Requirements to Check Rails of Railroad Switches

Irina Shishkina

Abstract The paper investigates the requirements to check rails of railroad switches (turnouts). Railroad switches of the most commonly used structures with rigid frogs always involve check rails. Check rails not attached to running rails allow performing the adjustment of flangeways under operation, which thereby significantly increases the durability of structures involving check rails. The safety criterion is the first and key requirement, since check rails as part of turnouts ensure safe passage of a wheelset of a rolling stock through the section with a crossing frog. The second most important criterion is a dynamic-kinematic one. The third criterion pertains to the provision of robustness of check rails. All the aforementioned criteria represent the essential and adequate requirements that must serve as the basis for working out permissible rate of wear for check rails and determining the size of flangeways for them. For the purposes of examining the stress–strain state of check rails, the reasonability of a the experimental-calculation method was estimated, protector checkrails were considered and efficiency and drawbacks of their implementation were analyzed.

Keywords Check rail structure · Check rail not attached to running rail · Requirements · Criteria · Wear · Width of flangeway · Protector checkrail

1 Introduction

Railroad switches of the most commonly used structures with rigid frogs always involve check rails. They are intended to direct wheelsets and prevent the wheel that passes through the frog from taking a wrong flangeway or striking against a tongue of the frog.

Railroad switches with check rails not attached to running rails provide the opportunity to adjust flangeways under operation, which thereby significantly increases the durability of check rails. In this regard, there arises an issue on regulation of the permissible position of a check rail in the structure, its wear and sizes of its

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I. Shishkina (✉)
Russian University of Transport (MIIT), Chasovaya str. 22/2, Moscow, Russia 125190
e-mail: shishkinaira@inbox.ru

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flangeways that proceed from this parameter [1, 2]. A worn check rail should ensure meeting the requirements imposed on railroad switches as much as a new one.

2 Research Technique and Results

Since check rails as part of turnouts ensure safe passage of a wheelset of a rolling stock through railroad sections with a crossing frog or sections of other types that involve check rails, then safety is the most important criterion and requirement [3, 4]. Parameters of the check rail and the section involving check rails should provide appropriate passage of wheelsets with excluding any impacts or striking against a tongue of the frog (item 5, Fig. 1) rolling onto a wing rail up to the throat (item 3, Fig. 1), onto the pick-up part of a wing rail or pick-up part of a check rail (item 1, Fig. 1). They also must prevent wheelsets from sprawling between a check rail and an inoperative wing rail (item 6, Fig. 1).

Another undesirable situation is when wheels roll onto an inoperative wing rail between the throat and the point of the frog tongue (item 4, Fig. 1).

The second key criterion is a dynamic-kinematic one. This criterion implies that abrupt displacements of wheelsets when passing through the frog crossing zone, rail overturning, destruction of the check rail zone and its failure after a short period of operation should be excluded. Quantitative expression of this criterion is the parameter associated with kinetic energy loss when a wheel strikes against the check rail (item 2, Fig. 1). This criterion limits bending angles of flare and pick-up parts of the frog crossing and the check rail in accordance with a design speed on the railroad switch [5, 6].

The third criterion is the provision of robustness of the check rail itself. The impact of wheels on the check rail should not cause dangerous defects or fracturing [7, 8]. This criterion is checked by comparing stresses arising in the most loaded part of the check rail with permissible stresses.

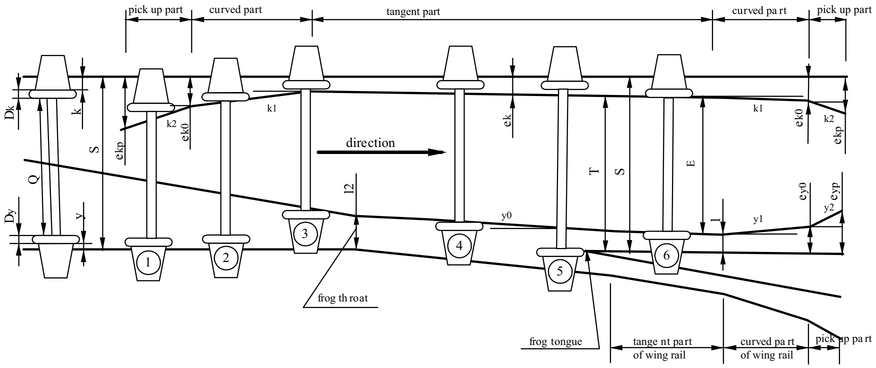

Fig. 1 Wheelset passing the frog section

All the aforementioned criteria represent the essential and adequate requirements that must serve as the basis for working out permissible rate of wear for check rails and determining the size of flangeways for them.

The levels of dynamic effects arising when trains pass through the railroad switch depend on the relative position of wheelsets and turnout elements, which is determined by a combination of their basic geometric dimensions [9, 10]. At each specific frog section, the track gage width has the value of S; dimensions of the flangeways of rails in their straight part, at the beginning of a flare and a pick-up part, respectively, are ek, eko, ekp (Fig. 1). Sizes of the flangeways of the frog in the throat, straight part of wing rails at the beginning of the flare and the pick-up part, respectively, are en, ey, eyo, eyp.

Let the wheelset entering the frog section have bottom distance between the inner edges of wheels Q, thickness of wheel flanges (with taking into account of fluting on the bottom side of a wheel) on the side of a wing rail Dy and on the side of a check rail Dk. When the wheelset approaches the frog crossing, there is a gap between the wheel flange and a gauge face of the running rail (on the side of a check rail) δk and a similar gap between the gauge face of a wing rail and the flange of the second wheel δy. Depending on particular values of all of the above dimensions, the following cases are possible when the wheelset passes through the frog crossing [11, 12]:

The bottom part of the wheel moving along the running rail strikes against the check rail at its pick-up part. The condition for this case to occur can be written as follows:

$$(\delta_k + D_k) > e_{k0} \tag{1}$$

The bottom part of the wheel moving along the running rail strikes against the check rail at its flare part. The condition for this case is as follows:

$$e_{k0} \geq (\delta_k + D_k) \geq e_k \tag{2}$$

The bottom part of the wheel moving along the frog crossing strikes against the wing rail of the crossing up to the throat. The condition for such a passage of the wheelset is as follows:

$$\left(\delta_y + D_y\right) > e_t \tag{3}$$

The bottom part of the wheel flange moving along the frog crossing strikes against the wing rail after passing the throat. This type of passing occurs under the following condition:

$$e_y \leq \left(\delta_k + D_y\right) < e_t \tag{4}$$

Impact (striking against) of the wheel moving along the frog crossing on the frog point. This can occur if:

$$Q + D_k + D_y + \delta_k \geq S - e_k = T \tag{5}$$

where T is the distance between the frog point and the gauge face of the check rail. Sprawling of the wheelset by the check rail and wing rail. This occurs on condition:

$$Q \leq S - e_k - e_y = E \tag{6}$$

where E is the distance between the gauge face of the check rail and the "inoperative" wing rail.

In addition, wheels may strike against the flare part and pick-up part of the check rail [13, 14]. Conditions entailing these cases are the same as conditions (1) and (2). It is also possible for bottom parts of wheels to strike against the pick-up and flare parts of wing rails of the frog crossing [15, 16]. The conditions for these phenomena are obtained from conditions (1) and (2) respectively by replacing index "k" with index "y":

$$(\delta_k + D_k) > e_{y0} \tag{7}$$

$$e_{y0} \geq \left(\delta_y + D_y\right) > e_y \tag{8}$$

Besides the aforementioned cases, wheels may freely pass the frog crossing zone. The condition for such a passage is opposite to conditions (1)–(8). To meet all safety requirements, dimensions of the track and flangeways, values T and E should be assigned so that conditions opposite to (1), (3), (5)–(7) are fulfilled for all possible combinations of sizes of wheelsets and frog crossings. Methods for analyzing such combinations can be different [17, 18].

Structurally, check rails consist of the main part lk0 that covers the dead space, two flares lk1 forwarding wheelsets to the frog flangeway of the needed line and two inoperative pick-up parts lk2 designed to ensure safety of train movement in cases when rules of maintaining the rail track are being violated and in other unusual situations (Fig. 2) [19, 20].

Lengths of check rail parts are determined as follows:

$$\begin{cases} \mathrm{l}_{k0} = (\mathrm{t_n} + \mathrm{w_c})\mathrm{N} + 2\mathrm{e}_k \\ l_{k1} = \frac{t_{k1} - t_{k0}}{\sin \gamma_{k1}} \\ l_{k2} \geq [l_{k2}]\,\mathrm{min} \\ l_k = l_{k0} + 2l_{k1} + 2l_{k2} \end{cases} \tag{9}$$

where N is the brand of the frog crossing;

γ_{k1} is check rail flare angle;

tn is the flangeway of the frog crossing throat;

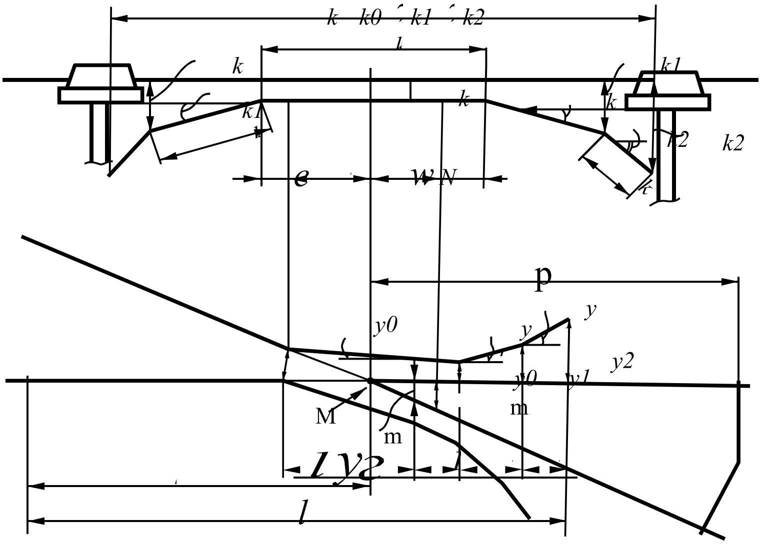

Fig. 2 Structural scheme of the check rail and frog crossing

t_{k0} is the flangeway at the main part of the frog crossing;

t_{k1} is the flangeway at the end of the flare;

w_c is the width of the tongue of the frog in the cross-section where the wheel completely rests on it;

e_k is the margin of covering the dead space;

$[l_{k2}]$ min is the minimum length of the pick-up part.

The angle of the check rail flare should not exceed the permissible angle of impact on the flare of the check rail, which is determined through the permissible value of the "impact effect" W_k according to the formula:

$$\sin \gamma_{k1} = \frac{W_k}{V_n} \tag{10}$$

where V_n is the design impact speed along the main track.

Large dynamic forces acting on the check rail entail the breakage of check rail bolts in structures that involve check rails of special RK-profile. Such a situation requires taking immediate measures, even up to interruption of train traffic (when two bolts in a row are broken) [21, 22]. In assemblies with check rails that are not connected to the running rail, the increased impact leads to fractures of check rail chairs. Wheelset displacements cause the appearance of saddles in rails of the frog during operation. This situation reduces the service life of rails and requires limiting the speed of trains [23, 24].

The level of impact of wheels on the rail is regulated by rationing values of the “impact effect” on the flare and the pick-up part of the rail. According to the standardized values of the “impact effect”, the angles of the flare and the pick-up part of rails are determined. These angles, taking into account manufacturing tolerances, are included in the design documentation of the railroad switch.

The structure of turnouts involving check rails of special PK-profiles, which are structurally attached to the running rail by filler blocks implies extremely hard adjustment of flangeways, which is rarely performed under operation. If the wear rate of the check rail does not ensure safety and required dimensions of flangeways, the check rail is replaced together with the rail of the frog crossing [25, 26].

The use of structures with check rails that are not connected with running rails allows adjusting the size of flangeways during operation by installing spacers between the check rail and the supporting part of check rail chairs. This makes it possible to extend the service life of check rails, since their wear does not obstruct setting the standardized sizes of flangeways and rates of safety.

Since wheels impact check rails along their length unevenly, check rails become worn out irregularly. The middle part of the check rail is mostly subjected to wear, so, when setting adjusting shims, flare angles of the check rail increase [27, 28]. The “impact effect” determined in accordance with formula (10) increases.

The mostly manifested wear of the check rail is limited by the maximum permissible angle of wheels running onto the check rail.

The criterion is checked by comparing stresses arising in the most loaded part of the check rail with the permissible stresses: $\sigma\max \leq [\sigma]$.

As the check rail wears out, dimensions of its cross section change. In this case, components of bending and torsion stresses increase, while geometric characteristics of the section (moment of inertia and moment of resistance) decrease. To resolve the issue of the permissible wear of check rail, we should proceed from the need to ensure robustness requirements not only for a new, but also for a worn out check rail. The impact of wheels on the check rail should not lead to critical defects or fracturing of a check rail. It is expensive and almost impossible to carry out tests covering all possible operating conditions for check rails of different wear rate at various combinations of sizes of a track and flangeways [29, 30]. Therefore, it is advisable to apply the experimental-calculation method to examine the stress–strain state of check rails.

The work is to be performed in two stages.

The first stage includes dynamic-strength tests with a detailed study of the parameters of the stress–strain state of check rails. The purpose of this stage is to obtain data on the most loaded sections of the check rail and ratios that allow checking the adequacy of models that are further used to calculate the robustness of the check rail and points of its attachment to sleepers.

The second stage implies carrying out calculations of the stress–strain state of check rails under various combinations of structure sizes and different rates of wear of the check rail itself. This stage is purposed to control the robustness of the check rail and points of its mounting to sleepers, as well as to determine the allowable rate of wear of check rails according proceeding from robustness conditions.

The simplest check rail model is a continuous beam of finite length resting on N supports. Such a model allows obtaining the demanded design stresses in the check rail. However, data obtained from such a calculation leads to unjustified margin of safety and unnecessary restrictions on values of permissible wear of check rails.

Models based on the finite element method give much more accurate results; therefore, when performing calculations, it is advisable to use finite element models based on using one of the standard computer software distribution packages.

Protector check rails are installed in turnouts before switch rails in the front offset of a stock rail. They are designed to improve the conditions of passing through switch panels of turnouts and to reduce the wear of switch rails and stock rails of turnouts, along which trains move to the diverging line in face direction.

It is also advisable to install protector check rails at symmetrical turnouts of hump-yards at the directions of priority movement.

The structure of protector checkrails and their attachment to bars are the same as that of check rails of frog crossings. Size of flangeways of protector checkrails, the allowable wear of check rails should be determined with applying the same methods as for check rails of frog crossings.

The most expedient length of a guiding part of the protector check rail is 10% more than the distance between the axles of wheelsets of a bogie of the most common rolling stock. In practice, length of the guiding part of the check rail is limited by options of its placement on the track. Protector check rails usually have such a length that allows them to be placed in the front offset of the stock rail of the turnout. In this case, the effect of their use is reduced, yet the expediency of using protector check rails remains.

The effectiveness of using protector check rails consists in 3–8 times increase in service life of the “stock rail—curved switch rail” set in terms of operating time until its wear rate reaches the lower limit.

The drawback of using protector check rails is a possible need to limit the speed of trains moving along the straight track of the turnout, since angles of wheels rolling on the flare of the check rail are high (restrictions on dynamic-kinematic criteria). First of all, this regards to shortened protector check rails, which have the angle of flare that can significantly exceed check rail flare angles at frog crossings.

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