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Railway applications — Railway rolling stock — Investigation of vehicles position on the reverse curve tracks during running and calculation of buffer overlap

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National foreword

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September 2019

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Railway applications - Railway rolling stock - Investigation of vehicles position on the reverse curve tracks during running and calculation of buffer overlap

Applications ferroviaires - Synthèse des calculs de la largeur des tampons pour appareils de choc et traction

Bahnanwendungen - Schienenfahrzeuge - Untersuchung der Fahrzeugstellungen im Gleis bei Durchfahrt von S-Bögen mit Ermittlung der Pufferüberdeckung

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European foreword

This document (CEN/TR 17373:2019) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

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Introduction

During CEN/TC 256/SC 2/WG 33/SG 2 meetings for the writing of the European Standard EN 15551, SNCF presented its experience about derailments in the space of time from 1976 to 1982 due to insufficient buffer overlap and proposed to modify the formulae written in EN 15551:2009, Annex J to make greater the width of buffer heads sufficient for safety operation service. The formulae SNCF proposed, based on the former assumptions acc. UIC-leaflet from January 1964, simply takes into account the maximal own play of the vehicles, instead of the 5 mm value given in UIC 527-1:2005, 3.2.2 and EN 15551:2009, K.6. Indeed, this 5 mm value is a realistic value for freight wagons but not for other types of vehicles. Regarding the modification of the formulae proposed by SNCF the other members of W 33 pointed out that:

— it is not possible to increase the internal half width of the buffer head over the limits specified by UIC 527-1:2005, Annex A and EN 15551:2009, 6.2.2;

— since 1965 there have been two language versions of UIC 527-1, a French version and a German version, and they have the following discrepancy in the formulae for calculation of the width of buffer head:

  — UIC 527-1 French version: calculates the half width of the buffer head with different formulae for vehicles with running bogies (e.g. coaches, wagons) or with power bogies (e.g. locomotives, power heads and motor vehicles). Thus, the width of the buffer head calculated for vehicles with power bogies will be greater than the width of the buffer head calculated for vehicles with running (non-power) bogies;

  — UIC 527-1 German version: calculates the half width of the buffer head with the same formulae for all types of bogie vehicles, namely: for vehicles with running bogies as well as for vehicles with power bogies.

— No cases of buffer locking due to an insufficient dimensioning of buffer width (with consequently insufficient buffer overlap) were really noticed in Germany, whereas also in German speaking countries the UIC 527-1 formulae in the German version have been used for decades to dimension the buffer heads width.

— The geometry of the outside half width of buffer heads (opposite to vehicle centre line) of SNCF derailed coaches have had a circular shape geometry that reduced the buffing surface in Geometry specified in UIC 527-1:2005, Annex A).

In order to develop a uniform methodology for the calculation of the width of buffer heads, WG 33 decided to create an ad hoc group whose mission was to analyse, by means of realistic simulations, realized with the multi-body Software SIMPACK, if the formulae, written in the standard EN 15551:2009, Annex J, provide the width of buffer head enough for required minimum buffer overlap and what the domain of use of these formulae was.

This document presents the work made by the WG 33 Ad hoc group and the conclusions of this Group.

The investigation is conducted for specified vehicles in different vehicle combinations (train sets) for defined running cases in curves.

The purpose of this investigation is evaluation of following parameters:

— lateral displacement of coupled vehicles on the track;

— lateral displacement of coupled vehicles to each other;

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— buffer overlap between two specified coupled vehicles with given buffers.

For this purpose, the types of vehicles defining the train sets and different operational conditions are specified. Position of the vehicles on the track at the moment of maximum lateral displacement to each other (minimum buffer overlap) is recorded.

The worst cases of lateral displacement and buffer overlap between two coupled vehicles as well as relation to UIC 527-1 and EN 15551 formulae are analysed.

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1 Scope

The purpose of this document is to analyse the conducted investigation and evaluation of lateral displacement and buffer overlap between each two specified vehicles of different train sets for defined running cases in curves.

For this purpose, the types of vehicles defining the train sets and different operating conditions are specified. Position of the vehicles on the track at the moment of maximum lateral displacement (minimum buffer overlap) is recorded during the calculation.

The worst cases of lateral displacement and buffer overlap between two coupled vehicles as well as relation to formulae in EN 15551:2009 are analysed.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Symbols and abbreviations

Symbol	Designation	Unit
a	Distance between end wheelsets of vehicles not fitted with bogies or between bogie centres	mm
dg_{a}	Geometric overthrow of the vehicle on the outside of the curve	mm
dg_{i}	Geometric overthrow of the vehicle on the inside of the curve	mm
dy_{i}	Distance from the centre line of the buffer to the contact point at the buffer head, index 1, 2 in accordance to the vehicle number	mm
dy_{p}	Distance between the centre lines of the 2 buffers	mm
F	Geometric overthrow of the vehicle on the outside of the curve for car body pivots on the track centre line	mm
F_{BC}	Compressive force with buffers in contact	kN
F_{LC}	Compressive force simulates the forces which occur on the vehicles during braking or pushing operation	kN
$j1$	Own lateral play (internal lateral displacement) of the vehicle ($j1$) in secondary suspension	mm
$j2$	Lateral play in primary suspension	mm
$j3$	Lateral play of the wheelset in a track	mm

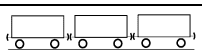
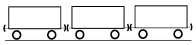
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Symbol	Designation	Unit
k	Coefficient of lateral displacement of the vehicle on the track	—
l	Track gauge, distance between the rail running edges	mm
l_{nom}	Nominal track gauge	mm
LoB	Length over buffer	mm or m
n	Distance from the section under consideration to the adjacent end wheelset or the closest bogie centre or bogie pivot	mm
n_a	Overhang, distance from buffer face to the closest singular wheelset or closest bogie centre	mm
n_i	n for the sections between the wheelsets or bogie centres	mm
p	Bogie wheelbase	mm
R	Horizontal curve radius	mm or m
R_{LC}	Horizontal curve radius, left curve	mm or m
R_{RC}	Horizontal curve radius, right curve	mm or m
v	Vehicle speed	m/s or km/h

5 Boundary conditions

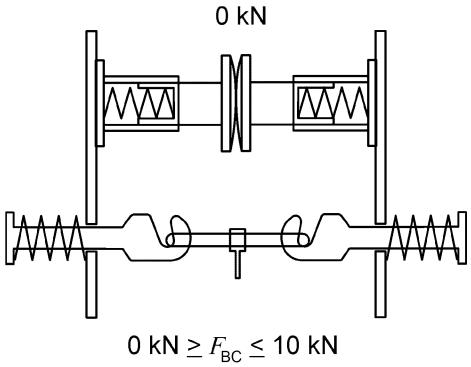
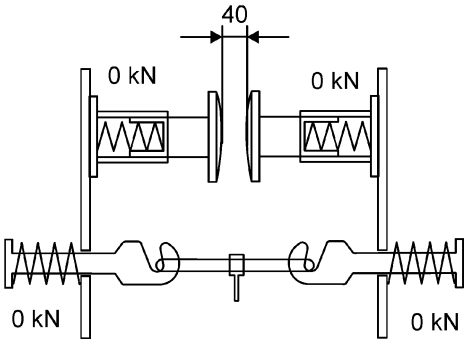
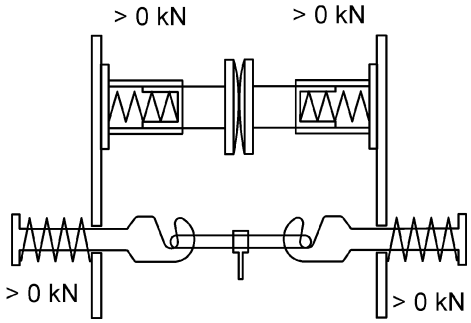
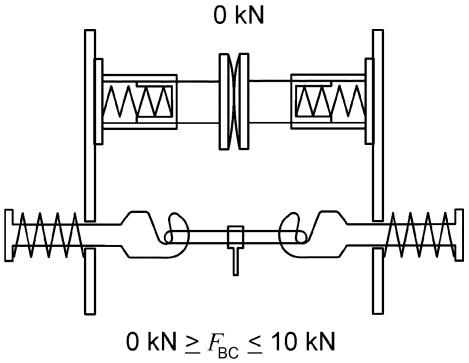
The configurations and scenarios studied are described in Table 1 and Table 2.

Table 1 — Boundary conditions

<table>
<tr><td rowspan="2">Velocity</td><td colspan="2">v = 30 km/h</td><td>constant</td><td>for R = 150 m</td></tr>
<tr><td colspan="2">v = 40 km/h</td><td>constant</td><td>for R = 190 m</td></tr>
<tr><td rowspan="2">Track</td><td colspan="2">R 150 m — 6,79 m — R 150 m</td><td>gauge</td><td>1 470 mm</td></tr>
<tr><td colspan="2">R 190 m — 0 m — R 190 m</td><td>gauge</td><td>1 458 mm</td></tr>
<tr><td>Number of vehicles</td><td colspan="4">3</td></tr>
<tr><td rowspan="4">Vehicle configuration</td><td>DB</td><td>1st class intercity “Avmz”
Avmz – Avmz - Avmz</td><td colspan="2">3 times the same type</td></tr>
<tr><td>SNCF 1</td><td>VTU coaches
VTU – VTU – VTU</td><td colspan="2">3 times the same type</td></tr>
<tr><td>SNCF 2</td><td colspan="3">Loco BB 27000 + 2 freight wagons (FW)
(FW, length over buffers, LoB = 18 m, a = 12 m)
Loco + Loco + coach</td></tr>
<tr><td>Siemens</td><td colspan="3">2 Loco (Vectron) + coach (UIC-type)
Loco + Loco + coach</td></tr>
<tr><td>Compressive force between vehicles[a]</td><td colspan="4">F_{LC} = 0 kN  = const
F_{LC} = 200 kN  = const</td></tr>
</table>

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Screw coupler tightening	nominal case (*N*)	degraded case (*D*)
— for locomotives or wagons		Dimension in millimetre 
— for coaches		
	Buffers in contact	
	— 2 turns before contact with nuts	
	— Specific rules (SNCF)	
a The compressive force simulates the forces which occur on the vehicles during braking or pushing operation.		

In Table 2, the configurations of the coupled vehicles studied are indicated by the sign “X”. The additional scenarios indicated by a footnote “a” for the “worst case” are the “special” cases where it is assumed that higher requirements might occur and the calculation of the buffer head width in accordance with the specified formulae are not valid for all vehicles.

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Table 2 — Configuration of coupled vehicles

Operator/ Manufacturer	Vehicle configuration	Screw coupler tightening	0 kN *R* 150 m *v* = 30 km/h	0 kN *R* 190 m *v* = 40 km/h	200 kN *R* 150 m *v* = 30 km/h	200 kN *R* 190 m *v* = 40 km/h
DB	3 coaches "Avmz"	*N*	X	X	X	X
		D			X[a]	
Siemens	2 locomotives + 1 UIC coach Locomotive = Siemens Vectron	*N*	X		X	
		D			X[a]	
SNCF 1	3 coaches "VTU"	*N*	X	X	X	X
		D			X[a]	
SNCF 2	1 locomotive + 2 freight wagons locomotive = BB27000	*N*			X	
		D			X[a]	

Key
N = nominal case, see Table 1, Screw coupler tightening
D = degraded case, see Table 1, Screw coupler tightening
X = configuration to be calculated/simulated

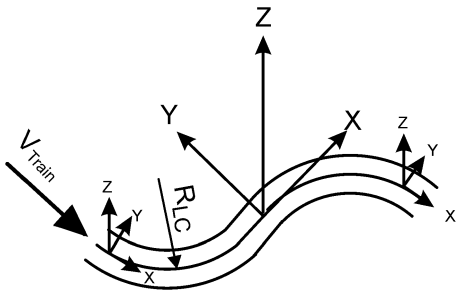
[a] Classified as "worst case"

As specified by the previous tables (Table 1 and Table 2), the two following parameters are taken into account, because they are considered as the most influential ones:

— Screw coupler tightening;

— Compressive force (as a reaction to the braking or pushing mode).

In order to compare the results between the calculations from the group members, a uniform coordinate system for the analysis of output data was determined. This coordinate system is defined in accordance with 3-finger rule of the right hand, where "x" follows the track in running direction of the train set, and it is shown in Figure 1.

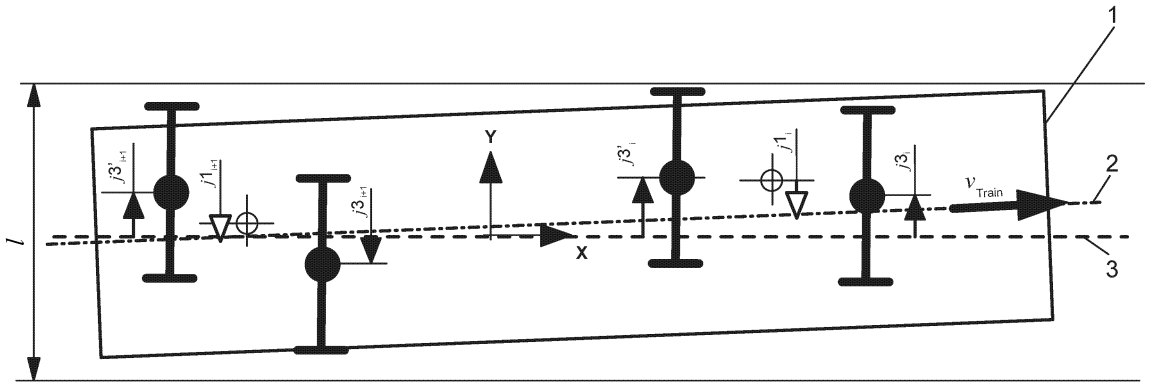


Key
v_{train} velocity of the train set
R_{LC} radius, left curve

Figure 1 — Coordinate system

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It is also necessary to fix of the variables to be registered. The following scheme presents the variable names for vehicle 1 (i is the position of the bogies: i = 1 is the first bogie entering in the S-curve).



Key

v_{train}	velocity of the train set
l	track gauge: 1 470 mm
1	vehicle body
2	vehicle body centre line
3	track centre line
x, y	axis of the coordinate system
	wheelset
	bogie pivot
	own play of the vehicle body on the bogie ($j1$): Example: $j1_i$, $j1_{i+1}$
	play of the wheelsets in a track ($j3$): Example: $j3_i$, $j3'_i$, $j3_{i+1}$, $j3'_{i+1}$
NOTE 1	i is the position of the bogie: i = 1 is the first bogie entering in the S-curve
NOTE 2	' indicates the second wheelset of the bogie
NOTE 3	The play $j2$ (bogie internal to primary spring) is neglected.

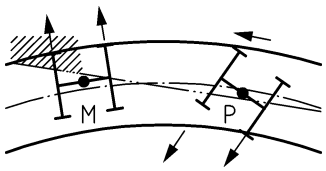
Figure 2 — Visualization of the names of analysed parameters

6 Vehicle dynamic

6.1 Coefficient of displacement *k*

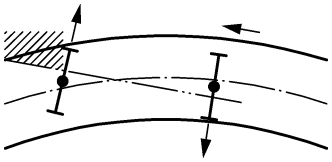
The lateral displacement of the wheelsets in the track ($j3$) is different for the bogie vehicles and other vehicles. Thus, there are two formulae for the calculation of the coefficient "*k*" for the position of the wheelsets of the bogies in the curve, see Figure 3.

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$$k = \frac{n_a + a}{a} \quad (1)$$

a) Bogie vehicles



$$k = \frac{2 \cdot n_a + a}{a} \quad (2)$$

b) All other vehicles

Key

a is the distance, in mm, between end wheelsets or bogie pivots of the vehicle concerned;

n_a is the overhang, in mm, of the buffer face in relation to the end wheelsets or bogie pivot;

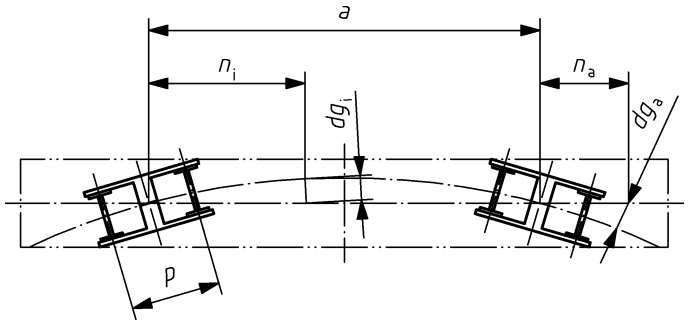
k is the coefficient of displacement of the vehicle in the track.

Figure 3 — Coefficient *k* for bogie vehicles and other vehicles

6.2 Geometric overthrow *dg* or *F*

For the definition of the Geometric overthrow (*dg*), see Figure 4.

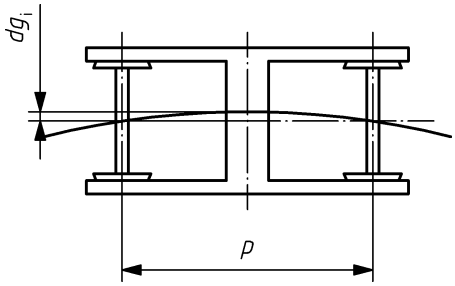
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$$dg_i = \frac{an_i - n_i^2}{2R} \quad (3)$$

$$F \equiv dg_\alpha = \frac{an_\alpha - n_\alpha^2}{2R} \quad (4)$$

a) *dg* of the vehicle on a curved track



$$dg_i = \frac{p^2}{8R} \quad (5)$$

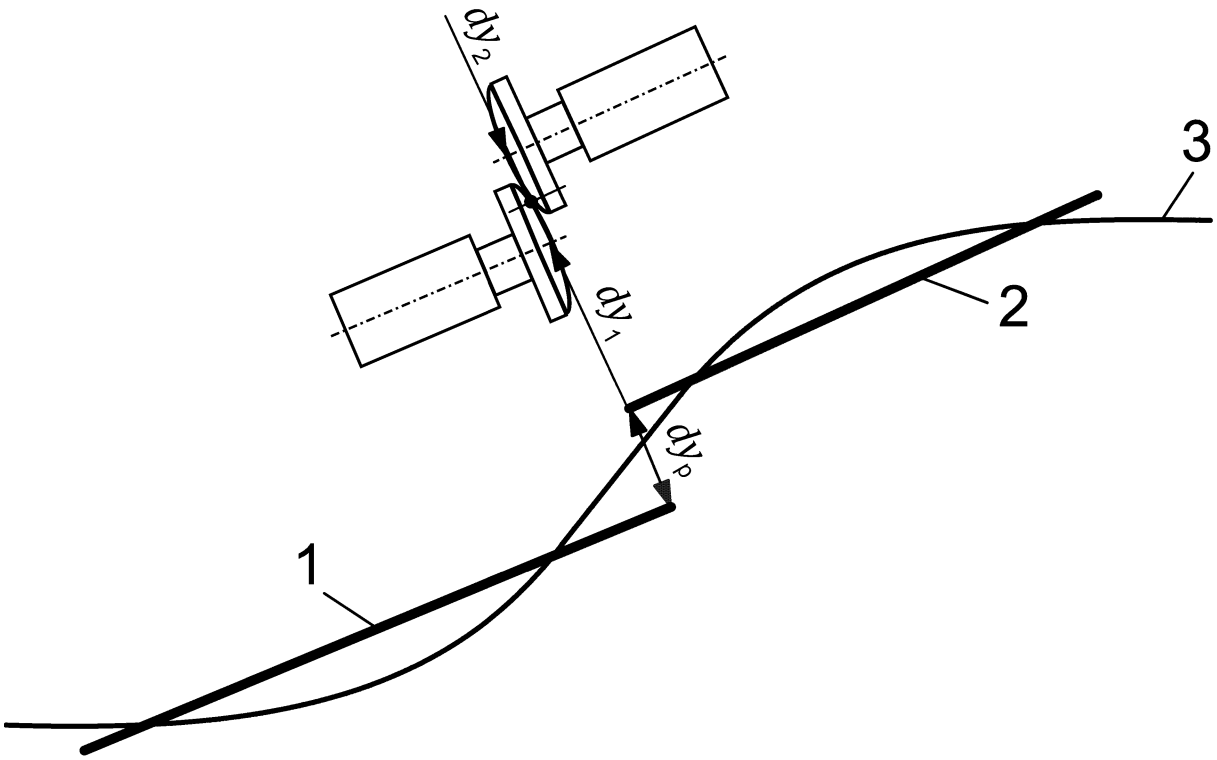
b) dg_i of the bogie on a curved track

Figure 4 — Geometric overthrow *dg*

6.3 Location of the vehicle in the track and displacement dy_p

The displacement of the centre lines of the two buffers dy_p to each other is the main parameter to be analysed and it is approximately the shortest distance between the two centre lines (see Figure 5, item 1 and item 2).

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Key

dy_p	distance between the centre lines of the two buffers
dy_1	distance from the centre line of the buffer to the contact point at the buffer head of vehicle 1
dy_2	distance from the centre line of the buffer to the contact point at the buffer head of vehicle 2
1	vehicle body centre line of vehicle 1
2	vehicle body centre line of vehicle 2
3	track centre line

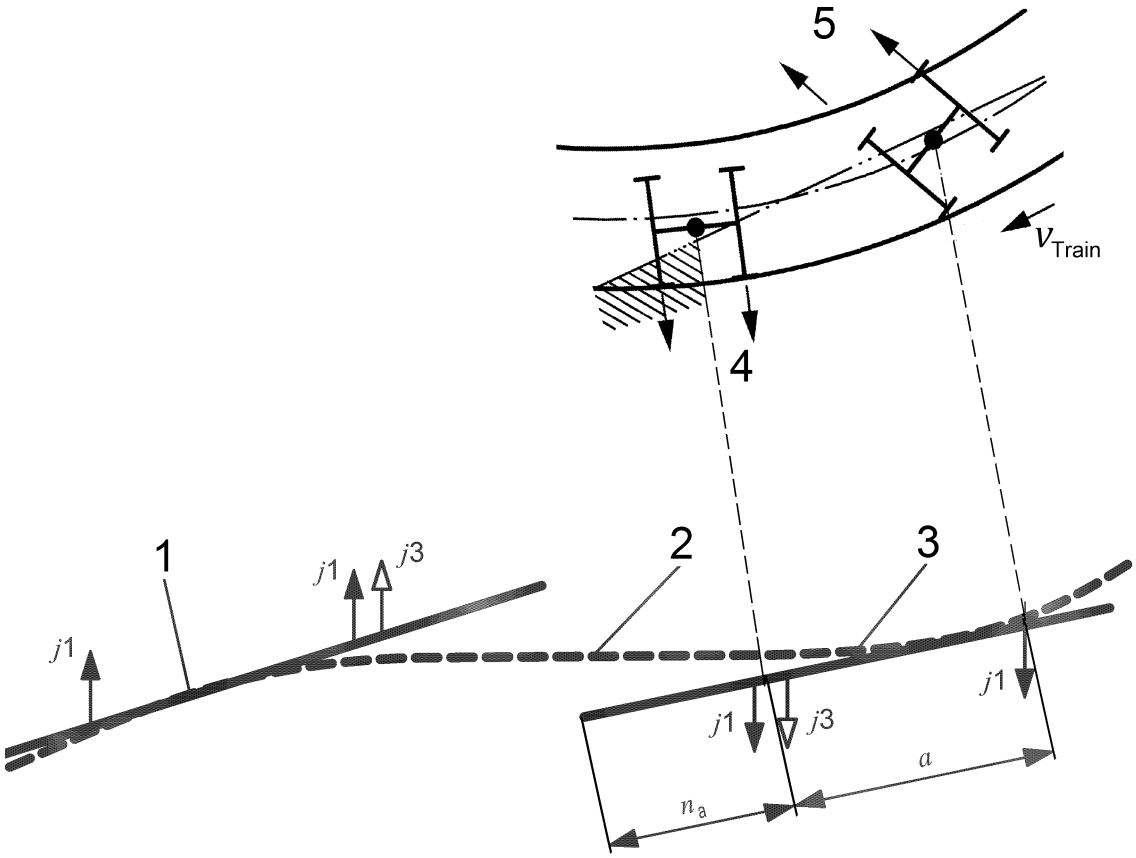
Figure 5 — Scheme of displacement of vehicle body centre line in a S-curve

6.4 Position of the vehicles in the S-curve

6.4.1 Bogie vehicles

Figure 6 shows the position of bogie vehicles in S-curve.

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Key

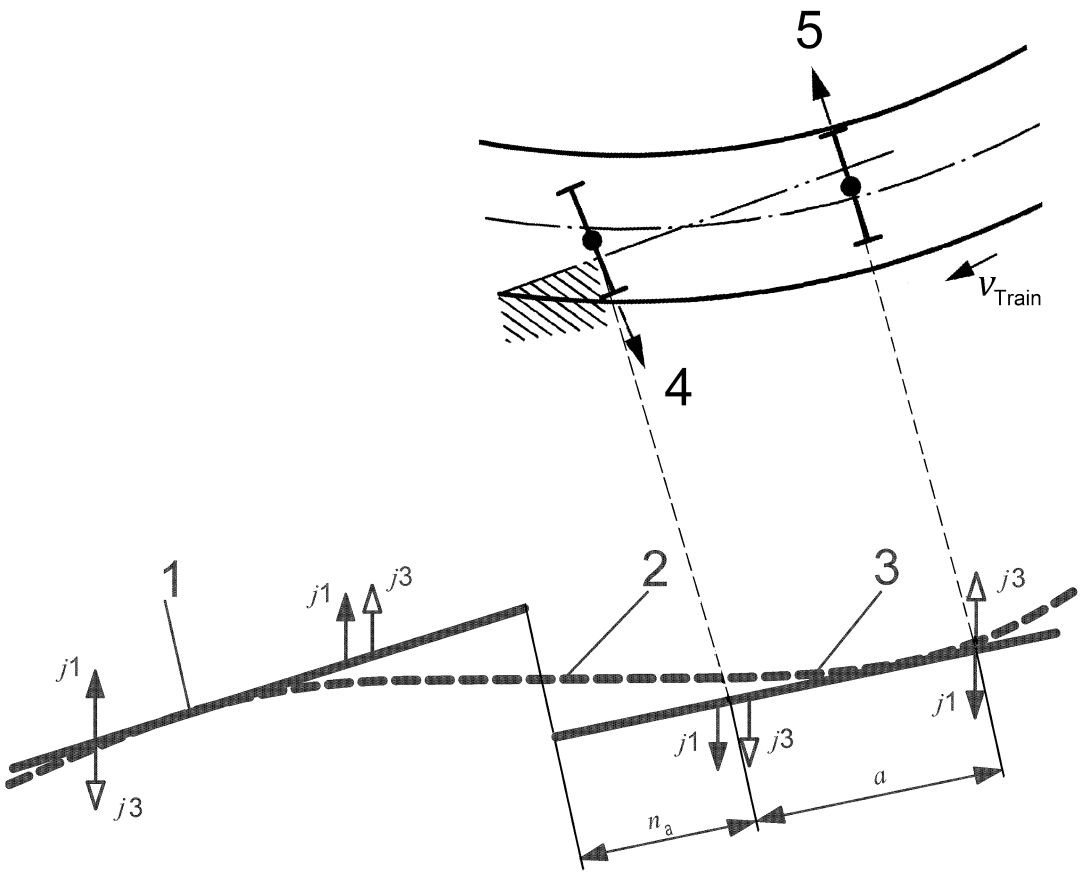
v_{train}	velocity of the train set and running direction
1	vehicle body centre line of vehicle 1
2	track centre line
3	vehicle body centre line of vehicle 2
4	wheelsets 30 mm outside from the centre line of the track
5	first wheelset in running direction 30 mm outside from the centre line of the track; second wheelset 30 mm inside from the centre line of the track
n_a	is the overhang, in mm, distance from the buffer face to the bogie pivot
a	is the distance, in mm, between bogie pivots of the vehicle concerned
→	own play of the vehicle ($j1$)
⇢	play of the wheelset in the track ($j3$)

Figure 6 — Position of the vehicles in the S-curve for bogie vehicles

6.4.2 Other vehicles

Figure 7 shows the position of other vehicles in S-curve, e.g. vehicles with two singular wheelsets.

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Key

v_{train}	velocity of the train set and running direction
1	vehicle body centre line of vehicle 1
2	track centre line
3	vehicle body centre line of vehicle 2
4	wheelset 30 mm outside from the centre line of the track
5	wheelset 30 mm inside from the centre line of the track
n_a	is the overhang, in mm, distance from the buffer face to the end wheelsets
a	is the distance, in mm, between end wheelsets of the vehicle concerned
→	own play of the vehicle ($j1$)
⇢	the play of the wheelset in the track ($j3$)

Figure 7 — Position of the vehicles in the S-curve for other vehicles

7 Calculation of the displacement of the vehicle body centre (dy_p) — Δdy_p calculated with UIC 527-1 assumptions

7.1 General

The formulae written in UIC 527-1 and in EN 15551:2009, Annex J, come from a study described by UIC Document [6] from January 1964 and are covered in UIC 527-1.

The formulae calculate the minimum half width of buffer heads so that the overlap of the buffers of any two vehicles running on a given S-curved track is not less than that of the buffers of two so-called

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"basic" vehicles running under the same conditions. The work of the UIC group from 1964 was divided into four stages:

1) Definition of a basic vehicle;

2) Determination of the tracks where two basic vehicles shall ensure the safe running without buffer locking (minimal straight line between two curves);

3) Determination of the minimum safe buffer width for any vehicles (input data are the dimensions of the vehicles);

4) Consideration about lateral plays (displacements), such as:

   — own play – internal lateral displacement of the vehicle;

   — play of the wheelsets on the track.

The created formulae assumed a corresponding singular position of two coupled consecutive vehicles on a track. It also distinguished the type of vehicle (bogie vehicles and other vehicles).

The formulae in UIC 527-1 and in EN 15551:2009, Annex J calculate the minimum half width of buffer heads for vehicles in S-curve of *R* 150 m —6 m — *R* 150 m with track gauge of 1 470 mm as a worst case.

7.2 Basic vehicle

The basic vehicle is described by the following criteria:

— minimum horizontal overlap of 25 mm of two buffer heads in contact, with vehicles running on tracks;

— distance between end wheelsets or bogie pivots: a = 12 m;

— overhang distance between buffer face and the singular end wheelset or bogie pivot: n_a = 3 m;

— own play of the vehicle: $j1$ = 5 mm;

— play of the wheelsets on a track 1 470 mm wide $j3_{Track}$ = 30 mm.

8 Determination of the minimum half width of the buffer head

8.1 Calculation (simplified formula derived from UIC 527-1)

Figures 3 to 7 show the position of the vehicles in an S-curve.

The minimum of the half width buffer head $\left(\frac{\Delta}{2}\right)$, taking into account the vehicle geometry, according to Formulae (1), (2), (4), and (5), is determined according to the respective Formulae (6) to (8) valid for the respective areas, which are schematically shown in Figure 8 as function $\left(a + n_a\right)$ versus *a.* The Figure 8 explains the index of 1 to 3 of $\frac{\Delta_i}{2}$.

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