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UNIFICATION OF THE CANT AND MAXIMUM VALUES FOR CANT DEFICIENCY

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Abstract. The article provides the analysis of the TSI requirement to technical specification of interoperability related to cant in curve. Based on the identified discrepancies it proposes to adopt uniform criteria for the established of maximum cant and cant deficiency for gauge 1435, 1520, 1600 and 1668 mm.

Keywords: Interoperability Directives, Technical Specifications for Interoperability (TSI), cant, cant deficiency, acceleration, conventional and high-speed rail network.

Introduction

In order to enable citizens of the Union, economic operators and regional and local authorities to benefit to the full from the advantages deriving from establishing an area without internal frontiers, it is advisable, in particular, to improve the interlinking and interoperability of national high-speed train networks, as well as access thereto.

Whereas the commercial operation of high-speed trains requires excellent compatibility between the characteristics of the infrastructure and those of the rolling stock; whereas performance levels, safety, quality of service and cost depend upon such compatibility as does, in particular, the interoperability of the European high-speed rail system.

Considering the Member States are responsible for ensuring compliance with the safety, health and consumer protection rules applying to the railway networks in general during the design, construction, placing in service and operation of those railways; whereas, together with the local authorities, they also have responsibilities in respect of rights in land, regional planning and environmental protection; whereas that is also especially pertinent with regard to high-speed train networks.

Over the years, this situation has created very close links between the national railway industries and the national railways, to the detriment of the genuine opening-up of contracts; whereas, in order to enhance their competitiveness at world level those industries require an open, competitive European market;

It is therefore appropriate to define essential requirements for the whole of the Community which will apply to the trans-European high-speed train system;

So for this purpose were prepared different technical specifications for interoperability (TSIs).

Technical specifications for interoperability mean the specifications by which each subsystem or part of subsystem is covered in order to meet the essential requirements and to ensure the interoperability of the European Community's high speed and conventional rail systems. The development of TSIs is one of the basic tasks of the Agency. The Agency performs the revision of existing TSIs, keeps them up to date, and supports the sector in their application by issuing application guides and by dissemination and training actions. When necessary, ERA may also draft new TSIs, based on a mandate from the Commission. Links to all TSIs including their accompanying documents and previous versions are to be found on the right hand side of this page. An overview of the chronology of all TSIs (including the repealed ones) with respective links is given in the chronology table. For drafting and revising TSIs, the Interoperability Unit works in close collaboration with experts from European Representative Bodies of the Railway sector (RBs), the Intergovernmental Organization for International Carriage by Rail (OTIF) and National Safety Authorities (NSAs).

For solution of the interoperability high-speed rail system in 1996 year have been adopted directive (Directive of the Council on the interoperability of the trans-European high-speed rail system) [1]. This directive has supposed creating the technical specification of the interoperability for various sub-system and including for the infrastructure of railway transport. In 2001 year, directive (Directive of the European Parliament and of the council on the interoperability of the trans-European conventional rail system) have been adopted by European Parliament. It was devoted to interoperability of the conventional railway communication, that have been supposed creating technical specification of the interoperability for various sub-system and including for infrastructure of conventional railway transport. On the basis of directive[1] in 2002 year the first TSIs for the infrastructure subsystem of the trans-European high-speed rail system (Commission Decision concerning the technical specification for interoperability relating to the infrastructure subsystem of the trans-European high-speed rail system) [4] have been adopted, but in 2008 year their new edition [5]. First and second edition almost have not touched on the railway with gauge of 1520mm.

For the development of the TSI infrastructure for the conventional railway lines took significantly more time. It was necessary to analyze the possibility of linking requirements to lines with track gauges 1435, 1520 and 1668 mm. For that have been created joint working group with representatives from European Railway Agency (ERA) and Organization For Co-Operation Between Railways (OSJD).

Despite of that in 2008 year new TSI of the interoperability have been adopted, that was incorporated high-speed and conventional railway system using results of analyze have been prepared by group of ERA-OSJD. Only in 2011 year TSI for the conventional infrastructure railway lines have been adopted.

Results of using already a generalized Directive have been showed, that it is needed in continuous improvement. For now, it contains six alterations. Last alteration has been adopted in 2014 year.

In 2014 year, technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union [8] instead of two TSIs of the infrastructure high-speed and conventional speed of railway communication have been adopted.

Interoperability implies uniform criteria for Railways with different track gauges. And despite the fact that the development of TSI standard infrastructure [7] and generalized TSI [8] have been used the analysis conducted by the working group of ERA-OSJD [9], not all problems of interoperability for lines with different track gauges have been resolved. One such problem is the maximum elevation of the outside rail – cant (^{h}max).

According to such uniform criteria, should be set to ^{h}max and cant deficiency ^{h} for railway with different track gauges.

1. The elevation of the outer rail

According to the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union [8]

«4.2.4.2. Cant

(1) The design cant for lines shall be limited as defined in Table 7.

Table 7. Design cant [mm]

	Freight and mixed traffic	Passenger traffic
Ballasted track	160	180
Non ballasted track	170	180

(2) The design cant on tracks adjacent to station platforms where trains are intended to stop in normal service shall not exceed 110 mm.

(3) New lines with mixed or freight traffic on curves with a radius less than 305 m and a cant transition steeper than 1 mm/m, the cant shall be restricted to the limit given by the following formula

$D \leq (R - 50)/1,5$

where: D is the cant in mm and R is the radius in m.

(4) Instead of points (1) to (3), for the 1 520 mm track gauge system the design cant shall not exceed 150 mm.

(5) Instead of point (1), for the 1 668 mm track gauge system, the design cant shall not exceed 180 mm.

(6) Instead of point (2), for the 1 668 mm track gauge system, the design cant on tracks adjacent to station platforms where trains are intended to stop in normal service shall not exceed 125 mm.

(7) Instead of point (3), for the 1 668 mm track gauge system, for new lines with mixed or freight traffic on curves with a radius less than 250 m, the cant shall be restricted to the limit given by the following formula:

$D \leq 0{,}9 * (R - 50)$

where D is the cant in mm and R is the radius in m.

(8) Instead of point (1), for the 1 600 mm track gauge system the design cant shall not exceed 185 mm.»

As you know [10–17], when driving on curved sections of railway track occurs centrifugal force I (1).

$$I = ma = m\frac{V^2}{R} \quad (1)$$

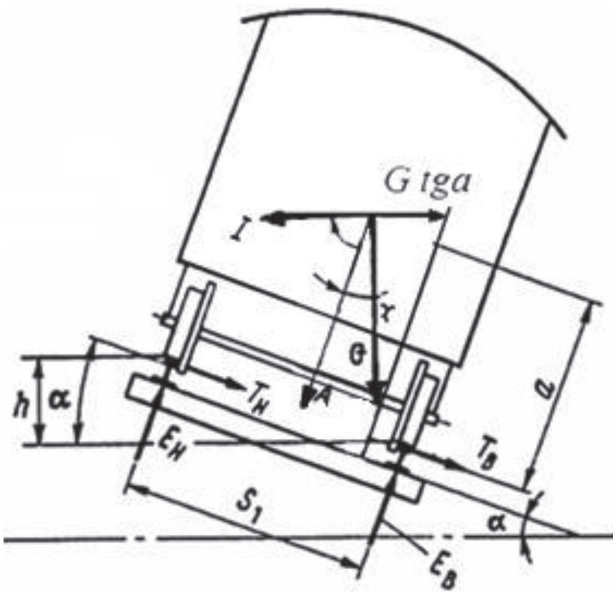

Figure 1. Schema for cant definition

Cant is made for reducing centrifugal force in curves section of railway[10–17].

When the cant the centrifugal force is reduced by the horizontal component of the weight of the crew is determined by the formula

$$T = mg\frac{h}{S_0} \quad (2)$$

where g – the acceleration of gravity; h – cant; S_0 – the distance between axes of rails (in the calculations usually take S_0=1.6 m forgauge 1520 mm and 1.5 m for gauge 1435 mm).

Thus the cant as "dampens" the value of the centrifugal force and the centripetal acceleration respectively. When there is insufficient cant for the rolling stock (and therefore passengers) will operate the so-called outstanding acceleration α

$$\alpha = \frac{V^2}{R} - g\frac{h}{S_0} \quad (3)$$

Maximum outstanding acceleration, which affects the passenger, should not depend on gauge. It follows that the cant

$$h = \frac{\left(\frac{V^2}{R} - \alpha\right)S_0}{g} \quad (4)$$

Therefore, at the same speed, the radius and the outstanding acceleration of the cant in direct proportion depends on the width of the gauge.

However, according to mentioned above extract from TSI, if such dependence is maintained for lines with track gauges 1435 mm and 1668, it is not saved for lines with a width of 1520 mm. And even at greater to width of gauge (1520 compared to 1435 mm) in TSI maximum cant for lines with a width of 1520 (h_{max} = 150 mm) is smaller than for lines with track gauges 1435 mm (h_{max} = 170 mm). Based in this, the maximum cant for lines should be increased.

2. Cant deficiency

To ensure equal vertical impact on both rails need to rise fully "extinguished" centripetal acceleration (α = 0). However, for some trains, moving at maximum speed, set the cant does not fully compensate for the centrifugal acceleration. Therefore, you receive outstanding acceleration which is caused by cant deficiency for maximum speed. In TSI, the cant deficiency is regulated by clause 4.2.4.3

«4.2.4.3. Cant deficiency

(1) The maximum values for cant deficiency are set out in Table 8.

Table 8. Maximum cant deficiency [mm]

Design speed [km/h]	v ≤ 160	160 < v ≤ 300	v > 300
For operation of rolling stock conforming to the Locomotives and Passenger TSI	153		100
For operation of rolling stock conforming to the Freight Wagons TSI	130	–	–

(2) It is permissible for trains specifically designed to travel with higher cant deficiency (for example multiple units with axle loads lower than set out in table 2; vehicles with special equipment for the negotiation of curves) to run with higher cant deficiency values, subject to a demonstration that this can be achieved safely.

(3) Instead of point (1), for all types of rolling stock of the 1 520 mm track gauge system the cant deficiency shall not exceed 115 mm. This is valid for speeds up to 200 km/h.

(4) Instead of point (1), for the 1 668 mm track gauge system, the maximum values for cant deficiency are set out in Table 9.

Table 9. Maximum cant deficiency for the 1 668 mm track gauge system [mm]

Design speed [km/h]	v ≤ 160	160 < v ≤ 300	v > 300
For operation of rolling stock conforming to the Locomotives and Passenger TSI	175		115
For operation of rolling stock conforming to the Freight Wagons TSI	150	–	–

…»

The cant deficiency and outstanding acceleration are directly proportional and their ratio depends on the width of the gauge (see formulas 3, 4). On the Railways of the EU countries decided to operate with the Cant deficiency, and on Railways with gauge of 1520 mm – outstanding acceleration.

If recalculate is regulated by the TSI values of the cant deficiency to 1435 and 1668 mm in the amount of outstanding acceleration, you'll get exactly the same values (see tab. 1). However, for lines with a width of 1,520 mm taken only one value of the lack of elevation of 115 mm, which corresponds to outstanding acceleration. Given that the maximum permitted outstanding acceleration 0.7 m/s² is accepted in the middle of the last century, and experience high-speed movement on the Railways of the EU, for lines with 1520 mm gauge can be set to the same value outstanding acceleration, as for lines 1435 and 1668 mm – 0,65, 0,85 and 1,0 m/s², and the corresponding The cant deficiency – 106, 139 and 164 mm. for Example, on the Railways of Ukraine [16] in certain cases allowed Unliquidated acceleration 1.0 m/s².

Table 1. Cant deficiency [mm]

S	1435	1520	1668
α [m/s²]	Δ*h* [mm]		
0,3	46	49	53
0,40	61	65	70
0,50	77	82	88
0,65	92	98	106
0,70	100	106	115
0,80	107	115	123
0,85	123	131	141
0,90	130	139	150
0,95	138	147	158
1,00	153	164	175

On lines with gauge of 1520 mm is drawn rolling stock for the transport of goods, which has certain features. When exposed to such a rolling of the outstanding acceleration of ±0,3 m/s², loaded slide, and therefore difficult to turn the truck under the car. Therefore, on Railways with gauge of 1520 mm, it is necessary to note that for freight wagons $\alpha_{нП}$ = 0,3 m/s² and therefore Δ*h* is equal 50 mm.

Thus paragraph (3) from p. 4.2.4.3 of the technical specifications for interoperability relating to the 'infrastructure' subsystem of the rail system in the European Union, should be stated in the following edition: «(3)

Instead of point (1), for the 1 520 mm track gauge system, the maximum values for cant deficiency are set out in Table 8*.

Table 8*. Maximum cant deficiency for the 1 520 mm track gauge system [mm]

Design speed [km/h]	v ≤ 160	160 < v ≤ 300	v > 300
For operation of rolling stock conforming to the Locomotives and Passenger TSI	163		106
For operation of rolling stock conforming to the Freight Wagons TSI	50	–	–

…»

Conclusions

The result of requirement analyze for maximum cant and cant deficiency adopted in the TSI and the above calculation based on the application of uniform criteria. Maximum cant is recommended to increase for gauge 1520 mm and to set cant deficiency for gauge 1520 mm corresponding to the outstanding values of accelerations adopted to lines 1435 and 1668 mm.

According to maximum cant and cant deficiency in TSI analysis and calculations made in article with usage of TSI uniform criteria, the recommendations are to increase the maximum cant for gauge 1520 mm and to set cant deficiency for gauge 1520 mm corresponding to the outstanding values of accelerations adopted to lines 1435 and 1668 mm/

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