



BSI Standards Publication

Railway applications — Wheelsets and bogies — Axles — Product requirements

National foreword

This British Standard is the UK implementation of EN 13261:2020. It supersedes BS EN 13261:2009+A1:2010, which is withdrawn.

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Contents

Page

European foreword.....	6
Introduction	7
1 Scope	8
2 Normative references	8
3 Terms and definitions	9
4 Product definition	11
4.1 Chemical composition	11
4.1.1 Values to be obtained	11
4.1.2 Sampling methods	11
4.1.3 Analysis method	11
4.2 Mechanical characteristics	11
4.2.1 Characteristics from the tensile testing	11
4.2.2 Impact resistance characteristics	14
4.2.3 Fatigue characteristics	16
4.3 Microstructural characteristics	18
4.3.1 Values to be obtained	18
4.3.2 Position of the test piece	18
4.3.3 Test method	18
4.4 Material cleanliness	18
4.4.1 Micrographic cleanliness	18
4.4.2 Internal integrity	20
4.5 Ultrasonic permeability	20
4.5.1 General	20
4.5.2 Level to be obtained	20
4.5.3 Test piece	20
4.5.4 Test method	21
4.6 Residual stresses	21
4.6.1 General	21
4.6.2 Values to be obtained	21
4.6.3 Test piece and measurement point location	21
4.6.4 Measurement method	22
4.7 Surface characteristics	22
4.7.1 Surface finish	22
4.7.2 Surface integrity	25
4.8 Geometrical and dimensional tolerances	26
4.9 Protection against corrosion and mechanical damage	31
4.9.1 Final protection	31
4.9.2 Temporary protection	36
4.10 Marking	37
5 Alternative manufacturing process	37
6 Product qualification	37
7 Conditions of supply of the product	37

Annexe A (informative) Sampling of the material from an axle journal overlength.....	38
A.1 Values to be reached.....	38
A.2 Sampling method.....	38
A.2.1 Overlength with a diameter identical to the journal diameter.....	38
A.2.2 Overlength with a diameter greater than the journal diameter	38
Annexe B (informative) Test piece drawings	39
Annexe C (normative) Gauge block for measuring ultrasound permeability.....	43
C.1 Gauge block.....	43
C.2 Gauge block tolerances.....	45
C.3 Steel grade of the gauge block.....	45
Annexe D (informative) Position of measurement zones for ultrasound permeability	46
Annexe E (informative) Residual stress measurement with strain gauges and saw cutting	47
Annexe F (informative) Post-machining shot peening method	48
F.1 Shot peening principle.....	48
F.2 Requirements.....	48
F.2.1 Shot peening product	48
F.2.2 Hardness	48
F.2.3 Roughness	48
F.2.4 Coverage rate	48
F.2.5 Fatigue limit.....	48
F.3 Parameters.....	49
F.4 Qualification of the shot-peening process	49
Annexe G (normative) Method to determine the impact resistance of the protective coating	50
G.1 YES.....	50
G.2 Test piece.....	50
G.3 Equipment.....	50
G.4 Operating procedure	50
G.5 Expression of results	50
Annexe H (normative) Method to determine the chipping resistance of the protective coating	51
H.1 YES.....	51
H.2 Test piece.....	51
H.3 Equipment.....	51
H.4 Operating procedure	51
H.5 Expression of results	51
Annexe I (normative) Method to determine the resistance of the coating to specific corrosive products	53

I.1	YES	53
I.2	Test piece	53
I.3	Equipment	53
I.4	Corrosive products	53
I.5	Operating procedure	54
I.6	Expression of results.....	54
Annexe J (normative) Method to determine the resistance of the protective coating under cyclic mechanical stress.....		55
J.1	Purpose	55
J.2	YES	55
J.3	Test piece	55
J.4	Equipment	55
J.5	Operating procedure	55
J.6	Expression of results.....	56
Annexe K (normative) Product qualification		57
K.1	Introduction	57
K.2	General.....	57
K.3	Requirements	58
K.3.1	Requirements to be met by the manufacturer	58
K.3.1.1	General.....	58
K.3.1.2	Quality organisation.....	58
K.3.1.3	Staff qualification	58
K.3.1.4	Equipment	58
K.3.2	Requirements to be met by the product	58
K.4	Qualification procedures.....	59
K.4.1	General.....	59
K.4.2	Documentation required.....	59
K.4.3	Evaluation of production facilities and production process	59
K.4.4	Laboratory tests.....	60
K.5	Validity of the qualification	60
K.5.1	Condition of validity.....	60
K.5.2	Modification and extension	60
K.5.3	Transfer	60
K.5.4	Expiry	61
K.5.5	Withdrawal.....	61
K.6	Qualification record	61

Annexe L (normative) Conditions of supply of the product	62
L.1 Introduction.....	62
L.2 General	62
L.3 Delivery state	63
L.4 Unit checks	63
L.5 Batch sampling check.....	63
L.5.1 Checks to be carried out.....	63
L.5.2 Ultrasonic permeability	64
L.5.3 Surface finish.....	64
L.5.4 Visual inspection.....	65
L.6 Quality plan.....	65
L.6.1 General	65
L.6.2 Objectives	65
L.6.3 Quality Plan terms of application	65
L.7 Permissible repairs.....	66
L.7.1 General	66
L.7.2 Heat treatment	66
L.7.3 Retesting	66
L.7.4 Axle straightening	66
L.7.5 Re-machining	66
Annexe M (normative) Measurement of the hydrogen content of steel for axles at the development stage	67
M.1 General	67
M.2 Sampling	67
M.3 Analysis methods.....	67
M.4 Precautions	67
Annexe ZA (informative) Relationship between this European Standard and the essential requirements of Directive 2016/797/EC to be fulfilled	68
Bibliography	70

European foreword

This document (EN 13261:2020) was prepared by the CEN/TC 256 “Railway Applications” Technical Committee, the secretariat of which is held by the DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, by March 2021 at the latest, and all conflicting national standards shall be withdrawn no later than March 2021.

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

This document supersedes EN 13261:2009+A1:2010.

This document has been prepared within the framework of a mandate given to CEN by the European Commission and the European Free Trade Association and supports the essential requirements of Directive 2016/797/EC.

For the relationship with Directive 2016/797/EC, see informative Annex ZA, which forms an integral part of this document.

For a description of the technical changes made in this new edition, see the Introduction.

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

NOTE 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.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are required 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, the Netherlands, Norway, Poland, Portugal, the Republic of North Macedonia, the Republic of Serbia, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

After several years of using the first two editions of this document (EN 13261: 2003 and EN 13261:2009), this new edition incorporates further improvements and data, such as the results of European projects.

The product requirements have been harmonised across all three standards for wheelsets, wheels and axles.

In addition, the annexes concerning the qualification of the product and the conditions of supply of the product, which were previously informative, have been modified taking the feedback into account and have become normative.

Also, the “freight wagon” and “locomotive and passenger vehicle” TSIs require the existence of a production verification process.

1 Scope

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

This document applies to heavy railway vehicles but may also apply to other vehicles such as light railway vehicles, trams or undergrounds.

It defines the characteristics of axles manufactured by forging or rolling, in vacuum-degassed steel, grade EA1N¹, EA1T¹ and EA4T¹. For hollow axles, this document only applies to those obtained by machining the hole in a solid forged or rolled axle.

The requirements defined in this standard apply to cylindrical wheel seats. Most of the requirements also apply to wheelsets with conical wheel seats. Specific requirements for conical wheel seats (e.g. geometric dimensions) are defined in the technical specification.

Some characteristics are given according to category 1 or category 2.

This document applies to axles whose design complies with the rules defined in EN 13103-1.

This document also allows variations in material characteristics in relation to alternative manufacturing processes (e.g. cold forging, shot peening, thermal spraying, steel cleanliness, reduction ratio, improvement of material properties through fusion or heat treatment processes, etc.).

2 Normative references

The following documents referred to in the text constitute, for all or part of their content, requirements of this document. For dated references, only the cited edition applies. For undated references, the last edition of the reference document applies (including any amendments).

EN 13103-1, *Railway applications – Wheelsets and bogies – Non-powered axles – Part 1: Design method for axles with external journals*

EN 22768-1, *General tolerances – Part 1: Tolerances for linear and angular dimensions without individual tolerance indications (ISO 2768-1)*

EN 22768-2, *General tolerances – Part 2: Geometrical tolerances for features without individual tolerance indications (ISO 2768-2)*

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

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

EN ISO 11997-1:2006, *Paints and varnishes - Determination of resistance to cyclic corrosion conditions - Part 1: Wet (salt fog)/dry/humid (ISO 11997-1:2006)*

EN ISO 2409:2013, *Paints and varnishes – Cross-cut test (ISO 2409:2013)*

EN ISO 2808, *Paints and varnishes – Determination of film thickness (ISO 2808)*

EN ISO 4624:2016, *Paints and varnishes - Pull-off test for adhesion (ISO 4624:2016)*

¹ N for a standardised metallurgical state;

T for a quenched and tempered metallurgical state.

EN ISO 6507-1, *Metallic materials – Vickers hardness test – Part 1: Test method (ISO 6507-1)*

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

EN ISO 9227, *Corrosion tests in artificial atmospheres – Salt spray tests (ISO 9227)*

EN ISO 14284:2002, *Steel and iron - Sampling and preparation of samples for the determination of chemical composition (ISO 14284:1996)*

EN ISO 16276-2, *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 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 9769²⁾, *Steel and iron – Review of available methods of analysis*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for standardisation, which can be accessed at the following addresses:

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

3.1

Technical specification

A document describing specific parameters and/or product requirements in addition to the requirements of this document

²⁾ See also CEN/TR 10261.

3.2

Batch

A batch is composed of axles assumed to have the same characteristics

Note 1 to clause: A batch consists of axles of the same design obtained by forging or rolling a raw material from a single cast and having undergone the same hot deformation process and having been heat treated at the same time with the same procedure. If the raw material is obtained from several casts with the expected chemical composition, the resulting axles can be combined in a batch. In this case, it is necessary to prove during product qualification that the axles from the different casts meet the product qualification requirements.

3.3

Axle categories

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

Note 1 to clause: Category 1 is generally selected when the traffic speed is greater than 200 km/h.

Note 2 to clause: Vehicles travelling at speeds of 200 km/h or less typically use Category 2 axles.

Note 3 to clause: These categories can also be defined in accordance with the technical specification.

4 Product definition

4.1 Chemical composition

4.1.1 Values to be obtained

The percentage limit values of the various elements must meet the indications in Table 1.

Table 1 — Limit levels by product analysis

Grade	C %	Si %	Min %	P ^a %	S ^{a b} %	Cr %	Cu %	Mb %	Ni %	\\tab 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	≥ 0.15	≥ 0.50			≥ 0.90		≥ 0.15		
	≤ 0.29	≤ 0.40	≤ 0.80	≤ 0.020	≤ 0.015 ^b	≤ 1.20	≤ 0.30	≤ 0.30	≤ 0.30	≤ 0.06

^a A maximum content of 0.025% may be agreed in the technical specification.

^b A minimum sulphur content may be agreed in the technical specification based on the steel development process to protect against hydrogen embrittlement.

4.1.2 Sampling methods

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

The chemical composition can alternatively be determined by analysing a sample from the cast.

For forged axles, if the method is included in the technical specification, a sample can be extracted from an overlength of the axle journals as specified in Annex A.

4.1.3 Analysis method

The chemical composition analysis must be performed in accordance with the methods and instructions described in ISO/TR 9769 unless another standard is defined in the technical specification.

NOTE ASTM E415-14 or ASTM E1019-11 may be used.

4.2 Mechanical characteristics

4.2.1 Characteristics from the tensile testing

4.2.1.1 Values to be obtained

Values to be obtained at the mid-radius of solid axles, or at the mid-distance between external and internal surfaces of hollow axles, are specified in Table 2.

Values to be obtained near the external surface of the axles must be ≥ 0.95 times the values measured at mid-radius of the solid axles or at mid-distance between the internal and external surfaces of hollow axles.

Values to be obtained at the centre of the solid axles, or near the internal surface of the hollow axles, must be ≥ 0.8 times the values measured at mid-radius or mid-distance between internal and external surfaces.

Table 2 — Values to be obtained at mid-radius of solid axles or mid-distance between internal and external 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 there is no apparent yield strength, the conventional $R_{p0.2}$ limit must be determined.			

4.2.1.2 Positions of the test pieces

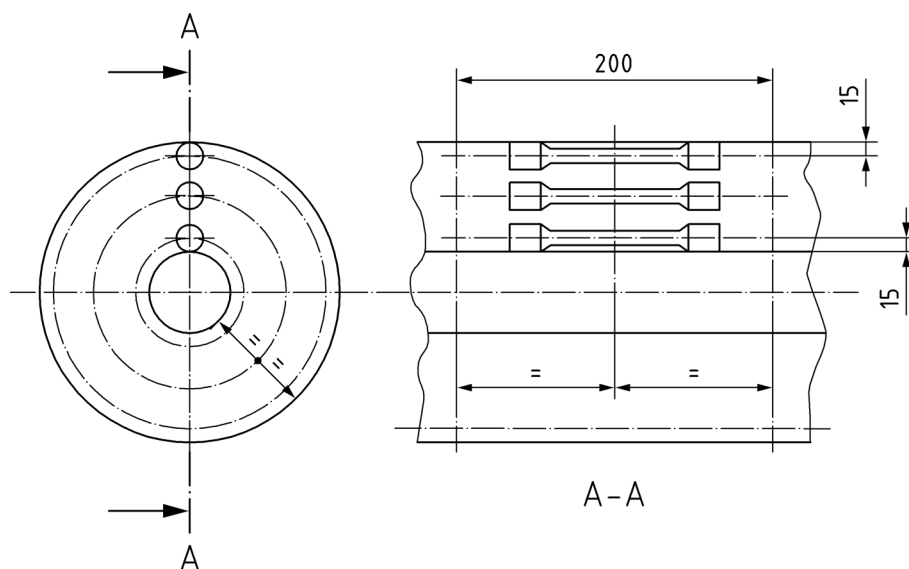
The test pieces must be collected at three levels from the largest diameter section of the axle:

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

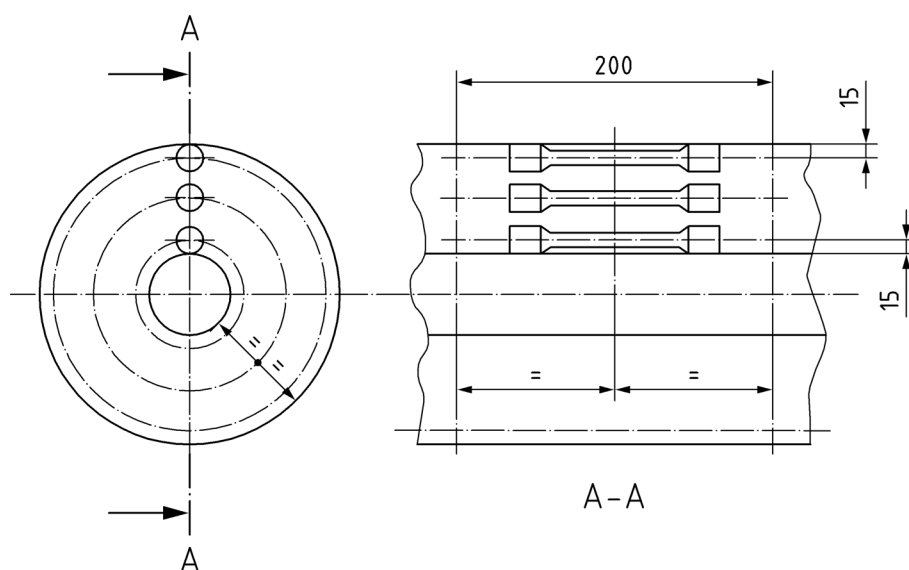
as shown in Figure 1 a) and b).

For forged axles, if the method is included in the technical specification, the test pieces can be extracted from an overlength of the axle journals as specified 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 must be carried out in accordance with the requirements of EN ISO 6892-1. The diameter of the test piece must be at least 10 mm in its calibrated part. The length of the measuring gauge must be 5 times the diameter.

4.2.2 Impact resistance characteristics

4.2.2.1 Values to be obtained

The impact resistance characteristics must be determined in the longitudinal and transverse directions of the axle.

Values to be obtained at the mid-radius of solid axles or at the mid-distance between internal and external surfaces of hollow axles are specified in Table 3.

Near the surface, the average value calculated from 3 samples must be ≥ 0.95 times the mean values measured at mid-radius or at mid-distance between internal and external surfaces for hollow axles.

At the centre of solid axles or near the internal surface of hollow axles, the mean value calculated from 3 samples must be ≥ 0.8 times the mean values measured at mid-radius or at mid-distance between internal and external surfaces.

For each position (surface, mid-radius, centre), the average value of the 3 test pieces (see 4.2.2.2) is defined in Table 3.

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

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

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

4.2.2.2 Position of the test pieces

The test pieces must be collected at three levels from the largest diameter section of the axle:

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

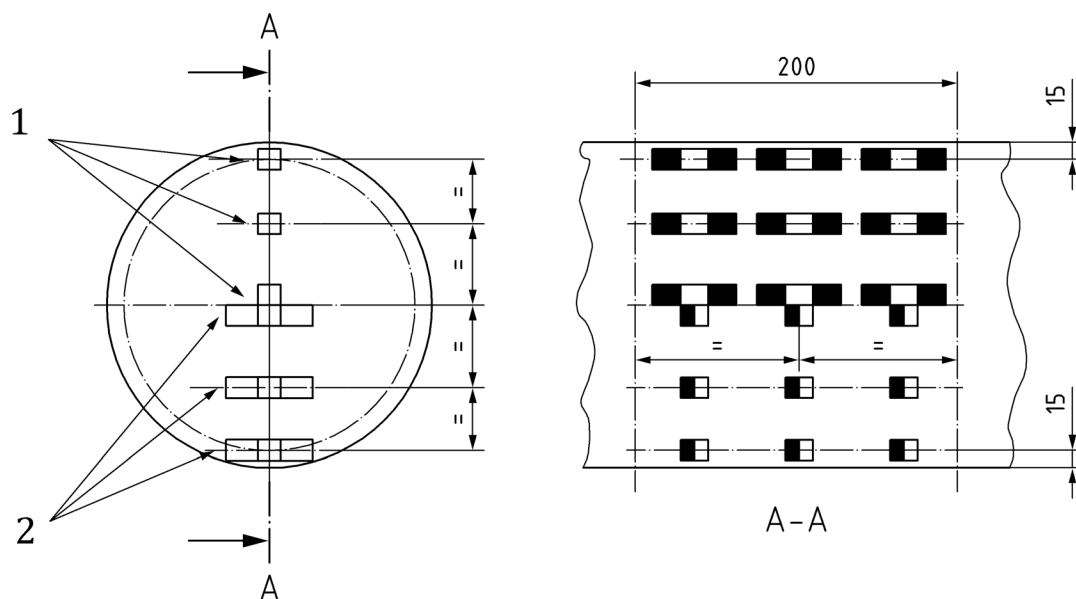
as shown in Figure 2 a) and b).

For forged axles, if the method is included in the technical specification, the test pieces can be extracted from an overlength of the axle journals as specified in Annex A.

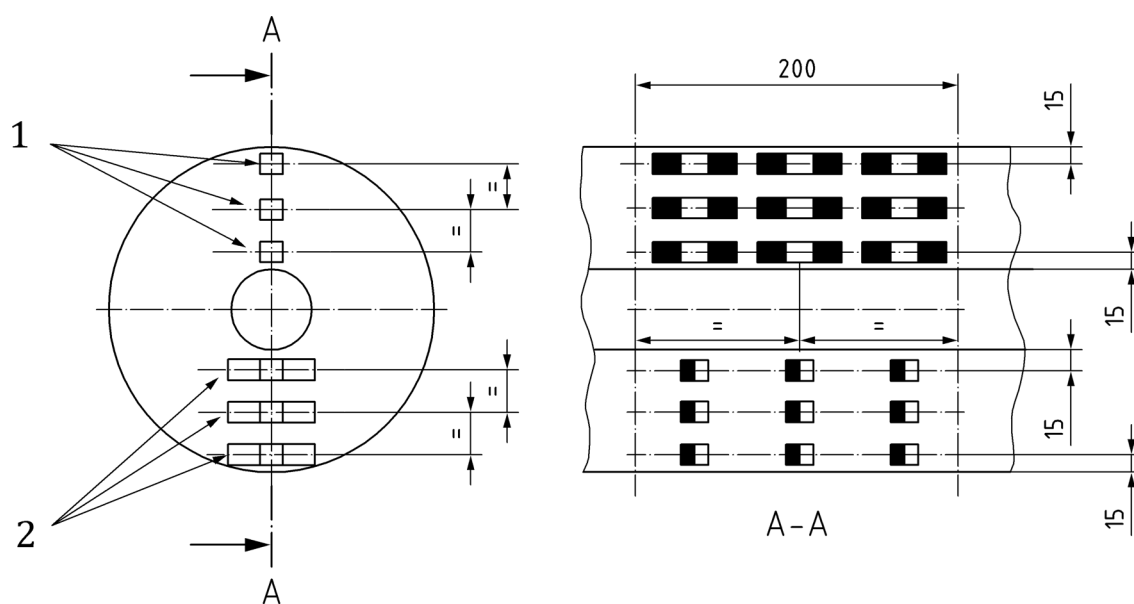
4.2.2.3 Test method

The impact bending test must be conducted in accordance with the requirements of EN ISO 148-1.

Dimensions in millimetres



a) Solid axle



b) Hollow axle

Wheel rejected

- 1 longitudinal test piece
- 2 transverse test piece

Figure 2 – Position of test pieces

4.2.3 Fatigue characteristics

4.2.3.1 11.2.3.1\tab General

4.2.3.1.1 Introduction

It is essential to check the fatigue characteristics to correctly size an axle. These characteristics affect the proper performance of the axle during operation. The values defined in these paragraphs are used as references to calculate the maximum allowable stresses, used in the design rules of EN 13103-1.

To obtain adequate assurance of how the axle will respond under stress in operation, the values of the fatigue limits must be estimated in the following two areas:

- at material level, by testing small test pieces independent of product geometry;
- at product level, by testing scale 1 test pieces with dimensions and manufacturing representative of the final product and its permissible manufacturing defects.

4.2.3.1.2 Fatigue limits on small test pieces

The fatigue limits determined on small test pieces are intended to verify that the susceptibility to the notch effect of the material used to manufacture the axle, complies with safety factor "S" defined in design standard EN 13103-1. They are determined:

- on a smooth test piece (fatigue limit R_{fL});
- on a notched test piece (fatigue limit R_{fE}).

4.2.3.1.3 Fatigue limits on scale 1 test pieces

The limits determined on scale-1 test pieces are intended to confirm that the axles have fatigue characteristics in accordance with those which make it possible to obtain the maximum allowable stresses, given in design standard EN 13103-1.

These fatigue limits characterise the different areas of an axle. This document only takes into account the fatigue limits that characterise the axle body.

NOTE The limits characterising the axle seats depend partially on the assembly and are discussed in EN 13260.

Two fatigue limits must be determined:

- on the surface of the body, limit F_1 ;
- on the surface of the bore for a hollow axle, limit F_2 . Limit F_2 should not be verified for the steel grades cited in the scope of this document.

4.2.3.2 Values to be obtained

The values to be obtained are provided 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	≤ 1.47
EA1T	≥ 200	≥ 80	≥ 250	≥ 170	≤ 1.47
EA4T	≥ 240	≥ 96	≥ 350	≥ 215	≤ 1.63

^a The fatigue limits for samples on smooth test pieces and notched test pieces in Table 4 are used as a reference to calculate safety factors in EN 1303-1, 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

To determine F_1 and F_2 , the test pieces, in their cracking zone, must have a geometry and surface finish similar to those of the axle whose area is to be characterised. To determine F_2 , the surface of the test pieces must have a 1-mm-deep notch as shown in Figure 3 b), with the notch on the external surface of the test piece. All these test pieces must be produced using the same manufacturing process as that used for the axles.

To determine R_{fL} and R_{fE} , the test pieces have a 10-mm diameter in their cracking zone. The roughness (R_a) of the test piece for determining R_{fL} is $\leq 0.4 \mu\text{m}$. The notch for determining R_{fE} has a geometry consistent with that in Figure 3 a). These test pieces are taken as close as possible to the surface of the axle body.

Dimensions in millimetres

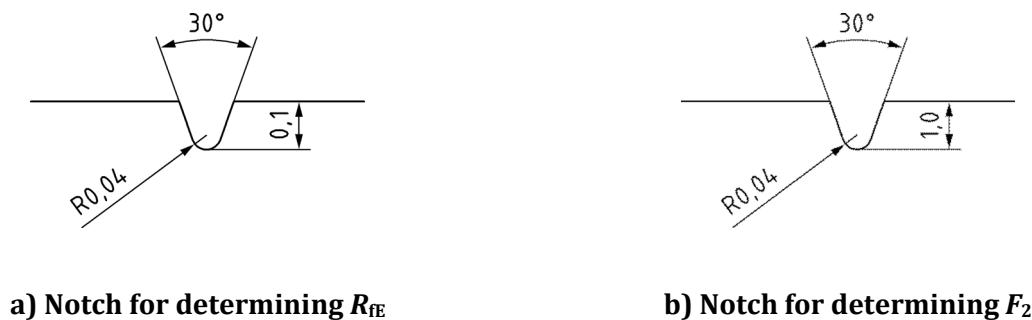


Figure 3 — Notches in fatigue test pieces

Examples of scale 1 and small test pieces are provided in Annex B.

4.2.3.4 Test method

Tests must be performed on machines that can create rotary bending stress in the cracking zone.

For each F_1 and F_2 limit, it must be checked that, for three test pieces, no cracks are observed after 10^7 surface stress cycles equal to F_1 or F_2 . Stress values are nominal stresses and must be calculated using conventional material resistance methods (beam theory), in relation to standard test pieces defined in Annex B. Alternatively, local stresses can be measured by strain gauges. These local stresses must be extrapolated, using stress concentration factors, in the nominal stresses to be checked, in the section where the fatigue crack starts. Stress concentration factors must be determined through a static test.

R_{fl} and R_{fe} must be determined at 10^7 cycles for a 50% probability of non-rupture; this requires the use of at least 15 test pieces for each limit and a statistical counting method.

The number of axles needed to obtain the test pieces may be defined in the technical specification.

4.3 Microstructural characteristics

4.3.1 Values to be obtained

The EA1N and EA1T grades must have a ferritic-pearlitic microstructure.

The EA4T grade has a tempered martensite/bainite microstructure. Ferrite traces can be observed.

The grain size of the EA1N, EA1T and EA4T grades (austenite grain size) must be equal to or finer than that of image type 5 of EN ISO 643:2012, Annex B.

4.3.2 Position of the test piece

The test pieces must be taken from the largest diameter section of the axle, on a flat, 200-mm² surface perpendicular to the F arrow, centred at mid-radius of the solid axles or mid-distance between the internal and external surfaces of the hollow axles, as shown in Figure 4.

For forged axles, if the method is included in the technical specification, the test pieces can be extracted from an overlength of the axle journals as specified in Annex A.

4.3.3 Test method

The tests must be carried out in accordance with EN ISO 643.

4.4 Material cleanliness

4.4.1 Micrographic cleanliness

4.4.1.1 Cleanliness level to be achieved

The cleanliness level must be determined from the micrographic examination defined in 4.4.1.2 and 4.4.1.3. The maximum inclusions are stated in Table 5.

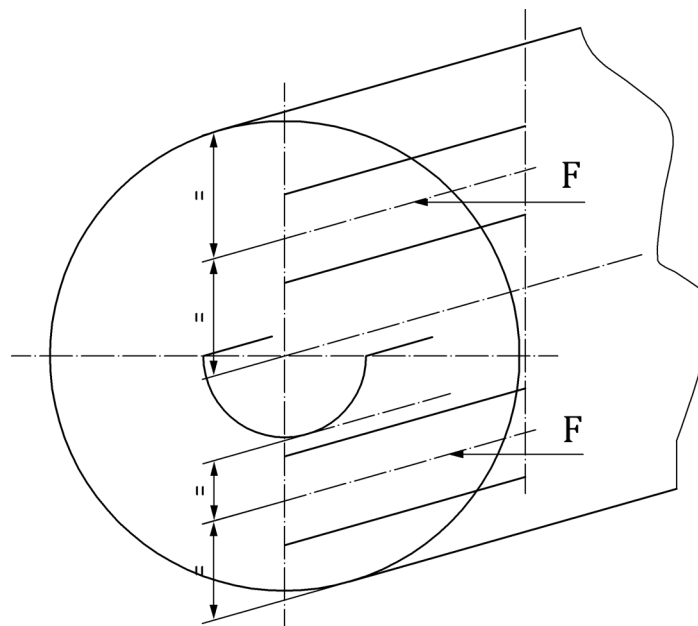
Table 5 — Maximum inclusions for thin and thick series

Type of inclusions	Category 1		Category 2	
	Thick series (maximum)	Thin series (maximum)	Thick series (maximum)	Thin series (maximum)
A (Sulphide)	1.5	1.5	1.5	2
B (Aluminates)	1	1.5	1.5	2
C (Silicates)	1	1.5	1.5	2
D (Globular oxides)	1	1.5	1.5	2
B + C + D	2	3	3	4
DS	1.5		2	

4.4.1.2 Location of the micrographic sample

The sampling position is shown in Figure 4.

The examination must be performed on a 200-mm² longitudinal section, perpendicular to the F arrow, centred at mid-radius of the solid axles or mid-distance between the internal and external surfaces of the hollow axles. The test pieces must be collected from the largest diameter part of the axle.

**Figure 4 — Micrographic examination sampling location (solid axle and hollow axle)**

For forged axles, if the method is included in the technical specification, the samples can be extracted from an overlength of the axle journals as specified in Annex A.

4.4.1.3 Test method

The level of cleanliness shall be determined in accordance with ISO 4967:2013, Method A.

4.4.2 Internal integrity

4.4.2.1 General

The internal integrity of the axles in the as-machined state or in the finished state must be defined through an ultrasound examination using an automated test rig. Standard defects must be flat-bottomed holes of varying depths.

4.4.2.2 Level to be obtained

The axles must not have internal defects indicating faults equal to or greater than those obtained for standing defects at the same depth. The diameter of these defects must be 2 mm for category 1 axles and 3 mm for category 2 axles. No bottom echo attenuation above 4 dB due to heterogeneities or internal defects must be observed.

4.4.2.3 Test piece

The test piece must include the axle itself, following heat treatment and machining before the final protective coating is applied.

If the axles have undergone a radial examination in their semi-finished state, they do not need to be examined in their finished state.

4.4.2.4 Examination method

The internal integrity of the axles must be verified by diametric probing using ultrasound, according to the Da method of ISO 5948:2018. The entire volume of each axle must be explored, excluding certain zones (fillets, grooves, etc.) in accordance with the technical specification.

4.5 Ultrasonic permeability

4.5.1 General

Permeability must ensure the feasibility of in-operation ultrasound examinations; it is verified by recording the response obtained on the axle after prior calibration of the equipment.

4.5.2 Level to be obtained

The bottom echo obtained on the axles to be checked must have an amplitude greater than or equal to 50% of the total screen height, after pre-setting the equipment on the gauge block described in Annex C. The background noise height must be less than 10% of the total screen height.

4.5.3 Test piece

The test piece must consist of the complete axle after heat treatment.

At the time of the inspection, the surface finish of the journal ends must be that required in the unprotected delivery state.

The examination is carried out before marking the axle and before machining the threads used to attach the axle end caps. The roughness R_a on the axle ends must not exceed 12.5 μm .

If the geometry, dimensions and final surface finishes of the axle ends can be accurately measured, the test can be carried out after marking the axle and after machining the threads to attach the end cap.

4.5.4 Test method

The ultrasonic permeability check must be carried out via a longitudinal axle survey using Method T of ISO 5948:2018.

Other methods of measuring permeability can be used (e.g. radial). However, these are considered additional methods to the longitudinal measurement and, if necessary, must be defined in the technical specification.

If the checks are not carried out automatically, the measurement must be performed on at least 6 points evenly distributed throughout the journal section of the axle.

The translators used are "piezoelectric", transmitter and receiver, in quartz or barium titanate BaTi with a round or rectangular section (between 80 mm² and 450 mm²). Their frequency and the echo height to be obtained at the flat-bottomed hole with a diameter of 1 mm of the calibration block, for each axle category, are described in Table 6. With these settings, the background noise must not exceed 5% of the screen height.

For this check, the equipment must operate with narrow bandwidths, centred on nominal frequencies " F_n " so that the band is between $F_n - 20\%$ and $F_n + 20\%$, for a 3 dB attenuation compared to the F_n frequency signal.

Table 6 — Permeability inspection settings

	Category 1	Category 2
Frequency F_n	5 MHz	2 MHz to 3 MHz
Calibration conditions (% of total screen height)	90%	40%

If other translators are used, the setting conditions and results to be obtained must be defined in the technical specification.

A recommendation for the position of measuring points is provided in Annex D.

4.6 Residual stresses

4.6.1 General

The finished axle must not have any residual stresses that can cause axle deformation or facilitate fatigue cracking.

4.6.2 Values to be obtained

Residual stresses, in the axial direction, must be less than or equal to +100 MPa, in traction, near the axle surface (no more than 0.1 mm below the surface, depending on the measurement method) and 2 mm below the axle surface.

At 2 mm below the surface, the difference in residual stress values measured at two different points must be less than or equal to 40 MPa.

4.6.3 Test piece and measurement point location

The test piece must constitute the axle in the delivery state. The measuring point location is shown in Figure 5. The measuring points of the wheel seats are located at the axis of the axle and on its inner rim.

Dimensions in millimetres