FACTORS INFLUENCING THE RAILWAY VEHICLE GUIDANCE SAFETY

NICOLAE ILIAȘ¹, IOAN COPACI², AURELIA TĂNĂSOIU³

Abstract: There has been a need for minimum safety regulations to be set for passenger cars, meaning that these cars must pass with maximum safety over various track geometries: transitions from alignment to a curve, curves and curve direction alterations. For railway vehicles the value of the loads on the attacking wheel depends both on the torsional rigidity of the vehicle and on the torsional rigidity of the bogies.

Keywords: railway vehicles, guidance safety

1. INTRODUCTION

There has been a need for minimum safety regulations to be set for passenger cars, meaning that these cars must pass with maximum safety over various track geometries: transitions from alignment to a curve, curves and curve direction alterations. In a constant radius curve the worst scenario is when there is no longitudinal motion on the contact area of the derailing wheel or during braking [11]. The incipient derailment conditions have been shown to depend on the effective angle of attack. Nadal’s criterion is very conservative where the effective angle of attack is small or negative. The general tests [3] did not include simultaneous measurements of lateral axle velocity and the angle of winding to allow the identification of the true limit of derailment providing that the value of Y/Q was measured. Many works [6], [7], [8], [9] contain approximations on the true angle of the contact plane relative to the increase in the angle of winding of the axle and the raising of the derailing wheel.

The true measure of the derailment possibility is the displacement of the wheel set relative to the track [5]. This is predictable through simulation but not through measurement. The wheel-rail contact force can be measured currently. The value of

¹ Prof. dr. eng. at University of Petroșani
² Prof. dr. eng. at University „Aurel Vlaicu” Arad
³ Lecturer dr. eng. at University „Aurel Vlaicu” Arad
Y/Q is used as a measure of traffic safety, it being able to indicate the derailment probability. However, an infringement of Nadal’s criterion does not necessarily indicate an imminent derailment. Thus, Nadal’s limit is used experimentally, and the vertical displacement limits in the derailment simulations using software such as: ADAMS/RAIL, A’GEM [1], MEDYNA [4], NUCARS [2], VAMPIRE.

2. EQUIVALENT TORSIONAL RIGIDITY

For railway vehicles the value of the loads on the attacking wheel depends both on the torsional rigidity of the vehicle and on the torsional rigidity of the bogies.

The bearing structures of the railway car and bogies, due to their elasticities and implicitly to their torsional rigidities, determine values of the discharging of the attacking wheel, \( \Delta Q_i^* \) and \( \Delta Q_i^{**} \). Consequently, a measure that characterizes the elasticity and the torsional rigidity of the wagon-bogie system is introduced, the equivalent torsional rigidity [10]. Considering the mechanical system of the vehicle, figure 1 shows the method to connect the wagon to the bogies.

Considering a parallel connection of bogie rigidities, connected in series with wagon rigidities, the equivalent rigidity is of the form:

\[
\frac{1}{C_{r, \text{ech}}} = \frac{1}{C_i^*} + \frac{1}{C_i^{**} + C_i^{**}}
\]

thus:

\[
C_{r, \text{ech}} = \frac{2C_i^*C_i^{**}}{2C_i^{**} + C_i^*}
\]

Fig. 1. Connection of the wagon to the bogies

We used the equivalent rigidity characteristic that includes both the influence of wagon hull torsional rigidity and of bogies’ torsional rigidities, since it is a measure which determines the value of the discharges of the attacking wheel due to the hull-bogie system torsional rigidity.

Total discharge due to wagon and bogies’ torsional rigidities is thus \( \Delta Q_t \), where:

\[
\Delta Q_t = \Delta Q_i^* + \Delta Q_i^{**}
\]

where: \( \Delta Q_i^* \) - total absolute decrease of wheel load as a result of rail twisting on the basis of the bogie axle base; \( \Delta Q_i^{**} \) - total absolute decrease of wheel load as a result of rail twisting on the basis of the wagon hull axle base.

The experimental determination of the torsional rigidity of the wagon hull, $C_i^*$, and that of the bearing structure of the bogie, $C_i^+$, offers us the possibility to calculate $Y_{max}/Q_{min}$ for a vehicle’s attacking wheel. The computation also comprises dimensional, massic and elastic characteristics, of very exact values since they are determined experimentally in the prototype phase. Thus, the value of $Y_{max}/Q_{min}$ is sufficiently close to the one during exploitation, even encompassing such that it may be a guarantee on the behaviour of the vehicle regarding guidance safety.

For a number of wagon prototypes [10], Table 1 shows the computation for $Y_{max}/Q_{min}$ for the attacking wheel conditioned by the experimental determination of hull and bogie torsional rigidities, $C_i^*$ and $C_i^+$ respectively.

<table>
<thead>
<tr>
<th>No.</th>
<th>Wagon type</th>
<th>$2a^*$ (mm)</th>
<th>$2a^+(mm)$</th>
<th>$Q_o$ (kN)</th>
<th>$C_i^*$ (kNmm²/rad)</th>
<th>$C_i^+$ (kNmm²/rad)</th>
<th>$C_i^{ech}$ (kNmm²/rad)</th>
<th>$Y/Q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40 m³ Cistern</td>
<td>9360</td>
<td>1800</td>
<td>29,479</td>
<td>1.68·10¹⁰</td>
<td>5.44·10¹⁰</td>
<td>2.077·10¹⁰</td>
<td>0.926</td>
</tr>
<tr>
<td>2</td>
<td>72 m³ Cistern Y25 Cs DB621</td>
<td>10660</td>
<td>1800</td>
<td>32</td>
<td>1.436·10¹⁰</td>
<td>13.864·10¹⁰</td>
<td>2.379·10¹⁰</td>
<td>0.908</td>
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<tr>
<td>3</td>
<td>72 m³ Cistern Y25 Lsd</td>
<td>10660</td>
<td>1800</td>
<td>32</td>
<td>1.613·10¹⁰</td>
<td>13.864·10¹⁰</td>
<td>2.617·10¹⁰</td>
<td>0.91</td>
</tr>
<tr>
<td>4</td>
<td>86 m³ Cistern Y25Cs bogie</td>
<td>10660</td>
<td>1800</td>
<td>28,204</td>
<td>1.66·10¹⁰</td>
<td>8.52·10¹⁰</td>
<td>2.389·10¹⁰</td>
<td>0.953</td>
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<td>5</td>
<td>86 m³ Cistern LHB 71 bogie</td>
<td>10660</td>
<td>1800</td>
<td>28,204</td>
<td>0.3159·10¹⁰</td>
<td>8.52·10¹⁰</td>
<td>0.588·10¹⁰</td>
<td>0.693</td>
</tr>
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<td>6</td>
<td>86 m³ Cistern LHB 74 bogie</td>
<td>10660</td>
<td>1800</td>
<td>28,204</td>
<td>0.408·10¹⁰</td>
<td>8.52·10¹⁰</td>
<td>0.745·10¹⁰</td>
<td>0.701</td>
</tr>
<tr>
<td>7</td>
<td>93 m³ Cistern</td>
<td>12140</td>
<td>1800</td>
<td>31,08</td>
<td>1.58·10¹⁰</td>
<td>23.871·10¹⁰</td>
<td>2.79·10¹⁰</td>
<td>0.93</td>
</tr>
<tr>
<td>8</td>
<td>Platform car Sgns/s</td>
<td>14200</td>
<td>1800</td>
<td>24.28</td>
<td>0.814·10¹⁰</td>
<td>1.799·10¹⁰</td>
<td>0.664·10¹⁰</td>
<td>0.87</td>
</tr>
<tr>
<td>9</td>
<td>Platform car Rijmns</td>
<td>10000</td>
<td>1800</td>
<td>34,512</td>
<td>1.61·10¹⁰</td>
<td>2.628·10¹⁰</td>
<td>1.232·10¹⁰</td>
<td>0.875</td>
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</table>

The results of the experimental determinations and the determined values of $Y/Q$ are shown in Table 1.

Figure 2 shows the variation of $Y/Q$ as a function of the equivalent rigidity $C_i^{ech}$.

In conclusion we underline the following:
- a linear variation of $Y/Q$ as a function of equivalent rigidity is observed, the
increase in the torsional rigidities of the bearing structures of the hull and bogie lead to an increase of the discharges and implicitly to the increase of the value of $Y/Q$ which in turn leads to an increase in the risk of derailment;

- the experimental determination of $C_t^{+}$ and $C_t^{-}$ along with computing of the value of $Y_{\text{max}}/Q_{\text{min}}$ for the attacking wheel can supply very useful information in the prototype phase, which can lead to adequate measures being taken during vehicle construction to improve guidance safety.

![Graph](image)

**Fig. 2.** Variation of $Y/Q$ as a function of $C_{t}^{\text{ech}}$

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