Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
September-October 2022 Page No. 460-468
Article History: Received: 05 April 2022, Revised: 27 April 2022, Accepted: 03 May 2022, Publication: 14 May 2022

Research on Maintenance Management Technology of Track Irregularity of High Speed Railway

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Abstract:

This paper aims to analyze and study the outstanding problems that exist in high-speed trains while they are in motion. It analyzes the impact of track irregularity and the interaction of vehicle wheels on the magnitude, the size of wavelength and the resonance frequency of the high-speed trains; it studies the types of track irregularity, and after the data are correctly measured concerning the variety of track irregularity, scientific evaluation will be made about the status of the track irregularity. Statistical indicators of irregularity amplitude such as the rail mass index will be used to prepare a track segment of 250 meters long characterized with continuous irregularity, using the composite index collected through dynamic checks concerning the height, direction, distance, level and distortion of the rails, taking 250 meter-long line segments as the basic length unit for track regularity assessment, judgment and maintenance; then all kinds of irregularity will be measured and evaluated with the standard deviation of this basic length unit, wherever standard deviation exceeds the allowable limits, the state will be determined as bad, and regardless of the extent of the track irregularity of the individual sites, they should all be repaired. In that way the statistical features of seriously irregular segments would be made prominent, enabling the scientific balance of the segments that need maintenance.

***Keywords**: high-speed train, acceleration, waveform, track irregularity.*

I. INTRODUCTION

Track irregularity affects the comfort and safety of train operation, intensifies the dynamic action between vehicle and track, and shortens the maintenance cycle and service life of train and track. High speed railway pays special attention to the high smoothness of track. In this paper, the track irregularity of high-speed railway is analyzed and studied, and the influence amplitude, influence wavelength and resonance frequency of the interaction between track irregularity and vehicle wheelset on high-speed train are analyzed, so as to highlight the statistical characteristics of sections with serious irregularity, scientifically weigh the sections requiring maintenance, realize fine line repair, improve operation efficiency, improve line smoothness and prolong the service life of the line, It has important practical significance[1].

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II. HIGH-SPEED TRACK IRREGULARITY, ITS INTERACTION WITH VEHICLE WHEELS AND THE CHARACTERISTICS OF ITS MAINTENANCE AND MANAGEMENT

Track irregularity is main cause for vibration and increased wheel-rail interaction. It has significant impact on the road traffic balance, comfort and safety, and is one of the main factors that directly limit the locomotive speed. In high-speed conditions, the impact of wheel-rail interaction is even greater, and more destructive for the rail devices. It has the following features:

2.1 Small Impact Amplitude

With the increasing speed of traffic, the impact of track irregularity amplitude on traffic balance and security will rapidly increases. In high-speed driving conditions, track irregularity with small magnitude may cause strong impact on the wheel-rail vibration, resulting in a large wheeltrack interactive force. For example: irregularity caused by small steps with a weld amplitude of less than 0.5mm in CWR track can lead to the formation of huge wheel-rail impact several times the weight of the static wheel load. Therefore, track irregularity that has small amplitude and generally considered unnecessary to correct, maintain and manage at low speed, must be strictly controlled when they appear in high speed 4T tracks[2].

2.2 Large Wavelength

When the locomotive speed increases, the range of wavelengths that influence the level of track irregularity will also expand accordingly. In low operation speed, wavelength influence caused by subgrade elevation bias, uneven settlement and deflected bridges is small and does need maintenance, monitoring and management. But in high speed condition, the vibration effects of long-wave irregularity on the locomotive can no longer be ignored. When the running speed approaches 140KM / H, sensitive wavelengths that can cause locomotive vibration can be as long as 40 meters. When the vehicle speed exceeds 160KM / H, the sensitive wavelength that can produce strong locomotive vibration can be as long as 50 meters. Therefore, the range of wavelength that must be corrected and maintained should also greatly increase, especially, greater efforts should be made to remedy small embankment problems caused by embankment sinking within a length of 20 – 50 meters.

2.3 Easy Resonance

When the vehicle speed is not high, the track direction irregularity with wavelengths of 44 meters and 50 meters has minimal impact and need not be treated. But when the speed reaches 140KM/H and 160KM/H, the frequency is equally 1HZ, and the self Frequency of the locomotive and the vehicle body is also 1HZ, the locomotive frequency and the vehicle body frequencies are the same or close to each other, so the vehicle body will inevitably suffer from a strong resonance. Therefore, in high speed conditions, there must be strict control over directional track irregularity with characteristics of resonance wavelength.

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2.4 Great Harm

In high-speed running conditions, such malignant orbital irregularity, once triggering derailment accidents, the harm caused will be much more serious than those occurred in low-speed running. For example: the German high-speed train derailment accident and China's Shenyang North vehicle derailment accident are both very harmful.

III. TRACK IRREGULARITY CLASSIFICATION

3.1 Vertical Track Irregularity

a. Height. Track irregularity refers to the uneven vertical height along the rails, it is caused by following factors: the height deviation after line construction and overhaul operations; bridge deflection; residual flexural deformation of the track bed and subgrade; uneven settlement; unequal gaps between the various components of the track; the existence of dark pits; empty hanging and empty hanging inconsistencies caused by improper maintenance of the rail vertical elastic digging and frothing.

b. Level. Track level refers to the elevation difference of the two rails in the same cross-section.

c. Plane distortions (i.e., Twist or Warp). Track plane distortion refers to the surface twist of the two rails on the right and left comparative to the track plane. It is measured with the algebraic difference of two cross section horizontal magnitudes of a certain space away.

3.2 Horizontal Track Irregularity

a. Direction. Track direction irregularity means the longitudinal irregularity along the inside top edge of the rails, which is caused by the following factors: track centerline position deviation in construction and overhaul operations; uneven wear of the rail head side of the transverse residual deformation; fastener failure, uncorrected rail dead curve, inconsistent transverse track elastic force, CWR temperature, etc.

b. Gauge bias. Gauge bias refers to the bias between the shortest distance of the two rails on the one hand and the standard rail gauge on the other, which is measured under the interaction of the two rails in the height of 16MM, which is usually caused by bad fasteners, ineffective sleeper shoulders, the side rail head wear, fasteners gap, insufficient fastening pressure, and the dynamic elastic squeeze of the train.

c. Gauge downslope rate. It is measured in the algebraic difference of the rail gauge deviation within a certain length.

3.3 Complex Irregularities and Deviation of Head and Tail of the Curve

At the same position on the track, the coexistence of vertical and horizontal irregularity is known as

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complex irregularity of track, which belongs to Class II or between Class II and Class III in terms of its amplitude, namely, it does not reach Class III and there is no traffic safety problem, but it has potential crisis in terms of its continuousness; continuous multi-wave complex irregularity can easily lead to violent vibration, and subject to increased derailment coefficient, seriously unstable traffic and even derailment. Periodic continuous irregularity can cause greater harm through resonance. Alighment, level and reverse complex irregularities are characterized with negative super elevation, and such irregularities may be the primary causes of derailment. [3]

Meanwhile, factors such as curve in the point of tangent to spiral, the increase of gently dot area, versine downslope start, end inconsistent or mismatched complex geometric irregularity, all have a significant impact on balanced, comfort and safety traffic.

IV. ASSESSMENT OF TRACK REGULARITY AND JUDGMENT OF BAD STATE

Currently in most cases, it is not enough to evaluate the local state of track irregularity and determine the sites that need frequent repairs, maintenance, temporary repairs only according to the size of magnitude. According to the influence of irregularity waveform characteristics, we should pay attention not only to overrun magnitude, we should also take into account the average rate of change in which the magnitude can approximately reflect the impact of the corresponding wavelength. For three or more consecutive cyclical irregularity, if they are in the resonance wavelength range, even if the amplitude does not exceed the limits of assessing the value of local irregularity, they should still need more maintenance and management[4].

4.1 Safety Management of Track Irregularity (i.e., temporary repairs)

To identify and judge serious irregularity, timely analysis should be made of some track irregularities that do not meet Class III, and timely treatment should be conducted accordingly. As for alignment and level reverse complex irregularities, in the case of the absence of maintenance complex value, relevant technical regulations should first be consulted before specific requirements are put forward.

4.2 Complex Irregularity Computing of Linear Segments

a. Irregularity computing

When the train passes the curves it will generate centrifugal force. To balance the centrifugal force generated, the track is provided with super elevation in the outside curve of the rail. Similarly, when the train is running in a straight line and encountering irregularity, centrifugal force will also be generated, but because of the absence of super elevation, the train will generate unbalanced centrifugal force and corresponding acceleration, namely, horizontal acceleration a. According to the principles of theoretical mechanics it is known that:

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$$a = V2 / K \tag{1}$$

K is the curvature of alignment irregularity, which is mostly round or parabola, V is the vehicle speed

If round is applied, the super elevation that the train requires while passing the curve should be:

$$h = 11.8V2 / R(V \text{ in } km / h\ s) \tag{2}$$

Take the scene chord length as h = 10M, the speed unit as m / s, it is concluded that the relationship between the level acceleration and super elevation is as follows:

$$a = h/153 \tag{3}$$

From the above equation it can be seen: In theory, super elevation value 153MM balance and can be accelerated by centrifugation 1M / S2, and a super elevation value of 15.3MM may be balanced with an ultra centrifugal acceleration of $0.1M/S^2$.

b. The calculation of the reverse phase complex of alignment and horizontal rail irregularity

Let (horizontal) acceleration be a1, then

$$a_1 = a + \Delta a \tag{4}$$

In the above formula a- is the horizontal acceleration caused by alignment irregularity

And △ a- is the horizontal level acceleration caused by horizontal irregularity, $a = h/153$. Similarly $\Delta a = \Delta h/153$

$$a_1 = (h + \Delta h)/153 = H/153 \tag{5}$$

H = h + △ h, which may be referred to as the equivalent of the total amount of horizontal irregularity.

c. Calculation of acceleration while the impact of the locomotive vehicle is taken into consideration

In fact, when the train passes the line of alignment irregularity, the vehicle will lean to the outside in the direction of the irregularity. So that the spring of that side is compressed, thus increasing the unbalanced centrifugal acceleration, the horizontal acceleration measured by the track inspection vehicle in dynamic testing also contains this value. According to the acceleration formula of orbital dynamics:

$$a_\beta = (a + \beta) \cdot a_1 \tag{6}$$

Where the actual level of acceleration is $a\beta$

$\beta$is the spring additional factor, which generally takes 0.2

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a1 is the theoretical value of horizontal acceleration resulted from alignment and horizontal reverse phase complex irregularities.

Based on the above calculations, the actual value of horizontal acceleration resulted from alignment and horizontal reverse phase complex irregularities is as follows:

$$a_\beta = (a+\beta)\cdot(h+\Delta h)/153+(h+\Delta h)/128 \tag{7}$$

d. Limit calculation

According to the provisions of section 7.2.2 of “Railway Maintenance Rules”: the horizontal acceleration limits of 160KM / H> V> 120KM / H, 120KM / H> V> 100KM / H are 0.06g in AI level, 0. log in AII level and 0.15g in AIII Level.

Use the allowable horizontal acceleration to estimate static permissible limit, take a_β=0.15g for the limit of 160KM / H> V> 120KM / H, AIII level, namely, $a_\beta = 0.15g = 1.47m/s^2$.

From 7 the following can be obtained

$$H = h+\Delta h = 128\times 1.47 = 188(MM) \tag{8}$$

According to "Railway Maintenance Rules" , the static value of temporary repairs, 160KM / H> V> 120KM / H, when the level reaches over 8MM and is equal to 9MM, which is the supercritical repair value, so it is gauged as 9MM , taking into account the elastic sinking difference 0-2MM, then △ h = 9-11MM, the calculation takes △ h = 11MM, H = 188, h = 177 (MM).

Taking the train speed as 140KM / H, irregularity as round curve, L = 10 meters.

After calculation, the reverse phase composite limit alignment of the corresponding super temporary repairs static alignment regularity and horizontal irregularity is 7MM, therefore, it requires that when the rail irregularity reaches 6MM, and where the level gauge value reaches -8MM, it is taken as the temporary repair value in timely processing. When performing maintenance and inspection, these reverse-phase composite irregularity lines are positioned as disqualification lines[5].

4.3 Analysis of the Horizontal Acceleration of the Vehicle Body

According to Article 3.7.6 of the "Railway Track Maintenance Rules", the curve should remain smooth, use 20 string to measure versine at 16MM under the rail surface, the deviation should not exceed the limits specified in 3.7.6. Head and tail position of the scene curves, spiral length and radius of curvature shall all be consistent with the equipment (As shown in Table I).

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Table I Allowable deviation of curve versine

Curve radius (M)	Transition curve versine and planned versine		Circular curve versine continuity		Largest to the smallest difference of circular curve versine	
	Main track and arrival and departure track	Other tracks	Main track and arrival and departure track	Other tracks	Main track and arrival and departure track	Other tracks
R <250	7	9	14	16	21	24
250<R<350	6	7	12	14	18	21
350<R<450	6	6	10	12	15	18
450<R<360	4	5	8	10	12	15
R> 650	3	4	6	8	9	12

For example: Khan Dan line Changjiangbu Track District is in charge of main track 206KM, in which there are 69 curve lines, three of them with a curve radius 1000 meters, and 30 of them with a curve radius 1200 meters. According to the above mentioned requirements of smoothness in "Railroad Track Maintenance Rules", it can be achieved on a daily basis, but after the speeding up, because of insufficient local smoothness, there once appeared three parts of horizontal acceleration. For the new situation after the speeding up, we consulted a lot of data indicating that the vehicle acceleration is directly related to ircular curve superelevation and smoothness.

When the train passes through a curved track with a radius R (m) and an appearance superelevation of h (mm) at a speed of V (m / s), due to the centripetal acceleration gtar = gh / s1 generated by centripetal force produced by centrifugal force, and due to the incompatibility of the passing speed of the train V with the outer rail superelevation h, there will produce unbalanced acceleration $a_o=v^2/R—gh/s_1$.

In the formula S_l is the distance between the centerlines of the two rails.

The unbalanced centrifugal acceleration should not be too high, otherwise, it will not only affect train running smoothness so that visitors will feel bad, in high-speed driving conditions, the vehicle will also suffer from loss of stability, endangering the train safety. Therefore, an allowable value of reasonable and unbalanced centrifugal acceleration a_o must be specified, Vmax is the maximum driving speed of the train.

$$V_{max}/R - gh/S_1<a_o \tag{9}$$

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g takes the value of 9.8m/ s^2, S1 the value of 1500mm, and substitute them into the above formula, and transform Vmax (m / s) into Vmax / 3.6 (km / h), then we will obtain $11.8V^2_{max}$ / R-h<153_a.

In the case of Vmax> Vo (average speed), △ h is positive, called deficient superelevation. While in the case of Vmax <V, △ h is negative, known as surplus superelevation. The relationship between deficient superelevation and surplus superelevation on the one side and unbalanced centrifugal acceleration and unbalanced centripetal acceleration is △ h = 153ao.

Once in thorough inspection by track inspection car, there appeared a total of 10 level-3 marks, and these 10 level-3 marks by track inspection car are all horizontal acceleration, the track division immediately organize personnel to the scene to inspect respectively, the result is as follows:

Driving speed is 145 KM / H, curve radius is 1200 meters, the established curve superelevation is 105MM, use 20-meter long chord to check the continuous curve versine, the difference does not exceed 6MM, superelevation meets requirements, but when checking with 10-meter long chord, versine all reaches 16MM, after calculation the following is obtained: R = 12500 / f

12500 should be checked with 10 m chord, f is substituted into 16MM, curve radius is obtained as 781 m, the curve deficient superelevation value △h=11.8V^2×1452÷781-75 =243MM. According to track maintenance rules, generally deficient superelevation value is specified as 75MM.

$$A = \Delta h / 153 \times 9.8 = 243 \div 153 \times 9.8 = 0.16g \quad (10)$$

0.16g just exceeds the level-3 criteria of horizontal acceleration 0.15g stipulated in article 7.2.1 in "Track Maintenance Rules".

The reasons for adverse direction are as follows:

① there is short distance (2-5 meters) unroundness in the curve;

②due to improper maintenance, the curve is long affected by simple curve lining layer, too many upper layers will make some curve radius smaller and versine larger.

Solutions:

① within 1200 meter-long curve, check use 10 m chord to control the appearance of 15MM versine to avoid the following situation: when the curve radius is too small, in the case of unchanged superelevation, when the vehicle passes, the curve deficient superelevation will be too large and horizontal acceleration will appear.

② add five meter checkpoints on the curve, the difference of the planned versine and the site versine of the transition curve should not exceed 2MM, circular curve continuity should not exceed 4MM, and the difference of the maximum and minimum versine should not exceed 6MM.

V. CONCLUSIONS

The maintenance and management of high-speed railway track irregularity plays a very important role in the daily maintenance and repair of railway, which must be studied and discussed in daily work constantly to find the best solution and to conduct scientific management. The prediction of track irregularity of high-speed railway can help railway department personnel better grasp the state of track equipment and realize the transformation from "post repair" to "state repair".

ACKNOWLEDGEMENTS

This work was supported by the Vocational Education Teaching Reform Research and Practice Project of Henan Province(yujiao(2021)57944).

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