BS EN 16079:2011

BSI Standards Publication

Founding — Compacted (vermicular) graphite cast irons

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National foreword

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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.

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Foreword

This document (EN 16079:2011) 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of an identical text or by endorsement, at the latest by May 2012, and conflicting national standards shall be withdrawn at the latest by May 2012.

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

Within its programme of work, Technical Committee CEN/TC 190 requested CEN/TC 190/WG 5 "Grey cast iron and compacted graphite cast iron" to prepare EN 16079.

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 the United Kingdom

Introduction

This European Standard classifies compacted (vermicular) graphite cast irons (CGI), in accordance with the mechanical properties of the material.

The properties of compacted (vermicular) graphite cast irons depend on their graphite and matrix microstructure.

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 or

— samples cut from a casting.

Annex A (informative) gives additional information on properties and typical applications of compacted (vermicular) graphite cast irons.

1 Scope

This European Standard defines the grades and the corresponding requirements for compacted (vermicular) graphite cast irons.

This European Standard specifies 5 grades of compacted (vermicular) graphite cast iron by a classification based on mechanical properties measured on machined test pieces prepared from cast samples.

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

2 Normative references

The following 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 10204, *Metallic products — Types of inspection documents*.

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

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

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

3 Terms and definitions

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

3.1
compacted (vermicular) graphite cast iron
cast material, iron and carbon based, the carbon being present mainly in the form of compacted (vermicular) graphite particles that appear vermicular on a two-dimensional plane of polish, the graphite particles being embedded in a matrix consisting of ferrite, ferrite/pearlite, or pearlite

3.2
graphite modification treatment
process that brings the liquid iron into contact with a substance to produce graphite in the predominantly compacted (vermicular) form during solidification

3.3
vermicularity
percentage of graphite particles that are of form III according EN ISO 945-1

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 Table 1.

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 EN 16079 grade designations with the grades from the ISO standard for compacted (vermicular) cast irons, ISO 16112:2006 [3], 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;

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 compacted (vermicular) graphite cast irons 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.

NOTE When compacted (vermicular) graphite cast iron is to be used for special applications, the chemical composition and heat treatment may be agreed between the manufacturer and the purchaser.

7 Requirements

7.1 General

The property values apply to compacted (vermicular) graphite cast iron 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

The mechanical properties of compacted graphite cast iron shall be as specified in Table 1.

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

Material designation		Relevant wall thickness t	0,2 % proof strength $R_{p0,2}$	Tensile strength R_m	Elongation A
		mm	MPa	MPa	%
Symbol	Number		min.	min.	min.
EN-GJV-300	5.2100	$t \leq 30$	210	300	2,0
		$30 < t \leq 60$	195	275	2,0
		$60 < t \leq 200$	175	250	2,0
EN-GJV-350	5.2200	$t \leq 30$	245	350	1,5
		$30 < t \leq 60$	230	325	1,5
		$60 < t \leq 200$	210	300	1,5
EN-GJV-400	5.2201	$t \leq 30$	280	400	1,0
		$30 < t \leq 60$	260	375	1,0
		$60 < t \leq 200$	230	325	1,0
EN-GJV-450	5.2300	$t \leq 30$	315	450	1,0
		$30 < t \leq 60$	280	400	1,0
		$60 < t \leq 200$	260	375	1,0
EN-GJV-500	5.2301	$t \leq 30$	350	500	0,5
		$30 < t \leq 60$	315	450	0,5
		$60 < t \leq 200$	280	400	0,5
NOTE For relevant wall thicknesses more than 200 mm, the manufacturer and the purchaser shall agree on the type and size of the cast sample and the minimum values to be obtained.					

7.3 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 D).

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).

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.

Information regarding hardness is given in Annex E.

7.5 Graphite structure

Compacted (vermicular) graphite cast irons shall have a minimum of 80 % of the graphite particles in the vermicular form (form III in accordance with EN ISO 945-1), when viewed on a two-dimensional plane of polish. The remaining 20 % of the graphite particles should be of form IV, form V and form VI in accordance with EN ISO 945-1.

Flake (lamellar) graphite (form I and form II according to EN ISO 945-1) is not permitted, except at the rim zone of the casting. The thickness of the rim zone shall be agreed between the manufacturer and the purchaser by the time of acceptance of the order.

Although the definition of compacted (vermicular) graphite cast iron is within the range of 80 % to 100 % of graphite particles of form III, a separate agreement may be made for a lower limit. However, this limit shall be not less than 70 %.

NOTE This could be the case for parts which require higher strength and/or parts with large wall thickness.

Compacted (vermicular) graphite cast iron reference images are shown in Annex F.

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 option left to the discretion of the manufacturer.

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

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

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

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 2.

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

Table 2 — 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 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 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 shall be produced to confirm the material grade, 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 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 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

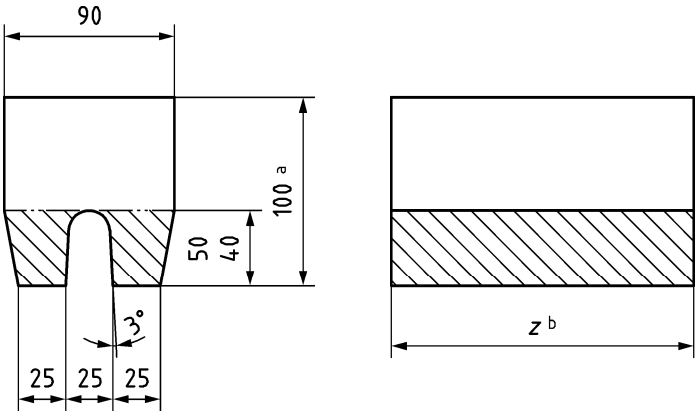
In addition to the requirements of the material, the manufacturer and the purchaser may agree on the properties required (for information, see Annex D) at stated locations in the casting.

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.

Dimensions in millimetres



Key

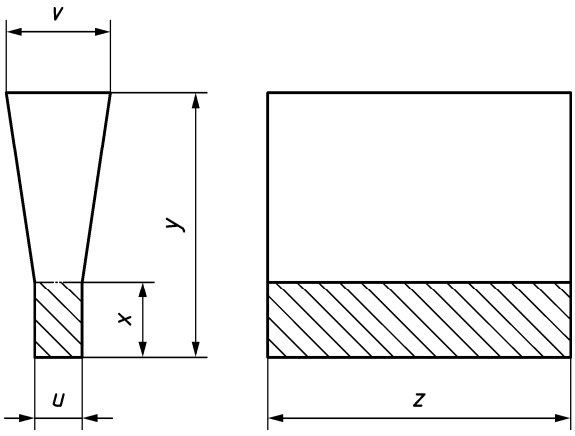
[a] For information only.

[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 cast 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.

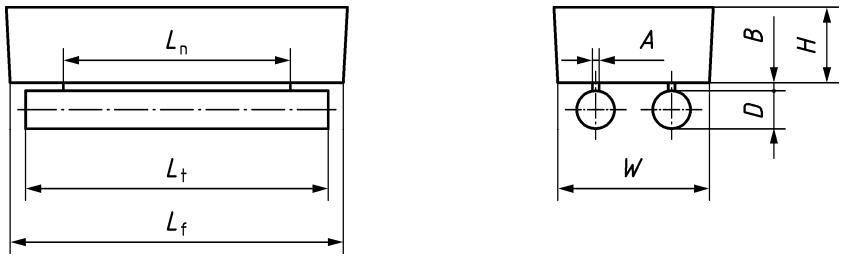
[b] z shall be chosen to allow a test piece of dimensions shown in Figure 5 to be machined from the sample.

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

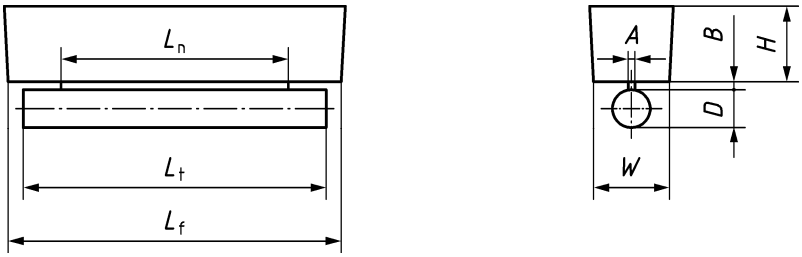
— 40 mm for types I and II, or

— 80 mm for type III and IV.

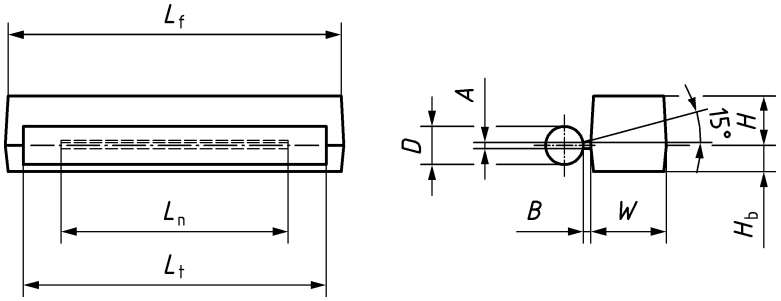
Figure 2 — Separately cast or side-by-side cast samples — Option 2: Y-shaped samples



Type a



Type b



Type c

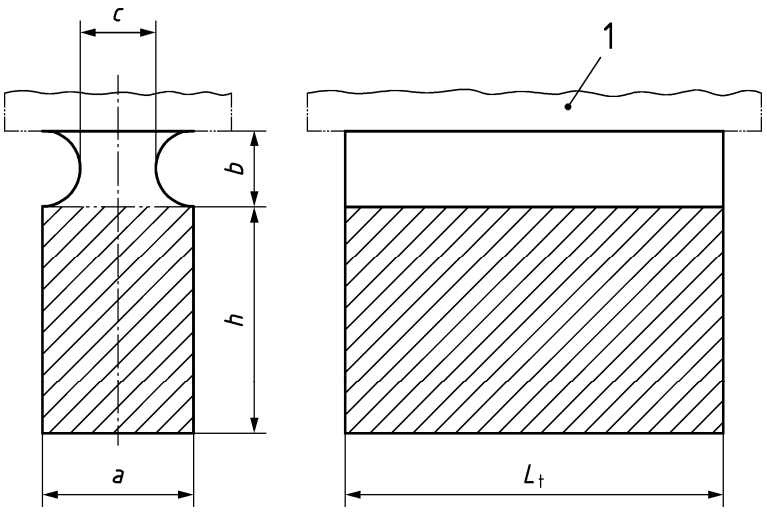
Dimensions in millimetres

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 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	$60 < t \leq 100$	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 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 following relationships apply:

$b = 0,75 \times a$

$c = 0,5 \times a$

Figure 4 — Cast-on sample

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 Equation:

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

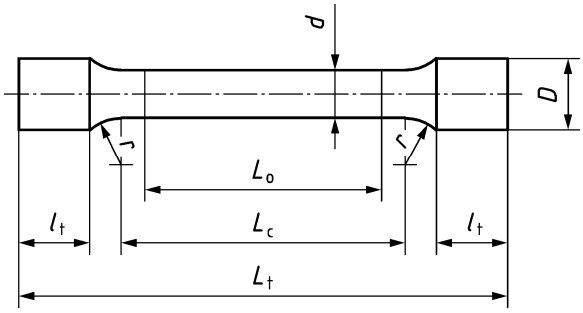
where

L_o is the original gauge length;

S_o is the original cross-sectional 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 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

As an alternative to the tensile test, the wedge penetration test can be used to determine the tensile strength. For further information, see Annex C.

9.2 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.

9.3 Graphite structure examination

The graphite structure shall be confirmed by metallographic examination according to EN ISO 945-1.

Samples for metallographic examination shall be taken from locations agreed between the manufacturer and the purchaser.

Information for the evaluation of vermicularity in compacted (vermicular) graphite cast iron microstructures is provided in informative Annex F.

When image analysis is used to evaluate the graphite structure, an agreement on the method used and set on parameters shall be made between manufacturer and purchaser.

Alternative methods, e.g. by non-destructive methods, may also be agreed upon. In case of a dispute, the result of the metallographic 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 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 Nonconforming 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 the results of one or both retests 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 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.

The number of re-heat treatment cycles shall not exceed two.

11 Inspection documentation

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

Annex A
(informative)

Additional information on properties and typical applications of compacted (vermicular) graphite cast irons

Additional information on mechanical and physical properties of compacted (vermicular) graphite cast irons is given in Table A.1.

Information on properties and typical applications of compacted (vermicular) graphite cast irons is given in Table A.2.

Table A.1 — Information on mechanical and physical properties of compacted (vermicular) graphite cast irons [3]

Property	Units	Temperature	Material designation				
			EN-GJV-300	EN-GJV-350	EN-GJV-400	EN-GJV-450	EN-GJV-500
Ultimate tensile strength, R_m [a]	MPa	23 °C	300 to 375	350 to 425	400 to 475	450 to 525	500 to 575
		100 °C	275 to 350	325 to 400	375 to 450	425 to 500	475 to 550
		400 °C	225 to 300	275 to 350	300 to 375	350 to 425	400 to 475
0,2 % proof stress, $R_{p0,2}$ [a]	MPa	23 °C	210 to 260	245 to 295	280 to 330	315 to 365	350 to 400
		100 °C	190 to 240	220 to 270	255 to 305	290 to 340	325 to 375
		400 °C	170 to 220	195 to 245	230 to 280	265 to 315	300 to 350
Elongation, A	%	23 °C	2,0 to 5,0	1,5 to 4,0	1,0 to 3,5	1,0 to 2,5	0,5 to 2,0
		100 °C	1,5 to 4,5	1,5 to 3,5	1,0 to 3,0	1,0 to 2,0	0,5 to 1,5
		400 °C	1,0 to 4,0	1,0 to 3,0	1,0 to 2,5	0,5 to 1,5	0,5 to 1,5
Elastic modulus [b]	GPa	23 °C	130 to 145	135 to 150	140 to 150	145 to 155	145 to 160
		100 °C	125 to 140	130 to 145	135 to 145	140 to 150	140 to 155
		400 °C	120 to 135	125 to 140	130 to 140	135 to 145	135 to 150
Endurance ratio:							
rotating-bending		23 °C	0,50 to 0,55	0,47 to 0,52	0,45 to 0,50	0,45 to 0,50	0,43 to 0,48
tension-compression		23 °C	0,30 to 0,40	0,27 to 0,37	0,25 to 0,35	0,25 to 0,35	0,20 to 0,30
3-point bending		23 °C	0,65 to 0,75	0,62 to 0,72	0,60 to 0,70	0,60 to 0,70	0,55 to 0,65
Poisson's ratio			0,26	0,26	0,26	0,26	0,26
Density	g/cm^3	23 °C	7,0 to 7,2	7,0 to 7,2	7,0 to 7,2	7,0 to 7,2	7,0 to 7,2
Thermal conductivity	W/(m·K)	23 °C	47	43	39	38	36
		100 °C	45	42	39	37	35
		400 °C	42	40	38	36	34
Thermal expansion coefficient	µm/(m·K)	100 °C	11	11	11	11	11
		400 °C	12,5	12,5	12,5	12,5	12,5
Specific heat capacity	J/(g·K)	100 °C	0,475	0,475	0,475	0,475	0,475
Matrix structure			predominantly ferritic	ferritic-pearlitic	pearlitic-ferritic	predominantly pearlitic	fully pearlitic

[a] Wall thickness 15 mm, modulus M = 0,75.

[b] Secant modulus (200 N/mm^2 to 300 N/mm^2).

Table A.2 — Properties and typical applications of compacted (vermicular) graphite cast irons

Material designation	Properties	Examples of typical applications
EN-GJV-300	Lowest strength and highest ductility. High thermal conductivity and low elastic modulus minimise the accumulation of thermally induced stresses. Predominantly ferritic matrix minimises growth during prolonged exposure to elevated temperatures.	Exhaust manifolds Cylinder heads for large marine and stationary engines
EN-GJV-350	Strength higher than alloyed grey cast iron with good ductility. Better castability, mould yield, and machinability than spheroidal graphite cast iron.	Bedplates Brackets and couplings Cylinder blocks and heads for large marine and stationary diesel engines Ingot moulds
EN-GJV-400	Combination of strength, stiffness and thermal conductivity. Good wear resistance.	Automotive cylinder blocks and heads Bedplates, brackets and couplings Truck brake drums Pump housings and hydraulic components Ingot moulds
EN-GJV-450	Higher strength, stiffness and wear resistance than EN-GJV-400, although less machinable.	Automotive cylinder blocks and heads Cylinder liners Train brake discs Pump housings and hydraulic components
EN-GJV-500	Highest strength and lowest ductility. Highest wear resistance and lowest machinability.	Highly stressed automotive cylinder blocks Cylinder liners

Annex B
(informative)

Comparison of compacted (vermicular) graphite cast iron material designations according to EN 1560 and ISO/TR 15931[4][5]

This informative annex compares the material designation of the standardized grades of compacted (vermicular) graphite cast iron based on the ISO and EN designation systems.

Table B.1 — Material designations of compacted (vermicular) graphite cast irons — Classification based on mechanical properties measured on machined test pieces prepared from cast samples

EN 16079:2011, Table 1		ISO 16112:2006, Designations	
Symbol	**Number**	**Table 1**	**Table 2**
EN-GJV-300	5.2100	ISO 16112/JV/300/S	ISO 16112/JV/300/U
EN-GJV-350	5.2200	ISO 16112/JV/350/S	ISO 16112/JV/350/U
EN-GJV-400	5.2201	ISO 16112/JV/400/S	ISO 16112/JV/400/U
EN-GJV-450	5.2300	ISO 16112/JV/450/S	ISO 16112/JV/450/U
EN-GJV-500	5.2301	ISO 16112/JV/500/S	ISO 16112/JV/500/U

Annex C
(informative)

Wedge penetration test

C.1 General

This informative annex specifies the method for wedge penetration testing of compacted (vermicular) graphite cast irons as an alternative test method for tensile strength. This test should only be used for the material grades EN-GJV-400, EN-GJV-450 and EN-GJV-500.

NOTE This test is not suitable for materials with higher elongation.

C.2 Principle

The test involves straining a test piece to the penetration of two sharp opposed and parallel wedges, resulting in orthogonal tensile stresses in the test piece to fracture, as shown in Figure C.1.

a) 3D perspective **b) 2D perspective**

Figure C.1 — Principle of wedge penetration test

C.3 Symbols

Symbols used in this Annex are listed in Table C.1.

Table C.1 — Symbols

Symbol	Designation	Unit
d_0	Width or diameter of test piece	mm
d_1	Length of the fracture	mm
t	Thickness of test piece	mm
F_m	Maximum force	N
R_{mW}	Wedge penetration strength	MPa
R_m	Tensile strength	MPa
K	Correction factor for thickness	MPa

C.4 Testing apparatus

C.4.1 General

Standard tensile testing machines equipped with a wedge penetration testing device, or a dedicated wedge penetration testing machine can be used.

An example of a wedge penetration testing device is shown in [6].

C.4.2 Accuracy of testing apparatus

The force-measuring system of the testing machine should be calibrated in accordance with EN ISO 7500-1 [8] and should be at least of class 1.

C.4.3 Wedges

The tolerance on the parallelism of the wedges, for a wedge length of 40 mm, should be maximum 0,1 mm, both horizontal and perpendicular.

In general, the wedge angle is $90^{o} \pm 30'$ and the radius at the tip of the wedge 0,15 mm to 0,20 mm.

Wedges are normally produced from quenched and tempered steel with a hardness of (740 ± 40) HV [(62 ± 2) HRC]

NOTE Dependent on the wedge angle and radius, for comparable test pieces, different values for wedge penetration strength will be obtained.

C.5 Test piece

The wedge penetration test can be performed on test pieces machined from samples cut from a casting or machined from cast samples.

The wedge penetration test enables the testing of the strength of a component even with thin wall thicknesses.

However, results can only be compared if the dimensions of the test pieces are identical.

It is recommended to use a test piece with dimensions in conformance with Table C.2.

Table C.2 — Wedge penetration test piece

Width [a] or diameter (d)	20,0 mm ± 0,1 mm
Thickness (t)	6,0 mm ± 0,1 mm
Tolerance on parallelism of thickness [b]	< 0,1 mm
Surface roughness [c]	R_z < 25 µm

[a] The length is minimum 20 mm; for multiple testing longer test pieces may be used.

[b] Thickness and parallelism effects the results considerably, therefore it is important to respect the required tolerances in order to guarantee parallel stress introduction.

[c] Corresponds approximately with roughness levels 1S1, A1 or 2S2 according to EN 1370.

C.6 Procedure

— For each cast sample or casting at least three tests should be performed.

— The test should be carried out at ambient temperature between 10 °C and 35 °C, unless otherwise specified.

— The stress rate should be between 2 MPa/s and 10 MPa/s.

— When multiple testing a long test piece, the distance between each test should be at least 10 mm.

C.7 Evaluation

For each test, the wedge penetration strength is to be calculated as follows:

$$R_{mW} = F_m / (t \times d_1) \quad \text{in MPa} \tag{C.1}$$

From the individual results, the average wedge penetration strength is to be calculated and in the report the number of tests is to be stated.

C.8 Correlation of wedge penetration strength with tensile strength

The tensile strength R_m correlates with the wedge penetration strength R_{mW} according the general linear equation:

$$R_m = a \times R_{mW} - b \quad \text{in MPa} \tag{C.2}$$

where

a is constant;

b is constant.

The regression coefficients mainly depends on test piece geometry, wedge angle, wedge radius and production conditions.

Therefore, it is necessary to establish manufacturer specific equations.

Additional information can be found in [6]

Annex D
(informative)

Guidance values for tensile properties measured on test pieces machined from samples cut from a casting

Table D.1 — Guidance values for tensile properties measured on test pieces machined from samples cut from a casting.

Material designation		Relevant wall thickness t mm	0,2 % proof strength $R_{p0,2}$ MPa min.	Tensile strength R_m MPa min.	Elongation A % min.
Symbol	**Number**				
EN-GJV-300C	5.2100	$t \leq 30$	210	300	2,0
		$30 < t \leq 60$	a, b		
		$60 < t \leq 200$			
EN-GJV-350C	5.2200	$t \leq 30$	245	350	1,5
		$30 < t \leq 60$	a, b		
		$60 < t \leq 200$			
EN-GJV-400C	5.2201	$t \leq 30$	280	400	1,0
		$30 < t \leq 60$	a, b		
		$60 < t \leq 200$			
EN-GJV-450C	5.2300	$t \leq 30$	315	450	1,0
		$30 < t \leq 60$	a, b		
		$60 < t \leq 200$			
EN-GJV-500C	5.2301	$t \leq 30$	350	500	0,5
		$30 < t \leq 60$	a, b		
		$60 < t \leq 200$			

[a] No reliable values available at the time of publication.

[b] Values to be agreed between the purchaser and the manufacturer

Annex E
(informative)

Guidance values for Brinell hardness

Table E.1 — Guidance values for Brinell hardness

Material designation		Brinell hardness range
Symbol	Number	HBW
EN-GJV-300	5.2100	140 to 210
EN-GJV-350	5.2200	160 to 220
EN-GJV-400	5.2201	180 to 240
EN-GJV-450	5.2300	200 to 250
EN-GJV-500	5.2301	220 to 260

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.

Annex F
(informative)

Compacted (vermicular) graphite structure evaluation

Vermicularity is defined by the equation F.1:

$$X_{\text{vermic}} = \frac{N_{\text{vermic}}}{N_{\text{graphite,tot}}} \times 100\% \qquad \text{(F.1)}$$

where

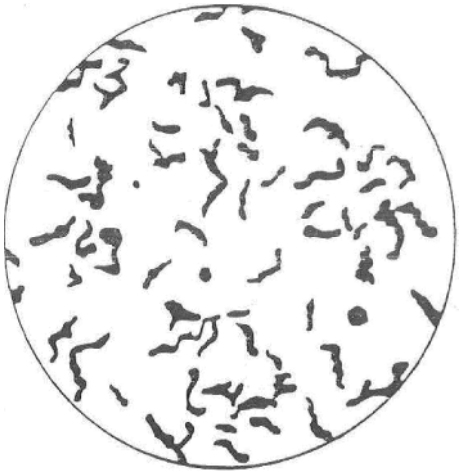
X_{vermic} Vermicularity;

N_{vermic} number of graphite particles of form III;

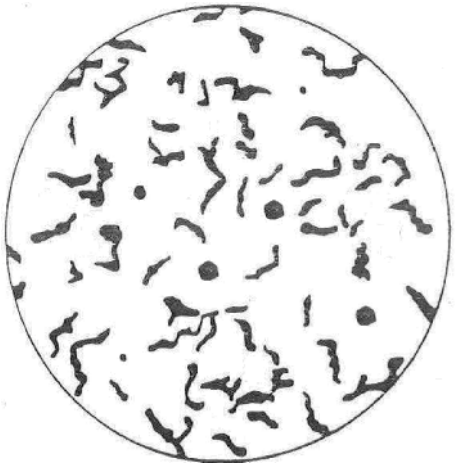
$N_{\text{graphite,tot}}$ total number of graphite particles.

NOTE Particles with a maximum axis length (defined as maximum distance between two points at the particle perimeter, when the particle is surrounded by a circle) being < 10 µm should not be counted.

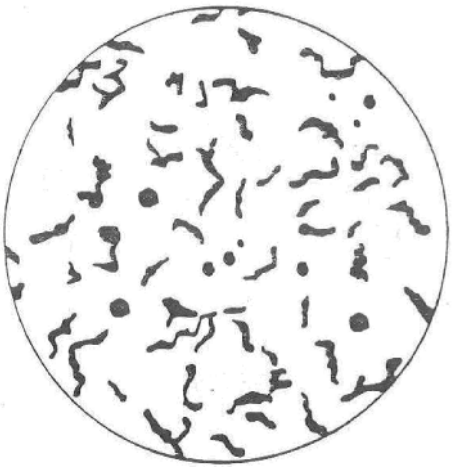
Typical compacted (vermicular) graphite cast iron reference images, containing 95 %, 90 %, 85 %, 80 %, 75 % and 70 % vermicularity, are given in Figure F.1 for the classification of the vermicularity.



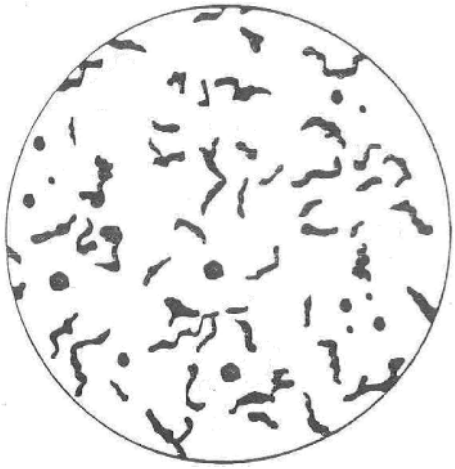
a) 95 % vermicularity



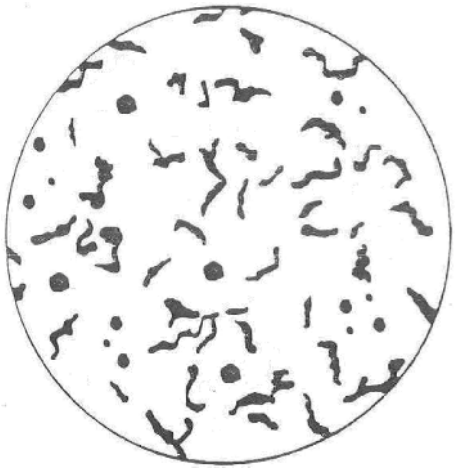
b) 90 % vermicularity



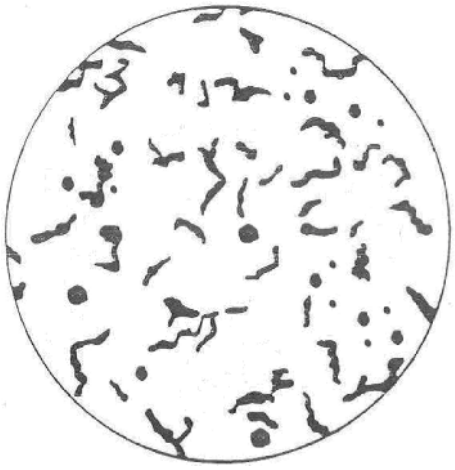
c) 85 % vermicularity



d) 80 % vermicularity



e) 75 % vermicularity



f) 70 % vermicularity

Figure F.1 — Compacted (vermicular) graphite cast iron reference images

Annex G
(normative)

Sectioning procedure for cast samples

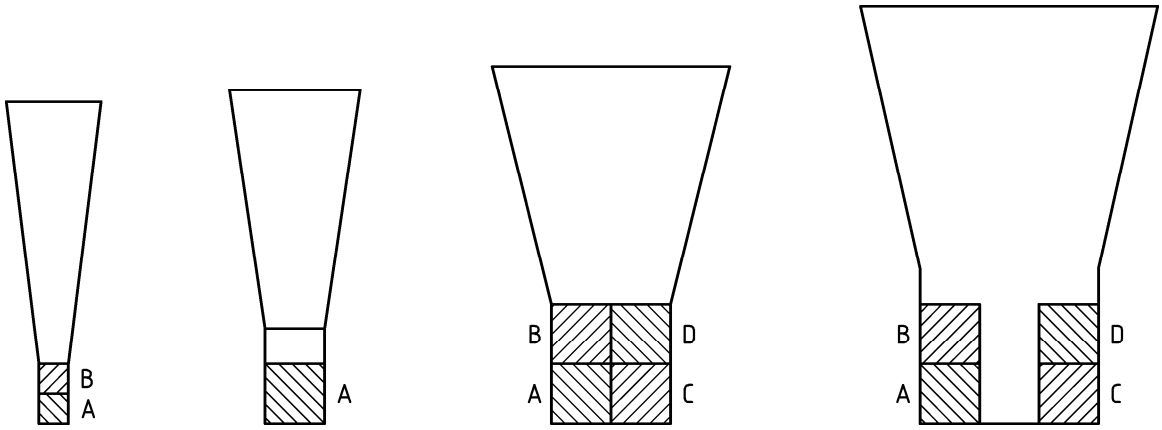


Figure G.1 — Sectioning procedure for Y-shaped samples (see Figure 2)

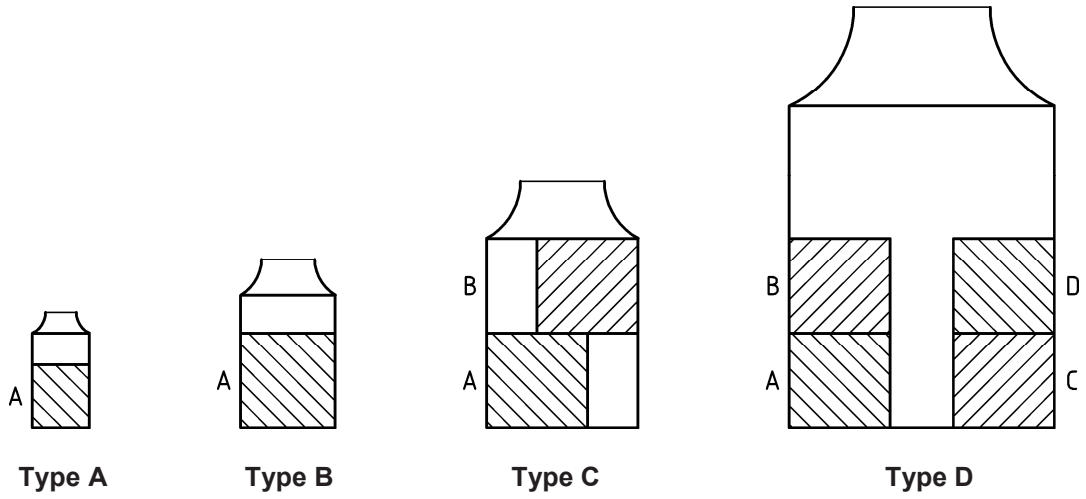


Figure G.2 — Sectioning procedure for cast-on samples (see Figure 4)

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

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

[3] ISO 16112:2006, *Compacted (vermicular) graphite cast irons — Classification*

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

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

[6] VDG-Merkblatt P340, *Wedge penetration test — Grey cast iron and compacted graphite cast iron*

[7] EN 1370, *Founding — Examination of surface condition*

[8] EN ISO 7500-1, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system (ISO 7500-1:2004)*

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