BS EN 1564:2011

BSI Standards Publication

Founding — Ausferritic spheroidal graphite cast irons

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National foreword

This British Standard is the UK implementation of EN 1564:2011. It supersedes BS EN 1564:1997 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/111, Steel Castings and Forgings.

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

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

ISBN 978 0 580 67230 9

ICS 77.080.10

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2011.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1564

November 2011

ICS 77.080.10

Supersedes EN 1564:1997

English Version

Founding - Ausferritic spheroidal graphite cast irons

Fonderie - Fontes ausferritiques à graphite sphéroïdal

Gießereiwesen - Ausferritisches Gusseisen mit Kugelgraphit

This European Standard was approved by CEN on 24 September 2011.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. EN 1564:2011: E

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Foreword

This document (EN 1564:2011) 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of an identical text or by endorsement, at the latest by May 2012, and conflicting national standards shall be withdrawn at the latest by May 2012.

This document supersedes EN 1564:1997.

Within its programme of work, Technical Committee CEN/TC 190 requested CEN/TC 190/WG 7 "Spheroidal graphite, silicon molybdenum and austempered ductile iron" to revise EN 1564:1997.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive 97/23/EC, see informative Annex ZA, which is an integral part of this document.

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.

Annex K provides details of significant technical changes between this European Standard and the previous edition.

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, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

Ausferritic spheroidal graphite cast iron is a cast alloy, iron, carbon and silicon based, the carbon being present mainly in the form of spheroidal graphite particles.

NOTE 1 Ausferritic spheroidal graphite cast iron is also known as austempered ductile iron (ADI).

Compared with the spheroidal graphite cast irons as specified in EN 1563 [1], this material combines higher strength and toughness properties as a result of the ausferritic matrix structure.

This European Standard classifies ausferritic spheroidal graphite cast irons in accordance with the mechanical properties of the material.

The mechanical properties of these ausferritic spheroidal graphite cast irons depend on the graphite and the matrix structure.

The required structure is obtained by selecting the appropriate composition and subsequent processing.

The mechanical properties of the material can be evaluated on machined test pieces prepared from cast samples or samples cut from a casting.

Five grades of ausferritic spheroidal graphite cast iron are defined by the mechanical properties measured on machined test pieces prepared from cast samples. When, for these grades, hardness is a requirement of the purchaser as being important for the application, Annex C provides guidance values for hardness.

Two grades of ausferritic spheroidal graphite cast iron are defined in Annex A in accordance with their hardness. These cast irons are used in applications (e.g. mining, earth moving) where high abrasion resistance is required.

In this standard a new designation system by number, as established in EN 1560 [2], is given.

NOTE 2 This designation system by number is based on the principles and the structure as set out in EN 10027-2 [3] and so corresponds with the European numbering system for steel and other materials.

Some ausferritic spheroidal graphite cast iron grades can be used for pressure equipment.

The permitted material grades of ausferritic spheroidal graphite cast iron for pressure applications and the conditions for their use are given in specific product or application standards.

For the design of pressure equipment, specific design rules apply.

Annex ZA gives information relating to the conformance of permitted ausferritic spheroidal graphite cast iron grades to the Pressure Equipment Directive 97/23/EC.

1 Scope

This European Standard defines the grades and the corresponding requirements for ausferritic spheroidal graphite cast irons.

This European Standard specifies five grades of ausferritic spheroidal graphite cast iron by a classification based on mechanical properties measured on machined test pieces prepared from cast samples.

This European Standard also specifies two grades by a classification as a function of hardness.

This European Standard does not cover technical delivery conditions for iron castings, see EN 1559-1 [4] and EN 1559-3 [5].

NOTE Grades given in Annex A are not intended for pressure equipment applications.

2 Normative references

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

EN 764-5:2002, *Pressure Equipment — Part 5: Compliance and Inspection — Documentation of Materials*

EN 10204:2004, *Metallic products — Types of inspection documents*

EN ISO 148-1:2010, *Metallic materials — Charpy impact test — Part 1: Test method (ISO 148-1:2009)*

EN ISO 945-1:2008, *Microstructure of cast irons — Part 1: Graphite classification by visual analysis (ISO 945-1:2008)*

EN ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method (ISO 6506-1:2005)*

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

3 Terms and definitions

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

3.1
ausferritic spheroidal graphite cast iron
iron based cast material with the carbon being present mainly in the form of spheroidal graphite particles, with an ausferritic matrix structure

NOTE Usually this ausferritic matrix structure is obtained by an austempering heat treatment.

3.2
graphite spheroidising treatment
operation that brings the liquid iron into contact with a substance to produce graphite in the predominantly spheroidal (nodular) form during solidification

NOTE This operation is often followed by a second one called inoculation.

3.3
austemper heat treatment of spheroidal graphite cast iron
process, consisting of heating the castings above the A_{C1} temperature and holding a sufficient time to increase the carbon content of the austenite, followed by cooling at a rate sufficient to avoid the formation of pearlite and transforming the matrix structure for a time and a temperature (above the martensite start temperature) sufficient to produce the desired properties

NOTE This process produces a microstructure that consists predominantly of ferrite and austenite. This microstructure is called ausferrite.

3.4
cast sample
quantity of material cast to represent the cast material, including separately cast sample, side by side cast sample and cast-on sample

3.5
separately cast sample
sample cast in a separate sand mould under representative manufacturing conditions and material grade

3.6
side-by-side cast sample
sample cast in the mould alongside the casting, with a joint running system

3.7
cast-on sample
sample attached directly to the casting

3.8
relevant wall thickness
wall thickness representative of the casting, defined for the determination of the size of the cast samples to which the mechanical properties apply

4 Designation

The material shall be designated either by symbol or by number as given in Tables 1, 2 or A.1.

In the case of samples cut from the casting the letter C is added at the end of the designation by symbol, see EN 1560.

NOTE The comparison of EN 1564 grade designations with the grades from the ISO standard for ausferritic spheroidal graphite cast irons, ISO 17804:2005 [6], is given in Annex B.

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 relevant wall thickness of the casting;

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

Unless otherwise specified by the purchaser, the method of manufacture of ausferritic spheroidal graphite cast irons and heat treatment required to obtain the specified mechanical properties and microstructure shall be left to the discretion of the manufacturer.

The manufacturer shall ensure that the requirements defined in this standard are met for the material grade specified in the order.

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

7 Requirements

7.1 General

The property values apply to ausferritic spheroidal graphite cast irons cast in sand moulds or moulds of comparable thermal behaviour. Subject to amendments to be agreed upon in the order, they can apply to castings obtained by alternative methods.

The material designation is based on the minimum mechanical properties obtained in cast samples with a thickness or diameter of 25 mm. The designation is irrespective of the type of cast sample.

Mechanical properties are wall thickness dependant as shown in Table 1.

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

7.2 Test pieces machined from cast samples

7.2.1 General

The mechanical properties of ausferritic spheroidal graphite cast iron test pieces shall be as specified in Table 1, and, if applicable, in accordance with the requirements given in 7.2.2.

7.2.2 Impact energy

The impact energy values given in Table 2 at room temperature, if applicable, shall only be determined if specified by the purchaser by the time of acceptance of the order.

7.3 Test pieces machined from samples cut from a casting

If applicable, the manufacturer and the purchaser shall agree on:

— the location(s) on a casting where the sample(s) shall be taken;

— the mechanical properties that shall be measured;

— the minimum values, or allowable range of values, for these mechanical properties (for information, see Annex C).

NOTE 1 The properties of castings are not uniform, depending on the complexity of the castings and variation in their section thickness.

NOTE 2 Mechanical properties for test pieces cut from a casting are affected not only by material properties (subject of this standard) but also by the local casting soundness (not subject of this standard).

Table 1 — Mechanical properties measured on test pieces machined from cast samples

Material designation		Relevant wall thickness [a]	0,2 % proof strength	Tensile strength	Elongation
		t	$R_{p0,2}$	R_m	A
			MPa	MPa	%
Symbol	Number	mm	min.	min.	min.
EN-GJS-800-10 EN-GJS-800-10-RT	5.3400 5.3401	$t \leq 30$	500	800	10
		$30 < t \leq 60$		750	6
		$60 < t \leq 100$		720	5
EN-GJS-900-8	5.3402	$t \leq 30$	600	900	8
		$30 < t \leq 60$		850	5
		$60 < t \leq 100$		820	4
EN-GJS-1050-6	5.3403	$t \leq 30$	700	1 050	6
		$30 < t \leq 60$		1 000	4
		$60 < t \leq 100$		970	3
EN-GJS-1200-3	5.3404	$t \leq 30$	850	1 200	3
		$30 < t \leq 60$		1 170	2
		$60 < t \leq 100$		1 140	1
EN-GJS-1400-1	5.3405	$t \leq 30$	1 100	1 400	1
		$30 < t \leq 60$		To be agreed between the manufacturer and the purchaser.	
		$60 < t \leq 100$			

NOTE 1 The relevant wall thickness does not affect the minimum 0,2 % proof strength provided the heat treatment parameters and alloying are adjusted as a function of the relevant wall thickness.

NOTE 2 Guidance values for Brinell hardness for these grades are given in Annex D.

[a] For relevant wall thicknesses more than 100 mm, the manufacturer and the purchaser shall agree on the type and size of the cast sample and the minimum values to be obtained.

Table 2 — Minimum impact energy values measured on V-notched test pieces machined from cast samples

Material designation		Relevant wall thickness [a]	Impact energy value at room temperature 23 ºC ± 5 ºC	
		t	Mean value of 3 tests	Individual value
Symbol	Number	mm	J	J
			min.	min.
EN-GJS-800-10-RT	5.3401	$t \leq 30$	10	9
		$30 < t \leq 60$	9	8
		$60 < t \leq 100$	8	7

[a] For relevant wall thicknesses more than 100 mm, the manufacturer and the purchaser shall agree on the type and size of the cast sample and the minimum values to be obtained.

7.4 Hardness

Brinell hardness and its range values for the grades listed in Table 1 shall only be specified when agreed between the manufacturer and the purchaser by the time of acceptance of the order.

For the five grades listed in Table 1, information regarding hardness is given in Annex D and Annex E.

For the two grades defined by hardness properties, Annex A applies.

7.5 Graphite structure

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 upon by the time of acceptance of the order.

NOTE Annex F gives more information regarding nodularity.

7.6 Matrix structure

The matrix structure of the various grades of ausferritic spheroidal graphite cast iron consists predominantly of ferrite and austenite – otherwise known as ausferrite. Other matrix constituents, (e.g. martensite, bainite, carbides) shall be minimised and may be present at a level that will not affect the required mechanical properties of the grades given in Table 1 and Table 2, but can be beneficial in the abrasion resistant grades as given in Annex A.

The cooling rate within some sections may not be sufficient to avoid the formation of pearlite or other high temperature transformation products. In such cases, the maximum acceptable quantities of these micro constituents, the locations within the casting, and the mechanical properties in these locations may be agreed upon between the manufacturer and the purchaser.

8 Sampling

8.1 General

Samples shall be made from the same material as that used to produce the casting(s) which they represent.

Several types of samples (separately cast samples, cast-on samples, side-by-side cast samples, samples cut from a casting) can be used, depending on the mass and wall thickness of the casting.

When relevant the type of sample should be agreed between the manufacturer and the purchaser. Unless otherwise agreed the choice of the option is left to the discretion of the manufacturer.

When the mass of the casting exceeds 2 000 kg and its relevant wall thickness exceeds 60 mm, cast-on samples or side-by-side samples should preferably be used; the dimensions and the location of the sample shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

If the spheroidizing treatment is carried out in the mould (in-mould process), the separately cast sample should be avoided.

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

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

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

8.2 Cast samples

8.2.1 Size of cast samples

The size of the sample shall be in correspondence with the relevant wall thickness of the casting as shown in Table 3.

If other sizes are used, this shall be agreed between the manufacturer and purchaser.

Table 3 — Types and size of cast sample and size of tensile test pieces in relation to relevant wall thickness of the casting

Relevant wall thickness t mm	Type of sample				Preferred diameter of tensile test piece [a] d mm
	Option 1 U-shaped (see Figure 1)	Option 2 Y-shaped (see Figure 2)	Option 3 Round bar (see Figure 3)	Cast-on (see Figure 4)	
$t \leq 12,5$	—	I	Types b, c	A	7 (Option 3: 14 mm)
$12,5 < t \leq 30$	—	II	Types a, b, c	B	14
$30 < t \leq 60$	[b]	III	—	C	14
$60 < t \leq 100$	—	IV	—	D	14

[a] Other diameters, in accordance with Figure 5, may be agreed between the manufacturer and the purchaser.

[b] The cooling rate of this cast sample corresponds to that of a 40 mm thick wall.

8.2.2 Frequency and number of tests

Samples representative of the material shall be produced at a frequency in accordance with the process quality assurance procedures adopted by the manufacturer or as agreed with the purchaser.

In the absence of a process quality assurance procedure or any other agreement between the manufacturer and the purchaser, a minimum of one cast sample for the tensile test shall be produced to confirm the material grade, at a frequency to be agreed between the manufacturer and the purchaser.

When impact tests are required, samples shall be produced at a frequency to be agreed between the manufacturer and the purchaser.

8.2.3 Separately cast samples

The samples shall be cast separately in sand moulds and under representative manufacturing conditions.

The moulds used to cast the separately cast samples shall have comparable thermal behaviour to the moulding material used to cast the castings.

The samples shall meet the requirements of either Figures 1, 2 or 3.

The samples shall be removed from the mould at a temperature similar to that of the castings.

8.2.4 Side-by-side cast samples

Side-by-side cast samples are representative of the castings concurrently cast and also of all other castings of a similar relevant wall thickness from the same test unit.

When mechanical properties are required for a series of castings belonging to the same test unit, the side-by-side cast sample(s) shall be produced in the last mould(s) poured.

The samples shall meet the requirements of either Figures 1, 2 or 3.

8.2.5 Cast-on samples

Cast-on samples are representative of the castings to which they are attached and also of all other castings of a similar relevant wall thickness from the same test unit.

When mechanical properties are required for a series of castings belonging to the same test unit, the cast-on sample(s) shall be produced in the last mould(s) poured.

The sample shall have a general shape as indicated in Figure 4 and the dimensions shown therein.

The location of the cast-on sample shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order, taking into account the shape of the casting and the running system, in order to avoid any unfavourable effect on the properties of the adjacent material.

8.2.6 Test pieces machined from cast samples

The tensile test piece shown in Figure 5 and, if applicable, the impact test piece shown in Figure 6 shall be machined from a sample shown in Figure 3 or from the hatched part of Figures 1, 2 or 4.

The sectioning procedure for cast samples shall be in accordance with Annex G.

Unless otherwise agreed, the preferred diameter for the test piece shall be used.

8.3 Samples cut from a casting

In addition to the requirements of the material, the manufacturer and the purchaser may agree on the properties required (for information, see Annex C) at stated locations in the casting. These properties shall be determined by testing test pieces machined from samples cut from the casting at these stated locations.

The manufacturer and the purchaser shall agree on the dimensions of these test pieces.

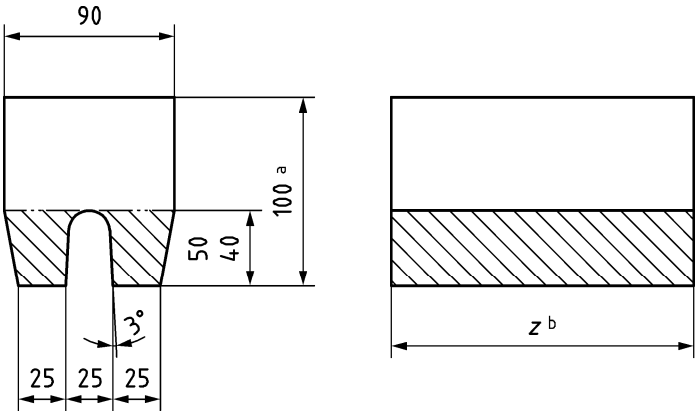
In the absence of any directions by the purchaser, the manufacturer may choose the locations from which to cut the samples and the dimensions of the test pieces.

The centreline of the test piece should be located at a point half way between the surface and the centre.

NOTE 1 When the zone of last solidification in the casting is included in the test piece diameter, the minimum elongation guidance value may not be obtained.

NOTE 2 In the case of large individual castings trepanned samples may be taken at agreed positions in the casting which are to be stated.

Dimensions in millimetres



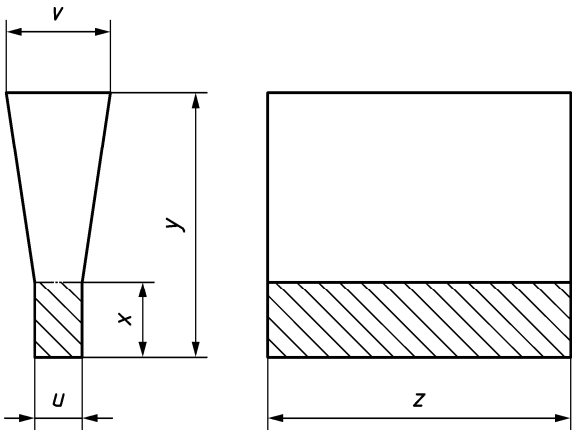
Key

[a] for information only

[b] the length *z* shall be chosen to allow a test piece of dimensions shown in Figure 5 to be machined from the sample

The thickness of the sand mould surrounding the samples shall be at least 40 mm.

Figure 1 — Separately cast or side-by-side cast sample — Option 1: U-shaped sample



Dimensions in millimetres

Dimension	Type			
	I	II	III	IV
u	12,5	25	50	75
v	40	55	100	125
x	25	40	50	65
y [a]	135	140	150	175
z [b]	A function of the test piece length			

[a] for information only.

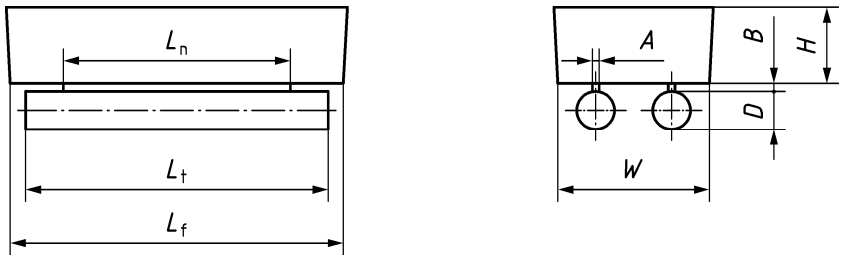
[b] z shall be chosen to allow a test piece of dimensions shown in Figure 5 to be machined from the cast sample.

The thickness of the sand mould surrounding the samples shall be at least:

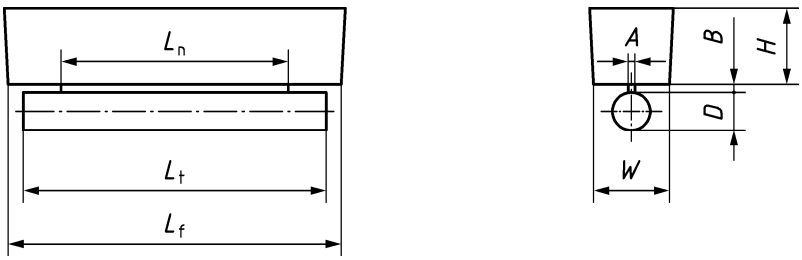
— 40 mm for types I and II;

— 80 mm for type III and IV.

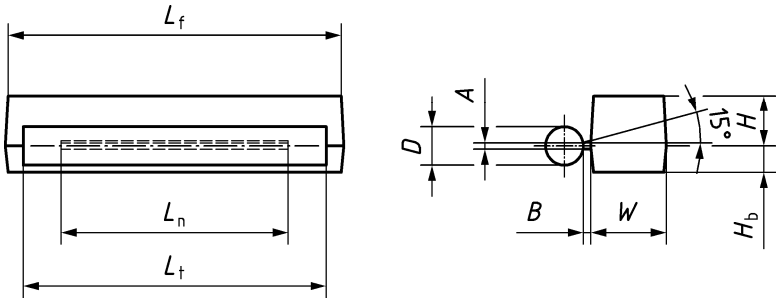
Figure 2 — Separately cast or side-by-side cast samples — Option 2: Y-shaped sample



Type a



Type b



Type c

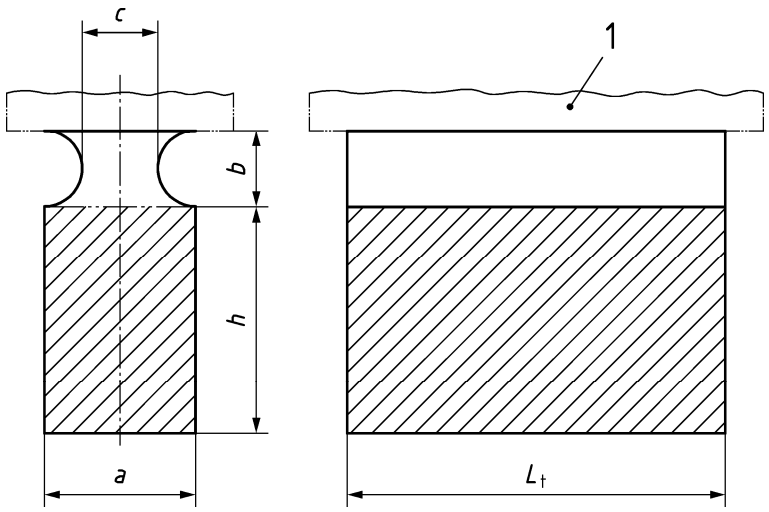
Dimensions in millimetres

Type	*A*	*B*	*D*	*H*	H_b	L_f	L_n	L_t	*W*
a	4,5	5,5	25	50	—	L_t + 20	L_t – 50	a	100
b	4,5	5,5	25	50	—	L_t + 20	L_t – 50		50
c	4,0	5,0	25	35	15	L_t + 20	L_t – 50		50

a L_t shall be chosen to allow a test piece of dimensions shown in Figure 5 to be machined from the cast sample.

The thickness of the sand mould surrounding the samples shall be at least 40 mm.

Figure 3 — Separately cast or side-by-side cast samples — Option 3: Round bar-shaped sample



Key

1 casting

Dimensions in millimetres

Type	Relevant wall thickness t	a	b max.	c min.	h	L_t
A	$t \leq 12{,}5$	15	11	7,5	20 to 30	a
B	$12{,}5 < t \leq 30$	25	19	12,5	30 to 40	
C	$30 < t \leq 60$	40	30	20	40 to 65	
D	$60 < t \leq 100$	70	52,5	35	65 to 105	

a L_t shall be chosen to allow a test piece of a dimension shown in Figure 5 to be machined from the cast sample.

The thickness of the sand mould surrounding the samples shall be at least:

— 40 mm for types A and B;

— 80 mm for type C and D.

If smaller dimensions are agreed, the followings relationships apply:

$b = 0{,}75 \times a$

$c = 0{,}5 \times a$

Figure 4 — Cast-on samples

9 Test methods

9.1 Tensile test

The tensile test shall be carried out in accordance with EN ISO 6892-1:2009.

The preferred test piece diameter is 14 mm but, either for technical reasons or for test pieces machined from samples cut from the casting, it is permitted to use a test piece of different diameter (see Figure 5).

In all cases the original gauge length of the test piece shall conform to the equation:

$$L_o = 5{,}65 \times \sqrt{S_o} = 5 \times d$$

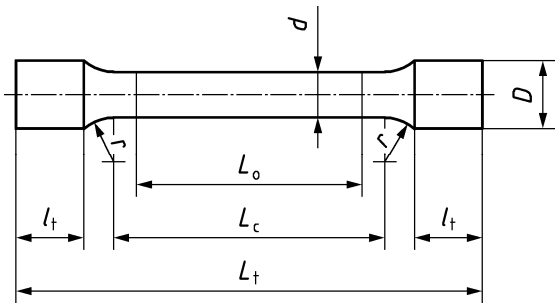
where

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 equation 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 [a]	70	84
20	100	120
[a] Preferred dimension for 25 mm cast sample diameter.		

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.

NOTE 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 5 — Tensile test piece

9.2 Impact test

The impact test shall be carried out on three Charpy V-notched impact test pieces (see Figure 6) in accordance with EN ISO 148-1:2010 using test equipment with an appropriate energy to determine the properties correctly.

Dimensions in millimetres

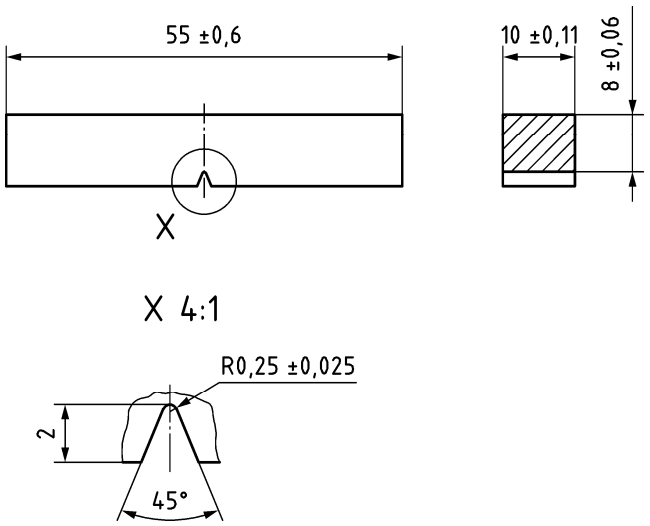


Figure 6 — Charpy V-notched impact test piece

9.3 Hardness test

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

Alternative hardness tests and the corresponding required hardness values may also be agreed.

The test shall be carried out on the test piece or at one or several points on the casting after preparation of the testing area in accordance with the agreement between the manufacturer and the purchaser.

If the measurement locations are not the subject of an agreement, they shall be chosen by the manufacturer.

If it is not possible to carry out the hardness test on the casting, then by agreement between the manufacturer and the purchaser, the hardness test may be carried out on a knob cast-on to the casting.

9.4 Graphite and matrix structure examination

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

Non-destructive methods can also give information regarding the graphite structure.

An indirect method to determine if the required microstructure after the heat treatment has been obtained is the impact testing of un-notched Charpy test samples.

The minimum impact energy values to be obtained and details of the un-notched Charpy impact test are given in Annex H.

In case of dispute, the results of the microscopic examination shall prevail.

10 Retests

10.1 Need for retest

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 cast sample or from a duplicate sample cast at the same time and having undergone the same heat treatment, 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 castings

In the case of castings which have undergone a heat treatment and for which the test results are not valid or not satisfactory, the manufacturer shall be permitted to re-heat treat the castings and the representative samples. In this event, the samples shall receive the same number of heat treatments as the castings.

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

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 10204:2004.

When ordering material for pressure equipment applications, the equipment manufacturer has the obligation to request appropriate inspection documentation according to the applicable product or application standard(s), EN 764-5:2002 and EN 10204:2004.

The material manufacturer is responsible for affirming conformity with the specification for the material ordered.

Annex A
(normative)

Abrasion resistant grades of ausferritic spheroidal graphite cast irons

A.1 General

This annex defines the grades of abrasion resistant ausferritic spheroidal graphite cast irons.

It specifies the grades in terms of hardness.

A.2 Requirements

The Brinell hardness for the different grades shall be as specified in Table A.1. Table A.1 also gives other properties for information only.

The manufacturer and the purchaser may agree on the maximum Brinell hardness.

Table A.1 — Abrasion resistant ausferritic spheroidal graphite cast irons

Material designation		Brinell hardness	Other properties (for information only)		
		HBW	$R_{p0,2}$	R_m	A
Symbol	Number	min.	MPa	MPa	%
EN-GJS-HB400	5.3406	400	1 100	1 400	1
EN-GJS-HB450	5.3407	450	1 300	1 600	—

A.3 Sampling

Unless otherwise specified by the purchaser by the time of acceptance of the order, the number and frequency of Brinell hardness tests shall be in accordance with the process quality assurance procedures used by the manufacturer.

If it is not possible to carry out the hardness test on the casting, then by agreement between the manufacturer and the purchaser, the hardness test may be carried out on a knob cast-on to, and heat treated with, the casting.

A.4 Hardness test

The Brinell hardness test shall be carried out in accordance with EN ISO 6506-1.

NOTE 1 Hardness determined by one test method is not necessarily comparable to hardness determined by other test methods. Hardness conversion from other test methods can be done by agreement between the manufacturer and the purchaser.

Each Brinell hardness test shall be carried out on a casting at locations agreed between the manufacturer and the purchaser, or on a cast–on test block.

Unless otherwise specified by the purchaser, the dimensions and location of the cast-on block shall be left to the discretion of the manufacturer.

NOTE 2 A cast-on test block can be used when the size of the casting or the number of castings to be tested makes direct testing on the castings impracticable.

If the test is to be carried out on a cast-on block the latter shall not be removed from the casting until after the heat treatment has been carried out.

When castings are too large or too difficult to be tested in a conventional hardness testing machine or when there is the need for on-line inspection of a large number of castings, a portable hardness testing device may be used.

When using portable hardness testing devices, reference shall be made to appropriately calibrated test blocks.

A.5 Retests

Retests shall be permitted and carried out under the same conditions as those specified in Clause 10.

Annex B
(informative)

Comparison of ausferritic spheroidal graphite cast iron material designations according to EN 1560 and ISO/TR 15931 [2] [7]

This informative annex compares the material designation of the standardized grades of ausferritic spheroidal graphite cast irons based on the ISO and EN designation systems.

Table B.1 — Material designations of ausferritic spheroidal graphite cast irons — Classification based on mechanical properties measured on machined test pieces prepared from cast samples

EN 1564:2011 – Table 1		ISO 17804:2005 – Table 1
Symbol	**Number**	**Designation**
EN-GJS-800-10	5.3400	ISO17804/JS/800-10
EN-GJS-800-10-RT	5.3401	ISO17804/JS/800-10RT
EN-GJS-900-8	5.3402	ISO17804/JS/900-8
EN-GJS-1050-6	5.3403	ISO17804/JS/1050-6
EN-GJS-1200-3	5.3404	ISO17804/JS/1200-3
EN-GJS-1400-1	5.3405 [a]	ISO17804/JS/1400-1
[a] The designation by number for this grade in the previous edition of this standard was: EN-JS1130.		

Table B.2 — Material designations of abrasion resistant grades of ausferritic spheroidal graphite cast irons — Classification based on hardness

EN 1564:2011 – Table A.1		ISO 17804:2005 – Table A.1
Symbol	**Number**	**Designation**
EN-GJS-HB400	5.3406	ISO17804/JS/HBW400
EN-GJS-HB450	5.3407	ISO17804/JS/HBW450

Annex C
(informative)

Guidance values for tensile strength and elongation for test pieces machined from samples cut from a casting

Table C.1 — Guidance values for tensile strength and elongation for test pieces machined from samples cut from a casting

Material designation	0,2 % proof strength $R_{p0,2}$ MPa min.	Tensile strength R_m MPa min.			Elongation A % min.		
		Relevant wall thickness in millimetres					
		$t \leq 30$	$30 < t \leq 60$	$60 < t \leq 100$	$t \leq 30$	$30 < t \leq 60$	$60 < t \leq 100$
EN-GJS-800-10C, EN-GJS-800-10C-RT	500	780	740	710	8	5	4
EN-GJS-900-8C	600	880	830	800	7	4	3
EN-GJS-1050-6C	700	1 020	970	940	5	3	2
EN-GJS-1200-3C	850	1 170	1 140	1 110	2	1	1
EN-GJS-1400-1C	1 100	1 360	To be agreed between the manufacturer and the purchaser.				

Annex D
(informative)

Guidance values for Brinell hardness

Table D.1 Guidance values for Brinell hardness

Material designation	Brinell hardness range HBW
EN-GJS-800-10, EN-GJS-800-10-RT	250 to 310
EN-GJS-900-8	280 to 340
EN-GJS-1050-6	320 to 380
EN-GJS-1200-3	340 to 420
EN-GJS-1400-1	380 to 480

When necessary or required for machinability, and by agreement between the manufacturer and the purchaser, a narrower range may be adopted at an agreed location on the casting.

A range between 30 HBW and 40 HBW units is commonly acceptable for grades EN-GJS-800-10 and EN-GJS-800-10-RT. Wider ranges may be required as tensile strength and hardness increase.

Annex E
(informative)

Determination of the hardness range

E.1 General

The following procedure may be used to determine the hardness range for a particular foundry process that is capable of meeting the requirements of a grade specified by tensile properties according Table 1. The procedure is most applicable to serial production of castings.

E.2 Procedure

E.2.1 Select the required material grade from Table 1.

E.2.2 Select the type of sample to be used according to Table 3.

E.2.3 Use test samples covering the given hardness range for the specified grade as shown in Table D.1.

E.2.4 Determine tensile strength, 0,2 % proof strength, elongation, and Brinell hardness for each test piece and for the corresponding castings at the agreed locations. Round the hardness values to the nearest 10 HBW. Conduct as many tests as necessary to obtain the minimum number for each HBW value, as agreed between the manufacturer and the purchaser or to obtain the desired statistical confidence level.

E.2.5 Plot tensile strength, 0,2 % proof strength and elongation versus hardness of castings and/or test pieces in histograms, with HBW as the independent variable.

E.2.6 For each HBW value, adopt the minimum value for each tensile property as the process capability indicator.

E.2.7 Specify the minimum hardness for casting and/or test pieces as the minimum HBW value for which tensile strength and 0,2 % proof strength meet the requirements of the specified grade in Table 1.

E.2.8 Specify the maximum hardness for castings and/or test pieces, a range between 30 HBW and 40 HBW units is commonly acceptable for grades EN-GJS-800-10 and EN-GJS-800-10-RT. Wider ranges may be required as tensile strength and hardness increase.

E.2.9 Using the graph plotted in E.2.5, determine if the required minimum elongation, as given in Table 1, is met at the maximum hardness specified in E.2.8.

If the required minimum elongation is not met, there are three options:

— maintain this maximum hardness and specify a lower minimum elongation;

— specify a lower maximum hardness and a narrower hardness range;

— specify a lower minimum and maximum hardness. In this case a lower minimum tensile strength and 0,2 % proof strength should be specified.

The chosen option should be agreed between the manufacturer and the purchaser.

E.2.10 If the required minimum elongation is met, a higher minimum elongation for the specified grade may be agreed between the manufacturer and the purchaser.

Annex F
(informative)

Nodularity

The nodularity of spheroidal graphite cast iron is defined as the percentage of graphite particles that are spheroidal or nodular in shape (form V and VI of EN ISO 945-1).

While the number of particles is detected by 100 × magnification, the determination of the form and its percentage should be done with a magnification which shows the graphite particles in approximately the size according to EN ISO 945-1:2008, Figure 1. While the classification of the graphite form is accomplished on the basis of this standard in comparison to reference pictures, the computer aided image analysis with specific software parameters might be applied for this material as well.

Ultrasonic velocity and sound resonance frequency are influenced by graphite structure. Their measurement, after calibration, can give information on nodularity. However, this measurement cannot replace metallographic examination.

The level of nodularity depends not only on the manufacturing process (charge material, residual magnesium content, inoculation mode, etc.) but also on the cooling modulus of the melt. Furthermore, the graphite form in the surface rim is affected by the contact with the mould.

The nodule roundness marks only one aspect of the material. Further parameters influencing the material qualities are, among others, the number of graphite particles and their distribution, the matrix or the microshrinkage. It is therefore not possible to define precisely the graphite structure for the various grades and thicknesses.

However, a level of nodularity of 90 % or more generally ensures (more than enough for $R_{p0,2}$) the minimum tensile properties appearing in this standard. Most of the remaining graphite not of forms V and VI is then of form IV.

Annex G
(normative)

Sectioning procedure for cast samples

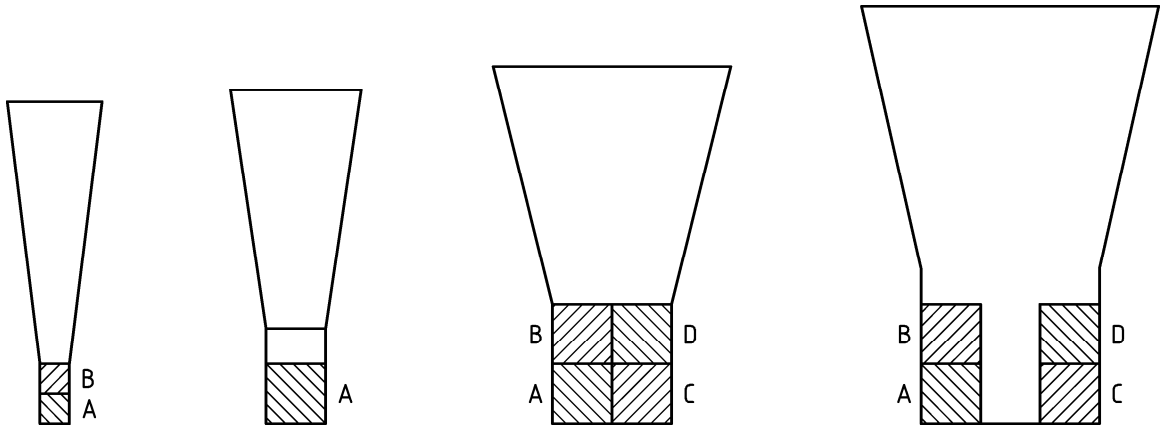


Figure G.1 — Sectioning procedure for Y-shaped samples (see Figure 2)

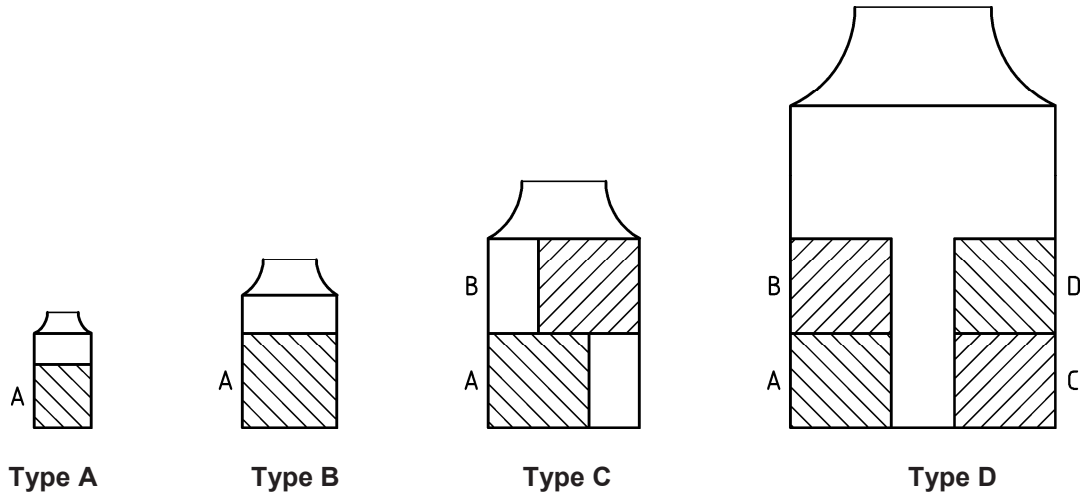


Figure G.2 — Sectioning procedure for cast-on samples (see Figure 4)

Annex H
(informative)

Un-notched impact test

H.1 General

This annex gives an indirect method to determine conformance to the required microstructure after heat treatment, provided that the required mechanical properties have been verified by other means.

This annex is applicable only when its requirements have been agreed between the manufacturer and the purchaser by the time of acceptance of the order.

H.2 Requirements

The minimum impact resistance values for the different material grades should be as specified in Table H.1.

Table H.1 — Un-notched impact energy values for ausferritic spheroidal graphite cast irons [6]

Material designation	**Impact energy values at 23 °C ± 5 °C** J min.
EN-GJS-800-10 EN-GJS-800-10-RT	110
EN-GJS-900-8	100
EN-GJS-1050-6	80
EN-GJS-1200-3	60
EN-GJS-1400-1	35
EN-GJS-HB400	25
EN-GJS-HB450	20
NOTE Values obtained from un-notched test pieces tested at 23 °C ± 5 °C. The values in the table are the average of the three highest values of four separate tests.	

H.3 Sampling

The casting process for the samples should be agreed between the manufacturer and the purchaser. Impact resistance requirements apply only after the test material has been austempered. The impact test pieces should be prepared un-notched to dimensions according to Figure 6 after heat treatment.

H.4 Test method

The impact test should be carried out on four un-notched test pieces based on EN ISO 148-1, using test equipment with an appropriate energy to determine the properties correctly.

The lowest impact energy value should be discarded, and the average of the three remaining values should be used.

H.5 Retests

Retests should be permitted and carried out under the same conditions as those specified in Clause 10.

Annex I
(informative)

Additional information on mechanical and physical properties

Table I.1 — Typical properties

Technical data for ausferritic spheroidal graphite cast irons [8]		**Material designation EN-GJS-**					
		800-10 800-10-RT	**900-8**	**1050-6**	**1200-3**	**1400-1 HB400**	**HB450**
Characteristic	**unit**	**Indicative values for properties** [a]					
Compression strength σ_{db}	MPa	1 300	1 420	1 675	1 900	2 200	2 500
0,2 % proof strength		620	700	840	1 040	1 220	1 350
Shear strength σ_{aB}	MPa	720	800	940	1 080	1 260	1 400
0,2 % proof strength		350	420	510	590	770	850
Torsional strength σ_{tB}	MPa	720	800	940	1 080	1 260	1 400
0,2 % proof strength		350	420	510	590	770	850
Fracture toughness K_{ic}	MPa$\sqrt{m}$	62	60	59	54	50	—
Fatigue limits (Wöhler) (rotating bend) unnotched (diameter 10,6 mm) $N = 2 \times 10^6$ cycles	MPa	375	400	430	450	375	300
Fatigue limits (Wöhler) (rotating bend) notched [b] (diameter 10,6 mm) $N = 2 \times 10^6$ cycles	MPa	225	240	265	280	275	270
Characteristic	**unit**	**Typical values**					
Modulus of elasticity E (tension and compression)	GPa	170	169	168	167	165	165
Poisson's ratio ν	—	0,27	0,27	0,27	0,27	0,27	0,27
Shear modulus	GPa	65	65	64	63	63	63
Density ρ	g/cm^3	7,1	7,1	7,1	7,0	7,0	7,0
Linear expansion coefficient α from 20 °C to 200 °C [1]	μM(m · K)	18 [c] to 14					
Thermal conductivity λ at 200 °C	W(m · K)	23 [d] to 20					

NOTE Unless otherwise specified, the values given in this table apply to measurements at ambient temperature.

[a] The minimum values can be obtained on wall thickness up to 50 mm. For heavier sections, an agreement between purchaser and manufacturer is recommended.

[b] Notched after heat treatment, with a circumferential 45° V-notch, having a radius of 0,25 mm.

[c] For the lower strength grades, the linear expansion coefficient α will be higher.

[d] For the lower strength grades, the thermal conductivity λ will be higher.

Table I.2 — Typical properties of ausferritic spheroidal graphite cast irons for gear design [9]

Technical data for ausferritic spheroidal graphite cast irons		Material designation			
		EN-GJS-800-10 EN-GJS-800-10-RT	EN-GJS-900-8	EN-GJS-1050-6	EN-GJS-1200-3
Characteristic	Unit	Typical values for properties			
Herzian pressure fatigue strength $\sigma_{H\ lim\ 90\%}$ N = 10^7 cycles	MPa	1 050	1 100	1 300	1 350
Tooth root bending fatigue strength $\sigma_{F\ lim\ 90\%}$ N = 10^7 cycles	MPa	350	320	300	290

Annex J
(informative)

Machinability of ausferritic spheroidal graphite cast irons

J.1 Introduction

In general, the machinability of a material can be described by four criteria:

— chip form;

— surface quality;

— cutting forces;

— tool wear and tool life.

The following paragraphs provide a general discussion of the machinability of ausferritic spheroidal graphite cast irons as regards these four criteria. In addition, consideration is given to the influence of chemical composition and heat treatment parameters on machinability.

J.2 Chip form

The chip form that results from machining ausferritic spheroidal graphite cast irons does not differ significantly from the chip obtained when machining other spheroidal graphite cast irons. In general, discontinuous segmented chips are produced which can be handled easily. In certain cases, when negative effective rake angles are present, needle chips can also be formed.

J.3 Surface quality

Surface quality of the machined surface is substantially determined by the embedded graphite nodules. The surface quality that results from machining ausferritic spheroidal graphite cast irons is therefore similar to the surface quality obtained when machining other cast irons with spheroidal graphite. Graphite nodules can break out or smear the machined surface. This means that the best surface quality is obtained with sharp positive cutting edges.

J.4 Cutting forces

Mean cutting forces increase with undeformed chip thickness. Because of the discontinuous segmented chips typical of cast irons, the mean cutting force for cast irons, including ausferritic spheroidal graphite cast irons, increases less rapidly with undeformed chip thickness than is the case for steels of comparable hardness.

In general, the mean cutting forces of cast irons are therefore substantially lower than those of steels of comparable hardness at higher feed rates and are not substantially higher for ausferritic spheroidal graphite cast irons than for pearlitic grades of spheroidal graphite cast irons. However, the cutting forces for ausferritic spheroidal graphite cast irons contain higher dynamic force factors compared to steels of comparable hardness and to pearlitic grades of spheroidal graphite cast irons.

Cutting force oscillations are relatively independent of the tensile strength of ausferritic spheroidal graphite cast irons and increase with higher feed rates and lower cutting speeds. A short and rigid design of the tool holder system and rigid clamping of the work piece are important because tool oscillations can reduce tool life due to chatter vibration tendency.

J.5 Tool wear and tool life

Ausferritic spheroidal graphite cast irons have higher hardness and higher ductility (elongation) than pearlitic grades of spheroidal graphite cast irons. Tool wear increases with material hardness, and cutting speed should be reduced approximately in proportion to increases in hardness. In addition, wear resistant cutting tools materials and coating should be applied. For turning, drilling, and milling, wear resistant tungsten carbides (K-grade) show good performance. Furthermore, higher strength and ductility lead to higher cutting temperatures, which can be counteracted by suitable coatings, for example, titanium aluminium nitride (TiAlN) or aluminium oxide (Al_2O_3). Ceramic tools are applicable in some cases. Tool life improvements can be attained (for example, when milling and drilling with tungsten carbide tools) by using optimised tool geometries that consider the high specific mechanical load on the cutting edge.

J.6 Other considerations

The quality of ausferritic spheroidal graphite cast iron microstructures can affect machinability significantly. The following influences should be considered:

— Variations in hardness through the microstructure lead to reductions in tool life.

— Tool wear increases as the tensile strength increases, and the applicable cutting speed should be correspondingly reduced.

— A higher percentage of alloying elements (in particular, of carbide-forming elements such as molybdenum) increases tool wear.

— Areas of the casting with insufficiently stabilized austenite have poorer machinability.

Annex K
(informative)

Significant technical changes between this European Standard and the previous edition

Table K.1 — Significant technical changes between this European Standard and the previous edition

Clause/Paragraph/Table/Figure	Change
3	Definitions added for: cast sample, separately cast sample, side-by-side cast sample, cast-on sample and relevant wall thickness
7.2, Table 1	Required minimum mechanical properties applies to several types of cast samples and are now given for 3 ranges of relevant wall thicknesses
7.2, Table 1	Required minimum elongation values increased for grades with minimum tensile strength up to 1 200 MPa
7.2, Table 1	Grade EN-GJS-1000-5 replaced by two grades: EN-GJS-900-8 and EN-GJS-1050-6
7.2, Table 1, Table 2, Table A.1	Structure and numbers of designation by numbers has been changed
Annex A	Normative Annex A added describing two new abrasion resistant grades defined with their hardness
Annex B	Informative Annex B for the comparison of ausferritic spheroidal graphite cast iron material designations according to EN 1560 and ISO/TR 15931 added
Annex C	Informative Annex C with guidance values for mechanical properties measured on test pieces machined from a casting added
Annex E	Informative Annex E describing the determination of the hardness range added
Annex F	Informative Annex F with information regarding the nodularity added
Annex G	Normative Annex G for the sectioning procedure of cast samples added
Annex H	Informative Annex H with details and requirements regarding the unnotched impact test added
Annex I	Informative Annex I for additional information on mechanical and physical properties added
Annex J	Informative Annex J with information on the machinability of ausferritic spheroidal graphite cast irons added
NOTE The technical changes referred include the significant technical changes from the EN revised but is not an exhaustive list of all modifications from the previous version.	

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 97/23/EC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide means of conforming to Essential Requirements of the New Approach Directive 97/23/EC.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA.1 confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential requirements of that Directive and associated EFTA regulations.

For this harmonized supporting standard for materials, presumption of conformity to the Essential Requirements of the Directive is limited to technical data of the material in the standard and does not presume adequacy of the material to the specific equipment. Consequently the technical data stated in the material standard should be assessed against the design requirements of the specific equipment to verify that the Essential Requirements of the Pressure Equipment Directive (PED) are satisfied.

Table ZA.1 — Correspondence between EN 1564 and Pressure Equipment Directive 97/23/EC

Clause(s) / subclause(s) of this European Standard	Subject	Qualifying remarks/Notes
Tables 1 and 2	Material properties	Annex I, 4.1 a) of the directive
11	Conformity of material and manufacturer's certified documentation	Annex I, 4.3 of the directive

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Bibliography

[1] EN 1563, *Founding — Spheroidal graphite cast irons*

[2] EN 1560, *Founding — Designation system for cast iron — Material symbols and material numbers*

[3] EN 10027-2, *Designation systems for steels— Part 2: Numerical system*

[4] EN 1559-1, *Founding — Technical conditions of delivery — Part 1: General requirements*

[5] EN 1559-3, *Founding — Technical conditions of delivery — Part 3: Additional requirements for iron castings*

[6] ISO 17804:2005, *Founding — Ausferritic spheroidal graphite cast irons — Classification*

[7] ISO/TR 15931, *Designation system for cast irons and pig irons*

[8] G.N.J Gilbert, BCIRA Journal, May 1986, Vol. 34, pp. 203-232 (BCIRA Research Report 1663)

[9] ISO 6336-5, *Calculation of load capacity of spur and helical gears — Part 5: Strength and quality of materials*

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