

BS 5892-7:2014

Incorporating Corrigendum No. 1



BSI Standards Publication

Railway rolling stock materials

**Part 7: Specification for product and
technical approval requirements for
cast wheels**

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Foreword

Publishing information

This part of BS 5892 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 November 2014. It was prepared by Panel RAE/3/-/1, *Wheels and Wheelsets*, under the authority of Technical Committee RAE/3, *Railway rolling stock materials*. A list of organizations represented on this committee can be obtained on request to its secretary.

Information about this document

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Relationship with other publications

BS 5892 is published in the following parts:

- BS 5892-1, *Railway rolling stock materials – Part 1: Specification for axles for traction and trailing stock*;
- BS 5892-2, *Railway rolling stock materials – Part 2: Specification for forged and rolled wheel centres*;
- BS 5892-3, *Railway rolling stock materials – Part 3: Specification for monobloc wheels for traction and trailing stock*;
- BS 5892-4, *Railway rolling stock materials – Part 4: Specification for forged and rolled tyres*;
- BS 5892-5, *Railway rolling stock material (metric) – Part 5: Specification for steel bars for retaining rings for tyred wheels*;
- BS 5892-6, *Railway rolling stock materials – Part 6: Specification for wheelsets for traction and rolling stock*;
- BS 5892-7, *Railway rolling stock materials – Part 7: Specification for product and technical approval requirements for cast wheels*;
- BS 5892-8, *Railway rolling stock materials – Part 8: Railway applications – Wheelsets and bogies – Powered and non-powered wheelsets with inboard bearings – Product requirements*.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is “shall”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

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

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

Introduction

Before the publication of this part of BS 5892, the only standards available to define quality and technical approval requirements for monobloc wheels were BS 5892-3, BS EN 13262 and BS EN 13979-1, which apply only to forged and rolled wheels, and DD CEN/TS 13979-2 and DD CEN/TS 15718, which were published as reference documents for cast wheels.

Cast wheels are commonly used by railways applying the Association of American Railroads (AAR) standards and have been introduced into Europe on some applications for freight wagons. The product and technical approval requirements of this British Standard are derived from BS 5892-3, BS EN 13262 and BS EN 13979-1.

This British Standard provides a complete definition of the product and delivery procedures for cast wheels by:

- a) defining all the wheel characteristics;

NOTE 1 These are either verified during the qualification procedures or for the delivery of the product (see Clause 4).

- b) defining qualification procedures (see Annex A); and

- c) defining delivery conditions (see Annex B).

NOTE 2 A choice is given to the supplier, of either:

- 1) *a traditional delivery procedure with a control by batch sampling as in existing documents (see B.4); or*
- 2) *a delivery procedure using quality assurance concepts (see B.4.6).*

This British Standard also describes how to assess the wheel design, following the principles of BS EN 13979-1 as set out for cast wheels in DD CEN/TS 13979-2. To be able to apply the specifications, the use of the wheel needs to be defined; this standard also states how to define this use.

At least four aspects are described with different purposes:

- a geometric aspect – to allow interchangeability of different solutions for the same application;
- a thermomechanical aspect for tread braked wheels – to manage wheel deformations and to ensure that braking does not cause wheels to break;
- a mechanical aspect – to ensure that no fatigue cracks occur in the web; and
- an acoustic aspect – to ensure that the solution chosen is as good as the reference wheel, for the use in question.

For each of these three latter aspects, the rules tend to limit the procedure; thus, the easier the objectives are to attain by the wheel under study.

The main content of the technical approval clauses of this standard is derived from BS EN 13979-1 with differences linked to the needs of the cast process for the product as proposed in DD CEN/TS 13979-2.

1 Scope

This British Standard specifies the characteristics of, and technical approval requirements for, cast railway wheels for conventional rail operation. It can be applied in conjunction with BS or BS EN standards for axles and wheelsets. This standard is not applicable to urban rail.

Three steel grades, C48, C56 and C64, are defined in this standard.

NOTE 1 For the purpose of this British Standard, the steels referred to as C48, C56 and C64 are based on those defined as AAR Class L, A and B respectively.

This British Standard is applicable to cast wheels which are rim-chilled and have their wheel webs shot peened.

NOTE 2 'Rim-chilled' is a heat treatment of the rim, the aim of which is to harden the rim and to create compressive residual stresses in the rim.

NOTE 3 Cast wheels are shot peened to improve the web fatigue strength.

The wheels defined in this British Standard are for applications up to 120 km/h (i.e. 75 mph).

It only applies to wheels of new design or new application.

These requirements are intended to be used to assess the validity of the design choice for the proposed use and constitute the technical approval procedure.

This British Standard does not cover assessment of the hub nor of the static mechanical dimensioning of the wheel.

2 Normative references

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ASTM E399-90:1997, *Test method for plane-strain fracture toughness of metallic materials*

ASTM E1245, *Standard practice for determining the inclusion or second-phase constituent content of metals by automatic image analysis*

BS EN 13103, *Railway applications – Wheelsets and bogies – Non-powered axles – Design method*

BS EN 13104, *Railway applications – Wheelsets and bogies – Powered axles – Design method*

BS EN 13979-1:2003+A2:2011, *Railway applications – Wheelsets and bogies – Monobloc wheels – Technical approval procedure – Part 1: Forged and rolled wheels*

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

BS EN ISO 6506-1, *Metallic materials – Brinell hardness test – Part 1: Test method*

BS EN ISO 6506-2, *Metallic materials – Brinell hardness test – Part 2: Verification and calibration of testing machines*

BS EN ISO 6506-3, *Metallic materials – Brinell hardness test – Part 3: Calibration of reference blocks*

BS EN ISO 6892-1:2009, *Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature*

BS EN ISO 9712, *Non-destructive testing – Qualification and certification of NDT personnel (ISO 9712:2012)*

ISO 5948:1994, *Railway rolling stock material – Ultrasonic acceptance testing*

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

ISO/TR 9769, *Steel and iron – Review of available methods of analysis*

Other publications

[N1] SOCIETY OF AUTOMOTIVE ENGINEERS. *SAE J827, High-carbon cast-steel shot*. Warrendale, PA: SAE International, 2013.

[N2] SOCIETY OF AUTOMOTIVE ENGINEERS. *SAE J444, Cast shot and grit size specifications for peening and cleaning*. Warrendale, PA: SAE International, 2012.

[N3] SOCIETY OF AUTOMOTIVE ENGINEERS. *SAE J442, Test strip, holder and gage for shot peening*. Warrendale, PA: SAE International, 2013.

[N4] SOCIETY OF AUTOMOTIVE ENGINEERS. *SAE J443, Procedures for using standard shot peening Almen strip*. Warrendale, PA: SAE International, 2013.

[N5] ASSOCIATION OF AMERICAN RAILROADS. *AAR Manual of standards and recommended practices: Section G – Wheels and axles – Specification M 107 M 208*. AAR, 2011. ¹⁾

[N6] ERRI report B169/RP12. *Production of a universal matrix representative of damage to a railway component with a view to performing fatigue tests*. October 1997.

[N7] ERRI report B169 RP10. *Definition of a specification for solid axisymmetrical wheels – Verification of mechanical design: fatigue strength – Towards a better shape for the wheel centre*. January 1999.

3 Terms and definitions

For the purposes of this part of BS 5892, the following terms and definitions apply.

3.1 Heat

identification of all the wheels produced from a single furnace load of liquid steel

3.2 technical specification

document describing the specific parameter/product requirements in addition to the requirements of this standard

4 Product definition

4.1 General

The application for which the wheel is to be approved shall be defined by the parameters in accordance with this British Standard and the additional requirements defined in the technical specification.

¹⁾ Available from <<http://www.ttc.aar.com/standards/publications.php>> [last viewed 10 November 2014].

The product sample shall be taken from the locations as indicated in this British Standard. Where the characteristics of the wheel vary due to the nature of the steel casting process, the test shall be taken from a worst case location as defined in the technical specification.

For any process change the locations shall be reviewed and, if necessary, defined again.

4.2 Chemical composition

4.2.1 Requirements

The defined chemical composition shall be within the ranges defined in Table 1 and Table 2.

To safeguard against hydrogen cracking the minimum sulfur content shall not be less than 0.005%; greater values may be defined in the technical specification.

Table 1 Maximum content of main elements within cast wheels

Steel grade	Maximum content %				
	C	Si	Mn	P	S (see Note)
C48	0.45–0.52	0.60	0.90	0.025	0.025
C56	0.52–0.60	0.60	0.90	0.025	0.025
C64	0.60–0.67	0.60	0.90	0.025	0.025

NOTE For special applications, variations within the maximum limit of these values may be defined in the technical specification.

Table 2 Maximum content of residual elements within cast wheels

Steel grade	Maximum content %								
	Cr	Cu	Mo	Ni	V	Al	Ti	Nb	Cr + M + Ni
C48	0.25	0.35	0.10	0.25	0.06	0.06	0.03	0.05	0.50
C56	0.25	0.35	0.10	0.25	0.06	0.06	0.03	0.05	0.50
C64	0.25	0.35	0.10	0.25	0.06	0.06	0.03	0.05	0.50

NOTE For special applications, variations within the maximum limit of these values may be defined in the technical specification.

4.2.2 Location of the sample

The sample for determining the chemical composition shall either be taken from the molten steel during the casting process or from a position 15 mm below the tread at its nominal diameter.

For product approval, both samples shall be taken.

4.2.3 Chemical analysis

The chemical composition analysis shall be performed in accordance with ISO/TR 9769.

4.2.4 Hydrogen analysis

The hydrogen content shall be determined for each Heat. The Heat shall conform to a maximum hydrogen percentage limit of 2.5 ppm.

4.3 Mechanical characteristics

4.3.1 Tensile test characteristics

4.3.1.1 Requirements

The rim and web characteristics of the cast wheels shall be, as a minimum, the values given in Table 3.

Table 3 Rim and web characteristics of the wheels

Steel grade	Rim			Web	
	$R_{eH}^{A)}$ N/mm ²	R_m N/mm ²	A_5 %	R_m reduction $B)$ N/mm ²	A_5 %
C48	≥460	760/940	≥6	≥100	≥4
C56	≥520	860/1 050	≥5	≥70	≥4
C64	≥570	940/1 140	≥4	≥50	≥4

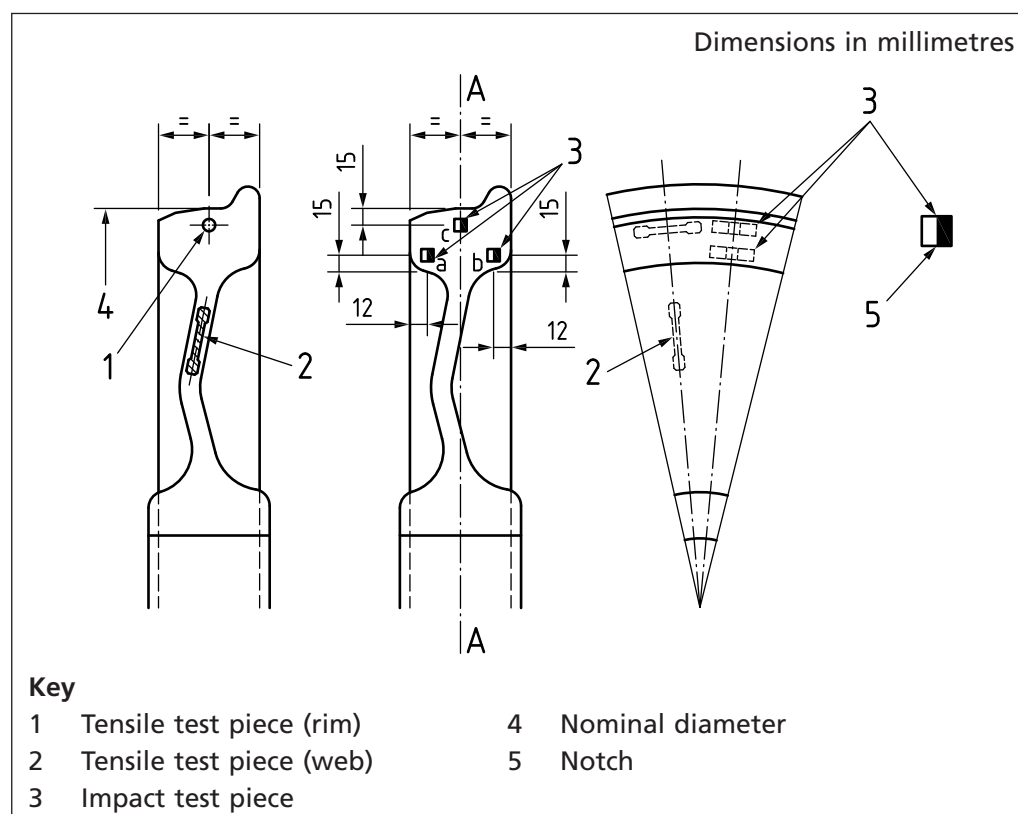
A) If no distinctive yield strength is present, the proof stress $R_{p0.2}$ is determined.

B) Reduction of tensile strength is relative to that of the rim on the same wheel.

4.3.1.2 Location of test pieces

Test pieces shall be taken from the rim and the web of the wheel, as shown in Figure 1.

Figure 1 Location of test pieces



4.3.1.3 Test method

The test shall be carried out in accordance with BS EN ISO 6892-1:2009, Method B. The diameter of the test piece shall be at least 10 mm in the parallel length and the gauge length shall be five times the diameter.

NOTE Where the wheel design prevents a sample of the stated size from being taken, a smaller sized sample may be taken if agreed in the technical specification.

4.3.2 Hardness characteristics in the rim

4.3.2.1 Requirements

The minimum values of Brinell hardness given in Table 4 and defined by B, C and D in Figure 2 shall be applicable up to a maximum wear depth of 35 mm under the tread.

If the wear depth is greater than 35 mm, the values shall be defined in the technical specification.

The hardness values in the rim-web transition (point A in Figure 2) shall be at least ten points lower than the wear limit values.

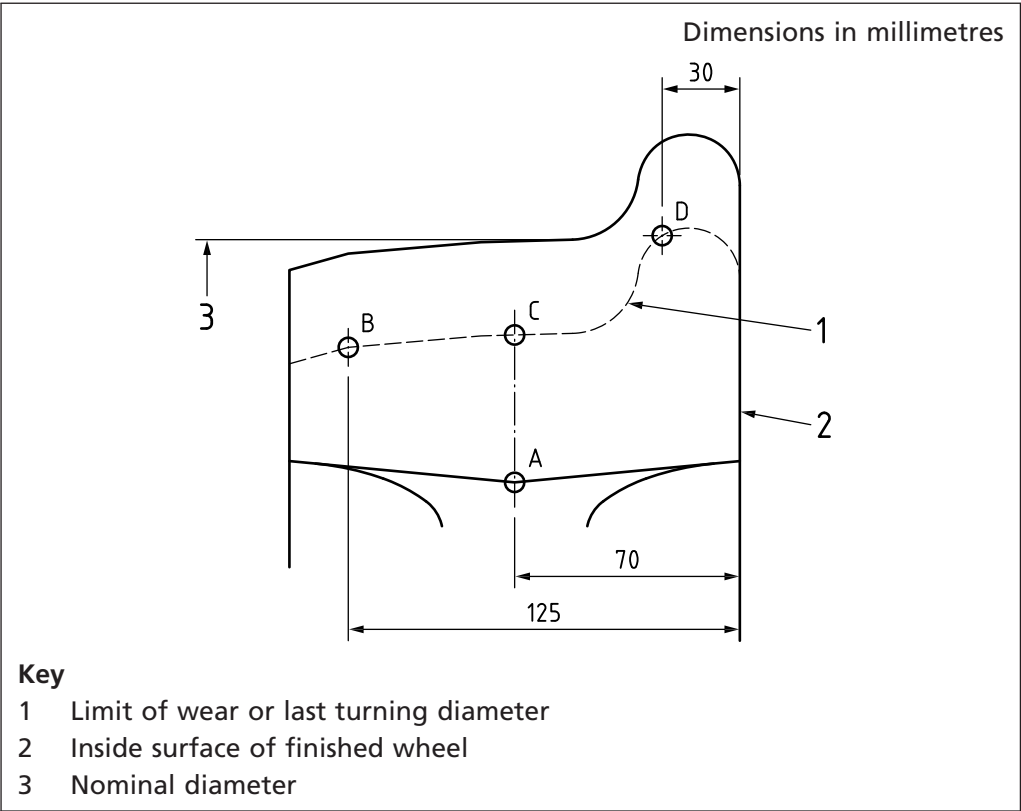
Table 4 Minimum hardness values

Steel grade	Minimum value for Brinell hardness
C48	235
C56	255
C64	277

4.3.2.2 Location of readings

Four readings shall be carried out on a radial section of the rim as shown in Figure 2. Where the microstructure of the wheel varies due to the casting process, e.g. between risers, the test positions shall occur in the worst-case locations, circumferentially around the wheel.

Figure 2 Readings taken on a radial section of the rim



4.3.2.3 Test method

The test shall be carried out in accordance with BS EN ISO 6506-1. The ball diameter shall be 5 mm.

4.3.3 Impact test characteristics

4.3.3.1 Values to be achieved

The average and minimum impact test values for cast wheels shall be as given in Table 5.

NOTE The values represent the average and minimum values for the three test specimens defined in 4.3.3.2.

At +20 °C, U-notch specimens (KU) shall be used. At –20 °C, V-notch specimens (KV) shall be used.

Table 5 Average and minimum impact test values

Steel grade	KU(J) at +20 °C		KV(J) at –20 °C	
	Average values	Minimum values	Average values	Minimum values
C48	≥8	≥6	≥4	≥3
C56	≥8	≥6	≥4	≥3
C64	≥8	≥6	≥4	≥3

4.3.3.2 Location of the test pieces

Test pieces shall be taken from the rim of the wheel, as shown in Figure 1.

The bottom notch axis shall be parallel to the A–A axis of Figure 1.

4.3.3.3 Test method

The test shall be carried out in accordance with BS EN ISO 148-1.

4.3.4 Fatigue test characteristics

4.3.4.1 Requirements

For all steel grades, the web shall withstand the stress variation, $\Delta\sigma$, given in Table 6 during 10^7 cycles without any crack initiation, with a probability of 99.7%.

Table 6 Minimum fatigue characteristics

State of delivery of the web	$\Delta\sigma$ N/mm ²
Partially machined or as cast and shot peened	315

NOTE 1 The aim of this characteristic is to ensure that product characteristics are higher than those used for the definition of permissible stresses for the fatigue design of the web.

NOTE 2 It is not realistic to distinguish between the steel grades due to the many approximations in a fatigue calculation.

4.3.4.2 Specimens for fatigue test

Specimens shall consist of wheels as delivered. Their surface appearance shall be in accordance with 4.7.1.

4.3.4.3 Test method

The test shall:

- allow bending stresses in a web section;
- be carried out such that results can be statistically evaluated; and
- be monitored by measuring the radial stresses, which exist in the crack initiation area.

NOTE For an example of this test method, see Annex C.

4.3.5 Fracture toughness characteristics of the rim

4.3.5.1 General

Fracture toughness shall only be verified for wheels where tread braking is the sole means of service braking.

4.3.5.2 Values to be achieved

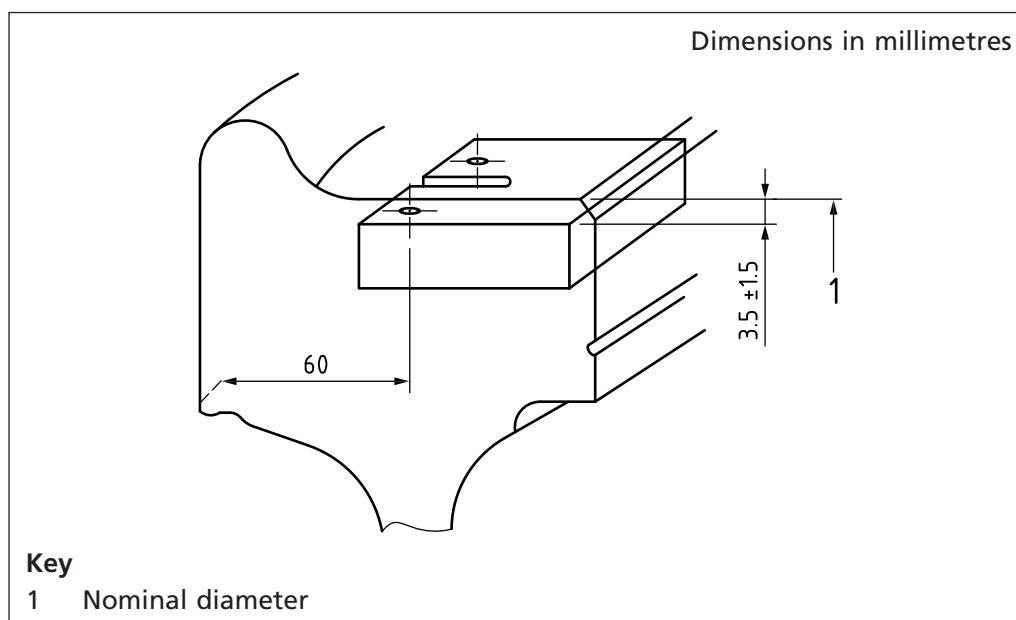
For steel grade C48, the average value obtained from six test pieces shall be greater than or equal to $65 \text{ N/mm}^2 \sqrt{\text{m}}$ and any single value shall not be below a minimum of $50 \text{ N/mm}^2 \sqrt{\text{m}}$.

For steel grades C56 and C64, the technical specification shall state the applicable values.

4.3.5.3 Location of test pieces

Six test pieces shall be taken from the rim as shown in Figure 3. Where the microstructure of the wheel varies because of the casting process, the test positions shall be in the worst-case locations of the wheel.

Figure 3 Test pieces taken from the rim



4.3.5.4 Test method

The test shall be carried out in accordance with ASTM E399-90.

The test conditions shall be:

- The compact specimen shall have a CT thickness of 30 mm (CT 30 specimen), with chevron notch having an aperture angle of 90° (see ASTM E399-90:1997, Figure 4).

- b) The temperature during the test shall be between +15 °C and +25 °C.
- c) The measurement of the crack displacement of the specimen shall be in accordance with ASTM E399-90:1997, Figure 3.
- d) The rate of increase of stress intensity, $\Delta K/s$ (stress intensity per second), shall be within the range $0.55 \text{ N/mm}^2 \sqrt{\text{m/s}}$ to $1 \text{ N/mm}^2 \sqrt{\text{m/s}}$ (see ASTM E399-90).
- e) The value of the toughness to be considered shall be the value K_Q , which is calculated from the value of the load F_Q from the load-displacement record.

4.4 Metallurgical structure

The wheel shall have a pearlitic structure, but the presence of bainite in addition to pearlite within areas that are subject to rim quenching shall be acceptable.

4.5 Material cleanliness

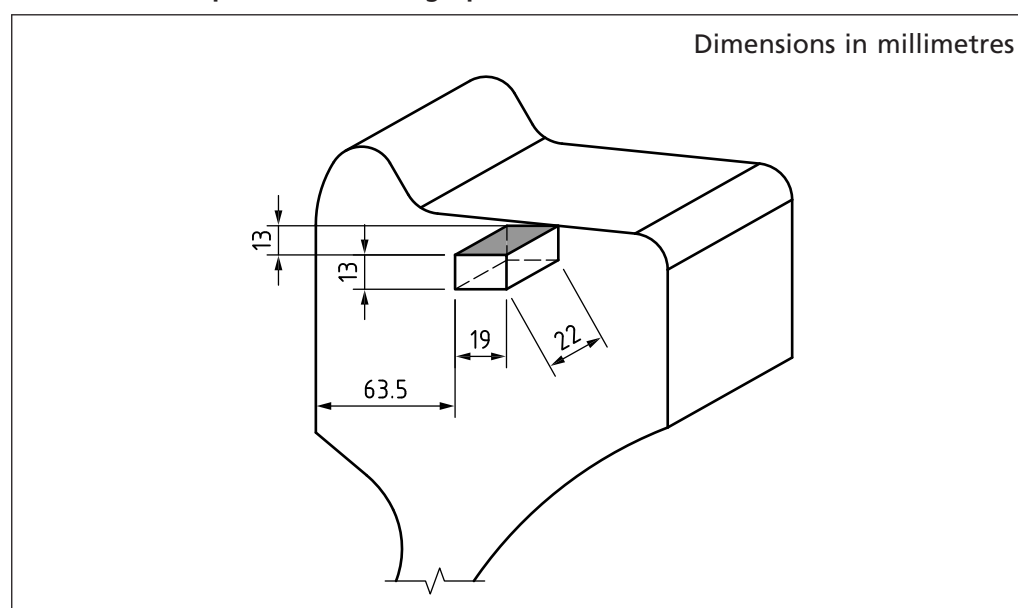
4.5.1 Micrographic cleanliness

4.5.1.1 Sample size and location

A minimum of six samples shall be taken from each wheel tested; these shall be approximately equidistant around the circumference of the wheel.

NOTE Figure 4 shows the location and size of each sample.

Figure 4 Location of sample for the micrographic examination



4.5.1.2 Sample preparation

Each 22 mm × 19 mm × 13 mm sample shall be prepared and evaluated in accordance with ASTM E1245. The flicker method shall be used to establish the correct setting of the grey-level threshold limits.

The total area evaluated for each sample shall be not less than 161 mm². All inclusions greater than 2.5 μm shall be counted.

4.5.1.3 Level to be achieved

The average and worst field area percentage of inclusions and voids shall be recorded.

The maximum permissible values for the six samples shall be:

- 0.1% for the average oxide inclusions plus voids; and
- 0.75% for the worst field sulphides and also 0.75% of oxides plus voids.

NOTE Demonstration that there is no fatigue crack propagation beneath the tread is subject to confirmation by in-service experience of wheels.

4.5.2 Internal integrity

4.5.2.1 General

Internal integrity shall be determined from ultrasonic examination.
The examination shall be carried out before shot peening.

NOTE Standard flat bottom holes for ultrasonic testing have different diameters for different types of ultrasonic testing.

4.5.2.2 Requirements

4.5.2.2.1 Rim

The rim shall have no internal defects that give echo magnitudes larger than or equal to 25% of that obtained for a standard defect situated at the same depth. The diameter of this standard defect shall be 3.12 mm (1/8 in), unless otherwise defined in the technical specification.

There shall be no attenuation of the back echo signal higher than 4 dB during the axial examination.

4.5.2.2.2 Web

The web shall not have:

- a) more than ten echoes with magnitudes greater than or equal to those obtained for standard defects of 3.12 mm (1/8 in) diameter, unless otherwise defined in the technical specification; and
- b) echoes of magnitude greater than or equal to those obtained for a standard defect of 5 mm diameter.

The distance between two acceptable defects shall be at least 50 mm.

4.5.2.2.3 Hub

The hub shall not have:

- a) more than three echoes of magnitude greater than or equal to those obtained for standard defects of 3.12 mm (1/8 in) diameter, unless otherwise defined in the technical specification; and
- b) echoes of magnitude greater than or equal to those obtained for a standard defect of 5 mm diameter.

The distance between two acceptable defects shall be at least 50 mm.

For one circumferential examination, there shall be no attenuation of the back echo signal equal to or greater than 6 dB.

4.5.2.3 Test piece

The complete wheel shall be examined after heat treatment, before shot peening and before any corrosion protection is applied.

4.5.2.4 Method of examination

4.5.2.4.1 General

Ultrasonic examination shall be carried out on samples in accordance with ISO 5948 and the requirements of **4.5.2.4.2**, **4.5.2.4.3** and **4.5.2.4.4**, with particular reference to the casting process and the inspection methods appropriate for that process.

The test method shall be documented in the technical specification, including any additional test methods specified by the manufacturer.

NOTE An alternative method for axial testing using the loss of back reflection may be agreed in the technical specification.

4.5.2.4.2 Rim

Unless otherwise specified in the technical specification, the following shall apply.

- a) The rim examination shall be in accordance with ISO 5948:1994, Table 1, Method D1 and Method D2.
- b) Defect estimation shall be made by comparison to artificial defects in the standard rim in accordance with ISO 5948:1994, Figure 1 and Figure 2.
- c) Ultrasonic examination shall be carried out to cover the rim to web transition.

4.5.2.4.3 Web

The web examination shall be carried out from both front and back surfaces of the web. The direction of the examination shall be perpendicular to the surface.

Defect estimation shall be made by comparison to artificial defects in a standard web.

The web shall be defined as the part of the wheel between the two diameters at m and n (see **4.8**).

The thickness, e , of the web shall be designated by the minimum thickness of the cross-section.

The artificial defects shall be positioned mid way between the transition radius from the underside of the rim and the transition radius of the hub. These shall be at least 100 mm apart in a circumferential orientation.

The depth of the artificial defects shall be given as a function of e and shall be:

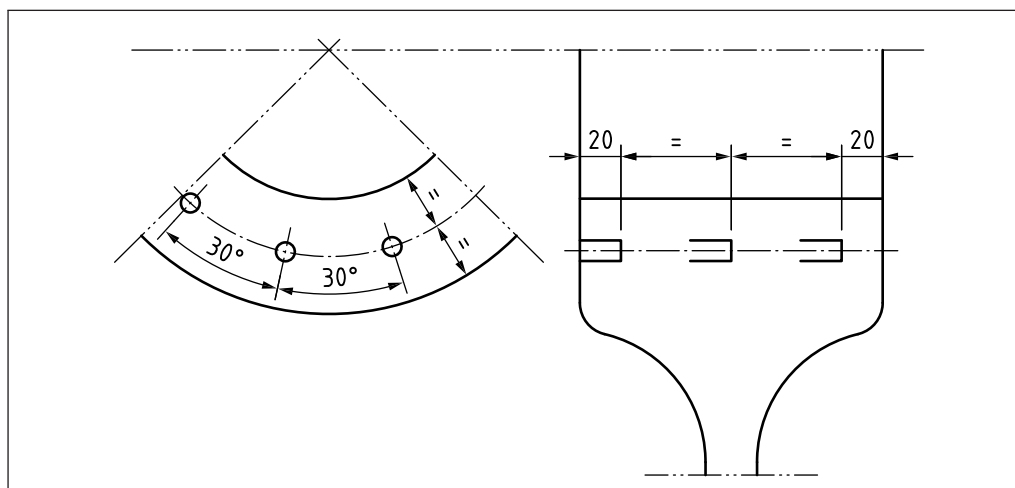
- a) Three flat bottom holes of 3.12 mm (1/8 in) diameter, located the first at 5 mm, the second at $(e/2)$ mm and the third at $(e - 5)$ mm below the back surface of the web.
- b) Three flat bottom holes of 5 mm diameter, located the first at 5 mm, the second at $(e/2)$ mm and the third at $(e - 5)$ mm below the back surface of the web.

4.5.2.4.4 Hub

The hub examination shall be carried out from both front and back surfaces of the hub. The direction of the examination shall be perpendicular to the surface.

Defect estimation shall be made by comparison to artificial defects in the standard hub shown in Figure 5.

Figure 5 Standard hub for ultrasonic examination



The artificial defects shall be spaced and have the depths as shown in Figure 5. These shall be:

- three flat bottom holes of 3.12 mm (1/8 in) diameter;
- three flat bottom holes of 5 mm diameter.

4.6 Residual stresses

4.6.1 General

A compressive circumferential residual stress field inside the rim shall be induced by wheel heat treatment.

4.6.2 Requirements

The circumferential residual stresses σ_{crs} at the surface of the tread of the finished wheel shall be in a compressive state with $-200 \text{ N/mm}^2 \leq \sigma_{crs} \leq -80 \text{ N/mm}^2$. If the magnitude of the circumferential residual stresses at the surface of the tread of the finished wheel is beyond -200 N/mm^2 , it shall be proved that the level of radial residual stresses in the web is acceptable regarding fatigue limit and notch sensitivity considering the applicable operating conditions.

NOTE The proof can be based on return of experience, calculation, fatigue test of the web.

The circumferential stresses shall be compressive to a depth of 35 mm. If the wear depth is greater than 35 mm, the value of the depth where the circumferential stresses are no longer compressive shall be defined in the technical specification.

4.6.3 Test piece

The test piece shall be the complete wheel after heat treatment.

4.6.4 Measurement methods

The variation of circumferential stresses located deep under the tread shall be estimated.

This method shall be stated in the technical specification.

NOTE Annex D gives an example method that can be used for this measurement.

4.7 Surface characteristics

4.7.1 Surface appearance

4.7.1.1 Characteristics to be achieved

The wheel surface shall not show any marks other than those at the positions required in this British Standard.

NOTE According to their use, wheels may be fully or part machined.

All "as cast" surfaces of the web shall be shot peened unless defined otherwise in the technical specification.

Average surface roughness, R_a , area values of "finished" or "ready for assembly" wheels shall be as given in Table 7.

Table 7 Average surface roughness

Area of the wheel	State of delivery	Roughness, R_a μm
Bore	Finished	≤ 12.5
	Ready for assembly ^{A)}	0.8 to 3.2
Web and hub	As cast ^{B)}	≤ 12.5
Rim tread	Finished ^{B)}	≤ 6.3
Rim faces	Finished ^{B)}	≤ 6.3

^{A)} If the wheel is to be fitted on a hollow axle, other values might be required for in-service ultrasonic inspection.

^{B)} If defined in the technical specification, this area of the wheel can remain unmachined, provided the fatigue characteristics indicated in Table 6 are achieved.

4.7.1.2 Measurement method

The roughness of the wheel surfaces, R_a , at the delivery stage given in Table 7 shall be inspected by comparison with the roughness specimen described or measured.

4.7.2 Surface integrity

4.7.2.1 General

To determine surface integrity, a magnetic particle test of the web shall be carried out in accordance with 4.7.2.4 and a visual inspection of the entire wheel shall be carried out to check for other visible defects, e.g. sand inclusions, shrinkage and/or shrinkage cracks, porosity, etc.

4.7.2.2 Level to be achieved

The maximum indicated length of permissible surface breaking defects on a finished wheel shall be 2 mm.

4.7.2.3 Test piece

The wheel shall be examined after heat treatment and after shot or other cleaning, but before shot peening and before the application of any temporary corrosion protection.

4.7.2.4 Methods of inspection

General requirements for the magnetic particle test shall be defined in accordance with ISO 6933 with the following exceptions: