology

In Figure 1, "╋" represents the force and moment between components, and "ǫ" represents the articulated relationship between system components

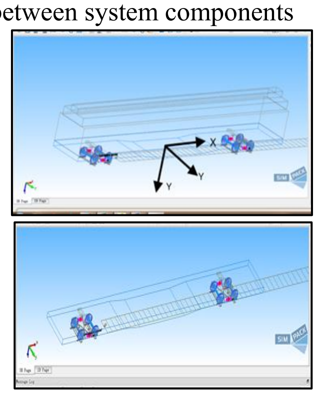


Fig. 2 Coordinate system and Vehicle virtual model

3 Simulation experiment scheme

3.1 Simulation Vehicle

The parameters of vehicles should be sufficiently representative to ensure that simulation can achieve good simulation results, and simulation results can be applied to railway vehicles currently used. Therefore, considering the above factors, this paper selects vehicle models with a 26m car length and 18m pin distance based on the *Code for the Design of Railway Lines (2006).*

3.2 Coordinate system

In this paper, the coordinates of the modelling process are unified by Cartesian coordinate system, and the rotation direction is determined by the right hand rule.

3.3 operation condition

The design of simulation conditions greatly affects the reliability of simulation results. To ensure that the simulation results are representative, the operating conditions of simulation should be reasonably set.

Three II-class lines and one I-class line are designed in this simulation according to railway line design code-1999, and the design speed of the freight train is 50, 60, and 70km/h. For the design speed 120, 100 and 80km/h, 800, 600 and 500m are chosen as the corresponding curve radius. Besides, when the curve radius of the circuit is larger than 1400m, the transition curve length is 20m. It's a special cases, so we design another operation condition——curve radius is 1400m.

3.4 Superelevation

According to *Code for the Design of Railway Lines (2006),* the range of superelevation is shown as table 1.

Table 1. Range of superelevation（mm）

H_{max}	H_{min}	Allowable low superelevation		Allowable superelevation	
		General	Hard	General	Hard
150	5	70	90	30	50

To sum up, this article has designed the following four operating conditions.

Table. 1 Setting Word's margins.

parameter \ condition	A	B	C	D
Design speed（km/h）	120	100	80	80
Curve radius (m)	800	600	500	1400
Transition curve length(m)	130	100	60	20
superelevation (mm)	120	110	105	50
Circular curve length (m)	80	60	50	100
sampling frequency（Hz）	100	100	100	100

3.4 Calculation point

Compared with the clearance of rolling stock, we set 9 (shown in Fig 3) calculation points from *a* to *i*, point *d*，*e*，*f* are located in the middle part of the vehicle inside the curve, and the other 6 are located at the end of the vehicle outside of the curve, the height is located at the distance rail surface 1250mm, 3600mm, and 4800mm respectively. In order to study the internal and external deviations caused by vibration and running on the curve during the running of the vehicle, 3 reference points（α,β and γ） are set on the central line of the track, which correspond to the middle and the two ends of the vehicle and follow the car body forward. There is a certain initial distance between the projection of the calculation point on the vehicle body and the corresponding reference point. With the running of the vehicle, the difference between the distance from the calculation point to the central line of the car body and the initial distance is the deviation.

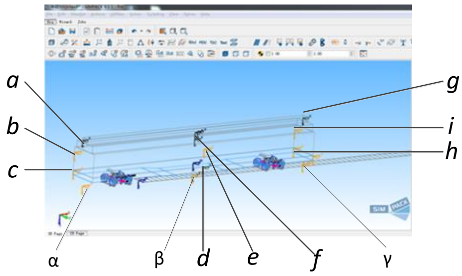


Fig. 3 Calculation point

4 Analysis of simulation results

4.1 The maximum offset to the centreline

4.1.1 Offset inside the curves

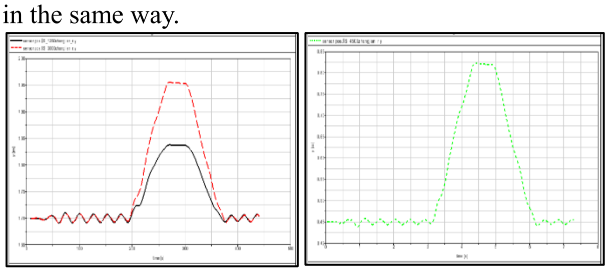
On the inside of the curve, the middle part of the vehicle has a larger offset to the centreline of the track. Therefore, calculation points d, e and f are set in the middle part of the vehicle from the rail surface heights of 1250 mm, 3600 mm, and 4800 mm, respectively. And, a reference point *β* is set on the central line of the cross section of the calculation point to move with the vehicle, and a sensor is established to connect the reference point and calculation point. The distance between the projections of these two points on the horizontal plane is the internal deviation of the vehicle. Since the distance from initial position of the calculation points d and e to central line of the track is same, so the deviation data of these two points are put in one figure.

The model operation data is obtained from the SIMPACK post-processing program.

4.1.2 Offset outside the curves

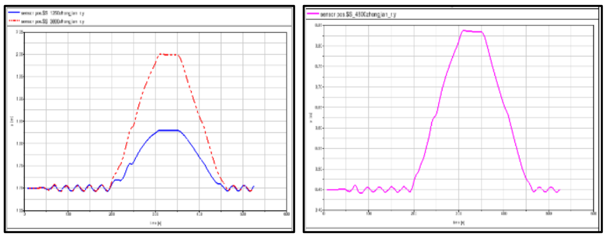
In this paper, the location of the vehicle centre pin represents the current position of the vehicle, so when the vehicle is in a certain position, the offset of the two opposite sides of the vehicle to the center line is different, as shown in Figure 4-(a)

Because of the coordination, the value of the offset is negative. And in order to get the maximum external offset, all the data are taken as an absolute value. And the maximum offset of the vehicle at each point are selected, we take point c and h as an example as shown in Figure.5-(b), and All points on the outside of the curve are treated in the same way.



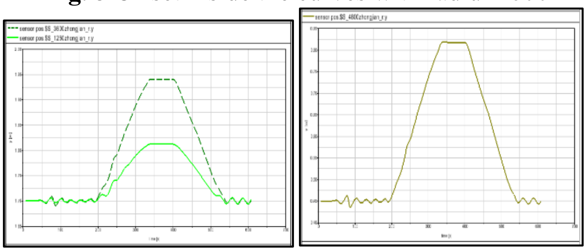
(a) (b)

Fig. 4 Offset inside the curves with radium 500m



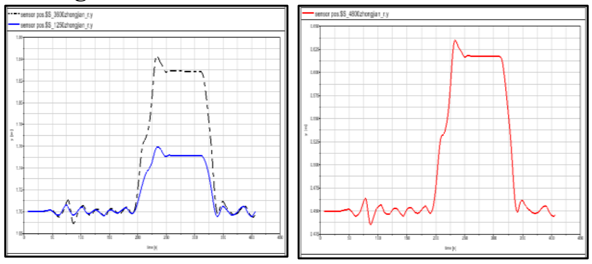
(a) (b)

Fig. 5 Offset inside the curves with radium 600m



(a) (b)

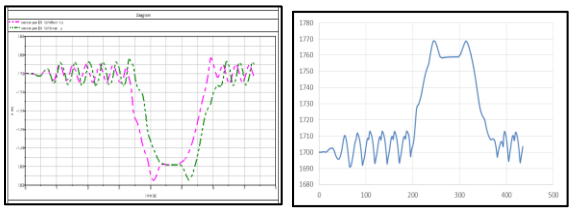
Fig.6 0ffset inside the curves with radium 800m



(a) (b)

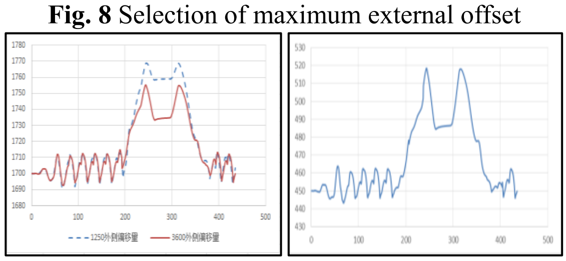
Fig.7 Offset inside the curves with radium 1400m

In fig.4-8, three curve lines represents the offset of point e, e, and f.



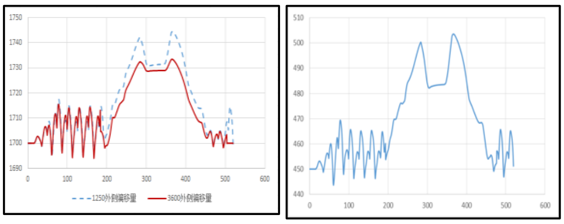
(a) (b)

Fig. 8 Selection of maximum external offset



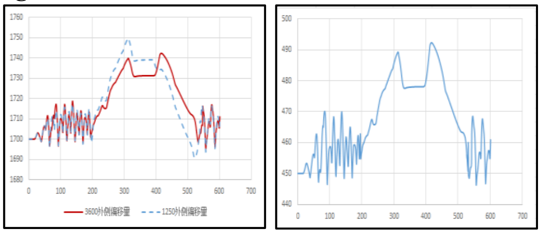
(a) (b)

Fig. 9 Offset external the curves with radium 500m



(a) (b)

Fig. 10 Offset external the curves with radium 600m



(a) (b)

Fig. 11 Offset external the curves with radium 800m

4.2 Widening range analysis

According to *"Code for the Design of Railway Routes - 2006",* the widening range of construction clearance in the curve part is: the widening value between the 13m before the midpoint of the transition curve and point of spiral to curve is the same as the circular curve. From the 22m before point of tangent to spiral to the 13m before the midpoint of the relaxation curve, the widening value is half the circular curve widening value.

According to the current widening regulations, widening range starts at 22m before the straight-forward point. As shown in Fig 12, the distance between the centre pin of the front bogie and the rear end of the vehicle is 22m. When the vehicle is passing through the transition curve , it begins to widen since the centre pin of the front bogie passes through the point of tangent to spiral. In fact, a bogie is composed of two pairs of wheels. When the front wheels of the front bogie pass through the point of tangent to spiral, the vibration and offset state of the vehicle has also changed compared to when it is running on a straight line. Therefore, the starting point of widening before the straight-going point should be when the front-wheel pair passes through the straight-straight point.

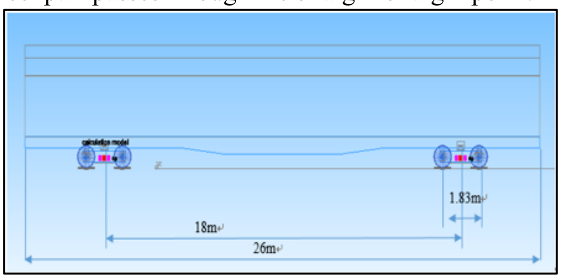


Fig.12 Calculation vehicle

The front wheel of the front bogie is 23m away from the rear end of the vehicle, so the widening starts from 23m before the point of tangent to spiral. The end position of the first widening stage is 13m before the midpoint of the transition curve, which is half the length of the captain, and this point is also the starting point for next widening stage.

When the front wheel of the bogie runs to the slow point, the vibration and offset state of the vehicle is different from the transition curve. Therefore, the third stage of the curve widening before the mid point 13m to the slow point of the transition curve is 23m. And the rest part, from the 13m before the midpoint of the transition curve to the 23m before the rounding point, is the second stage.

4.3 Optimization of construction clearance

4.3.1 Optimization of construction clearance on the curve inside

According to the provisions of the *Railway Line Design Specification-2006*, the following comparisons of construction clearance and offsets are obtained. Take point *d* an example. Compared with the actual offset, the current standard can not be fully utilized, and there is much space for refinement.

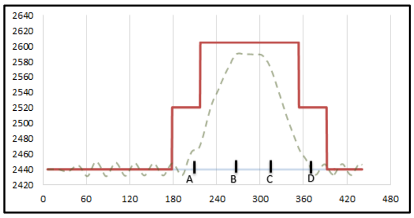


Fig.13 Comparison of offset and current rules

For this clearing interval, the correction coefficients β_i is proposed to be independent of the factors such as line grade and curve radius, and represents only the widening correction factor of the *i*-th stage. Therefore, the following optimization schemes are available for the widening values of the widening stages.

$$W_i = \beta_i \left(\frac{40500}{R_i} + \frac{H}{1500} h \right) \quad (1)$$

Where:

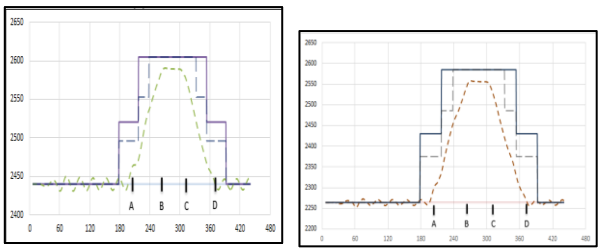
W_i- inside widening value of the i-th stage, $i = 1, 2, 3$;

β_i- correction coefficients of the i-th widening phase, where $\beta_1 = 1/3$, $\beta_2 = 2/3$, $\beta_3 = 1$;

H - the height of the calculated point from the rail surface (mm);

h - superelevation (mm).

According to Formula (1), the comparison between the widening of the new construction clearance and the widening of the original construction clearance is as follows.



(a) (b)

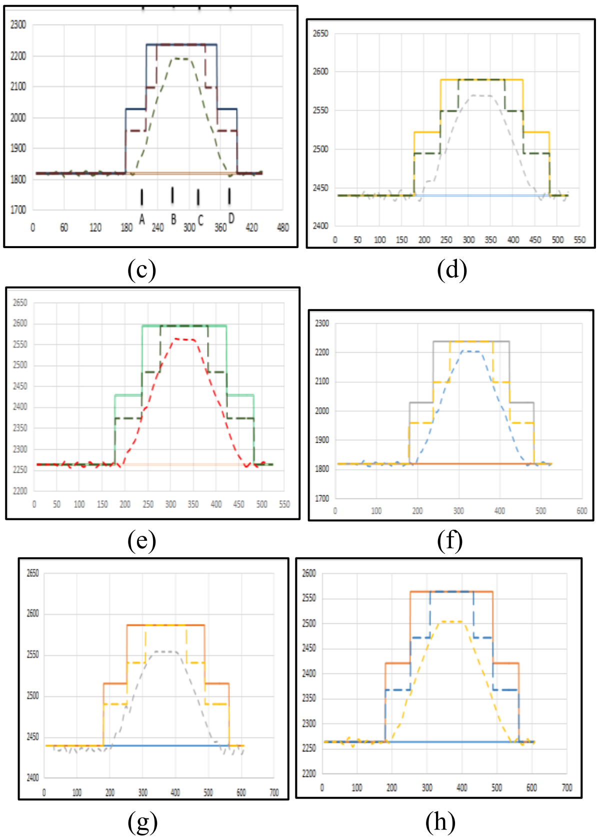


Fig. 14 Comparison of new and original inside clearance

In Fig.14, polyline represents the original construction and dotted polyline represents the new. Besides, (a), (b), (c) respectively represent points *d, e* and *f* when the radius is 500m. (d), (e), (f) are for when radius is 600m. And the rest are for when radius is 800m.

Fig.14 shows that the improved clearance still meets the requirement of the inside offset to widen the clearance, and there is enough space between the vehicle and the construction clearance.

4.3.2 Construction clearance widening of special line

When the curve radius is greater than 1400m, the comparison is as follows.

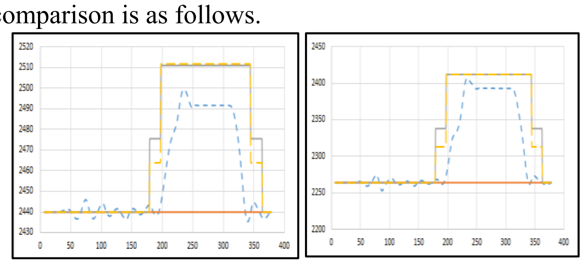


Fig. 15 Comparison of new and original inside clearance

The third stage starting point of the widening is 23m before the slow point, which coincides with the starting point of the second stage proposed in this paper. So, when the transition curve length is 20m, the second stage is omitted.

4.3.3 Optimization of construction clearance on the curve inside

According to current standard, the comparison of offset curve and current construction clearance is as follows.

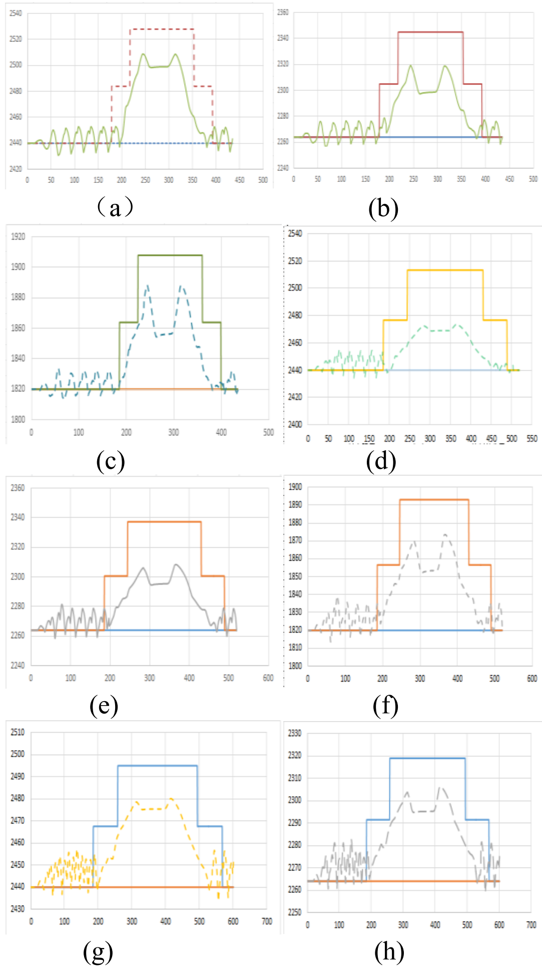


Fig. 16 Comparison of new and original inside clearance

In Fig.16, polyline represents the original construction and dotted line represents the offset. Besides, (a), (b), (c) respectively represent when radius is 500m. (d), (e), (f) are for when radius is 600m. And the rest are for when radius is 800m.Current construction clearance is in good agreement with the actual situation and it can not be optimized any more.

5 conclusion

In this paper, 9 calculation points and four operation condition are designed. Offset data is obtained by the simulation, and compared with the current construction clearance, a correction coefficient is introduced to the widening formula, and the result shows that the new formula can meet the offset better.

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