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Behaviour of the rail load parameter B defined by the standard EN 14363

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1. Introduction

The mechanical system of railway vehicle running on the rails is a very complicated system with many bodies and also degrees of freedom. Probably the vehicle/track interaction is the most important part of this system and the forces acting on wheel/rail contact area are the most watched quantities of the whole mechanical system. This is confirmed, for example, in standard EN 14363 [1] which deals with testing and simulation of railway vehicles for their approval. Vertical wheel forces, lateral guiding forces or their combination are the main quantities used in this standard. Among other things, the standard describes the conditions for testing of rail load during railway vehicle running.

This paper is focused on the evaluation methods of a rail load according to the standard EN 14363. The standard takes into account the fundamental forces acting on wheel/rail contact area for evaluation of the rail load. For this evaluation, the limit values of quantities and test conditions are defined. But the standard also mentions the new quantities and parameters for this evaluation. These parameters that will be discussed in this paper are

- quasi-static rail load parameter $B_{a,qst}$,
- maximum rail load parameter B_{max}.

The other two parameters listed in the standard are the maximum guiding force and the rail surface damage parameter.

In order to determine the behaviour of the rail load parameters, multi-body simulations of railway vehicle running can be performed then it is possible to export and process records of required quantities.

2. Rail load evaluation according to EN 14363

Standard EN 14363 [1] defines the assessed quantities for running behaviour of railway vehicles. The quantities are used for evaluation of the vehicle/track interaction and describe the dynamics of the wheel/rail contact. It is possible to obtain reference values of these quantities as an output of multi-body simulations.

One of the fields covered by the standard is the evaluation of the track load. The assessment quantities are monitored and evaluated. For the evaluation of the rail load, the quasi-static guiding force Y_{qst}, quasi-static vertical wheel force Q_{qst} and maximum vertical wheel force Q_{max} are considered in this standard. The values of all these quantities are compared with their limit values. Both are listed in Table 1. The standard [1] sets the limit value for quasi-static

Table 1. Assessment quantities and their limit values for rail load evaluation according to the standard EN 14363 [1]

Assessment quantity	Limit value
quasi-static guiding force Y_{qst}	60 kN
quasi-static vertical wheel force Q_{qst}	145 kN for $P_{F0} \leq 225$ kN 155 kN for 225 kN $< P_{F0} \leq 250$ kN
maximum vertical wheel force Q_{max}	MIN(90 kN + Q_0; 200 kN) for vehicle speed $\leq$ 160 km/h

vertical wheel force $Q_{a,qst}$ under the condition of axle load P_{F0} value, which is defined as

$$P_{F0} = Q_1 + Q_2, \tag{1}$$

where Q_1 and Q_2 are vertical wheel forces of one wheelset. The limit value of maximum vertical wheel force Q_{max} is defined as smaller value of the two options mentioned. The sign Q_0 represents static vertical wheel force. This limit value only applies to vehicle speeds of 160 km/h or less. Higher vehicle speeds are not considered in this paper.

According to the ERA technical document [2], the values of quasi-static guiding force Y_{qst} are normalized by the relation

$$Y_{R,qst} = Y_{qst} - \left(\frac{10500}{R} - 30\right), \tag{2}$$

where R is the curve radius. This applies to curves of very small radii. However, for a curve radius of 350 m, the value calculated according to Eq. (2) is the same as the value without normalization.

According to the informative Annex J of the standard [1], the task of these quantities (see Table 1) is to control the following phenomena:

- rail internal fatigue, due to bending stresses in the rail,
- abrasive wear of rail,
- surface fatigue of the rail top due to high contact force,
- failure of fastening components due to high lateral forces or torsion moment.

However, it turns out that the quantities are not able to sufficiently represent these phenomena. This is the reason, why the additional parameters have been used in some countries. The additional parameters are following:

- maximum guiding force Y_{max},
- quasi-static and maximum rail load parameter B_{qst}, B_{max},
- track loading assessment quantity (Y/Q).

All these parameters are evaluated only for the outer rail in the curves.

The rail load parameters B were designed in the context of the demand for better evaluation of bending stress of rails. This two parameters are defined according to the standard [1] as

$$B_{qst} = |Y_{qst}| + 0.83 \cdot Q_{qst}, \tag{3}$$

$$B_{max} = (|Y| + 0.91 \cdot Q)_{max}\,. \tag{4}$$

For example in the standard UIC 518 [3], the quasi-static rail load parameter B_{qst} is defined as

$$B_{qst} = |Y_{qst}| + 0.83 \cdot Q_{qst} + \left[67.5 - \left(30 + \frac{10500}{R}\right)\right], \quad (5)$$

where R is the curve radius. However, for the purposes of this paper, the Equation 3 will be used.

3. Simulation conditions

Simulations of the railway vehicle running were performed in the computer program SIMPACK. A conventional passenger vehicle with 4 axles was considered. In order to obtain different values of the rail load parameter, the values of the vehicle body weight M and the longitudinal stiffness of the secondary spring k_{x2} (stiffness on one side of the bogie) were changed. The specific values of these quantities are listed in Table 2.

For the simulations, a curved track with a radius of 350 m was used. The cant of $D = 150$ mm and the cant deficiency of $I = 130$ mm were considered. This mean that the vehicle speed of $v = 25.3$ m/s was set. In order to consider a real model of the track, reference track irregularities were used and a model of a elastic track foundation was created.

Table 2. Considered vehicle parameters for the simulations

vehicle body weight M	**longitudinal stiffness** k_{x2}
40 tons	0.5 kN/mm
50 tons	1.0 kN/mm
60 tons	1.5 kN/mm
70 tons	2.0 kN/mm

4. Simulation results

The quasi-static rail load parameter B_{qst}, the quasi-static guiding force Y_{qst} and the quasi-static vertical wheel force Q_{qst} were evaluated for the different vehicle design conditions listed in Table 2. These values were calculated as the mean values of the time records of these quantities on a 300 m long curved track.

Dependences of all these quantities on longitudinal stiffness of secondary suspension on one side of bogie for different values of vehicle body weight are shown in Fig. 1. These quantities are calculated and plotted only for the first outer wheel of the vehicle. The black lines shown in the graphs indicate the limit values of the stated quantities. The limit value of the rail load parameter B_{qst} was calculated according to Eq. (3) where the limit values of guiding and vertical forces were set, therefore:

$$B_{qst,lim} = |Y_{qst,lim}| + 0.83 \cdot Q_{qst,lim}, \quad (6)$$

$$B_{qst,lim} = |60| + 0.83 \cdot 145 = 180.35\ kN. \quad (7)$$

Fig. 1 shows that the behaviour of the rail load parameter B_{qst} is similar to the behaviour of the vertical wheel force Q_{qst}. The best examples of the behaviour of the rail load parameter are the vehicle design with the highest values of longitudinal stiffness k_{x2} and the vehicle body weight of 40 and 50 tons. Because vehicles with these conditions meet the requirement of the rail load parameter B_{qst} but do not meet the requirement of guiding force Y_{qst}. Therefore, these

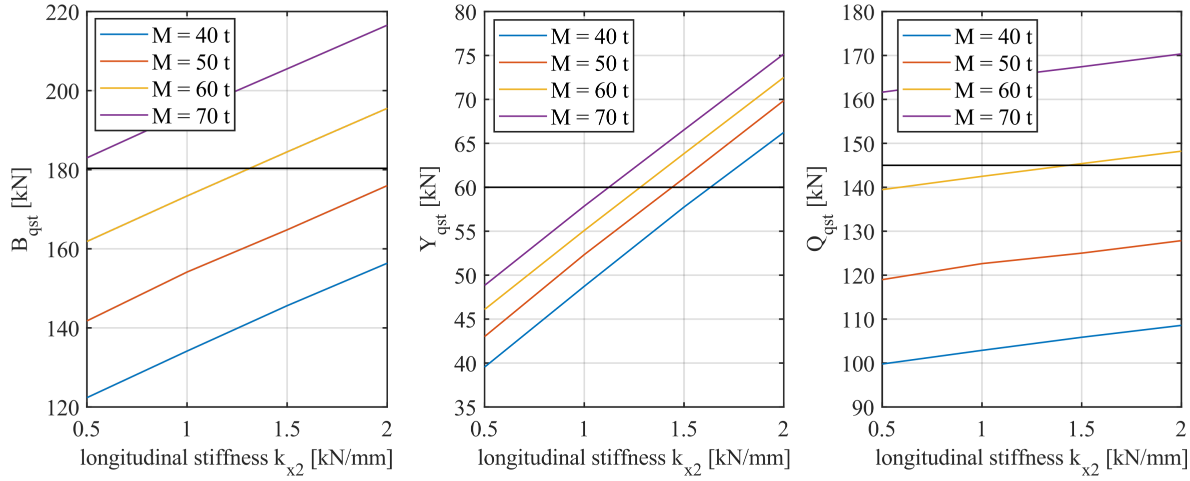

Fig. 1. Dependence of the rail load parameter B_{qst} (*left*), guiding force Y_{qst} (*middle*) and vertical wheel force Q_{qst} (*right*) on longitudinal stiffness k_{x2} of the secondary suspension for different vehicle body weights; the black lines represent limit values

vehicles do not comply according to the original evaluation method, but they comply according to the new method of evaluation, which uses the combined quantity B_{qst}.

It can be considered that a vehicle with a vehicle body weight of 65 tons and a longitudinal stiffness of secondary suspension $k_{x2} = 0.5$ kN/mm will not meet the requirement of vertical wheel force Q_{qst} but will meet the requirements in terms of rail load parameter B_{qst}.

5. Conclusion

As described above, the rail load parameter B_{qst} allows, under the specific conditions, the approval of vehicles that do not meet one of the original requirements, i.e. the vertical wheel force or the guiding force. This situations are stated in the standard [1] but there is no explanation or example of this behaviour. Therefore, the results of this paper confirm the assumption of this standard.

The second aspect is the dynamic effect of the vehicle on the rails and the rail loads. The requirements of guiding force and vertical wheel force are stricter and safer. The option of the rail load parameter offers the approval of vehicles that do not meet one of the original requirements. Therefore, the safety of using the rail load parameter needs to be further investigated.

Acknowledgement

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References

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