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Founding — Ausferritic spheroidal graphite cast irons — Classification

Fonderie — Fontes ausferritiques à graphite sphéroïdal — Classification

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 25, *Cast irons and pig irons*.

This second edition cancels and replaces the first edition (ISO 17804:2005), which has been technically revised. The main changes compared with the previous edition are as follows:

a) the normative references have been updated;

b) the terms and definitions have been improved and supplemented;

c) a side-by-side cast sample has been included;

d) the method of manufacturing has been made more detailed (including pouring/heat treatment);

e) a subclause (9.4) for graphite structure examination has been added;

f) in Annex C (formerly Annex B), a new conversion table for tensile test results has been added;

g) in Annex H (formerly Annex G), new fatigue data have been added for five different test methods from an international survey;

h) in Annex I (formerly Annex H), nodularity has been made more detailed, in accordance with ISO 945-4[2];

i) the previous Annex I on machinability has been deleted as it is no longer necessary;

j) in Annex J, Chinese GB/T grades have been added and several other international grade changes have been made;

k) the Bibliography has been revised.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

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

Compared to the spheroidal graphite cast iron grades (see ISO 1083[3]), four material grades combine high strength, ductility and toughness properties while two grades combine higher strength with wear resistance as a result of ausferrite matrix structures.

This document deals with the classification of ausferritic spheroidal graphite cast irons in accordance with the mechanical properties of the material.

The mechanical properties of these ausferritic spheroidal graphite cast irons depend on their structure, e.g. the form of the graphite and the structure of the matrix.

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

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

— separately cast samples with an appropriate gating system, able to provide metallurgical conditions similar to those of the castings they represent;

— samples cast in the mould alongside the casting, with a joint running system, hereafter called “side-by-side cast samples”;

— samples cast onto either the casting or the running system, hereafter referred to as “cast-on samples”;

— samples cut from a casting (only by agreement between the manufacturer and the purchaser, the agreement specifying, in particular, the conditions of sampling and the values to be obtained).

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

Five grades of ausferritic spheroidal graphite cast iron are specified by their mechanical properties. When, for these grades, hardness is a requirement for the application, Annex D provides the means for determining appropriate hardness ranges.

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

Founding — Ausferritic spheroidal graphite cast irons — Classification

1 Scope

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

This document specifies five grades of ausferritic spheroidal graphite cast iron by a classification based on mechanical properties determined on machined test pieces prepared from:

— separately cast samples, side-by-side cast or cast-on samples;

— samples cut from a casting.

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

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.

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

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

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

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

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

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:

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

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

3.1
ausferritic spheroidal graphite cast iron
austempered ductile iron
ADI
cast material, iron, carbon and silicon based, carbon being present mainly in the form of spheroidal graphite particles, subjected to an austempering heat treatment in order to produce an ausferritic matrix

3.2
graphite spheroidizing treatment
process that brings the liquid iron into contact with a substance to produce graphite in the spheroidal form (predominantly form VI) during solidification

3.3
austempering
<of spheroidal graphite cast iron> heat treatment process, consisting of heating the castings to a temperature at which austenite starts to form during heating and holding a sufficient time for carbon diffusion into the austenite, followed by cooling at a rate sufficient to avoid the formation of pearlite, and transforming the matrix structure for a time and a temperature (above the martensite start temperature) sufficient to produce the desired properties

Note 1 to entry: This process produces a microstructure that consists predominantly of ferrite and high carbon austenite. This microstructure is called "ausferrite". Examples of ausferritic microstructures are given in ISO/TR 945-3[1].

3.4
ausferrite
cast iron microstructure, produced by a controlled thermal process, which consists of predominantly acicular ferrite and high carbon austenite

3.5
cast sample
quantity of material cast to represent the cast material, including 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 the 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
section of the casting, agreed between the manufacturer and the purchaser, to which the determined mechanical properties apply

Note 1 to entry: Relevant wall thickness may be associated with a range of casting sections and/or with a sample type and size according to Table 3. The association is made by considering the cooling conditions during solidification and heat treatment.

3.10
test unit
inspection lot
test batch
number of pieces or the tonnage of castings to be accepted or rejected together, on the basis of the tests carried out on the test pieces in accordance with the requirements of the relevant specification, material standard or order

4 Designation

The material shall be designated in accordance with ISO/TR 15931.

Annex J gives a selection of approximate cross-references of grade designations from this document to standard grades from EN, ASTM, JIS, GB/T and SAE standards.

5 Order information

The following information shall be supplied by the purchaser:

a) the complete designation of the material;

b) any special requirements (including the relevant wall thickness, when necessary)

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

6 Manufacture

The method of producing ausferritic spheroidal graphite cast iron shall be left to the joint discretion of the foundry and the heat treater.

The chemical composition shall be agreed upon between the manufacturer of the casting and the heat treater.

The method of producing spheroidal graphite cast iron to be austempered shall be left to the discretion of the foundry.

The heat treatment shall be left to the discretion of the heat treater.

Both shall ensure that the casting process and heat treatment process are carried out with the same process parameters as the approved first sample(s).

7 Requirements

7.1 General

The property values of these materials apply to castings 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 separately cast, cast side-by-side or cast-on samples with a thickness or diameter of 25 mm, cast in a sand mould or a mould of comparable thermal behaviour, corresponding to a relevant wall thickness t ≤ 30 mm, as given in Table 1.

For samples cut from the casting, the location shall be agreed between the manufacturer and the purchaser.

The designation is irrespective of the type of cast sample.

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

Tensile, impact and any other mechanical testing requires sound material in the test pieces to provide representative test results.

7.2 Test pieces machined from cast samples

7.2.1 General

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

Table 1 — Mechanical properties determined on test pieces machined from separately cast samples, side-by-side cast samples or cast-on samples[4]

Material designation	Relevant wall thickness of the casting t mm	Tensile strength R_m MPa min.	0,2 % proof strength $R_{p0,2}$ MPa min.	Elongation after fracture A_5 % min.
ISO 17804/JS/800-10 ISO 17804/JS/800-10RT	$t \leq 30$	800	500	10
	$30 < t \leq 60$	750		6
	$60 < t \leq 100$	720		5
ISO 17804/JS/900-8	$t \leq 30$	900	600	8
	$30 < t \leq 60$	850		5
	$60 < t \leq 100$	820		4
ISO 17804/JS/1050-6	$t \leq 30$	1 050	700	6
	$30 < t \leq 60$	1 000		4
	$60 < t \leq 100$	970		3
ISO 17804/JS/1200-3	$t \leq 30$	1 200	850	3
	$30 < t \leq 60$	1 170		2
	$60 < t \leq 100$	1 140		1
ISO 17804/JS/1400-1	$t \leq 30$	1 400	1 100	1
	$30 < t \leq 60$	1 170	To be agreed between the manufacturer and the purchaser	
	$60 < t \leq 100$	1 140		

NOTE 1 The properties of castings are not uniform because of the complexity and variation in section thickness.

NOTE 2 With the appropriate heat treatment, the specified minimum 0,2 % proof strength values according to this table can be maintained. However, with increasing casting wall thickness, the tensile strength and elongation values will decrease.

NOTE 3 1 MPa = 1 N/mm^2.

7.2.2 Impact test

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

Table 2 — Minimum impact energy values determined on V-notched test pieces machined from separately cast samples, side-by-side cast samples or cast-on samples[4]

Material designation	Relevant wall thickness of the casting t mm	Minimum impact energy value at room temperature (23 ± 5 °C) Mean value of 3 tests J	 Individual value J
ISO 17804/JS/800-10RT	$t \leq 30$	10	9
	$30 < t \leq 60$	9	8
	$60 < t \leq 100$	8	7

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 determined;

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

Tables 1 and 2 may be used for guidance on the likely mechanical properties of the castings. These properties may be equal to or lower than those given in these tables.

7.4 Hardness

Guidance values for the Brinell hardness range of the material grades are given in Annex C.

The grades of abrasion-resistant ausferritic spheroidal graphite cast irons in terms of hardness shall be as specified in Annex A.

7.5 Graphite structure

The graphite structure shall be predominantly of form VI in accordance with ISO 945-1. A more precise definition may be agreed upon at the time of the acceptance of the order.

This structure shall be confirmed by metallographic examination. The technique, visual or image analysis, should be agreed upon at the time of the acceptance of the order.

Additional information regarding nodularity is given in Annex H.

7.6 Matrix structure

Information on matrix structure is given in ISO/TR 945-3:2016, Table 4.6[1].

The matrix structure of the various grades of ausferritic spheroidal graphite cast iron consists predominantly of ferrite and austenite, otherwise known as ausferrite. Other matrix constituents (e.g. martensite, carbides) may be present at a level that will not affect the required mechanical properties.

Intercritical austenitization may be used to produce ISO 17804/JS/800-10 or 800-10/RT. This will result in the formation of a mixed microstructure that includes the presence of proeutectoid ferrite. Intercritical austenitization requires a higher hardenability than the grades specified in Table 1.

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

8 Sampling

8.1 General

Samples shall be provided to represent the castings produced.

Samples shall be made from the same material as that used to produce the castings which they represent. The same melt and heat treatment processes shall be applied.

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 (see Table 3).

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

When the mass of the casting exceeds 2 000 kg and its relevant wall thickness exceeds 60 mm, cast-on samples or side-by-side cast samples should be preferably used. Representative dimensions and the location of the sample shall be agreed between the manufacturer and the purchaser at 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. Tensile and impact test pieces shall be finally machined from the samples after the heat treatment.

8.2 Cast samples

8.2.1 Size of cast samples

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

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

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

Dimensions in millimetres

Relevant wall thickness	Type of cast sample				Preferred diameter of tensile test piece[a]
	Option 1 U-shaped	Option 2 Y-shaped	Option 3 Round bar shaped	Cast-on sample	
t mm	(see Figure 1)	(see Figure 2)	(see Figure 3)	(see Figure 4)	d mm
$t \leq 12{,}5$		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 in-process quality assurance procedures adopted by the manufacturer or as agreed with the purchaser.

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

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

8.2.3 Separately cast samples

The samples shall be cast separately in sand moulds at the same time 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.

It is an option of the manufacturer to use an adequate running system that reproduces conditions similar to those of the castings.

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

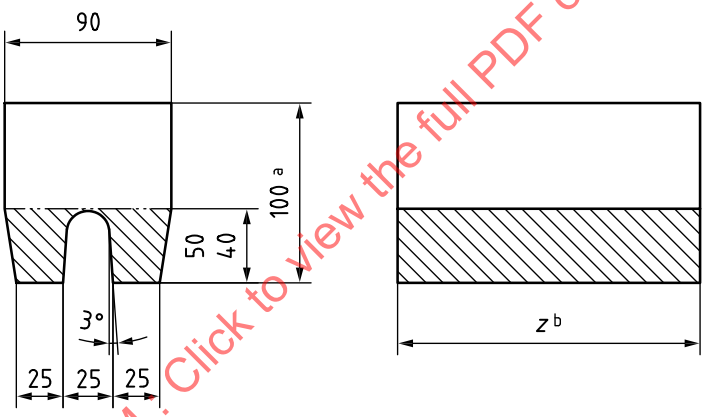
The samples shall be removed from the mould at a temperature similar to that of the castings.

If the graphite spheroidizing treatment is carried out in the mould (in-mould process), the samples shall be:

— either cast alongside with the castings, with a joint running system; or

— cast separately using a similar treatment method in the sample mould as the method used to produce the castings.

The samples shall be given the same heat treatment as the castings they represent.



a For information only

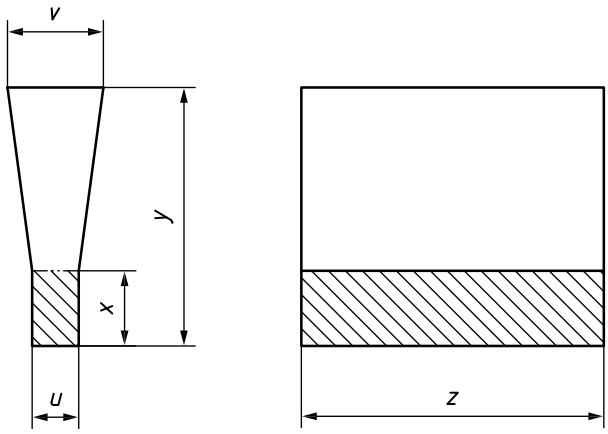
b The length *z* shall be chosen to allow a test piece of dimensions shown in Figure 5 to be machined from the sample

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

For the manufacture of thin-walled castings or castings in metal moulds, the tensile properties may be determined, by agreement between the manufacturer and the purchaser, on test pieces taken from samples of thickness less than 12,5 mm.

Figure 1 — Separately cast or side-by-side cast samples — Option 1: Y- and 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:

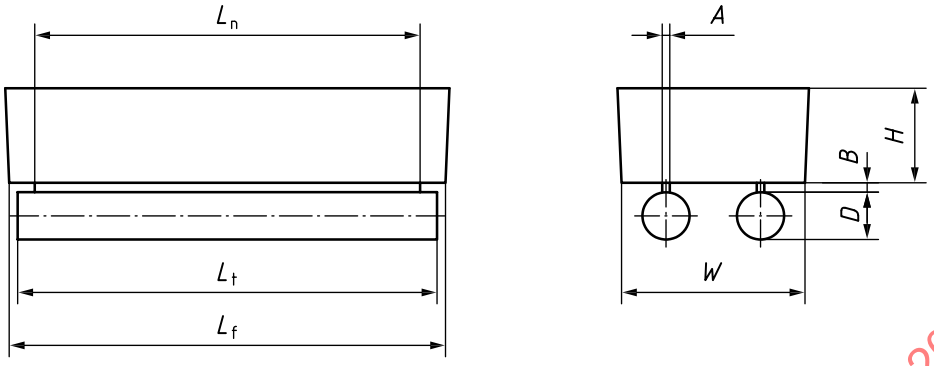
— 40 mm minimum for types I and II;

— 80 mm minimum for types III and IV.

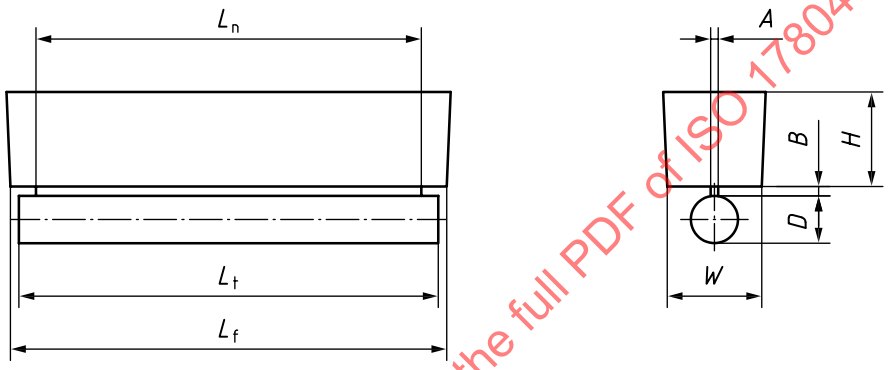
For the manufacture of thin-walled castings or castings in metal moulds, the tensile properties may be determined, by agreement between the manufacturer and the purchaser, on test pieces taken from samples of thickness less than 12,5 mm.

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

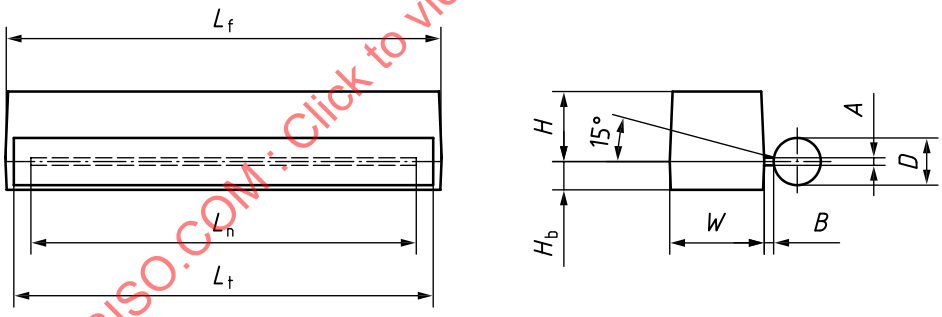
Dimensions in millimetres



a) Type a



b) Type b



c) Type c

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, cast side-by-side and cast-on samples — Option 3: Round bar-shaped sample

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 samples shall be produced in the last moulds poured.

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

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.

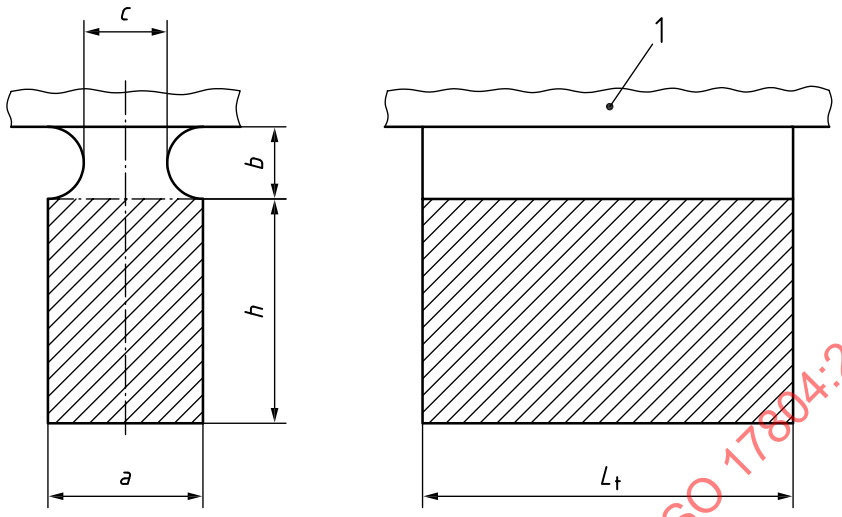
When mechanical properties are required for a series of castings belonging to the same test unit, the cast-on samples shall be produced in the last moulds poured.

The location of cast-on samples shall be agreed between the manufacturer and the purchaser at 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.

The samples shall have a general shape as indicated in Figures 3 and 4 and the dimensions shown therein.

Unless otherwise agreed between the manufacturer and the purchaser, when castings are to be heat treated, the cast-on samples shall not be separated from the castings until after the heat treatment.

Dimensions in millimetres



Key

1 casting

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	[a]
C	$30 < t \leq 60$	40	30	20	40 to 65	[a]
D	$60 < t \leq 200$	70	52,5	35	65 to 105	[a]

[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 for types A and B;

— 80 mm for types C and D.

If smaller dimensions are agreed upon by the manufacturer and the purchaser, the following relationships apply:

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

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

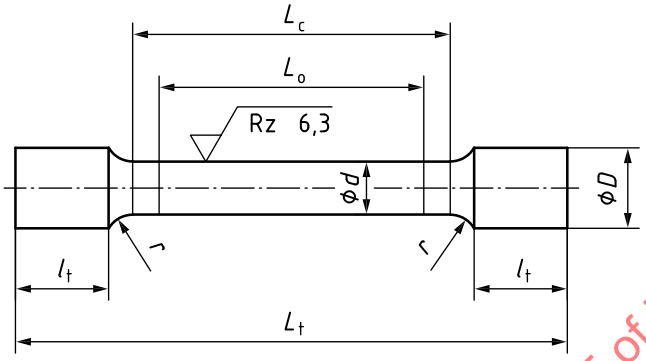
Figure 4 — Cast-on sample

8.2.6 Test pieces machined from cast samples

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

The sectioning procedure for cast samples should be in accordance with Annex I.

Dimensions in millimetres



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

[a] In principle.

[b] Preferred dimension.

where

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

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 grip length of the test piece;

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

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

Rz is the surface roughness condition, expressed in µm.

The method of gripping the ends of the test piece may be agreed between the manufacturer and the purchaser.

Figure 5 — Tensile test piece

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 E) at stated locations in the heat-treated 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 diameter of these test pieces.

In the absence of any directions by the purchaser, the manufacturer may select 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.

8.4 Formation of test units and number of tests

8.4.1 General

A test unit is formed with the castings consecutively poured under uniform controlled conditions from one or more ladles and submitted to one or more heat treatments operated under uniform controlled conditions. Unless otherwise agreed, one sample per test unit will represent the material quality of the test unit.

8.4.2 Examples of test units

Examples of test units are as follows:

— castings poured from the same ladle: up to 2 000 kg of fettled castings; this may vary, where practicable, by agreement between the manufacturer and the purchaser;

— a single casting, if its mass equals or exceeds 200 kg;

— for continuous pouring of large tonnages of spheroidal graphite cast iron, the maximum size of test unit shall be restricted to the castings produced in a two-hour period of pouring;

— when the graphite spheroidizing treatment is carried out on less than 2 000 kg, the test unit to be taken shall be the number of castings produced from that quantity of treated metal.

NOTE After heat treatment, a test unit remains the same unless different heat treatments have been applied to distinct parts of the test unit. In such cases, these distinct parts become separate test units.

8.4.3 Number of tests per test unit

Sampling and testing shall be carried out in accordance with Clauses 8, 9 and 10. Sampling and testing shall be carried out on each test unit unless the in-process quality assurance system makes provision for amalgamation of lots. When the graphite spheroidizing treatment has been carried out in the mould, the formation of test units and the number of tests shall be agreed between the manufacturer and the purchaser at the time of acceptance of the order.

9 Test methods

9.1 Tensile test

The tensile test shall be carried out in accordance with 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). For either of these exceptions, the original gauge length of the test piece shall conform to Formula (1):

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

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 Formula (1) 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. In this case, the minimum elongation values as shown in Table B.1 shall be used.

NOTE The preferred test bar diameter is given in Table 3.

9.2 Impact test

The impact test shall be carried out on three Charpy V-notched impact test pieces in accordance with ISO 148-1.

Test equipment with an appropriate energy shall be used to determine the properties correctly.

The 2 mm radius striker shall be used.

NOTE 1 This procedure applies only to grade 800-10 RT.

NOTE 2 Additional test piece dimensions and tolerances are given in ISO 148-1.

NOTE 3 Information on the unnotched impact test is given in Annex F.

Dimensions in millimetres

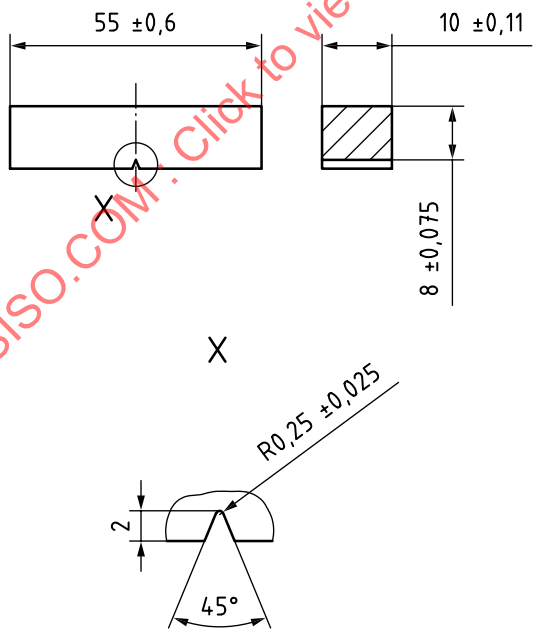


Figure 6 — Charpy V-notched impact test piece

9.3 Hardness test

The hardness shall be determined as Brinell hardness in accordance with ISO 6506-1. Alternative hardness tests may also be agreed upon.

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

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 onto the casting.

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

Further information on hardness is given in Annexes C and D.

9.4 Graphite structure examination

The graphite structure shall be confirmed by metallographic examination in accordance with ISO 945-1.

Non-destructive methods can also give information.

10 Retests

10.1 Need for retesting

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 requirement 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 sample or from a duplicate sample cast at the same time and having undergone the same heat treatment.

The results of the retest shall be used to replace invalid test results.

10.3 Nonconforming test results

If any test gives results that 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 document.

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

10.4 Heat treatment of samples and castings

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

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

11 Additional information

Annex G gives additional information on mechanical and physical properties of ausferritic spheroidal graphite cast irons.

Annex A
(normative)

Abrasion-resistant grades of ausferritic spheroidal graphite cast iron

A.1 General

This annex defines the grades of abrasion-resistant ausferritic spheroidal graphite cast iron. It specifies the grades in terms of hardness.

A.2 Requirements

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

Table A.1 — Abrasion-resistant ausferritic spheroidal graphite cast iron grades

Material designation	Brinell hardness	Other properties (for information only)		
	HBW minimum	R_m MPa	$R_{p0,2}$ MPa	A_5 %
ISO 17804/JS/HBW400	400	1 400	1 100	1
ISO 17804/JS/HBW450	450	1 600	1 300	—
NOTE 1 The manufacturer and the purchaser may agree on the maximum Brinell hardness.				
NOTE 2 1 MPa = 1 N/mm^2.				

A.3 Sampling

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

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

A.4 Hardness test

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

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

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

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

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

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

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

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

A.5 Retests

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

Annex B
(normative)

Minimum elongation values for a test piece with original gauge length $L_o = 4 \times d$

Minimal elongation values are given in Table B.1.

Table B.1 — Mechanical properties measured on test pieces machined from separately cast samples, cast side-by-side samples or cast-on samples — Tensile test piece with original gauge length $L_o = 4 \times d$[5]

Material designation	Relevant wall thickness of the casting	Tensile strength	0,2 % proof strength	Elongation after fracture
		R_m	$R_{p0,2}$	$A_{(L_o=4\times d)}$
	mm	MPa	MPa	%
		min.	min.	min.
ISO 17804/JS/800-10	$t \le 30$	800		11
ISO 17804/JS/800-10RT	$30 < t \le 60$	750	500	7
	$60 < t \le 100$	720		6
ISO 17804/JS/900-8	$t \le 30$	900		9
	$30 < t \le 60$	850	600	6
	$60 < t \le 100$	820		5
ISO 17804/JS/1050-6	$t \le 30$	1 050		7
	$30 < t \le 60$	1 000	700	5
	$60 < t \le 100$	970		4
ISO 17804/JS/1200-3	$t \le 30$	1 200		4
	$30 < t \le 60$	1 170	850	3
	$60 < t \le 100$	1 140		2
ISO 17804/JS/1400-1	$t \le 30$	1 400	1 100	1
	$30 < t \le 60$	1 170	To be agreed between the manufacturer and purchaser	
	$60 < t \le 100$	1 140		

NOTE 1 The properties of castings are not uniform because of the complexity and variation in section thickness.

NOTE 2 With the heat treatment, the specified minimum 0,2 % proof strength values according to this table can be maintained. However, with increasing casting wall thickness, the tensile strength and elongation values will decrease.

NOTE 3 1 MPa = 1 N/mm^2.

The choice of a test piece with a gauge length of $L_o = 4 \times d$ instead of $L_o = 5 \times d$ shall be agreed upon between the manufacturer and the purchaser.

If a test piece with a gauge length of $L_o = 4 \times d$ is used, the dimensions of the test piece shown in Figure B.1 shall be used.

Dimensions in millimetres

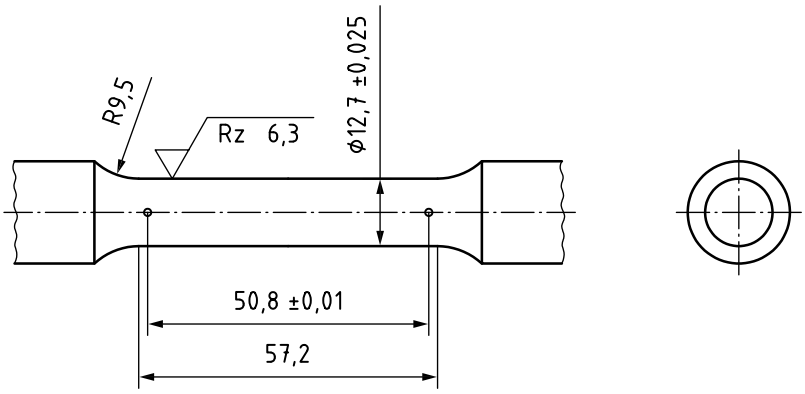


Figure B.1 — Tensile test piece with a gauge length $L_o = 4 \times d$

Table B.2 gives the relationship between the values for elongation to fracture for both test pieces.

Table B.2 — Relationship between elongation values for $L_o = 5 \times d$ and $L_o = 4 \times d$ test pieces

Elongation ($L_o = 5 \times d$) %	Elongation ($L_o = 4 \times d$) %
10	11
8	9
6	7
3	3,5
2	2,5
1	1

The values for elongation using a gauge length of $L_o = 4 \times d$ are calculated according to Formula (B.1):

$$A_{L_o=4\times d} = A_{L_o=5\times d} \times 1{,}047 + 0{,}39 \quad \text{(B.1)}$$

NOTE Values given in Table B.2 have been calculated from a statistically determined regression using values from separately cast test pieces.

Annex C
(informative)

Guidance values for Brinell hardness

Guidance values are given in Table C.1.

Table C.1 — Guidance values for Brinell hardness

Material designation	Brinell hardness range HBW
ISO 17804/JS/800-10	250 to 310
ISO 17804/JS/800-10RT	
ISO 17804/JS/900-8	280 to 340
ISO 17804/JS/1050-6	320 to 380
ISO 17804/JS/1200-3	340 to 420
ISO 17804/JS/1400-1	380 to 480

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

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

Annex D
(informative)

Procedure for the determination of the hardness range

D.1 General

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

The procedure is most applicable to the serial production of castings.

D.2 Procedure

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Annex E
(informative)

Guidance values for tensile strength and elongation after fracture for test pieces machined from samples cut from a casting[4]

Guidance values are given in Table E.1

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

Material designation	0,2 % proof strength $R_{p0,2}$ MPa min.	Tensile strength R_m MPa			Elongation after fracture A %		
		Relevant wall thickness (mm)					
		t ≤ 30	30 < t ≤ 60	60 < t ≤ 100	t ≤ 30	30 < t ≤ 60	60 < t ≤ 100
ISO 17804/JS/800-10/C	500	790	740	710	8	5	4
ISO 17804/JS/900-8/C	600	880	830	800	7	4	3
ISO 17804/JS/1050-6/C	700	1 020	970	940	5	3	2
ISO 17804/JS/1200-3/C	850	1 170	1 140	1 110	2	1	1
ISO 17804/JS/1400-1/C	1 100	1 360	To be agreed between the manufacturer and the purchaser.				

Annex F
(informative)

Unnotched impact test

F.1 Purpose

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

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

F.2 Requirements

The minimum impact energy values for the different material grades shall be as specified in Table F.1.

Table F.1 — Unnotched impact energy values for ausferritic spheroidal graphite cast iron[6][10]

Material designation	Minimum impact energy values at (23 ± 5) °C J
ISO 17804/JS/800-10	110
ISO 17804/JS/800-10RT	
ISO 17804/JS/900-8	100
ISO 17804/JS/1050-6	80
ISO 17804/JS/1200-3	60
ISO 17804/JS/1400-1	35
ISO 17804/JS/HBW400	25
ISO 17804/JS/HBW450	20
NOTE Values obtained from unnotched test pieces tested at (23 ± 5) °C. The values in this table are the average of the three highest values of four separate tests.	

F.3 Sampling

The casting process for the samples shall be agreed between the manufacturer and the purchaser. Impact energy requirements apply only after the test material has been austempered. The impact test pieces should be prepared unnotched with outer dimensions (55 ± 0,6 mm × 10 ± 0,11 mm × 10 ± 0,11 mm) finish machined after heat treatment.

F.4 Test method

The impact test shall be carried out on four unnotched test pieces using test equipment with an appropriate energy to determine the properties correctly.

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

F.5 Retests

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

Annex G
(informative)

Additional information on mechanical and physical properties

Table G.1 gives technical data for ausferritic spheroidal graphite cast irons. Table G.2 gives typical properties of ausferritic spheroidal graphite cast irons for gear design. All properties were determined at ambient temperature, if not otherwise stated.

Table G.1 — Typical properties

Technical data for ausferritic spheroidal graphite cast iron[12][13]		Material designation ISO 17804/JS/					
		800-10 800-10RT	900-8	1050-6	1200-3	1400-1 HBW400	HBW450
Characteristic	Unit	Indicative values for properties[a]					
Compression strength, σ_{db}	MPa	1 300	1 450	1 675	1 900	2 200	2 500
0,2 % proof strength	MPa	620	700	840	1 040	1 220	1 350
Shear strength, σ_{aB}	MPa	720	800	940	1 080	1 260	1 400
0,2 % proof strength	MPa	350	420	510	590	770	850
Torsional strength, σ_{tB}	MPa	720	800	940	1 080	1 260	1 400
0,2 % proof strength	MPa	350	420	510	590	770	850
Fracture toughness, K_{IC}	MPa$\sqrt{m}$	62	60	59	54	50	—
Alternating tension-compression, $\sigma_W = \sigma_{(R=-1)}$[b,e] Mean fatigue strength amplitude, σ_W (standard deviation: approximately 22,3 %)	MPa	272	288	304	312	308	304
Strength ratio, σ_W/R_m approximately 0,50 – 0,000 2 × R_m		0,34	0,32	0,29	0,26	0,22	0,21

NOTE 1 1 N/mm² = 1 MPa.

NOTE 2 Unless otherwise specified, the values given in this table apply to measurements at room temperature.

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

[b] Unnotched – Mean fatigue strength of unnotched specimens (⌀ ≤ 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] For the lower strength grades, the linear expansion coefficient α will be higher.

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

[e] Stress-controlled fatigue tests according to Wöhler.

[f] 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.

EXAMPLE For specimens of 10,6 mm diameter at notch with a circumferential 45° V-notch having a radius of 0,25 mm ($K_t \approx 1{,}7$) the fatigue strength decreases to a value of about 0,68 × fatigue strength of unnotched specimens in spheroidal graphite cast irons with a tensile strength of 400 MPa.