

Railway applications — Testing for the acceptance of running characteristics of railway vehicles — Testing of running behaviour and stationary tests

The European Standard EN 14363:2005 has the status of a
British Standard

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National foreword

This British Standard is the official English language version of EN 14363:2005.

BS EN 14363 is a candidate “harmonized” European standard and fully takes into account the requirements of the European Commission mandate M/275 given under the EU Construction Products Directive (96/48/EC), and intended to lead to CE marking. The date of applicability of BS EN 14363:2005 as a harmonized European standard, i.e. the date after which this standard may be used for CE marking purposes, is subject to an announcement in the *Official Journal of the European Communities*.

The Commission in consultation with Member States has agreed a transition period for the co-existence of harmonized European Standards and their corresponding national standard(s). It is intended that this period will comprise a period, usually nine months, after the date of availability of the European Standard, during which any required changes to national regulations are to be made, followed by a further period, usually of 12 months, for the implementation of CE marking. At the end of this co-existence period, the national standard(s) will be withdrawn.

There are no conflicting national standards to be withdrawn.

The UK participation in the preparation of EN 14363:2005 was entrusted by Technical Committee RAE/1, Railway applications, to its Subcommittee, RAE/1/-/8, Vehicle/track interaction, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary

The acceptance criteria within this standard are derived using the levels of track quality developed by UIC 7G Working Group “Geometric Parameters” to reflect international operation. Use of any of the limits in BS EN 14363:2005 for vehicle acceptance should take into account whether or not the track quality on the intended routes of operation of the vehicle is consistent with these levels. Where track quality differs from these levels due account should be taken of “national technical rules”.

Summary of pages

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English version

**Railway applications - Testing for the acceptance of running
characteristics of railway vehicles - Testing of running behaviour
and stationary tests**

Applications ferroviaires - Essais en vue de l'homologation
du comportement dynamique des véhicules ferroviaires -
Essais en ligne et à poste fixe

Bahnanwendungen - Fahrtechnische Prüfung für die
fahrtechnische Zulassung von Eisenbahnfahrzeugen -
Prüfung des Fahrverhaltens und stationäre Versuche

This European Standard was approved by CEN on 3 March 2005.

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Foreword

This document (EN 14363:2005) has been prepared by Technical Committee CEN/TC 256 "Railway Applications", the secretariat of which is held by DIN.

NOTE WG10 have recently been reactivated and have defined their future workload. Following this, it was considered necessary to complement EN 14363 by further parts.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2005, and conflicting national standards shall be withdrawn at the latest by December 2005.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

— Council Directive 96/48/EC of 23 July 1996 on the Interoperability of the trans-European high-speed rail system¹⁾.

For relationship with EU Directive, see informative Annex ZA which is an integral part of this document.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

1) Official Journal of the European Communities No L 235/6 of 17.09.96

Introduction

This document covers the testing for acceptance of the running characteristics of railway vehicles. It was established by Working Group 10 Vehicle/Track Interaction of CEN Technical Committee 256 Railway Applications.

The establishment of this document was based on existing rules, practices and procedures. The following principles were applied:

- 1) The railway system requires comprehensive technical rules in order to ensure an acceptable interaction of vehicle and track.
- 2) Due to the numerous national and international regulations new railway vehicles had to be tested and homologated before putting them into service. In addition, existing acceptance had to be checked when operating conditions were extended.
- 3) In view of the increasing significance of international traffic, in particular of high speed traffic, the standardisation of existing regulations is required. In some cases, additional rules are required as well. An update of existing regulations is also needed due to the considerable progress achieved in the field of railway-specific methods for measuring, evaluation and data processing.
- 4) It is of particular importance that the existing level of safety and reliability is not compromised even when changes in design and operating practices are demanded, e.g. by the introduction of higher speeds, higher wheel forces, etc.

This document takes account of the present state of the art which is generally applicable for test procedures and the evaluation of stationary and 'on-track' tests.

This document is derived in essential parts from UIC 518 which has not yet been fully validated by experience. In addition, the regulations about running characteristics of freight wagons of UIC 432 will be implemented after the discrepancies between UIC 432 and UIC 518 are solved by the expert group of UIC. The Working Group is aware that the combination of the test conditions is not always achievable. In some cases, the existing regulations may require exceptions for which justification will be provided to the acceptance body. In this event, the conditions which are not fulfilled will be identified.

This also concerns the future inclusion of turnout runs in switches with $R \leq 190$ m in the normal and simplified measurement method. The assessment will be done based on the stresses in critical sections (e.g. switch blade) of a switch. The test conditions will be fixed after further investigations.

The group expects that existing shortcomings will be recognized in further investigations and during frequent application of the rules.

1 Scope

This document regulates the testing for acceptance of the running characteristics of railway vehicles (hereafter called vehicles). The testing of the running characteristics applies principally to all vehicles used in public transport which operate without restriction on standard gauge tracks (1 435 mm).

NOTE 1 The testing of the running characteristics of:

- railways with different track layout, e.g. tramways, metros and underground railways;
- railways with non-standard gauge tracks

can be conducted by analogy with this document.

The testing of running characteristics is part of the type testing of vehicles which

- are newly developed,
- have had relevant design modifications, or
- have changes in their operating regimes.

The testing and acceptance of running characteristics refers to the complete vehicle including the running gear. If a running gear, which has already been tested and accepted, is to be used under a vehicle body of another design, this is considered to be a design modification. The procedure as described in 5.2 is used.

NOTE 2 In addition to the testing of running characteristics for the acceptance of vehicles, the regulations can be generally applied in other technical tasks, e.g.:

- the checking for compliance against development contracts;
- the optimisation of components, vehicles or running gear;
- the testing of influences, influencing parameters and relationships of dependence;
- the monitoring of track or vehicles in operational use.

Testing of running characteristics consists of preliminary approval tests (mainly stationary tests) and tests of running behaviour (on-track tests).

The application of the full method and the stated limit values reflect (unrestricted) international operation.

Variations from the conditions specified in this document are allowed as specified by the article 7.1 of directive 91/440 of EC.

Testing for acceptance of vehicles is based on some reference conditions of track. If these are not respected on certain lines, appropriate measures will be taken (speed modifications, additional tests, etc.).

For national or multinational operations the infrastructure managers concerned may authorize variations to the defined conditions. Permissible deviations are indicated in this document.

It is allowed to deviate from the rules laid down if evidence can be furnished that safety is at least the equivalent to that ensured by complying with these rules.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13674-1, *Railway applications; Track — Rail — Part 1: Vignole railway rails 46 kg/m and above*

prEN 13715, *Railway applications — Wheelsets and bogies — Wheels — Tread profile*

EN 13848-1, *Railway applications -Track — Track geometry quality — Part 1: Characterisation of track geometry*

WI 00256129, *Railway applications — Method for determining the equivalent conicity*

UIC 432:2002, *Wagons — Running speeds — Technical conditions techniques to be observed²⁾*

UIC 505-1:2003, *Railway transport stock — Rolling stock construction gauge²⁾*

UIC 505-4:1977, *Effects of the application of the kinematic gauges defined in the 505 series of leaflets on the positioning of structures in relation to the tracks and of the tracks in relation to each other²⁾*

UIC 505-5:1977, *Basis conditions common to leaflets 505-1 to 505-4 — Notes on the preparation and provisions of these leaflets²⁾*

UIC 518:2003, *Testing and approval of railway vehicles from the point of view of their dynamic behaviour — Safety — Track fatigue; Ride quality²⁾*

UIC 530-2:1997, *Wagons — Running safety²⁾*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

testing for acceptance of running behaviour

obtaining numerical values of evaluation variables which describe the running and ride characteristics. The evaluation variables together with limit values are used in the acceptance process of the vehicle

The purpose of testing running characteristics is either

- testing of vehicles which are newly developed, or
- extending the scope for an already proven vehicle (e.g. relevant design modification of the vehicle or alteration of the operation conditions)

3.2

test elements

related regulations for the

- measurement of parameters (accelerations, forces, displacements, on the vehicle) and evaluation of variables which characterise the performance of the vehicle;

2) May be purchased from: Railway Technical Publications (ETF) 16 rue Jean Rey, F-75015 Paris

- collection of the relevant conditions of the track, operation and environment;
- description of test procedures, measurement and evaluation methods;
- assessment of conditions for acceptance

NOTE Figure 1 shows the structure of the test elements.

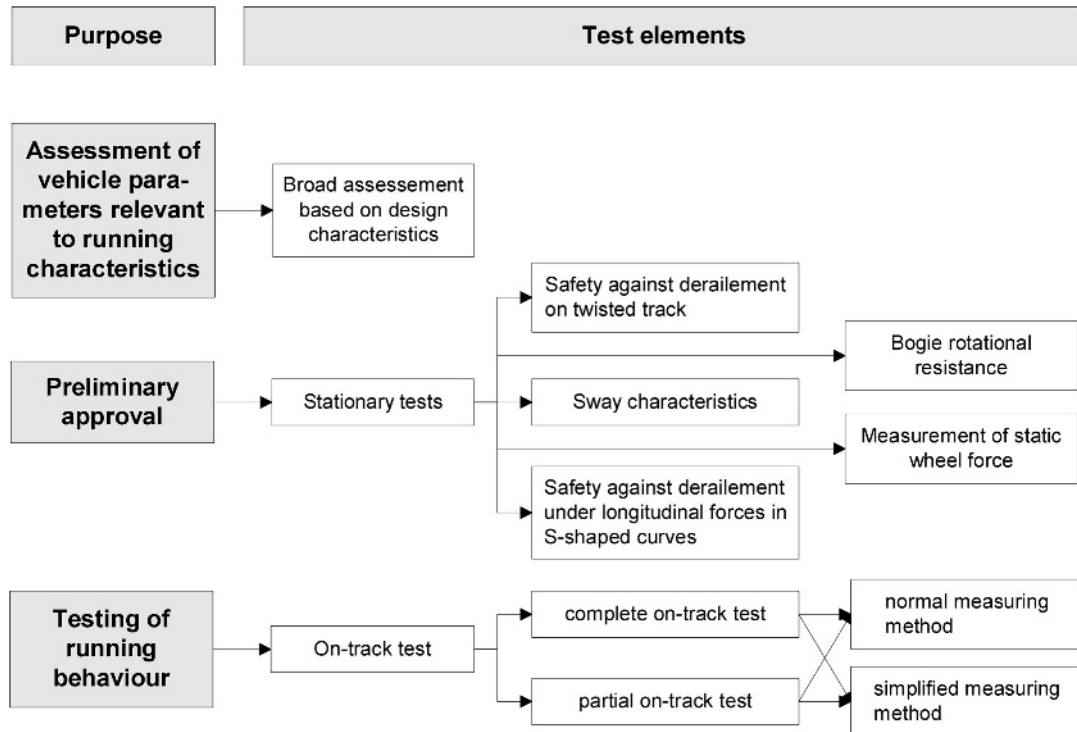


Figure 1 — Structure of test elements

3.3

vehicle parameters relevant to running characteristics

technical data of a vehicle relevant to running characteristics, e.g.:

- planned maximum permissible speed of the vehicle;
- planned permissible cant deficiency;
- smallest curve radius that shall be negotiated;
- wheel arrangement;
- wheel-base and distance between bogie centres;
- centre of gravity height;
- weight of the vehicle;
- wheel force and axle force distribution;
- unsprung mass;
- primary suspended mass;
- secondary suspended mass;
- moments of inertia of vehicle body (around z-axis);

- torsional stiffness of vehicle body;
- torsional stiffness of bogie frame;
- tractive effort;
- dimensions of wheel and wheelset;
- wheel profiles;
- characteristics of primary vertical suspension;
- characteristics of secondary vertical suspension;
- characteristics of axle guiding;
- characteristics of secondary lateral suspension;
- rotational torque of bogie;
- moment of inertia of bogie (around z-axis).

These parameters are defined and comply with the relevant construction and maintenance requirements. Compliance will be confirmed prior to the testing of running characteristics.

3.4

preliminary approval tests

testing of vehicles capability to operate under geometrical limit conditions of track layout

NOTE Preliminary approval tests are generally static and/or quasistatic. They mainly include the measurement of forces and displacements between the different components of a vehicle. They should be carried out before commencing the 'on-track' testing.

3.4.1

measurement of static wheel force

test to determine the individual vertical forces per wheel

3.4.2

bogie rotational resistance

test to evaluate the torque required to rotate a bogie while supporting a vehicle

3.4.3

safety against derailment on twisted track

test to evaluate the safety against derailment of a vehicle during negotiating track with limit conditions of twist

3.4.4

safety against derailment under longitudinal forces in S-shaped curves

test to evaluate safety against derailment of a vehicle under longitudinal forces in S-shaped curves

3.4.5

sway characteristics

test to measure the lateral and roll displacements of a vehicle when subjected to cant excess or deficiency

3.5

running behaviour

characteristics of a vehicle or running gear with regard to the interaction between vehicle and track. Running behaviour is a general term covering the following specific terms:

- running safety,
- track loading, and
- ride characteristics.

The following parameters are used for the assessment:

- forces between wheel and rail, or
- lateral forces between wheelset and axle-box (lateral axle-box forces), and/or
- accelerations.

The testing is based on 'on-track' tests.

3.6

on-track' tests

tests taking place on selected, relatively short sections of test track with specific characteristics of track layout. 'On-track' tests are used for the assessment of running behaviour within the planned range of speed and cant deficiency of the vehicle.

Depending on the test conditions 'on-track' tests may be:

- complete 'on-track' tests;
- partial 'on-track' test

3.6.1

complete 'on-track' test

test of running behaviour in the full defined test range

3.6.2

partial 'on-track' test

test of running behaviour used for an extension of acceptance (see explanation in Clause 1) which allows a reduced extent of test

3.7

measuring method

type and number of measuring quantities used during on-track test. Depending on the characteristics of the vehicle and the purpose of test

- normal measuring method, or
- simplified measuring method

is used

3.7.1

'on-track' test with normal measuring method

test of running behaviour for the assessment of

- running safety,
- track loading and
- ride characteristics of the vehicle

with direct measured forces between wheel and rail and accelerations in running gear and in the vehicle body

3.7.2

'on-track' test with simplified measuring method

test of running behaviour for the assessment of

- running safety and
- ride characteristics of the vehicle

with measured lateral axle-box forces and/or accelerations at the bogie frame and in the vehicle body

3.8

extent of tests

fixed number of test variants during 'on-track' test. The amount of tests is defined by:

- test zones, given by track layout;
- loading conditions of the test vehicle;
- degraded suspension conditions;
- rail inclination of test tracks

3.9

test track

selected section of the track for the 'on-track' test. It is chosen depending on:

- track layout;
- track geometry;
- rail inclination;
- wheel-rail contact geometry;
- type and number of the evaluation sections

corresponding to the planned operational area

3.10

test vehicle

vehicle representative of the production vehicles and which respects:

- the vehicle parameters relevant to running characteristics;
- construction and maintenance status

of the vehicle series.

3.10.1

conventional-technology vehicle

vehicles which

- are operated under normal operating conditions and
- correspond completely or in those construction parts which are relevant to the running behaviour to the proven state of the art

3.10.2

special vehicle

vehicles which are either unique or found in low numbers, belonging to either of the following types

- track maintenance vehicles (including rerailing vehicles);
- vehicles for special transport.

3.10.3

new-technology vehicle

all vehicles which are not categorized as conventional-technology vehicles or special vehicles

3.10.4

equivalent conicity $\tan \gamma_e$

parameter for characterization of the wheel-rail contact. For a given wheelset running on given track it equals the tangent of the taper angle of a tapered profile wheelset whose transverse movement has the same wavelength of kinematic yaw as the wheelset under consideration. To determine the numerical values of the equivalent conicity, the wheel profiles are combined with track with the parameters

- rail profile,
- installed inclination of rails and
- track gauge

and then the function $\tan \gamma_e = f(y)$ is calculated, then evaluated for an amplitude ± 3 mm

NOTE An extensive evaluation of the curve of the calculated function $\tan \gamma_e = f(y)$, for example for the range $1 \text{ mm} \leq y \leq 8 \text{ mm}$, may be necessary to clarify any questions relating to the running behaviour.

Calculation of equivalent conicity should be done respecting the regulations in WI 00256129.

4 Stationary tests

4.1 Safety against derailment for railway vehicles running on twisted track

4.1.1 General

The tests described in this clause are intended to ensure that vehicles can run safely on twisted tracks. The existence of track twist in railway tracks is fundamental. They are a result of transition layout between levelled track and canted track as well as cross level deviations (maintenance limits).

This test shall be done for initial acceptance of all vehicles. For the extension of acceptance (see NOTE in 5.2.1) the test shall be repeated if the variation of parameters increases the risk of derailment. The most important factors influencing the safety against derailment are given in A.1.

The limit value $(Y/Q)_{lim}$ for initiating flange climbing is influenced by:

- the flange angle;
- the friction forces between flange and rail. These forces are determined by the characteristic of the surface of wheel and rail at the contact point and by the angle of attack between wheel and rail.

If there is a tested reference vehicle with a validated calculation of safety against derailment according to the test conditions, tests may be dispensed if the new calculation results are lower than a reduced limit value $(Y/Q)_{lim} = 0,9 * 1,2 = 1,08$ (safety margin of 10 % to the limit value).

4.1.2 Test conditions

4.1.2.1 General

The risk of flange climbing is described by the ratio between horizontal guiding force Y and vertical wheel force Q .

The evaluation considers the quasistatic guiding force of the outer leading wheel negotiating a curve of $R = 150$ m.

Reduction of vertical wheel force includes the following effects:

- twist on bogie wheel base (see 4.1.2.2.3);
- twist on bogie centre distance or axle distance for non bogied vehicles (see 4.1.2.2.3);
- torsional hysteresis during the twisting;
- eccentricity of centre of gravity and twist of the bogie and vehicle body as a result of tolerances;
- eccentricity of the centre of gravity due to cant excess or deficiency - this influence is eliminated in the test;
- roll torque of the lateral axle-box forces.

So, the influence of cant excess is not considered. It is assumed that the reduction in the guiding forces in larger curve radii have a stronger influence on the safety against derailment than the higher offloading of the guiding wheel due to the higher allowed cant excess in these radii.

4.1.2.2 Track conditions

4.1.2.2.1 General

In practice it is possible to anticipate a combination of all of the worst condition which could occur. The simultaneous application of these conditions would result in an unrealistic situation, which experience has shown is not necessary.

Information about the relations that have led to the definition of the test conditions for European mainline railways can be found in the reports of B 55 and C 138. In the present document no information about different track layout can be given.

NOTE These test conditions have been developed by ERRI and are documented in several reports of B 55 and C 138. They have been applied since 1983 in Europe and have resulted in the safe operation of vehicles.

4.1.2.2.2 Track twist limit

The track twist limit, including design twist and the cross level deterioration before maintenance, which is used in European railways is:

$$g_{\text{lim}} = \min(7, 0; \frac{20}{2a} + 3, 0)$$

with $2a$ as longitudinal base in m and g_{lim} in ‰. The validity of the formula is limited to $2a \leq 20$ m. ³⁾

4.1.2.2.3 Vehicle test twist

Recognising the above remarks the condition to be used for vehicle test is

— for bogie test twist:

$$g_{\text{lim}}^+ = 7 \quad \text{if } 2a^+ \leq 4 \text{ m and}$$

$$g_{\text{lim}}^+ = \frac{20}{2a^+} + 2,0 \quad \text{if } 2a^+ > 4 \text{ m}$$

with $2a^+$ as the bogie wheel base in m and g_{lim}^+ in ‰.

— for vehicle body test twist:

$$g_{\text{lim}}^* = 7 \quad \text{if } 2a \leq 4 \text{ m and}$$

$$g_{\text{lim}}^* = \frac{20}{2a} + 2,0 \quad \text{if } 4 \text{ m} < 2a \leq 20 \text{ m}$$

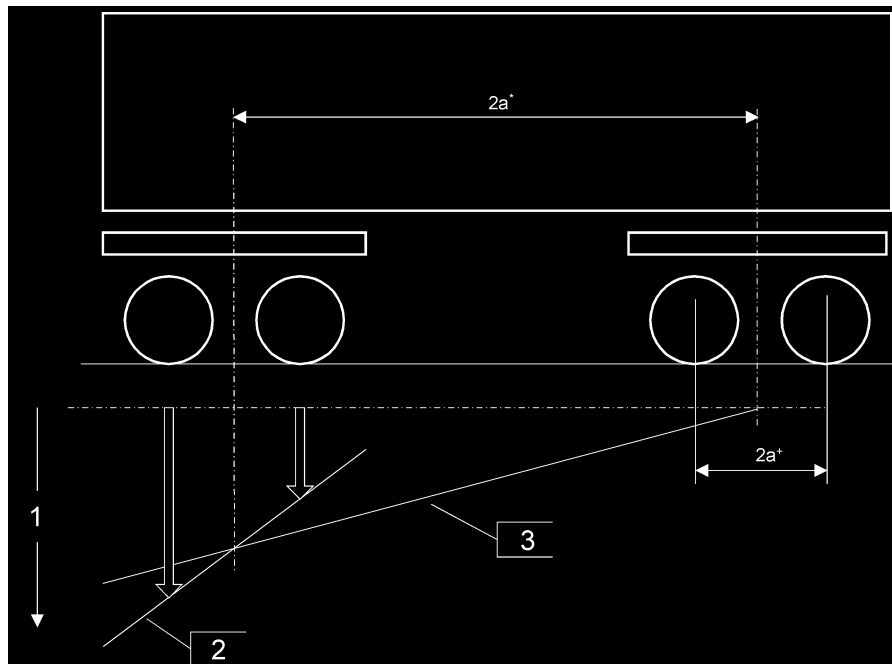
$$g_{\text{lim}}^* = 3 \quad \text{if } 20 \text{ m} < 2a \leq 30 \text{ m}$$

³⁾ Several measurements were made on the tracks of DB, NS, ÖBB, PKP and SNCF which lead to a limit for track twist in relation of the longitudinal basis. The analysis of the measurements was carried over a range of 1,8 m to 19,8 m.

$$g_{\text{lim}}^* = \frac{90}{2a} \quad \text{if } 2a > 30 \text{ m}$$

with $2a$ as the longitudinal dimension of twist in m (for single cars the longitudinal dimension of twist equals $2a^*$, the distance between center pivots for bogied single cars or the distance of the axles for non bogied vehicles) and g_{lim}^* in ‰.

For bogied vehicles the twist due to the bogie wheel base $2a^*$ and the twist due to the bogie center distance $2a$ shall be combined as shown in Figure 2.

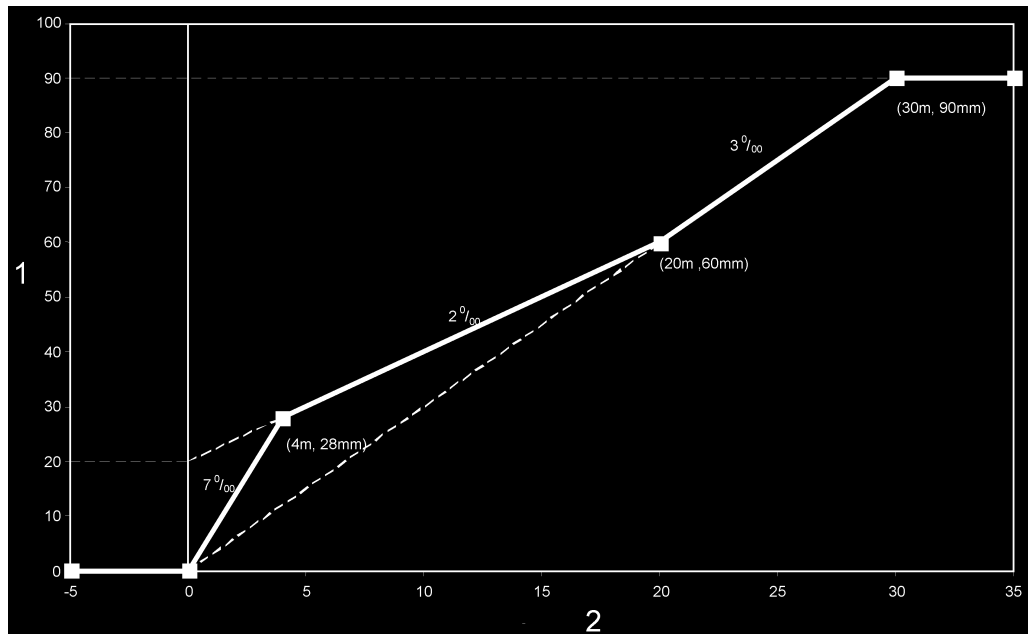


Key

- 1 vertical displacement
- 2 bogie test twist
- 3 vehicle body test twist

Figure 2 — Combination of bogie and vehicle body test twist

The given vehicle test twist values are only valid up to a longitudinal basis $2a^*$ of 20 m. For values of $2a^*$ greater than 20 m a vehicle test twist value of $g_{\text{lim}}^* = 3 \text{ ‰}$ will be used. Figure 3 shows the test twist values depending on length dimensions $2a^*$ and $2a$. The maximum vertical height difference from twist shall be 90 mm which corresponds to a twist value of 3 ‰ at 30 m. For lengths greater than 30 m the vertical height difference from twist shall be 90 mm.

**Key**

- 1 twist height h
 2 twist length $2a$

Figure 3 — Test twist values**4.1.2.2.4 Curve radius for determination of guiding force**

The track shall contain a curve of $R = 150$ m.

The evaluation considers the quasistatic guiding force of the outer leading wheel.

4.1.2.2.5 Rail conditions

Tests shall be done under dry conditions in order to consider high friction forces between wheel and rail.

Information used in the determination of the rail conditions shall be gathered when measuring

- Y_i and Q_i on the inner leading wheel,
- angle of attack α , and
- average wheel force of the leading axle

and evaluated as described below.

During tests the friction coefficient is to be at least 80 % of the value expected for dry rails. Therefore, the condition

$$(Y/Q)_i \geq 0,8 \tau_{dry} + \gamma$$

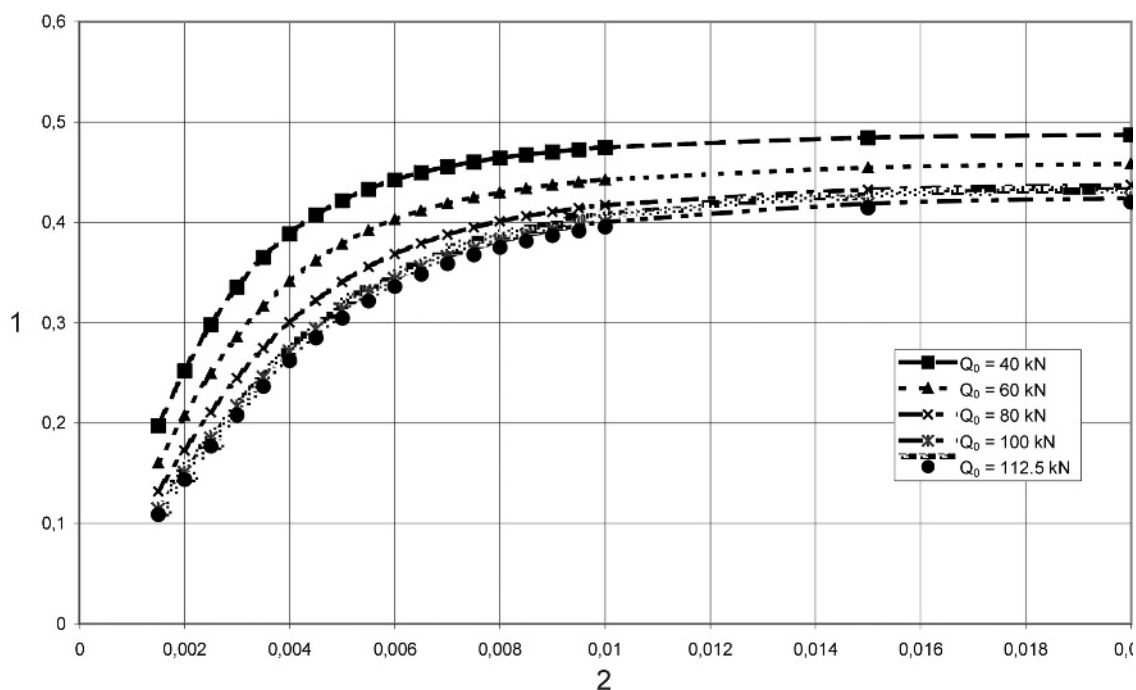
as a function of the angle of attack shall be respected. In the above formula the contact angle of the tread γ shall be inserted. For example as

$$\gamma = 0,025$$

for wheel profile S1002 according to prEN 13715.

The friction coefficient τ_{dry} represents the ratio of the lateral friction force and the vertical force. Figure 4 shows this relationship for different wheel forces. Explanations and the corresponding equation are given in A.3.

If during the tests a friction coefficient higher than 100 % of τ_{dry} occurred, the tests may be repeated.



Key

- 1 ratio lateral friction force – vertical force τ_{dry}
- 2 angle of attack [rad]

Figure 4 — Ratio of lateral friction force to vertical force for dry friction conditions

To determine friction during tests, the measurement of the angle of attack is necessary.

The method is not appropriate if the angle of attack is very small (e.g. below 0,0015 rad). In the case of bogies with a low angle of attack determination of the friction conditions is to be done by measuring on a leading axle of a vehicle which generates a higher angle of attack.

4.1.2.3 Vehicle conditions

4.1.2.3.1 General

Taking the vehicle design and the load distribution in the vehicle into consideration, the effects of the running direction and the direction of curvature shall be analyzed. The test conditions and the wheelsets to be tested are to be determined as a result of this analysis (for one-unit vehicles with two wheelsets or bogies, the two outer wheelsets, the leading ones, are to be analyzed).

4.1.2.3.2 Load condition

The test vehicle shall be in its normal operating condition. With respect to loading, passenger or freight vehicles are to be tested in the empty condition.

If the suspension is non-linear, safety against derailment shall be tested in the worst combination of load and stiffness (e.g. this will occur for a two-rate spring at the smallest loading point above the application point of

the second stiffness where at full vehicle test twist the relieved second stiffness just remains in contact/operation).

4.1.2.3.3 Conditions for vehicles with air springs

Safety against derailment shall be tested with inflated and deflated air springs.

With inflated air spring wheel load distribution may be changed by the response time of the levelling system. The type of the levelling system has an important influence (e.g. 4-point levelling, 3-point levelling, 2-point levelling), Annex A gives some additional information.

The effect of the levelling system's response time shall be investigated. During the test the effects of the levelling system shall be measured by including breaks in the test procedure to enable the system to stabilize.

4.1.2.3.4 Conditions for vehicles with active systems in suspension

Several additional effects have to be considered in planning the tests including:

- systems response time;
- tolerances on system's position and force measurements;
- credible failure modes.

4.1.2.3.5 Conditions for bogied vehicles with more than two axles per bogie

Vehicle test twist for a bogie is related to the extreme wheel base of the bogie. Twist displacements of intermediate wheelsets are to be interpolated.

4.1.2.3.6 Conditions for articulated vehicles

In the case of articulated vehicles where adjacent vehicle-bodies are suspended on a common running gear or articulation, the influence of inter-vehicle constraints shall be analyzed in order to determine their significance. The test conditions and the wheelsets to be tested shall be determined as a result of this analysis. Intermediate running gears or bogies shall also be tested. It could be necessary to test more than one vehicle body at the same time.

A.5 gives some additional information and examples.

4.1.2.3.7 Conditions for vehicles with more than two suspension levels

The word suspension is used to indicate freedom between adjacent bodies which may or may not include springs or dampers. A.6 shows two examples of such arrangements, many other different types exist.

The relevant vehicle test twist for the individual suspension levels have to be defined by analogy to the rules given for bogied vehicles in 4.1.2.2.3. A.6 gives examples for the vehicles illustrated.

4.1.2.3.8 Conditions for vehicles with steered wheelsets

For vehicles including mechanisms which steer the wheelsets, the track conditions (e.g. S-curves) may lead to angles of attack which are larger than those obtained on the test track. That shall be considered in the test. The worst conditions occurring in operation with regard to the angle of attack shall be determined. Normally, in full curves the angles of attack and therefore the guiding forces are low. However, in transitions or reverse curves the steering mechanism may generate adverse angles of attack.

In order to get the highest guiding forces during the test, these additional angles of attack shall be simulated by suitable methods (e.g. by removing the steering mechanism and fixing the wheelsets to this angle of attack).

For vehicles with self steering wheelsets or other running gears which show a major influence of wheel-rail contact geometry, on the steering effect and the resulting angle of attack, appropriate investigations (e.g. forced angle of attack, variation of wheel-rail geometry) shall be carried out.

4.1.3 Test methods

4.1.3.1 General

For universal application there are two methods to prove the safety against derailment:

- 1) **Twisted test track**
Measurement of the safety against derailment by running through a twisted test track.
- 2) **Twist test rig and flat test track**
 - Measurement of the minimum wheel force $Q_{a,min}$ on a vehicle test rig;
 - measurement of the guiding force Y_a on an appropriate test track;
 - calculation of the ratio $(Y/Q)_a$.

A third method is also possible, but this shall only be applied under the specific conditions defined in 4.1.3.4.1. This method is as follows:

- 3) **Twist test rig and yaw test rig**
 - Measurement of the minimum wheel force $Q_{a,min}$ on a vehicle test rig;
 - measurement of wheel forces and the torque required to rotate (yaw) the bogie in a small radius curve.

Test methods 1 and 2 require the direct measurement of forces between wheel and rail.

4.1.3.2 Method 1: Test on twisted test track

4.1.3.2.1 General

The evaluation of safety against derailment is carried out by measuring vertical and lateral forces when running through a twisted test track.

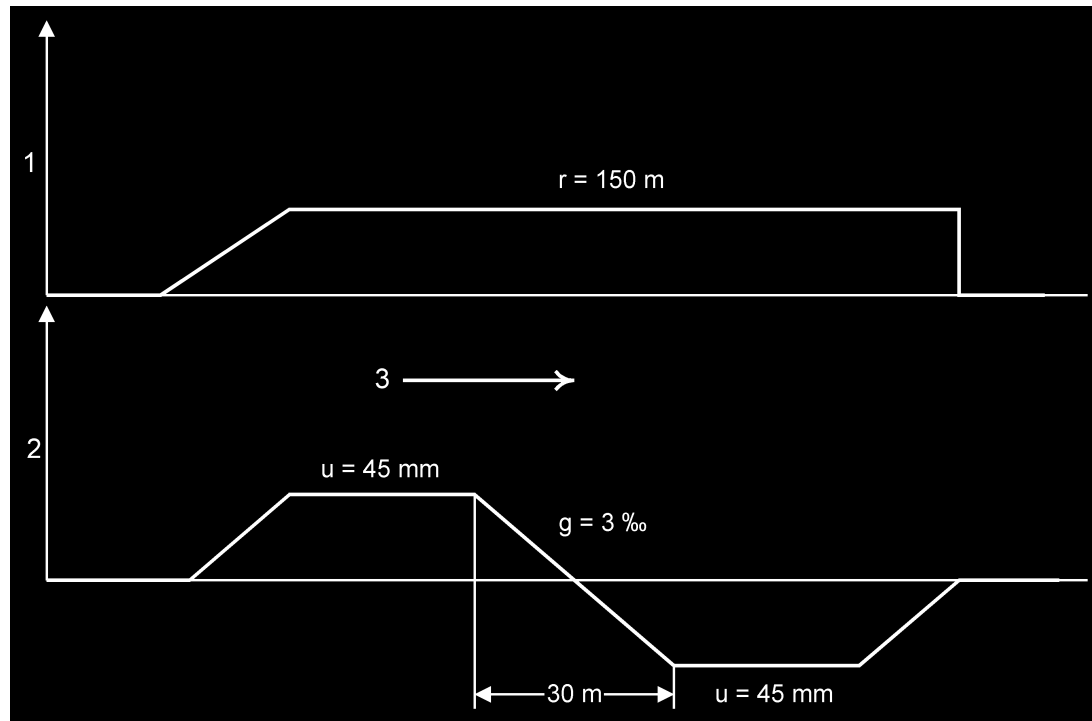
4.1.3.2.2 Test conditions

4.1.3.2.2.1 Track conditions

Tests shall be done on a specific test track with the following characteristics:

- curve radius $R = 150$ m;
- section of twisted track with constant curvature and twist of 3 ‰;
- the twist is realised by varying the height of the outer rail;
- test track shall reflect the normal condition of typical track considering the rail profile, track gauge and state of maintenance.

Figure 5 contains an example for installing such a test track.

**Key**

- 1 curvature
- 2 cant
- 3 running direction

Figure 5 — General layout of test track

Test conditions as described 4.1.2.2.5 (dry rail conditions) shall be fulfilled.

The influence of longitudinal forces in the trainset shall be minimized. The vehicle shall not be braked. The speed shall be constant and not exceed 10 km/h.

Tests shall be done a minimum of 3 times.

4.1.3.2.2.2 Vehicle conditions

If the vehicle test twist is greater the 3 ‰ the additional twist is included within the vehicle e.g. by packing the springs with shims in an appropriate way. A.7 contains suggestions for calculating the thickness of the shims and precise their location.

The test shall be planned to ensure that the direction of running and track curvature are in such a way that the wheel with the lowest wheel load is tested in the leading position running on the outer rail of the curve (this may include additional packing of the suspensions).

The influence of longitudinal forces in the train set shall be minimized. The vehicle shall not be braked. The speed shall be constant and not exceed 10 km/h.

4.1.3.2.3 Measured values, measuring positions and processing of measurements

The following values shall be measured:

- guiding forces on the inner and outer wheel of the tested wheelset Y_i , Y_a ;

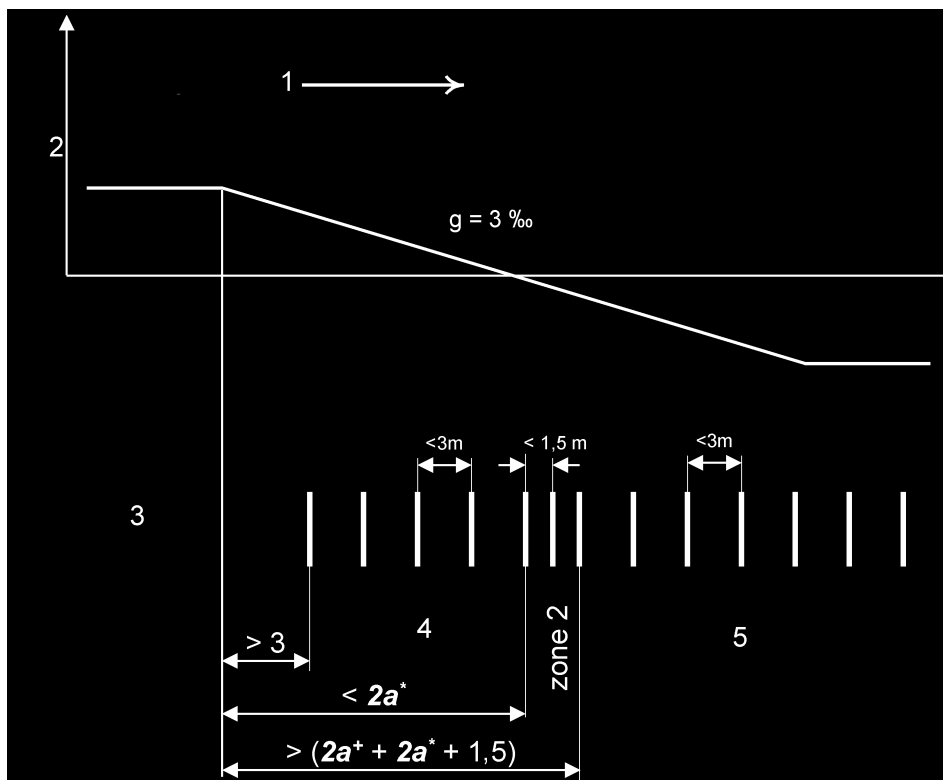
- vertical wheel forces on the inner and outer wheel of the tested wheelset Q_i , Q_a ;
- angle of attack of a leading wheelset α (see 4.1.2.2.5);
- wheel lift of the guiding wheel of the tested wheelset Δz in the whole curve.

Forces may be measured by

- appropriate devices on the rails, or
- appropriate devices on the vehicles.

In the case of rail measurements the measuring positions have to fulfill the following conditions as shown in Figure 6:

- measuring positions shall be within the twisted part of the track;
- in zone 2 where the track twist first influences the whole vehicle the distance between two measuring sections shall not be greater than 1,5 m;
- in the other areas of the twisted track the distance between two measuring sections shall not be greater than 3 m.



Key

- | | | | |
|---|---------------------|---|--------|
| 1 | running direction | 4 | zone 1 |
| 2 | cant | 5 | zone 3 |
| 3 | measuring positions | | |

Figure 6 — Track based measuring positions to be used in method 1

For each measuring section the value of $(Y/Q)_a$ of the leading wheelset shall be recorded. Wheel lift of the outer wheel of the leading wheelset Δz shall be recorded continuously.

To determine the friction conditions $(Y/Q)_i$ and α have to be evaluated as mean values of all measuring sections or of a continuous recorded signal.

If vehicle based measurement is used processing of measuring signals shall be done by analogy to the above conditions.

4.1.3.2.4 Assessment values

Assessment is done with the maximum value of all measuring sections $(Y/Q)_{a,max}$ and the maximum value Δz_{max} of wheel lift of the outer wheel of the tested wheelset.

4.1.3.2.5 Limit values

A vehicle is considered to be safe against derailment if the condition

$$(Y/Q)_{a,max} \leq (Y/Q)_{lim}$$

is fulfilled on each test.

Following investigations by European railway administrations⁴⁾ the limit value for $(Y/Q)_{lim}$ was defined as 1,2 for a flange angle of 70° (this corresponds to $\mu = 0,36$ from A.2). For different flange angles, the limit value is calculated by

$$\frac{Y}{Q} = \frac{\tan \gamma - 0,36}{1 + 0,36 \tan \gamma}.$$

A.2 gives some background information for the evaluation parameter (Y/Q) and the limit value.

If the limit value $(Y/Q)_{lim}$ is exceeded the performance of the vehicle may be reviewed by considering if the condition

$$\Delta z_{max} \leq \Delta z_{lim} = 5 \text{ mm}$$

is respected (that means the vehicle is actually not derailed). In this case the vehicle may be accepted if the following conditions are fulfilled:

- the flange angle exceeds 70° in no position of the profile (the wheel profile shall be recorded and added to the test report),
- it can be documented that the flange of the outer rail is considered to be dry and no residual lubrication is present, and
- the test was executed at least 3 times and under no circumstances the condition $\Delta z_{max} \leq \Delta z_{lim} = 5 \text{ mm}$ failed.

4.1.3.3 Method 2: Test on twist test rig and flat test track

In Method 2 the calculation of the ratio $(Y/Q)_a$ is based on measurements Q_a of the vertical wheel force reduction on a test rig which simulates twisted track and measurement of the guiding force Y_a on an appropriate test track.

⁴⁾ The investigations are documented in several reports of ERRI B55, see [4] in the Bibliography.

4.1.3.3.1 Test conditions for measurement of minimum vertical wheel force on twist test rig

The vehicle test twist limit conditions in 4.1.2.2.3 are used as a basis of this test, in practice a wheel lift up to 5 mm is permissible according to 4.1.3.2.5. Consequently, the effective twist for the vehicle is reduced.

Following values shall be used on the twist test rig:

— for bogie test twist:

$$g_{\text{lim}}^+ = 7 - \frac{5}{2a^+} \quad \text{if } 2a^+ < 4 \text{ m}$$

$$g_{\text{lim}}^+ = \frac{15}{2a^+} + 2,0 \quad \text{if } 2a^+ \geq 4 \text{ m}$$

with $2a^+$ as the bogie wheel base in m and g_{lim}^+ in ‰.

— for vehicle body test twist

$$g_{\text{lim}}^* = 7 - \frac{5}{2a^*} \quad \text{if } 2a^* < 4 \text{ m and}$$

$$g_{\text{lim}}^* = \frac{15}{2a^*} + 2,0 \quad \text{if } 4 \text{ m} \leq 2a^* \leq 20 \text{ m}$$

$$g_{\text{lim}}^* = 3 - \frac{5}{2a^*} \quad \text{if } 20 \text{ m} < 2a^* \leq 30 \text{ m}$$

$$g_{\text{lim}}^* = \frac{85}{2a^*} \quad \text{if } 2a^* > 30 \text{ m.}$$

with $2a^*$ as the longitudinal dimension of the vehicle (distance between centre pivots for bogied single vehicles or axles for non bogied vehicles) in m and g_{lim}^* in ‰.

For bogied vehicles the twist on the bogie wheel base $2a^+$ and the twist on the bogie center distance $2a^*$ shall be combined as shown in Figure 2.

An appropriate test rig shall be used on which at least the supports of the two wheelset of one bogie may be lifted and lowered. With this the twist of the track on bogie wheel base as well as on bogie center distance can be simulated.

4.1.3.3.2 Measured values, measuring positions and processing of measurements for minimum vertical wheel force on twist test rig

The displacements Δz_{jk} of the wheels shall be measured continuously during the twist test. Additionally the wheel forces Q_{jk} of all wheels shall be measured by suitable devices.

By testing the vehicle on the test rig the following vehicle parameters are evaluated:

$Q_{0,j}$ average wheel force for each wheelset for level track (twist $g = 0$);

ΔQ_{jk} deviation of wheel force from Q_0 due to the combined bogie and body twist and eccentricity of center of gravity including friction and tolerances;

$Q_{jk,min}$ minimum wheel force due to the combined bogie and body twist and eccentricity of center of gravity including friction and tolerances.

A.8 and A.9 contain guidelines for testing and evaluating.

4.1.3.3.3 Test conditions for measurements in the flat test track

The test track consists of a tangent and a curve with $R = 150$ m without transition, twist and cant. The test track shall reflect the normal condition of typical track considering the rail profile, track gauge and state of maintenance.

Direction of running and direction of curvature shall be in such a way that the wheel with the lowest wheel load of the extreme wheelset is in the leading position running on the outer rail of the curve.

Test conditions concerning the state of the rail as described 4.1.2.2.5 (dry rail conditions) shall be fulfilled.

The influence of longitudinal forces in the train set shall be minimized. The vehicle shall not be braked. The speed shall be constant and not exceed 10 km/h.

Tests shall be done a minimum of 3 times.

4.1.3.3.4 Measured values, measuring positions and processing of measurements in the flat test track

Forces may be measured by

- appropriate devices on the rails, or
- appropriate devices on the vehicles.

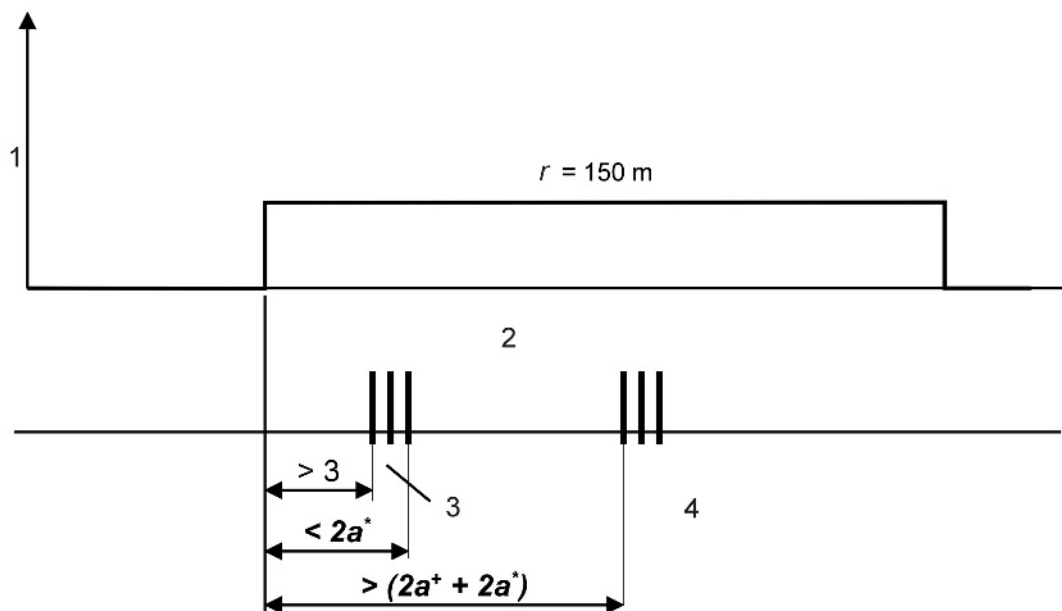
The following values shall be measured:

- guiding forces on the inner and outer wheel of the tested wheelset Y_i , Y_a ;
- vertical wheel force on the inner wheel of the tested wheelset Q_i ;
- angle of attack of a leading wheelset α (see 4.1.2.3.6).

In the case of rail measurements the measuring positions shall fulfill the following conditions:

- at least 3 measuring positions shall be in zone 1 at the beginning of the curve area between 3 m and up to $2a^*$ from the start of the curve (this ensures that the body-bogie yaw is still taking place),
- at least 3 measuring positions shall be within in zone 2 in a curve area where the whole vehicle is in the constant curve.

Figure 7 shows an example of the measuring position in a 150 m curve radii.

**Key**

- 1 curvature
- 2 measuring positions
- 3 zone 1
- 4 zone 2

Figure 7 — Track based measuring positions for determination of Y and Q

For each measuring position the values of Y_a and Y_i of the tested wheelset shall be recorded. Assessment is done with the mean value $Y_{a,med}$ and $Y_{i,med}$ of the measuring positions separately for zone 1 and zone 2.

For the evaluation of Y_i the direction of forces shall be noted (in most cases opposite to Y_a).

To determine the friction conditions $(Y/Q)_i$ and α shall be evaluated as mean values of all measuring positions or of a continuous recorded signal.

If vehicle based measurement is used the results shall be analyzed equivalently to the above conditions.

4.1.3.3.5 Assessment values

Analysis of safety against derailment shall be done for the tested wheelsets of the vehicle. The following formula shall be evaluated for each tested wheelset:

$$\left(\frac{Y}{Q}\right)_{ja} = \frac{Y_{ja,med}}{Q_{jk,min} + \Delta Q_{jH}}$$

where

- $Y_{ja,med}$ is the quasistatic guiding force evaluated by the tests described in 4.1.3.3.5;
- $Q_{jk,min}$ is the smallest wheel force evaluated by twist test described in 4.1.3.3.3;
- ΔQ_{jH} is the change of wheel force due to the moment of the sum of guiding forces:

$$\Delta Q_{jH} = (Y_{ja} + Y_{ji}) \frac{h}{2b_A}$$

where

h is the effective height above rail of the primary lateral suspension;
 $2b_A$ is the lateral distance of wheel/rail contact points (normally 1 500 mm).

A vehicle is considered to be safe against derailment if the conditions

$$(Y/Q)_{ja} \leq (Y/Q)_{lim}$$

is fulfilled.

4.1.3.3.6 Limit values

Following investigations by European railway administrations⁴⁾ the limit value for $(Y/Q)_{lim}$ was defined as 1,2 for a flange angle of 70° (this corresponds to $\mu = 0,36$ from A.2). For different flange angles the limit value is calculated by

$$\frac{Y}{Q} = \frac{\tan \gamma - 0,36}{1 + 0,36 \tan \gamma}$$

A.2 shows some background information for the evaluation parameter (Y/Q) and the limit value.

4.1.3.4 Method 3: Test on twist test rig and yaw test rig

4.1.3.4.1 General

Method 3 combines laboratory based wheel unloading and bogie rotation tests. It may be used under the following conditions:

- Conventional-technology vehicle as defined in 3.10 with
 - two-axle bogies, two bogies per vehicle,
 - flange angles of wheels between 68° and 70°.

NOTE Method 1 and 2 determine the ratio of lateral to vertical force at the wheel-rail interface. Long experience has shown that the more indirect assessment used in method 3 is easier to implement.

Where it is not possible to demonstrate an acceptable performance using Method 3, validated computer simulations according to Annex B may be used. If this fails either method 1 or 2 is to be used.

4.1.3.4.2 Test conditions for measurement of minimum wheel force on twist test rig

The track twist limit conditions in 4.1.2.2.2 are used as a basis of this test.

Following values shall be used on the twist test rig:

- for bogies:

$$g_{lim}^+ = 7$$

if $2a^+ < 5$ m and

$$g_{lim}^+ = \frac{20}{2a^+} + 3,0 \quad \text{if } 2a^+ \geq 5 \text{ m}$$

with $2a^+$ as the bogie wheel base in m and g_{lim}^+ in ‰.

— for vehicle bodies

$$g_{lim}^* = \frac{20}{2a^*} + 3,0$$

with $2a^*$ as the longitudinal dimension of the vehicle (distance between centre pivots) in m and g_{lim}^* in ‰.

Tests shall be done as a combined body and bogie twist test as described in A.9.3. This type of test is identical with test used in method 2 but with different twist conditions.

A test rig shall be used on which at least the supports of the two wheelset of one bogie may be lifted and lowered. With this the twist of the track on bogie wheel base as well as on bogie center distance can be simulated.

4.1.3.4.3 Measured values, measuring positions and processing of measurements for minimum vertical wheel force on twist test rig

The displacements Δz_{jk} of the wheels shall be measured continuously during the twist test. Additionally the wheel forces Q_{jk} of the wheels seeing the greatest percentage off-loading shall be measured by suitable devices.

4.1.3.4.4 Test conditions for measurement of bogie rotational resistance

The test conditions described in 4.4.2 shall be respected.

4.1.3.4.5 Measured values, measuring positions and processing of measurements for bogie rotational resistance

This is described in 4.4.3.

4.1.3.4.6 Assessment values

Analysis of track twist performance shall be done for the leading wheelset using the wheel unloading factor $\frac{\Delta Q}{Q_0}$ and the bogie rotational resistance factor X ,

where

Q_0 is the average wheel force for the tested wheelset on level track (twist $g^0 = 0$);

ΔQ is the deviation from Q_0 at maximum twist condition.

Based on the results of the measurement of bogie rotational resistance in small radius curves (see 4.4.2), the bogie X -factor shall be computed from the formula

$$X = \frac{M_{z,Rmin}}{2a + 2Q_0}$$

where

$M_{z,Rmin}$ is the torque required to rotate the bogie relative to the body, evaluated at $\psi = a^* / R_{min}$

The test is described in 4.4.

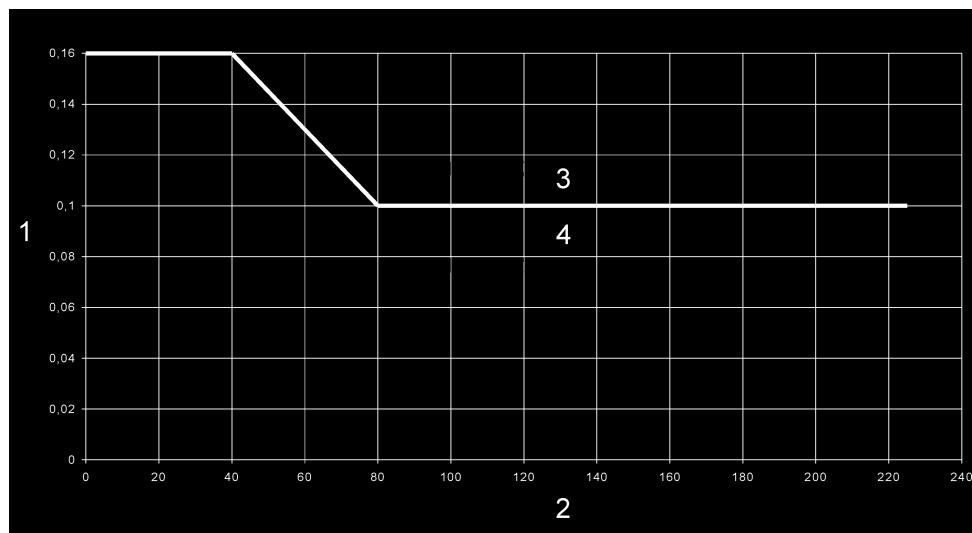
4.1.3.4.7 Limit values

The following criteria's shall be respected:

$$\frac{\Delta Q}{Q_0} \leq 0,6$$

$X \leq 0,1$ for passenger vehicles and locomotives,
for freight vehicles it shall be below the limits shown in Figure 8.

Both criteria shall be respected simultaneously.



Key

- 1 'X' Factor
- 2 axle load $2Q_0$ in kN
- 3 unacceptable
- 4 acceptable

Figure 8 — Maximum permissible factor X for freight vehicles

4.2 Safety against derailment under longitudinal forces in S-shaped curves

It is recognized that longitudinal forces within trains have the potential to increase the risk of derailment when negotiating S-shaped curves. For conventional trains (except for freight) this risk is regarded as low. However, this risk should be considered when non-conventional configurations are developed. In the case of freight vehicles the procedure defined in UIC 530-2 shall be used.

4.3 Sway characteristics

4.3.1 General

The test described in this subclause is intended to evaluate the vehicle bodies displacement in the transverse and roll direction caused by a lateral acceleration (acting in track plane). The test may be necessary to

- validate vehicle data used for determination of its kinematic envelope, and
- determine the transverse movement of the pantograph (for a powered vehicle with overhead lines) to confirm that the risk of loss of contact between pantograph and contact wire is low.

NOTE Applying the test may be also useful to confirm that the displacements of the vehicle in roll and the characteristics for the installed suspension components are within the design limits.

Two methods are used to determine the characteristics of the vehicle:

- 1) Test on special test rig
Measurement of roll angle and transverse movement on a test rig which simulates canted track and subsequent analysis of roll coefficient.
- 2) On-track test
 - Measurement of lateral accelerations in vehicle body and cant deficiency in curves and analysis of roll coefficient, or
 - measurement of roll angles in the suspension levels and analysis of roll coefficient.

Method 1 allows determination of the sway characteristics (i.e. roll and transverse movements), method 2 is limited to determination of the roll characteristics and shall be completed for certain vehicles by measurement and analysis of lateral movement between bogie and body.

The test method chosen shall be consistent with the gauge clearance method to be used.

4.3.2 Test conditions

4.3.2.1 General vehicle conditions

In general the test shall be done for a single vehicle. In the case of articulated vehicles where adjacent vehicle bodies are suspended on a common bogie the influence of inter-vehicle constraints shall be analyzed in order to determine their significance. Test conditions shall be determined as a result of this analysis and it may be necessary to test more than one vehicle synchronously.

It may be desirable to disconnect dampers to reduce hysteresis in the system.

4.3.2.2 Load condition

The test vehicle shall have the usual operating equipment. With respect to occupancy with passengers or freight load

- multiple units,
- passenger coaches, and
- freight wagons

are to be investigated empty and loaded.

Any simulation of the loaded condition shall include the simulation of the height of centre of gravity of the loaded vehicle body.

4.3.2.3 Conditions for vehicles with air springs

The effect of the levelling system's response time shall be investigated. If the response time may not be neglected, compared to a passive system, tests using method 1 (test rig) shall be done without the influence of the levelling system. The levelling valves shall be disconnected.

Using method 2 the levelling system cannot be disconnected, here the influence of the response time is included as experienced in service.

4.3.2.4 Conditions for vehicles with active systems in suspension

Several additional effects have to be considered in planning the tests including:

- systems response time;
- tolerances on positions and forces;
- credible failure modes.

4.3.2.5 Conditions for test rig

Using method 1 test shall be done on a specialized site consisting of calibrated, initially flat track. The plane of the rails shall be able to be canted in both directions under all wheelsets of the vehicle.

The test cant shall be sufficient to include the forces arising from steady state cant deficiency / excess and dynamic effects.

The inclination of the rails shall be applied in steps to a maximum value applicable to the vehicle. The load path through the suspension shall at all times be consistent with that seen when on the track. Tests shall be done for positive and negative cant. A closed hysteresis loop shall be achieved. To enable unambiguous evaluation of the roll coefficient, cant shall be 10 % to 20 % higher than the specified test cant.

4.3.3 Measured values and assessment values

4.3.3.1 Method 1: Test on special test rig

Vertical and horizontal deflections on marked points of vehicle body and one axle shall be measured by an adequate equipment in such a way that it is possible to derive

- η^* vehicle roll angle relative to the rotational axis of the wheelsets;
- h_P the height above the running plane of a defined point P in the longitudinal centre plane of the vehicle;
- y_P lateral movement of the vehicle body at a defined point P relative to the perpendicular axis of the wheelsets;
- Δy^* lateral movement in the secondary suspension at the height of the secondary bump stops (necessary for the analysis of roll centre);
- η^+ bogie roll angle relative to the rotational axis of the wheelsets;
- y_{bog} lateral movement of the bogie at a defined point relative to the perpendicular axis of the wheelset;
- η^0 roll angle of the wheelsets relative to the un-canted track plane (cant angle).

Figure 9 shows the situation on the test rig. At each value of cant – from maximum negative to maximum positive value – measured values and derived values shall be measured and evaluated.

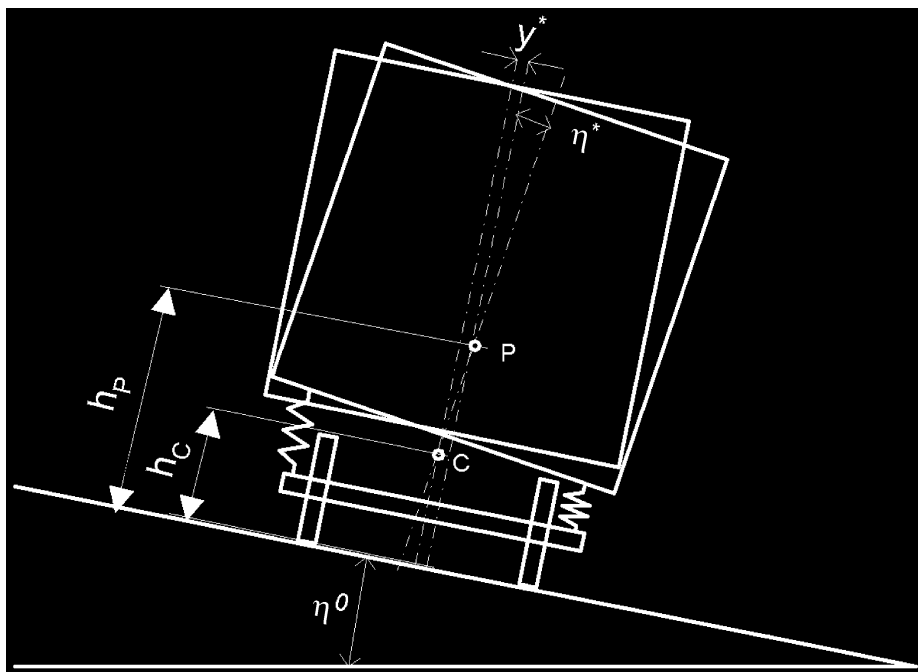


Figure 9 — Standing vehicle on canted track

Diagrams shall be produced showing $\eta^* = f(\eta^0)$ and $y_P = f(\eta^0)$.

Figure 10 shows an example of a diagram $\eta^* = f(\eta^0)$. The crosses in the diagram indicate the measured values at different cant angles. It shows a hysteresis of the measured roll angles which is caused by friction in the suspension. There is some play in the suspension which leads to discontinuity in the curve. If the behaviour is linear, roll coefficient shall be calculated by fitting to a straight line.

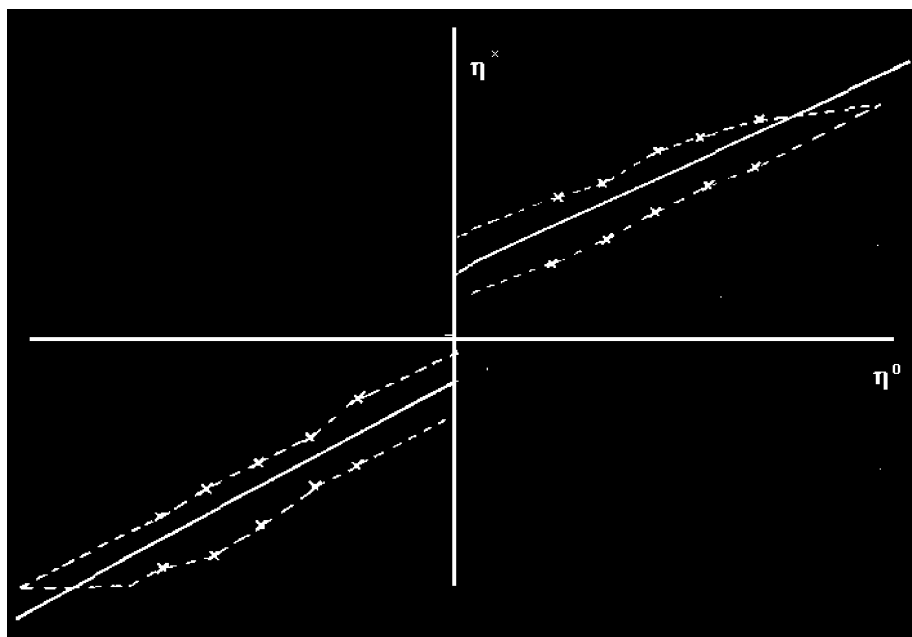


Figure 10 — Example of roll angle diagram

4.3.3.2 Method 2 - On-track test

Determination of vehicle roll characteristics during on-track tests is possible by measurement of

- $\ddot{y}^*$ lateral acceleration in vehicle body,
- $\ddot{y}$ lateral acceleration of the wheelsets (lateral acceleration on track level)

or by measurement of

- $\Delta\eta^*$ roll angle difference between vehicle body and bogie frame for bogied vehicles or between vehicle body and wheelset for non-bogied vehicles,
- $\Delta\eta^*$ roll angle difference between bogie frame and wheelset for bogied vehicles, and
- $\ddot{y}$ lateral acceleration of the wheelsets (lateral acceleration on track level).

Analysis is to be done using the mean values in track sections of curved track. Processing of the measuring signals is to be done as described in 5.5. At least 25 track sections shall be used.

4.3.4 Assessment values

4.3.4.1 General

Analysis may be done using different approaches:

- 1) Sway of specific locations on the vehicle body including pantograph
From $\eta = f(\eta^0)$ and $y = f(\eta^0)$ it is possible to determine the sway of the vehicle in general.
- 2) Roll coefficient s_R and roll centre height h_C .
- 3) Roll coefficient s_R .

The approaches using roll coefficient assume approximate linear behaviour. In the case of relevant non-linearities (e.g. side bearer clearances, lateral suspensions with progressive rigidity), a more detailed analysis shall be carried out.

Analysis 2) and 3) relate to the method for vehicle gauging defined in UIC 505.

4.3.4.2 Method 1 – Test on test rig

When measured on a test rig, the roll coefficient is derived as

$$s_R = \frac{\eta^*}{\eta^0}$$

Roll center height may be calculated as

$$h_C = h_P - \frac{y_P - \Delta y^*}{\eta^*}$$

4.3.4.3 Method 2 – On-track test

Analysis based on on-track tests is limited to determination of the roll coefficient. It can be derived from

$$s_R = g \frac{\Delta\eta^+ + \Delta\eta^*}{\ddot{y}} \quad \text{for on-track test and measurement of roll angle differences}$$

in primary and secondary suspension, or

$$s_R = \frac{\ddot{y}^*}{\ddot{y}} - 1 \quad \text{for on-track test and measurement of vehicle body accelerations.}$$

The approach using roll coefficient assumes approximate linear behaviour. In the case of relevant non-linearities (e.g. side bearer clearances) a more detailed analysis shall be carried out.

4.3.5 Limit values

If appropriate the displacement values shall be compared to values specified for the vehicle's kinematic envelope or for vehicle gauging analysis defined in UIC 505.

For a pantograph vehicle the lateral displacement of the pantograph (which can be derived from the measured values) shall be compared to the specified value.

4.4 Rotational resistance

4.4.1 General

The test described in this clause is intended to evaluate body-to-bogie yaw torque. One application is the measurement of yaw torque which is generated by the passage of the vehicle through curves, switches and crossings etc. It may be carried out for the proof of the safety against derailment according to Method 3 (see 4.1.3.4).

4.4.2 Test conditions

4.4.2.1 General

Tests shall be carried out in both directions up to a body/bogie yaw angle of

$$\Delta\psi^* = \frac{a^*}{R_{\min}} + \frac{0,020}{2a^+}$$

This reflects the yaw angle which is achieved in the minimum curve radius $R_{\min}$ specified for the vehicle and includes the effect of wheel-rail clearances.

The test shall be continued beyond the zero yaw angle to enable the hysteresis loop to be closed.

Yaw velocity shall be constant at 1 degree/s over at least ± 75 % of the yaw angle amplitude.

NOTE It is possible to achieve higher yaw velocities than this figure. This will occur at smaller yaw angles. A combination of the maximum yaw angle and velocity is considered as unrealistic.

4.4.2.2 Vehicle conditions

The test vehicle shall have the usual operating equipment. With respect to occupancy with passengers or freight load,

- multiple units,
- passenger coaches, and