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DEUTSCHE NORM

May 1985

Flake graphite cast iron (grey cast iron)
Properties

DIN 1691

Gußeisen mit Lamellengraphit (Grauguß); Eigenschaften

Supersedes August 1964 edition
and DIN 50 108, January 1967 edition.

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

1 Field of application

In conjunction with the general technical delivery conditions specified in DIN 1690 Part 1, this standard specifies the properties of carbon and low alloy flake graphite cast iron (grey cast iron) in castings manufactured in sand moulds or moulds of comparable thermal diffusivity.

The following characteristics to be considered are distinguished:

a) the tensile strength in separately cast or cast-on (test) samples (see table 1), or

b) the hardness of the material in the castings (see table 3).

2 Concepts

2.1 Flake graphite cast iron (grey cast iron)

Flake graphite cast iron is an iron-carbon casting material, the carbon in which, present as graphite, predominates as flakes.

2.2 Lightweight castings

Lightweight castings as defined in this standard are in general castings with a mass of up to 200 kg.

2.3 Medium-weight castings

Medium-weight castings as defined in this standard are in general castings with a mass of over 200 and up to 1000 kg.

2.4 Heavy castings

Heavy castings as defined in this standard are in general castings with a mass of over 1000 kg.

3 Designation

3.1 Grade designation

The grade designation of flake graphite cast iron as specified in this standard is based on:

a) the minimum value of tensile strength of test pieces taken from separately cast samples, the diameter of the raw casting being 30 mm, or

b) the mean value of Brinell hardness in a wall 15 mm thick, measured at a depth of about 2 mm below the surface of the casting.

3.2 Standard designation

In drawings, on patterns and in the order, the material symbols or material numbers for the characteristic to be considered (see tables 1 and 3) shall be used as follows.

3.2.1 Example with tensile strength as the characteristic to be considered

A flake graphite cast iron with a minimum value of tensile strength of 250 N/mm^2 in the separately cast sample, identified by material symbol GG-25 and material number 0.6025 shall be designated as follows:

Cast iron DIN 1691 – GG-25

or **Cast iron DIN 1691 – 0.6025**

3.2.2 Example with Brinell hardness as the characteristic to be considered

A flake graphite cast iron with a mean value of Brinell hardness of 190 HB for a wall thickness of 15 mm, identified by material symbol GG-190 HB and material number 0.6022 shall be designated as follows:

Cast iron DIN 1691 – GG-190 HB

or **Cast iron DIN 1691 – 0.6022**

4 Information to be given in the order

In addition to the specifications given in DIN 1690 Part 1, the following points are to be observed for flake graphite cast iron.

4.1 Characteristic to be considered

The order shall clearly specify whether the characteristic to be considered is the tensile strength or the Brinell hardness, see subclauses 5.1 and 5.2.

4.2 Verification of the characteristic to be considered

The characteristic to be considered is only to be verified if this is agreed at the time of ordering; otherwise, quality assurance is left to the manufacturer.

4.2.1 Tensile strength

The type of the sample shall be specified in the order, see subclause 5.1, e.g.:

a) test piece G: for separately cast sample;

b) test piece A: for cast-on sample, if the shape of the sample is left to the manufacturer's discretion;

c) test piece K: for type K of cast-on sample;

d) test piece H: for type H of cast-on sample.

4.2.2 Hardness

The order shall specify where the hardness is to be measured, see subclause 5.2, e.g.:

a) at set points on the casting itself, or

b) on cast-on samples.

Continued on pages 2 to 7

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Table 1. **Tensile strength of flake graphite cast iron**

Grade		Wall thickness		Tensile strength R_m [1] Values to be obtained		Anticipated values in the casting [3], [6]	
				in separately cast sample [2]	in cast-on sample [3]	Tensile strength [4] R_m	Brinell hardness [4]
Material		mm		N/mm^2	N/mm^2	N/mm^2	HB 30
symbol	number	over	up to		min.	min.	max.
GG-10	**0.6010**	5 [5]	40	min. 100	–	–	–
GG-15	**0.6015**	2,5 [5]	5	150 to 250	–	180	270
		5	10		–	155	245
		10	20		–	130	225 [7]
		20	40		120	110	205
		40	80		110	95	–
		80	150		100	80	–
		150	300		90 [6]	–	–
GG-20	**0.6020**	2,5 [5]	5	200 to 300	–	230	285
		5	10		–	205	270
		10	20		–	180	250 [7]
		20	40		170	155	235
		40	80		150	130	–
		80	150		140	115	–
		150	300		130 [6]	–	–
GG-25	**0.6025**	5 [5]	10	250 to 350	–	250	285
		10	20		–	225	265 [7]
		20	40		210	195	250
		40	80		190	170	–
		80	150		170	155	–
		150	300		160 [6]	–	–
GG-30	**0.6030**	10 [5]	20	300 to 400	–	270	285 [7]
		20	40		250	240	265
		40	80		220	210	–
		80	150		210	195	–
		150	300		190 [6]	–	–
GG-35	**0.6035**	10 [5]	20	350 to 450	–	315	285 [7]
		20	40		290	280	275
		40	80		260	250	–
		80	150		230	225	–
		150	300		210 [6]	–	–

[1] If verification of the tensile strength has been agreed at the time of ordering, the type of sample shall be specified in the order, see subclause 4.2.
[2] These values relate to samples, the raw casting diameter of which is 30 mm, corresponding to a wall thickness of 15 mm.
[3] Where it has not been possible to make specifications for a particular wall thickness range, this is indicated by a dash.
[4] These values are for information, see subclause 5.1.3.
[5] This dimension is included as the lower limit of the wall thickness range.
[6] These values are guide values.
[7] The values given for the wall thickness range over 10 up to 20 mm, cover also test results obtained on separately cast samples, the raw casting diameter of which is 30 mm.

4.3 Other characteristics

If other characteristics have to be met in addition to the characteristics to be considered, e.g. leak tightness to liquids and gases, these characteristics, the values to be complied with and, where applicable, the relevant test methods shall be agreed at the time of ordering, see subclause 5.3.

4.4 Additional specifications

Where necessary, the areas of castings to which special requirements apply, e.g. with regard to hardness or tensile strength, shall be marked in the drawing and/or on the pattern.

4.5 Documents on materials testing

The nature of the documents on materials testing complying with DIN 50 049 shall be specified, see clause 10.

5 Requirements

Unless otherwise agreed at the time of ordering, the choice of the manufacturing process and the composition of the material shall be left to the casting manufacturer's discretion.

Notes on choice of materials by designers are given in Supplement 1 to DIN 1691.

5.1 Tensile strength as the characteristic to be considered

The tensile strength shall only be verified by a test, if it is specified in the order that either separately cast or cast-on samples shall be manufactured, see clause 4.

5.1.1 Tensile strength in separately cast samples

The values of tensile strength to be obtained in separately cast samples are given in table 1.

Separately cast samples shall be manufactured as the standard samples for lightweight castings, and, unless otherwise agreed, for medium-weight castings also; see clause 2.

5.1.2 Tensile strength in cast-on samples

The minimum values of tensile strength to be obtained in cast-on samples are specified in table 1.

Cast-on samples shall be manufactured as the standard sample for heavy castings; they may also be agreed for medium-weight castings.

In the case of cast-on samples, a distinction is made between types K and H; see subclause 8.2.

The type of the sample shall be specified at the time of ordering, see subclause 4.2.

Because of the closer thermal coupling of the sample with the casting in the case of type K test pieces, the properties of these more closely ressemble those of the casting than do those of type H test pieces.

It should be noted that the minimum value of tensile strength of a grade of cast iron as a function of the wall thickness range is lower for cast-on samples than the minimum value for a separately cast sample.

If, for medium-weight and heavy castings, specified minimum values of Brinell hardness are to be obtained in particular areas of the castings in addition to achieving the tensile strength, for example in order to obtain increased wear resistance on sliding tracks, the values specified in table 2 may be agreed. If in addition, an upper limit of Brinell hardness is required, this shall, for manufacturing and testing reasons, be at least 40 Brinell units above the lower limit specified and shall also be agreed. The areas of the castings for which the Brinell hardness is required shall be marked in the drawing.

Table 2. **Minimum values of Brinell hardness for specified areas of the castings, e.g. sliding tracks, obtained when using chills**

Material		Minimum values of Brinell hardness HB for wall thicknesses mm		
symbol	number	Up to 80	Over 80 up to 150	Over 150 up to (300)
GG-20	**0.6020**	160	150	–
GG-25	**0.6025**	180	170	160
GG-30	**0.6030**	200	190	180
GG-35	**0.6035**	210	200	190

If compliance with values of Brinell hardness at set points of the castings has been agreed, it should be noted that it is not always possible at the same time to obtain the specified minimum values of tensile strength in cast-on samples.

5.1.3 Tensile strength in the casting

The notes on the minimum values of tensile strength and the maximum values of Brinell hardness are given for guidance.

If values are to be obtained at set points of a casting, these minimum or maximum values and the shape and position of the samples, which are to be taken from the casting, shall be agreed at the time of ordering and the relevant points of the casting marked in the drawing.

5.2 Brinell hardness as the characteristic to be considered

The Brinell hardness is specified for preference as the value to be considered, when castings are, for example, to be subjected to abrasive stress or are to be machined at high cutting speeds.

The ranges of Brinell hardness for various wall thicknesses of castings are specified in table 3.

Agreement shall be made at the time of ordering on the areas of the castings where the Brinell hardness is to be verified; in general, not more than two test areas shall be agreed, each of which shall exhibit a largely uniform wall thickness. Areas of the castings with major transitions of cross section or with junctions shall be excluded. In cases of dispute, the wall thickness shall be defined as twice the solidification modulus of the relevant area of the casting; see Supplement 1 to DIN 1691. The relevant areas of the casting shall be marked in the drawing.

When specifying the ranges of Brinell hardness, it should be borne in mind that in table 3 the hardness values given in each case have been assigned to ranges of wall thickness, whilst the agreed test points on the castings have exactly defined wall thicknesses. For this reason, it is possible, on the basis of the actual wall thickness, to agree narrower ranges of Brinell hardness than those specified in table 3. The range of permissible hardness however, for manufacturing and testing reasons, should not be less than 40 Brinell units.

5.3 Other properties

Guide values are given in Supplement 1 to DIN 1691 for other mechanical, physical and technological properties.

If, in addition to the tensile strength and the Brinell hardness, other properties (e.g. leak tightness to liquids and gases) are to be maintained at certain points of the casting, these properties, the values to be obtained and the shape and location of the samples to be taken from the casting shall be agreed at the time of ordering and the relevant areas of the casting shall be indicated in the drawing.

Table 3. **Brinell hardness of castings made from flake graphite cast iron** (values to be met at set test points)

Grade Material		Wall thicknesses mm		Brinell hardness [2] HB 30	
symbol [1]	number	over	up to	min.	max.
GG-150 HB	**0.6012**	2,5	5	–	210
		5	10	–	185
		10	20	–	170
		20	40	–	160
		40	80	–	150
GG-170 HB	**0.6017**	2,5	5	170	260
		5	10	140	225
		10	20	125	205
		20	40	110	185
		40	80	100	170
GG-190 HB	**0.6022**	4	5	190	275
		5	10	170	260
		10	20	150	230
		20	40	135	210
		40	80	120	190
GG-220 HB	**0.6027**	5	10	200	275
		10	20	180	250
		20	40	160	235
		40	80	145	220
GG-240 HB	**0.6032**	10	20	200	275
		20	40	180	255
		40	80	165	240
GG-260 HB	**0.6037**	20	40	200	275
		40	80	185	260

[1] The numerical part of the symbol represents the anticipated value of Brinell hardness in a 15 mm thick wall, rounded to the nearest decimal place. Grades GG-170 HB to GG-260 HB correspond approximately to grades GG-15 to GG-35 in table 1.

[2] The ranges of Brinell hardness shall apply for the wall thickness range specified in each case. Since a casting has a particular wall thickness, it is possible to derive from the relevant hardness range in this table a narrow range of tolerance for Brinell hardness. The hardness range should not however be less than 40 Brinell units, see subclause 5.2.

5.4 Shape and sizes

DIN 1680 Part 1 and Part 2, and in particular DIN 1686 Part 1 shall apply in addition to the general specifications given in DIN 1690 Part 1, for the shape and sizes of castings made from flake graphite cast iron.

In the case of castings made from flake graphite cast iron, shrinkage is generally 1 % of the nominal dimensions. Deviations from this figure can occur, depending on the shape of the casting and the solidification process and also as a result of heat treatment.

6 Production welds

Production welds require the purchaser's approval. The welding process and the filler metals shall be appropriate to the use of the casting in the manner intended.

7 Heat treatment

Castings are generally supplied without having been heat treated.

Heat treatments shall be agreed at the time of ordering, e.g. heat treatments to reduce internal stresses in the casting [1], for hardening, quenching and tempering or for improving machinability.

8 Sampling

If verification of the tensile strength has been agreed at the time of ordering, according to the type, size and application of the castings, the following types of sample shall be manufactured for the tensile specimens specified in DIN 50 109, for which the general tolerances given in DIN 1686 Part 1 shall apply.

8.1 Separately cast samples

The samples, the raw casting diameter of which is 30 mm, shall be poured from the same ladle of metal and cast in moulds made of the same material as far as possible as for the casting itself. Care should be taken to ensure that there is sufficient spacing between the samples in the mould to avoid mutual thermal effects as far as possible. The sample shall only be removed from the mould when its temperature has fallen to below 500 °C.

In the case of lightweight castings with wall thicknesses of less than 10 mm, samples with a raw casting diameter of less than 30 mm may be agreed.

8.2 Cast-on samples

Cast-on samples shall be manufactured as type K or type H cast-on test pieces, see tables 4 and 5 and figures 1 and 2. They shall preferably be cast upright on vertical walls of the castings.

8.3 Samples taken from the casting

The shape and position of the samples to be taken from the casting shall be agreed at the time of ordering and specified in the drawing.

8.4 If castings are to be heat treated, in general, the associated samples shall be heat treated together with the castings.

8.5 A sufficient number of samples shall be provided for retests.

[1] See *VDG-Merkblatt* (VDG Instruction sheet) N 1.

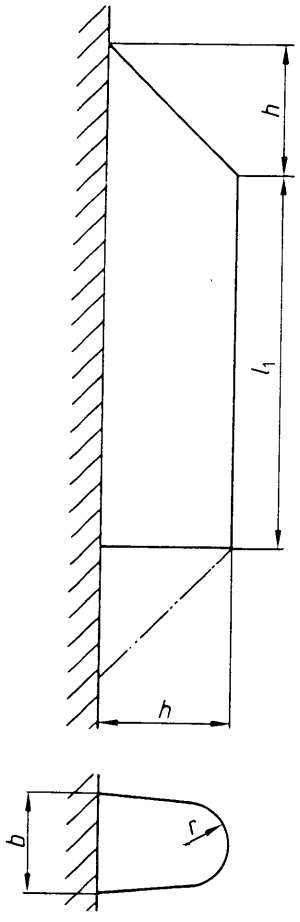

Figure 1. Type K cast-on test piece

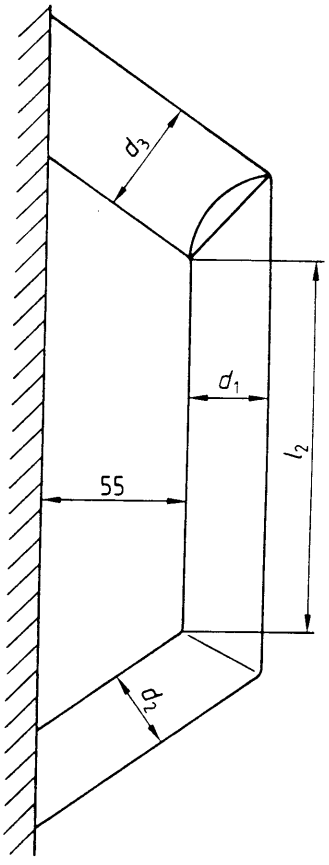

Figure 2. Type H cast-on test piece

Table 4. **Type K cast-on test piece**

Size	Dimensions				Used for wall thicknesses mm
	b mm	h mm	r mm	l_1 mm	
K 30	33	50	15	min. 140	up to 80
K 50	53	70	25		over 80

Table 5. **Type H cast-on test piece**

Size	Dimensions				Used for wall thicknesses mm
	d_1 mm	d_2 mm	d_3 mm	l_2 mm	
H 30	30	30	50	min. 140	up to 80
H 50	50	50	70		over 80

Table 6. **Tensile test pieces**

Wall thickness, in mm		Type of tensile test piece
over	up to	
2,5	10	By agreement, e.g. tensile test piece E as in DIN 50 125
10	20	Tensile test piece with 6 mm nominal diameter as in DIN 50 109
20	30	Tensile test piece with 12,5 mm nominal diameter as in DIN 50 109
30	–	Tensile test piece with 20 mm nominal diameter as in DIN 50 109

9 Testing

9.1 Test methods

The tests shall be carried out if verification of the properties has been agreed at the time of ordering.

The following standards shall apply:

for tensile testing: DIN 50 109 and DIN 50 145,

for hardness testing: DIN 50 351.

Test methods for other properties shall be agreed.

9.2 Tensile test pieces

9.2.1 A tensile test piece complying with DIN 50 109 with a nominal diameter of 20 mm shall be machined from the separately cast sample.

9.2.2 A tensile test piece complying with DIN 50 109 with a nominal diameter of 20 or 32 mm shall be machined from the cast-on sample.

9.2.3 Tensile test pieces as in table 6 shall be machined from samples taken from the casting.

9.3 Hardness testing

9.3.1 Brinell hardness testing shall be carried out as specified in DIN 50 351 with a degree of loading of 30. The test ball diameters given in table 7 shall be used according to the wall thickness.

Table 7. **Diameter of test balls**

Wall thicknesses mm	From 4 up to 6	Over 6 up to 12	Over 12
Diameter of test ball, in mm	2,5	5	10
Test force, in kN	1,839	7,355	29,42

As a preparation for hardness testing, the casting skin shall be removed without generating heat such as would alter the structure.

The surface of the test pieces shall be metallically bright on the test surface, flat, free from defects and of a quality such that the diameters of the hardness test indentation can be satisfactorily measured.

9.3.2 For medium-weight and heavy castings, on which it is difficult to carry out a direct hardness test, a test on cast-on samples, for example as in figure 3, may be agreed.

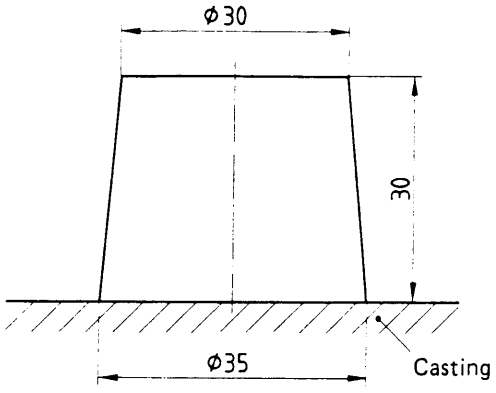

Figure 3. Cast-on sample for testing Brinell hardness

Cast-on test pieces shall only be separated after heat treatment where this applies.

The parting surface should be ground and the hardness measured on it.

9.3.3 For castings on which the Brinell hardness as in DIN 50 351 cannot be measured, some other hardness test method and the required hardness values shall be agreed.

9.4 Retests

The specifications given in DIN 1690 Part 1 shall apply.

10 Documents on materials testing

If a document complying with DIN 50 049 is to be issued, the type of document shall be specified at the time of ordering.

Standards and other documents referred to

DIN 1680 Part 1	Raw castings; general tolerances and machining allowances; general
DIN 1680 Part 2	Raw castings; general tolerance system
DIN 1686 Part 1	Raw castings made from flake graphite cast iron; general tolerances; machining allowances
DIN 1690 Part 1	Technical delivery conditions for castings made from metallic materials; general conditions
Supplement 1 to DIN 1691	Flake graphite cast iron (grey cast iron); general information on the selection of material and design; guide values for mechanical and physical properties
DIN 50 049	Documents on materials testing
DIN 50 109	Testing of flake graphite cast iron (grey cast iron); tensile test
DIN 50 125	Testing of metallic materials; tensile test pieces; rules for their preparation
DIN 50 145	Testing of metallic materials; tensile test
DIN 50 351	Testing of metallic materials; Brinell hardness testing
VDG-Merkblatt N 1 *)	*Vermeiden und Beseitigung von Eigenspannungen in Gußstücken aus Gußeisen mit Lamellengraphit* (Prevention and removal of internal stresses in castings made from flake graphite cast iron) (June 1981)

Previous editions

DIN DVMA 109: 09.33; DIN 50 108: 01.47, 10.50, 01.67; DIN 1691: 04.28, 08.29, 07.33, 08.42, 11.49x, 08.64

Amendments

The following amendments have been made in comparison with the August 1964 edition and DIN 50 108, January 1967 edition:

a) A range has been given for the permissible tensile strength in the separately cast sample.
b) Minimum values have been adopted for the tensile strength in the cast-on sample.
c) Anticipated values of tensile strength and Brinell hardness in the casting have been adopted.
d) Values of Brinell hardness have been adopted for castings.
e) A distinction has been made between the tensile strength and Brinell hardness as the characteristic to be considered.
f) Grade GG-40 and the data on bending strength and magnetic induction have been deleted.
g) The specifications on sampling have been taken from DIN 50 108.
h) The text has been completely revised.

Explanatory notes

The connection with ISO/DIS 185 – 1983, Grey cast iron; classification, can be described as follows.

ISO/DIS 185 – 1983 deals with the characteristics to be considered separately:

- the tensile strength in the separately cast sample;
- the tensile strength in the cast-on sample;
- the Brinell hardness is dealt with in an appendix.

DIN 1691 deals with the values of tensile strength in the separately cast sample and those for the cast-on sample in one table and gives values for Brinell hardness in a separate table, the latter being part of the standard.

The values specified for tensile strength and hardness are identical in both standards; the differences are only of editorial nature.

International Patent Classification

C 22 C 37/00
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UDC 669.131.6 : 621.74.001.66 : 620.1

May 1985

Flake graphite cast iron (grey cast iron)

General information on the selection of material and design
Guide values of mechanical and physical properties

Supplement 1 to DIN 1691

Gußeisen mit Lamellengraphit (Grauguß); allgemeine Hinweise für die Werkstoffwahl und die Konstruktion; Anhaltswerte der mechanischen und physikalischen Eigenschaften

Supersedes Supplement to DIN 1691, August 1964 edition.

In keeping with current practice in standards published by the International Organization for Standardization (ISO), a comma has been used throughout as the decimal marker.

This supplement contains information additional to that given in DIN 1691, but no additional standard specifications.

1 Introduction

Flake graphite cast iron is a material used in many technical fields. For this reason, the requirements regarding the design of castings and their properties are extensive; the masses of such castings varying from a few grammes to more than 100 tonnes and the wall thicknesses also covering wide ranges.

The properties of the castings must meet the technical requirements of a wide range of applications. Examples of these properties are:

- strength properties;
- machineability;
- damping capacity;
- resistance to wear;
- resistance to high temperatures and to thermal shock;
- resistance to chemical exposure;
- thermal conductivity;
- density;
- electrical and magnetic properties.

2 Notes on the selection of material

The properties of flake graphite cast iron are determined by the quantity of precipitated graphite, the graphite form and the structure of the metallic matrix. These are dependent on the manufacturing conditions, the chemical composition, the solidification time and the rate of cooling in the mould. The wall thickness, mass and shape of the casting have a significant effect on these.

For lightweight castings with a mass of up to 200 kg, the tensile strength in the separately cast 30 mm diameter sample may be used for quality control and as a guide to the properties in the casting. Smaller sample diameters may be agreed in the case of wall thicknesses of less than 10 mm. For heavy castings with a mass exceeding 1000 kg, normally cast-on samples shall be used for assessing the properties of the casting. Castings falling in the intermediate range shall be treated as lightweight castings, except in cases where cast-on samples have been specified.

For heavy individual castings, instead of giving the tensile strength for certain parts of the casting, e.g for sliding tracks of machine tools, minimum values of Brinell hardness may be specified as a guarantee against premature wear. To comply with such a requirement, alloying elements, such as chromium, molybdenum, nickel, copper, tin, may be added and/or locally mould materials with a higher thermal diffusivity than sand (chills) may be used.

For a lot of castings, the requirements set chiefly relate to hardness, e.g.:

- in the case of machining at high cutting speeds (transfer lines), maximum values shall not be exceeded;
- if a certain resistance to wear is to be given, the values shall not go below the minimum required values. Requirements regarding hardness in a particular area of the casting shall be agreed on the basis of maximum or minimum values. If narrower ranges of hardness than those specified are necessary, these should cover at least 40 units of Brinell hardness.

3 Notes on the design

Cast iron is a material with almost unlimited design potential, the main reasons for this being:

- a good fluidity and cavity filling capacity of the liquid iron;
- no change or very little change of volume during solidification (± 0,5 % by volume), which means that the necessity for placing gates and risers is minimized and that large feeding lengths are possible.

The properties of the material are significantly influenced by the crystallization period and thus by the mass and wall thickness of the castings. The solidification modulus, i.e. the quotient of the volume and the surface area of the casting is used as the geometrical measure for this. The relationship between the solidification modulus and the solidification time is approximately as follows:

$$\text{solidification time [min]} = K\left[\frac{\text{min}}{\text{cm}^2}\right] \times \left(\frac{\text{volume [cm}^3\text{]}}{\text{surface [cm}^2\text{]}}\right)^2$$
$$= K \times (\text{solidification modulus [cm]})^2$$

The factor K takes into account the casting temperature and the thermal properties of the metal and the mould material.

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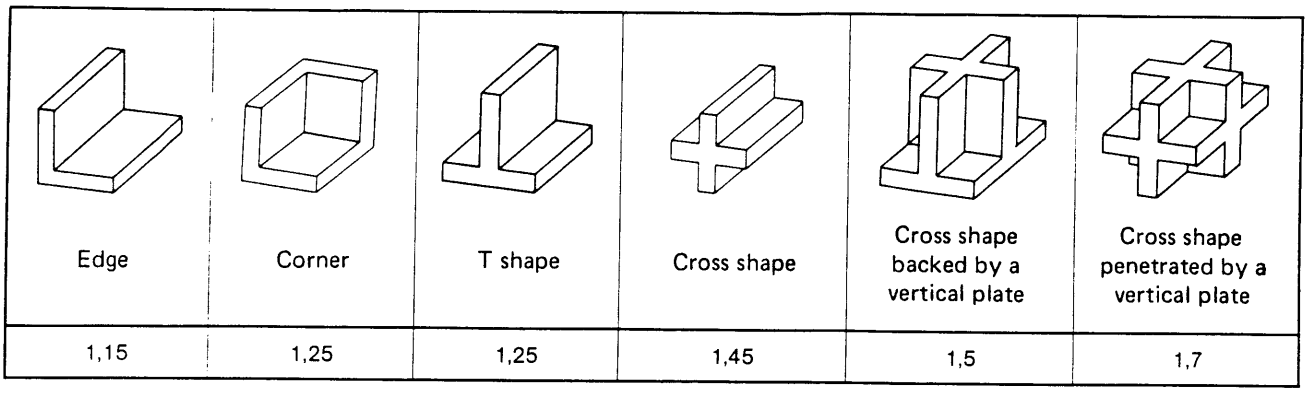

Edge	Corner	T shape	Cross shape	Cross shape backed by a vertical plate	Cross shape penetrated by a vertical plate
1,15	1,25	1,25	1,45	1,5	1,7

Figure 1. Multiplication factor for the modulus in the case of junctions of plates of equal thickness

The heat content is proportional to the volume and the heat exchange area is proportional to the casting surface area [1].

In order to determine the solidification moduli of the castings the castings proper have to be divided up into separate areas:

- in the case of flat areas of the casting, e.g. plates, the modulus shall be taken as half the wall thickness (in cm);
- in the case of bar-shaped areas of the casting, the modulus can be determined from the ratio of the cross-sectional area to the circumference;
- if plates of equal thickness are joined or interpenetrate, the modulus can be estimated by multiplying the plate modulus by the factors given in figure 1.

In the case of junctions of plates of unequal thickness, the following can be expected:

if plates of smaller thickness branch off, the modulus becomes reduced and can even fall below 1,0 if the branches act as cooling surfaces.

The following notes should be observed for the design of castings:

a) A right angle shall be used as far as possible for branches and junctions.

b) In the case of sudden changes in wall thickness (resulting in changes in the modulus) and internal edges, the use of a fillet is advisable.

c) Differences in wall thickness exceeding a ratio of 5 : 1 shall be avoided. In the case of GG-30 cast iron, the ratio should be less than 4 : 1 and in the case of GG-35 cast iron less than 3 : 1.

d) Concentrations of material, e.g. as in the case of cross shapes, should be avoided as far as possible or resolved into staggered T shapes.

4 Relationship between tensile strength and Brinell hardness

Hardness, tensile strength, and also the modulus of elasticity and the shear modulus are determined by the quantity of the graphite flakes, their form and size and by the chemical composition and the structure of the metallic matrix. An increase in one of these parameters generally results in an increase in the measured value of one of the other parameters [2].

Because of the large number of influencing factors, however, the relationship between tensile strength and hardness is not close enough to allow conversion from one parameter into the other, as with non-alloy and low alloy steels, without considerable dispersion.

There is an empirically determined relationship:

$$\text{Brinell hardness} = C\,(100 + 0{,}44 \times \text{tensile strength})$$

The constant of proportionality C [3] can however exhibit a dispersion of more than ± 15 %, see figure 2.

Within a foundry it is however generally possible to maintain the relationship between tensile strength and Brinell hardness within narrow limits, for example in the case of lightweight castings. In the case of heavy castings, deviations from this relationship can occur (when chills on sliding tracks are used, for example) if minimum values of Brinell hardness are to be specified.

5 Dependence of tensile strength and Brinell hardness on wall thickness

The wall thicknesses (moduli) influence the tensile strength and Brinell hardness in the casting, via the solidification and cooling rates. The anticipated values of tensile strength and Brinell hardness are shown in figures 3 and 4 for casting wall thicknesses of 2,5 to 300 mm.

These diagrams do not necessarily provide a basis of agreements but they give a rundown of the relationships. Tensile strength and Brinell hardness are higher in the outer zones of the casting cross section than in the mid zone. The reason for this is the difference in the rate of crystallization in the outer zone and in the mid zone of a casting during solidification of liquid iron in the mould.

6 Guide values of mechanical and physical properties

Guide values of mechanical and physical properties in separately cast samples are given in tables 1 and 2.

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1) For the principles, see Wlodawer, R. *Gelenkte Erstarrung von Stahlguß* (Controlled solidification of cast steel), *Giesserei-Verlag* 1961.

2) A. Collaud. *Giess.-Forsch.* **14** (1954), pp. 709/26 and **15** (1955), pp. 767/99.

3) W. Patterson. *GIESSEREI* **45** (1958), pp. 385/87.

Table 1. **Mechanical properties in a separately cast sample with a raw casting diameter of 30 mm**

Material grade [1]			GG-15	GG-20	GG-25	GG-30	GG-35	Literature
Basic structure			Ferritic/ pearlitic	Pearlitic				–
Tensile strength	R_m	N/mm²	150–250	200–300	250–350	300–400	350–450	DIN 1691
0,1 % proof stress	$R_{p\,0,1}$	N/mm²	98–165	130–195	165–228	195–260	228–285	[1]
Elongation after fracture	A	%	0,8–0,3	0,8–0,3	0,8–0,3	0,8–0,3	0,8–0,3	[2]
Compressive strength	σ_{dB}	N/mm²	600	720	840	960	1080	[1]
0,1% compressive yield strength	$\sigma_{d\,0,1}$	N/mm²	195	260	325	390	455	[1]
Bending strength	σ_{bB}	N/mm²	250	290	340	390	490	[1]
Shear strength	σ_{aB}	N/mm²	170	230	290	345	400	[1]
Torsional strength	τ_{tB}	N/mm²	170	230	290	345	400	[1]
Modulus of elasticity [2]	E	kN/mm²	78–103	88–113	103–118	108–137	123–143	[1]
Poisson's ratio	ν	–	0,26	0,26	0,26	0,26	0,26	[2]
Brinell hardness	HB 30	–	125–205	150–230	180–250	200–275	220–290	DIN 1691
Fatigue strength under reversed bending stresses [3]	σ_{bW}	N/mm²	70	90	120	140	145	[3]
Fatigue strength under reversed tension-compression stresses [4]	σ_{zdW}	N/mm²	40	50	60	75	85	[3]
Fracture toughness	K_{1c}	N/mm$^{3/2}$	320	400	480	560	650	[4]

[1] Grade GG-10 is obtained in some cases by heat treatment to alter the structure, when there are particular requirements with regard to machineability or magnetic properties, and is not included here.
[2] Dependent on the quantity of graphite and the form in which it is present and the mechanical loading.
[3] $\sigma_{bW} \approx 0{,}35$ to $0{,}50 \times R_m$ [3] applies approximately.
[4] $\sigma_{zdW} \approx 0{,}53 \times \sigma_{bW} \approx 0{,}26 \times R_m$ [3] applies approximately.
Torsional fatigue strength at alternating load $\tau_{tW} \approx 0{,}42 \times \tau_{tB}$ [3].
[1] Engineering data on grey cast irons. BCIRA Alv. Birm. 1977.
[2] Nechtelberger, E. *Österr. Gießerei-Institut* (Austrian Foundry Institute). Report A No. 18.670. Leoben 1973.
[3] Hänchen, R. *Dauerfestigkeitsbilder für Stahl und Gußeisen* (Fatigue strength diagrams for steel and cast iron). *Carl Hanser Verlag*, München, 1963.
[4] Speidel, M. O. *Bruchzähigkeit und Ermüdungsrißwachstum von Gußeisen* (Fracture toughness and fatigue crack growth in cast iron), *Z. Werkstofftech.* 12 (1981), pp. 387–402.

Table 2. **Physical properties in a separately cast sample with a raw casting diameter of 30 mm**

Material grade [1]			GG-15	GG-20	GG-25	GG-30	GG-35	Literature
Density	ϱ	g/cm³	7,10	7,15	7,20	7,25	7,30	DIN 1691
Specific heat capacity At 20 to 200 °C At 20 to 600 °C	c	J/(kg · K)	460 535					[1]
Coefficient of thermal expansion At −100 to + 20 °C At 20 to 200 °C At 20 to 400 °C	α	l/(106 · K)	10,0 11,7 13,0					[1]
Thermal conductivity At 100 °C At 200 °C At 300 °C At 400 °C At 500 °C	λ	W/(m · K)	52,5 51,0 50,0 49,0 48,5	50,0 49,0 48,0 47,0 46,0	48,5 47,5 46,5 45,0 44,5	47,5 46,0 45,0 44,0 43,0	45,5 44,5 43,5 42,0 41,5	[1]
Electrical conductivity	ϱ	Ω · mm²/m	0,80	0,77	0,73	0,70	0,67	[1]
Coercive force	H_c	A/m	560 to 720					[1], [2]
Maximum permeability	μ	μH/m	220 to 330					[1], [2]
Hysteresis losses at $B = 1\,T$		J/m³	2500 to 3000					[1], [2]

[1] Grade GG-10 is obtained in some cases by heat treatment to alter the structure when there are particular requirements with regard to machineability or magnetic properties and is not included here.
[1] Angus, H. T. Cast iron: Physical and Engineering Properties. Publ. Butterworths, London 1976.
[2] Dietrich, H. *Giesserei Techn.-wiss. Beih.* **14** (1962) No. 2, pp. 79/91.

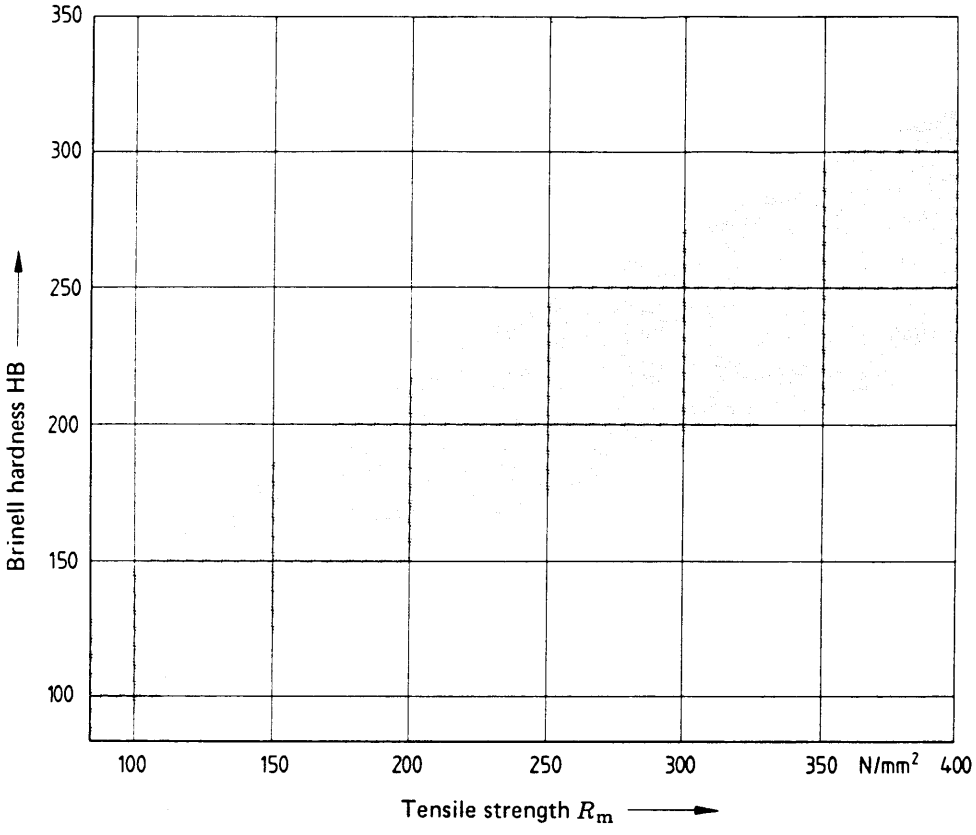

Figure 2. Relationship between tensile strength and Brinell hardness of flake graphite cast iron

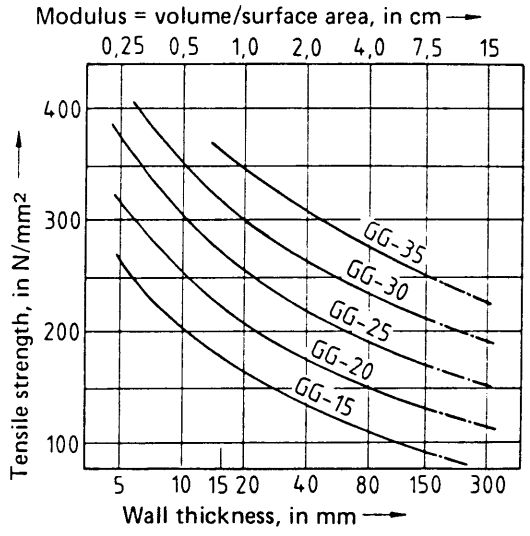

Figure 3. Expected mean values of tensile strength as a function of the wall thickness of castings

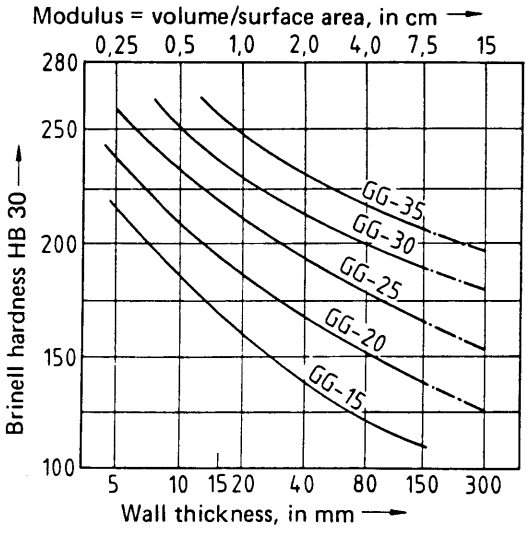

Figure 4. Expected mean values of Brinell hardness as a function of the wall thickness of castings

Previous editions

Supplement to DIN 1691: 08.64

Amendments

The following amendments have been made in comparison with the Supplement to DIN 1691, August 1964 edition:

a) Notes on design and selection of materials have been included.

b) A summary of the mechanical properties in separately cast samples has been included.

c) A summary of the physical properties in separately cast samples has been included.

d) Whilst revising DIN 1691, the contents of this Supplement have been editorially and factually modified to bring it into line with DIN 1691, May 1985 edition.

International Patent Classification

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