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English Version

Railway applications - Wheelsets and bogies - Axles - Product requirements

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Bahnanwendungen - Radsätze und Drehgestelle - Radsatzwellen - Produktanforderungen

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Contents

Page

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of an identical text or by endorsement, by March 2021 at the latest, and all conflicting national standards shall be withdrawn no later than March 2021.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 EA1N[1], 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)*

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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 9769[2)], *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 ≤ 0.29	≥ 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 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;

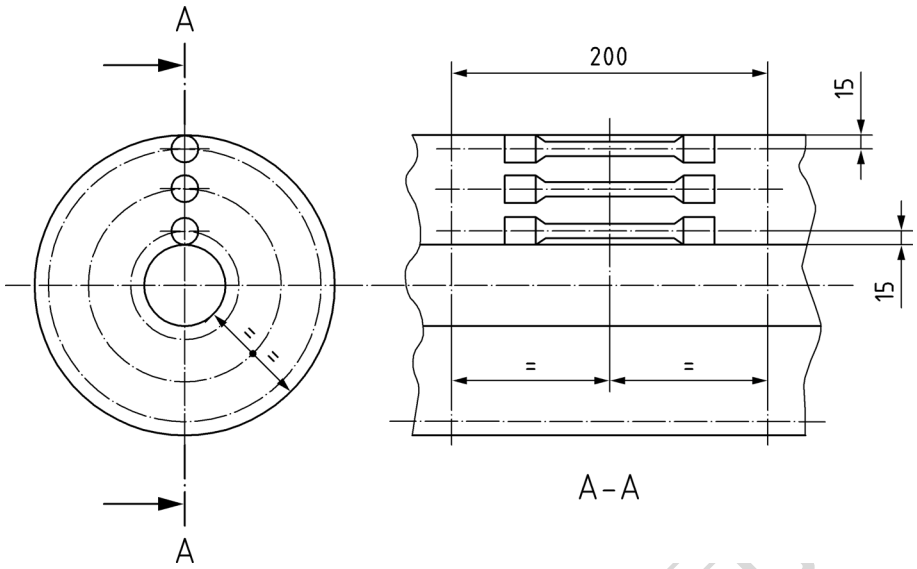
2) at mid-radius and in the centre of the solid axles;

3) at mid-distance between internal and external surfaces, and near the internal surface, for hollow axles;

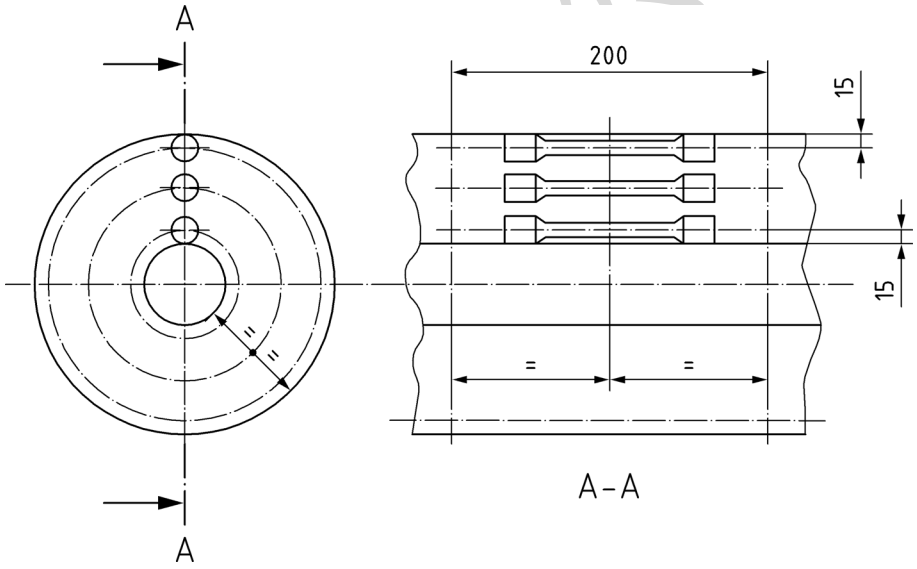
as shown in Figure 1 a) and b).

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 *KU* (J)	Minimum longitudinal *KU* (J)	Average transverse *KU* (J)	Minimum transverse *KU* (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;

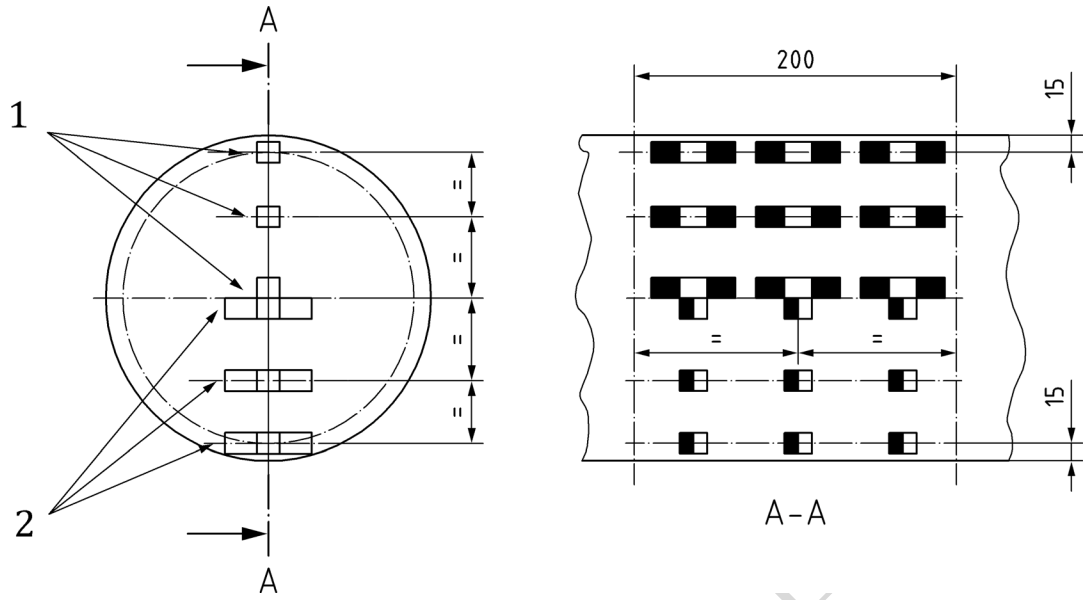
as shown in Figure 2 a) and b).

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.

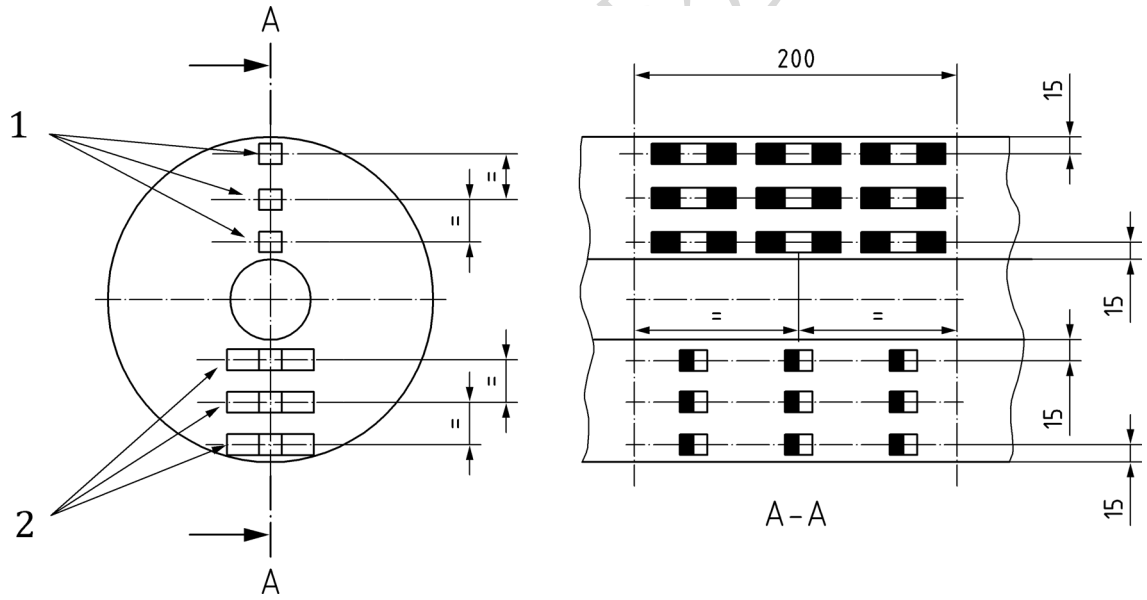
4.2.2.3 Test method

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⩽1.47 for EA1N and EA1T and q⩽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 (Ra) of the test piece for determining R_{fL} is ≤ 0.4 µm. 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

a) Notch for determining R_{fE} **b) Notch for determining F_2**

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-mm²longitudinal 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.

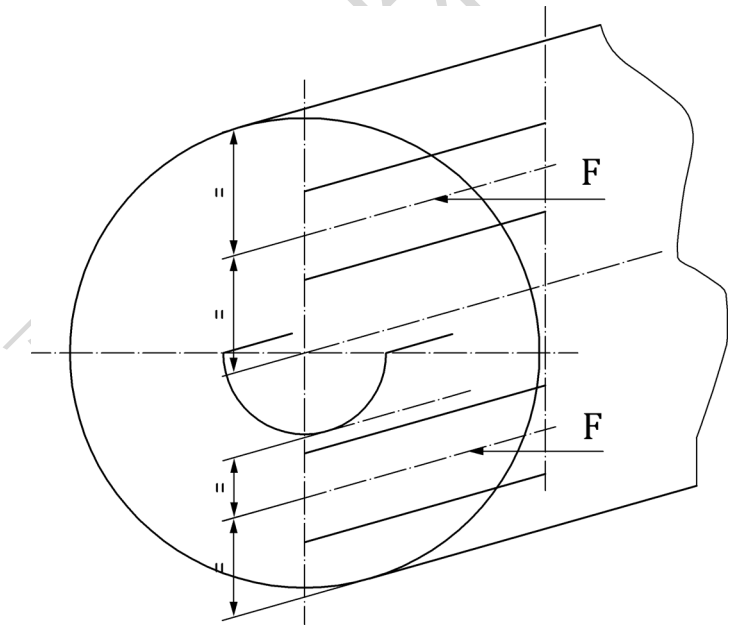


Figure 4 — Micrographic examination sampling location (solid axle and hollow axle)

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 *Ra* 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 mm^2 and 450 mm^2). 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

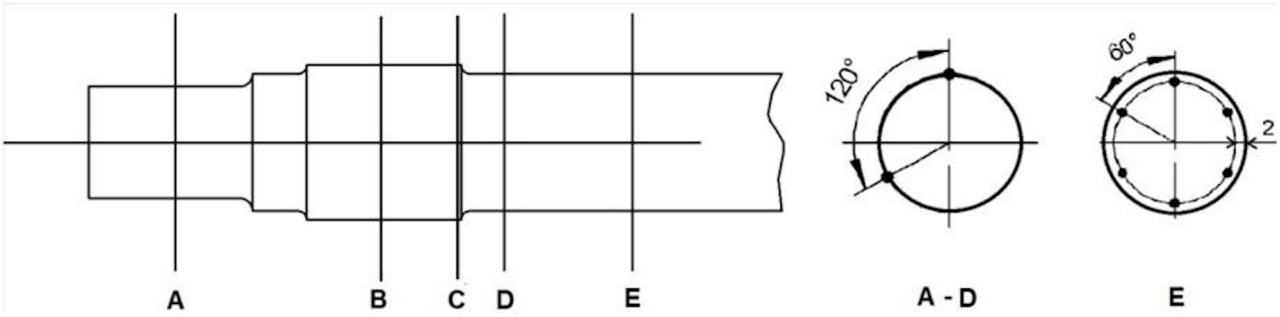
Residual stresses, in the axial direction, must be less than or equal to +100 MPa, in traction, near the axle surface (no more than 0.1 mm below the surface, depending on the measurement method) and 2 mm below the axle surface.

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



Wheel rejected

A, B, C, D and E: residual stress measuring points

Figure 5 — Measurement point location

Section C must be positioned as close as possible to the end of the wheel seat, depending on the measurement method.

4.6.4 Measurement method

Residual stresses can be measured with, for example, strain gauges and saw cutting (Annex E), or with strain gauges and hole drilling (ASTME837), or by X-ray diffraction (EN 15305). The method must be documented and agreed in the technical specification.

4.7 Surface characteristics

4.7.1 Surface finish

4.7.1.1 Characteristics to be obtained

The surfaces must not have any marks other than those specified in this document.

The average roughness (*Ra*) of the surfaces is provided in Table 7. The symbols are defined in Figure 6.

Table 7 — Surface finishes

Description	Symbol (see Figure 6)	Surface finish[a] *Ra* (µm)	
		Rough	Finished or ready-for-assembly
End of axle			
- End of axle and chamfer	Key	-	6.3
- Centre hole (solid and hollow axle)	See details R1 and R2	-	3.2
Journal			
- Journal surface	b	12.5	0.8 [d]
- Relief grooves	c (detail V)	-	0.8
Flange seat			
- Flange seat	d1	12.5	1.6 [d]
- Flange seat free surface	d2	12.5	1.6 [b]
Wheel seat			
- Wheel seat surface	e	12.5	Minimum 0.8 Maximum 1.6 [cd]
- Conical inlet	f (detail U)	-	1.6
Body			
- Fillet with wheel seat	g (detail T)	-	1.6 [b]
- Axle body surface	l		3.2 [b]
- Cog wheel and brake disc seat surface	h	12.5	Minimum 0.8 Maximum 1.6 [cd]
- Bearing and roller bearing seat surface	j	12.5	0.8 [d]
- Relief groove between two seats	k (detail S)	-	1.6
Bore			
- Bore surface	m (detail R1)		3.2 [c]

[a] For old axle types with bearing journals, the requirements are to be taken from the Standards governing these products.

[b] After machining and shot peening, a value of 6.3 may be accepted and documented in the technical specification if fatigue limits F_1 or F_2 specified in 4.2.3.2 and the sensitivity required for ultrasonic testing during operation are obtained simultaneously. Annex F provides guidance on evaluating shot-peening parameters.

[c] Non-destructive examinations of axles in operation may require thinner surface finishes, e.g. *Ra* 2 µm for the bore.

[d] For seats with a molybdenum coating, a roughness *Ra* of 3.2 is acceptable

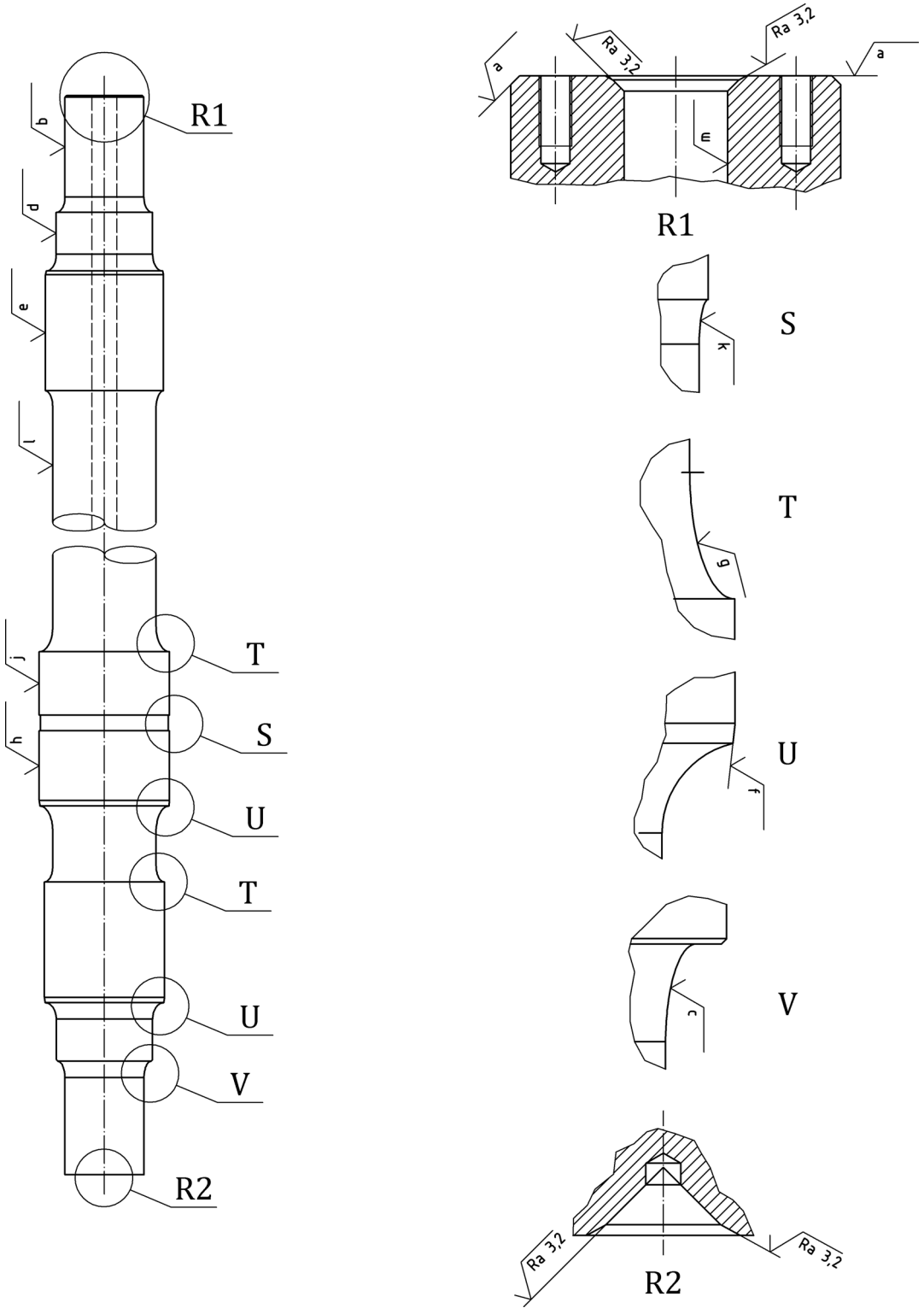


Figure 6 — Surface finish symbols

4.7.1.2 Measurement method

The average surface roughness *(Ra)* of the axles in the delivery state indicated in Table 7 must be measured using a roughness meter. In the connecting radii, the roughness must be evaluated by comparison with visual-tactile samples agreed in the technical specification.

The roughness measurement must not be performed in an area with a surface defect.

4.7.2 Surface integrity

4.7.2.1 General

Axle surface integrity must be defined through magnetic particle examination for the external surfaces and by ultrasound examination, or by any other means recognised as an equivalent as agreed in the technical specification, for the surface of the hollow axle bore.

4.7.2.2 Level to be obtained

On the external surface of the axle:

— transverse indications are not tolerated;

— longitudinal indications are tolerated outside the 'Z_0' connection zones (see Figure 7), provided that they are within the limits provided in Table 8 (see also L.7).

NOTE Indications that are not visible to the naked eye or that cannot be measured are marked as 'No indication'. The common detection threshold for a linear indication is 1 mm.

An indication is considered longitudinal if its inclination in relation to the axle axis is less than 10°.

Dimensions in millimetres

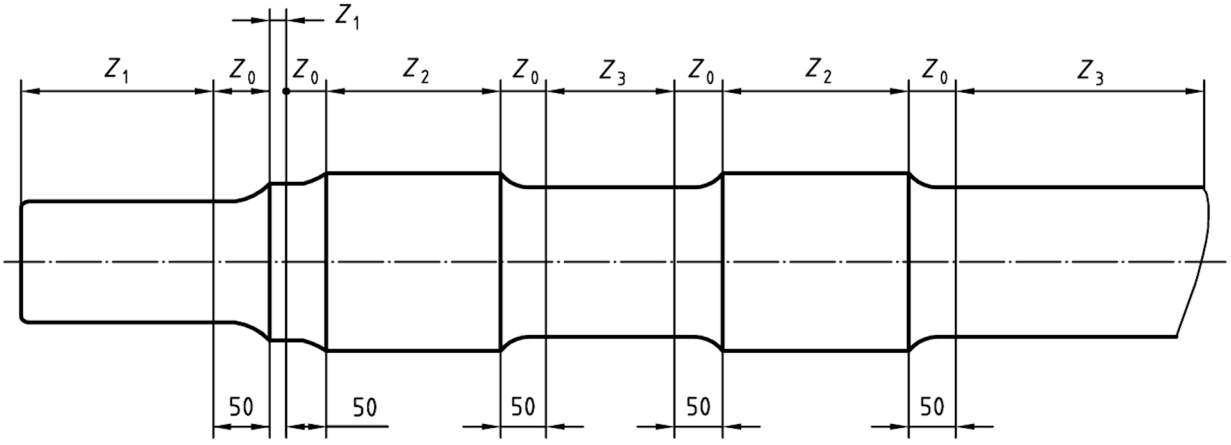


Figure 7 — Zones

In the bore of hollow axles, transverse indications are permitted if their depth is less than 0.5 mm and there is no more than one per metre long.

Table 8 — Longitudinal indication limits

	Category 1		Category 2	
Zones	Maximum length of an isolated indication[a]	Cumulative maximum length of isolated indications	Maximum length of an isolated indication[a]	Cumulative maximum length of isolated indications
Z_0	No indication	No indication	No indication	No indication
Z_1	≤ 6 mm	≤ 6 mm	≤ 6 mm	≤ 6 mm
Z_2	≤ 6 mm	≤ 15 mm	≤ 6 mm	≤ 15 mm
Z_3	≤ 6 mm	≤ 15 mm	≤ 10 mm	≤ 30 mm

[a] Defects must be considered isolated if the distance between them on the same circumferential line is greater than 10 mm.

4.7.2.3 Test piece

The test piece must comprise the axle after heat treatment in the delivery state specified in the order but before the protective coating is applied.

4.7.2.4 Examination methods

4.7.2.4.1 External surface of the axle

Magnetic particle examination is carried out under the general conditions prescribed by ISO 6933:1986, with the exception of:

— the density of the magnetic flux on the surface which must be greater than 4 mT;

— the irradiance of ultraviolet light which must be greater than 15 W/m^2.

The magnetisation methods are those specified by ISO 6933:1986:

— circumferential magnetisation for longitudinal defect finding (see Figure "a" of ISO 6933:1986);

— longitudinal magnetisation for transverse defect finding (see Figure "b" of ISO 6933:1986).

4.7.2.4.2 Axle bore surface

The method used must be agreed in the technical specification. If no other requirement is stipulated, ultrasound inspection with a 45°-incidence from the external surface is to be used.

The surface of the axle bore can be pre-examined visually using an endoscope/videoscope, or with an illuminated mirror, or with other NDT methods. If a transverse indication is visible, it must be further processed to assess its conformity with Clause 4.7.2.2.

4.8 Geometrical and dimensional tolerances

The geometrical tolerances are shown in Table 9. The symbols used are defined in Figure 8.

The dimensional tolerances are shown in Table 10. The symbols used are defined in Figure 9.

Table 9 — Geometrical tolerances

Description	Symbol (See Figure 8)	Geometrical tolerances[a] [b] (mm)	
		Rough	Ready-for-assembly
Journal - Cylindricity	*m*		0.015
Reference plane - Run-out[c]	*n*	-	0.03
Flange seat - Cylindricity - Run-out[c]	*o* *o*	- -	0.015 0.03
Wheel seat - Cylindricity - Run-out[c]	*p* *p*	0.1 1.5	0.015 0.03
Ball bearing or drive axle flange seat - Cylindricity - Run-out[c]	*r* *r*	0.1 1.5	0.02 0.015
Coupling, cog wheel or brake disc seat - Cylindricity - Run-out[c]	*s* *s*	0.1 1.5	0.015 0.03
Axle body - Run-out[c]	*t*	-	0.5[d]
Bore - Coaxiality[c]	*u*	-	0.5
Holes for securing covers - Position[c]	*v*	-	0.5
Centring holes for machining - Run-out[c] (with hollow bore) - Run-out[c] (without hollow bore)	w_2 (detail R1) w_1 *(detail* R2)	- -	0.02 0.03

[A] For parameters that are not toleranced in this table, the general tolerances of EN 22768-2 must be applied.

[b] For old axle types with bearing journals, the requirements are to be taken from the Standards governing these products.

[c] Reference axis: the reference axis is the common axis of the two journals of the axle, marked Y-Z in Figure 8.

[d] 0.3 mm for category 1 axles.

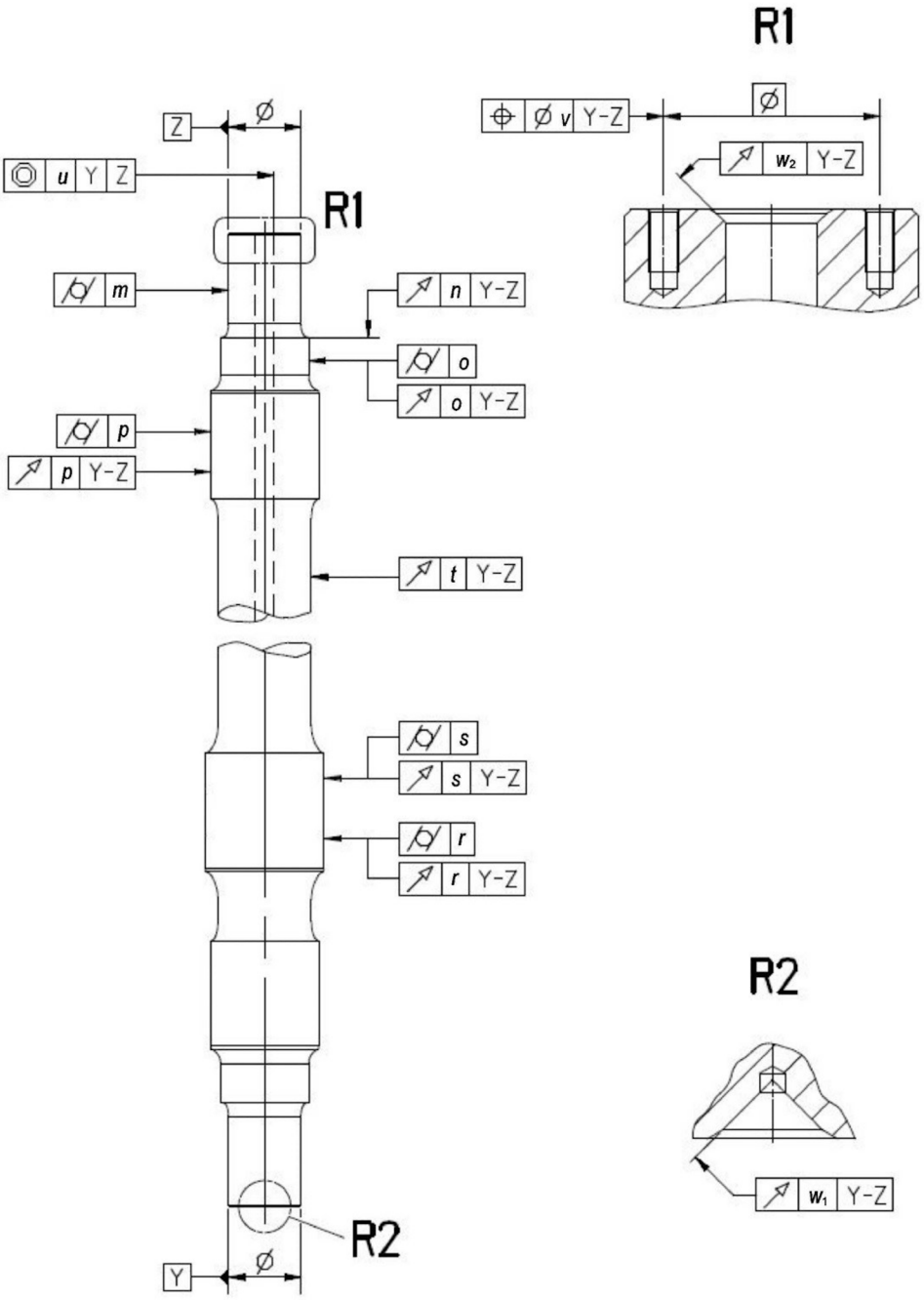


Figure 8 — Geometrical tolerance symbols

Table 10 — Dimensional tolerances

Description	Symbol (see Figure 9)	Dimensional tolerances[a] (mm)	
		Rough	Ready-for-assembly
Longitudinal dimensions			
- Axle length [b]	*A*	+2/0	±1
- Wheel seat length (including flange)	*B*	+2/0	0/-0.5
- Length between reference planes	*C*	+2/0	±0.5 [d]
- Flange seat length	*dm*	0/-2	+1/0
Diameters			
- Journal diameter	*H*	+2/0	[c]
- Wheel seat diameter	*K*	+2/0	[c]
- Diameter of the cog wheel seat, or brake disc seat, or spacer seat, or bearing seat or ball bearing seat	*J*	+2/0	[c]
- Flange seat diameter	*N*	+2/0	± 0.25
- Body diameter	*P*	+4/0	+2/0
- Bore diameter	*O*	-	±1

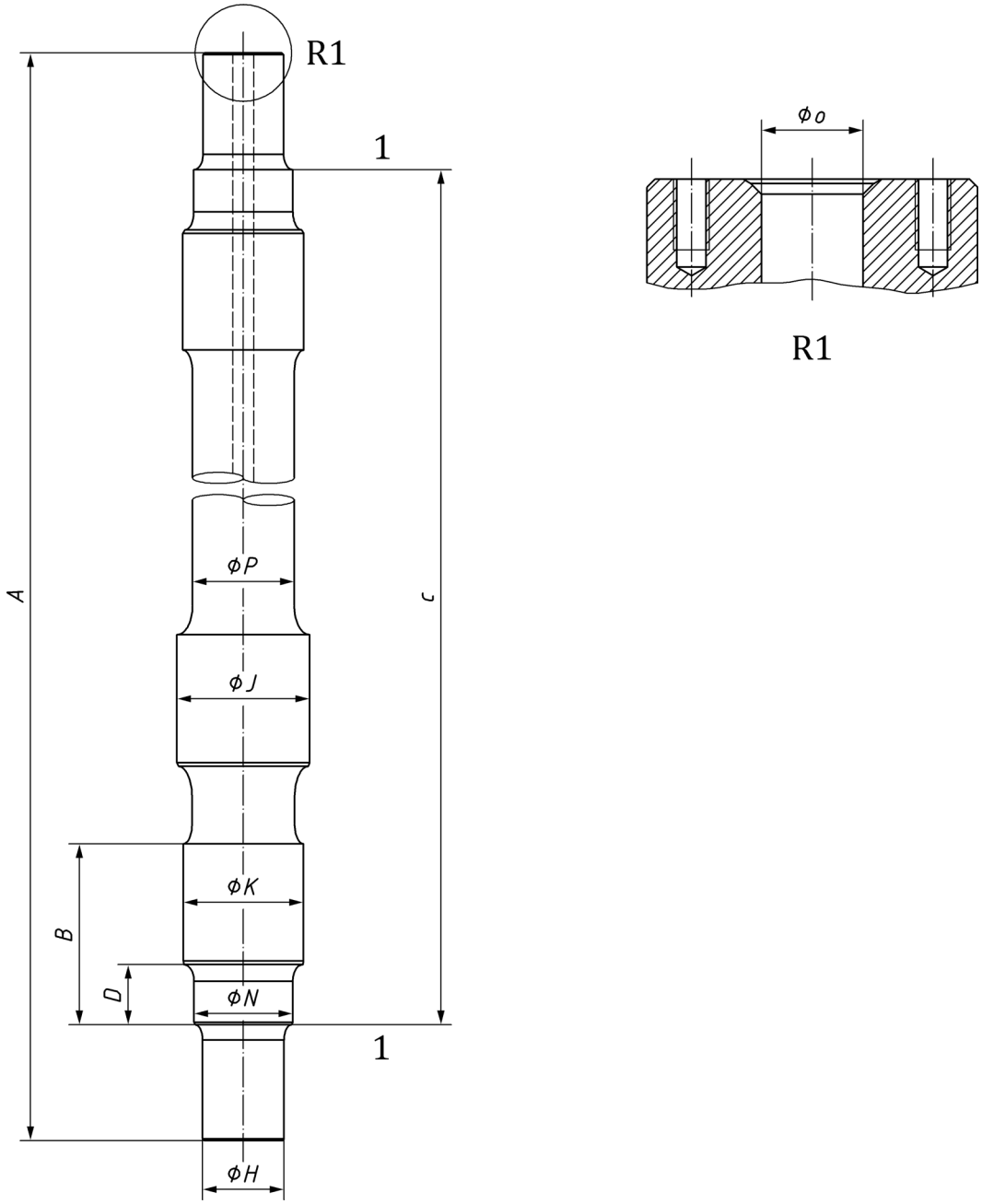
[a] For parameters that are not toleranced in this table, the general tolerances of EN 22768-1 must be applied.

[b] It should be noted that compliance with the tolerances on the total length "A" does not allow all individual tolerances to be applied cumulatively to the practical dimensions.

[c] According to the drawing or technical specification requirements.

[d] Other geometries may be proposed or specified in the technical specification.

Dimensions in millimetres



Wheel rejected

1 reference planes

Figure 9 — Dimensional tolerance symbols

4.9 Protection against corrosion and mechanical damage

4.9.1 Final protection

4.9.1.1 General

All axles put into service must be corrosion-protected in all areas where there are no fitted parts. Some axles can be protected against mechanical damage (impacts, chipping, etc.).

Four protection classes are considered based on the use of the axle and the maintenance rules applied to the axle:

— class 1: axle sections subject to atmospheric corrosion and mechanical impact;

— class 2: axle sections subject to the effect of specific corrosive products;

— class 3: axle sections subject to atmospheric corrosion;

— class 4: unpainted axles subject to atmospheric corrosion;

— different classes are allowed on the same axle.

The choice of protection among these four classes must be specified in the technical specification.

Protective coatings for each class are, at a minimum, defined by the characteristics shown in Table 11. Other characteristics may also be indicated in the technical specification depending on the specific operating conditions of the axles.

To evaluate a coating system, the tests shown in Table 11 must be carried out.

For axle evaluation and quality control during production, only coating thickness measurement and coating adhesion testing should be carried out.

The tests must be carried out several days after the coating is applied, depending on the paint system and paint supplier recommendations. If no information is provided, a period of 14 days may be adopted.

Hollow axle bores must be protected against corrosion with a product whose type is defined in the technical specification.

Table 11 — Protective coatings – Test requirement

	Class 1	Class 2	Class 3	Class 4
Coating thickness	X	X	X	-
Coating adhesion	X	X	X	-
Impact resistance	X	-	-	-
Chipping resistance	X	X	X	-
Salt spray resistance	X	X	X	-
Resistance to specific corrosive products	-	X	-	-
Resistance of coating to cyclic mechanical stress	X	X	X	-

Particular attention should be paid to the environmental impact of the coating system used. In order to limit the emission of volatile organic compounds (VOC), aqueous paints are recommended.

Requirements for conventional coating systems (e.g. organic systems) are defined in the following sections. For another application (e.g. an inorganic system), the requirements for achieving comparable characteristics must be defined in the technical specification.

4.9.1.2 Protective coating thickness

4.9.1.2.1 Values to be documented after evaluating a protective coating

The minimum and maximum thickness of the axle's protective coating must be determined from the tests carried out in accordance with Table 11 and must be defined in the technical specification.

4.9.1.2.2 Values to be obtained for qualifying a manufacturer or for quality control

The value of the protective coating thickness must match the value defined in the technical specification.

4.9.1.2.3 Test piece

The test piece must be the axle with its protective coating.

4.9.1.2.4 Measurement method

The measurement must be taken using a non-destructive method in accordance with EN ISO 2808, when the coating thickness permits. In other cases, the measurement method must be defined in the technical specification.

Method 7C is recommended for conventional coatings.

4.9.1.3 Protective coating adhesion

4.9.1.3.1 General

Adhesion represents the bonding strength between the coating and the axle's surface.

4.9.1.3.2 Characteristics to be obtained

For coatings with a thickness of 250 µm or less, the coating adhesion must correspond to class 1 of the cross-cut test of EN ISO 2409:2013.

For thicknesses greater than 250 µm and less than or equal to 1000 µm, the adhesion of the coating must correspond to class 1 of the X-cut test of EN ISO 16276-2.

Unless otherwise specified in the technical specification, adhesive tape must be used with a bonding strength of between 6 N per 25 mm of width and 10 N per 25 mm of width (determined in accordance with EN 60454-2). The width of the tape must be at least 50 mm. Clear tape is recommended.

For thicknesses greater than 1000 µm, the method to be used and the acceptable values must be defined in the technical specification.

The tensile test classification B or *n* (cohesive break greater than 90%) of EN ISO 4624:2016, Clause 8.5 is an acceptable method. A minimum value of 4 MPa is recommended.

The tensile test is recommended as a complementary test regardless of the thickness as part of the coating qualification or qualification of a manufacturer of protective-coated axles.

4.9.1.3.3 Test piece

The test piece must be a coated axle or a coated axle section representative of the finished product.

4.9.1.3.4 Test method

The cross-cut test method must be that recommended by EN ISO 2409.

The X-cut test method must be that recommended by EN ISO 16276-2.

If the tensile test is selected, it must be carried out in accordance with the recommendations of EN ISO 4624 with a 20-mm diameter stud.

If necessary, the shape of the stud can be adapted to the axle's geometry.

4.9.1.4 Impact resistance

4.9.1.4.1 General

This feature defines the capacity of the coating to protect the axle against damage due to projectile impacts, e.g. ballast. This characteristic applies only to class 1 protections.

4.9.1.4.2 Characteristics to be obtained

After the test defined in 4.9.1.4.4 is completed, no damage to the axle surface must be observed.

4.9.1.4.3 Test piece

The test piece must be a coated axle or a coated axle section representative of the finished product.

4.9.1.4.4 Test method

The test must involve impacting the protected surface with a defined force based on the requirements of Annex G.

4.9.1.5 Chipping resistance

4.9.1.5.1 General

This feature defines the capacity of the coating to protect the axle against damage due to repeated projections of gravel or sand.

4.9.1.5.2 Characteristics to be obtained

After the test defined in 4.9.1.5.4 is completed, the coating surface must comply with:

— level 3 for class 1 and 2 protection;

— level 4 for class 3 protection.

as described in Annex H.

4.9.1.5.3 Test piece

The test piece must be a coated axle or a coated axle section representative of the finished product.

4.9.1.5.4 Test method

The method for determining chipping resistance is provided in Annex H.

4.9.1.6 Salt spray resistance

4.9.1.6.1 General

This characteristic defines how the surface of a coated axle reacts against corrosion accelerated by artificial salt spray.

4.9.1.6.2 Characteristics to be obtained

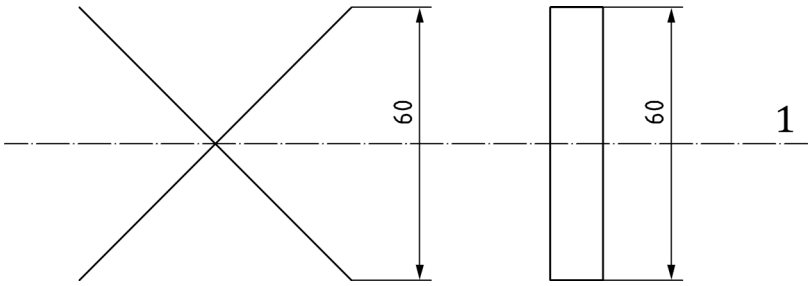
After the test defined in 4.9.1.6.4 is completed, there must be no corrosion under the coating and no corrosion present more than 2 mm (average value) from the notches in the coating.

The length of the incision is divided into successive 10 mm sections. The maximum corrosion width is noted for each section. The average of these measurements constitutes the increase in corrosion.

4.9.1.6.3 Test piece

The test piece must include a section of coated axle to be characterised in which X-shaped incisions (for coatings ≤ 250 µm thick) and an opening (for coatings > 250 µm thick) have been made (see Figure 10).

Dimensions in millimetres



Wheel rejected

1 Centre of the line/incision plot

Figure 10 — Salt spray test pieces

4.9.1.6.4 Test methods

The test method used (1 or 2) and the duration of the test must be defined in the technical specification.

— **Method 1**:

The salt spray resistance must be determined in accordance with EN ISO 9227; the solution used must comply with the NSS test of the aforementioned standard.

A minimum test time of 480 hours is recommended for class 1 and class 3. A longer duration is recommended for class 2, with 1000 hours being a standard duration.

— **Method 2**:

The salt spray resistance may be determined in an alternative manner in accordance with the VDA test of EN ISO 11997-1:2006 over 6 cycles.

4.9.1.7 Resistance to specific corrosive products

4.9.1.7.1 General

This feature, which only applies to class 2 protection, evaluates the coating's resistance to specific corrosive products (corrosive environments, transported products, etc.).

4.9.1.7.2 Characteristics to be obtained

After the test defined in 4.9.1.7.4 is completed, no damage to the test piece coating or surface must be observed. In addition, compliance with an adhesion test must be demonstrated.

The characteristics to be obtained are identical to those of 4.9.1.3.2.

4.9.1.7.3 Test piece

The test piece must be a section of axle with the protective coating to be characterised.

4.9.1.7.4 Test method

Resistance to specific corrosive products must be determined using a test with repeated immersions and emersions. This test is described in Annex I (normative). It must be followed by an adhesion test defined by EN ISO 2409 or EN ISO 16276-2 or EN ISO 4624, carried out 24 hours after the end of the corrosion test phase.

4.9.1.8 Resistance of coating to cyclic mechanical stress

4.9.1.8.1 General

This characteristic, which defines the coating's ability to withstand cyclic mechanical stresses, must be verified using test pieces. The pieces must be stressed by rotary bending, using increasing stress levels until they break. The stress levels reached before breaking represent the coating's resistance.

4.9.1.8.2 Characteristics to be obtained

Under the test conditions defined in 4.9.1.8.4;

— stress level 5 must be reached without breaking for class 1 and 3 coatings;

— stress level 10 must be reached for the class 2 coating.

4.9.1.8.3 Test piece

The rotary bending test piece (8.5 mm diameter in its active part) must be made of EA1N grade steel, protected by the coating to be evaluated.

A drawing of a typical test piece is provided in Annex B.

4.9.1.8.4 Test method

The test method and conditions are provided in Annex J.

4.9.2 Temporary protection

Prior to assembly, the various parts of the axle prepared to receive other components must be temporarily protected against corrosion and impact, in accordance with the delivery conditions compliant with the technical specification.

The characteristics of this protection must be defined in the technical specification, taking into account the transport and storage conditions (handling, environment, etc.).

Unless specified in the technical specification, this protection must be effective for at least 3 months under normal atmospheric conditions.

4.10 Marking

Each axle must be identified by at least the following stamped indications:

— manufacturer's mark;

— cast number;

— steel grade;

— month and last two digits of the year of manufacture;

— axle serial number, after heat treatment.

These markings must be located on one journal end only and must occupy only half of the journal end surface. The other half of the surface must be reserved for the wheelset markings.

On the other end of the journal, half of the surface must contain no marking. This is reserved for maintenance.

The configuration of this marking must be specified in the technical specification. The excess thicknesses due to the markings must be rectified in order to allow ultrasonic testing in operation.

The manufacturer's marking is the unique reference for quality monitoring and component characterisation. The manufacturer's marking must be applied at the final production stage before supply. Final machining of the wheel seats is not considered the final manufacturing stage.

5 Alternative manufacturing process

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.) must be qualified in accordance with the methods described in Annex K. Different characteristics must be documented and may be applied.

6 Product qualification

Product qualification must be carried out in accordance with the requirements of Annex K.

7 Conditions of supply of the product

The conditions of supply of the product must comply with the requirements of Annex L.

Annexe A
(informative)

Sampling of the material from an axle journal overlength

A.1 Values to be reached

Samples for product definition can be taken from an axle journal overlength where this is stated in the technical specification.

Samples collected from an axle journal overlength must meet the requirements of Subclause 4.2.1 for the tensile test and Subclause 4.2.2 for the impact test and the results must meet the following requirements:

- For AE1N in accordance with Table 2 and Table 3;
- For EA4T in accordance with Table A.1 and Table A.2 when the ratio of the journal diameter to the largest-diameter seat is less than or equal to 0.75. If these values cannot be reached in the sample collected from an axle journal overlength, sampling must be carried out in the largest section of the axle.

For other steel grades, the values to be met should be defined in the technical specification.

Table A.1 — Values to be met at mid-radius for solid axles and at mid-distance of the external and internal surfaces for hollow axles

Grade	R_{eH} [a] MPa	R_m MPa	A_5 %
EA4T	≥ 500	700–800	≥ 18

[a] If there is no apparent yield strength, the stress $R_{p0.2}$ must be determined.

Table A.2 — Values to be met at mid-radius for solid axles and at mid-distance of the external and internal surfaces for hollow axles

Grade	Longitudinal *KU* (J)	Transverse *KU* (J)
EA4T	≥ 70	≥ 45

A.2 Sampling method

A.2.1 Overlength with a diameter identical to the journal diameter

The axle journal overlength should be a minimum of 200 mm long in a material homogeneous with the axle journal. At least three axle journal overlengths must be manufactured per batch.

A.2.2 Overlength with a diameter greater than the journal diameter

Another possibility is to take the samples from an axle journal overlength with a diameter equal to the largest section of the axle with a minimum length of 400 mm. In this configuration, the requirements are those used for samples from the largest-diameter section in accordance with Clause 4.

Annexe B
(informative)

Test piece drawings

Dimensions in millimetres

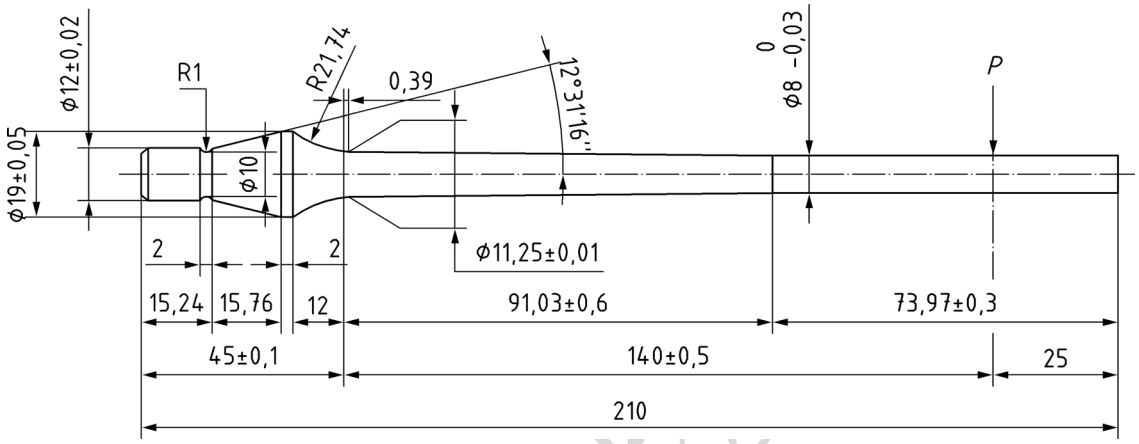
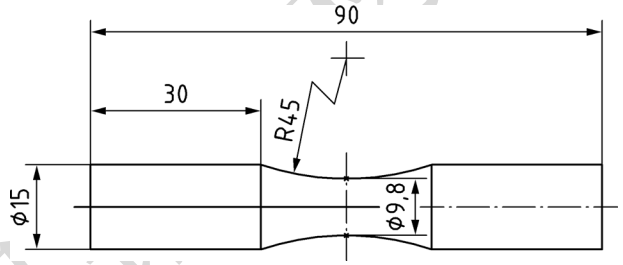
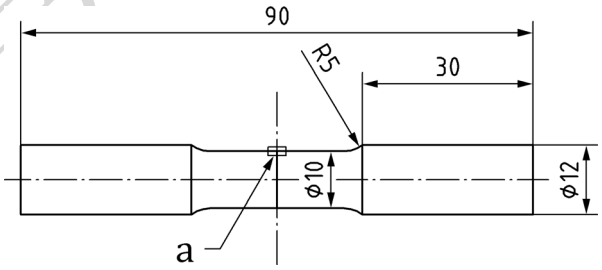


Figure B.1 — Small test piece for determining steel fatigue limit (example 1)

Dimensions in millimetres



a) Smooth test piece



b) Notched test piece

Wheel rejected

Key notch as shown in Figure 3a)

Figure B.2 — Small test piece for determining steel fatigue limit (example 2)

Dimensions in millimetres

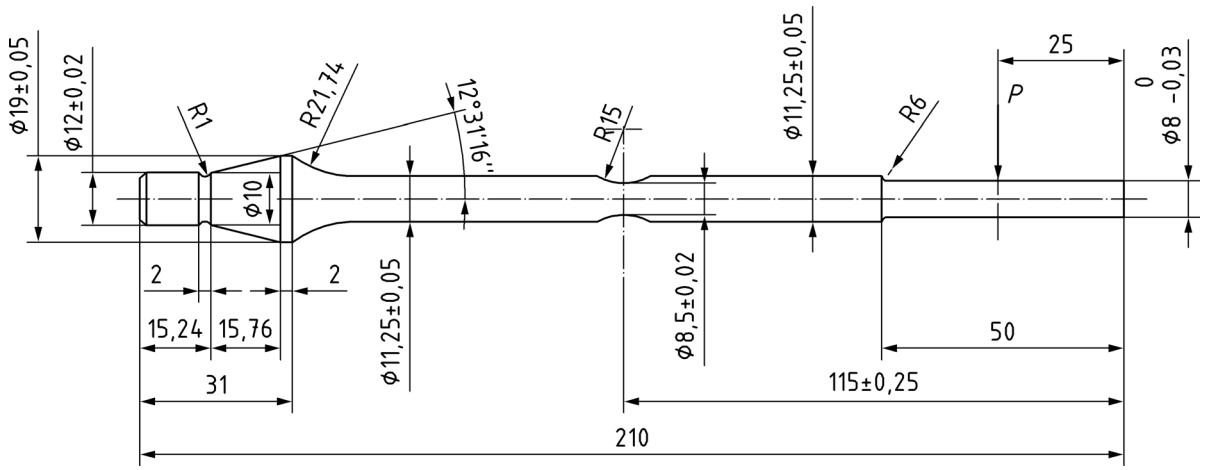
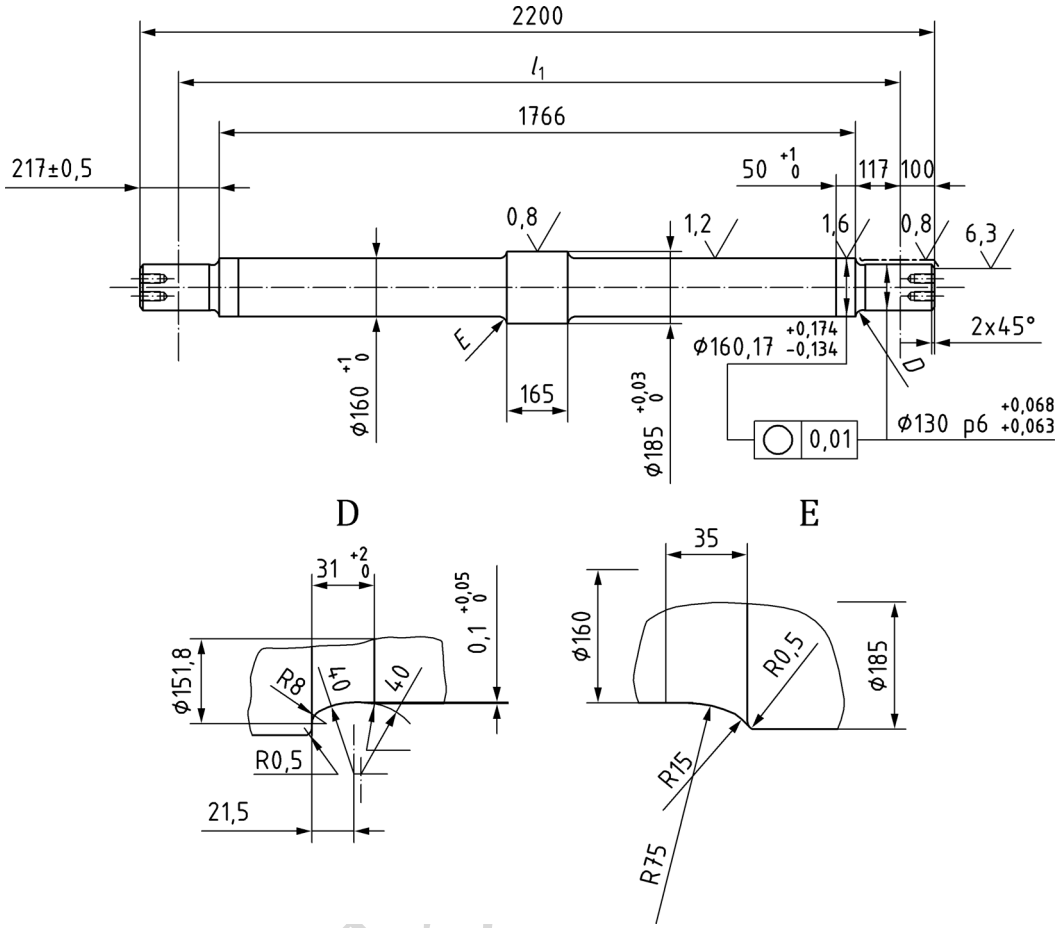


Figure B.3 — Small test piece for determining the resistance of the protective coating to cyclic stress

Dimensions in millimetres

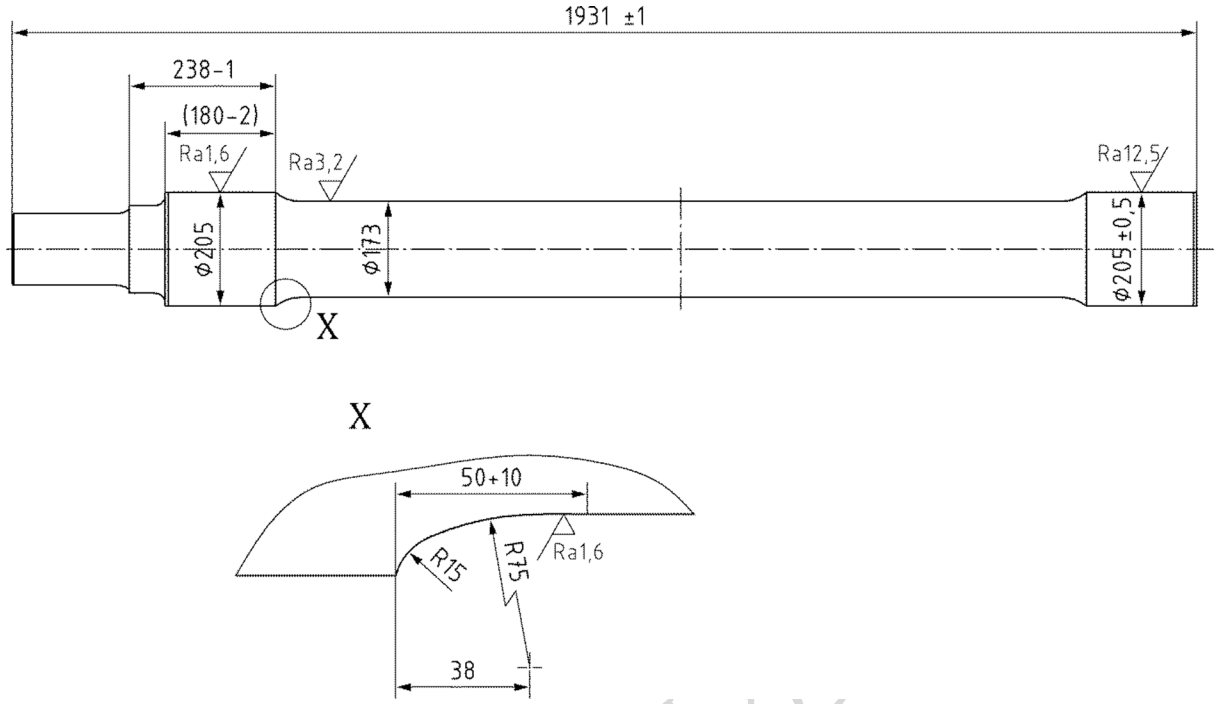


Wheel rejected

l_1 journal centre distance 2000

Figure B.4 — Scale 1 test piece for fatigue testing (example 1)

Dimensions in millimetres



Wheel rejected

X: detailed view of the transition area

Figure B.5 — Scale 1 test piece for fatigue testing (example 2)

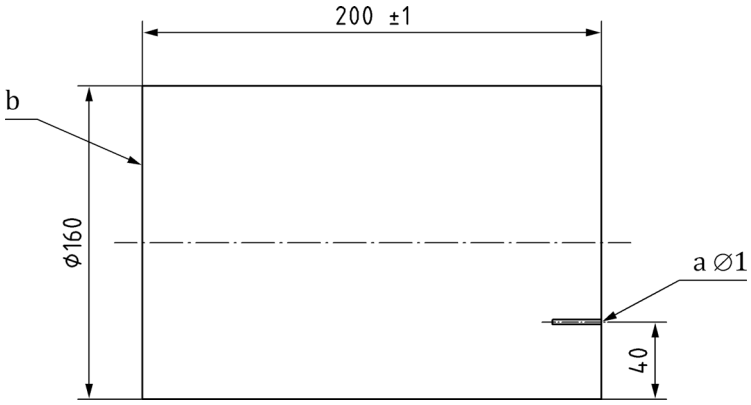
Annexe C
(normative)

Gauge block for measuring ultrasound permeability

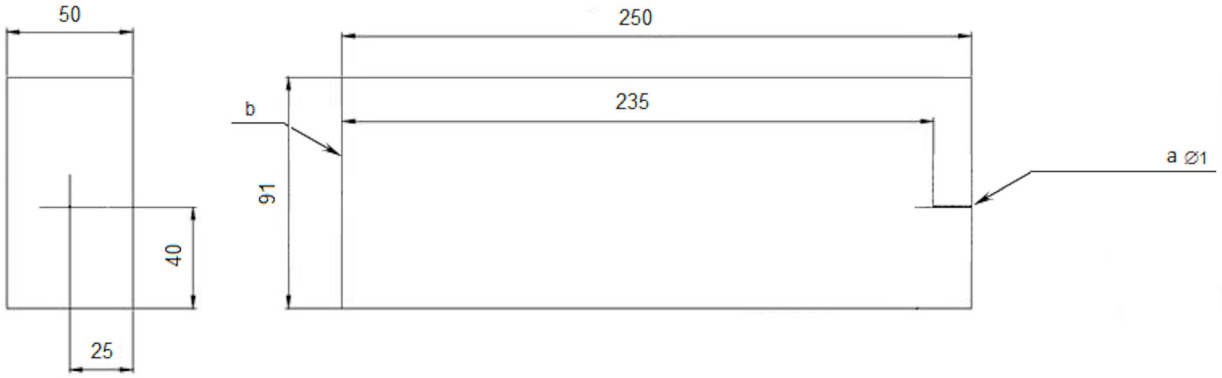
C.1 Gauge block

The gauge block is taken lengthwise from an axle previously checked by ultrasound to ensure that it is free from defects.

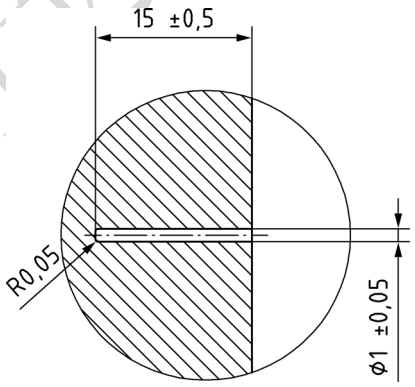
Dimensions in millimetres



a) Example one



b) Example two



c) Flat-bottomed hole detail

Wheel rejected

Key Flat-bottomed hole

b Examination face

NOTE A flat-bottomed hole of another depth may be defined in the technical specification.

Figure C.1 — Gauge block examples

C.2 Gauge block tolerances

General tolerance	±0.5 mm
Flat-bottomed hole diameter	±0.05 mm
Perpendicularity between faces	≤ 1°
Roughness	$1.6 \leq Ra \leq 3.2$

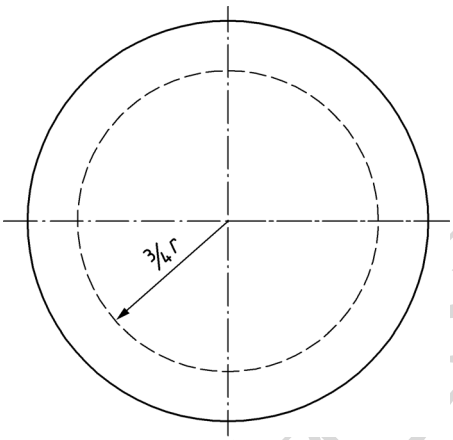
C.3 Steel grade of the gauge block

The gauge block must be made in the same steel grade as the axle being tested.

Annexe D
(informative)

Position of measurement zones for ultrasound permeability

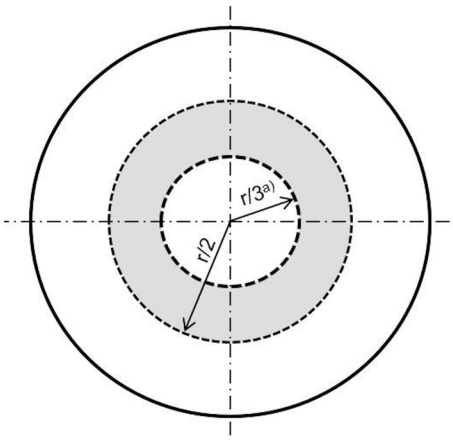
The recommended positions for measurement zones to determine ultrasound permeability based on the potential existence of a hollow bore are shown in Figure D.1 and Figure D.2.



Wheel rejected

r: Radius of the journal

Figure D.1 — Axles with bore and solid axles: Position of the measurement zone



Wheel rejected

r: Radius of the journal

a) at least 25 mm from the centre

Grey area: measurement zone for permeability

Figure D.2 — Solid axles: Position of measurement zones

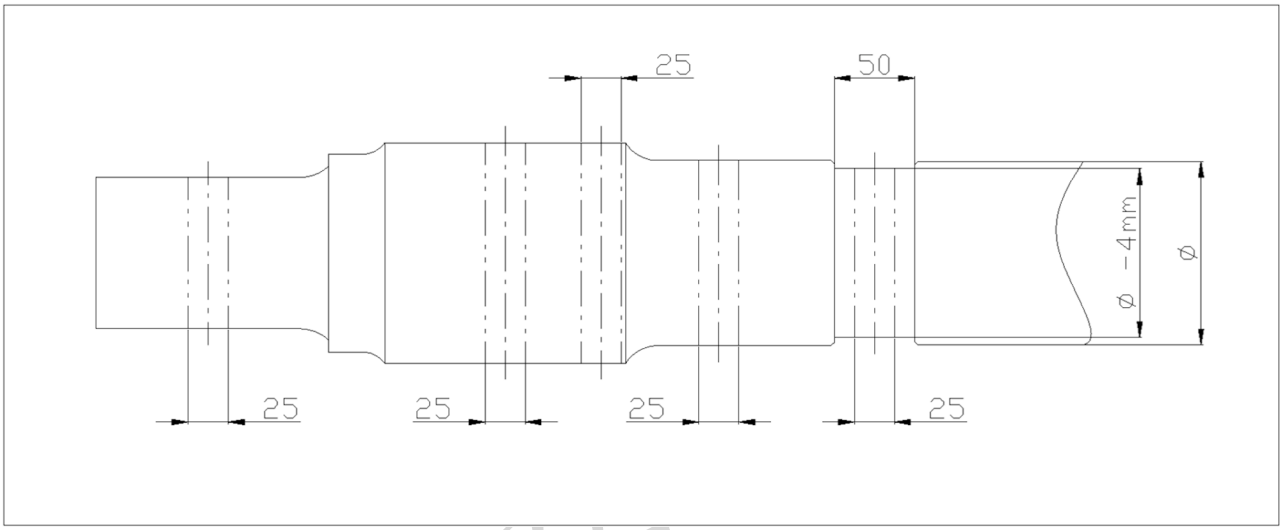
Annexe E
(informative)

Residual stress measurement with strain gauges and saw cutting

Strain gauges must be monoaxial and positioned in the axial direction.

The measurement must be taken after saw cutting (Figure E.1).

Dimensions in millimetres



Wheel rejected

——— - - ——— strain gauge position

- ——— - ——— - saw cut position

Figure E.1 — Strain gauge and saw cut positions

Annexe F
(informative)

Post-machining shot peening method

F.1 Shot peening principle

Shot peening can be used to modify the finish condition of axles in order to improve adhesion of the paint to the free surface of the axle body. In this case, the roughness *Ra* of these surfaces may exceed the requirements of Subclause 4.7.1.1.

NOTE The purpose of the shot peening process described in this Annex is to improve adhesion of the paint and not to act as pre-stress shot peening (the aim of the latter being to improve fatigue resistance.

F.2 Requirements

F.2.1 Shot peening product

The shot peening product must be a high carbon steel with angular abrasion, form M/HCS G, in accordance with EN ISO 11124-1 and EN ISO 11124-3.

F.2.2 Hardness

The selected shot peening product must satisfy one of the hardness classes of EN ISO 11124-3:

— 470 to 610 HV;

— 570 to 710 HV;

— 700 HV and above.

F.2.3 Roughness

After shot peening, the roughness *Ra* must be less than or equal to 6.3 µm.

For good paint adhesion, a number of RPc peaks (-0.5, 0.5) in the 50 to 60 range is recommended, as defined in EN 10049.

F.2.4 Coverage rate

After shot peening, the affected area must have a 100% coverage rate.

The coverage rate represents the ratio between the surface of the area affected by the shot impacts and the total surface of the measurement area.

NOTE The coverage rate can be measured in accordance with ISO 26910-1.

F.2.5 Fatigue limit

The shot peening process must be integrated into the axle qualification process. The fatigue limit F_1 must meet the requirements defined in Subclause 4.2.3.2.

F.3 Parameters

The technical specification must define the shot peening parameters, including:

— Size of the shot peening product;

— Nozzle diameter;

— Rotation speed of the nozzle or axle;

— Flow rate;

— Distance between the nozzle and the axle;

— Shot peening pressure and/or air pressure;

— Number of passes.

NOTE To check the process, the almen strip can be measured in accordance with ISO 26910-1.

F.4 Qualification of the shot-peening process

The shot-peening process must be fully integrated into the overall qualification process (Annex K).

Annexe G
(normative)

Method to determine the impact resistance of the protective coating

G.1 YES

The test method involves impacting the coated surface, then examining any damage to the axle's surface.

G.2 Test piece

The test piece must be an axle or an additional axle section, with a protective coating, representative of the finished product.

G.3 Equipment

The projectile is defined by a 105° tip angle and must be made in a steel grade that ensures a Vickers hardness of 400 HV. The projectile mass must be adapted to ensure the expected impact energy.

G.4 Operating procedure

The test must be carried out using a repeatable procedure on a test device. The test device must be able to produce the predefined impact energy. For high-speed applications, an impact energy of 90 J is recommended; other values may be defined in the technical specification. The impact must be perpendicular to the coated surface.

The impact resistance test must be performed at -25°C and at room temperature.

G.5 Expression of results

After impact, the appearance of the coating surface must be examined with the naked eye, as well as the appearance of the test piece surface after the coating is removed. Damage must be noted and compared to the criteria provided in this document.

Annexe H
(normative)

Method to determine the chipping resistance of the protective coating

H.1 YES

The test method involves projecting a determined quantity of shot onto the coated surface and then examining any damage to the coating.

H.2 Test piece

The test piece must be an axle or an additional axle section, with a protective coating, representative of the finished product.

H.3 Equipment

The equipment consists of a straight tube with an internal diameter of 38 mm and a height of 5 m, positioned vertically. It must be topped with a funnel for the shot, this funnel being closed by a hatch at the bottom.

The shot is one kilogram of class 8.8 steel HM6 nuts, defined by EN ISO 6507-1:2006.

H.4 Operating procedure

Place the test piece with its coating 30 mm below the tube so that the drop direction of the shot makes an average angle of 45° with the tangent to the test surface.

Open the hatch and drop the shot in one go.

Examine the shot surface and record the results.

H.5 Expression of results

Record the percentage P of chipped surface [3] where the metal surface is visible using the levels in Table H.1 below:

[3] Surface defined by the projection of the tube surface onto the test piece, with a value of 1600 mm^2.

Table H.1 — Results

Level	*P* %	Level	*P* %
1	10	6	60
2	20	7	70
3	30	8	80
4	40	9	90
5	50	10	100

Annexe I
(normative)

Method to determine the resistance of the coating to specific corrosive products

I.1 YES

The test method involves subjecting a test piece, protected by the coating to be characterised, to a series of immersions in the corrosive product under review, alternated with periods of emersion, and examining any damage to the coating and to the protected surface of the test piece.

I.2 Test piece

The test piece must be an axle or an additional axle section, with a protective coating, representative of the finished product.

I.3 Equipment

The equipment consists of a sealed enclosure kept at constant temperature, with a system that allows the test pieces to undergo alternating immersion and emersion cycles.

I.4 Corrosive products

The corrosive products in which the test piece is immersed must be selected according to the specific aggressive agents that the axle is subjected to during operation.

The three solutions

1) 3% by volume aqueous solution, comprising sulphuric acid at 95-97%, in demineralised water with resistivity greater than 10 MΩ.m;

2) 10% by mass aqueous solution, comprising potassium chloride in demineralised water with resistivity greater than 10 MΩ.m;

3) 10% by mass aqueous solution, comprising sodium hydroxide in demineralised water with resistivity greater than 10 MΩ.m;

represent the majority of aggressive agents that the axles will be subjected to during operation. After testing with these three solutions, other products may be defined in the technical specification for specific applications.

I.5 Operating procedure

The tests must be carried out on the test piece with each specific corrosive product under review and under the following conditions:

— temperature of the enclosure and solution: 23 ± 2°C;

— duration of an immersion period: 4 hours;

— duration of an emersion period: 4 hours;

— number of immersion/emersion cycles: 32.

Other test conditions may be agreed in the technical specification, depending on the specific aggressive product under review.

After testing, the test pieces must be rinsed with clean water and air dried at room temperature for 1 hour.

I.6 Expression of results

After testing, rinsing and drying, any damage to the coating must be checked for with the naked eye; an adhesion test must also be carried out in accordance with EN ISO 2409 or EN ISO 16276-2.

Annexe J
(normative)

Method to determine the resistance of the protective coating under cyclic mechanical stress

J.1 Purpose

The purpose of the test is to characterise the resistance of the protective coating to cyclic mechanical stress.

J.2 YES

The test involves subjecting a steel test piece with the protective coating to be characterised to rotary bending in successive increments until it breaks.

A corrosive product is applied to initiate cracking of the test piece when the coating is torn.

J.3 Test piece

The test pieces are the same type as those defined in Figure B.2. They have a diameter of 8.5 mm in their active part.

The test pieces are made of a steel axle of a grade defined by this document; their active parts are covered with the protective coating to be characterised.

J.4 Equipment

The equipment must allow rotary bending tests to be performed on test pieces of the type previously defined by incrementally varying the stress applied to the test pieces in their active parts.

The equipment must also allow a corrosive product to be applied to the test piece during the tests.

J.5 Operating procedure

The tests must be carried out on four test pieces, in successive stages, for which the maximum value of the surface stress of the test pieces is given by the following relationship:

$\sigma n = 160 + n \times 10$ in N/mm^2

with

σ: the maximum surface stress of the test piece in its active part;

n: stress level number ($n>0$).

The test starts with n = 1.

Each stress level consists of (13×10^6) cycles under the simultaneous action of mechanical stress and the specified corrosive product. The stress levels must be separated by 96-hour rest times, without any stress and or corrosive product action.

The corrosive product used must be demineralised water, with resistivity greater than 100 MΩ/m, distributed "drop-by-drop", with one drop every (15 ± 2) seconds applied to the active part of the test piece.

J.6 Expression of results

Three out of four test pieces must reach the indicated stress level without breaking.

NOTE Fatigue limits for EA1N and EA1T steels are close to the stresses used in this test. As a result, a material failure does not constitute a failure of the coating to meet resistance requirements and it is possible to repeat the test stage with another sample.

Annexe K
(normative)

Product qualification

K.1 Introduction

This Annex describes the minimum requirements for the qualification of the product and its manufacture.

Additional requirements may be given in the technical specification.

K.2 11.2.3.1\tab General

This clause defines the requirements and procedures to be applied for the qualification of the product and its manufacture.

The qualification of an axle is directly related to the manufacturing process, and an axle can only be qualified if the manufacturing process meets the requirements defined in K.3.

These requirements and procedures only apply only to axle designs that have already been approved:

— either by prior use in European rail services;

— or by a recognised technical approval procedure[4].

The qualification of a product is based on the concept of product groups. Product groups are defined by the combination of the following requirements and can be adapted in the technical specification:

— unqualified manufacturing process;

— material:

  — EA1N;

  — EA1T;

  — EA4T;

  — new material;

— change in the manufacturing process of a qualified axle;

— speed category (category 1 includes category 2);

— solid or hollow axle;

— manufacturing process (forging, rolling).

[4] See EN 13103-1.

— the qualification process must be applied if the axle does not belong to a group of qualified axle products from the manufacturer.

Any change in the manufacturing process:

— Raw material (steel);

— forging or rolling;

— Heat treatment;

— machining and finishing processes;

— Location of the place of manufacture;

must be documented, communicated to the parties concerned and may lead to partial or complete re-qualification of the product group, depending on the changes made.

K.3 Requirements

K.3.1 Requirements to be met by the manufacturer

K.3.1.1 11.2.3.1\tab General

If the axle manufacturing operations to be qualified involve more than one manufacturer, the following requirements must be met for each one.

K.3.1.2 Quality organisation

The manufacturer must implement a quality assurance system.

NOTE EN ISO 9001 is a means of achieving this requirement.

K.3.1.3 Staff qualification

Personnel responsible for non-destructive testing must be qualified.

EN ISO 9712 must be used to meet this requirement.

K.3.1.4 Equipment

The equipment used by the supplier for manufacturing, control and monitoring shall enable compliance with the requirements of this document.

For ultrasound inspection, an automatic method must be used. For non-automatic methods, the reproducibility of examinations must be demonstrated.

K.3.2 Requirements to be met by the product

The product must comply with the product requirements defined in Clause 4.

The traceability of each axle must be established from the cast.

K.4 Qualification procedures

K.4.1 General

The product qualification procedure consists of three successive phases described below:

— Supply of a record by the manufacturer;

— an evaluation of the production facilities and production process;

— laboratory testing.

After each step, a report must be produced.

K.4.2 Documentation required

For qualification, a file must be produced which includes:

a) a description of the axles being qualified;

b) a description of the manufacturing company mentioning:

   1) size of the company (number of employees, with distribution between manufacturing, control and quality assurance);

   2) annual axle production;

   3) list of all manufacturing and control equipment;

   4) organisational data, along with organisation charts;

c) a description of the manufacturing processes with explanations of the various manufacturing stages, including the reduction ratio of the rolling or forging process;

d) raw material data with a list of manufacturers;

e) test results on the products subject to the qualification request;

f) qualification reports, if the product was previously qualified.

If a manufacturer has already provided a file for the qualification of another axle or axle group, the file to be provided by said manufacturer, for the qualification of a new axle or axle group, must only contain items specific to the new axle or axle group, or elements new to the company.

K.4.3 Evaluation of production facilities and production process

This evaluation includes:

— An audit of the production facilities and monitoring of the production process;

— An audit of the raw material production facilities and a follow-up of the production process;

— An assessment of the data provided by the manufacturer regarding full compliance with the requirements in accordance with K.3.1;

— An assessment of compliance with the data provided in the file defined in K.4.2.

At the end of this stage, a report must be written. It must identify all phases of production, including those of the raw material that are of critical importance to the quality of the finished product for which qualification is requested. It must state whether the requirements of K.3.1 have been met and whether the procedure will continue depending on this outcome.

The technical specification should define the parties responsible for producing the required reports.

K.4.4 Laboratory tests

The achievement of all the characteristics defined in Clause 4, excluding those for fatigue, must be verified on two axles taken from an industrial manufacturing process.

For the fatigue characteristics defined in 4.2.3, verification must be carried out on axles to be qualified or on test pieces taken from products from the same manufacturing process.

NOTE The scale 1 fatigue tests are related to the qualification of the manufacturing process and not to the validation of a specific design.

Residual stresses as defined in Subclause 4.6 must be determined as an integral part of the manufacturer's product qualification process. The method for verifying the residual stress level must be defined in the technical specification (see 4.6.4).

A report must be produced. It must describe the parts subject to testing and the various tests carried out. It must provide the results and specify whether the product meets the requirements.

K.5 Validity of the qualification

K.5.1 Condition of validity

The qualification must specify the limits of validity of this qualification in relation to the product group (see Clause K.2).

K.5.2 Modification and extension

The scope of validity of the qualification can be modified or extended if:

— Other products are considered;

— The main parameters have been modified (manufacturing processes, quality organisation, etc.).

— Any modifications or changes in the scope of qualification must be approved and documented.

K.5.3 Transfer

In the event of a transfer of ownership, an existing certificate may, upon request, be transferred to another company if the material content and prerequisites for the qualification have not been modified.

K.5.4 Expiry

The equipment and production processes described in Subclause K.4.3 must be reassessed in the following cases:

— If, after 5 years, 30 axles have not been supplied following the current qualification;

— If, within 3 years, no axles have been supplied within the scope of the product subject to the qualification.

K.5.5 Withdrawal

If significant defects on the product have been found, the parts of the qualification procedure concerned must be repeated.

If the manufacturer has failed to meet important qualification conditions, qualification may be withdrawn.

K.6 Qualification record

For each qualified product, a qualification record must be created. It must contain:

— the documents provided by the manufacturer (see K.4.2);

— the assessment reports (see K.4.3);

— the laboratory test reports (see K.4.4);

— the qualification report (see K.5);

— The definition of the batch characteristics.

Annexe L
(normative)

Conditions of supply of the product

L.1 Introduction

This Annex describes the minimum conditions for the supply of the product.

Other requirements may be indicated in the technical specification.

L.2 General

The technical specification must set out the following:

- the axle-axis geometry and dimensions (drawings);
- the steel grade;
- the axle category (1 or 2, see Clause 1);
- the delivery state (see L.3);
- the final protection class against corrosion and mechanical damage, and whether or not this protection must be applied to the axle before assembly of the wheelset (see 4.9.1);
- the nature and characteristics of the temporary protection of the finished parts (see 4.9.2);
- the axle end marking configuration (see 4.10).

The technical specification must set out the procedures for monitoring the product manufacturing quality:

- either a sampling inspection of manufacturing batches in accordance with the requirements of L.5.1;
- or an approved quality plan in accordance with L.6.

The technical specification must also define:

- internal integrity: parts that may not be examined (see 4.4.2.4);
- ultrasonic permeability: types of translators (see 4.5.4);
- residual stress measurement method (see 4.6.4)
- surface integrity: bore examination method (see 4.7.2.4);
- corrosion protection of the bore (see 4.9.1.1);
- coating thickness: measurement method (see 4.9.1.3);

— coating adhesion: test method (see 4.9.1.3.4);

— choice of controls (Table L.1);

— connection radii roughness condition: measurement method by comparison with visual-tactile samples (see 4.7.1.2);

At a minimum, manufacturers must be identified and documented in the product supply compliance certificates for the following steps of the production process:

— Steel development;

— Forging;

— Heat treatment;

— Machining.

L.3 Delivery state

The finish of the various axle parts on delivery must be one of the following:

— unmachined (as-forged or as-rolled), where the part concerned has not undergone machining other than that which the manufacturer must perform to make the axle compliant with this document;

— rough-machined, when the part concerned has been machined and requires further machining;

— finished, when the part concerned has undergone final machining (not applicable for seats);

— finished, ready-for-assembly, when a seat has undergone final machining ready for assembly.

L.4 Unit checks

Whether product manufacturing quality is checked by batch sampling (see L.5) or using a quality plan (see L.6), checks are required to ensure that specific properties as defined in Clause 4 are obtained. These checks must be carried out on each delivered axle and are:

— ultrasonic permeability (see 4.5 or L.5.2);

— internal integrity (see 4.4.2);

— surface integrity (see 4.7.2).

L.5 Batch sampling check

L.5.1 Checks to be carried out

The type and number of checks to be carried out are defined in Table L.1. A batch consists of axles from the same cast and heat treated under the same conditions.

The selected measurement positions and the number of documented values for surface finishes and the geometry must be defined in the technical specification.

Table L.1 — Type and minimum number of checks to be carried out

Characteristics to be checked	Number of axles to be inspected per batch		References
Maximum batch size	≤ 100	> 100	
- Chemical analysis[e]	1	1	4.1
- Hydrogen content	Key	Key	b
- Tensile test (mid-radius)[e]	1	1 per 100 parts	4.2.1
- Impact test (mid-radius of solid axles and mid-distance of internal and external surfaces of hollow axles)			
- longitudinal	1	1 per 100 parts	4.2.2
- transverse	1	1 per 100 parts	
- Micrographic cleanliness [e]	1	1 per 100 parts	4.4.1
- Ultrasonic permeability	100%	100%	4.5 or L.5.2
- Internal integrity[f]	100%	100%	4.4.2
- Surface integrity[dg]	100%	100%	4.7.2
- Surface finish	100%	100%	4.7.1 or L.5.3
- Geometrical and dimensional tolerances	100%	100%	4.8
- Final protection:			
- thickness of the dry film	10%	10%	4.9.1.1

[a] One analysis per cast. Particular care should be taken to ensure that the maximum value of the hydrogen content thus determined is representative of the cast in its entirety.

[b] The hydrogen content is determined using the methods described in Annex M (normative). It must be less than 2 ppm for Category 1 axles and 2.5 ppm for Category 2 axles.

[c] Three test pieces are used for each test.

[d] If stated in the technical specification, magnetic particle examination for longitudinal defects may be replaced by a visual inspection as defined in L.5.4.

[e] The test pieces can be taken from a journal overlength.

[f] If stated in the technical specification, the AVG method may be used.

[g] Depending on the magnetisation process, demagnetisation may be necessary. The method must be defined in the technical specification.

L.5.2 Ultrasonic permeability

The ultrasonic permeability characteristics must be in accordance with the requirements of Subclause 4.5.

For hollow axles, the technical specification may permit other methods for checking the transverse ultrasound permeability.

L.5.3 Surface finish

Surface finish characteristics must comply with 4.7.1.1.

The finish can be estimated by comparison with surface finish reference standards, which are defined in the technical specification.

L.5.4 Visual inspection

The visual inspection should be performed under normal conditions of vision.

The acceptability criteria must be established on the basis of the reference images defined in the technical specification.

L.6 Quality plan

L.6.1 General

If the products being supplied are monitored via a quality plan, this must be defined in the technical specification.

NOTE Quality plan as defined in EN ISO 9001 or equivalent.

This quality plan should refer to the manufacturer's quality manual and contain product-specific items.

L.6.2 Objectives

This plan, which must be established in the technical specification, is intended to:

— describe the measures taken to obtain and control the quality of the products concerned;, including justifications for the choices made.

— provide at least the same confidence in the conformity of the product as that obtained by the batch sampling tests.

This quality plan must specify the checks carried out during manufacture and on the products delivered. These checks can be collated in a manufacturing control plan.

L.6.3 Quality Plan terms of application

Any changes to the quality plan must be documented.

In the event of non-compliance of supplied products, the terms of application of the quality plan must be questioned and if the results are not satisfactory, the quality plan may be suspended.

In this case, the checks and tests defined by "batch sampling control" mode must be applied in full until further agreement is reached.

L.7 Permissible repairs

L.7.1 General

Surface defects can be eliminated by fine grinding or machining, provided that, after repair, dimensional and geometric requirements are met in the section where the repair was performed. This can be done by machining or by gentle grinding, provided that these processes do not cause excessive heating or cracks and that they allow dimensional tolerances to be respected. In addition, the repaired surface must be correctly connected to the neighbouring surfaces.

In zones z_0 (see Figure 7), such repairs are authorised if the depth of the defect to be repaired is less than 0.25 mm.

All work must be examined to ensure that the requirements provided in 4.7.2 have been met.

L.7.2 Heat treatment

If the physical and mechanical properties are not met, the axle may be subjected once to additional heat treatment cycles. The additional heat treatment must be recorded.

L.7.3 Retesting

If the requirements are not met during mechanical testing, a technical analysis of the non-conformity must be carried out to justify retesting, if the technical specification allows this.

For example, when the tensile test and impact test do not meet the requirements, they can be repeated a second time in their entirety in accordance with Table 2 and Table 3, otherwise the batch must be discarded. The retest must be carried out on test pieces from two separate axles (if there are not more than 100 axles in the batch), or two separate axles per 100 axles (if there are more than 100 axles in the batch). The batch shall be withdrawn if any of the individual results of a retest do not reach the required value. All test results must be documented.

L.7.4 Axle straightening

The axles must be straightened before any other operation or before any test piece is taken for mechanical testing or microstructural examination. If straightening is performed at ≤ 500°C, the axles must undergo the following heat treatment after straightening:

— Standardised axles: these axles must be tempered at between 500°C and 650°C to eliminate stress, or must undergo further standardisation treatment;

— Quenched and tempered axles: these axles must be tempered at between 500°C and the actual tempering temperature decreased by 30°C in order to eliminate stress, otherwise the quenching and tempering treatment must be repeated.

L.7.5 Re-machining

Any re-machining in zone Z_0 must be done by turning within the tolerances.

Annexe M
(normative)

Measurement of the hydrogen content of steel for axles at the development stage

M.1 General

As there is no European Standard on this subject, this Annex defines the requirements for carrying out this measurement.

M.2 Sampling

The sampling is carried out in the liquid bath. It must be performed to meet the requirements of the specification using one of the following 4 methods:

— Copper mould;

— Fire-resistant glass vacuum tube;

— Open quartz tube (the use of translucent quartz is prohibited due to its hygroscopic power);

— Probe immersion method (carrier gas method with thermal conductivity detectors). In this case, the samplings are not taken physically.

M.3 Analysis methods

Two methods are accepted:

— vacuum extraction apparatus operating at temperatures between 650°C and 1050°C;

— injection of carrier gas (N_2) into the molten metal. The resulting diffused gas containing hydrogen is recovered for re-circulation, then analysed.

Other methods may be accepted in the technical specification if the same accuracy can be achieved.

M.4 Precautions

When sampling is performed on molten metal, the sampling and preparation must be carried out in accordance with EN ISO 14284:2002, Clause 6.5.

Operators should have specific training to perform the analysis.

Annexe ZA
(informative)

Relationship between this European Standard and the essential requirements of Directive 2016/797/EC to be fulfilled

This European Standard has been developed within the framework of standardisation mandate M/483 given by the European Commission in order to provide a means to comply on a voluntary basis with the essential requirements of Directive 2016/797/EC on the interoperability of the rail system.

Once this Standard has been quoted in the Official Journal of the European Union (OJ) under the aforementioned Directive, compliance with the normative clauses of this Standard given in Table ZA.1 for freight wagons and Table ZA.2 for Locomotives and Passenger Vehicles, confers, within the scope of the Standard, a presumption of conformity with the essential requirements applicable to the aforementioned Directive and the associated EFTA Regulation.

Table ZA.1 — Correspondence between this European standard, Commission Regulation (EU) No. 321/2013 of 13 March 2013 (and its amendments 1236/2013 and 2015/924) regarding the technical specification for interoperability concerning the "rolling stock – freight cars" subsystem of the railway system in the European Union and repealing Decision 2006/861/EC (published in OJ *L 104, 12.4.2013, p.1*) and Directive 2016/797/EC

Corresponding text, clauses/§/annexes to Directive 2016/797/EC	Chapters/§/points and annexes to the TSI	Clauses/subclauses of this European Standard	Comments
Annex III, Essential Requirements 1 General requirements 1.1 Safety Clauses 1.1.1, 1.1.2, 1.1.3 1.2 Reliability and availability 1.5 Technical compatibility 2 Essential requirements specific to each subsystem 2.4 Rolling stock 2.4.2 Reliability and availability Technical compatibility §3	4 Characterisation of the subsystem 4.2 Technical and functional specification of the subsystem 4.2.3 Interaction with the track and gauge 4.2.3.6 Bogies § 4.2.3.6.4 Axle characteristics 5 Interoperability constituents 5.3 Specification of interoperability constituents § 5.3.4 Axles 6 Conformity assessment and EC verification 6.1 Interoperability constituent 6.1.2 Conformity assessment procedures § 6.1.2.4 Axles	The entire standard is applicable.	

Table ZA.2 — Correspondence between this European standard, Commission Regulation (EU) No. 1302/2014 of 18 November 2014 regarding the technical specification for interoperability concerning the "rolling stock – locomotives and passenger vehicles" subsystem of the railway system in the European Union and repealing Decision 2006/861/EC (published in OJ *L 356, 12.12.2014, p.228*) and Directive 2016/797/EC

Corresponding text, clauses/§/annexes to Directive 2016/797/EC	Chapters/§/points and annexes to the TSI	Clauses/subclauses of this European Standard	Comments
Annex III, Essential Requirements 1 General requirements 1.1 Safety Clauses 1.1.1, 1.1.2, 1.1.3 1.2 Reliability and availability 1.5 Technical compatibility 2 Essential requirements specific to each subsystem 2.4 Rolling stock 2.4.2 Reliability and availability Technical compatibility §3	4 Characterisation of the rolling stock subsystem 4.2 Technical and functional specification of the subsystem 4.2.3 Interaction with the track and gauges 4.2.3.5 Running components 4.2.3.5.2 Wheelset § 4.2.3.5.2.1 Mechanical and geometric characteristics of wheelsets 6 Assessment of conformity or suitability for use and EC verification 6.2 Rolling stock subsystem 6.2.3 Special procedures for the evaluation of subsystems § 6.2.3.7 Mechanical and geometric characteristics of wheelsets	The entire standard is applicable.	

WARNING 1 — The presumption of conformity remains valid as long as the reference to this European Standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult this list frequently.

WARNING 2 — Other EU regulations may apply to products falling within the scope of this standard.

Bibliography

[1] EN 10049, *Measurement of roughness average Ra and peak count RPC on metallic flat products*

[2] CEN/TR 10261, *Iron and steel - European standards for the determination of chemical composition*

[3] EN 13260, *Railway Applications - Wheelsets and bogies - Wheelsets - Product requirements*

[4] EN 15305, *Non-destructive testing - Test method for residual stress analysis by X-ray diffraction*

[5] EN 20898-2, *Mechanical properties of fasteners – Part 2: Nuts with specified proof load values - Coarse thread (ISO 898-2)*

[6] EN ISO 9001, *Quality Management Systems - Requirements (ISO 9001)*

[7] EN ISO 9712, *Non-destructive testing - Qualification and certification of NDT personnel (ISO 9712)*

[8] EN ISO 11124-1, *Preparation of steel substrates before application of paints and related products- Specifications for metallic blast-cleaning abrasives - Part 1: General introduction and classification (ISO 11124-1)*

[9] EN ISO 11124-3, *Preparation of steel substrates before application of paints and related products - Specifications for metallic blast-cleaning abrasives - Part 3: High-carbon cast-steel shot and grit (ISO 11124-3)*

[10] ISO 26910-1, *Springs - Shot peening - Part 1: General procedures*

[11] ASTM E415-14, *Standard Test Method for Analysis of Carbon and Low-Alloy Steel by Spark Atomic Emission Spectrometry*

[12] ASTM E837, *Standard Test Method for Determining Residual Stresses by the Hole-Drilling Strain-Gage Method*

[13] ASTM E1019-11, *Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Inert Gas Fusion Techniques*

[14] EN 13103-1, *Railway applications - Wheelsets and bogies - Part 1: Design method for axles with external journals*