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BSI Standards Publication

Founding - Spheroidal graphite cast irons

bsi.

National foreword

This British Standard is the UK implementation of EN 1563:2018. It supersedes BS EN 1563:2011, which is withdrawn.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.

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English Version

Founding - Spheroidal graphite cast irons

Fonderie - Fontes à graphite sphéroïdal

Gießereiwesen - Gusseisen mit Kugelgraphit

This European Standard was approved by CEN on 9 April 2018.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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Contents

European foreword

This document (EN 1563:2018) 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of an identical text or by endorsement, at the latest by February 2019 and conflicting national standards shall be withdrawn at the latest by February 2019.

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

This document supersedes EN 1563:2011.

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 2014/68/EU, see informative Annex ZA, which is an integral part of this document.

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 1563:2011.

Annex I provides details of significant technical changes between this European Standard and the 2011 edition (previous edition).

Annex J provides details of significant technical changes between the 1997 edition and the 2011 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, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The properties of spheroidal graphite cast irons depend on their structure.

Spheroidal graphite cast irons covered by this European Standard are divided in two groups:

1) ferritic to pearlitic spheroidal graphite cast irons;

2) solid-solution strengthened ferritic spheroidal graphite cast irons.

The two groups present specific properties, for example:

— the ferritic grades of the first group present the highest impact energy;

— the pearlite containing grades are more suitable for wear resistance applications;

— the solid-solution strengthened ferritic grades present for an equivalent tensile strength a higher proof strength and a higher elongation after fracture than that of the ferritic to pearlitic grades;

— a significant property of these solid-solution strengthened ferritic grades is the reduced hardness variation resulting in an improved machinability.

The mechanical properties of the material can be evaluated on machined test pieces prepared from:

— separately cast samples;

— side-by-side cast samples;

— cast-on samples;

— samples cut from a casting.

The material grade is defined by mechanical properties measured on machined test pieces prepared from cast samples.

If hardness is a requirement of the purchaser as being important for the application, then Annex C provides means for its determination.

It is well known that tensile properties and hardness of spheroidal graphite cast irons are interrelated. When considered by the purchaser as being important for the application, both tensile and hardness properties may be specified.

Further technical data on spheroidal graphite cast irons is given in Annexes A, E and H.

In this European Standard, a designation system by number, as established in EN 1560 [1], is given.

NOTE This designation system by number is based on the structure and rules of EN 10027-2 [2] and so corresponds with the European numbering system for steels and other materials.

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

The permitted material grades of spheroidal graphite cast irons 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 the spheroidal graphite cast iron grades to the Pressure Equipment Directive 2014/68/EU.

1 Scope

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

This European Standard specifies 2 groups of spheroidal graphite cast iron grades by a classification based on mechanical properties measured on machined test pieces prepared from cast samples. The first group deals mainly with ferritic to pearlitic grades. The second group deals with solid-solution strengthened ferritic grades.

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

This European Standard does not cover:

— ausferritic spheroidal graphite cast irons which are specified in EN 1564 [5];

— low alloyed ferritic spheroidal graphite cast irons which are specified in EN 16124 [6];

— continuous cast iron bars which are specified in EN 16482 [7];

— austenitic cast irons which are specified in EN 13835 [8];

— spheroidal graphite cast irons used for pipes, fittings and their joints which are the subject of EN 545 [9], EN 598 [10] and EN 969 [11];

— the grades of spheroidal graphite cast irons as specified in EN 545 which are used for products such as industrial valves, non-industrial manually operated shut-off valves and flanges and their joints, which are the subject of the applicable European product standards.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 764-5:2014, *Pressure equipment - Part 5: Inspection documentation of metallic materials and compliance with the material specification*

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

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

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.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
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.

3.2
ferritic to pearlitic spheroidal graphite cast iron
spheroidal graphite cast iron with a matrix containing ferrite or pearlite or a combination of both

Note 1 to entry: Pearlite can be partially or totally replaced by quenched microstructures in grades having higher strength.

3.3
solid-solution strengthened ferritic spheroidal graphite cast iron
spheroidal graphite cast iron with a matrix mainly consisting of ferrite, solution strengthened by increasing the amount of silicon compared to ferritic to pearlitic spheroidal graphite cast iron

3.4
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.

3.5
cast sample
quantity of material cast to represent the cast material

Note 1 to entry: This includes separately cast samples, side-by-side cast samples and cast-on samples.

3.6
separately cast sample
sample cast in a separate sand mould under representative manufacturing conditions and material grade

3.7
side-by-side cast sample
sample cast in a mould alongside the casting, with a joint running system

3.8
cast-on sample
sample attached directly to the casting

3.9
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 3.

In the case of samples cut from the casting the letter "C" is added at the end of the designation by symbol.

NOTE The comparison of the grades of EN 1563:1997 [12] and EN 1563:2011 [13] with the grades of ISO 1083:2004 [14] is given in Annex G.

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;

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 metallurgical method of producing spheroidal graphite cast irons and their chemical composition 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.

— Ferritic to pearlitic spheroidal graphite cast irons:

  For these grades, the level of the mechanical properties is determined by the ferrite to pearlite ratio. This ratio is normally adjusted by alloying with pearlite stabilizing elements or, less commonly, by heat treatment.

— Solid-solution strengthened ferritic spheroidal graphite cast irons:

  For these grades, the level of the mechanical properties is determined by the extent of solid solution strengthening of the ferritic matrix. This extent is normally governed by the silicon content.

NOTE For spheroidal graphite cast irons to be used in special applications, the chemical composition and heat treatment can 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 General

The property values apply to 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 Tables 1, 2 and 3. For relevant wall thicknesses more than 200 mm, the manufacturer and the purchaser shall agree on the minimum values to be obtained and the type and size of the cast sample.

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

7.2 Ferritic to pearlitic spheroidal graphite cast irons

7.2.1 Test pieces machined from cast samples

7.2.1.1 Tensile properties

The mechanical properties of ferritic to pearlitic spheroidal graphite cast iron test pieces shall be as specified in Table 1.

Table 1 — Mechanical properties measured on test pieces machined from cast samples for ferritic to pearlitic grades

Material designation		Relevant wall thickness t mm	0,2 % proof strength $R_{p0,2}$ MPa min.	Tensile strength R_m MPa min.	Elongation after fracture A % min.
Symbol	Number				
EN-GJS-350-22-LT [a]	5.3100	$t \leq 30$	220	350	22
		$30 < t \leq 60$	210	330	18
		$60 < t \leq 200$	200	320	15
EN-GJS-350-22-RT [b]	5.3101	$t \leq 30$	220	350	22
		$30 < t \leq 60$	220	330	18
		$60 < t \leq 200$	210	320	15
EN-GJS-350-22	5.3102	$t \leq 30$	220	350	22
		$30 < t \leq 60$	220	330	18
		$60 < t \leq 200$	210	320	15
EN-GJS-400-18-LT [a]	5.3103	$t \leq 30$	240	400	18
		$30 < t \leq 60$	230	380	15
		$60 < t \leq 200$	220	360	12
EN-GJS-400-18-RT [b]	5.3104	$t \leq 30$	250	400	18
		$30 < t \leq 60$	250	390	15
		$60 < t \leq 200$	240	370	12
EN-GJS-400-18	5.3105	$t \leq 30$	250	400	18
		$30 < t \leq 60$	250	390	15
		$60 < t \leq 200$	240	370	12
EN-GJS-400-15	5.3106	$t \leq 30$	250	400	15
		$30 < t \leq 60$	250	390	14
		$60 < t \leq 200$	240	370	11
EN-GJS-450-10	5.3107	$t \leq 30$	310	450	10
		$30 < t \leq 60$	to be agreed upon between the manufacturer and the purchaser		
		$60 < t \leq 200$			
EN-GJS-500-7	5.3200	$t \leq 30$	320	500	7
		$30 < t \leq 60$	300	450	7
		$60 < t \leq 200$	290	420	5
EN-GJS-600-3	5.3201	$t \leq 30$	370	600	3
		$30 < t \leq 60$	360	600	2
		$60 < t \leq 200$	340	550	1
EN-GJS-700-2	5.3300	$t \leq 30$	420	700	2
		$30 < t \leq 60$	400	700	2
		$60 < t \leq 200$	380	650	1
EN-GJS-800-2	5.3301	$t \leq 30$	480	800	2
		$30 < t \leq 60$	to be agreed upon between the manufacturer and the purchaser		
		$60 < t \leq 200$			
EN-GJS-900-2	5.3302	$t \leq 30$	600	900	2
		$30 < t \leq 60$	to be agreed upon between the manufacturer and the purchaser		
		$60 < t \leq 200$			

NOTE The mechanical properties of test pieces machined from cast samples can be different from the properties of the casting itself. Values for tensile properties of the casting are given in Annex B for guidance.

[a] LT for low temperature.

[b] RT for room temperature.

7.2.1.2 Impact energy

The impact energy values given in Table 2 for room temperature (RT) and low temperature (LT) applications, if applicable, shall only be determined if specified by the purchaser by the time of acceptance of the order.

The mean value of the three Charpy impact tests and the individual values shall meet the specified requirements in Table 2.

NOTE The use of impact energy is currently being reassessed regarding its limited relevance as an assessment of the resistance to brittle fracture in castings subject to application loads. Annex H gives information about the fracture mechanical approach to spheroidal graphite cast irons.

Table 2 — Minimum impact energy values measured on V-notched test pieces machined from cast samples for ferritic grades of the ferritic to pearlitic group

Material designation		Relevant wall thickness	Minimum impact energy values J					
			Room temperature (23 ± 5) °C		Low temperature (− 20 ± 2) °C		Low temperature (− 40 ± 2) °C	
Symbol	Number	t mm	Mean value (3 tests)	Individual value	Mean value (3 tests)	Individual value	Mean value (3 tests)	Individual value
EN-GJS-350-22-LT	5.3100	$t \leq 30$	—	—	—	—	12	9
		$30 < t \leq 60$	—	—	—	—	12	9
		$60 < t \leq 200$	—	—	—	—	10	7
EN-GJS-350-22-RT	5.3101	$t \leq 30$	17	14	—	—	—	—
		$30 < t \leq 60$	17	14	—	—	—	—
		$60 < t \leq 200$	15	12	—	—	—	—
EN-GJS-400-18-LT	5.3103	$t \leq 30$	—	—	12	9	—	—
		$30 < t \leq 60$	—	—	12	9	—	—
		$60 < t \leq 200$	—	—	10	7	—	—
EN-GJS-400-18-RT	5.3104	$t \leq 30$	14	11	—	—	—	—
		$30 < t \leq 60$	14	11	—	—	—	—
		$60 < t \leq 200$	12	9	—	—	—	—

NOTE The mechanical properties of test pieces machined from cast samples can be different from the properties of the casting itself.

7.2.2 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 B).

NOTE 1 The properties of castings can vary, 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 European Standard) but also by the local casting soundness (not subject of this standard).

7.2.3 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.

Information regarding hardness is given in Annex C.

7.2.4 Graphite morphology

The graphite morphology 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.

More information on nodularity is given in Annex D.

7.2.5 Matrix microstructure

Information regarding the matrix microstructure is given in Table E.1.

NOTE Designations, descriptions and reference micrographs of the matrix structures of cast irons are given in ISO/TR 945-3.

7.3 Solid solution strengthened ferritic spheroidal graphite cast irons

7.3.1 Test pieces machined from cast samples

The mechanical properties of solid solution strengthened ferritic spheroidal graphite cast iron test pieces shall be as specified in Table 3.

Table 3 — Mechanical properties measured on test pieces machined from cast samples for solid solution strengthened ferritic grades

Material designation		Relevant wall thickness	0,2 % proof strength	Tensile strength	Elongation after fracture
Symbol	Number	t mm	$R_{p0,2}$ MPa min.	R_m MPa min.	A % min.
EN-GJS-450-18	5.3108	$t \leq 30$	350	450	18
		$30 \leq t \leq 60$	340	430	14
		$t > 60$	to be agreed upon between the manufacturer and the purchaser		
EN-GJS-500-14	5.3109	$t \leq 30$	400	500	14
		$30 \leq t \leq 60$	390	480	12
		$t > 60$	to be agreed upon between the manufacturer and the purchaser		
EN-GJS-600-10	5.3110	$t \leq 30$	470	600	10
		$30 \leq t \leq 60$	450	580	8
		$t > 60$	to be agreed upon between the manufacturer and the purchaser		

NOTE The mechanical properties of test pieces machined from cast samples can be different from the properties of the casting itself. Values for tensile properties of the casting are given in Annex B for guidance.

7.3.2 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 B).

NOTE The properties of castings can vary, depending on the complexity of the castings and variation in their section thicknesses.

7.3.3 Hardness

Brinell hardness and its range values for the grades listed in Table 3 shall only be specified when agreed between the manufacturer and the purchaser by the time of acceptance of the order.

Information regarding hardness is given in Annex C.

7.3.4 Graphite morphology

The graphite morphology 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 1 Annex A, A.2.3 gives more information on graphite morphology.

NOTE 2 Annex D gives more information regarding nodularity.

7.3.5 Matrix microstructure

Information on matrix microstructure is given in Table E.1 and A.2.2.

NOTE Designations, descriptions and reference micrographs of the matrix structures of cast irons are given in ISO/TR 945-3.

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 or its relevant wall thickness 60 mm, cast-on samples or side-by-side samples should preferably be used; representative 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 sample

The size of the sample shall be in correspondence with the relevant wall thickness of the casting as shown in Table 4.

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

Table 4 — Types and sizes of cast samples and sizes 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 sample (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
$60 < t \leq 200$	—	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 wall thickness.

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.

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 cast-on samples 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 test piece for the impact test 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 F.

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 B) 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.

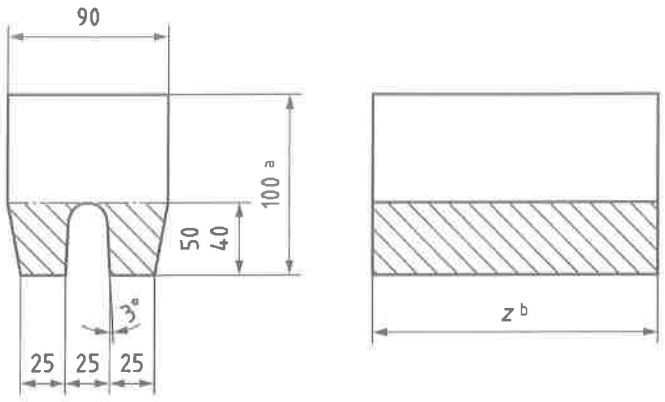
In the absence of any directions by the purchaser, the manufacturer may choose the locations from which to cut the samples and the dimensions of the test pieces.

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

NOTE When the zone of last solidification in the casting is included in the test piece diameter, the minimum elongation after fracture guidance value will usually not be obtained.

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

Dimensions in millimetres



Key

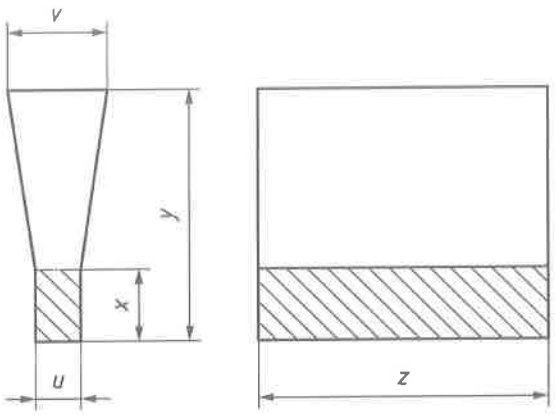
a for information only.

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 samples — Option 1: U-shaped sample

Dimensions in millimetres



Key

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.

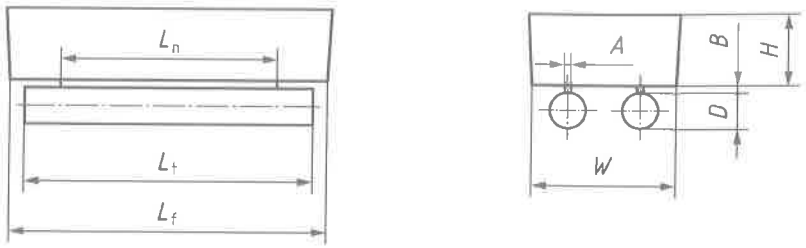
The thickness of the sand mould surrounding the samples shall be at least:

— 40 mm for types I and II;

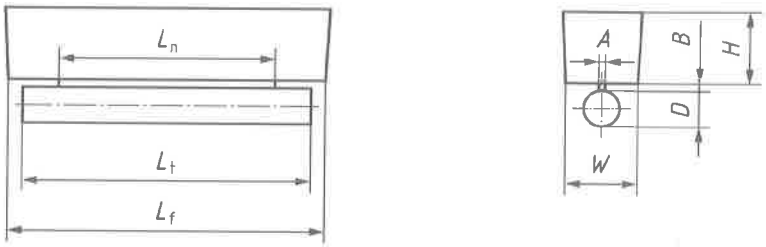
— 80 mm for type III and IV.

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

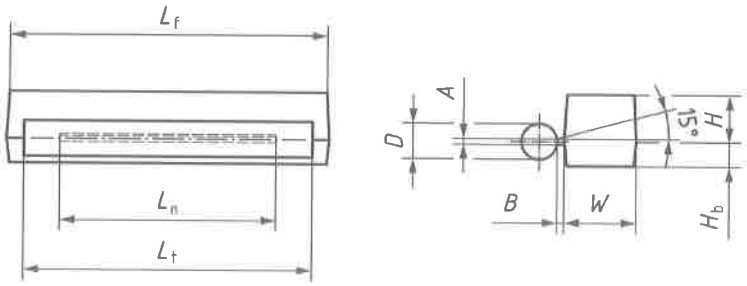
Dimensions in millimetres



a) Type a



b) Type b



c) Type c

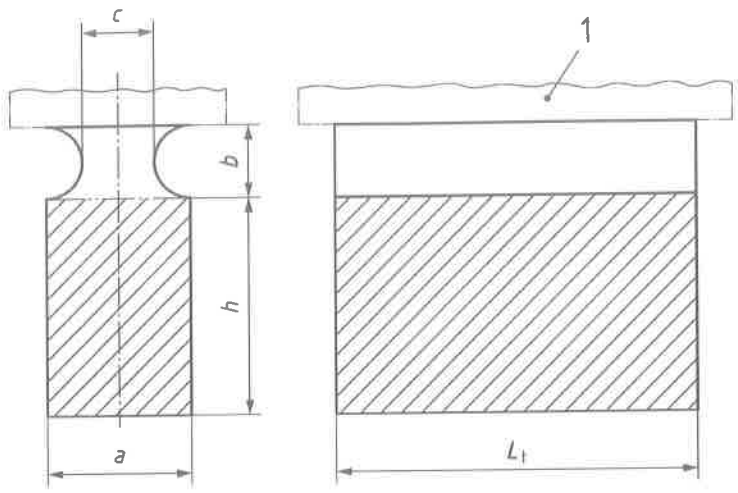
Key

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 of castings 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	$60 < t \leq 200$	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 types 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.

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 formula:

$$L_o = 5,65 \times \sqrt{S_o} = 5 \times d \quad (1)$$

where

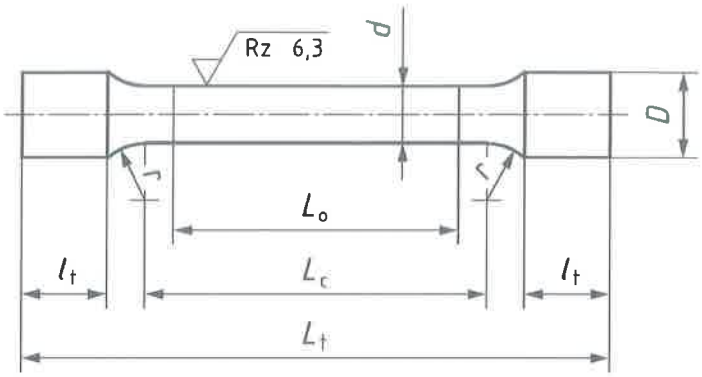
L_o is the original gauge length;

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



Key

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;

Rz is the maximum surface roughness.

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 standard Charpy V-notched impact test pieces (see Figure 6) in accordance with EN ISO 148-1, using test equipment with an appropriate energy to determine the properties correctly and using the 2 mm radius striker.

Dimensions in millimetres

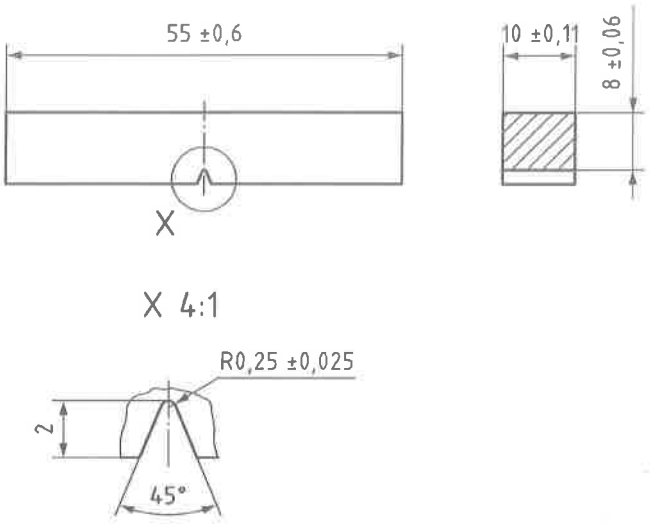


Figure 6 — Standard Charpy V-notched impact test piece

9.3 Hardness test

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

Alternative hardness tests may also be agreed upon as well as specific hardness values.

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

If the measuring 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 morphology examination

The graphite morphology shall be confirmed by metallographic examination.

Non-destructive methods can also give information.

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

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 cast sample or from a duplicate sample cast at the same time, 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 test pieces in case of tensile test and two sets of three test pieces in case of impact test shall be tested 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

Unless otherwise specified, in the case of castings 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 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 reheat 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 reheat treated samples are satisfactory, then the reheat treated castings 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 10204:2004.

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 764-5:2014 and EN 10204:2004.

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

Annex A
(informative)

Additional information on solid solution strengthened ferritic spheroidal graphite cast irons

A.1 General

This annex applies to solid solution strengthened ferritic spheroidal graphite cast iron grades as specified in Table 3.

A.2 Material constitution

A.2.1 Chemical composition

In order to fulfil the requirements for the mechanical properties, a ferritic structure solid solution strengthened by silicon is recommended (see Table A.1).

Table A.1 — Guidance values for silicon content

Designation		Silicon
Symbol	Number	% approx. [a, b]
EN-GJS-450-18	5.3108	3,20
EN-GJS-500-14	5.3109	3,80
EN-GJS-600-10	5.3110	4,20

[a] Silicon content may be lower due to other alloying elements or for thick sections.

[b] With increasing silicon content, the carbon content should be decreased correspondingly.

A.2.2 Matrix microstructure

The matrix should be predominantly ferrite with a maximum pearlite content of 5 %. The amount of free cementite should not exceed 1 %.

A.2.3 Graphite morphology

The graphite morphology should be mainly of form V and VI in accordance with EN ISO 945-1.

Due to the increased silicon content, solid solution strengthened ferritic spheroidal graphite cast irons may show graphite deviations (from forms V and VI) in thick sections. However, ferritic matrices are, also for higher levels of solution strengthening by silicon, much less sensitive to reduced nodularity than cast irons strengthened by substantial amounts of pearlite. A proportion of form III can be accepted, provided the remainder is mainly of form V and VI, to fulfil the minimum tensile properties specified in this European Standard.

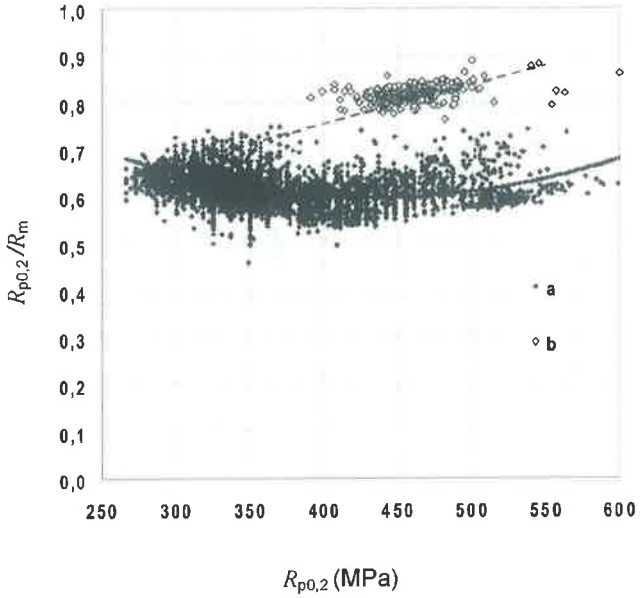
A.3 Supplementary information

A.3.1 Mechanical properties

A.3.1.1 0,2 % proof strength

One of the characteristic properties of these solution strengthened ferritic spheroidal graphite cast irons is the high ratio "0,2 % proof strength/tensile strength" being 75 % to 85 % as compared to the lower ratio being 55 % to 65 % for ferritic to pearlitic spheroidal graphite cast irons (see Figure A.1 as an example).

Despite this higher ratio, the ductility determined as percentage elongation after fracture values are concurrently considerably higher for solid solution strengthened ferritic spheroidal graphite cast irons (compare Table 1 and Table 3).



Key

a	ferritic, ferritic-pearlitic and pearlitic spheroidal graphite cast irons
b	solution strengthened ferritic spheroidal graphite cast irons
$R_{p0,2}$	stress at which the plastic extension is equal to a 0,2 percentage of the extensometer gauge length
$R_{p0,2}/R_m$	ratio between the stress at which the plastic extension is equal to a 0,2 percentage of the extensometer gauge length and the stress corresponding to the maximum force

Figure A.1 — Spheroidal graphite cast irons — 25 mm cast samples — Ratio 0,2 % proof strength/tensile strength, determined at room temperature and quasi static loading

Another characteristic property of these solid solution strengthened ferritic spheroidal graphite cast irons is that for an equal value in hardness, proof strength is significantly higher (compare the values for these properties in Table 1, Table 3 and Table C.1).

A.3.1.2 Other mechanical and physical properties

For information see Annex E.

A.3.2 Machinability

Compared to the corresponding ferritic/pearlitic grades, the solid solution strengthened ferritic spheroidal graphite cast iron grades exhibit considerably less hardness variation due to their single-phase matrix microstructure. For a same level of hardness, this reduction in hardness variation (see Table C.1), combined with a negligible amount of pearlite, may result in improved machinability and dimensional accuracy.

Annex B
(informative)

Guidance values for mechanical properties determined on test pieces machined from samples cut from the castings

Tables B.1 and B.2 give guidance values for mechanical properties determined on test pieces machined from samples cut from the castings.

Table B.1 — Guidance values for mechanical properties determined on test pieces machined from samples cut from the castings for ferritic to pearlitic grades

Material designation		Relevant wall thickness t mm	0,2 % proof strength $R_{p0,2}$ MPa min.	Tensile strength R_m MPa min.	Elongation after fracture A % min.
Symbol	Number				
EN-GJS-350-22C-LT	5.3100	$t \leq 30$	220	340	20
		$30 < t \leq 60$	210	320	15
		$60 < t \leq 200$	200	310	12
EN-GJS-350-22C-RT	5.3101	$t \leq 30$	220	340	20
		$30 < t \leq 60$	210	320	15
		$60 < t \leq 200$	200	310	12
EN-GJS-350-22C	5.3102	$t \leq 30$	220	340	20
		$30 < t \leq 60$	210	320	15
		$60 < t \leq 200$	200	310	12
EN-GJS-400-18C-LT	5.3103	$t \leq 30$	240	390	15
		$30 < t \leq 60$	230	370	12
		$60 < t \leq 200$	220	340	10
EN-GJS-400-18C-RT	5.3104	$t \leq 30$	250	390	15
		$30 < t \leq 60$	240	370	12
		$60 < t \leq 200$	230	350	10
EN-GJS-400-18C	5.3105	$t \leq 30$	250	390	15
		$30 < t \leq 60$	240	370	12
		$60 < t \leq 200$	230	350	10
EN-GJS-400-15C	5.3106	$t \leq 30$	250	390	12
		$30 < t \leq 60$	240	370	11
		$60 < t \leq 200$	230	350	8
EN-GJS-450-10C	5.3107	$t \leq 30$	300	440	8
		$30 < t \leq 60$	Guidance values to be provided by the manufacturer		
		$60 < t \leq 200$			
EN-GJS-500-7C	5.3200	$t \leq 30$	300	480	6
		$30 < t \leq 60$	280	450	5
		$60 < t \leq 200$	260	400	3
EN-GJS-600-3C	5.3201	$t \leq 30$	360	580	3
		$30 < t \leq 60$	340	550	2
		$60 < t \leq 200$	320	500	1
EN-GJS-700-2C	5.3300	$t \leq 30$	410	680	2
		$30 < t \leq 60$	390	650	1
		$60 < t \leq 200$	370	600	1
EN-GJS-800-2C	5.3301	$t \leq 30$	460	780	2
		$30 < t \leq 60$	Guidance values to be provided by the manufacturer		
		$60 < t \leq 200$			
In the case when the purchaser requires minimum mechanical property values to be obtained in a stated location of the casting, this needs to be agreed with the manufacturer.					

Table B.2 — Guidance values for mechanical properties determined on test pieces machined from samples cut from the castings for solid solution strengthened ferritic grades

Material designation		Relevant wall thickness	0,2 % proof strength	Tensile strength	Elongation after fracture
		t	$R_{p0,2}$	R_m	A
		mm	MPa	MPa	%
Symbol	Number		min.	min.	min.
EN-GJS-450-18C	5.3108	$t \leq 30$	350	440	16
		$30 < t \leq 60$	340	420	12
		$60 < t \leq 200$	Guidance values to be provided by the manufacturer		
EN-GJS-500-14C	5.3109	$t \leq 30$	400	480	12
		$30 < t \leq 60$	390	460	10
		$60 < t \leq 200$	Guidance values to be provided by the manufacturer		
EN-GJS-600-10C	5.3110	$t \leq 30$	450	580	8
		$30 < t \leq 60$	430	560	6
		$60 < t \leq 200$	Guidance values to be provided by the manufacturer		
In the case when the purchaser requires minimum mechanical property values to be obtained in a stated location of the casting, this needs to be agreed with the manufacturer.					

Annex C
(informative)

Guidance values for hardness

C.1 General

When hardness is required in addition to the tensile properties, the procedure given in C.3 and C.4 is recommended.

Table C.1 — Guidance values for Brinell hardness

Material designation		Brinell hardness range HBW Relevant wall thickness t	
Symbol	Number	$t \leq 60$ mm	60 mm < $t \leq 200$ mm
EN-GJS-350-22	5.3102	< 160	< 160
EN-GJS-400-18	5.3105	130 to 175 [a]	130 to 175 [a]
EN-GJS-400-15	5.3106	135 to 180 [a]	135 to 180 [a]
EN-GJS-450-18	5.3108	170 to 200	160 to 190
EN-GJS-450-10	5.3107	160 to 210 [a]	160 to 210 [a]
EN-GJS-500-14	5.3109	185 to 215	170 to 200
EN-GJS-500-7	5.3200	170 to 230 [a]	150 to 230 [a]
EN-GJS-600-10	5.3110	200 to 230	190 to 220
EN-GJS-600-3	5.3201	190 to 270 [a]	180 to 270 [a]
EN-GJS-700-2	5.3300	225 to 305 [a]	210 to 305 [a]
EN-GJS-800-2	5.3301	245 to 335 [a]	240 to 335 [a]
EN-GJS-900-2	5.3302	270 to 360 [a]	270 to 360 [a]

NOTE 1 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.

NOTE 2 Eutectic carbides increase hardness but they are normally undesirable and only likely to be present in minor amounts.

[a] By agreement between the manufacturer and the purchaser, a narrower hardness range may be adopted; a tolerance range of between 30 and 40 Brinell hardness units is commonly acceptable. This hardness range may be wider for grades with a ferritic-pearlitic matrix microstructure.

C.2 Sampling

Each hardness test should be carried out either on a casting or on a test piece at locations agreed between the manufacturer and the purchaser. In the absence of an agreement the test should be carried out at representative locations chosen by the manufacturer.

C.3 Test method

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

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

If the test is carried out on a knob cast-on to the casting, it should not be separated before concluding any required heat treatment.

If the test is carried out on a test piece taken from a separately cast sample, this should be subjected firstly to any heat treatment required for the castings of which it is representative.

C.4 Number and frequency of hardness tests

The number and frequency of hardness tests can be the subject of an agreement between the manufacturer and the purchaser by the time of acceptance of the order.

Annex D
(informative)

Nodularity

The nodularity of spheroidal graphite cast irons 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. 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.

Nodularity not only depends on the production process influenced, for example, by the chemical composition, the remaining magnesium concentration or the inoculation method, but also on the solidification rate of the melt in the respective wall areas. Furthermore, it is possible to influence the graphite form in the contact area of the mould as well.

The nodularity marks only one aspect of the material quality. Further parameters influencing the material qualities are, among others, the nodule count, the pearlite content and its arrangement, the solid solution strengthening of the ferrite and possible imperfections. Concerning the minimum material properties specified in this European Standard, it is impossible to define a concrete nodularity value for certain solidification modulus.

However, experience shows that a nodularity of 80 % or more generally ensures the minimum tensile properties specified in this European Standard, as long as the matrix of the chosen variety is adjusted accordingly. Most of the 15 % to 20 % of graphite not being in form V and VI is then in form IV and possibly in form III (and may even be of forms I and II in thick walled castings).

For castings subjected to severe loading, in particular under fatigue conditions or toughness requirements a higher nodularity (including requirements for a specific percentage of form V and VI graphite) may be required, especially for ferritic-pearlitic to pearlitic grades due to segregation of pearlite promoting elements. Such a requirement should be evaluated by an experimental study, specific to the casting and the material grade.

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

Annex E
(informative)

Additional information on mechanical and physical properties

Information on mechanical and physical properties is given in Tables E.1 and E.2 (in addition to that given in Table 1 and Table 3).

Table E.1 — Typical properties [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-800-2	EN-GJS-900-2	EN-GJS-450-18	EN-GJS-500-14	EN-GJS-600-10
Shear strength	MPa	315	360	405	450	540	630	720	810	—	nd[b]	—
Torsional strength	MPa	315	360	405	450	540	630	720	810	—	nd[b]	—
Modulus of elasticity E (tension and compression)	GN/m^2	169	169	169	169	174	176	176	176	170	170	170
Poisson's ratio v	—	0,275	0,275	0,275	0,275	0,275	0,275	0,275	0,275	0,28 to 0,29	0,28 to 0,29	0,28 to 0,29
Compression strength	MPa	—	700	700	800	870	1 000	1 150	—	—	nd[b]	—
Thermal conductivity at 300 °C	W/(K·m)	36,2	36,2	36,2	35,2	32,5	31,1	31,1	31,1	—	—	—
Specific heat capacity 20 °C to 500 °C	J/(kg·K)	515	515	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	12,5	12,5	—	—	—
Density	kg/dm^3	7,1	7,1	7,1	7,1	7,2	7,2	7,2	7,2	7,1	7,0	7,0
Maximum permeability	µH/m	2 136	2 136	2 136	1 596	866	501	501	501	nd [b]	nd [b]	nd [b]
Hysteresis loss (B = 1T)	J/m^3	600	600	600	1 345	2 248	2 700	2 700	2 700	nd [b]	nd [b]	nd [b]
Resistivity	µΩ·m	0,50	0,50	0,50	0,51	0,53	0,54	0,54	0,54	nd [b]	nd [b]	nd [b]
Predominant matrix microstructure	—	ferrite	ferrite	ferrite	ferrite-pearlite	pearlite-ferrite	pearlite	pearlite or tempered martensite	tempered martensite or bainite [c]	ferrite	ferrite	ferrite

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

b Not determined.

c For large castings, it can also be pearlite.

Table E.2 — Guidance values for mechanical properties measured on specimens (Ø ≤ 25 mm) machined from samples cut from castings (relevant wall thickness $t \leq 30$ mm) [16]

Characteristic	Unit	Material designation											
		EN-GJS-350-22	EN-GJS-400-18	EN-GJS-400-15	EN-GJS-450-10	EN-GJS-500-7	EN-GJS-600-3	EN-GJS-700-2	EN-GJS-800-2	EN-GJS-900-2	EN-GJS-450-18	EN-GJS-500-14	EN-GJS-600-10
Tensile strength R_m	MPa	350	400	400	450	500	600	700	800	900	450	500	600
Alternating tension-compression $\sigma_W = \sigma_{(R=-1)}$ [a] Mean fatigue strength amplitude σ_W [b] (standard deviation: approximately 22,3 %)	MPa	150	168	168	185	200	228	252	272	288	185	200	228
Strength ratio σ_W/R_m approximately $0{,}50 - 0{,}0002 \times R_m$		0,43	0,42	0,42	0,41	0,40	0,38	0,36	0,34	0,32	0,41	0,40	0,38
Pulsating tension $\sigma_{max} = 2 \times \sigma_{(R=0)}$ [a] Mean fatigue strength σ_{max} [b] (standard deviation: approximately 9 %) [b]	MPa	210	235	235	259	280	319	353	381	403	259	280	319
Relationship $\sigma_{(R=0)} / \sigma_{(R=-1)}$ approximately 0,7													
Alternating torsion $\tau_W = \tau_{A(R=-1)}$ [a] Mean torsional fatigue strength amplitude τ_W [b] (standard deviation: approximately 14 %)	MPa	138	152	152	166	180	204	224	240	252	166	180	204
Strength ratio τ_W / R_m approximately $0{,}46 - 0{,}0002 \times R_m$		0,39	0,38	0,38	0,37	0,36	0,34	0,32	0,30	0,28	0,37	0,36	0,34

Characteristic	Unit	Material designation											
		EN-GJS-350-22	EN-GJS-400-18	EN-GJS-400-15	EN-GJS-450-10	EN-GJS-500-7	EN-GJS-600-3	EN-GJS-700-2	EN-GJS-800-2	EN-GJS-900-2	EN-GJS-450-18	EN-GJS-500-14	EN-GJS-600-10
Rotating bending $\sigma_W = \sigma_{bW\,(R=-1)}$ [a]													
Mean fatigue strength amplitude σ_W [b] (standard deviation: approximately 14,2 %)	MPa	168	188	188	207	225	258	287	312	333	207	225	258
Strength ratio $\sigma_{bW(R=-1)} / R_m$ $\approx 0{,}55 - 0{,}0002 \times R_m$		0,48	0,47	0,47	0,46	0,45	0,43	0,41	0,39	0,37	0,46	0,45	0,43
Rotating bending $\sigma_W = \sigma_{bWK(R=-1)}$ [a]													
Mean fatigue strength amplitude σ_W [c] (standard deviation: approximately 21,8 %)	MPa	115	128	128	139	150	168	182	192	198	139	150	168
Strength ratio $\sigma_{bWK(R=-1)} / R_m$ $\approx 0{,}40 - 0{,}0002 \times R_m$		0,33	0,32	0,32	0,31	0,30	0,28	0,26	0,24	0,22	0,31	0,30	0,28

a Stress controlled fatigue tests according to Wöhler.

b Unnotched – Mean fatigue strength of unnotched specimens (Ø ≤ 25 mm) in the long life fatigue regime at the number of 10 Million cycles ($N = 1 \times 10^7$) and the failure probability P = 50 %. The corresponding fatigue strength ratio decreases with increase in tensile strength.

c Notched – Mean rotating bending fatigue strength of notched specimens ($K_t \leq 3$) in the long life fatigue regime at the number of 10 Million cycles ($N = 1 \times 10^7$) and the failure probability P = 50 %. The corresponding fatigue strength ratio decreases with increase in tensile strength.

Annex F
(normative)

Sectioning procedure for cast samples

Figures F.1 and F.2 show the sectioning procedure for Y-shaped samples and for cast-on-samples.

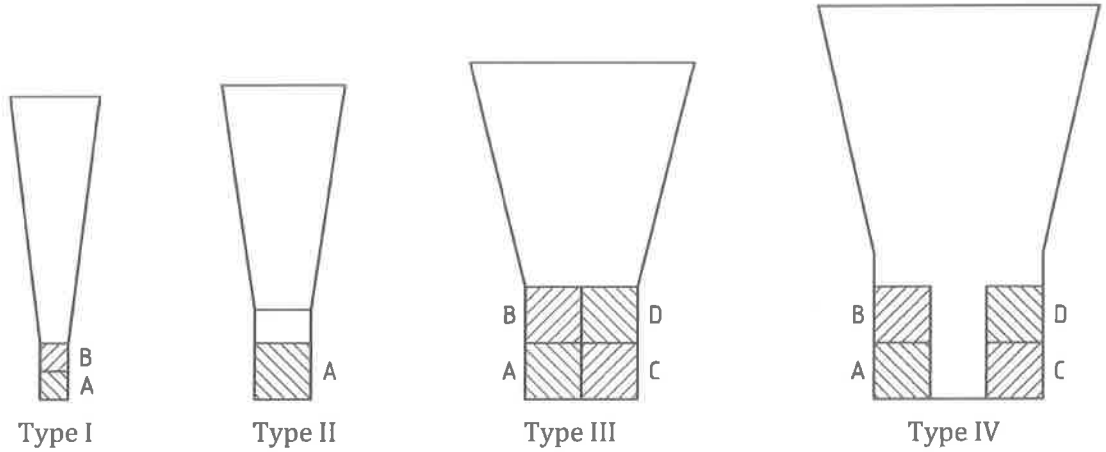


Figure F.1 — Sectioning procedure for Y-shaped samples Type I, Type II, Type III and Type IV (see Figure 2)

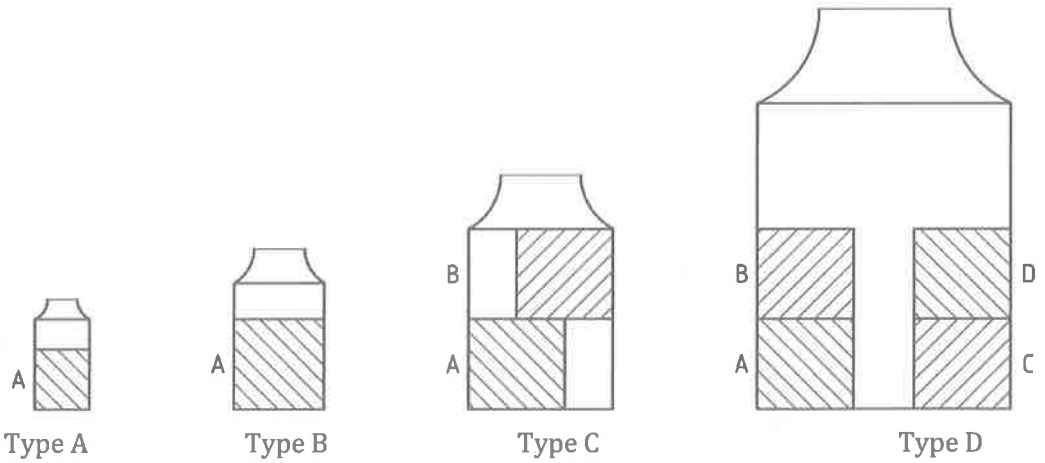


Figure F.2 — Sectioning procedure for cast-on samples Type A, Type B, Type C and Type D (see Figure 4)

Annex G
(informative)

Comparison of spheroidal graphite cast iron material designations according to EN 1560 [1] and ISO/TR 15931 [15]

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

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

EN 1563, editions 2011 [13] and 2018, Table 1 and Table 3		EN 1563:1997 [12]		ISO 1083:2004 [14]	
Symbol	Number	Table 1	Table 3	Table 1 and A.1	Table 3 and A.1
EN-GJS-350-22-LT	5.3100	EN-JS1015	EN-JS1019	ISO 1083/JS/350-22-LT/S	ISO 1083/JS/350-22-LT/U
EN-GJS-350-22-RT	5.3101	EN-JS1014	EN-JS1029	ISO 1083/JS/350-22-RT/S	ISO 1083/JS/350-22-RT/U
EN-GJS-350-22	5.3102	EN-JS1010	EN-JS1032	ISO 1083/JS/350-22/S	ISO 1083/JS/350-22/U
EN-GJS-400-18-LT	5.3103	EN-JS1025	EN-JS1049	ISO 1083/JS/400-18-LT/S	ISO 1083/JS/400-18-LT/U
EN-GJS-400-18-RT	5.3104	EN-JS1024	EN-JS1059	ISO 1083/JS/400-18-RT/S	ISO 1083/JS/400-18-RT/U
EN-GJS-400-18	5.3105	EN-JS1020	EN-JS1062	ISO 1083/JS/400-18/S	ISO 1083/JS/400-18/U
EN-GJS-400-15	5.3106	EN-JS1030	EN-JS1072	ISO 1083/JS/400-15/S	ISO 1083/JS/400-15/U
EN-GJS-450-18	5.3108	—	—	—	—
EN-GJS-450-10	5.3107	EN-JS1040	EN-JS1132	ISO 1083/JS/450-10/S	ISO 1083/JS/450-10/U
EN-GJS-500-14	5.3109	—	—	—	—
—	—	—	—	ISO 1083/JS/500-10/S	ISO 1083/JS/500-10/U
EN-GJS-500-7	5.3200	EN-JS1050	EN-JS1082	ISO 1083/JS/500-7/S	ISO 1083/JS/500-7/U
—	—	—	—	ISO 1083/JS/550-5/S	ISO 1083/JS/550-5/U
EN-GJS-600-10	5.3110	—	—	—	—
EN-GJS-600-3	5.3201	EN-JS1060	EN-JS1092	ISO 1083/JS/600-3/S	ISO 1083/JS/600-3/U
EN-GJS-700-2	5.3300	EN-JS1070	EN-JS1102	ISO 1083/JS/700-2/S	ISO 1083/JS/700-2/U
EN-GJS-800-2	5.3301	EN-JS1080	EN-JS1112	ISO 1083/JS/800-2/S	ISO 1083/JS/800-2/U
EN-GJS-900-2	5.3302	EN-JS1090	EN-JS1122	ISO 1083/JS/900-2/S	ISO 1083/JS/900-2/U

Annex H
(informative)

Fracture mechanical approach to spheroidal graphite cast irons

H.1 General

NOTE Referenced documents in this annex are marked with (H01) to (H39) and listed in H.6.

By applying fracture mechanical criteria to the selection of materials and the safety evaluation of a component, the conventional criteria based on uniaxial tensile testing are supplemented and expanded. This enables to include the fracture mechanical properties (which are defined as material resistance to crack initiation or crack propagation) into the evaluation of the resistance to fracture. The designers are now in a position to make a material selection which corresponds far better with the specific loading situation in castings than a selection made on the basis of the notched bar impact energy (H01).

The notched bar impact energy is not suitable for component design and evaluation.

Ductility determined as percentage elongation after fracture of test pieces in uniaxial tensile tests is erroneously used as synonym to the term material toughness. Percentage elongation after fracture, however, can only give information regarding elasto-plastic constitutive models for design (H02).

H.2 Fracture mechanics concept

Fracture mechanical concepts cover quantitative relations between the load acting on the component, the size of present or hypothetically assumed cracks or crack-like stress concentration spots (e.g. casting imperfections), subcritical cracks grown under fatigue conditions and the material's fracture mechanical properties (H03 to H04).

One basic pre-requisite for the fracture mechanical evaluation of the material and the component is that both applied loading and loading resistance, i.e. the material's resistance to crack initiation and propagation, are available on the basis of the same fracture mechanical concept and under the same loading conditions.

H.3 Determination of fracture mechanical properties

For the experimental determination of the fracture mechanical properties of spheroidal graphite cast irons under quasi-static loading mainly test standards such as ISO 12135 (H05), ASTM E 1820 (H06) or ASTM E 399 (H07) are used. These standards are also called on for the purposes of testing under dynamic loading conditions since specific standards for dynamic fracture mechanics testing have not yet been finalized (H08 to H15).

With regard to the initiation of instable crack propagation under linear-elastic conditions, fracture toughness values K_{Ic} in accordance with (H05 to H07) are considered as transferable to the component (denoted K_{Id} under dynamic loading).

The only characteristic material values to be considered as transferable to the component with regard to the initiation of stable crack propagation under elastic-plastic conditions are physical crack initiation toughness values (e.g. J_i in accordance with ISO 12135) excluding any crack growth. The characteristic crack initiation toughness value J_{Ic} according to ASTM E 1820 contains considerable amounts of ductile tearing and does not fulfil the above condition unless additional validity requirements are met (H06, H15).

For the experimental determination of fracture mechanical characteristic values of spheroidal graphite cast irons under fatigue conditions, mainly the standards ASTM E 647 (H16) or ISO 12108 (H17) are used. Threshold value for the stress intensity factor ΔK_{th} is the most common parameter used by designers for the assessment of fatigue life when imperfections and/or sharp notches are considered.

Due to the variety of the possible related definitions of characteristic values, the user of fracture mechanical characteristic material values shall be particularly careful. Usually, fracture mechanical tests are carried out on relatively small test pieces taken from a casting or a semi-finished product. In order to avoid errors in the evaluation of safety or unintentional non-conservatives, the transferability of the determined characteristic values to the component shall be ensured on the basis of the validity requirements formulated in the test standards.

H.4 Influences on fracture mechanical properties

The fracture mechanical properties of spheroidal graphite cast irons under quasi-static, dynamic and cyclic mechanical loading are determined by the microstructure and the chemical composition as well as by loading factors such as temperature and loading rate. With regard to the microstructure, both the metallic matrix and the distribution and morphology of the graphite particles should be considered.

In addition to the size of the used fracture mechanics samples, the mentioned influences determine whether the material behaviour is linear-elastic or elastic-plastic and, based on this behaviour, which fracture mechanics concept can be applied for the description of the material toughness.

H.5 Publications

H.5.1 Testing

In the course of the increasing use of spheroidal graphite cast irons, investigations regarding the fracture behaviour as well as the load- and microstructure-dependent fracture mechanical material characterization have been performed, particularly over the past 25 years, as it can be seen in references (H08 to H15, H18 to H30).

Based on the proceeding development of the fracture mechanical test methods, the focus of afore-mentioned investigations has been on the determination of the quasi-static and the dynamic fracture toughness (H08 to H15, H18 to H25) and the cyclic fracture-mechanical properties (H25 to H27), respectively.

Furthermore, the examinations have focused on aspects of the establishment of correlations between microstructural parameters and fracture mechanical properties (H22 to H23) as well as the welding-related processing of spheroidal graphite cast irons (H28).

H.5.2 Component assessment

As far as performing fracture mechanical assessments on spheroidal graphite cast iron components is concerned, compilations of engineering rules and regulations such as the British Standard BS 7910 (H31) or the European FITNET procedure (H32) are available. Furthermore, subject-specific provisions for fields of application having higher safety or reliability requirements, such as nuclear technology (H33 to H34), generation of wind energy (H35), mechanical engineering (H36) or welding technology (H37) can be used.

The publications (H29, H30 and H38) give a selection of examples of the application of fracture mechanical design procedures for components made of spheroidal graphite cast irons or of metallic materials in general (H39).

H.6 Literature

This clause contains referenced documents given in Annex H.

(H01) Pusch, G.: Bruchmechanische Sicherheitskonzepte und ihre Anwendung auf Gusseisenwerkstoffe, konstruieren + giessen 17 (1992) 3, pp. 29-35; 17 (1992) 4, pp. 4-12; 18 (1993) 1, pp. 4-11 as well as 18 (1993) 2, pp. 4-10

(H02) Baer, W. and R. Häcker: Werkstoffcharakterisierung von Gusseisenwerkstoffen mit Kugelgraphit - dynamische Zugversuche unter dem Aspekt der Bauteilsicherheitsbewertung, MP Materials Testing 47 (2005) 1-2, pp. 34-44

(H03) Blumenauer, H. und G. Pusch: Technische Bruchmechanik, Deutscher Verlag für Grundstoffindustrie, 3. Auflage, 1993

(H04) Anderson, T. L.: Fracture Mechanics: Fundamentals and Applications, CRC Press Taylor and Francis Group, Boca Raton, FL, USA, 3rd edition, 2005

(H05) ISO 12135:2016, Metallic materials - Unified method of test for the determination of quasistatic fracture toughness

(H06) ASTM E 1820:2017, Standard Test Method for Measurement of Fracture Toughness

(H07) ASTM E 399:2012, Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials

(H08) Baer, W., Wossidlo, P., Abbasi, B., Cassau, M., Häcker, R. and R. Kossert: Large scale testing and statistical analysis of dynamic fracture toughness of ductile cast iron, Engineering Fracture Mechanics 76 (2009) 8, pp. 1074-1086

(H09) Bradley, W.L., Fracture toughness of Graphitic Cast Iron, Proceedings of the International Conference on Mechanical Behaviour of Ductile Cast Iron and Other Cast Metals, Kitakyushu, Japan, 30 July – 1 August, 1993, pp. 402-412

(H10) Kobayashi, T. and S. Yamada: Evaluation of Static and Dynamic Fracture Toughness in Ductile Cast iron, Metallurgical and Materials Transactions A, Vol. 25A (1994) 11, pp. 2427-2437

(H11) McConnell, P.: Dynamic Fracture Toughness of Ductile Iron, Rapid Load Fracture Testing, ASTM/STP 1130, R. Chona and W.R. Corwin, Eds., ASTM Philadelphia, 1991, pp. 104-117

(H12) Baer, W.: Adequate Measurement of Force, Displacement and Crack Initiation in Dynamic Fracture Mechanics Experiments, In: Fracture Mechanics for Durability, Reliability and Safety, 19th European Conference on Fracture ECF19, Editors: R. Goldstein and V. Shlyannikov, ESIS European Structural Integrity Society, Kazan, Russia, Aug 26-31, 2012, 8 pages

(H13) Baer, W., Bösel, D., Eberle, A. and D. Klingbeil: Determination of dynamic crack resistance of ductile cast iron using the compliance ratio key curve method, Engineering Fracture Mechanics 77 (2010), pp. 374-384

(H14) Baer, W.: Advanced Fracture Mechanics Testing of DCI – A Key to Valuable Toughness Data, Proceedings of the 2013 Keith Millis Symposium on Ductile Cast Iron, American Foundry Society and Ductile Iron Society (ISBN 978-0-87433-419-7), Oct. 15-17, 2013, Nashville, TN, USA, pp. 223-232

(H15) Baer, W.: Experimentelle Ermittlung dynamischer Bruchzähigkeitswerte von ferritischem Gusseisen mit Kugelgraphit - Normung und aktuelle Datenbasis; Tagung Werkstoffprüfung - Fortschritte der Kennwertermittlung für Forschung und Praxis, ed. H. Frenz and W. Grellmann, DVM Verlag, 2008, pp. 275-282

(H16) ASTM E 647:2013, Standard Test Method for Measurement of Fatigue Crack Growth Rates

(H17) ISO 12108:2012, Metallic materials - Fatigue testing - Fatigue crack growth method

(H18) Pusch, G.: Bruchmechanische Kennwerte von Gusseisenwerkstoffen, konstruieren + gießen 33 (2008) 4, pp. 2-34

(H19) Rosenfield, A.R., Ahmad, J., Cialone, H.J., Landow, M.P., Mincer, P.N. and V. Papaspyropoulos: Crack Arrest Toughness of Nodular Iron, Nuclear Engineering and Design 116 (1989), pp. 161-170

(H20) Arai, T, Saegusa, T., Yagawa, G, Urabe, N. and R. E. Nickell: Determination of Lower-Bound Fracture Toughness for Heavy-Section Ductile Cast Iron (DCI) and Estimation by Small Specimen Tests, Fracture Mechanics: 24th Volume, ASTM STP 1207, J. D. Landes, D. E. McCabe and J.A.M. Boulet, Eds., ASTM Philadelphia, 1994, pp. 355-368

(H21) McKinney, K.E., Bradley, W.L. and P.C. Gerhardt Jr.: An Evaluation of the Toughness of Ductile Iron vs Cast Steel Using Modified Charpy Test Specimens, AFS Transactions 92 (1984) 84-122, pp. 239-250

(H22) Baer, W., Pusch, G. and A. Michael: Investigations on the Fracture Mechanical Behaviour of Ferritic Nodular Cast Iron in Dependence on the Applied Load and Temperature, Int. Journal of Radioactive Materials Transport (RAMTRANS) 6 (1995) 2/3, pp. 149-154

(H23) Salzbrenner, R. and K. Sorenson: The Relationship of Mechanical Properties to Microstructure and Composition in a Set of Ferritic Ductile Cast Irons, Report for Research Project DE-AC0476DP00789 by the US. Department of Energy, Sandia National Laboratories, Albuquerque, NM, 1986, 32 pages

(H 24) Berger, C., Roos, E., Mao, T., Udoh, A., Scholz, A. and A. Klenk: Behaviour of ductile cast iron at high temperatures, Giessereiforschung 58 (2006) 2, pp. 18-28

(H25) Pusch, G., Ludwig, A., Biermann, H., Mottitschka, T. und K. Nagel: Mechanische und bruchmechanische Kennwerte Si-mischkristallverfestigter GJS-Werkstoffe im Hinblick auf ihren Einsatz in Windkraftanlagen, Giessereipraxis 6 (2015), S. 253-270

(H 26) Hübner, P., Schlosser, H., Pusch, G. and H. Biermann: Load history effects in ductile cast iron for wind turbine components, Int. Journal of Fatigue 29 (2007), pp. 1788-1796

(H 27) Zybell, L., Chaves, H., Kuna, M., Mottitschka, T., Pusch, G. and H. Biermann: Optical *in situ* investigations of overload effects during fatigue crack growth in nodular cast iron, Engineering Fracture Mechanics 95 (2012), pp. 45-56

(H 28) Pusch, G., Udoh, A. and W. Baer: Fließbruchmechanische Bewertung einer artgleichen Schweißverbindung an Gusseisen mit Kugelgraphit GGG-40 bei statischer und dynamischer Beanspruchung, konstruieren + giessen, 24 (1999) 3, pp. 25-30

(H 29) Fussenegger, F., Mathis, R., Titze, E., Rammelsberg, J. und M. Schütze: Bruchmechanisch bemessene Turbinenleitung aus duktilen Gussrohren, konstruieren + giessen 23 (1998) 2, pp. 14-19

(H 30) Urabe, N. and Y. Harada: Fracture Toughness of Heavy Section Ductile Iron Castings and Safety Assessment of Cast Casks, Proceedings of the 9th International Symposium on the Packaging and Transportation of Radioactive Materials PATRAM, June 11-16, 1989, Washington DC, pp. 743-752

(H 31) BS 7910:2013, Guide to methods for assessing the acceptability of flaws in metallic structures, British Standards Institution

(H 32) Kojak et al. Edt. FITNET Fitness for Service Procedure, Revision MK8, 2008, ISBN 978-3-940923-00-4, GKSS Research Center, Germany

(H 33) BAM – GGR 007, Leitlinie zur Verwendung von Gusseisen mit Kugelgraphit für Transport- und Lagerbehälter für radioaktive Stoffe, Rev. 0, BAM Berlin, June 2002

(H 34) ASME Code Case N-670, Use of Ductile Cast Iron Conforming to ASTM A 874/A 874M-98 or JIS G 5504-1992 for Transport Containments, ASME Section III, Division 3, BC01-810, finally approved June 2005

(H 35) Guideline for the Certification of Wind Turbines, Germanischer Lloyd Industrial Services GmbH, Hamburg, edition 2010

(H 36) Fracture Mechanics of proof strengths for engineering components, Forschungskuratorium Maschinenbau, Frankfurt/Main, 3rd edition 2009

(H 37) DVS 2401:2004, Bruchmechanische Bewertung von Fehlern in Schweißverbindungen, DVS Verlag

(H 38) Broeckmann, C., Keusemann, S., Özden, U., Utku, A., Bartz, M., Krull, F. and P. Langenberg: A fracture mechanically based strength analysis of planet carriers for wind turbines made of high strength cast iron, CWD 2013, 1. Conference for Wind Power Drives, Conference Report, Aachen, Germany, 19./20. March 2013

(H 39) Zerbst, U., Schödel, M., Webster, S. and R. Ainsworth: Fitness-for-Service Fracture Assessment of Structures Containing Cracks, A Workbook based on the European SINTAP/FITNET Procedure, Elsevier Publishers, first edition, 2007

Annex I
(informative)

Significant technical changes between this European Standard and the 2011 edition

Table I.1 — Significant technical changes between this European Standard and the 2011 edition

Clause/paragraph/table/figure	Change
8.2.6 – Figure 5	Modified
Annex A – Table A.1	Modified.
Annex E	Guidance values for fatigue added
Annex F	Was the previous Annex G
Annex G	Was the previous Annex H
Annex H	Was the previous Annex F, entirely reworded
Former Annex I "Un-notched impact test"	Deleted.
NOTE The technical changes mentioned include the significant technical changes from the revised European Standard, but is not an exhaustive list of all modifications from the 2011 edition.	

Annex J
(informative)

Significant technical changes between the 1997 edition and the 2011 edition

Table J.1 — Significant technical changes between the 1997 edition and the 2011 edition

Clause/paragraph/table/figure	Change
1	Addition of solid solution strengthened ferritic spheroidal graphite cast iron grades.
3	Definitions added: ferritic to pearlitic spheroidal graphite cast iron, solid-solution strengthened ferritic spheroidal graphite cast iron, cast sample, separately cast sample, side-by-side cast sample, cast-on sample and relevant wall thickness.
7	Mechanical properties are wall thickness dependant as shown in Tables 1, 2 and 3.
7	Classification as a function of hardness (Annex A from the EN 1563:1997) was withdrawn; Annex C gives guidance values for hardness of different grades.
7.2, Tables 1 and 2	Structure of designation by numbers has been changed.
7.2.1.1, Table 1	Ferritic to pearlitic spheroidal graphite cast irons: the required minimum mechanical properties applies to several types of cast samples and are given for 3 ranges of relevant wall thickness.
7.2.1.2, Table 2	Ferritic to pearlitic spheroidal graphite cast irons: the minimum impact energy values applies to several types of cast samples and are given for 3 ranges of relevant wall thickness.
7.3.1, Table 3	Solid solution strengthened ferritic spheroidal graphite cast irons: the required minimum mechanical properties applies to several types of cast samples and are given for 3 ranges of relevant wall thickness.
8.2.1, Table 4	Types and sizes of cast samples and sizes of tensile test pieces are given in relation to relevant wall thickness of the casting.
Annex A	Informative Annex A giving additional information on solid solution strengthened ferritic spheroidal graphite cast irons added
Annex B	Informative Annex B (Annex D from the EN 1563:1997) where guidance values for mechanical properties measured on test pieces machined from a casting are given for 3 ranges of relevant wall thickness.
Annex C	Informative Annex C giving guidance values for hardness.
Annex D	Informative Annex D with information regarding the nodularity added.

Clause/paragraph/table/figure	Change
Annex E	Informative Annex E (Annex B from the EN 1563:1997) where the additional information on mechanical and physical properties of the solid solution strengthened ferritic spheroidal graphite cast iron grades are also given. The normative Annex E: "Formation of test units and number of test" from the EN 1563:1997 version was withdrawn.
Annex F	Informative Annex F where the toughness (resistance to crack propagation under a given stress) is presented, discussed and compared with impact energy added.
Annex G	Normative Annex G for the sectioning procedure of cast samples added.
Annex H	Informative Annex H for the comparison of spheroidal graphite cast iron material designations according to EN 1560 and ISO/TR 15931 added.
Annex I	Informative Annex I with details regarding the un-notched impact test added.
NOTE The technical changes referred include the significant technical changes from EN 1563:2011 but is not an exhaustive list of all modifications from the 1997 edition.	

Annex ZA
(informative)

Relationship between this European Standard and the essential safety requirements of Annex I of the Directive 2014/68/EU aimed to be covered

This European Standard has been prepared under a Commission's standardization request M/071 to provide one voluntary means of conforming to essential safety requirements of Directive 2014/68/EU of the European Parliament and of the Council of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment.

Once this standard is cited in the Official Journal of the European Union under that Directive 2014/68/EU, compliance with the normative 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 safety requirements of that Directive 2014/68/EU, 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 shall be assessed against the design requirements of this specific item of equipment to verify that the Essential Requirements of the Pressure Equipment Directive (PED) are satisfied.

Table ZA.1 — Correspondence between this European Standard and Annex I of the Directive 2014/68/EU

Essential Requirements of the Directive 2014/68/EU	Clauses/sub-clauses of this EN	Remarks/Notes
Annex I, 4.1 a) of the Directive	7.1 7.2.1.1: Tables 1, 2 and 3	Material properties
Annex I, 4.3 of the Directive	Clause 11	Conformity of material and manufacturer's certified documentation

WARNING 1 — Presumption of conformity stays valid only as long as a reference to this European Standard is maintained in the list published in the Official Journal of the European Union. Users of this standard should consult frequently the latest list published in the Official Journal of the European Union.

WARNING 2 — Other Union legislation may be applicable to the product(s) falling within the scope of this standard.

Bibliography

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

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

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

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

[5] EN 1564, *Founding - Ausferritic spheroidal graphite cast irons*

[6] EN 16124, *Founding - Low-alloyed ferritic spheroidal graphite cast irons for elevated temperature applications*

[7] EN 16482, *Founding - Continuous cast iron bars*

[8] EN 13835, *Founding - Austenitic cast irons*

[9] EN 545, *Ductile iron pipes, fittings, accessories and their joints for water pipelines - Requirements and test methods*

[10] EN 598, *Ductile iron pipes, fittings, accessories and their joints for sewerage applications - Requirements and test methods*

[11] EN 969, *Ductile iron pipes, fittings, accessories and their joints for gas pipelines - Requirements and test methods*

[12] EN 1563:1997, *Founding - Spheroidal graphite cast irons*

[13] EN 1563:2011, *Founding - Spheroidal graphite cast irons*

[14] ISO 1083:2004, *Spheroidal graphite cast irons - Classification*

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

[16] Klubberg, F., Broeckmann, C. and Rösler, D.: Fatigue Strength of Spheroidal Ductile Cast Iron, Forschungskuratorium Maschinenbau, Frankfurt/Main, 13. Sept. 2016, Meeting "Redaktionskreis FKM-Richtlinien", (Publication in preparation)

[17] ISO/TR 945-3, *Microstructure of cast irons - Part 3: Matrix structures*

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BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

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