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BSI Standards Publication

Founding — Continuous cast iron bars

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National foreword

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

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Foreword

This document (EN 16482:2014) has been prepared by Technical Committee CEN/TC 190 “Foundry technology”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2014 and conflicting national standards shall be withdrawn at the latest by December 2014.

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

Within its programme of work, Technical Committee CEN/TC 190 requested CEN/TC 190/WG 7 “Spheroidal graphite, silicon molybdenum and ausferritic cast iron” to prepare the following standard:

EN 16482, *Founding — Continuous cast iron bars*

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The European Standards EN 1561 [4] and EN 1563 [5] classify grey cast irons and spheroidal graphite cast irons respectively, which are cast in sand moulds or moulds of comparable thermal behaviour.

This European Standard classifies grey cast iron and spheroidal graphite cast iron bars, which are produced by the continuous casting process.

Due to the high cooling rate during solidification and further cooling, both graphite and matrix structure differ from those obtained by sand casting and consequently the mechanical properties in relation to section thickness [8], [9].

The mechanical properties of continuous cast iron bars are evaluated on machined test pieces prepared from samples cut from the bars.

However, for many applications tensile strength or hardness are not the only interesting or determining properties. Other mechanical or physical properties can be decisive for the use of grey cast iron or spheroidal graphite cast iron, for example: thermal capacity, thermal diffusivity, damping capacity, thermo-cycle fatigue and toughness.

Additional technical data for grey cast irons is given in EN 1561 and for spheroidal graphite cast irons in EN 1563 and Annex D of this European Standard.

1 Scope

This European Standard defines the grades of grey cast iron and spheroidal graphite cast iron bars, which have been produced by the continuous casting process.

This European Standard specifies the characterizing properties of grey cast iron bars by either:

a) the tensile strength measured on machined test pieces prepared from samples cut from the bars, or

b) the hardness measured on the bars.

If agreed by the manufacturer and the purchaser, the combination of both tensile strength from option a) and hardness from option b) may be specified.

This European Standard specifies the characterizing properties of spheroidal graphite cast iron bars by the tensile strength measured on machined test pieces prepared from samples cut from the bars.

This European Standard specifies 4 grades of grey cast iron and 14 grades of spheroidal graphite cast iron by a classification based on tensile strength and 4 grades of grey cast iron by a classification based on Brinell hardness.

This European Standard specifies also the straightness of the bars.

This European Standard does not cover technical delivery conditions for iron castings (see EN 1559-1 [1] and EN 1559-3 [2]).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 10204, *Metallic products - Types of inspection documents*

EN ISO 945-1, *Microstructure of cast irons - Part 1: Graphite classification by visual analysis (ISO 945-1)*

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

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

3 Terms and definitions

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

3.1
grey cast iron
cast material, mainly iron and carbon based, carbon being present mainly in the form of flake (lamellar) graphite particles

Note 1 to entry: Grey cast iron is also known as flake graphite cast iron, and less commonly as lamellar graphite cast iron.

[SOURCE: EN 1561:2011, 3.1]

3.2
spheroidal graphite cast iron
cast material, iron, carbon and silicon based, the carbon being present mainly in the form of spheroidal graphite particles

Note 1 to entry: Spheroidal graphite cast iron is also known as ductile iron, and less commonly as nodular iron.

[SOURCE: EN 1563:2011, 3.1]

3.3
ferritic to pearlitic cast irons
grey cast iron and spheroidal graphite cast iron with a matrix containing ferrite or pearlite or a combination of both

3.4
solid-solution strengthened ferritic spheroidal graphite cast iron
spheroidal graphite cast iron with a matrix mainly consisting of ferrite, solution strengthened mainly by silicon

3.5
graphite spheroidizing treatment
operation that brings the liquid iron into contact with a substance to produce graphite in the predominantly spheroidal (nodular) form during solidification

Note 1 to entry: This operation is often followed by a second one called inoculation.

[SOURCE: EN 1563:2011, 3.4]

3.6
sample
quantity of material cut from the continuous cast bar to represent the cast material

4 Designation

The material shall be designated in accordance with Table 1, Table 2, or Table 3.

NOTE The designation system is specified in EN 1560 [3].

5 Order information

The following information shall be supplied by the purchaser:

a) the number of this European Standard;

b) the designation of the material;

c) the dimensions of the bar;

d) any special requirements.

All requirements shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order, e.g. technical delivery conditions according to EN 1559-1 and EN 1559-3.

6 Manufacture

The methods of producing grey cast iron and spheroidal graphite cast iron continuous cast bars and their chemical compositions shall be left to the discretion of the manufacturer who shall ensure that the requirements of this European Standard are met for the material grade specified in the order.

For the cast irons to be used in special applications, the chemical composition and the heat treatment may be the subject of an agreement between the manufacturer and the purchaser.

All agreements between the manufacturer and the purchaser shall be made by the time of the acceptance of the order.

7 Requirements

7.1 Characterizing properties

The order shall specify in an unambiguous manner whether the tensile strength measured on a test piece machined from samples cut from the continuous cast bars or the Brinell hardness measured on the bars is the characterizing property. If it does not do so, then the manufacturer shall characterize the material according to tensile strength.

7.2 Tensile properties

7.2.1 General

The property values apply to grey cast iron and spheroidal graphite cast iron bars produced by the continuous casting process.

Tensile properties are dependant of the bar diameter as shown in Table 1 and Table 2.

For rectangular bars, the corresponding diameter *D* for the determination of the minimum tensile properties shall be calculated with Formula (1):

$$D = \frac{2 \times (H \times B)}{(H + B)} \quad (1)$$

where

D is the corresponding bar diameter in millimetres (mm);

H is the height of the bar in millimetres (mm);

B is the width of the bar in millimetres (mm).

NOTE Tensile testing requires sound test pieces in order to guarantee pure uni-axial stress during the test.

For bar diameters > 400 mm, the minimum tensile properties to be obtained shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

7.2.2 Test pieces machined from samples cut from the bar

The tensile properties, when measured in accordance with 9.1 using test pieces machined from samples cut from the bar, shall be in accordance with the requirements of Table 1 for grey cast irons or Table 2 for spheroidal graphite cast irons.

Table 1 — Tensile properties of continuous cast grey cast iron bars

Material designation		Bar diameter	Tensile strength	Matrix structure
		D	R_m	
		mm	MPa	(for information only)
Symbol	Number		min.	
EN-GJL-150C	5.1102	20 < D ≤ 50	110	ferritic, annealed
		50 < D ≤ 100	100	
		100 < D ≤ 200	90	
		200 < D ≤ 400	80	
EN-GJL-200C	5.1202	20 < D ≤ 50	155	ferritic-pearlitic
		50 < D ≤ 100	140	
		100 < D ≤ 200	125	
		200 < D ≤ 400	115	
EN-GJL-250C	5.1203	20 < D ≤ 50	195	pearlitic-ferritic
		50 < D ≤ 100	180	
		100 < D ≤ 200	165	
		200 < D ≤ 400	155	
EN-GJL-300C	5.1308	20 < D ≤ 50	220	predominantly pearlitic
		50 < D ≤ 100	205	
		100 < D ≤ 200	195	
		200 < D ≤ 400	185	

Table 2 — Tensile properties of continuous cast spheroidal graphite cast iron bars

Material designation		Bar diameter	0,2 % proof strength	Tensile strength	Elongation after fracture	Matrix structure
		D	$R_{p0,2}$	R_m	A	
		mm	MPa	MPa	%	
Symbol	Number		min.	min.	min.	
EN-GJS-350-22C-LT	5.3120	20 < D ≤ 60	220	350	22	ferritic
		60 < D ≤ 120	210	330	18	
		120 < D ≤ 400	200	320	15	
EN-GJS-350-22C-RT	5.3121	20 < D ≤ 60	220	350	22	ferritic
		60 < D ≤ 120	220	330	18	
		120 < D ≤ 400	210	320	15	
EN-GJS-350-22C	5.3122	20 < D ≤ 60	220	350	22	ferritic
		60 < D ≤ 120	220	330	18	
		120 < D ≤ 400	210	320	15	
EN-GJS-400-18C-LT	5.3123	20 < D ≤ 60	240	400	18	ferritic
		60 < D ≤ 120	230	380	15	
		120 < D ≤ 400	220	360	12	
EN-GJS-400-18C-RT	5.3124	20 < D ≤ 60	250	400	18	ferritic
		60 < D ≤ 120	250	390	15	
		120 < D ≤ 400	240	370	12	
EN-GJS-400-18C	5.3125	20 < D ≤ 60	250	400	18	ferritic
		60 < D ≤ 120	250	390	15	
		120 < D ≤ 400	240	370	12	
EN-GJS-400-15C [a]	5.3126	20 < D ≤ 60	250	400	15	ferritic
		60 < D ≤ 120	250	390	14	
		120 < D ≤ 400	240	370	11	
EN-GJS-400-7C [a]	5.3202	20 < D ≤ 60	250	400	7	ferritic-pearlitic
		60 < D ≤ 120	250	390	7	
		120 < D ≤ 400	240	370	11	
EN-GJS-450-18C [b]	5.3127	20 < D ≤ 60	350	450	18	ferritic
		60 < D ≤ 120	340	430	14	
		120 < D ≤ 400	to be agreed upon between the manufacturer and purchaser			
EN-GJS-450-10C [a]	5.3128	20 < D ≤ 60	310	450	10	predominantly ferritic
		60 < D ≤ 120	to be agreed upon between the manufacturer and purchaser			
		120 < D ≤ 400				
EN-GJS-500-14C [b]	5.3129	20 < D ≤ 60	400	500	14	ferritic
		60 < D ≤ 120	390	480	12	
		120 < D ≤ 400	360	470	10	
EN-GJS-500-7C [a]	5.3203	20 < D ≤ 60	320	500	7	ferritic-pearlitic
		60 < D ≤ 120	300	450	7	
		120 < D ≤ 400	290	420	5	
EN-GJS-600-3C [a]	5.3204	20 < D ≤ 60	370	600	3	pearlitic-ferritic
		60 < D ≤ 120	360	600	2	
		120 < D ≤ 400	340	550	1	
EN-GJS-700-2C [a]	5.3303	20 < D ≤ 60	420	700	2	predominantly pearlitic
		60 < D ≤ 120	400	700	2	
		120 < D ≤ 400	380	650	1	

[a] Depending on the process, these materials may contain minor quantities of free carbides.

[b] Solid-solution strengthened ferritic spheroidal graphite cast iron.

7.3 Hardness properties

The Brinell hardness of the grey cast iron grades specified by hardness, when measured in accordance with 9.2, shall be in accordance with the requirements of Table 3.

This classification is applicable principally where machinability or wear resistance are of importance.

Brinell hardness and its range values for the spheroidal graphite cast iron grades listed in Table 2 shall only be specified when agreed between the manufacturer and the purchaser by the time of acceptance of the order.

Information regarding hardness of spheroidal graphite cast iron bars is given in Annex A.

Table 3 — Brinell hardness of continuous cast grey cast iron bars

Material designation		Brinell hardness [a] HBW		Matrix structure (for information only)
Symbol	Number	min.	max.	
EN-GJL-HB150	5.1103	110	180	ferritic, annealed
EN-GJL-HB175	5.1204	140	210	ferritic-pearlitic
EN-GJL-HB200	5.1205	170	240	pearlitic-ferritic
EN-GJL-HB250	5.1309	220	290	predominantly pearlitic
[a] For each grade, Brinell hardness decreases with increasing wall thickness.				

7.4 Impact energy

Impact energy values shall only be determined if specified by the purchaser by the time of acceptance of the order.

The manufacturer and the purchaser shall agree on the testing conditions and the minimum values, or allowable range of values, for this mechanical property (for information see EN 1563).

NOTE 1 The use of impact energy is currently being reassessed regarding its limited relevance as a measure of resistance to brittle fracture in castings subject to application loads. EN 1563:2011, Annex F gives information about fracture toughness, impact energy and ductility.

NOTE 2 Although impact energy values for ductile cast irons are low compared to other materials, fracture mechanical testing of ductile cast irons shows that these fracture mechanical properties can be at least equal or even superior [10].

Information regarding the fracture toughness of spheroidal graphite iron cast continuous bars is given in Table D.2.

7.5 Graphite structure

7.5.1 Grey cast iron

The graphite structure shall be mainly of form Type A in accordance with EN ISO 945-1. A more precise definition may be agreed between the manufacturer and the purchaser.

If the graphite structure is agreed upon, the test shall be carried out in accordance with 9.3.

Due to the fast cooling during solidification of the rim zone, this will not contain Type A graphite, but mainly fine Type D and Type E graphite with a predominantly ferritic matrix and can be removed by machining.

NOTE In case of larger diameters, in the centre of the bar, due to slow cooling during solidification, the graphite structure will be coarser. Besides graphite of form A, also graphite form B can be present.

7.5.2 Spheroidal graphite cast iron

The graphite structure shall be mainly of form V and VI in accordance with EN ISO 945-1. A more precise definition may be agreed between the manufacturer and the purchaser.

If the graphite structure is agreed upon, the test shall be carried out in accordance with 9.3.

NOTE 1 The fast cooling rate during solidification in the surface rim results in a higher nodule count and smaller nodule size as compared with the centre of the bar. Due to this higher nodule count the rim zone will be more ferritic than the centre area.

NOTE 2 EN 1563 gives more information on nodularity.

7.6 Matrix structure

Information regarding the matrix structure is given in Table 1, Table 2 or Table 3.

A more precise definition regarding the matrix structure may be agreed between the manufacturer and the purchaser.

If the matrix structure is agreed upon, the test shall be carried out in accordance with 9.3.

The rim zone may contain some dispersed fine carbides.

7.7 Straightness

The straightness of unmachined grey cast iron and spheroidal graphite cast iron bars with a diameter ≥ 50 mm shall be in accordance with the requirements of Table 4.

For smaller diameters, the straightness shall be agreed between manufacturer and purchaser by the time of acceptance of the order.

Table 4 — Straightness of continuous cast bars

Dimensions in millimetres

Length	**Maximum deviation from straight line**	
l	as cast	annealed
1 000	2	3
2 000	4	6
3 000	6	9

Information regarding the machining allowances, ovality allowances and swell allowances for unmachined grey cast iron and spheroidal graphite cast iron bars is given in Annex B.

8 Sampling

8.1 General

Samples shall be made from the same continuous cast batch as that used to produce the bar(s) which they represent.

All samples shall be adequately marked to guarantee full traceability to the bars which they represent.

The samples shall be subject to the same heat treatment, as that of the bars they represent, if any.

Tensile test pieces shall be finally machined from the samples after the heat treatment.

8.2 Samples cut from a bar

Unless otherwise agreed between the manufacturer and the purchaser at the time of acceptance of the order, samples for tensile test pieces shall be cut from the bar at stated locations as shown in Annex C.

For bars with larger sections, the samples for tensile test pieces may be cut perpendicular to the length of the bar provided the length of the tensile test piece fits within the section of the bar.

For special section geometries, the location of the sample shall be agreed between the manufacturer and purchaser.

9 Test methods

9.1 Tensile test

9.1.1 General

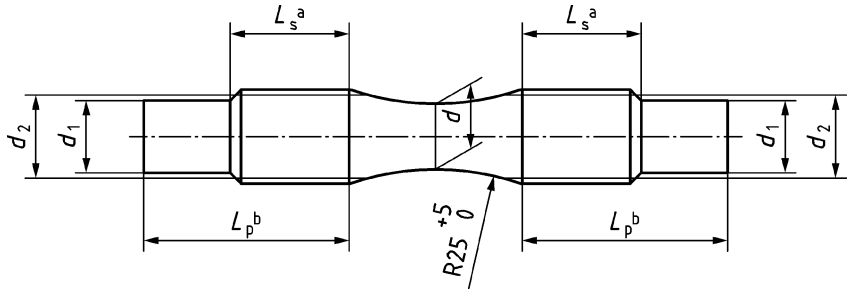
The tensile test shall be carried out in accordance with EN ISO 6892-1.

9.1.2 Tensile test for grey cast irons

The dimensions of the test piece shall conform to the dimensions given in Figure 1.

The preferred test piece diameter is 20 mm but, for technical reasons, it is permitted to use a test piece of different diameter.

Dimensions in millimetres



Key

a threaded

b plain

Diameter d [a]	Thread type for threaded test piece [b]	Thread length L_s [b]	Diameter d_1 for plain ends [b]	Threaded test piece total length
6 ± 0,1	M10	13	8	46
8 ± 0,1	M12	16	10	53
10 ± 0,1	M16	20	12	63
12,5 ± 0,1	M20	24	15	73
16 ± 0,1	M24	30	20	87
20 ± 0,1	**M30**	**36**	**23**	**102**
25 ± 0,1	M36	44	30	119
32 ± 0,1	M45	55	40	143

NOTE $L_p > L_s$, to suit clamping device.

[a] The cross-sectional area S_o shall be calculated.

[b] Recommended dimensions.

Figure 1 — Dimensions of grey cast iron tensile test pieces

9.1.3 Tensile test for spheroidal graphite cast irons

The dimensions of the test piece shall conform to the dimensions given in Figure 2.

The preferred test piece diameter is 14 mm but, for technical reasons, it is permitted to use a test piece of different diameter.

In all cases the original gauge length of the test piece shall conform to Formula (2):

$$L_o = 5{,}65 \times \sqrt{S_o} = 5 \times d \quad (2)$$

where

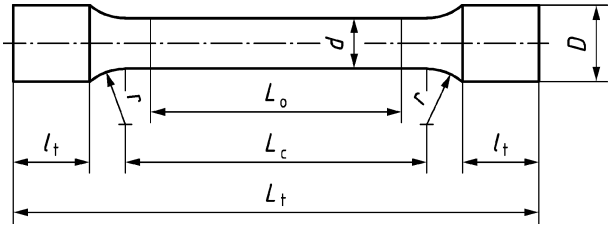
L_o is the original gauge length;

S_o is the original cross-section area of the test piece;

d is the diameter of the test piece along the gauge length.

If the above formula for L_o is not applicable, then an agreement shall be made between the manufacturer and the purchaser on the dimensions of the test piece to be made. A test piece with a different gauge length may be agreed upon between the manufacturer and the purchaser.

Dimensions in millimetres



d	L_o	L_c min.
5	25	30
7	35	42
10	50	60
14	**70**	**84**
20	100	120

where

L_o is the original gauge length, i.e. $L_o = 5 \times d$;

d is the diameter of the test piece along the gauge length;

L_c is the parallel length, $L_c > L_o$ (in principle, $L_c - L_o \geq d$);

L_t is the total length of the test piece, which depends on L_c;

r is the transition radius, which shall be at least 4 mm.

The method of gripping the ends of the test piece, together with their length l_t may be agreed between the manufacturer and the purchaser.

Figure 2 — Dimensions of spheroidal graphite cast iron tensile test pieces

9.2 Hardness test

The hardness shall be determined as Brinell hardness in accordance with EN ISO 6506-1.

NOTE In case of cast irons, larger nominal ball diameters, e.g. 5 mm or 10 mm, will give more consistent average Brinell hardness results.

Alternative hardness tests may also be agreed upon.

The test shall be carried out on the samples cut from the bar. If the measuring points are not the subject of an agreement, they shall be chosen by the manufacturer.

9.3 Graphite and matrix structure examination

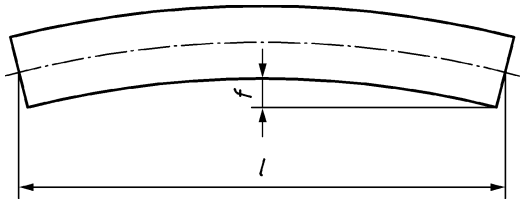
The graphite and matrix structure shall be confirmed by metallographic examination.

Non-destructive methods can also give information.

In case of a dispute, the result of a microscopic examination shall prevail.

9.4 Measurement of straightness

According to EN ISO 1101 [6], straightness is included with form and orientational tolerances. The tolerance f is delineated by two parallel straight lines separated by a distance in the plane of measurement.



Key

f deviation from straight line

l distance of measurement

Figure 3 — Deviation from straightness

10 Retests

10.1 Need for retests

Retests shall be carried out if a test is not valid.

Retests are permitted to be carried out if a test result does not meet the mechanical property requirements for the specified grade.

10.2 Test validity

A test is not valid, if there is:

a) a faulty mounting of the test piece or defective operation of the test machine;

b) a defective test piece because of incorrect pouring or incorrect machining;

c) a fracture of the tensile test piece outside the gauge length;

d) a casting defect in the test piece, evident after fracture.

In the above cases, a new test piece shall be taken from the same bar or another bar cast from the same batch to replace those invalid test results.

10.3 Non-conforming test results

If any test gives results which do not conform to the specified requirements, for reasons other than those given in 10.2, the manufacturer shall have the option to conduct retests.

If the manufacturer conducts retests, two retests shall be carried out for each failed test.

If both retests give results that meet the specified requirements, the material shall be deemed to conform to this European Standard.

If one or both retests give results that fail to meet the specified requirements, the material shall be deemed not to conform to this European Standard.

10.4 Heat treatment of samples and bars

Unless otherwise specified, in the case of bars in the as cast condition with mechanical properties not in conformance with this European Standard, a heat treatment may be carried out.

In the case of bars which have undergone a heat treatment and for which the test results are not valid or not satisfactory, the manufacturer shall be permitted to repeat the heat treatment of the bars.

If the results of the tests carried out on the test pieces machined from the reheat treated bars are satisfactory, then the reheat treated bars shall be regarded as conforming to the specified requirements of this European Standard.

The number of reheat treatment cycles shall not exceed two.

11 Inspection documentation

When requested by the purchaser and agreed with the manufacturer, the manufacturer shall issue for the products the appropriate inspection documentation according to EN 10204.

Annex A
(informative)

Guidance values for hardness of spheroidal graphite cast iron bars

Table A.1 — Guidance values for Brinell hardness

Material designation		Brinell hardness range	Matrix structure
Symbol	Number	HBW	
EN-GJS-350-22C-LT	5.3120	less than 170	ferritic
EN-GJS-350-22C-RT	5.3121	less than 170	ferritic
EN-GJS-350-22C	5.3122	less than 170	ferritic
EN-GJS-400-18C-LT	5.3123	120 to 180	ferritic
EN-GJS-400-18C-RT	5.3124	120 to 180	ferritic
EN-GJS-400-18C	5.3125	120 to 180	ferritic
EN-GJS-400-15C [a]	5.3126	120 to 180	ferritic
EN-GJS-400-7C [a]	5.3202	140 to 210	ferritic-pearlitic
EN-GJS-450-18C [b]	5.3127	170 to 200	ferritic
EN-GJS-450-10C [a]	5.3128	160 to 210	predominantly ferritic
EN-GJS-500-14C [b]	5.3129	180 to 210	ferritic
EN-GJS-500-7C [a]	5.3203	170 to 240	ferritic-pearlitic
EN-GJS-600-3C [a]	5.3204	200 to 290	pearlitic-ferritic
EN-GJS-700-2C [a]	5.3303	210 to 305	predominantly pearlitic

NOTE The lowest hardness is achieved with a ferritic matrix and low silicon content. The hardness increases with the amount of pearlite or increased silicon content.

[a] Depending on the process, these materials may contain small quantities of free carbides.

[b] Solid-solution strengthened ferritic spheroidal graphite cast iron.

Annex B
(informative)

Dimensional allowances for continuous cast bars

B.1 Machining allowances

The machining allowance is a surface layer of material on a cast product, which needs to be machined off in order to remove specific features, including ovality or swell, rim zone and surface imperfections, resulting from the casting process.

For continuous cast bars the minimum machining allowances as a function of bar dimensions and bar shapes are given in Table B.1.

Table B.1 — Machining allowances for continuous cast iron bars

Dimensions in millimetres

Bar diameter D or width B [a]	**Minimum machining allowance** [b]			
	Grey cast iron		Spheroidal graphite cast iron	
	round bar	rectangular bar	round bar	rectangular bar
$20 < (D \text{ or } B) \leq 50$	2,0	2,5	3,0	3,5
$50 < (D \text{ or } B) \leq 100$	3,0	3,5	4,0	4,5
$100 < (D \text{ or } B) \leq 200$	4,0	4,5	5,0	5,5
$200 < (D \text{ or } B) \leq 300$	6,0	6,5	7,0	7,5
$300 < (D \text{ or } B) \leq 400$	7,0	7,5	8,0	8,5
$400 < (D \text{ or } B) \leq 500$	9,0	9,5	10,0	10,5
$500 < (D \text{ or } B) \leq 650$	11,0	11,5	12,0	12,5

[a] For rectangular bars the width is the longest dimension of the cross section.

[b] The machining allowance refers to the radius or half width of the bar.

B.2 Ovality allowances

The ovality allowance is to compensate for any out-of-roundness of the bar (see Table B.2).

Table B.2 — Ovality allowances for round bars

Dimensions in millimetres

Bar diameter D	**Maximum ovality allowance**	
	Grey cast iron	Spheroidal graphite cast iron
$20 < D \leq 50$	by agreement	
$50 < D \leq 100$	1	2
$100 < D \leq 200$	2	3
$200 < D \leq 300$	4	4
$300 < D \leq 400$	5	5
$D > 400$	by agreement	

B.3 Swell allowances

The swell allowance is to compensate for any swell on square or rectangular bar (see Table B.3).

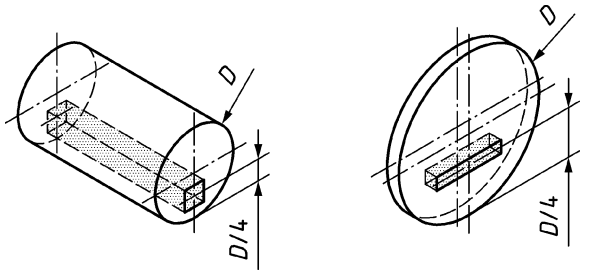
Table B.3 — Swell allowances for square or rectangular bars

Dimensions in millimetres

Bar width B	**Maximum swell allowance**	
	Grey cast iron	Spheroidal graphite cast iron
$20 < B \leq 50$	5	5
$50 < B \leq 100$	7	7
$100 < B \leq 200$	10	10
$200 < B \leq 300$	12	12
$300 < B \leq 400$	15	15
$B > 400$	by agreement	

Annex C
(normative)

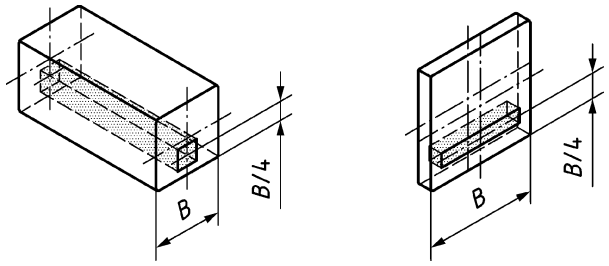
Location of samples cut from a bar



Key

D diameter

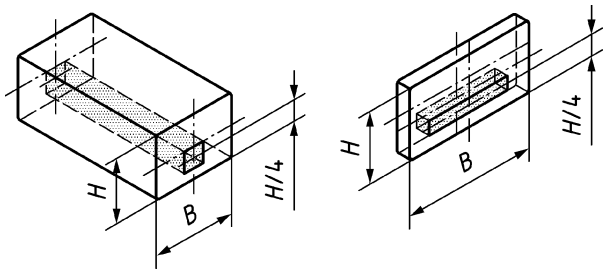
Figure C.1 — Round bars



Key

B width

Figure C.2 — Square bars

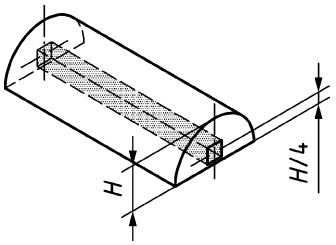


Key

H height

B width

Figure C.3 — Rectangular bars $B > H$



Key

H height

Figure C.4 — Half round bar

Annex D
(informative)

Additional information on mechanical and physical properties of spheroidal graphite cast irons

Typical values for mechanical and physical properties are given in Table D.1 (in addition to that given in Table 2 and Table A.1).

Examples of mechanical properties measured on continuous cast iron bars with a diameter of 160 mm are given in Table D.2.

Table D.1 — Typical values for mechanical and physical properties of spheroidal graphite cast irons [a]

Characteristic	Unit	Material designation							
		EN-GJS-350-22	EN-GJS-400-18	EN-GJS-450-10	EN-GJS-500-7	EN-GJS-600-3	EN-GJS-700-2	EN-GJS-450-18	EN-GJS-500-14
Shear strength	MPa	315	360	405	450	540	620	—	nd[b]
Torsional strength	MPa	315	360	405	450	540	620	—	nd [b]
Modulus of elasticity E (tension and compression)	GN/m^2	169	169	169	169	174	176	170	170
Poisson's ratio v	—	0,275	0,275	0,275	0,275	0,275	0,275	0,28 to 0,29	0,28 to 0,29
Fatigue limit [c] (rotating bending) unnotched [d] (ø 10,6 mm)	MPa	180	195	210	224	248	280	210	225
Fatigue limit [c] (rotating bending) notched [e] (ø 10,6 mm)	MPa	114	122	128	134	149	168	120	140
Compression strength	MPa	—	700	700	800	870	1 000	—	nd [b]
Thermal conductivity at 200 °C	W/(K·m)	36,2	36,2	36,2	35,2	32,5	31,1	—	—
Specific heat capacity 20 °C to 500 °C	J/(kg·K)	515	515	515	515	515	515	—	—
Linear expansion coefficient 20 °C to 400 °C	μm/(m·K)	12,5	12,5	12,5	12,5	12,5	12,5	—	—
Mass density	kg/dm^3	7,1	7,1	7,1	7,1	7,2	7,2	7,1	7,0
Hysteresis loss (B = 1T)	J/m^3	600	600	600	1 345	2 248	2 700	nd [b]	nd [b]
Resistivity	µΩ·m	0,50	0,50	0,50	0,51	0,53	0,54	nd [b]	nd [b]
Matrix structure		ferrite	ferrite	ferrite [f]	ferrite-pearlite	pearlite-ferrite	pearlite	ferrite	ferrite

[a] Unless otherwise specified, the values given in this table come from measurements at room temperature.

[b] Not determined.

[c] Fatigue limit test pieces according to Wöhler.

[d] Unnotched – In annealed ferritic spheroidal graphite cast irons the fatigue limit is about 0,5 × tensile strength in spheroidal graphite cast irons with a tensile strength of 370 MPa. The ratio decreases with increase in tensile strength until, in pearlitic and quenched and tempered spheroidal graphite cast irons, the fatigue limit is approximately 0,4 × tensile strength. The ratio decreases further when tensile strength exceeds 740 MPa. This ratio remains at around 0,45 in solid solution strengthened ferritic grades also at the higher tensile strengths.

[e] Notched – For a test piece of 10,6 mm diameter at notch with a circumferential 45° V-notch having a radius of 0,25 mm, the fatigue limit of annealed spheroidal graphite cast irons decreases to a value of about 0,63 × fatigue limit of unnotched test pieces in spheroidal graphite cast irons with a tensile strength of 370 MPa.

[f] This grade may contain minor quantities of pearlite.

Table D.2 — Examples of mechanical properties measured on continuous cast iron bars with a diameter of 160 mm [11]

Material designation	Test temperature	0,2 % proof strength [a] $R_{p0,2}$ MPa	Tensile strength [a] R_m MPa	Elongation after fracture [a] A %	Modulus of elasticity [b] E GN/m^2	Fracture toughness [a, c] K_J MPa • $\sqrt{m}$
EN-GJS-400-18C-LT	RT	256	372	22,6	169	43,7
	−20 °C	277	397	19,6	170	—
EN-GJS-400-18C	RT	300	424	25,9	171	50,3
	−20 °C	330	453	23,3	172	—
EN-GJS-500-7C	RT	354	533	15,1	177	41,0
	−20 °C	382	558	15,9	178	—
EN-GJS-500-14C	RT	391	504	19,7	173	46,5
	−20 °C	421	535	20,3	175	—
EN-GJS-600-3C	RT	448	782	7,0	166	26,3 (K_{IC})
	−20 °C	473	753	2,9	167	—

[a] Average of 3 measurements.

[b] Average of 5 measurements.

[c] Tested according ISO 12135 on SENB 10 × 20 × 100 test piece [7], [11].

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1) Continuous cast iron for innovative parts manufacture.

2) Continuous cast iron, quality assessment.

3) Fracture mechanical properties of cast irons.

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