BS EN 15827:2011

BSI Standards Publication

Railway applications — Requirements for bogies and running gears

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 15827:2011.

The UK participation in its preparation was entrusted to Technical Committee RAE/3, Railway Applications - Rolling Stock Material.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 68169 1

ICS 45.040

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2011.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 15827

March 2011

ICS 45.040

English Version

Railway applications - Requirements for bogies and running gears

Applications ferroviaires - Exigences pour bogies et organes de roulement

Bahnanwendungen - Anforderungen für Drehgestelle und Fahrwerke

This European Standard was approved by CEN on 26 February 2011.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN 15827:2011: E

Contents

Page

Foreword 4
Introduction 5
1 Scope 6
2 Normative references 6
3 Terms and definitions 8
4 Technical specification and interface management 11
4.1 General bogie requirements 11
4.2 Specification of structural information 12
4.3 Specification of dynamics information 13
4.4 Component specifications 14
4.5 Maintenance specification 15
5 Engineering process 15
6 Structural design criteria 15
6.1 Load definition 15
6.1.1 Principles for establishing design loads 15
6.1.2 Exceptional loads 16
6.1.3 Ultimate loads 17
6.1.4 Fatigue loads 18
6.2 Structural acceptance criteria 19
6.2.1 Principle 19
6.2.2 Utilisation 19
6.2.3 Safety factor 20
6.3 Material strength 21
6.3.1 Requirement 21
6.3.2 Static strength 21
6.3.3 Ultimate strength and stability 22
6.3.4 Fatigue strength 23
6.3.5 Stiffness criteria 24
6.4 Component structural design requirements 25
6.4.1 General 25
6.4.2 Bogie frame 25
6.4.3 Body/bogie connection 25
6.4.4 Axleboxes 25
6.4.5 Axles 26
6.4.6 Wheels 26
6.4.7 Suspension components 26
6.4.8 Attachments and connections 26
6.5 Corrosion protection 27
7 Dynamic performance criteria 27
7.1 Introduction 27
7.2 Dynamic acceptance criteria 28
7.2.1 General 28
7.2.2 Safety against derailment at low speed 28
7.2.3 Running safety and track loading 29
7.2.4 Vibration dose and noise levels 29
7.2.5 Gauging 29
7.3 Ride characteristics and ride comfort 30
7.4 Component dynamic performance requirements 30
8 Acceptance criteria 30

9 Validation of the design ... 30
9.1 Validation plan ... 30
9.2 Structural integrity validation ... 32
9.3 Dynamic performance validation ... 32
9.4 Use of existing validation records ... 33

10 Quality requirements ... 33

11 Maintenance plan ... 34
11.1 Maintenance plan objective and scope ... 34
11.2 Content of a maintenance plan ... 35
11.3 Competences ... 36
11.3.1 Qualification of equipment and systems ... 36
11.3.2 Staff certification and competence ... 36
11.3.3 Maintenance organization ... 36
11.3.4 Qualification of an undertaking for maintenance ... 37
11.4 Records and traceability ... 38
11.5 Unplanned maintenance ... 39
11.6 Revision of plan ... 39
11.7 Implementation of the maintenance schedule ... 40
11.8 Validation of the maintenance plan ... 40
11.9 Maintenance quality requirements ... 40
11.10 Incident/accident damage repair ... 41
11.11 Material disposal ... 41

12 Proven operating envelope ... 41
12.1 General requirement ... 41
12.2 Standardised bogies/running gear for freight wagons ... 42

Annex A (informative) Technical Specification ... 43

Annex B (informative) Engineering process requirements ... 46

Annex C (informative) Design loads ... 47

Annex D (normative) Component related standards ... 48

Annex E (informative) Design development and simulation ... 49

Annex F (informative) Acceptance process flow diagram ... 51

Annex G (informative) Dynamic performance validation by numerical simulation ... 52

Annex H (normative) Minimum requirements for maintenance inspections ... 66

Annex I (informative) Proven operating envelope ... 69

Annex J (normative) Standardised bogies/running gear for freight wagons ... 73

Annex ZA (informative) Relationship between this European Standard and the Essential Requirements of EU Directive 2008/57/EC ... 75

Bibliography ... 78

Foreword

This document (EN 15827:2011) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

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 September 2011, and conflicting national standards shall be withdrawn at the latest by September 2011.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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 2008/57/EC.

For relationship with EU Directive 2008/57/EC, 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, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

The objective of this European Standard is to bring all the separate requirements related to the design and validation of bogies and running gear into one document. Since bogies and running gear are frequently produced by a different organisation to that responsible for the overall rail vehicle it starts by identifying the essential information needed to produce the required design.

The performance requirements for bogies and running gear fall into two related areas, covering functionality and safety, as required by TSI Essential requirements. Functionality relates to such things as speed, load capacity, ride quality and operating life. Safety covers gauging, structural integrity, dynamic performance, resistance to derailment and maintenance, etc.

Taking the requirements as a whole they involve three particular areas of expertise and discipline. Since each of these areas form a different part of the engineering process they have been addressed individually in the following main clauses of this standard, namely:

— structural requirements; Clause 6;

— dynamic requirements; Clause 7;

— maintenance requirements; Clause 11.

These clauses provide details of how the overall objectives are to be achieved in these important specific areas. This document structure is typical of the engineering process for the design, validation and maintenance support of bogies.

A bogie or running gear designed and validated in accordance with this standard will satisfy the Essential Requirements of the rolling stock TSIs.

1 Scope

This European Standard consolidates all the separate requirements specified in rolling stock TSIs and European Standards relating to bogies and running gear together into an overall requirement and process that ensures a functional and safe design is achieved for a defined operating envelope.

There are many European Standards that specify the design requirements and associated processes of bogie and running gear components and sub-assemblies. There are also European standards that specify vehicle performance and validation requirements that depend directly on the bogies or running gear. The objective of this standard is to bring all these separate design criteria together. This is accomplished by specifying the design and validation processes to be used for bogies and running gear with particular focus on the two key disciplines of dynamic behaviour and structural integrity. To ensure that safe operation can be continued throughout the product life the definition of a maintenance plan is also required.

This European Standard is applicable to bogies and running gear intended for vehicles that will operate under the Interoperability Directives on designated TEN routes. The requirements, however, can be used in other applications at the discretion of the interested parties. It specifies the requirements to achieve a satisfactory design of bogie or running gear and to validate the design against the relevant performance and safety criteria. Technical requirements are specified directly or by making reference to the relevant European standards and include the nature and content of an auditable record that should be produced of the design and validation processes.

The requirements address only the design and validation of bogies and running gear. No requirements are set for other systems components that are attached to the bogies or running gear, except to establish that a satisfactory interface has been provided.

NOTE Specifications that relate to bogies and running gear can only be considered in the context of a specific vehicle application. Therefore the performance, both safety and otherwise, can relate only to the bogies and running gear as part of a vehicle configuration and not to the individual elements of the bogies or running gear.

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 473, *Non-destructive testing — Qualification and certification of NDT personnel — General principles*

EN 12080, *Railway applications — Axleboxes — Rolling bearings*

EN 12081, *Railway applications — Axleboxes — Lubricating greases*

EN 12082, *Railway applications — Axleboxes — Performance testing*

EN 12299, *Railway applications — Ride comfort for passengers — Measurement and evaluation*

EN 12663-1, *Railway applications — Structural requirements of railway vehicle bodies — Part 1: Locomotives and passenger rolling stock (and alternative methods for freight wagons)*

EN 12663-2, *Railway applications — Structural requirements of railway vehicle bodies — Part 2: Freight wagons*

EN 13103, *Railway applications — Wheelsets and bogies — Powered axles — Design method*

EN 13104, *Railway applications — Wheelsets and bogies — Non-powered axles — Design method*

EN 13260, *Railway applications — Wheelsets and bogies — Wheelsets — Products requirements*

EN 13261, *Railway applications — Wheelsets and bogies — Axles — Product requirements*

EN 13262, *Railway applications — Wheelsets and bogies — Wheels — Product requirement*

EN 13298, *Railway applications — Suspension components — Helical suspension springs, steel*

EN 13597, *Railway applications — Rubber suspension components — Rubber diaphragms for pneumatic suspension springs*

EN 13715, *Railway applications — Wheelsets and bogies — Wheels — Wheels tread*

EN 13749:2005, *Railway applications — Wheelsets and bogies — Methods of specifying structural requirements of bogie frames*

EN 13802, *Railway applications — Suspension components — Hydraulic dampers*

EN 13913, *Railway applications — Rubber suspension components — Elastomer-based mechanical parts*

EN 13979-1, *Railway applications — Wheelsets and bogies — Monobloc wheels — Technical approval procedure — Part 1: Forged and rolled wheels*

EN 14200, *Railway applications — Suspension components — Parabolic springs, steel*

EN 14363, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles — Testing of running behaviour and stationary tests*

EN 14535-1, *Railway applications — Brake discs for railway rolling stock — Part 1: Brake discs pressed or shrunk onto the axle or drive shaft, dimensions and quality requirements*

prEN 14535-2, *Railway applications — Brake discs for railway rolling stock — Part 2: Brake discs mounted onto the wheel — Dimensions and quality requirements*

EN 14817, *Railway applications — Suspension components — Air spring control elements*

EN 15049, *Railway Applications — Suspension components — Torsion bar, steel*

EN 15085-1, *Railway applications — Welding of railway vehicles and components — Part 1: General*

EN 15085-2, *Railway applications — Welding of railway vehicles and components — Part 2: Quality requirements and certification of welding manufacturer*

EN 15085-3, *Railway applications — Welding of railway vehicles and components — Part 3: Design requirements*

EN 15085-4, *Railway applications — Welding of railway vehicles and components — Part 4: Production requirements*

EN 15085-5, *Railway applications — Welding of railway vehicles and components — Part 5: Inspection, testing and documentation*

EN 15227, *Railway applications — Crashworthiness requirements for railway vehicle bodies*

EN 15273-1, *Railway applications — Gauges — Part 1: General — Common rules for infrastructure and rolling stock*

EN 15273-2, *Railway applications — Gauges — Part 2: Rolling stock gauge*

EN 15313, *Railway applications — In-service wheelset operation requirements — In-service and off-vehicle wheelset maintenance*

EN 15437-1, *Railway applications — Axlebox condition monitoring — Interface and design requirements — Part 1: Track side equipment and rolling stock axlebox*

prEN 15437-2, *Railway applications — Axlebox condition monitoring — Performance requirements — Part 2: Onboard systems*

EN 15528, *Railway applications — Line categories for managing the interface between load limits of vehicles and infrastructure*

EN 15663, *Railway applications — Definition of vehicle reference masses*

EN 15686, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles with cant deficiency compensation system and/or vehicles intended to operate with higher cant deficiency than stated in EN 14363:2005, Annex G*

EN 15687, *Railway applications — Testing for the acceptance of running characteristics of freight vehicles with static axle loads higher than 225 kN and up to 250 kN*

prEN 15839, *Railway applications — Testing for the acceptance of running characteristics of railway vehicles — Freight wagons — Testing of running safety under longitudinal compressive forces*

prEN 15892, *Railway applications — Noise emission — Measurement of noise inside driver's cabs*

EN 50125-1, *Railway applications — Environmental conditions for equipment Part 1: Equipment on board rolling stock*

EN 60721-3-5, *Classification of environmental conditions — Part 3: Classification of groups of environmental parameters and their severities — Section 5: Ground vehicle installations (IEC 60721-3-5:1997)*

EN ISO 3095, *Railway applications — Acoustics — Measurement of noise emitted by railbound vehicles (ISO 3095:2005)*

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1:2009)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13749:2005 and the following apply.

3.1
analysis
assessment of performance by calculation, comparison or simulation that does not require the presence of an actual product (though it may use the results of physical measurements or testing)

3.2
bounce
vertical translational motion, perpendicular to the axis of the running rail, where the two ends of the vehicle, bogie or component part move in phase with the same amplitude

3.3
broadly acceptable risk
level of risk that society considers trivial and is consistent with that experienced in normal daily life and any effort to reduce the risk further would be disproportionate to the potential benefits achieved

3.4
coupling element
component that transfers force and provides relative motion between other components but, though not necessarily intended as its primary function to act as a suspension element, can have characteristics that affect the dynamic motion (e.g. bush for damper/link)

3.5
exceptional load case
extreme load case representing the maximum load at which full serviceability is to be maintained and used for assessment against static strength (see 6.3.2)

3.6
fatigue load case
repetitive load case used for assessment against fatigue strength (see 6.3.4)

3.7
fatigue strength
resistance against failure resulting from cyclic loading

3.8
immediate risk
condition that results in a hazardous situation before there is an opportunity to detect it and take mitigating action

3.9
laboratory testing
performing of tests within a building or restricted area where there is the capability of applying the required inputs and with the equipment capable of monitoring and recording the response

3.10
lateral motion
horizontal translational motion, perpendicular to the axis of the running rail, where the two ends of the vehicle, bogie or component part move in phase with the same amplitude

3.11
load case
set of loads or combinations of loads that represents a loading condition to which a structure or component is subjected

3.12
load spectrum/load collective
defines the numbers of cycles for one or more levels of a repetitive load

3.13
permanent deformation
residual plastic deformation of ductile material, that is not recoverable when the applied load is removed

3.14
pitch
rotational motion about a lateral axis

3.15
proven operating envelope
envelope of safe operation determined by the product validation process expressed in terms of the relevant parameters

3.16
regulations
requirements stipulated by legislation or rules and conditions mandated by legislation or prescribed by an infrastructure controller or relevant industry body, or similar

3.17
roll
rotational motion about a longitudinal axis, parallel to the axis of the running rail

3.18
safety critical component
component, the single point failure of which creates a serious hazard (as identified by the vehicle risk assessment) before there is an opportunity for the risk to be detected and mitigating action taken

3.19
safety factor
factor applied during the strength assessment which makes an allowance for a combination of the uncertainties and the safety criticality

3.20
significant permanent deformation
permanent deformation of an amount that infringes on the functionality of the structure by exceeding the component geometric tolerances

3.21
simulation
numerical method that uses a set of parameters and rules to describe a system (product or component) in a manner that enables a representative response to be determined from a given set of inputs

3.22
structural component
any component or constituent part of a structure that transfers or transmits load from one part of the structure to another

3.23
suspension element
bogie component that is designed to change in geometry when subject to load and in so doing control the motion of one part of the vehicle relative to the other (e.g. spring, damper)

3.24
sway
combination of lateral and roll motion

NOTE Sway often results when lateral forces are induced at the centre of gravity of a vehicle body (due to its inertia) and the suspension/support elements are below or above it.

3.25
testing
subjecting a sample (or samples) of a product to a selection of specified inputs and measuring and recording its responses

3.26
track testing
performing of tests under expected service conditions, on railway infrastructure that represents the actual operating environment, and monitoring and recording the responses

NOTE This is different to on-track testing as required by EN 14363, which requires the test track to have specific characteristics of track layout and the test to cover the planned speed range and cant deficiency applicable to the vehicle.

3.27
type testing
subjecting a sample (or samples) of an identified product type to a selection of specified inputs and measuring and recording its responses

3.28
utilisation
in structural analysis, the extent to which a component is subject to stress relative to the permissible value when taking into account an appropriate safety factor (see 6.2.2)

3.29
validation
process of demonstrating by analysis and/or test that the system under consideration meets in all respects the specification, including requirements due to regulations, for that system

NOTE When applied to a numerical model, validation is the process of demonstrating that the model of the system responds in the manner of the actual system to a sufficient level of accuracy for its purpose.

3.30
verification
process of demonstrating by comparison or testing that an analytical result or estimated value is of an acceptable level of accuracy

3.31
yaw
rotational motion about a vertical axis

4 Technical specification and interface management

4.1 General bogie requirements

The supply of bogies/running gear shall be based on a comprehensive specification. This specification shall consist of all the information describing the functional requirements and the interfaces with associated components and assemblies as indicated below. It shall also comprise the conditions associated with maintenance and any other particular requirements relevant to the application.

The design and validation process requires the integration of different disciplines and areas of expertise and the knowledge associated with them. Therefore, the specification shall include information defining the intended operating conditions of the bogie or running gear. This shall include at least the following:

— vehicle space envelope;

— bogie space envelope;

— physical connections;

— vehicle body mass, payload and load inputs;

— operating speed and cant deficiency limit;

— vehicle body stiffnesses and/or natural frequencies;

— traction system interfaces and performance;

— brake system interfaces and performance;

— hot axlebox detection (HABD);

— other auxiliary systems (e.g. track/train communications);

— vehicle gauge;

— track characteristics;

— static axle load, dynamic wheel load limits;

— operating environment (including environmental conditions);

— duty cycles;

— noise and vibration regulations.

This European Standard applies to the bogies or running gear but they are part of the vehicle as a dynamic system. Therefore, the basic dynamic properties of the vehicle body shall be provided.

The bogie and running gear requirements shall be determined taking into account the overall vehicle characteristics (e.g. the vehicle mass states as specified in EN 15663 and the body structure as specified in EN 12663), the overall dynamic behaviour requirements (e.g. as specified in EN 14363), gauging requirements as required by EN 15273-1 and EN 15273-2 or an alternative standard relevant to the infrastructure and hot axlebox detection as required by EN 15437-1.

There are no general requirements for static axle load, dynamic wheel loads and track loading. The specification shall indicate the infrastructure requirements that apply.

The operating environmental conditions shall be specified in terms of the parameters listed in EN 50125-1 covering, altitude, temperature, humidity, rain, snow and hail, ice, solar radiation and resistance to pollution, plus sea spray according to EN 60721-3-5, Class 5C2. Freight wagons shall comply with altitude class AX with the range set at 2000 m.

The fire standards applicable to the vehicle shall be identified.

The design of bogies and running gear shall take into account any movement constraints imposed by mounted systems (track brakes, antenna, etc.). Requirements shall be stated in the specification.

If the bogie design is to incorporate active components then relevant electrical and pneumatic system interfaces and applicable standards shall be identified. Any electrical bonding requirements shall also be defined.

Some applications may require failure detection systems to be fitted to the bogie or its components. The specification of these systems is outside the scope of this standard except that they shall be treated as any other piece of mounted equipment.

Further guidance on the general content of the specification and the identification of interfaces is given in Annex A.

NOTE If the initial specification does not include all of the necessary information then the missing information should be agreed between the customer, supplier and any other involved parties. It should be recognised that the design is an iterative process and if it is necessary to revise parameters to achieve the desired performance, any changes shall be agreed between the involved parties.

4.2 Specification of structural information

The aspects of the specification that apply to the structural design, and for which specific data shall be provided, are those that affect the geometry and loading, namely:

— bogie/running gear space envelope;

— bogie/running gear physical connections;

— bogie/running gear component masses and attachments, etc.;

— payload and load inputs, including load/unload cycles;

— traction system components, traction characteristic and duty cycle, operating states including fault conditions (e.g. short circuit torque);

— brake system components, brake system characteristics and duty cycle.

Where the loads are dependent on the vehicle masses these shall be expressed as a function of the reference masses given in EN 15663 or to the specific requirements given in the normative references. However, greater details of specific elements than are defined in EN 15663 are required for the purposes of this European Standard.

The masses and inertias of significant components mounted on the bogie and that are not in the bogie designer's control shall be defined. When equipment is resiliently mounted, and the resulting dynamic response can affect the integrity of the system to a significant degree, then the effective characteristics of dynamic parameters (mass, inertias, stiffnesses, damping) shall also be included.

4.3 Specification of dynamics information

The specification shall include those aspects that are particularly relevant to the design and assessment of dynamic behaviour, namely:

— bogie mechanical connections with the vehicle body;

— masses and inertias (e.g. vehicle body parameters) included in the specification;

— other relevant vehicle body characteristics (e.g. stiffness/bending modes) influencing dynamics;

— gauge reference profile (i.e. the vehicle permissible movement envelope);

— bogie movement envelope;

— operating conditions and track characteristics;

— wheel profiles (new to worn) and/or conicity limits if specified.

To correctly design the bogies/running gear the operating condition of the train shall be specified. This shall include at least:

— maximum speed;

— minimum radius curve (including reverse curve);

— maximum cant;

— maximum cant deficiency;

and the following track characteristics:

— track gauge (including any variation due to track widening in small curves);

— rail head profile (new and typical worn);

— inclination of the rail;

— track twist;

— track quality (track geometry deviation relative to line speed).

The track parameters, including the track quality, shall be representative of the intended service routes.

NOTE 1 The way these data are presented will differ, depending on custom and practise of the railway undertaking, the infrastructure manager and the methods employed by the bogie supplier. The Annex of EN 14363 covering "Actual geometry of test tracks" is one form of presentation but may not include all the required data. EN 13803-1 and EN 13803-2 provide data on cant, alignment and minimum curve radii, etc. and will be applicable to new TENS infrastructure.

NOTE 2 The vertical stiffness of the track has a direct effect on the wheel/rail contact forces but it is not usually necessary to consider it when assessing bogie/running gear dynamics. However, it may be relevant in some cases; for example, if high frequency wheel/rail contact force limits are to be considered; then a value for this parameter has to be included in the specification.

Due to limitations on bridges and similar structures, limits may be specified on static and/or dynamic wheel loads and their distribution. If dynamic limits are specified the relevant track characteristics shall also be specified.

The maximum static axle load and the geometric arrangement of the wheelsets on the vehicle shall be specified to enable the vehicle to operate on lines as categorised in EN 15528. Where necessary, alternative limits shall be specified for infrastructure that does not comply with Interoperability requirements.

The shape of the wheel profile has (together with the rail profiles and the track gauge) an influence on the dynamics of the bogies or running gear, such as running stability, curving capabilities, wear, noise generation and ride comfort. EN 13715 defines the tread profiles of wheels with a diameter greater than or equal to 330 mm to fulfil Interoperability requirements. These profiles apply to new wheels. Any profile that does not conform to this standard shall be used only when permitted by the infrastructure manager.

NOTE 3 The specification may include detail of the wheel profile to be used however, if it does not, an appropriate one should be selected to achieve the required performance criteria (see 8.2).

NOTE 4 The specification may include conicity limits together with reference rail profiles and displacement values for the calculation of conicity. EN 15302 details the method to be used to determine the equivalent conicity.

The vehicle body mass and inertias are required for the working order, normal payload and exceptional payload conditions.

The masses, inertias and locations of components mounted on the bogies/running gear that affect the dynamic performance to an extent that the influence is evident (e.g. traction motors, gear boxes, brake system components), and that are not in the bogie designer's control, shall be defined. When such equipment is resiliently mounted on the vehicle body or bogie, the additional dynamic parameters (stiffnesses, damping) shall also be defined.

To enable dynamic and/or quasi-static analysis to be carried out, the relevant vehicle body characteristics shall be defined. Depending on the analysis, this shall include at least:

— vehicle body torsional stiffness;

— vehicle body vertical bending stiffness;

— structural frequencies and associated mode shapes of the above;

— stiffness characteristics of the suspension component's attachment points (e.g. anti-yaw damper attachments).

The vehicle body characteristics used shall be consistent with those achieved in meeting the structural integrity requirements in Clause 6.

The gauge reference profile and its associated set of rules and the proposed vehicle body cross section dimensions shall be specified in a form consistent with the analysis methodology that will enable acceptance in accordance with EN 15273 or an alternative standard permitted by a TSI Special Case or other specified variation.

4.4 Component specifications

Once the global characteristics of the bogies or running gear have been established they shall be translated into the required dynamic performance, structural integrity and other associated characteristics of the constituent parts.

All the functional components shall have a specification that defines their key behavioural characteristics. Examples of these are:

— springs: stiffness, free length, compressed length, minimum and maximum load, etc.;

— dampers: damping rate, stroke, blow-off value, series stiffness, etc.

In general, the individual European standards for components that are referenced in this standard give the corresponding appropriate specification parameters, the design requirements and the performance validation processes. If there is no requirement presented in a component standard then the philosophy given in this standard shall be followed.

All parts of the bogie and running gear have to carry the associated operational loads. For some components, such as the bogie frame or axlebox, transferring loads from one point to another is their primary function but springs, dampers, etc. are also inherent load carrying components. Clause 6 defines in general how structural integrity shall be achieved and demonstrated. For some components (e.g. axles) the design rules in the component standard are a simplification of the general rules, made possible because the component characteristics and/or the design are dominated by a particular load case. In such cases, the simplified approach shall be applied.

The design of attachment brackets, connecting elements, etc, shall be consistent with that of the associated components.

4.5 Maintenance specification

The maintenance requirements are determined by the engineering process and the safe working limits of components in the application.

However, if a railway undertaking or customer has constraints or specific requirements related to the maintenance implementation schedule and that of any associated parameters this shall also be part of the specification.

The specification shall include the information describing the maintenance requirements of the bogies/running gear, and the interfaces with associated components and assemblies, that shall be compatible with the safe operation and maintenance of the vehicle as a whole.

5 Engineering process

Bogies and running gear shall be designed and validated by a consistent engineering process that incorporates all the requirements of this standard. It shall include a quality management system that controls and provides traceability of decision making. Guidance on the content of the process is given in Annex B.

NOTE A process consistent with EN ISO 9001 would meet the above requirements.

6 Structural design criteria

6.1 Load definition

6.1.1 Principles for establishing design loads

The structural design of the bogie and running gear shall be based on a complete definition of the loads to be carried. These shall be interpreted to form a set of design load cases. These load cases then define the loading for each structural component.

All loads to be considered shall be realistic and representative for the bogie/running gear design under consideration taking into account the suspension characteristics, track conditions and vehicle loading profiles.

This shall include both the external loads from the track and vehicle body and loads resulting from the operation of the bogies/running gear and equipment mounted on them. A list of factors that need to be considered in preparing a complete set of design load cases is given in Annex C.

Due to the variety of bogie/running gear designs, configurations and the degree of interaction with the vehicle as a mechanical system it is impossible to define a general exhaustive set of specific design load cases. The requirement of this standard is to implement a process that covers the essential aspects and is consistent with the actual emerging design, configuration and application. When design loads are specified in the normative text of existing component ENs, they shall be used (see 6.4).

The following clauses specify, in terms of their contexts, a minimum set of design load cases that shall be applied. All load cases that do not represent a vertical loading shall be considered in conjunction with the effect of loads due to gravity (e.g. a 1g vertical load case) and any other inherent loading that is present.

All loads used as a basis for the strength assessment of the bogie structural elements shall incorporate any necessary allowances to account for uncertainties in their values or have such an allowance added by adjusting the safety factor used in the acceptance criteria as indicated in 6.2.

NOTE Guidance on design loads due to inertia effects on mounted equipment is given in EN 13749 if no specific information is available that is relevant to the application.

6.1.2 Exceptional loads

6.1.2.1 Basis of exceptional loads

The exceptional load cases for the bogie are derived from the limiting operating conditions under which the vehicle is required to remain fully operational. As a minimum, one of the following exceptional load cases shall be applied in each case for the bogie/running gear as a whole. If the application or specification requires them then the other exceptional cases shall also be applied. For different components of the bogie different load cases may be the most relevant. Additional exceptional load cases will arise due to active systems (traction, braking, tilt, etc.) carried by the bogie/running gear.

NOTE The load cases indicated below are compatible with the load cases specified for the vehicle body in EN 12663. The load factors used for vehicle body loads may not be appropriate for bogie/running gear design.

6.1.2.2 Vertical exceptional load

The following exceptional load case shall be applied:

— exceptional dynamic response to track input.

Where the application or the specification requires them the following load cases shall also be considered:

— low speed derailment (fall from rail to track bed);

— sudden application of bulk loads (freight vehicles).

6.1.2.3 Lateral exceptional load

One of the following exceptional load cases shall be applied:

— vehicle on point of roll over (this will have associated vertical and roll loads);

— Prud’homme limit multiplied by number of axles.

Where the application or the specification requires it the following load case shall also be considered:

— forces due to the mass of the bogie, if the vehicle has rolled over and has to be lifted on its side during recovery.

6.1.2.4 Longitudinal exceptional load

The following exceptional load case shall be applied:

— exceptional shunt acceleration.

6.1.2.5 Twist loading

The following exceptional load case shall be applied:

— load due to maximum track twist.

Where the application or the specification requires it the following load case shall also be considered:

— excessive wheel unloading.

6.1.2.6 Steering loads

The following exceptional load case shall be applied:

— maximum shear forces due to wheelset steering acting across the bogie.

6.1.2.7 Lifting and jacking loads

The situations shall be determined as required by the operating/maintenance procedure.

The following exceptional load case shall be applied:

— lifting/jacking the whole vehicle via designated points on the bogie.

Where the application or the specification requires them the following load cases shall also be considered:

— lifting the bogie directly;

— lifting the bogie via the vehicle body.

The specific strength and safety requirements of any permanently attached lifting fittings and their local attachment shall be considered.

NOTE If there are special requirements for the lifting, transportation or storage of bogies they should be included in the technical specification.

6.1.2.8 Component exceptional loads

The bogie/running gear exceptional load cases shall be interpreted to give the exceptional design loads for each component and its attachments. Load cases that have little influence on the global strength of the bogie/running gear can determine the strength requirements of specific components. For example, the exceptional load case for a primary damper can, in some cases, be due to the mass of the wheelset and any residual force from the primary suspension when the bogie is lifted.

Exceptional loads due to active components shall take into account potential failure modes.

6.1.3 Ultimate loads

In specific cases (e.g. accident scenarios), it may be necessary for safety reasons to prevent rupture and global instability of the structure but to allow permanent deformation when the exceptional load cases are exceeded (see 6.3.3).

The ultimate load case for the body/bogie attachment is specified as that due to the maximum mean accelerations as generated in the crashworthiness scenarios of EN 15227.

NOTE In most cases, where ductile materials are being used, the assessment of exceptional load cases against permanent deformation is sufficient to also cover the potential risks due to rupture and instability due to the large margins between beginning of yielding and ultimate structural failure of components.

6.1.4 Fatigue loads

6.1.4.1 Basis of fatigue load cases

The design fatigue load cases for the bogie shall be representative of the service operating conditions which the vehicle experiences regularly during its operational life. The fatigue load cases shall be based on the vehicle reference mass states in EN 15663. However, for some applications and assessment methods it will be necessary to use additional vehicle loading conditions (expressed as functions of the cases in EN 15663) to obtain an accurate description of the vehicle payload spectrum for design purposes.

The fatigue design loading shall be defined in terms of a number of load cases consisting of load cycles specified in magnitude and number. Combinations of loads shall also be considered and expressed in a manner appropriate to the form of fatigue analysis being used.

The load cases to be used as the basis for the design shall be verified as relevant to the application. This can be done by using data from standards, the results of simulations/calculations, tests, or previous experience consistent with best practice. Where the component inertias contribute significantly to the loading the resulting loads shall be incorporated into the design load cases.

The way in which the load cases are expressed and the material acceptance criteria are defined (see 6.3.4) shall be consistent.

NOTE 1 The way in which the loading is quantified and applied has to correspond with the way in which the permissible stresses are defined. This is particularly important in fatigue analysis; with the endurance limit approach, the stress due to the worst combinations of service loads should be considered, whereas for a cumulative damage approach, the effective stress spectrum due to the combined effect of the load scenarios is required.

NOTE 2 Test requirements specified in standards to demonstrate the endurance of bogie components or the endurance of bogie mounted equipment in a vibration environment are not always intended for structural design purposes and should be used as a suitable basis for structural design only when they can be demonstrated to be appropriate.

Where strength assessments are undertaken using fatigue loads derived from simulations or tests an appropriate factor shall be included in the analysis to reflect the uncertainty in the design load.

As a minimum the following fatigue load cases shall be considered for the bogie/running gear. Additional fatigue load cases will arise due to active systems (traction, braking, etc.) carried by the bogie/running gear and shall also be taken into account.

6.1.4.2 Vertical fatigue loading

A vertical fatigue load case shall be defined representing the vertical dynamic response to track inputs.

For high density commuter applications and some types of freight vehicles it is also necessary to consider a fatigue load case due to vehicle load/unload cycles.

6.1.4.3 Lateral fatigue loading

A lateral fatigue load case shall be defined representing the lateral dynamic response to track inputs (including curving forces). With active suspensions or tilting vehicles the loads resulting from the system operation as well as potentially higher curving forces shall be taken into account.

6.1.4.4 Other fatigue load cases

Depending on the application, the following additional fatigue load cases can be significant and shall be considered when relevant:

— longitudinal load case (related to the vehicle inertia and the expected number of starts/stops and incorporating associated traction/braking equipment forces);

— steering forces, including those generating shear across the bogie frame;

— track twist inputs.

6.1.4.5 Component fatigue load cases

The requirements of the applicable normative references shall be used (see 6.4). When there is no applicable normative reference, the component fatigue design load cases shall be determined from the bogie/running gear loads as described above.

6.2 Structural acceptance criteria

6.2.1 Principle

The requirement covered by this clause for bogies and running gear is the demonstration of structural integrity. The structural integrity is essential for safe operation and compliance with the Essential Requirements of the TSIs and applies to all component parts. Therefore, the associated design and validation process needs to follow a consistent and thorough approach. The approach specified in the following clauses meets this requirement and is also compatible with that specified in EN 12663 for vehicle bodies (the other major part of a vehicle where structural integrity is foremost). Demonstration of structural integrity is based on a combination of static strength and fatigue life assessments using numerical calculations and/or testing.

If the normative standards covering bogie components (e.g. as for axles) contain specific acceptance criteria related to the strength these shall be followed. These criteria do not conflict with the requirements given below but represent a simplification of the general design criteria because of the nature of the component and the dominant loading. If there are no such criteria then the acceptance criteria outlined below shall be adopted.

The reliability of the input data (i.e. loads/geometry) and the assessment method together with the level of utilisation shall be used as the basis to define the level of testing (both laboratory and track tests) and manufacturing quality inspection requirements.

Acceptance criteria for tests need to consider additional parameters (e.g. statistical variations, simplifications necessary for the test arrangement).

If the analytical acceptance criteria cannot be achieved for the structure as a whole (e.g. when the acceptance criteria has been exceeded locally in the analytical procedure) it is permissible to carry out a test that reproduces the design case or the real operating conditions. If the test result meets the acceptance criteria (which shall be adjusted as indicated above) then the requirement can be considered proven.

NOTE The acceptance strategy may involve variations such as adopting a high safety factor with minimal type testing or a low safety factor and extensive type testing.

6.2.2 Utilisation

The utilisation of the component shall be less than or equal to 1 according to the following general equation:

$$U = \frac{R_\mathrm{d}\, S}{R_\mathrm{C}} \leq 1$$

where

U is the utilisation of the component;

R_d is the determined detail stress result from design calculation or test;

S is the design safety factor (see 6.2.3);

R_C is the physical limit stress value of the material (including all appropriate local effects such as surface finish, thickness, etc.).

NOTE In some design codes the safety factor is not explicitly defined but is effectively implemented within the applied load, or by a reduction in the permissible stress value, or a combination of both.

6.2.3 Safety factor

The safety factor shall cover the following uncertainties in the design, manufacturing and validation process:

a) dimensional tolerances

It is normally acceptable to base calculations on the nominal component dimensions. It is necessary to consider minimum dimensions only if there is a large tolerance on thickness (e.g. with castings), there is subsequent machining, or significant reductions in thickness (due to wear, etc.) are inherent in the operation of the component. Adequate protection against corrosion will be an integral part of the vehicle specification. The loss of material by this cause can normally be neglected.

b) manufacturing process

The performance characteristics exhibited by materials in actual components may differ from those derived from test samples. Such differences are due to variations in the manufacturing processes and workmanship, which cannot be detected in any practicable quality control procedure.

NOTE The variations in the manufacturing process with respect to weld quality may be taken into consideration by the adoption of an appropriate inspection frequency as defined by EN 15085 without further allowance.

c) analytical accuracy

Every analytical procedure incorporates approximations and simplifications. It is within the responsibility of the supplier to apply appropriate assumptions in the application of analytical procedures to the design and validation process.

The value of the safety factor shall consider the following with respect to criticality of the component failure:

— consequence of failure;

— redundancy;

— accessibility for inspection;

— level/frequency of quality control;

— detection of component failure;

— maintenance interval.

The safety factor, designated S (≥ 1,0), shall be applied when determining the utilisation. It shall be consistent with the assessment method being used.

When established methods of analysis are being used that have produced safe designs in the past (for example loads from EN 13749 in combination with FE calculations and static/dynamic tests as described in EN 13749), the safety factor can be based on this experience. If the methods have a conservatism included in the approach (i.e. loads of EN 13749) then the safety factor may be an inherent part of the method and S can be taken as 1,0.

6.3 Material strength

6.3.1 Requirement

Structural integrity shall be demonstrated for all components with respect to:

— static strength – i.e. assessment against instability, rupture and permanent deformation which infringes the functionality of the component;

— fatigue strength – i.e. assessment against fatigue failure (crack initiation) resulting from cyclic loading.

The material performance criteria shall be based on the normative references, current European, national or international standards, or alternative sources of equivalent standing. Where no such data is available from standards other data can be used provided it is verified and supported by an appropriate quality control process (equivalent to that adopted in the material standards) to ensure the strength values used in the assessment correspond to the minimum for the material. The material properties shall be compatible with the assessment method applied and the operating conditions as defined in the specification (e.g. applications with extreme low temperatures).

The methods and criteria that are applied in the processes described below are based on accepted industry practice and state of the art knowledge. The same criteria shall be applicable during design and validation testing.

The approach described in this chapter is fully applicable to ferrous and most other metallic materials. For other types of material this approach might need to be adapted and equivalent appropriate assessment methods and criteria applied that are based on the same basic principles.

6.3.2 Static strength

6.3.2.1 Requirement

The static strength requirements correspond to the exceptional load conditions (see 6.1.2) under which the bogie/running gear shall remain fully functional. It shall be demonstrated by calculation and/or testing, that no significant permanent deformation, instability or fracture of the structure as a whole, or of any individual element, will occur under the exceptional design load cases.

Where static strength properties for a grade of material are defined by a range of values the lower limit values shall be used for design purposes.

6.3.2.2 Permanent deformation

The acceptance criterion for the avoidance of permanent deformation is normally taken as the material yield/proof strength (R_{eH} or $R_{\mathrm{p0,2}}$ according to EN ISO 6892-1) A safety factor S_1, as defined in 6.2.3, shall be incorporated when comparing the permissible stress to the determined stress.

For the case of a linear static stress calculation the following applies:

$$U = \frac{\sigma_{\mathrm{c}} S_1}{R_{\mathrm{eH}}} \leq 1$$

where

R_{eH} is the material proof or yield stress in N/mm^2. If R_{eH} is not available then $R_{p0,2}$, the 0,2 % proof stress, shall be used;

σ_c is the determined stress, in N/mm^2;

S_1 is the safety factor according to 6.2.3.

An appropriate failure criterion shall be chosen for the determination of the stress (σ_c) depending on the type of material. For example, for a ductile material it is common to use the Von Mises stress criteria and for high strength brittle materials it is common to use principal stress criteria. The criteria to be used for the choice of the failure mode shall be based on the material ductility and the crack initiation mechanism.

In cases where local plasticity occurs, it shall be demonstrated that the functionality and durability of the structure is not impaired under the exceptional load cases. In determining the stress levels in ductile materials with a linear calculation, the occurrence of stresses above the yield limit shall not automatically imply that the function of the structure is impaired. If the analysis does incorporate local stress concentrations, then it is permissible for the theoretical stress to exceed the yield strength or 0,2 % proof strength of the material. The areas of local plastic deformation associated with stress concentrations shall be sufficiently small so as not to cause any significant permanent deformation (see definition) when the load is removed. The avoidance of significant permanent deformation can be demonstrated by the following approaches as appropriate:

— analytical verification indicating the size of the affected area is sufficiently small to avoid significant permanent deformation;

— use of a plastic shape factor to demonstrate full section plasticity has not taken place; this factor can be determined by analytical methods, non-linear numerical simulations or tests with overload, up to a destructive test.

— the use of realistic or simplified non linear material behaviour to demonstrate that the total maximum strain of the respective material is not exceeded and the permanent deformation is acceptable after removal of the load i.e. still within geometrical tolerances;

— by test to demonstrate that after several load applications the stress/strain behaviour in the measurement positions show a linear behaviour and the permanent deformation is acceptable after removal of the load (i.e. still within geometrical tolerances).

NOTE The determination of allowable values for ultimate total strain and allowable residual strain should be based on the guidance of technical literature considering the type of material and the application.

6.3.3 Ultimate strength and stability

It is necessary to provide a margin of safety between the maximum design load and the ultimate load. This can be achieved by introducing a safety factor, S_2, such that the ratio between material ultimate strength and calculated stress shall be greater than or equal to S_2 by satisfying:

$$U = \frac{\sigma_c \, S_2}{R_m} \leq 1$$

where

R_m is the material ultimate strength, in N/mm^2;

σ_c is the determined stress, in N/mm^2;

S_2 is the safety factor for ultimate strength.

For most applications S_2 = 1,5 is a reasonable value, but this can be adjusted in special cases.

As an alternative to a linear calculation using the above equation, a non-linear calculation with a realistic or simplified material law or a (destructive) test can be performed. Then the required safety factor shall be applied according to the following equation:

$$U = \frac{L_E \, S_2}{L_C} \leq 1$$

where

L_E is the maximum exceptional design load;

L_c is the ultimate load (i.e. the onset of fracture or instability) determined by calculation or by test;

S_2 is the ultimate safety factor for exceptional loads.

There may be internal load effects that shall remain constant (for example shrink fits, bolt pre-load, pre-load due to static masses, etc.) when considering the applied loads that constitute the exceptional load cases.

6.3.4 Fatigue strength

6.3.4.1 General requirement

The behaviour of materials under fatigue loading shall be based on current European or national standards, or alternative sources of equivalent standing, wherever such sources are available. For the design assessment verified data shall be used. If such data is not available, it shall be determined by suitable tests appropriate to the application.

Fatigue strength shall be evaluated using S-N curves derived in accordance with the following:

— a survival probability of at least 95 %;

— classification of details according to the component or joint geometry (including stress concentration);

— interpretation of the limiting values from small-scale samples by the use of a test techniques and previous experience to guarantee applicability to full size components.

The fatigue strength shall be demonstrated by one of the following methods:

a) endurance limit approach (see 6.3.4.2);

b) cumulative damage approach (see 6.3.4.3):

c) other established methods.

The methods can be applied to predicted and/or measured stresses resulting from analysis and testing respectively.

The nature and quality of the available data influence the choice of method to be used as described in 6.1.4. The material performance data shall take into account residual stress in the structure as a result of fabrication processes such as fusion welding. It is permissible to take advantage of techniques to reduce the influence of residual stress such as stress relieving, shot blasting and ultrasonic impact treatments where evidence of their benefit can be verified.

Test methods to demonstrate the fatigue performance or to verify the calculation results may be part of the validation plan described in Clause 9.

Other established methods of carrying out life assessment and determining safe inspection intervals, such as a fracture mechanics approach, can be used in the design and validation processes when appropriate.

6.3.4.2 Endurance limit approach

This approach can be used for areas where all dynamic stress cycles remain below the material endurance limit commensurate with its application (including effects of size, surface finish, etc.). Where a material has no defined endurance limit or some repetitive stress cycles exceed the limit, the cumulative damage approach shall be followed.

The required fatigue strength is demonstrated provided the stress, due to all appropriate combinations of the fatigue load cases defined in 6.1.4 or measurement results determined in accordance with 9.2 remain below the material endurance limit.

It is permissible for stress cycles due to exceptional load cases to exceed the endurance limit since, by definition, they do not occur sufficiently often to significantly affect the durability.

6.3.4.3 Cumulative damage approach

This approach is an alternative to the endurance limit approach. Representative histories for each load case shall be expressed in terms of magnitude and number of cycles. Due regard shall be given to combinations of loads which act in unison. The damage due to each such case in turn is then assessed, using an appropriate material stress - cycle diagram (Wöhler Curve), and the total damage determined in accordance with an established damage accumulation hypothesis (such as Palmgren-Miner).

It is permissible to simplify the load histories and combinations, provided this does not affect the validity of the results.

The required fatigue strength is demonstrated provided the total damage at each critical detail, due to all appropriate combinations of the fatigue load cases, is below unity (1,0). Similarly, when applied to test results, the cumulative damage at such details (as determined from stress cycles measured during tests as required in Clause 9) shall remain below unity when the test results are extrapolated to represent the stress history over the full vehicle life.

NOTE Some fatigue design codes/standards recommend that a lower cumulative damage summation limit should be applied (< 1,0). The use of a lower value should be consistent with the code/standard being adopted.

6.3.5 Stiffness criteria

Stiffness requirements arise in two main areas.

The first requirement is that deflections under load shall be confined to levels that will not impair functionality. This limitation applies to the structure as a whole and the need to constrain all movements to the permissible vehicle envelope (reference profile). Deflection limits can also be relevant at a global or detailed level to the functioning of equipment and mechanisms, etc. that are carried by or form an integral part of the bogies/running gear.

The second requirement is to ensure that the stiffnesses of the bogie structural components and equipment attachments are such that no unacceptable structural resonances occur. In this context the body/bogie connection needs to be designed so that bogie natural vibration modes are separated or otherwise decoupled from those of the vehicle body.

Where such requirements involve a scope of supply other than that of the supplier of the bogie it is necessary for the parameters associated with these requirements to be part of the specification.

6.4 Component structural design requirements

6.4.1 General

Demonstration of component strength shall be according to the requirements in the standards referenced in the following sections. If the standards do not specify sufficient verification then additional requirements shall be added based on the principles given in this standard.

The strength of attachment brackets and coupling elements shall be consistent with that of the associated components.

If part of the bogie structure is loaded by internal pressure and this is the dimensioning design load then this structure shall be designed and maintained as a pressure vessel. If the design is dimensioned by loads other than internal pressure (e.g. forces, moments) then it shall be designed and maintained as normal structure.

NOTE In making the above distinction, fracture mechanics, or similar techniques, can be used to demonstrate whether unstable crack propagation will occur at the working pressure levels. Where the components have been developed from an earlier design a validation process as described in 9.4 may be applied.

Changes shall not be made to the manufacturing process without checking that the conditions assumed in the design process are still achieved.

Annex D summarises the standards applicable to bogie component design.

6.4.2 Bogie frame

The process to be followed when specifying and demonstrating the structural requirements for bogie frames shall be as given in EN 13749.

The design loads shall be determined as described in 6.1 above and shall be consistent with those in 6.4.3 below. They shall include the loading due to accelerations of self mass and bogie mounted equipment.

6.4.3 Body/bogie connection

The design loads shall be determined as described in 6.1 above and shall be consistent with the body/bogie connection loads for the body structure (see EN 12663).

To provide a resistance to bogie detachment during a collision the ultimate strength of the longitudinal body/bogie attachment shall be consistent with the highest mean deceleration rate as determined when satisfying the vehicle crashworthiness requirements in the scenarios in EN 15227 and as required by EN 12663-1.

No analytical strength assessments shall be produced for freight vehicle body/bogie attachments if the vehicle is shown to have passed the tests defined in EN 12663-2.

NOTE A customer may require that the body/bogie connection be designed to deform before the main vehicle body and bogie structural members (and so reduce the risk of more serious damage). This is a contractual issue and not a requirement of this European Standard, but the solution shall ensure that all normative interface requirements are still satisfied.

6.4.4 Axleboxes

The process to be followed when specifying and demonstrating the structural requirements for axleboxes shall be as given in EN 13749.

The design loads shall be determined as described in 6.4.2 above and shall include the loading due to accelerations of self mass and axlebox mounted equipment.

The axlebox design shall also take account of the axlebox condition monitoring requirements of EN 15437-1 and prEN 15437-2 when they apply.

6.4.5 Axles

The structural design requirements for standard axles shall be as specified in EN 13103 and EN 13104 for non powered and powered axles respectively.

Axles with inboard bearings shall be designed to modified load cases derived using the same external inputs as those applied to standard axles. The same rules for the permissible stresses shall be applied.

NOTE When designing inboard bearing axles particular attention should be paid to the bending moments resulting from axle mounted equipment such as drive units and axle mounted brake discs as these can have a greater influence on the axle stresses than with a conventional outboard bearing axle.

6.4.6 Wheels

The structural requirements for the design and technical approval of rolled and forged wheels shall be as specified in EN 13979-1.

NOTE If cast wheels are used they should be compliant with standards demonstrated to be suitable for the application.

6.4.7 Suspension components

The standards specifying the requirements of suspension components are included in Annex D.

Suspension components shall be supplied to specified performance characteristics that shall include the exceptional and service loads that they have to sustain. They shall be tested to demonstrate that they are suitable for their purpose. If data is not available from the supplier the necessary demonstration shall be incorporated in the validation plan described in Clause 9.

When European standards are insufficient and it is necessary to use data from national standards (e.g. when designing steel springs) a consistent set of national standards shall be used.

6.4.8 Attachments and connections

6.4.8.1 Fusion welding

The welding of railway vehicle bogies and running gear shall be carried out in accordance with EN 15085 or an alternative equivalent set of procedures.

6.4.8.2 Bolted connections

Bolted connections shall be designed and assembled to standards that have been shown to be appropriate for the application.

NOTE Examples of published design guidelines/standards are VDI 2230, DIN 25201 and NF E 25 030.

It is normal practice to design bolted connections not to slip or separate under exceptional loads. However, if such an extreme event (as for example an accident) will be known to have occurred and the maintenance requirements require the joint to be subsequently inspected and checked after the event, this can be permissible.

The design standards and the quality system used in the assembly of bolted connections shall be consistent.

Risks associated with the use of bolted connections and the need for locking and/or secondary restraint shall be assessed as required in Clause 5. The need for (and the choice of) locking systems shall be based on satisfactory past experience in similar applications.

6.4.8.3 Interference fits

The requirements for the fitting of wheels to axles shall be as defined in EN 13260.

Other interference fit connections should be designed using established procedures. It is normal practice to design them not to slip under exceptional loads. However, if such an exceptional event will be known to have occurred and the maintenance requirements require the joint to be subsequently inspected and checked after the event, this can be permissible.

NOTE Examples of published design standards for interference fits are DIN 7190, NF E 22 620, NF E 22 621 and NF E 22 622.

The method of assembly and the quality system used to control the production and assembly process shall be consistent with the design assumptions.

6.5 Corrosion protection

The principal purpose of the corrosion protection treatment is to preserve all components in a state compatible with maintaining the intended structural integrity. If the bogie corrosion protection system is not specified in regulations or as part of the supply contract a suitable protection system shall be applied.

The corrosion protection of wheels and axles shall be as covered by EN 13262 and EN 13261 and other wheelset components by EN 13260.

Corrosion protection of other bogie components shall be in accordance with the standards applicable to the components, taking account of the operating environment.

The interior areas of the bogie structures that form air reservoirs shall be given suitable protection against corrosion for the material. The protection shall be consistent with that specified for other reservoirs in the vehicle air system.

At interfaces involving different materials suitable measures shall be taken to prevent electro-chemical corrosion.

Closed sections that are not protected against corrosion shall be made water tight or provided with drain holes to avoid water collecting inside.

The application of the corrosion protection system shall be compatible with the design requirements and the assembly and maintenance instructions.

Suitable corrosion protection shall be specified and applied to parts for delivery and storage prior to assembly.

7 Dynamic performance criteria

7.1 Introduction

Factors within the control of the bogie designer and that have a strong influence on the dynamic behaviour or on the derailment resistance of the vehicle are:

- the masses, inertias and the distance between wheelsets;
- the stiffness and damping characteristics of suspension components and the positions of their connections;
- the connections between the bogie frame, axles and vehicle body;

- the interactions between the bogie dynamics and the vehicle body and its mounted equipment; this interaction can be the result of frequency coincidence between the natural modes of vibration of the bogie, the body and the body mounted equipment or as a result of the geometric location of attachment points (e.g. modal vibration due to the bogie pitch frequency being coincident with the natural body bending frequency);

- the geometrical tolerances between components;

- the forces resulting from the above including the contact forces between the wheel and the rail which are relevant for the structural design of the bogie frame (see Clause 6), the running safety and the track loading (see 7.2);

- wheel profile.

The wheel-rail interface characteristics are influential but the designer has limited influence over these characteristics other than by the choice of the wheel profile.

Annex E gives guidance on the processes involved in the development of a bogie/running gear dynamic design.

It is recognised that because of manufacturing tolerances and variations in the operating environment the values of bogie and running gear component parameters will vary. Therefore, the normal acceptance criteria include a margin that takes account of this and that more extreme values/conditions than those in the actual test will usually be possible. This safety margin is inherent in the acceptance criteria and, unless a standard specifically states otherwise, typical component values shall be used in tests. Similarly, the nominal parameters shall be used in simulations supporting validation.

NOTE 1 The French standard NF F 32 101 gives guidance on dimensional tolerances and specifies values that are appropriate to some applications.

The bogies or running gear can satisfy the applicable regulations and the specification of the railway undertaking in accordance with the relevant standards only in combination with the vehicle body and associated equipment. This is inherent in the requirements considered in the following clauses.

For dynamic performance validation, it is permissible to use numerical simulations in place of testing as described in 9.3.

NOTE 2 Ride characteristics, ride comfort and the vibration dose are assessment quantities based on the frequency and magnitude of accelerations experienced within a rail vehicle. They can be generated by a number of different sources dependent upon the vehicle type. Vehicle body mounted rotating equipment such as diesel engines or electric motors can be a significant source of these accelerations. The accelerations that derive from the bogies/running gear interface with the track are, therefore, only part of the overall accelerations experienced. The significance of the various sources will depend on each specific design.

7.2 Dynamic acceptance criteria

7.2.1 General

The following requirements are essential to the safe performance and acceptance of the bogies and running gear. Though they are specified as vehicle safety criteria, the bogies or running gear are either the controlling contributors in achieving compliance with the requirements or otherwise influence the results. Therefore, they are requirements with which the design of the bogies/running gear has to comply.

7.2.2 Safety against derailment at low speed

7.2.2.1 Twisted and curved track – all vehicles

Derailment resistance shall be demonstrated by meeting the criteria defined in EN 14363 under “Safety against derailment for railway vehicles running on twisted track”.

To ensure the margin of safety against derailment is not reduced unacceptably, in some cases the variations in static wheel loads require control. The variation shall be limited to the level required for the application. In this case, the control shall be reflected in the quality requirements referred to in Clause 10.

7.2.2.2 S-shaped curve - freight wagons

The running safety requirement concerning S-shaped curves, for the operation of freight wagons that come within its scope, is specified in prEN 15839.

7.2.3 Running safety and track loading

The acceptance criteria related to:

— running safety including running stability;

— track loading;

are specified in EN 14363 under "'On-track' tests" together with the relevant test procedures and conditions for dispensation, use of simplified measuring methods, or a reduced acceptance programme under defined circumstances.

NOTE 1 Target in-service equivalent conicity limits for operating are given in the CR TSI RST. At the time of publication, the contribution to overall effective conicity due to the wheel and the rail contact geometry and the method of control of each subsystem is an open point.

The scope of EN 14363 is restricted to vehicles with axle loads up to 22,5 t and to vehicles accepted for cant deficiencies up to 165 mm. For wagons with higher axle loads, up to 25 t, the corresponding requirements are given in EN 15687. For railway vehicles equipped with a cant deficiency compensation system and/or vehicles intended to operate with a higher cant deficiency than stated in EN 14363 the corresponding requirements are given in EN 15686.

NOTE 2 Vehicles subject to the HS TSI RST will need to comply with its requirements for stability monitoring.

7.2.4 Vibration dose and noise levels

The accelerations (vibration) experienced by workers (train crew) are limited by the Physical Agents (Vibration) Directive, 2002/44/EC.

NOTE This directive specifies a maximum daily vibration dose of 1,15 m/s^2 (A(8) criterion) and requires that if a daily vibration dose exceeds 0,5 m/s^2 every reasonable practical effort has to be made to reduce it to as low a level as possible. If measurements are required they should be made in accordance with ISO 2631-1 and EN 1032 for a nominal 8 hour working period. Often most of the relevant vibrations associated with a high level of dose come from sources that are in the vehicle body and are not related to the bogies/running gear and their suspensions, which make only a small contribution.

There is no mandatory vibration dose limit for passengers. For guidance on ride characteristics and ride comfort see 7.3.

The permitted pass-by noise and the noise level to which train crew are subjected is specified in regulations (e.g. RST Noise TSI and HS TSI RST) and the bogies/running gear contribution has to be taken into account. Measurement shall be in accordance with EN ISO 3095 or prEN 15892 or an equivalent standard specified in the applicable regulations.

7.2.5 Gauging

Gauging acceptance shall be as specified in EN 15273-1 and EN 15273-2 or by an alternative method relevant to the infrastructure (see 4.1) required by regulations or the specification. Given the vehicle body dimensions, compliance with the specified reference profile is largely determined by the vehicle's sway characteristics. The sway characteristics are dependant on:

- the suspension parameters controlling movement in the vertical and lateral planes and roll stiffness,
- the position of the centre of gravity of the vehicle body,
- the suspended masses of the vehicle.

Methods for validation of the assumed sway characteristics by testing are given in EN 14363, under “Sway characteristics”. In some cases, with a sufficient margin, a calculation of the roll coefficient is, in itself, an acceptable method of gauging.

7.3 Ride characteristics and ride comfort

The bogies/running gear (except for TSI compliant freight vehicles), in combination with the vehicle body, shall satisfy the specification of ride comfort of the railway undertaking when determined in accordance with standards such as EN 12299.

The ride quality values given in EN 14363, under “’On-track’ tests”, are presented as good practice values for accelerations and are not safety or obligatory limits. This clause of EN 14363 also gives guidance on appropriate considerations if values above the stated limits occur.

NOTE The above are important to the performance and acceptance of the vehicle by the customer but are not specific to the TSI Essential Requirements. These characteristics, which are directly dependent on the performance of the bogies or running gear, are usually part of the contractual requirements.

7.4 Component dynamic performance requirements

The characteristics of the main suspension components determine the dynamic behaviour of bogies and running gear. The component parameters needed in their specifications and the required performance criteria are given in the European standards that cover each type of component. The list of components and the corresponding standards to which they need to comply is given in Annex D.

All parts incorporated into the bogies/running gear (wheels, axles, bogie frame, brake gear, etc.) also have an influence on dynamic behaviour. This is a result of their mass and inertia and, where necessary, permissible limits shall be made clear in their specification.

8 Acceptance criteria

Safety, reliability and availability are achieved by complying with the requirements of this standard as expressed in the structural requirements of Clause 6, the dynamic requirements of Clause 7 and the maintenance requirements of Clause 11 and the associated component standards listed in Annex D.

In addition, the design shall satisfy the environmental conditions, electrical and pneumatic system performance, fire resistance and HABD compatibility as indicated in 4.1.

9 Validation of the design

9.1 Validation plan

A validation plan shall be prepared covering all necessary validation activities and the strategy for demonstrating compliance. The validation is an integral part of the engineering process and shall be developed from the initial concept and the subsequent evolution of the design.

A validation plan shall consider the following elements:

- analysis;

- laboratory tests;
- track tests.

The initial validation that a design has met all the requirements is to be provided by the associated design documentation and analysis (drawings, calculations, component specifications and tests, etc.). The general scope of the validation data will be the same for all bogies and running gear. The testing will be primarily concerned with confirming the bogies/running gear structural integrity and dynamic performance as part of a vehicle. This shall include validation of the bogie/running gear interfaces with adjacent equipment under all static and dynamic conditions for the designated range of payloads and track inputs. In particular, movements and design clearances shall be confirmed under all potential operational conditions (including, for example, those related to failed active suspension components). The details of the structural and dynamic tests required to demonstrate the acceptance of the bogie/running gear are given in 9.2 and 9.3 respectively.

The extent of laboratory or track testing will depend on the degree of originality and change and the level of confidence in the analytical results. The test programme shall consider primarily the areas of originality or change.

Any existing design and test data from a previous design that is still relevant can be used in support of the validation of the new bogie or running gear variant as discussed in 9.4. This principle also applies to any subsequent modifications.

When track tests are performed, or laboratory tests are representing track inputs, the track or its representation relevant to the scope of the tests shall be consistent with the required operating conditions.

It is permissible to use simulation in place of (or to supplement) dynamic testing in accordance with the constraints of 9.3 if a validated vehicle model and track input data are available that conform to the stated requirements.

Specimens subject to test shall be of the same type and manufacture as those to be used in service (i.e. they shall have no differences in any critical factors that could influence the outcome of the tests). In the case of an order for a small number of bogies/vehicles it may be impractical to justify performing a normal programme of laboratory and/or track testing. However, if these steps are not used as part of the validation other measures shall be taken to compensate for the lack of testing. This can be done, for example, by using simulation in conjunction with higher safety margins in the design process or by applying more or tighter controls during the maintenance processes. Any such decision shall be documented, with supporting justifications.

NOTE 1 A typical overall acceptance programme and the interactions between the parties involved are presented as a flow diagram in Annex F. This process applies to both the constituent parts and to the bogies or running gear as a whole assembly. The parties comprising the supplier and customer, etc. will not always be the same. The successful completion of the validation of the design constitutes an intrinsic part of the acceptance process and is the only part within the scope of this document.

NOTE 2 The validation plan is generally prepared by the supplier and then, agreed by the customer and/or the approval authority. A safety assessment/risk analysis is an appropriate tool in determining the content of a validation plan but it is recognised that a comprehensive formal recording of potential hazardous events at the design stage is not normal practice for individual mechanical components (e.g. wheels and axles) and risk is addressed by adopting proven safe practice in the design, manufacture and maintenance procedures of these components.

NOTE 3 Validation specifications should include procedures, inputs, measurement accuracy, pass/fail criteria and quality management.

NOTE 4 All software used for theoretical analysis, simulation or the analysis of test data that is submitted as part of the validation process should have an established pedigree in its field of application or be supported by specific corroboration of its suitability and accuracy. Similarly, test facilities used in the validation process should be suitably qualified for the type of work being undertaken.

9.2 Structural integrity validation

Due to the variety of bogie concepts, configurations, applications and validation strategies it is not possible to define a generally applicable exhaustive structural validation plan. This standard specifies requirements for the formal composition and minimum content of a validation plan, which allows compliance to be demonstrated. Although this process is not specific for bogies the safety relevance requires such a mandatory process. The plan shall detail all the validation steps necessary to demonstrate that the risk of structural failure is broadly acceptable.

When an applicable normative reference deals with a component, the structural integrity validation of the component shall follow the requirement of the normative reference.

Generally the structural validation shall include (but not be limited to) the following:

- analytical strength assessment;
- laboratory testing (static and fatigue as appropriate);
- life assessment from on track measurements.

All structural components shall be analysed and/or tested to demonstrate that they will carry the loads to which they are subject.

In principle, the same acceptance criteria shall be applied to both the design and testing phase; e.g. if the endurance limit approach is used for the analytical verification of the design it shall also be applied for testing. During testing, if the design cannot be verified using the basis of the endurance limit approach then a life assessment using an appropriate cumulative damage approach can be undertaken.

It is acceptable for the structural analysis results of some areas of the structure to show that the requirements are not met if it is subsequently demonstrated that the requirements are achieved in laboratory tests (which apply the design conditions) or by tests under representative service conditions (track tests).

The changes associated with the structure and/or the application shall always be validated by analysis. Where a test of the original component was not considered necessary or the global load path is unchanged and the stresses remain below the acceptable limits it is sufficient to demonstrate acceptability only by analysis unless the regulations specifically require testing.

The extent of laboratory or track testing shall follow the principles in 9.1 and the requirements in the component standards (in particular EN 13749) and shall consider primarily the areas of originality or change in the design, the applied loads and the manufacturing processes. The content of the test programme shall also be based on the level of utilisation and the criticality of the components.

NOTE 1 It is acceptable to introduce explicit additional safety factors to reduce the probability of failure of a component and, therefore, the necessary degree of testing.

NOTE 2 The load cases for freight wagon bogies are often based on the experience of the railways over a long period of time and these loads are generally applicable to all similar freight bogie designs. It is common practice that a freight bogie which has passed an appropriate fatigue test will not be subject to on-track structural assessment tests (only to those validating the dynamic behaviour).

9.3 Dynamic performance validation

The validation of the vehicle dynamic performance shall consist of demonstrating compliance with the acceptance criteria specified in 7.2 of this standard. In addition, the validation shall consider the following aspects that may influence the safety of the vehicle even if they are not directly assessed by the safety related criteria, namely:

- where features of the design have a strong influence on a dynamic performance;

— where, as part of the product risk assessment, the design has been identified as containing especially critical features.

The dynamic performance of the bogies/running gear shall be validated by tests (static tests and track tests), or by simulation under controlled conditions. The objective when using simulation is to achieve the same level of confidence in the results as would be achieved by testing. The simulation process described in Annex G (until this option is incorporated into a CEN Technical Specification or a revision of EN 14363) sets out one means by which this can be achieved. Other simulation procedures that achieve the same level of confidence are also acceptable.

When track testing or simulation is carried out, the vehicle, bogies/running gear configuration and the track conditions shall conform to the applicable clauses in EN 14363 and be representative of the intended operational conditions.

9.4 Use of existing validation records

In practice, a design is often a development of a previously proven design. Where validation evidence from an earlier product is still applicable it may be used to support the new product or application. The validation plan shall demonstrate how and why the earlier evidence is still applicable and then focus on the validation of the changes. In this context, evidence can be in the form of previous analysis or test results or it can be in the form of accumulated satisfactory service experience.

NOTE 1 Evidence that a component has functioned in a comparable operating environment with only the planned level of scheduled attention can be used as demonstration of satisfactory performance without any further analysis or test data.

The effects of any changes shall always be established by analysis and/or testing.

For small changes it is not necessary to carry out any further testing, especially if the original analysis and test results agree and give high confidence in the predicted effect of the change, or there is a large reserve of safety, or the detail was not originally considered of sufficient importance to require validation by test.

NOTE 2 For dynamic validation the above concept is already incorporated in EN 14363.

10 Quality requirements

Bogies and running gear are inherently safety critical components. Therefore, it is essential to ensure that all manufactured products behave as demonstrated by the validation process of this standard. A quality plan provides the only link between the design and validation data and the final manufactured products. To produce a proven safe end product the production programmes shall be subject to a quality plan such that all manufactured bogies/running gear are of a quality consistent with the assumptions and data used as the basis of the design and validation. The quality plan shall also ensure that necessary maintenance requirements to guarantee continued safety and functionality are identified and defined in a maintenance plan.

Changes shall not be made to the manufacturing process without confirmation that the conditions assumed in the design process are still achieved.

The quality plan shall encompass the introduction of subsequent modifications with the same levels of control as the original design, validation and manufacturing processes and the associated maintenance.

The detailed specification of this quality plan is outside the scope of this document.

11 Maintenance plan

11.1 Maintenance plan objective and scope

All bogies and running gear incorporate components that are subject to wear and deterioration during their working life. Therefore, to maintain functionality and safety it is necessary to follow a prescribed maintenance plan.

Bogies/running gear shall be operated in service only within the period for which an appropriate maintenance plan is provided as follows:

— Initial plan: at least the regular day-to-day maintenance requirements when a product first goes into service.

— Longer term plan: additional maintenance and overhaul instructions developed taking into account service experience.

The objective of maintenance actions carried out on the bogies or running gear shall be primarily aimed at ensuring that the bogies or running gear (and hence the vehicle) remain in a condition that enables the safe performance to be sustained. The maintenance limits shall be set (e.g. the allowable operating distance in which a worn wheel profile would develop to give the maximum permitted equivalent conicity) to ensure the characteristics of the components that affect the performance of the bogie in relation to the operating envelope stay within the proven limits as determined by the design and validation requirements of this standard.

The maintenance rules for elements of the bogie or running gear shall be determined by consideration of the particular features of the concept, analysis of the specific function, significance (in terms of influence on safe performance) of the suspension elements and previous experience. This previous experience shall take into consideration any change to the characteristics of the bogie components compared with their use in similar previous operations and the intended service schedule.

The maintenance plan shall incorporate the following features:

— inspection frequency;

— checks to be carried out;

— pass/fail criteria;

— corrective action;

— facilities;

— staff competence.

NOTE The use of condition monitoring can influence how the above features are addressed.

Since bogies range from simple (for example those fitted to freight vehicles) to complex designs, including those fitted with active components (for example on a tilting train), the maintenance rules shall reflect the specific needs of the application.

The following clauses specify in more detail the constituents of a suitable maintenance plan, the methods of specification and mechanisms for implementation and record keeping.

A list of bogie component parts (and the associated standards) that need to be considered in the maintenance plan is included in Annex D, though the plan shall require the general inspection of all parts of the bogie for damage, wear, corrosion, etc.

The scope of the maintenance plan for the bogies or running gear comprises a list of actions that need to be carried out to the bogies/running gear configuration in order to satisfy the above objective.

11.2 Content of a maintenance plan

To ensure a product meets the required functional performance criteria and is safe to operate throughout its life it is necessary to have clear definitions of the necessary actions to be taken. The formation of this knowledge base during the design and validation process is an essential prerequisite to the production of a maintenance plan.

The aspects of the bogie or running gear design that are particularly relevant to a maintenance plan are:

- construction and assembly details;
- bogie physical connections (bogie to body, bogie to wheelset, etc.);
- wheelsets;
- wheel profiles;
- suspension components (springs, dampers, etc.);
- attachments of other system components on the bogies/running gear:
  - traction system parts;
  - brake system parts;
  - auxiliary equipment parts (flange lubrication, current collection, etc.);
  - safety parts and safety system components (lifeguards, antenna, etc.).

Further requirements on the scope and content of maintenance actions are given in Annex H.

The vehicle maintenance plan shall identify the frequency and content of planned safety examinations/routine maintenance necessary to preserve vehicle safety. It shall also indicate those situations that will initiate additional specific safety examinations and actions under defined circumstances.

The plan shall consist of the following three main elements:

- identification of inspection/maintenance tasks and acceptance criteria:

  All components of the bogie which can present risk with respect to their continued functionality shall be identified. Deterioration in performance may be due to component design life (e.g. distance or time), wear, corrosion, etc. In each case, the safe limit for operation shall be identified along with the inspection procedure to be used to establish the condition. Any special skills or equipment needed to carry out the inspection tasks shall also be identified.

- Inspection/maintenance intervals:

  The necessary inspection interval shall be defined such that the component will not deteriorate to an unsafe condition or unacceptable functionality between inspections.

- Corrective/remedial action:

  The actions to be taken when the acceptance criteria are not satisfied shall be defined. This shall include materials, handling equipment, special tooling and skills required to carry out the corrective action.

The presence of condition monitoring systems can be used to influence the way in which the above activities are addressed.

The organisations undertaking the maintenance of bogies and running gear shall have a quality management system in place that incorporates the competence and skills of personnel and suitability of equipment (see 11.3).

Wheelset maintenance shall be in compliance with the requirements of EN 15313.

NOTE An organisation compliant with EN ISO 9001 satisfies the quality management system requirements.

11.3 Competences

11.3.1 Qualification of equipment and systems

All relevant equipment, tools, gauges and systems for bogie maintenance shall be qualified to ensure that:

- the mandatory requirements of this European Standard are met;
- mandatory operations can be carried out.

A qualification file shall be created for all relevant equipment in order to ensure that it meets the specifications. This file shall indicate that the equipment or system has the appropriate levels of sensitivity and repeatability in line with the desired objective. Performance sustainability shall be demonstrated by means of calibrated reference equipment. In addition, when new methods are used, it shall be ensured that the results achieved with the new equipment or system are at least equivalent to those obtained with the former (differentiation between parts with or without defects, etc.).

11.3.2 Staff certification and competence

Certification of competence is necessary for staff carrying out specialized tasks, including:

- non-destructive testing;
    - the staff qualification shall be according to EN 473 or to an equivalent standard;
    - the workshop manager shall authorise them to work only on specific processes for which they are qualified.
- welding operations;
    - processes and staff shall be qualified according to EN 15085-1 to EN 15085-5 or to equivalent requirements.

11.3.3 Maintenance organization

The general maintenance of the bogies and running gear is to be organized as shown in Figure 1.

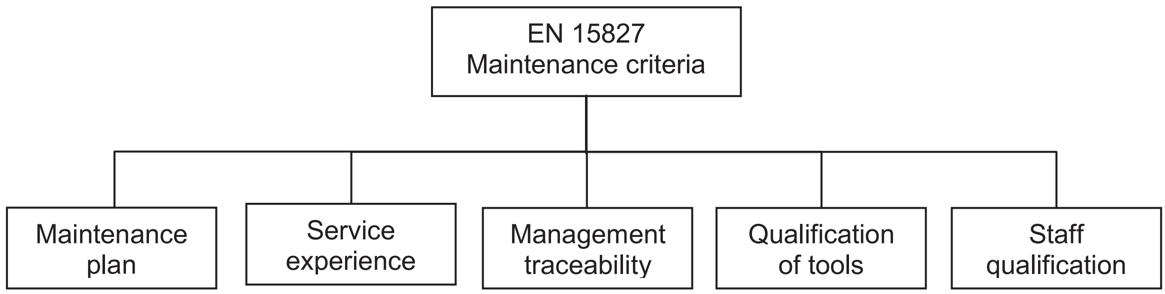


Figure 1 — General maintenance organisation

11.3.4 Qualification of an undertaking for maintenance

For an undertaking carrying out maintenance the qualification principle shown in Figure 2 applies to:

— maintenance of in-service bogies and running gear;

— maintenance of off-vehicle bogies and components.

The qualification shall be adapted when any new bogies or running gear are introduced.

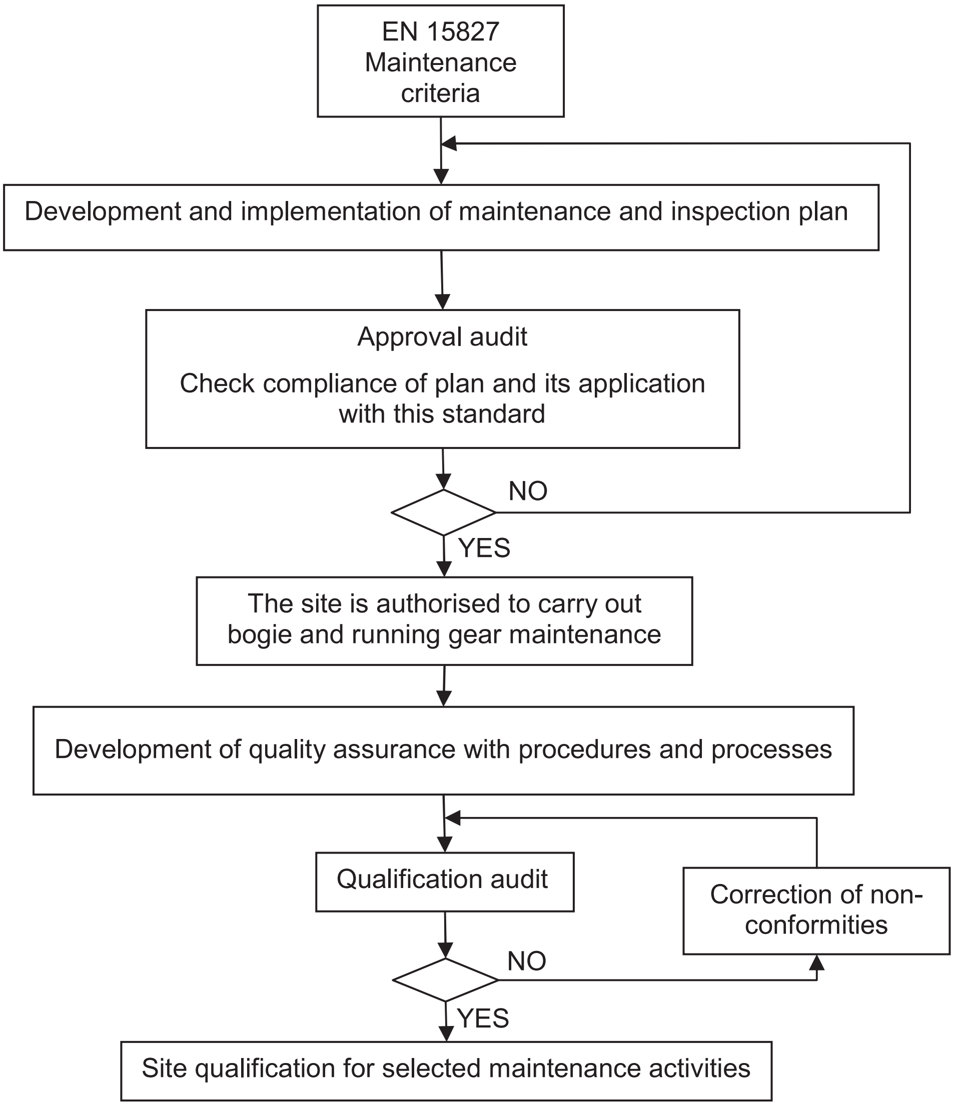


Figure 2 — Maintenance undertaking qualification flow chart

11.4 Records and traceability

Records of the maintenance process shall be kept to:

- demonstrate that the plan is being followed;
- provide traceability of safety critical components;
- provide traceability of limited life materials;
- provide a basis for review and revision of necessary maintenance activity.

Additional records that may be required in conformance to regulations are outside scope of this European Standard.

11.5 Unplanned maintenance

Maintenance outside the provisions of the plan may be instigated by a noted deterioration in vehicle, system or component performance or as a result of an incident.

Examples of such events are:

- track force limit excedence;
- loose or detached components;
- rough riding/instability;
- tread and flange damage;
- hot axlebox detection (HABD);
- derailment/collision;
- obstacle strike.

Investigation and remedial action will be dependent on the nature and seriousness of the event. The immediate actions shall return the vehicle to a serviceable condition or one in which it can be safely moved to a location for rectification as set out in 11.10. To manage the situation in the longer term it may be necessary to revise the maintenance plan as indicated in 11.6.

11.6 Revision of plan

The maintenance plan shall be periodically reviewed in accordance with the requirements of the railway undertaking's quality system.

The maintenance plan shall also be reviewed in the following circumstances:

- modifications to the vehicle;
- changes to operational requirements (usage, utilisation, local conditions, etc.);
- changes in operating environment (characteristics and quality of infrastructure, signal spacing, weather conditions, etc.);
- changes in regulations;
- failures/incidents.

If it is subsequently decided to operate a maintenance plan that results in a greater degradation of component performance before corrective action is taken or a repair does not restore full performance then the proven operating envelope will need to be reassessed (see Clause 12).

The maintenance plan shall be revalidated if the following are changed:

- the operating envelope;
- maintenance criteria or limits.

Changes to component maintenance that do not change the maintenance criteria or limits do not require reassessment of the proven operating envelope unless they are associated with safety critical components.

11.7 Implementation of the maintenance schedule

The way in which the maintenance plan is implemented on a particular type of vehicle is not fixed; it may be adapted to suit the vehicle operational requirements and the availability of suitable maintenance facilities. However, the schedule shall ensure that the requirements of the plan are achieved. In particular, the inspection intervals shall not be exceeded and the skills and facilities shall be available to carry out all the necessary actions when they are required.

11.8 Validation of the maintenance plan

The requirements for the bogies or running gear validation programme are outlined in Clause 9. Validation of the maintenance plan is in addition to this programme.

As for the vehicle as a whole, the aim of the bogies/running gear maintenance plan validation programme is to demonstrate that the bogies/running gear can be kept in a safe and functional condition and that the performance when constructed according to the design and suitably maintained will continue without unacceptable degradation or occurrence of defects. It shall further demonstrate that there is no adverse influence on the performance of the associated vehicle, components or sub-assemblies.

All necessary means shall be used to develop, modify and validate the maintenance plan (e.g. calculations, drawings, component specifications, tests, service data, etc.). As indicated in 9.4, the adoption of proven existing practice in similar applications can be used to support this objective.

A record shall be retained of the rationale on which the activities contained in the plan have been developed to form a basis for future changes.

NOTE Under Interoperability regulations, the Notified Body is required to confirm that a maintenance plan is in place for the bogies or running gear.

11.9 Maintenance quality requirements

Clause 10 requires that the bogie components and the assembly processes that affect the functionality shall be encompassed in the quality plan. The actions required by the maintenance plan shall be of a consistent standard.

All replacement component parts shall be of a quality consistent with the original design and manufacturing specifications. There shall be suitable controls in place to ensure that there is no deterioration prior to use. In particular, material that has a limited operational or shelf life shall be identified and controls shall be defined to ensure that supply, storage and application remains within the prescribed safe limits.

Annex D identifies the parts and processes that are covered by European Standards. In addition, the following standards are applicable to maintenance activity:

— EN 14535-1, Railway applications – Brake discs for railway rolling stock – Part 1: Brake discs pressed or shrunk onto the axle or drive shaft, dimensions and quality requirements[1)];

— prEN 14535-2, Railway applications – Brake discs for railway rolling stock – Part 2: Brake discs mounted onto the wheel rim, wheel web or wheel hub, dimensions and quality requirements[1)];

— EN 13715, Railway applications – Wheelsets and bogies – Wheels – Wheels tread[2)].

1) These items are included as an integral part of a wheelset, but brake system components in general are outside the scope of this European Standard.

2) The wheel profile is not a component but it does have a related standard that may be called up in some applications and its preservation within acceptable limits is a maintenance function.

When there is deterioration in the tread of a wheel outside normal wear, the requirements of EN 15313 shall be followed.

11.10 Incident/accident damage repair

In the course of their operating lives all types of vehicle are likely to be involved in incidents (including accidents) that impair their operation.

The actions taken to recover and repair the bogies or running gear subsequent to an incident shall normally ensure that the original design and manufacturing conditions are restored. Where this is not possible any design change to incorporate a repair shall be validated or additional controls shall be instigated and maintained for the remainder of the service life (11.6). Wheelset assessment and recovery shall comply with EN 15313. All repairs shall be documented and the vehicle's maintenance plan reviewed and revised accordingly. If rectification cannot be achieved by replacement or by following the routine maintenance procedures then guidance on the necessary action shall be obtained from an appropriate expert.

11.11 Material disposal

Consumables, waste material and discarded components from the maintenance process shall be disposed of in accordance with current regulations.

12 Proven operating envelope

12.1 General requirement

The results of the design and validation process, as required by this document, will establish the proven operating envelope for the bogies/running gear in question. The vehicle configuration, the validated operating conditions and bogies/running gear configuration and associated allowable component tolerances define the proven operating envelope. This envelope shall be recorded in terms of the parameters and acceptable tolerances. The maintenance action shall ensure that the bogies or running gear remain within their proven operating envelope for the required life and that appropriate action is taken following an incident.

The proven operating envelope defines the scope of applications under which a bogie/running gear type can be considered as an Interoperable Constituent.

Provided there are no discontinuities in the bogie characteristics it is permitted to interpolate within the validated parameters but not to extrapolate beyond these values without further validation.

For each application used in the determination of the proven operating envelope, the nominal bogie/running gear configuration shall be the same.

The proven operating envelope for the structural aspects of the bogie or running gear is defined by the maximum and minimum values of the parameters used as input to the design load cases and associated validation process. The main parameters that determine the operating envelope related to structural considerations are defined in Annex C.

NOTE 1 Values can be expressed as limit values or as nominal values with a tolerance. In strength assessment it is usually the maximum value that defines the proven envelope, but in some cases the minimum can be important as it determines the operating range and hence the magnitude of the associated repetitive stress cycles.

For the parameters that control the vehicle dynamics envelope, EN 14363:

— identifies the main relevant parameters;

— identifies the vehicle configurations and operating conditions that have been validated;

- defines the conditions and limits under which the proven performance can be expanded from the conditions actually demonstrated without further validation;
- indicates the circumstances in which a further validation programme is necessary to extend the proven performance.

For each configuration used to determine the proven operating envelope the nominal relevant bogie/running gear characteristics shall be the same or differ only to the extent as defined in EN 14363 under the heading "Choice of on-track test type".

The concept of the proven operating envelope in terms of its relevant parameters and when additional validation is required for a new application is shown in Annex I.

NOTE 2 Where acceptance is subject to confirmation by an independent approval authority, that organisation should confirm the proven operating envelope.

The proven operating envelope can be affected by modifications to the design, manufacturing changes and changes to the maintenance regime. When design changes are proposed, the potential consequences shall be established and the necessary steps taken to determine and validate any change to the proven envelope.

12.2 Standardised bogies/running gear for freight wagons

In order to obtain general type approval for new bogies/running-gear designs for freight wagons (without having to subsequently carry out tests for each application), it is necessary to perform the tests described in Annex J (until this requirement is incorporated into a new European standard or a revision of EN 14363).

Annex A
(informative)

Technical Specification

A.1 General requirements

The customer should indicate the type of bogie and running gear required in terms of its use. The customer should also indicate in the technical specification the intended life of the bogie and running gear, its average annual distance run and its total intended distance run.

A.2 Vehicle conditions and interfaces

The specification should include, but not be limited to, information on:

- vehicle masses and centre of gravity positions;
- vehicle geometry and space envelope
- body–bogie connections (e.g. mechanical, pneumatic, electric);
- body structural vibration modes;
- braking equipment and performance;
- traction system motors and transmissions;
- active suspension systems (including tilt where applicable).

NOTE Vehicle masses and payloads should be expressed as a function of the reference masses given in EN 15663 but these may need to be interpreted or adjusted according to the requirements of the normative references applicable to specific bogie components (e.g. axles).

A.3 Operational characteristics

The specification should include, but not be limited to, information on the operational characteristics to which the bogie and running gear is to be designed:

- loading conditions (e.g. changes in payload and frequency, dynamic load spectra);
- method of loading (e.g. progressive or sudden);
- maintenance loading due to lifting, jacking, etc.;
- maximum axle loads;
- maximum operating speed;
- speeds on curves and cant deficiency;

- starts and stops (i.e. number and frequency, acceleration rates, deceleration rates, including non-scheduled stops);
- wheel slip/slide control system characteristics;
- exceptional conditions (e.g. derailments, lifting, recovery, allowable instability).

A.4 Line characteristics

The specification should include information on the characteristics of the railway network for which the bogies or running gear is to be designed that have an influence on the dynamic performance and the applied loads, including representative data on the following:

- limit values of the track features, including service depot tracks, (e.g. minimum radius of curves, maximum twist);
- indication of distribution of straight lines and curves, cant, maximum and normal levels of twist, frequency of use on service depot tracks;
- types of track (e.g. classification of quality: roughness and discrete irregularities);
- gauge reference profile and the associated set of rules to provide the method of conformance demonstration.

NOTE 1 The information in the second bullet may be supplied by a route reference.

NOTE 2 Demonstration of conformance to the gauge can be in accordance with EN 15273-1 and EN 15273-2 or to the requirements of an equivalent process specified by the infrastructure manager.

A.5 Environmental conditions

The specification should include information on the characteristics of the environment that can have an influence on the behaviour of the bogie and running gear and that it should be designed to withstand, including:

- climatic conditions (e.g. temperature, humidity, rain, snow, floods, wind; see EN 50125-1);
- aggressive agents (e.g. corrosion, erosion, ballast impacts, dirt).

The risk of snow packing, ice formation, damp intrusion and the need of hot water de-icing should be addressed in the design process for bogies operating in a sub-arctic climate.

Ballast impact is a potential problem and has to be addressed in the design process but there are no normative requirements for resistance to ballast damage. In many applications within the scope of this standard the use of established components and materials avoids the need to give specific consideration to ballast damage. However, particularly in high speed applications, low operating temperatures and when non-ferrous materials are used it is necessary to give more careful consideration to potential damage and take necessary mitigating measures.

A.6 Maintenance and inspection

All the conditions of maintenance planned for the bogie and running gear and which can have an influence on its design and behaviour should be indicated in the technical specification, including the following:

- description of maintenance operations, including their frequency;

- the use of machines for washing or de-icing (cleaning agents, temperature, water pressure, etc.);
- handling requirements (e.g. lifting, towing, recovery);
- depot facilities.

It is also important to consider the handling and recovery requirements in the event of a service incident (see A.3). These may include additional lifting and jacking requirements, provision for wheel skates or other specific equipment.

A.7 Particular requirements

The customer should indicate in the technical specification any particular requirements that are not covered by the above clauses, for example; constraints imposed by mounted systems, materials, components, types of construction and methods of assembly, operating and maintenance staff skills.

Annex B
(informative)

Engineering process requirements

The engineering process should incorporate all the requirements of this standard. It should include a quality management system that controls and provides traceability of decision making with respect to:

- the development of the design concept;
- the originality of the concepts employed;
- verification of the design data;
- the criticality of components or design features;
- the technical methodology for risk management;
- the degree of detailed analysis and testing required and the associated techniques;
- validation against the requirements;
- specific factors relevant to maintenance.

As the design progresses the criticality of features should be determined by a risk assessment. The results will determine the level of analysis and testing to be carried out and so determines the content of the design activity and the validation plan. FMECA and Hazops processes are examples of methods of carrying out risk assessments. Risk may be controlled by measures such as multiple fixings, safety retention systems or the adoption of higher safety factors, production controls and/or additional maintenance, etc. Control measures contained in the normative references are a suitable means of risk management. Safety factors for strength assessment are discussed further in Clause 6 and allowance for tolerances on component performance is addressed under performance criteria in Clause 7.

If validation against the requirements of this standard are not achieved the critical parameters should be identified, reviewed and adapted until compliance can be achieved.

The methods used in the design process should be based on accepted industry practice. The analysis tools should be consistent with this principle, though it is accepted that their level of detail and accuracy will vary according to the subject under investigation and the required level of confidence.

Generally a new bogie design starts from an existing piece of equipment (a similar type of bogie that has a related operational performance). The supplier will look at those performance requirements that are different and concentrate on adjusting the bogie parameters to achieve the new performance requirements. For practical and commercial reasons existing components are usually adopted or adapted to fulfil the requirements.

The design of the bogies or running gear should be validated by the supplier against the requirements of this standard, applicable regulations and the customer specification (contract).

Annex C
(informative)

Design loads

The design loads are determined by the vehicle configuration and its intended operating envelope. It is necessary to establish how these factors contribute to the design requirements and the validation process. The following parameters should be considered:

a) vehicle parameters:

— vehicle mass, inertias and centre of gravity, including tolerances;

— vehicle configuration/layout;

— vehicle body stiffnesses (especially torsional);

— payload conditions;

— wind loads (effective area and centre of pressure);

b) bogie/running gear parameters:

— internal system loads (driveline, brake, inertia forces, etc.);

— attachment points;

— component masses;

— component performance (spring stiffness, damper rates, etc. and tolerances);

— internal loads resulting from assembly/manufacturing (e.g. bolt pretension or interference fits; residual stress from welding is not intended to be a design load case in this context, but it has to be considered within the acceptance criteria);

c) application and operating envelope:

— track quality;

— line characteristics (including depot track) : type of track, radii of curves, number of curves, track twist, cant, percentage of distance covered on straight lines and on curves;

— operational characteristics: loading cycles, traction cycles, braking cycles, brake control characteristics, wheel slip/slide control, velocity profile, cant deficiency, service life/distance run.

For design purposes it is necessary to consider the load cases in two groups, namely:

— the exceptional loads, which are the maximum loads under which the bogie is to remain fully serviceable (and which are used for static strength assessment), and

— the fatigue loads which quantify the normal repetitive service loading conditions (and which are used for fatigue strength assessment).

Annex D
(normative)

Component related standards

The following table indicates the railway applications European Standards that shall be applied to components used on bogies and running gear and which cover design, manufacturing or maintenance issues.

Table D.1 — Component related standards

Suspension/wheelset component	**Relevant European Standards**
Axle boxes – Rolling bearings Axleboxes – Lubricating greases Axleboxes – Performance testing Method of specifying the structural requirements of bogie frames (includes axleboxes)	EN 12080 EN 12081 EN 12082 EN 13749
Non-powered axles Powered axles Axles – Product requirements	EN 13103 EN 13104 EN 13261
Hydraulic dampers	EN 13802
Method of specifying the structural requirements of bogie frames	EN 13749
Rubber suspension components – Elasotmer based mechanical parts	EN 13913
Helical suspension springs – Steel	EN 13298
Parobolic springs – Steel	EN 14200
Rubber suspension components – Rubber diaphragms for pneumatic suspension springs Air spring control elements	EN 13597 EN 14817
Torsion bar – Steel	EN 15049
Wheels – Product requirements Monobloc wheels – Technical approval procedure – Forged and rolled wheels Wheels – Wheels tread	EN 13262 EN 13979-1 EN 13715
Wheelsets – Product requirements Wheelset maintenance	EN 13260 EN 15313

Annex E
(informative)

Design development and simulation

E.1 Process

The bogie/running gear design process is iterative and frequently starts from an existing concept. This is then modified to address the revised aspects related to safety, ride comfort, track loading, vehicle sway, vehicle loading and operating conditions.

The design process related to dynamics is becoming more accurate and controlled with the development of simulation packages. It is now normal practice to establish the bogie/running gear dynamic behaviour first by analysis/simulation.

Simulations of dynamic behaviour can be made for the following reasons:

— internal research and product development;

— part of the design process (iteration) to verify that the characteristics have been chosen correctly;

— to define the behaviour, environment and structural loading;

— to demonstrate to the customer that the design is satisfactory.

E.2 Level of model detail

The appropriate level of detail in a dynamic model will depend on the precision and level of detail needed at the stage of the design and development process to which it is contributing. Sufficient detail and precision is required to give confidence in the predicted vehicle performance under consideration.

In the dynamic model it is necessary to include the main components such as wheelsets, bogies/running gear, vehicle body and all of the relevant connections between them. Data describing the vehicle body has to be included to the level of detail required to represent dynamic effects that are prominent in the dynamic performance (e.g. masses, inertias, position of centre of gravity, significant eigen modes).

It is recommended that the model represent the components as precisely as reasonably possible taking account of their characteristics (e.g. geometry, stiffness, damping, clearances, etc.) and the technical requirements for the bogie.

If the aim of calculations is to predict forces between components to enable structural or other analysis to be carried out, the model has to be precise enough to adequately represent the components and associated load paths under consideration.

E.3 Model validation

The software used has to conform to the principles in Clause 9. At the development stage, the parameters of the vehicle dynamic model shall be verified as far as possible against actual data from existing or similar components. This standard does not require evidence of the suitability of the software or the validation of the modelling used during the bogie and running gear development process. However, the use of unproven modelling techniques will increase the risk of an inadequate design being produced. Software with a suitable pedigree and model validation is required if it is intended to subsequently use the simulation in place of, or in conjunction with, validation tests (see Annex G).

E.4 Track data, quality and curves

Depending on the objectives of the study, the track data needs to include all parameters necessary for the level of simulation being carried out, such as; rail profile and inclination, characteristics of curves, cant, stiffness, track irregularities and roughness and associated wavelengths, etc.

E.5 Range of simulations - loading, operating conditions and degraded conditions

Depending on the objectives of the study, the simulations can cover the operating envelope of the bogie or running gear, namely:

— vehicle loading from tare to exceptional load (see EN 15663) and asymmetrical load configuration when applicable;

— operating conditions up to maximum speed, extreme cant deficiency and excess and maximum track twist, etc.;

— degraded conditions of active systems (e.g. loss of air in airsprings, tilt system failure).

Annex F
(informative)

Acceptance process flow diagram

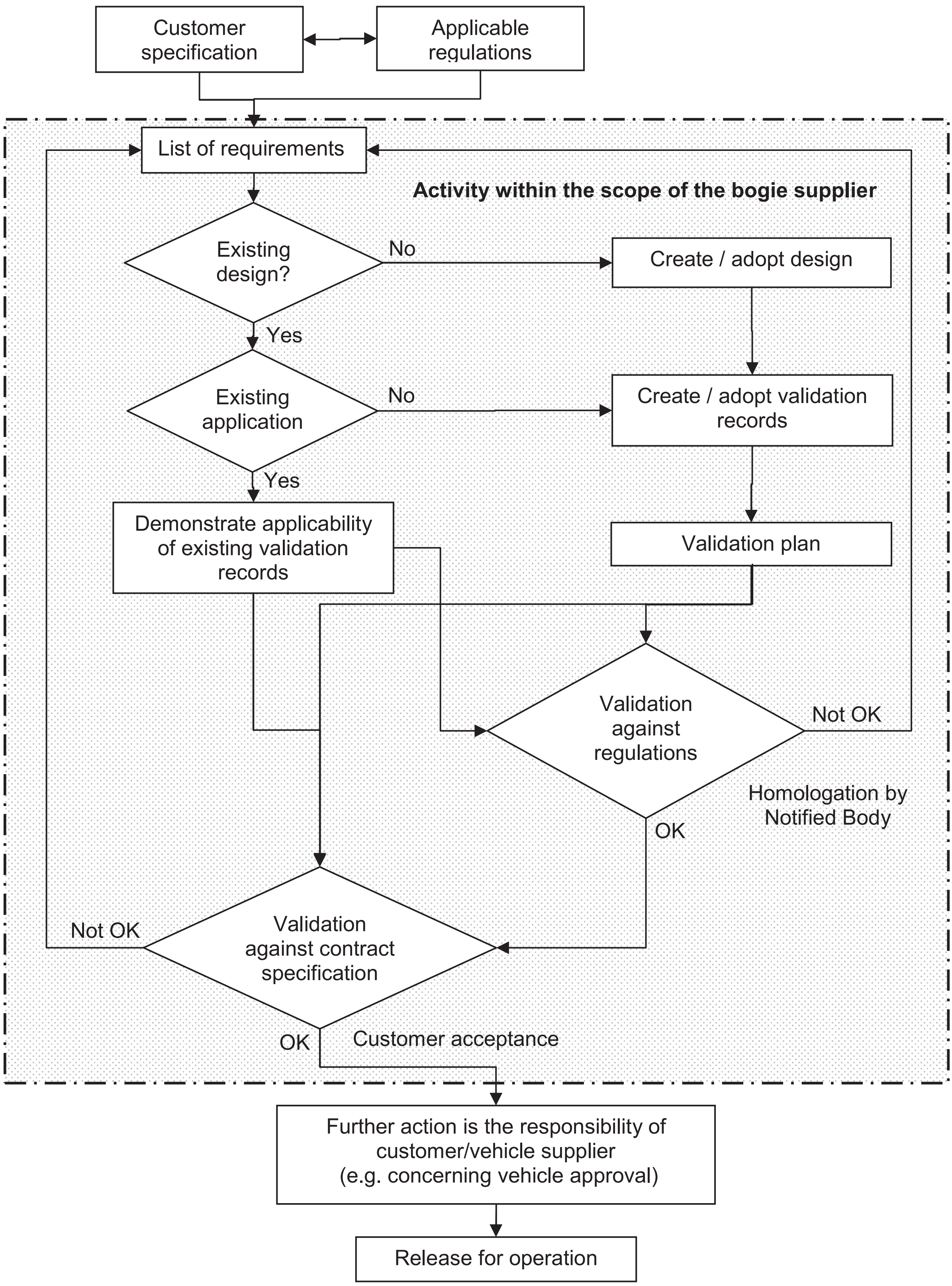


Figure F.1 — Acceptance process flow diagram

Annex G
(informative)

Dynamic performance validation by numerical simulation

G.1 Conditions for application of numerical simulations

G.1.1 Preface

This Annex presents a process for the use of simulation in support of, or in place of, testing based on the UIC 518:2009-09 recommendations. It is an interim annex which will become redundant (and should be ignored) when superseded by a more comprehensive process in a CEN Technical Specification or a subsequent revision of EN 14363.

G.1.2 Introduction

Numerical simulations are required to be validated (see G.2) by comparing a representation of the vehicle with a vehicle design that has been tested both statically and on the track, this vehicle is known as the Base Design.

A Base Design vehicle will have been tested according the complete method of EN 14363.

It is necessary that the following conditions are also satisfied:

— test results for the Base Design vehicle and data of the track are available for model validation. It is necessary that these tests and data include a representative range of track conditions, curves, cant deficiency, wheel/rail contact conditions, etc.;

— track data is available from the original test route to enable validation to be undertaken.

The extent of any modification to a vehicle is limited to changes that do not change the concept of the suspension. Changes to components, such as springs, are allowed provided an accurate representation of the component is simulated. Changes to the vehicle body parameters including inertia and stiffness, but excluding dimensions relating to the attachment of suspension systems, are allowed. The existing and changed parameters are to be included in the simulation to demonstrate the influence of the changes on the performance.

G.1.3 Areas of application

Three areas of application where numerical simulations can be used in place of track testing are considered in this Annex. These are:

— approval of vehicles following modification;

— approval of new vehicles by comparison with an already approved Base Design;

— extension of the range of test conditions where the full test programme has not been completed;

— examination of ride characteristics after achieving system operating limit values or the effect of system malfunctions (air springs, anti-roll bars, etc.).

The scope of these areas of application, and the conditions for use of numerical simulation, are described in the following subclauses.

It is necessary that the validation of vehicle models is independently reviewed and the whole process described by this Annex is presented in a comprehensive report as required by G.2.5 and G.6 respectively.

The performance evaluation when using simulation should follow the normal method adopted when testing; namely the determination of wheel-rail interactions (Y and Q forces) and accelerations in the vehicle body, etc.

G.1.4 Modifications of an existing vehicle

Where an existing vehicle (i.e. the base design), or vehicle fleet, is modified then it is permissible to use validated numerical simulations, rather than track or static testing, to demonstrate the effect of the modifications on the dynamic behaviour of the vehicle.

NOTE Vehicle modifications may be carried out for a number of different reasons, for example:

- to change the use of the vehicle;
- to upgrade the vehicle;
- to improve the running behaviour.

If a Base Design vehicle has been tested, according to EN 14363, and found to exceed some of the limit values for track fatigue or running behaviour, then it is permitted to use numerical simulations to demonstrate that modifications to the vehicle will improve the behaviour sufficiently to meet the limits. In addition, it is necessary that all safety parameters remain within their limit values.

A numerical model of the original vehicle has to be developed and validated against the test results for that vehicle, in accordance with G.2. Modifications can then be made to the model and the dynamic behaviour simulated and the results compared to the limit values.

To confirm that the modifications have been correctly applied to the modified vehicle model, it is necessary that a limited set of tests on the actual modified vehicle are undertaken. The tests required will depend on the type of modification undertaken and can include:

- wheel load and load distribution;
- static tests on the full vehicle;
- slow speed / quasi-static tests;
- laboratory tests of components;
- limited track tests, for example vehicle body accelerations.

It is required that confirmation that the modifications have been correctly applied to the model is provided by an independent reviewer (see G.3) and noted in the final report.

G.1.5 Comparison with a base design

Where new vehicles are being introduced which are similar to the Base Design vehicle then it is permissible to use numerical simulations, rather than track tests, to demonstrate that the behaviour of the new vehicles is satisfactory.

For example, where new vehicles are being introduced with a range of different types within the fleet (e.g. multiple units with a number of different vehicle body and/or mass configurations.) then it is appropriate to define one vehicle type as the Base Design. The other vehicle types can then be approved by reference to the Base Design and the use of numerical simulation if:

- the changes from the Base Design are within the parameter ranges defined in G.1.7 for use of simulations;

- the application of the new vehicle is similar to the Base Design as defined by the limits in G.1.7.

A numerical model of the Base Design vehicle should be developed and validated against the test results for that vehicle, in accordance with G.2. It is necessary that models of the other vehicles are then developed from the Base Design and the dynamic behaviour simulated and the results compared to the limit values.

To confirm that the differences have been correctly applied to the new vehicle model, it is necessary that a limited set of tests on the actual new vehicle are undertaken. The tests required will depend on the type of modification undertaken and may include:

- wheel load and load distribution;
- static tests on the full vehicle;
- slow speed / quasi-static tests;
- laboratory tests of components;
- limited track tests, for example vehicle body accelerations.

It is required that confirmation that the modifications have been correctly applied to the model is provided by an independent reviewer (see G.3) and noted in the final report.

G.1.6 Additions to the range of test conditions

Where tests according to EN 14363 have been carried out, but the full range of conditions has not been satisfied, then it is permissible to use numerical simulation to cover the deficiencies in support of the vehicle approval.

This situation could arise where:

- sufficient track length is not available to meet the requirements for some zones;
- the full range of speed and cant deficiency has not been tested;
- the range of wheel-rail (contact) conditions has not been covered.

The following conditions have also to be satisfied by the available test results to allow model validation:

- maximum test speed (service speed +10%) has been tested over track of a suitable length and quality to demonstrate stability;
- maximum cant deficiency (cant deficiency limit +10 %) has been tested;
- tests have included some very small radius curves and an adequate range of wheel-rail contact conditions;
- track conditions are sufficiently rough to excite the vehicle suspension.

It is necessary that a vehicle model is developed and validated by comparison with the available test results in accordance with G.2. Numerical simulations have then to be undertaken for any test zone where the test results are not complete. The combined track sections from tests and simulations for each test zone shall meet the requirements of EN 14363 (see G.3). It is not permitted to use the same track section for both tests and simulations unless this condition is achieved.

G.1.7 Extent of parameter variations from base design that may be demonstrated by simulation

The following tables summarise the range of vehicle parameter variations, relative to the base design, over which it is permissible to demonstrate conformance to the specification using simulation in place of testing.

Table G.1 — Permitted parameter variation — Non freight vehicles

Vehicle characteristics		Permitted parameter variation
Vehicle wheel-base		-7 %, + 20 %
Height of centre of gravity		-40%, + 20 %
Mass	non suspended	-10 %, + 7 %
	with a single suspension-level (total mass if the vehicle has no secondary suspension)	-10 %, + 7 %
	with two suspension-levels	± 15 %
Moment of inertia of the vehicle body relative to the vertical central axis		-20 %, + 10 %
Increase in operating speed		0, + 10 km/h
Wheel-base of bogie		0, + 20 %
Nominal wheel diameter		-10 %, +15 %
Stiffness of vertical primary suspension [a]		± 20 %
Stiffness of secondary vertical suspension [a]		± 40 %
Axleguiding	Stiffnesses	- 5 %, + 10 %
	damping, clearances...	± 10 %
Bogie rotational torque		± 20 %
Moment of inertia of the bogie relative to the vertical central axis [b]		± 10 %
Secondary lateral suspension (stiffnesses, damping, clearances...)		± 15 %

[a] Bump stop effects have to be correctly represented.

[b] This may be changed to -100 %, +10 % for multiple units, locomotives and passenger coaches.

Table G.2 — Permitted parameter variation — Freight vehicles

Vehicle characteristics		Permitted parameter variation for	
		Bogie wagon	**Non-bogie wagon**
Vehicle bogie centre distance - $2\alpha^*$	$2\alpha^* \geq 9$ m	-30 %, + lim [a] with $2\alpha^* \geq 8{,}10$ m	
	$2\alpha^* < 9$ m	-10 %, + lim [a]	
Vehicle wheel-base - $2\alpha^*$	$2\alpha^* \geq 8$ m		-30 %, + lim [a] with $2\alpha^* \geq 7{,}20$ m
	$2\alpha^* < 8$ m		-10 %, + lim [a]
Height of centre of gravity, h_G	empty wagon,	-100 %, + lim [a]	-100 %, + lim [a]
	loaded wagon	-100 %, + lim [a]	-100 %, + lim [a]
Body torsional stiffness c_t^* (10^{10} kN·mm²/rad)	$c_t^* \leq 3$	-66 %, + 200 %	-66 %, + 200 %
	$c_t^* > 3$	-50 %, + lim [a]	-50 %, + lim [a]
Tare mass	≥ 16 t	-15 %, + lim [a]	-15 %, + lim [a]
Increase in maximum axle-load ($2Qo_{max} \leq 250$ kN/axle)		0, + 10 %	0, + 10 %
Increase in operating speed		0, + 10 km/h	0, + 10 km/h
Wheel-base of bogie		0, + 20 %	N/A
Nominal wheel diameter		-10 %, +15 %	-10 %, + 15 %
Vertical suspension [b] primary or secondary	Increased stiffness(es)	0, +50 %	0, + 50 %
	Lower transitional load	± 10 %	± 10 %
Axle-guiding	Stiffnesses	-5 %, + 10 %	-5 %, + 10 %
	Damping, clearances	± 10 %	± 10 %
Bogie rotational torque		± 20 %	N/A
Moment of inertia of the bogie relative to the vertical central axis		-100 %, + 20 %	N/A [c]
Secondary lateral suspension (stiffnesses, damping, clearances...)		± 10 %	± 10 %

[a] lim, indicates that the parameter can increase up to the permitted limiting value.

[b] Bump stop effects have to correctly represented.

[c] For a non-bogie wagon the change in the moment of inertia of the vehicle body relative to the vertical central axis should be within the range -100 %, + 10 %.

G.2 Vehicle model and its validation process

G.2.1 Introduction

In order to generate valid results, it is necessary that numerical simulations are carried out with care to ensure that:

- the vehicle model is a good representation of the actual vehicle;
- the software used is appropriate for the application;
- the correct conditions have been covered;
- the engineers undertaking the simulations are competent;

and, therefore, the simulation results will be valid.

The following clauses describe the process to be used to ensure that the numerical model is a good representation of the actual vehicle and it is suitable to use for vehicle approval.

This process is based on comparisons between physical test results of the vehicle and numerical simulations of the same tests.

It is required that the results of all appropriate work carried out in accordance with G.2.2, G.2.3 and/or G.2.4 is presented in a report.

G.2.2 Principles of vehicle model validation

It is necessary that a vehicle model is a correct representation of all the aspects of the actual vehicle that influence the dynamic behaviour. This will require a full 3-dimensional non-linear numerical model of the vehicle which includes:

- masses, inertias and load distribution;
- suspension stiffnesses, damping, friction, bump-stops, etc.;
- wheel-rail interface characteristics;
- when necessary, flexible modes of the vehicle body or bogie that occur within the relevant frequency range.

The primary purpose of validating a numerical vehicle model is to use that model to simulate vehicle behaviour in-lieu of actual on-track tests. Vehicle approval requires assessment of vehicle static, quasi-static and dynamic behaviours; therefore, the numerical model should include validation against the static, quasi-static and the dynamic tests. The validation process should also be made across the appropriate dynamic frequency range. All comparisons between simulation and actual on-track test results should be made using the same numerical vehicle model and software. A numerical model that has been validated should not be changed for subsequent simulations, except in accordance with the intended vehicle changes (within the limits set out in G.1.7).

G.2.3 Static tests or slow speed tests

G.2.3.1 Objective

As part of the model's validation process, it is necessary to use results from static or slow speed tests. The results of existing static and slow speed tests can be used.

Depending on the analysis undertaken, these results are used to validate different aspects of the vehicle model, namely:

- wheel loads and load distribution;
- behaviour on twisted track;
- bogie rotation;
- sway or roll coefficient.

G.2.3.2 Wheel loads and load distribution

For wheel loads and load distributions it is necessary that the following values are calculated and compared with the test results:

- load on each individual wheel;
- load on each axle (sum of two wheels);
- load on each bogie (sum of wheels);
- load on each side of the vehicle (sum of wheels on that side).

It is required that the results of the comparison are reported including differences as a percentage of the appropriate test result.

Table G.3 presents the greatest differences between simulation and test results that are acceptable for a well validated model. There are separate values for maximum difference (e.g. for any one wheel) and average difference (e.g. over the wheels of the whole vehicle).

Table G.3 — Vehicle wheel load difference limits

Load considered	**Maximum difference**	**Average difference**
Individual wheel loads	15 %	7 %
Wheelset loads	6 %	3 %
Bogie loads	3 %	3 %
Side loads (left or right)	3 %	3 %

G.2.3.3 Behaviour on twisted track

Where tests are undertaken for behaviour on twisted track the appropriate measurement quantities should be calculated and compared with the test results. This will normally include (dependent of the method of test):

- wheel loads during the testing;
- suspension displacement during the testing;
- plots of wheel load against applied twist;
- hysteresis value for friction suspensions;

— magnitude of any wheel lift.

G.2.3.4 Bogie rotation

Where bogie rotation tests are undertaken the appropriate measurement quantities should be calculated and compared with the test results. This can include:

— bogie rotation angle;

— applied force;

— plots of rotation angle against applied force.

The tests shall be undertaken at different rotational speeds if the suspension includes viscous yaw dampers.

G.2.3.5 Sway or roll coefficient

Where static sway/roll tests are undertaken the appropriate measurement quantities should be calculated and compared with the test results. This includes:

— vehicle body roll angle;

— bogie roll angle;

— lateral displacement of specific positions on body / bogie;

— vertical displacement of specific positions on body / bogie.

G.2.4 Dynamic tests

G.2.4.1 Scope

The range of conditions of the dynamic validation determines the scope for which the model is then approved for simulations. It is, therefore, important that the validation tests and simulation comparisons cover the widest practical range of conditions.

G.2.4.2 Range of validation

It is necessary to consider the parameters given below in determining the range of applicability of the validated model. The vehicle model is to be considered as validated for the range of conditions covered in the comparisons, assuming that satisfactory results are obtained. As permitted by EN 14363, in some areas a limited amount of extension, beyond the conditions assessed is permitted.

The following parameters should be considered and the range of conditions covered has to be reported:

— track geometric irregularities – shall be sufficient to excite the vehicle suspension in all directions and shall include track with irregularity at both ends of the quality range;

— vehicle speed – validation is limited to the speed range tested;

— vehicle cant deficiency – validation is limited to the cant deficiency range tested;

— straight track – a sufficient length to demonstrate vehicle stability is required (suggested at least 5 km);

— curve track sections – shall include maximum cant deficiency;

— very small radius curves shall be included to assess behaviour in these conditions;

- wheel rail contact conditions to cover range required for approval;
- wheel rail friction conditions – shall include a significant length of dry rail conditions;
- vehicle load conditions – as required for approval;
- position of vehicle in the trainset – (if relevant – see G.3.9);
- suspension component failure conditions – as identified by risk assessment for approval.

G.2.4.3 Assessment quantities

Vehicle assessment quantities measured during the tests and obtained from the simulations should include appropriate quantities from EN 14363.

NOTE It may also be helpful for the validation process to include additional measurement quantities (e.g. suspension displacements).

The following data will be required in order to undertake validation of the numerical simulations:

- track geometry data for the test sections (layout or design geometry and irregularities – see G.3.3 for wavelength and accuracy requirements);
- actual speed profile for each test section;
- wheel and rail profiles;
- vehicle condition and loading;
- any other external effects relevant to the dynamic performance.

Simulations should be undertaken for the same test sections and the results analysed and reported. The simulations shall be compared with the test results for at least the following parameters:

- assessment quantities according to EN 14363 (section values, mean, standard deviation and estimated maximum as appropriate – see the EN 14363 annex on “Statistical evaluation”)
- power spectral densities (PSDs) and key frequencies of the following measurement quantities over a sample of sections:
  - vehicle body lateral and vertical accelerations at each end;
  - vehicle body bounce and pitch accelerations (derived from in and out of phase values of body end vertical accelerations);
  - calculated vehicle body lateral and yaw accelerations (derived from in and out of phase values of body end lateral accelerations);
  - bogie lateral and yaw accelerations;
  - bogie vertical and pitch accelerations (if available);
- net lateral (Y) forces (key frequencies);
- distribution plot of values for Y and Q forces (as appropriate);
- sample time histories over straight and curved track sections for all the measurement quantities.

G.2.5 Independent review of model validation

G.2.5.1 Content of review

The results of the model validation exercise should be submitted to an independent reviewer for approval and endorsement. The reviewer has to:

— consider the results of the test and simulation comparisons as determined by the above;

— investigate any areas that are considered critical;

— determine whether the vehicle model is a good representation of the actual vehicle.

If the reviewer is satisfied that the model is a good representation then the model is to be declared as validated and suitable for use in numerical simulations for vehicle validation acceptance. The reviewer is required to confirm the range of parameters for which the validation is approved and to document this in a report or in a covering letter.

If modifications have been made to the vehicle the reviewer should confirm that they have been adequately incorporated into the model.

G.2.5.2 Reviewer

The reviewer should be a person who was not directly involved with either the testing or the numerical simulation, but is permitted to be part of the same organisation/department (Second Party Independence). This person should be knowledgeable in the areas of safety, vehicle dynamic behaviour, vehicle-track interaction, vehicle approval and numerical simulations. It is necessary that the identity of the reviewer, together with their experience and competence to carry out the review is documented and included in the validation report (G.2.6).

G.2.6 Validation report

G.2.6.1 Content

The results of the validation should be reported as part of the overall simulation report. The report should include the information indicated in the following clauses.

G.2.6.2 Vehicle model description

This section should include a general description of the vehicle together with the types of suspension element (coil spring, air spring, friction elements, etc.) used and any normal modes of vibration included in the model.

G.2.6.3 Software used

This section should include the name of the software, version number and details of any special options or modules used. Any particular input data required (e.g. track stiffness and damping) or assumptions made in using the software shall also be documented.

G.2.6.4 Validation tests

This section should include details of the static tests and dynamic test routes, curvature ranges, speeds, cant deficiency ranges, track geometric quality, etc. Wheel-rail contact conditions covered shall also be reported.

G.2.6.5 Results of the validation

This section should include the assessment quantities specified in G.2.4.3, together with graphical results. Sample time history graphs for both tests and simulations shall also be included.

G.2.6.6 Review report and reviewer qualifications

The reviewer's report and conclusions should be included in this part of the report. A signed copy of the reviewer's statement or letter of approval should be included as an attachment or annex to the main report together with a statement of the reviewer's qualifications relative to the application.

G.2.6.7 Conclusions and scope of validated model

This section should summarise the results of the validation exercise and state clearly the scope of application for which the model has been validated.

G.3 Input conditions for numerical simulations

G.3.1 Introduction

The input information requiring special attention for numerical simulation is given below. In all cases the conditions used, and the explanations and assumptions should be included in the simulation report. These are:

- vehicle configuration and modification state (see G.1);
- track geometric quality;
- track stiffness;
- wheel-rail contact geometry;
- rail surface condition (friction coefficient);
- direction of travel;
- speed;
- position of vehicle in trainset.

The following subclauses consider these in more detail.

G.3.2 Vehicle configuration

The vehicle configuration, load condition, etc. for the numerical simulation should be in accordance with the EN 14363 clause covering "Test vehicle". In the case that failure conditions (for example deflated air suspensions) shall be assessed then the model will need to be validated for this condition. Variations in suspension parameters, centre of gravity position, etc. shall be included if these significantly influence the behaviour.

G.3.3 Track geometric quality

The track sections selected for the numerical simulations should meet the requirements of the EN 14363, annex dealing with "Actual geometry for track tests" for the proposed speed range of the vehicle. The track sections shall be taken from measurements of actual track and not be artificially created or modified. In particular it is not acceptable for curve radius and track geometry irregularities to be artificially scaled in order to meet the required distributions. Further detail of track data requirements is provided below.

If the quality distributions of EN 14363 are not met with the proposed track sections then data should be obtained for additional sections. If the curve radius ranges of EN 14363 are not met with the proposed track sections then data should be obtained for additional curved track sections.

Although some standards require the track roughness to be determined over a wavelength range of 3 m to 25 m this is not sufficient for use in simulations. The wavelength content of the measured track irregularity data, when taken in combination with the vehicle speeds, shall correspond to the significant vehicle response frequencies (typically within the range of 0,4 Hz to 20 Hz).

NOTE 1 This may also apply to high speed vehicles that are tested at low speed in small or very small radius curves.

The track layout (sometimes called design geometry) is required to give the necessary conditions for curve radius, cant deficiency and transition curves. In the case that design geometry and track irregularities are measured and recorded in separate channels it is important to ensure that the separation and addition takes place in a way that will not distort the final result.

NOTE 2 It is not recommended that the design geometry is taken from a track design and layout database. If this approach is used, extreme care should be taken to avoid missing or duplicated data and the process should be described in the report.

The track data recording accuracy, after transfer function filtering (if required), should be in accordance with the requirements in EN 13848-1.

Track irregularity data should represent the full three dimensional track, including vertical alignment, cross level, lateral alignment and track gauge.

The vertical alignment and cross level may be given as vertical alignment of two rails.

The lateral alignment and gauge may be given as lateral alignment of two rails.

G.3.4 Track stiffness

The track stiffness and damping properties used in the simulations are not normally very significant. However, the values used shall be representative of practical conditions.

G.3.5 Geometry of the wheel-rail contact

A range of rail profiles should be used for the numerical simulations. The rail profiles shall be selected to cover the range expected during running on the proposed routes and to represent the distribution of profiles from new to worn rail. The profiles used for particular track sections shall be appropriate to those sections (for example: high speed tangent track or very small radius curves).

The wheel profiles used for the numerical simulations shall be appropriate for the vehicle being assessed. These may be new wheel profiles or they may represent a wheel profile worn in service.

The wheel-rail contact conditions shall be consistent with the range of conditions that would be considered for testing.

G.3.6 Rail surface condition

For a test on track there will be a natural variation in the wheel-rail friction conditions, whilst respecting the condition for dry rails. For numerical simulations some variation is required to avoid the possibility of the results being distorted by use of a single value.

It is essential that the condition of dry rails is represented and therefore the wheel-rail friction has to be at least 0,36. The following distribution is proposed, for each test zone, but alternatives can be used if they are justified in the test report:

— single sided normal distribution from 0,36 with standard deviation of 0,075.

G.3.7 Direction of travel

For the case of a symmetrical vehicle, all necessary assessment values can be obtained for all required positions from the same simulation and so there is no requirement to reverse the direction of travel.

If the vehicle being assessed is significantly asymmetric then the numerical simulations shall be carried out with the vehicle in both directions of travel to determine the worst condition for each assessment value.

G.3.8 Speed

For a test on track there will be a natural variation in the vehicle speed. For numerical simulations some variation is required to avoid distortion of the results from use of a single value. The method and amount of variation should be representative of normal conditions and the process used has to be documented.

G.3.9 Position of vehicle in the trainset

The need for connections to other vehicles has to be considered during the model validation and during the simulations:

- for articulated vehicles the numerical simulation will need to include a suitable number of adjacent vehicles in order to ensure that the effects are properly included;
- for conventional vehicles (which would be tested loose coupled) a single vehicle can be simulated;
- for trainsets with permanently coupled vehicles then the characteristics of the coupling system will need to be assessed and the effects included in the model unless the influence of adjacent vehicles on dynamic behaviour is shown to be insignificant.

The conditions applied and the reasons shall be included in the simulation report and to be covered by the model validation.

G.4 Frequency content of simulations

The assessment quantities output by simulations should be subject to the same processing as for measured quantities in tests and shall satisfy the requirements for frequency content. This requires controls on the vehicle model, the input data (in particular the track), and the output data. It is necessary that the model represents accurately the frequency contents that are shown by the validation to be relevant and that the ranges of the filter characteristics specified in EN 14363 are covered. The requirements for track input data to ensure that the required input frequency range is provided to the model were given in G.3.3. It is necessary that the output data from the model covers the frequencies specified in EN 14363 without risk of aliasing.

G.5 Application of results and proven operating envelope

The area of vehicle validation proven by the simulation should be considered in the same way as that for comparable test results. It has to be clearly defined and documented and it is necessary to include the vehicle parameters that have changed and relevant general conditions such as:

- the range of speed;
- the range of cant deficiency;
- the range of curve radius;
- wheel-rail contact conditions;
- vehicle load conditions;

- position of the vehicle in the trainset;
- any relevant failure modes.

If the simulation results assessed against the limit values are acceptable then the proven operating envelope is modified, as appropriate, to incorporate the scope of the simulation results.

G.6 Reporting

The full process described above is required to be documented in a formal report. The report has to include:

- a full validation report in accordance with G.2.6 for the original vehicle model (Base Design);
- description of any modifications to the vehicle and model and how these have been validated;
- a full report of the input conditions and results of the simulations, in accordance with the normal format of equivalent test reports;
- a description of how any specific issues identified in the above clauses have been managed in the simulations;
- the scope of proven operating envelope covered by the simulations.

The validation report (see G.2.6) can be presented as a referenced document.

Annex H
(normative)

Minimum requirements for maintenance inspections

The specified safe limits of wear and degradation and inspection intervals shall be included in the maintenance plan. For the bogies and running gear the permitted component in-service wear limits shall be consistent with keeping the vehicle safely on the track and within its defined gauge reference profile. Contractual requirements specifying levels of ride and comfort may modify the conditions under which maintenance actions need to be taken. Consideration shall be given to the following non-exhaustive list, where the issues are applicable, during the production of the maintenance plan.

a) General requirements:

— wear and corrosion limits: - the tolerable degradation that will instigate repair or replacement of each component;

— corrosion protection: – the maintenance applied to corrosion protection systems of the bogie and its components shall be compatible with the design specification;

— bolted joints: – the maintenance plan shall include instruction on the procedures to be applied when maintaining bolted joints (compatible with the design), these will normally include the need for replacement of used fasteners, torque tightening procedures, flatness and cleaning of bolted/clamped faces, etc.;

— damage: - deterioration due to an external source that will potentially affect the safety and/or function of the component;

— cleaning: – arrangements shall be included in the maintenance requirement for the cleaning of bogies/running gear and their associated components. Instructions relating to cleaning shall include the following; vehicle washing plant, high pressure washing, bogie heavy maintenance washing, sealing of bearings and access/fastener holes, allowable cleaning agents, etc.;

— handling, storage and transportation: – appropriate handling equipment, support frames and packaging shall be used to ensure that bogies/running gear and their components are preserved in a serviceable condition.

b) Wheelset and constituent parts:

— the requirements of EN 15313 shall be addressed.

c) Bearings:

— floats, clearances;

— grease;

— damage indication (e.g. signs of overheating, seal failure).

d) Axleboxes:

— attachments (to the bogie and the equipment to the axlebox);

— axle earth return brushes and associated cabling;

- lubrication leakage;
- seal integrity;
- wheelslide detection equipment.

e) Primary and secondary suspensions (including traction and pivot arrangements):

- spring integrity, rules for changing;
- anti-roll equipment;
- elastomer suspension components;
- bump stops;
- linkage wear, dimensional limits;
- suspension clearances (settlement);
- damper integrity;
- air systems, reservoirs, levelling valve setting, etc.;
- tilting equipment.

f) Bogie frames and structural elements:

- integrity and condition of all load bearing members;
- integrity, operation and security of brackets and linkages;
- integrity and security of all equipment attachments;
- geometrical alignment.

g) Attachments of bogie mounted equipment (including bolted & riveted connections):

- brake equipment;
    - brake shoes/pads;
    - discs;
    - callipers and linkage;
    - actuator;
    - hoses;
    - cocks;
    - pipework;
    - safety loops;
    - track brake;
- traction equipment;
    - motor;
    - mechanical drive equipment (gearbox, cardan shaft, coupling, torque reaction link, etc.);

  - earthing conditions and integrity;
- shoegear and associated equipment (arc shields, cabling, etc.);
- lifeguards;
- sanding equipment;
- flange lubrication equipment;
- bogie mounted safety antenna (ERTMS, etc.);
- track circuit assistors;
- other bogie mounted equipment not identified above.

h) Labelling and identification (presence, position, condition, cleanliness, etc.):

- lifting and jacking identification;
- safety and warning (electrical and mechanical);
- equipment serial numbers where appropriate;
- axlebox position identification where required.

The above list of topics is not exhaustive or necessarily representative of all types of rail vehicles and shall be adjusted as necessary for each application.

The maintenance requirements for the systems installed on bogies and running gear are outside the scope of this European Standard.

Annex I
(informative)

Proven operating envelope

The proven operating envelope is the performance envelope defined by all parameters (with maximum and minimum values) that are relevant to safety and functionality of the vehicle configuration and which have been shown to be acceptable during the design and validation processes. These parameters may be expressed as nominal values with a tolerance or by the limiting value.

The proven operating envelope is defined by three groups of parameters, namely:

— the bogie/running gear characteristics;

— the body characteristics;

— the operating conditions.

The bogie/running gear characteristics include such parameters as:

— wheel base;

— track gauge;

— pivot/axle load;

— bogie mass and inertias

— wheel diameter;

— wheel profile;

— braking forces;

— traction forces;

— primary suspension stiffnesses;

— secondary suspension stiffnesses;

— primary vertical damping;

— secondary vertical damping;

— lateral damping;

— anti yaw damping or rotational torque;

— primary clearance;

— secondary clearance.

NOTE 1 These may be identified by the particular bogie or running gear type designation.

The body characteristics include such parameters as:

— body wheel base/pivot distance;

— body mass and inertias;

— centre of gravity position;

— body torsional stiffness;

— body natural frequencies.

The operating characteristics include such parameters as:

— speed;

— cant excess/cant deficiency;

— wheel load;

— track quality.

NOTE 2 In some parts of Europe there is a common understanding of the track quality and the track conditions under which a vehicle should be tested to be acceptable by an infrastructure manager. Where such common standards exist and the vehicle has been tested over the prescribed track then track quality is not a variable parameter in the proven operating envelope for this area of operation. However, there is not a common track quality requirement throughout the whole region to which this European Standard applies and track quality will need to be included as an operating condition parameter where it is relevant.

For each application the proven configuration is defined by:

— a bogie configuration;

— one body configuration;

— one set of operating conditions.

The overall proven operating envelope for a bogie type is the relevant combination of all such applications that have been validated. This combination of applications is illustrated in Figure I.1 below.

In the Figure I.1 it is assumed that the bogie configuration is unique. If this is not the case then several proven operating envelopes shall be defined; one for each configuration (e.g. with and without anti yaw dampers).

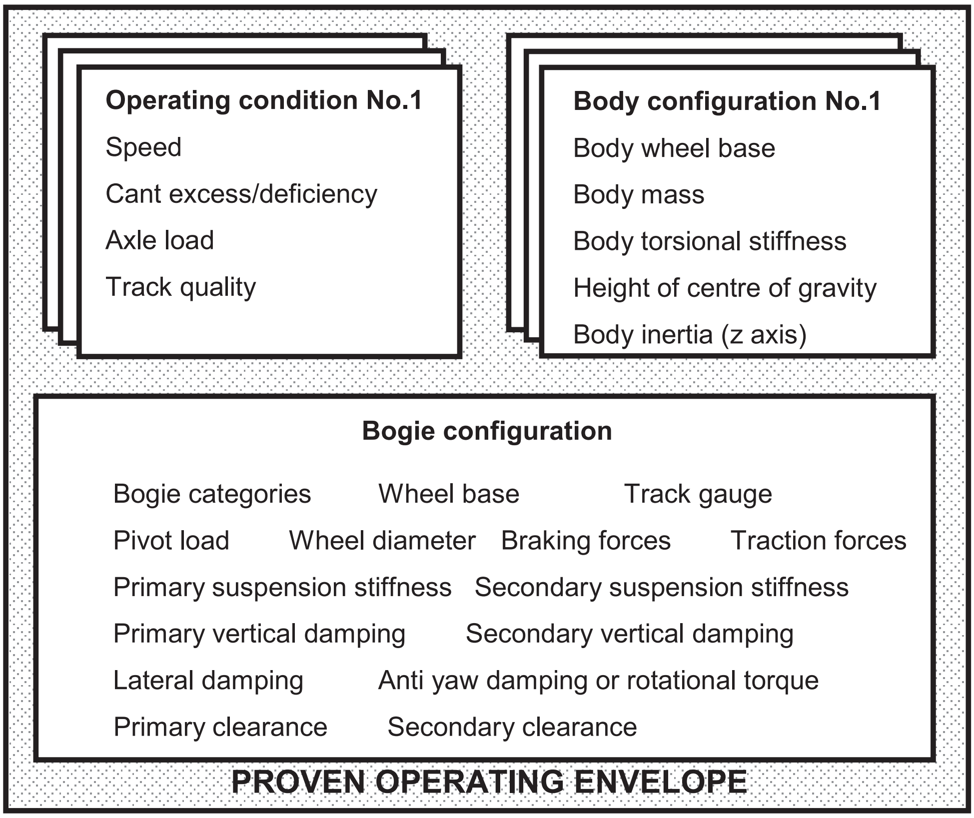
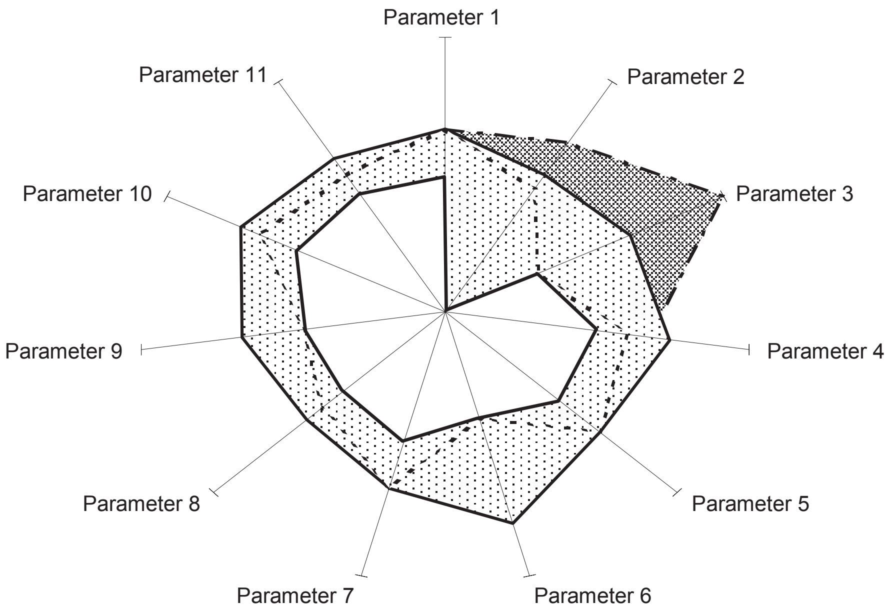


Figure I.1 — Composition of proven operating envelope



Key

Proven operating envelope

Further validation required

New application 1

New application 2

Figure I.2 — Proven operating envelope

Figure I.2 illustrates in graphical form how the combination of parameters defines the proven envelope. In this figure parameter 2 represents speed and hence covers zero to maximum operating speed.

In the figure, new application 1 is contained wholly within the existing proven operating envelope and so no new validation is necessary.

In new application 2, parameters 2 and 3 are extended beyond the range that has been previously validated. For this application further validation work is required to demonstrate that the bogie/running gear meets the additional requirements and can be safely operated up to the boundaries of this extended envelope.

Annex J
(normative)

Standardised bogies/running gear for freight wagons

This Annex presents a process for the testing of wagon bogies and running gear. It is an interim annex which will become redundant (and shall be ignored) when superseded by a more comprehensive process in a new European standard or subsequent revision of EN 14363.

In order to give general type approval to new bogies/running-gear designs for freight wagons (without having to subsequently carry out tests for each application), at least four tests according to EN 14363, "On-track tests" shall be performed. These tests shall be successfully carried out on the following types of wagons fitted with the new type of bogies/running gear:

1) short wheelbase or short bogie pivot centre wagon:

- rigid (stiff) body;
- flexible body.

2) long wheelbase or long bogie pivot centre wagon:

- rigid (stiff) body;
- flexible body.

The values of vehicle body stiffness to be used are given in the Table J.1.

Table J.1 — Body stiffness parameters

$2\alpha^*$ [m]	**2-axle wagons**		**Bogie wagons**	
	Short ≤ 7	Long ≥ 8	Short ≤ 7	Long ≥ 13
Flexible body c_t^* [kNmm²/rad]	$\leq 1 \times 10^{10}$	$\leq 1 \times 10^{10}$	$\leq 1 \times 10^{10}$	$\leq 1 \times 10^{10}$
Rigid (stiff) body c_t^* [kNmm²/rad]	$> 2 \times 10^{10}$	$> 2 \times 10^{10}$	$> 2 \times 10^{10}$	$> 2 \times 10^{10}$

Where $2\alpha^*$ is the distance between wheelsets for 2-axle wagons or the distance between bogie centres for bogie wagons and c_t^* is the vehicle body torsional stiffness coefficient.

The order of the above tests is not specified, but the first type approval test shall be a test carried out according to the complete 'On-track' tests procedure in EN 14363. The other tests can be carried out according to the partial 'On-track' tests procedure in EN 14363, using the normal or simplified method of measurement.

The above approval procedure applies only to the track tests as required in the relevant clauses of EN 14363. It does not give approval for safety against derailment on twisted track and under longitudinal compressive forces in S-shaped curves as required by other clauses in EN 14363.

NOTE For bogies accepted according to the above procedure it is intended to define the proven operating envelope in a new European standard under development (based on UIC leaflet 432) containing:

- relevant parameters for vehicle bodies to be equipped with the bogies listed in Annex Y of CR TSI RST WAG;
- ranges of accepted relevant parameters for the bogies listed in Annex Y of CR TSI RST WAG.

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2008/57/EC

This European Standard has been prepared under a mandate given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the Directive 2008/57/EC[3)].

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in table ZA.1 for HS Rolling Stock and ZA.2 for CR Freight Wagons and Table ZA.3 for CR Locomotives and Passenger Rolling Stock, confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA.1 — Correspondence between this European Standard, HS TSI RST published in the OJEU dated 26 March 2008 and Directive 2008/57/EC

Clause/subclauses of this European Standard	Chapter/§/annexes of the TSI	Corresponding text, articles/§/annexes of the Directive 2008/57/EC	Comments
Clauses 1 to 4 Clause 7 Clause 11 Annex H	4. Characterisation of the subsystem 4.2 Functional and technical specification of the subsystem 4.2.3 Track interaction and gauging 4.2.3.4 Rolling stock dynamic behaviour § 4.2.3.4.1 General § 4.2.3.4.5 Design for vehicle stability 4.2.10 Maintenance §4.2.10.2 The maintenance file §4.2.10.3 Management of the maintenance file	Annex III, Essential requirements 1 General requirements 1.1 Safety Clauses 1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5 1.2 Reliability and availability 1.4 Environmental protection Clauses 1.4.2, 1.4.4, 1.4.5 1.5 Technical compatibility 2 Requirements specific to each subsystem 2.4 Rolling stock 2.4.2 Reliability and availability 2.4.3 Technical compatibility §3 2.6 Operation and traffic management 2.6.1 Safety §2 2.6.2 Reliability and availability	

3) This Directive 2008/57/EC adopted on 17th June 2008 is a recast of the previous Directives 96/48/EC ‘Interoperability of the trans-European high-speed rail system’ and 2001/16/EC ‘Interoperability of the trans-European conventional rail system’ and revisions thereof by 2004/50/EC ‘Corrigendum to Directive 2004/50/EC of the European Parliament and of the Council of 29 April 2004 amending Council Directive 96/48/EC on the interoperability of the trans-European high-speed rail system and Directive 2001/16/EC of the European Parliament and of the Council on the interoperability of the trans-European conventional rail system’.

Table ZA.2 — Correspondence between this European standard, the CR TSI RST Freight Wagons dated July 2006, published in the OJEU on 8 December 2006 and its intermediate revision published in the OJEU on 14 February 2009 and Directive 2008/57/EC

Clause/subclauses of this European Standard	Chapter/§/annexes of the TSI	Corresponding text, articles/§/annexes of the Directive 2008/57/EC	Comments
Clauses 1 to 12 inclusive Annex D Annex H Annex J of this standard are applicable	4.Characterisation of the subsystem 4.2. Functional and technical specifications of the subsystem 4.2.3 Vehicle track interaction and gauging §4.2.3.1 Kinematic gauge §4.2.3.2 Static axle load and linear load §4.2.3.4 Vehicle dynamic behaviour 4.2.7 System protection §4.2.7.2 Fire safety 4.2.8 Maintenance: maintenance file 5. Interoperability constituents 5.3 List of constituents §5.3.2.1 Vehicle track interaction and gauging, Bogie and running gear 5.4 Constituents performances and specifications §5.4.2.1 Vehicle track interaction and gauging, Bogie and running gear 6. Assessment of conformity and/or suitability for use of the constituents and verification of the subsystem 6.1 Interoperability constituents §6.1.3.2.1 Specification of ICs, Vehicle track interaction and gauging, Bogie and running gear Annex J Vehicle track interaction, Bogie and running gear Annex Q Assessment procedures, Interoperability constituents – Table Q.1 Annex Y Constituents – Bogies and running gear Annex Z Structure and mechanical parts – Impact (buffing) test	Annex III, Essential requirements 1 General requirements 1.1 Safety Clauses 1.1.1, 1.1.2, 1.1.3, 1.1.4 1.1.5 1.2 Reliability and availability 1.4.2, 1.4.4, 1.4.5 Environmental protection 1.5 Technical compatibility 2 Requirements specific to each subsystem 2.4 Rolling Stock 2.4.2 Reliability and availability 2.4.3 Technical compatibility §3 2.6 Operation and traffic management 2.6.1 Safety §2 2.6.2 Reliability and availability	Bogie and running gear is categorised as an Interoperability Constituent in the TSI.

Table ZA.2 *(continued)*

Clause/subclauses of this European Standard	Chapter/§/annexes of the TSI	Corresponding text, articles/§/annexes of the Directive 2008/57/EC	Comments
	Intermediate Revision 4.Characterisation of the subsystem 4.2. Functional and technical specifications of the subsystem 4.2.3 Vehicle track interaction and gauging §4.2.3.4.2.1 Safety against derailment and running stability §4.2.3.4.2.2 Safety against derailment when running on twisted tracks		

Table ZA.3 — Correspondence between this European Standard, the CR TSI Locomotives and Passenger RST (final draft ST05EN05 dated 10 June 2010) accepted by RISC in June 2010and Directive 2008/57/EC

Clause/subclauses of this European Standard	**Chapter/§/annexes of the TSI**	**Corresponding text, articles/§/annexes of the Directive 2008/57/EC**	**Comments**
Clauses 1 to 4 Clauses 6 to 11 Annex D Annex H	4.Characterisation of the Rolling stock subsystem 4.2 Functional and technical specifications of the subsystem 4.2.3 Track interaction and gauging § 4.2.3.4.2 Running dynamic behaviour § 4.2.3.4.2.1 Limit values for running safety 4.2.3.5 Running gear 4.2.12 Documentation for operation and maintenance 4.2.12.3 Documentation related to Maintenance §4.2.12.3.1 The maintenance design justification file §4.2.12.3.2 The maintenance description file	Annex III, Essential requirements 1 General requirements 1.1 Safety Clauses 1.1.1, 1.1.2, 1.1.3, 1.1.4, 1.1.5 1.2 Reliability and availability 1.4 Environmental protection Clauses 1.4.2, 1.4.4, 1.4.5 1.5 Technical compatibility 2 Requirements specific to each subsystem 2.4 Rolling stock 2.4.2 Reliability and availability 2.4.3 Technical compatibility §3 2.6 Operation and traffic management 2.6.1 Safety §2 2.6.2 Reliability and availability	

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Bibliography

[1] CR TSI RST WAG, *Technical Specification for Interoperability relating to the subsystem Rolling Stock — Freight Wagons*

[2] HS TSI RST, *Technical Specification for Interoperability relating to the subsystem High Speed Rolling Stock*

[3] EN 1032, *Mechanical vibration — Testing of mobile machinery in order to determine the vibration emission value*

[4] EN 1993-1-9:2005, *Eurocode 3: Design of steel structures — Part 1-9: Fatigue*

[5] EN 1999-1-3:2007, *Eurocode 9: Design of aluminium structures — Part 1-3: Structures susceptible to fatigue*

[6] EN 13803-1, *Railway applications — Track — Track alignment design parameters — Track gauges 1435 mm and wider — Part 1: Plain line*

[7] EN 13803-2, *Railway applications — Track — Track alignment design parameters — Track gauges 1435 mm and wider — Part 2: Switches and crossings and comparable alignment design situations with abrupt changes of curvature*

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

[9] EN 15302, *Railway applications — Method for determining the equivalent conicity*

[10] ISO 2631-1, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

[11] EN ISO 9001, *Quality management system — Requirements (ISO 9001:2008)*

[12] CEN/TS 45545-2:2009, *Railway applications — Fire protection on railway vehicles — Part 2: Requirements for fire behaviour of materials and components*

[13] DIN 7190, *Interference fits — Calculation and design rules*

[14] DIN 25201-1, *Design guide for railway vehicles and their components — Bolted joints — Part 1: Classification of bolted joints*

[15] DIN 25201-2, *Design guide for railway vehicles and their components — Bolted joints — Part 2: Design — Mechanical application*

[16] NF E 22 620, *Pressed-on assemblies — Dimensions, tolerances and surface condition of usual assemblies*

[17] NF E 22 621, *Pressed-on assemblies on cylindrical bearings — Function, realisation, calculation*

[18] NF E 22 622, *Transmissions mécaniques — Assemblages frettés sur portée conique — Fonction, réalisation, calcul Mechanical transmissions — Pressed-on assemblies on conical bearings — Function, realisation, calculation*

[19] NF E 25 030-1, *Fasteners — Threaded connections — Part 1 :General rules for design, calculation and mounting*

[20] NF F 32 101, *Railway transport equipment — Two axle carrying bogie frames — Determination of reference elements — Geometrical checks*

[21] NF E 90 401-2, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 2 : Risks for health*

[22] RFU-RST-033, *NB-RAIL Recommendation for Use, Scope of Applicability of Subsystem Fire Requirements*

[23] VDI 2230 Blatt 1, *Systematic calculation of high duty bolted joints — Joints with one cylindrical bolt*

[24] UIC 432, *Wagons — Speed of circulation — Technical conditions to respect*

[25] UIC 518:2009-09, *Testing and approval of railway vehicles from the point of view of their dynamic behaviour — Safety — Track fatigue — Running behaviour*

[26] FprCEN/TS 13979-2, *Railway applications — Wheelsets and bogies — Monobloc wheels — Technical approval procedure — Part 2: Cast wheels*

[27] FprCEN/TS 15718, *Railway applications — Wheelsets and bogies — Product requirements for cast wheels*

This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™