

BS EN 15827:2011



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Railway applications — Requirements for bogies and running gears

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**Railway applications - Requirements for bogies and running
gears**

Applications ferroviaires - Exigences pour bogies et
organes de roulement

Bahnanwendungen - Anforderungen für Drehgestelle und
Fahrwerke

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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of an identical text or by endorsement, at the latest by September 2011, and conflicting national standards shall be withdrawn at the latest by September 2011.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:

$$U = \frac{R_d S}{R_C} \leq 1$$

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 ($\geq 1,0$), 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 $R_{p0,2}$ 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:

$$U = \frac{\sigma_c S_1}{R_{eH}} \leq 1$$

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.