



BSI Standards Publication

Railway applications — Wheelsets and bogies — Axles — Product requirements

National foreword

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The UK participation in its preparation was entrusted to Technical Committee RAE/3/-/1, Railway Applications - Wheels and Wheelsets.

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

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European foreword

This document (EN 13261:2024) 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of an identical text or by endorsement, at the latest by May 2025, and conflicting national standards shall be withdrawn at the latest by May 2025.

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

This document supersedes EN 13261:2020.

The main changes compared with EN 13261:2020 are as follows:

- an improved definition of the product groups submitted to qualification;
- improved requirements to assess product qualification after changes made in the manufacturing process;
- additional possibilities to carry out tests with axle journal extensions;
- an improved definition of the aim of the full-size fatigue test;
- an improved definition of the requirements regarding material microstructure;
- some additional information or requirements on the qualification and NDT tests of hollow-bore axles;
- the replacement of the historical test to check the resistance of the paint to bending stress by more pragmatic and cheaper tests;
- new requirements on the traceability of the qualification and of the batch control.

The informative annexes to this document provide additional guidance that is not mandatory but that helps to understand or use the document.

The informative annexes may contain optional requirements. For example, a test method that is optional, or presented as an example, may contain requirements, but it is not necessary to meet these requirements to be in compliance with the document.

This document has been prepared under a standardization request addressed to CEN by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

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

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations 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, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.

1 Scope

This document specifies the characteristics of axles for all heavy rail track gauges.

This document applies to heavy rail vehicles and applies, in principle, to other vehicles such as urban rail vehicles.

It specifies characteristics of forged or rolled solid and hollow axles, made from vacuum-degassed steel grade EA1N¹⁾, EA1T¹⁾ and EA4T¹⁾. For hollow axles, this document applies only to those that are manufactured by machining of a hole in a forged or rolled solid axle.

The requirements specified in this document are applicable for cylindrical seats. Most of the requirements are also applicable for axles with conical seats. Specific requirements for conical seats (e.g. geometrical dimensions of the seats...) are defined in the technical specification.

Some characteristics are given as a function of a category 1 or of a category 2.

This document is applicable to axles that are designed in accordance with the requirements of EN 13103-1:2017+A1:2022.

This document also permits variations of the material characteristics linked to alternative manufacturing processes (e.g. cold rolling, shot blasting, thermal spraying, steel cleanliness, reduction ratio, improved material properties from melting and heat treatment process, etc.).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 13103-1:2017+A1:2022, *Railway applications — Wheelsets and bogies — Part 1: Design method for axles with external journals*

EN ISO 148-1:2016, *Metallic materials — Charpy pendulum impact test — Part 1: Test method (ISO 148-1:2016)*

EN ISO 643:2012, *Steels — Micrographic determination of the apparent grain size (ISO 643:2012)*

EN ISO 1519:2011, *Paints and varnishes — Bend test (cylindrical mandrel) (ISO 1519:2011)*

EN ISO 1520:2006, *Paints and varnishes — Cupping test (ISO 1520:2006)*

EN ISO 2409:2020, *Paints and varnishes — Cross-cut test (ISO 2409:2020)*

EN ISO 2808:2019, *Paints and varnishes — Determination of film thickness (ISO 2808:2019)*

EN ISO 4624:2023, *Paints and varnishes — Pull-off test for adhesion (ISO 4624:2023)*

EN ISO 6892-1:2019, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1:2019)*

¹⁾ N for a normalized metallurgical condition

T for a quenched and tempered metallurgical condition

EN ISO 9227:2022, *Corrosion tests in artificial atmospheres — Salt spray tests (ISO 9227:2022)*

EN ISO 11997-1:2017, *Paints and varnishes — Determination of resistance to cyclic corrosion conditions — Part 1: Wet (salt fog)/dry/humid (ISO 11997-1:2017)*

EN ISO 14284:2022, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition (ISO 14284:2022)*

EN ISO 16276-2:2007, *Corrosion protection of steel structures by protective paint systems — Assessment of, and acceptance criteria for, the adhesion/cohesion (fracture strength) of a coating — Part 2: Cross-cut testing and X-cut testing (ISO 16276-2:2007)*

EN ISO 22081:2021, *Geometrical product specifications (GPS) — Geometrical tolerancing — General geometrical specifications and general size specifications (ISO 22081:2021)*

ISO 4967:2013, *Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams*

ISO 5948:2018, *Railway rolling stock material — Ultrasonic acceptance testing*

ISO 6933:1986, *Railway rolling stock material — Magnetic particle acceptance testing*

ISO/TR 9769:2018,²⁾ *Steel and iron — Review of available methods of analysis*

CEN/TS 13103-2:2020, *Railway applications — Wheelsets and bogies — Part 2: Design method for axles with internal journals*

3 Terms and definitions

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

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

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

3.1 technical specification

document specifying parameter and/or product requirements as an addition to the requirements of this document

3.2 batch

group of axles supposed to have the same characteristics

Note 1 to entry: A batch consists of axles of the same design forged or rolled with raw material of a single heat in an identical hot forming process and heat treated at the same time in an identical procedure. If the raw material is produced in several heats with the expected chemical composition, the axles made thereof can be combined to a batch. In this case, it needs to be proven within the frame of the product qualification that the axles made of the various heats comply with the requirements of the product qualification.

²⁾ See also CEN/TR 10261:2023.

3.3

axle category

classification of the component, based on operational aspects, which determines the list of requirements to be applied

Note 1 to entry: Category 1 is generally selected when the operating train speed is greater than 200 km/h.

Note 2 to entry: Category 2 is generally selected when the operating speed is 200 km/h or less.

Note 3 to entry: These categories can also be defined according to the technical specification.

4 Product definition

4.1 Chemical composition

4.1.1 Values to be achieved

The values for percentage contents of the various elements shall be in accordance with Table 1.

Table 1 — Limit values by product analysis

Grade	C %	Si %	Mn %	P ^a %	S ^{a, b} %	Cr %	Cu %	Mo %	Ni %	V %
EA1N	≤ 0,40	≤ 0,50	≤ 1,20	≤ 0,020	≤ 0,015 ^{a, b}	≤ 0,30	≤ 0,30	≤ 0,08	≤ 0,30	≤ 0,06
EA1T	≤ 0,40	≤ 0,50	≤ 1,20	≤ 0,020	≤ 0,015 ^{a, b}	≤ 0,30	≤ 0,30	≤ 0,08	≤ 0,30	≤ 0,06
EA4T	≥ 0,22 ≤ 0,29	≥ 0,15 ≤ 0,40	≥ 0,50 ≤ 0,80	≤ 0,020	≤ 0,015 ^b	≥ 0,90 ≤ 1,20	≤ 0,30	≥ 0,15 ≤ 0,30	≤ 0,30	≤ 0,06
^a A maximum content of 0,025 % may be defined in the technical specification. ^b A minimum sulphur content may be defined in the technical specification according to the steelmaking process, in order to safeguard against hydrogen embrittlement.										

4.1.2 Sampling methods

The test sample shall be taken at mid-radius of solid axles or at mid-distance between external and internal surfaces of hollow axles.

The chemical composition can alternatively be determined by ladle analysis. In this case, the limit values shall be defined in the technical specification.

For forged axles, when defined in the technical specification, the sample may be taken from an axle journal extension as stated in Annex A.

4.1.3 Chemical analysis

The chemical composition analysis shall be performed according to the methods and definitions specified in ISO/TR 9769:2018 unless another standard is defined in the technical specification.

NOTE ASTM E415-21 and ASTM E1019-18 can be applied.

4.2 Mechanical characteristics

4.2.1 Characteristics from the tensile test

4.2.1.1 Values to be achieved

The values to be achieved at mid-radius of solid axles or at mid-distance between external and internal surfaces of hollow axles are given in Table 2.

The values to be achieved near the external surface shall be greater than or equal to 0,95 times the values measured at mid-radius of solid axles or at the mid-distance between external and internal surfaces of hollow axles.

The values to be achieved in the centre of solid axles or near the internal surface of hollow axles shall be greater than or equal to 0,8 times the values measured at mid-radius or at mid-distance between external and internal surfaces.

Table 2 — Values to be achieved at mid-radius of solid axles or at mid-distance between external and internal surfaces of hollow axles

Grade	R_{eH}^a MPa	R_m MPa	A_5 %
EA1N	≥ 320	550 - 650	≥ 22
EA1T	≥ 350	550 - 700	≥ 24
EA4T	≥ 420	650 - 800	≥ 18
^a If no distinctive yield strength is present, the proof stress $R_{p0,2}$ shall be determined.			

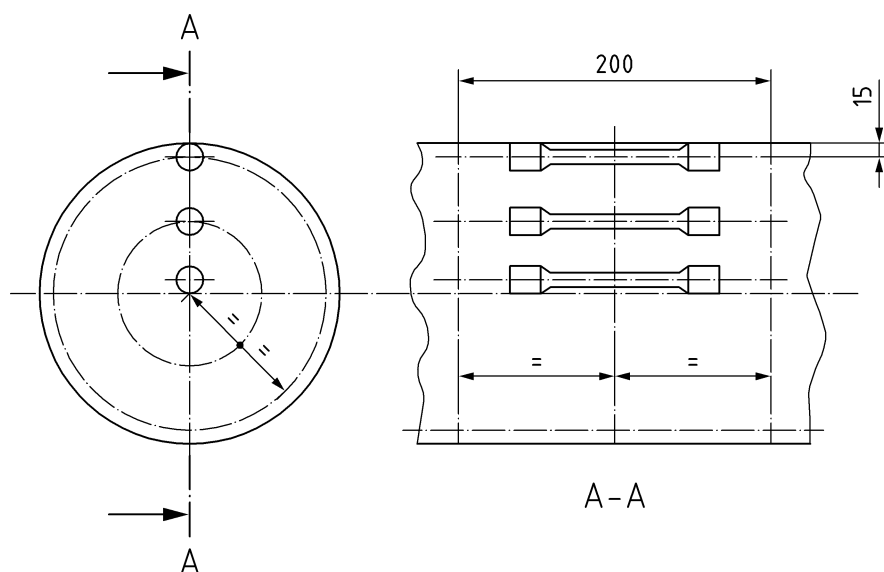
4.2.1.2 Position of the test pieces

The test pieces shall be taken at three levels from the largest diameter section of the axle:

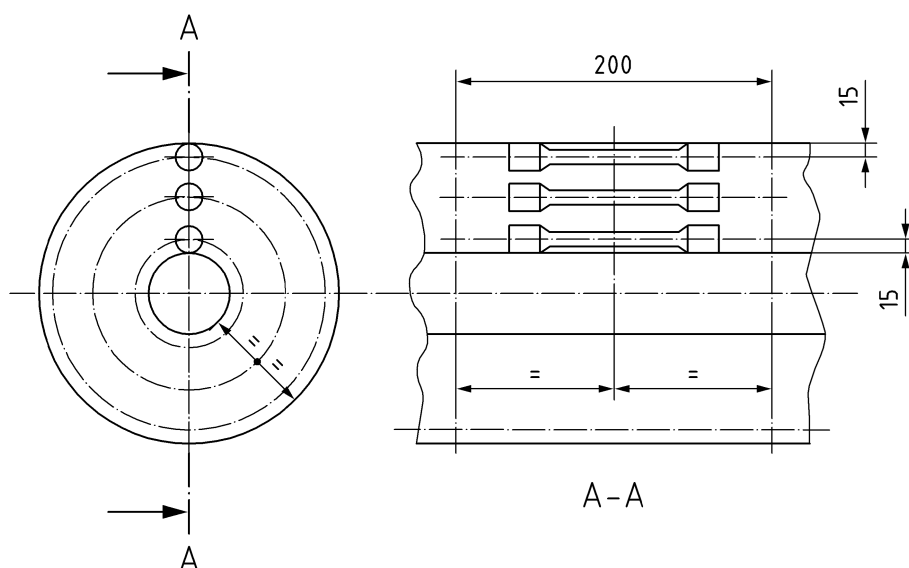
- as near as possible to the external surface for all the axles,
- at mid-radius and in the centre of solid axles,
- at mid-distance between external and internal surfaces, and near the internal surface of hollow axles, as shown in Figure 1 a) and b).

For forged axles, when defined in the technical specification, the sample may be taken from an axle journal extension as stated in Annex A.

Dimensions in millimetres



a) — Solid axle



b) — Hollow axle

Figure 1 — Position of test pieces

4.2.1.3 Test method

The test shall be carried out in accordance with EN ISO 6892-1:2019. The test piece diameter shall be at least 10 mm in the machined-down portion. The gauge length shall be five times the diameter.

4.2.2 Impact test characteristics

4.2.2.1 Values to be achieved

Impact test characteristics shall be determined in the longitudinal and the transverse directions.

Values to be achieved at mid-radius of solid axles, or at mid-distance between external and internal surfaces of hollow axles, are given in Table 3.

Near the surface, the average value calculated from 3 specimens shall be greater than or equal to 0,95 times the average values measured at mid-radius or at mid-distance between external and internal surfaces of hollow axles.

In the centre of solid axles or near the internal surface of hollow axles, the average value calculated from 3 specimens shall be greater than 0,8 times the average values measured at mid-radius or at mid-distance between external and internal surfaces.

For forged axles, when defined in the technical specification, the sample may be taken from an axle journal extension as stated in Annex A.

No individual value shall be less than the minimum values defined in Table 3.

Table 3 — Values to be achieved at mid-radius of solid axles or at mid-distance between external and internal surfaces of hollow axles

Grade	Average <i>KU</i> longitudinal J	Minimum <i>KU</i> longitudinal J	Average <i>KU</i> transverse J	Minimum <i>KU</i> transverse J
EA1N	≥ 30	≥ 21	≥ 20	≥ 14
EA1T	≥ 40	≥ 28	≥ 25	≥ 18
EA4T	≥ 40	≥ 28	≥ 25	≥ 18

4.2.2.2 Position of test pieces

The test pieces shall be taken from three levels in the largest axle section:

- as near as possible to the external surface for all the axles;
- at mid-radius and in the centre of solid axles;
- at mid-distance between external and internal surfaces, and near the internal surface of hollow axles;

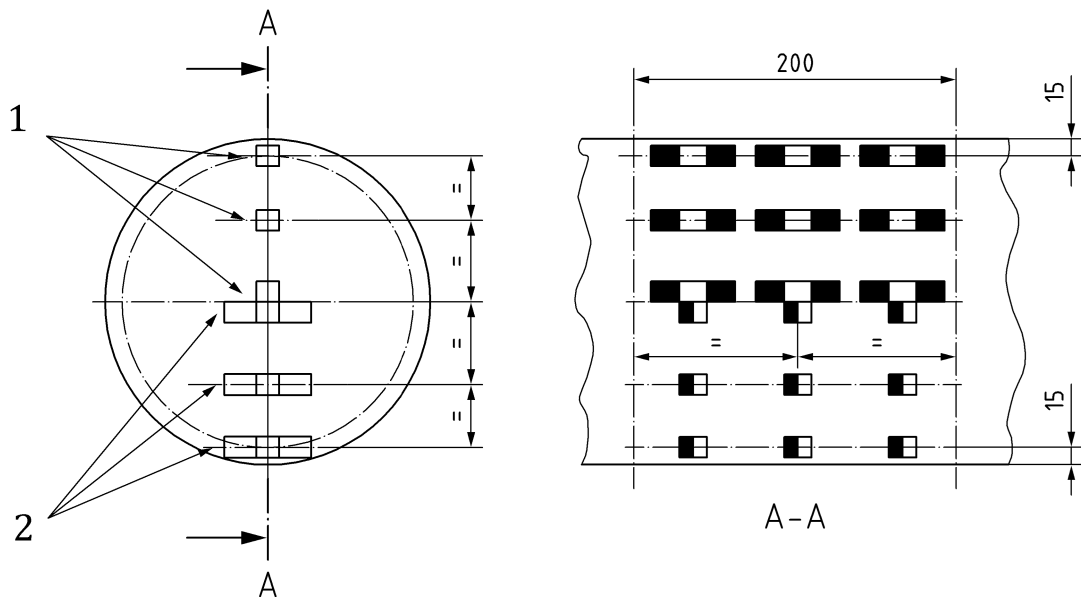
as shown in Figure 2a) and 2b).

For forged axles, when defined in the technical specification, a test piece may be taken from axle journal extensions as stated in Annex A.

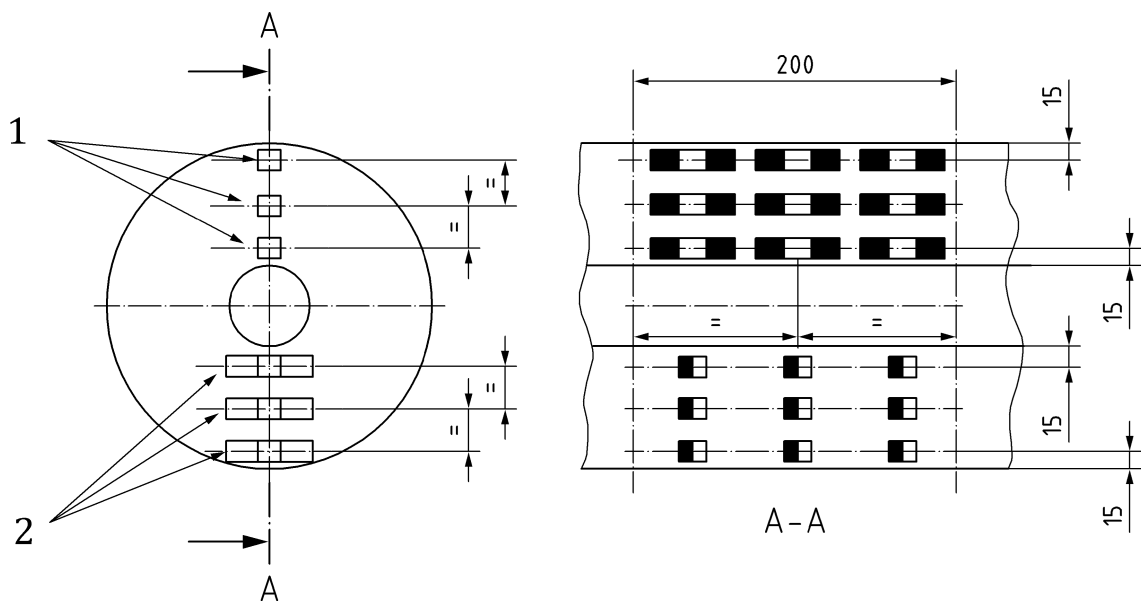
4.2.2.3 Test method

The Charpy pendulum impact test shall be carried out in accordance with EN ISO 148-1:2016.

Dimensions in millimetres



a) Solid axle



b) Hollow axle

Key

- 1 longitudinal test piece
- 2 transverse test piece

Figure 2 — Position of test pieces

4.2.3 Fatigue characteristics

4.2.3.1 General

4.2.3.1.1 Principles

Verification of the fatigue characteristics is essential in order to have a correctly dimensioned axle. The satisfactory performance of an axle in service depends upon these characteristics. The values defined in this subclause shall be used for the calculation of the maximum permissible stresses that are referred to in the design rules in EN 13103-1:2017+A1:2022 and CEN/TS 13103-2:2020.

It is necessary to determine the fatigue limits in the following two areas, in order to predict the behaviour of the axle under in-service stresses:

- for the material, tests are performed on small-scale test pieces, for which the shapes do not depend upon the product geometry;
- for the product, tests are performed on full-scale test pieces, for which the dimensions and manufacturing process are similar to the final product and its associated permissible manufacturing defects.

4.2.3.1.2 Fatigue limits on small-scale test pieces

The fatigue limits defined for reduced test pieces are used to verify that the notch effect of the material used for the manufacture of the axle is in accordance with the safety coefficient “S” defined in design standard EN 13103-1:2017+A1:2022 and CEN/TS 13103-2:2020. They are determined from:

- unnotched surface test pieces (fatigue limit R_{fL});
- notched test pieces (fatigue limit R_{fE}).

4.2.3.1.3 Fatigue limits on full-scale test pieces

The limits determined on full-scale test pieces are intended to verify that the fatigue characteristics are in accordance with those that are used to calculate the maximum permissible stresses referred to in design standards EN 13103-1:2017+A1:2022 and CEN/TS 13103-2:2020.

These fatigue limits apply to different axle areas. Only the fatigue limits applying to the axle body are taken into account in this standard.

NOTE The limits applying to the axle seats depend partly on the assembly and are referred to in EN 13260:2020.

It is necessary to define two fatigue limits:

- on the body surface, limit F_1 ;
- on the bore surface in the case of a hollow axle, limit F_2 . The limit F_2 has not to be verified for the steel presented in the scope of this standard.

4.2.3.2 Values to be achieved

The values to be achieved are given in Table 4.

Table 4 — Fatigue limit values

Grade	F_1 MPa	F_2 MPa	R_{fL} MPa	R_{fE} MPa	$q = R_{fL} / R_{fE}^a$ (informative values)
EA1N	≥ 200	≥ 80	≥ 250	≥ 170	$\leq 1,47$
EA1T	≥ 200	≥ 80	≥ 250	≥ 170	$\leq 1,47$
EA4T	≥ 240	≥ 96	≥ 350	≥ 215	$\leq 1,63$
^a The fatigue limits for samples of unnotched test pieces and notched test pieces in Table 4 are used as a reference to calculate safety factors in EN 13103-1:2017+A1:2022, which are valid for: $q \leq 1,47$ for EA1N and EA1T and $q \leq 1,63$ for EA4T.					

4.2.3.3 Fatigue test pieces

Examples of drawings of full-size and reduced dimension test pieces are given in Annex B and are intended to test a nominal stress as defined in Table 4.

To determine F_1 and F_2 , the test pieces shall be representative of the manufacturing process and product group (see Annex K) to qualify.

The full-scale geometries defined in Annex B lead to test a local stress that is between 1,20 and 1,23 times the nominal stress (i.e. stress concentration factor). In case of failure during this test on an axle with a different design than the ones described in Annex B, the influence of the test arrangement or this geometry should be analysed, to verify if they lead to a higher stress concentration factor. If so, the test should be adapted and repeated, in order to have the same local stress conditions as with the test pieces described in Annex B.

To determine F_2 , surface of the test pieces shall have a 1 mm deep notch as defined in Figure 3b. All these test pieces shall be produced using the same manufacturing process as that used for the axle.

To determine R_{fL} and R_{fE} , the test pieces shall have a diameter around 10 mm. The surface roughness (R_a) of the test piece for determining R_{fL} is less than or equal to $0,4 \mu\text{m}$. The notch for determining R_{fE} is defined in Figure 3a. These test pieces are taken as close as possible to the surface of the axle body.



Figure 3 — Fatigue test piece notches

4.2.3.4 Test method

The tests shall be performed with machines that induce rotating bending stresses in the verification area. For each limit, F_1 and F_2 , it shall be verified that for three test pieces there is no crack after 10^7 cycles of load that generates a surface stress level equal to F_1 and F_2 . The values of the stresses are nominal stresses to be applied at the section corresponding to the inner edge of the wheel seat at the axle body diameter. They are calculated by classical beam theory in relation to the standard samples for the tests described in Annex B. Regarding F_2 tests, the stresses are nominal stresses calculated at the outer body diameter in the section of the notch.

Alternatively, the local stresses can be measured by strain gauges. Those local stresses shall be scaled, through strain concentration factors, to the intended nominal stress to be verified, in the cross-section where the fatigue cracks initiate. The strain concentration factor should be determined by a static test or by a dynamic test.

R_{fL} and R_{fE} shall be determined for 10^7 cycles for a non-fracture probability of 50 %, which requires the use of at least 15 test pieces for each limit and a statistical method for the interpretation of the results.

NOTE The number of axles used to obtain the test pieces can be defined in the technical specification.

4.3 Microstructure characteristics

4.3.1 Values to be achieved

The microstructure of EA1N steel grade is derived from normalizing heat treatment and shall be ferritic-pearlitic.

The microstructure of EA1T steel grade is derived from quenching and tempering heat treatment and shall be ferritic-pearlitic.

NOTE In some specific cases (e.g. small-size axles), tempered bainite and tempered martensite can be found

The microstructure of EA4T steel grades is derived from quenching and tempering heat treatment and it shall be tempered bainite and/or tempered martensite. Ferrite and pearlite are permissible.

The grain size of EA1N, EA1T and EA4T (austenite grain size) shall be equal to or finer than that defined by the reference diagram 5 of EN ISO 643:2012, Annex B.

4.3.2 Position of the test piece

The test pieces shall be taken from the largest axle section in a 200 mm^2 plane, perpendicular to the arrow F, at mid-radius of solid axles, or at mid-distance between the external and internal surface of hollow axles, as shown in Figure 4.

For forged axles, when defined in the technical specification, a test piece may be taken from axle journal extensions as stated in Annex A.

4.3.3 Test method

Tests shall be performed in accordance with EN ISO 643:2012.

4.4 Material cleanliness

4.4.1 Micrographic cleanliness

4.4.1.1 Cleanliness level to be achieved

The level of cleanliness shall be measured by micrographic examination as defined in 4.4.1.2 and 4.4.1.3. The maximum values of inclusions to be obtained are given in Table 5.

Table 5 — Maximum values of inclusions in fine and thick series

Type of inclusions	Category 1		Category 2	
	Thick series (maximum)	Thin series (maximum)	Thick series (maximum)	Thin series (maximum)
A (sulphur)	1,5	1,5	1,5	2
B (Aluminate)	1	1,5	1,5	2
C (Silicate)	1	1,5	1,5	2
D (Globular oxide)	1	1,5	1,5	2
B + C + D	2	3	3	4
DS	1,5		2	

4.4.1.2 Position of the micrographic sample

The position of the samples is given in Figure 4.

The examination shall be made in a 200 mm² plane, perpendicular to arrow F, at mid-radius of the solid axles, or at mid-distance between external and internal surface of hollow axles. The test pieces shall be taken from the largest axle section.

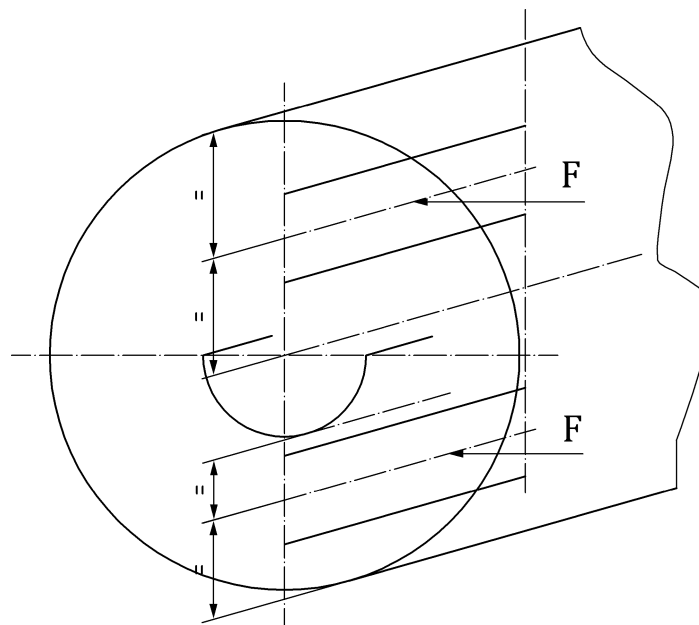


Figure 4 — Position of sample for micrographic examination (solid axle and hollow axle)

For forged axles, when defined in the technical specification test piece may be taken from axle journal extensions as stated in Annex A.

4.4.1.3 Test method

Cleanliness level determination shall be carried out in accordance with ISO 4967:2013, method A.

4.4.2 Internal integrity

4.4.2.1 General

Internal integrity of the axle in its rough machined or finished state shall be determined by ultrasonic examination using a mechanized computer-based test process. When the automatic system is temporarily not available, a manual process can be used, if specified in the technical specification.

Standard defects shall be flat bottom holes at different depths.

4.4.2.2 Level to be achieved

The axles shall have no internal defects that give echo magnitudes equal to or greater than those obtained for a reference defect situated at the same depth. The diameter of this reference defect shall be 2 mm for category 1 axles and 3 mm for category 2 axles. No attenuation of the back echo higher than 4 dB due to inhomogeneities or internal defects shall be accepted.

For the zone 20 mm below the surface, it is recommended, if the ultrasonic inspection equipment enables it, to record, for information, lower indication size (1 mm for axles of category 1 and 1,5 mm for axles of category 2).

4.4.2.3 Test piece

The examination shall be made on the axle itself after heat treatment and machining before the final protection is applied.

If axles are subjected to radial testing in their rough-machined state, they do not need to be tested in their finished state.

4.4.2.4 Method of examination

The axle internal integrity shall be verified by ultrasonic diametral examination according to ISO 5948:2018, method Da. The whole axle shall be examined, except certain parts (fillets, grooves, etc.) in accordance with the technical specification.

4.5 Permeability to ultrasound

4.5.1 General

The permeability shall ensure the feasibility of ultrasonic testing during service and is verified by producing a record for the axle after a calibration of the testing apparatus.

4.5.2 Level to be achieved

The echo obtained on the axles being checked shall have an amplitude equal to or greater than 50 % of full screen height, after calibration of the apparatus on the standard sample block specified in Annex C. The height of the background noise shall be less than 10 % of the screen height.

4.5.3 Test piece

The test piece to be examined shall be the axle, after full heat treatment.

The condition of the journal ends, at the moment of inspection, shall be the same as that required for delivery, without protection.

The test is carried out once before marking the axle and before the threaded holes for fixing the axle bearing end caps are machined. The roughness parameter Ra of the axle ends shall not exceed 12,5 μm .

If the geometry, dimensions, and final surface axle ends conditions allows efficient measurement, the test can be carried out after marking the axle and after the threaded holes for fixing the axle end caps are machined.

4.5.4 Test method

The ultrasonic permeability examination shall be performed by longitudinal checking of the axle according to ISO 5948:2018, method T.

Other methods to measure permeability are possible (for example by radial measurement). Nevertheless, they are considered as additional to the longitudinal measurement and, if required, shall be defined in the technical specification.

If the tests are not performed by an automated process, the measurement shall be performed at a minimum of 6 points, equally distributed around the axle journal section.

The probes used are the piezoelectric type, transmitter and receiver, in quartz or barium titanate (BaTi) with round or rectangular sections (between 80 mm² and 450 mm²). Their frequency and the height of the echo obtained in front of the flat bottom of diameter 1 mm are specified in Table 6 for each category of axle. The noise during the calibration shall not exceed 5 % of the full screen height.

For this test, the instrument shall operate with narrow frequency bands centred on the nominal frequencies " F_n " so that the band is between $F_n - 20\%$ and $F_n + 20\%$, for an attenuation of 3 dB in relation to the frequency signal F_n .

Table 6 — Calibration for permeability examination

	Category 1	Category 2
Frequency F_n	5 MHz	2 MHz to 3 MHz
Conditions for calibration (% of full screen height)	90 %	40 %

If other probes are used, the calibration and results to be achieved shall be defined in the technical specification.

A recommendation for the position of the testing points is described in Annex D.

4.6 Residual stresses

4.6.1 General

The final axle shall not have residual stresses that can cause deformations of axles or facilitate fatigue crack initiation.

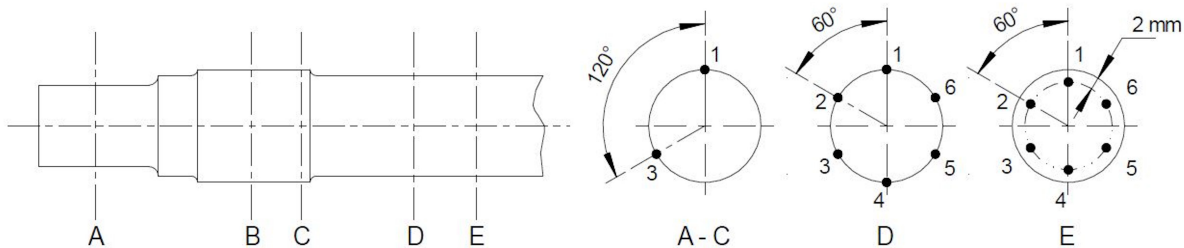
4.6.2 Values to be achieved

Residual stresses, in the axial direction, shall be less than or equal to +100 MPa, in tension, near the axle surface (no more than 0,1 mm under the surface, depending on the measurement method) and at 2 mm under the surface of the axle.

The difference between residual stress values measured at any two different points 2 mm under the surface shall be less or equal to 40 MPa.

4.6.3 Test piece and position of measurement points

The test piece shall be the axle in the delivery condition. The position of measurement points is given in Figure 5. The measuring points of the wheelseat are located at its centerline and on its inner edge.



Key

A, B, C, D and E measuring points for residual stresses

Figure 5 — Position of measurement points

Position of section C should be the closest possible of the seat edge, depending on the measurement method.

4.6.4 Measurement method

The measurements to determine the residual stresses can be made e.g. with strain gauges with saw cutting (see Annex E) or with strain gauges with hole-drilling (see ASTM E837-20) or by X-ray diffraction (see EN 15305:2008). The method shall be documented and defined in the technical specification.

4.7 Surface characteristics

4.7.1 Surface finish

4.7.1.1 Characteristics to be achieved

The axle surface shall not show any other marks than those stipulated in this standard.

The surface roughness (R_a) is given in Table 7. The symbols are those defined in Figure 6.

Table 7 — Surface finish

Designation	Symbol (see Figure 6)	Surface roughness ^a <i>Ra</i> μm	
		Rough-machined	Finished or ready for assembly
End of the axle – axle end and chamfer – axle centre face (solid and hollow axle)	a See details R1 and R2	- -	6,3 3,2
Journal – journal surface – stress relieving grooves	b c (detail V)	12,5 -	0,8 ^d 0,8
Abutment – abutment ring seat – abutment free surface	d1 d2	12,5 12,5	1,6 ^d 1,6 ^b
Wheelseat – wheelseat surface – lead in taper	e f (detail U)	12,5 -	Minimum 0,8 Maximum 1,6 ^{c, d} 1,6
Body – inner transitional radii to wheelseat – axle body surface – gearwheel, seat and brake disc seat surface – bearing seat and seal seat surface – transitional radii between two seats	g (detail T) l h j k (detail S)	- - 12,5 12,5 -	1,6 ^b 3,2 ^b Minimum 0,8 Maximum 1,6 ^{c, d} 0,8 ^d 1,6
Bore – bore surface	m (detail R1)	-	3,2 ^c
^a For old axle types with plain bearing journals, the requirements are in the standards that deal with these products. ^b After machining and blasting, a value of 6,3 may be defined and documented in the technical specification if fatigue limit F_1 or F_2 defined in 4.2.3.2 and the sensitivity required for the in-service ultrasonic control are achieved. Annex F gives guidance on blasting parameters assessment. ^c In-service Non-Destructive Examination may require smaller values of surface finish, e.g. Ra 2 μm for the bore. ^d For seats with molybdenum coating a roughness of Ra = 3,2 is allowable.			