UDC 669.131.7 : 669.15-196 : 539.4 : 620.1 October 1977

Cast Iron with Nodular Graphite

Unalloyed and Low Alloy Grades
Properties in Cast-on Test Piece

DIN 1693 Part 2

Gusseisen mit Kugelgraphit, unlegiert und niedriglegiert; Eigenschaften im angegossenen Probestück

1 Scope and application

This Standard applies to the properties of specimens from cast-on test pieces of cast iron with nodular graphite corresponding to Table 1, primarily for casting weights over 2000 kg and/or section thicknesses from 50 to 200 mm (compact castings).

If this Standard is applied to castings with lower weights and smaller section thicknesses [1] and/or with section thicknesses larger than 200 mm separate agreements shall be reached at the time of ordering regarding the cast-on specimen and the properties to be guaranteed.

Cast-on test pieces are more informative about the properties of the castings indicated above under Scope than are separately cast test pieces.

The properties of specimens taken from separately cast test pieces are covered by DIN 1693 Part 1.

2 Properties in cast-on test pieces

Table 1 gives the criteria to be met by the properties of cast-on test pieces. Any additional requirements, such as mechanical properties in specific parts of the casting, are to be agreed at the time of ordering. For this purpose areas of the casting which are severely stressed mechanically and/or required to exhibit special technological or physical properties, are to be clearly identified by the customer (e.g. in drawings).

Table 1. **Properties in cast-on test pieces**

Grade according to DIN 1693 Part 1		Ruling wall thickness of the casting	Thickness of cast-on test piece	Tensile strength R_m	0.2 % yield limit $R_{p\,0.2}$ [1]	Elongation at break A_5	Absorbed energy [2] (DVM specimens) at −20 °C A		Reference data
							average of 3 specimens	individual value	Structure
Symbol	Material number	mm	mm	N/mm² min.	N/mm² min.	% min.	Joule min.		
GGG-40.3	0.7043	from 30 to 60 over 60 to 200	40 70	390 370	250 240	15 12	14 12	11 9	predominantly ferritic
GGG-40	0.7040	from 30 to 60 over 60 to 200	40 70	390 370	250 240	15 12	–		predominantly ferritic
GGG-50	0.7050	from 30 to 60 over 60 to 200	40 70	450 420	300 290	7 5	–		ferritic/ pearlitic
GGG-60 [3]	0.7060	from 30 to 60 over 60 to 200	40 70	600 550	360 340	2 1	–		pearlitic/ ferritic
GGG-70 [3]	0.7070	from 30 to 60 over 60 to 200	40 70	700 650	400 380	2 1	–		predominantly pearlitic

1) Instead of the 0.2 % yield limit it is permissible in the case of the ferritic grade to quote the yield point obtained from the testing machine diagram, due regard being paid to the more restricted process conditions compared with DIN 50 145, as referred to in the Explanations.

2) For other test temperatures the values for absorbed energy are to be agreed.

3) Tensile strength and elongation are not guaranteed if minimum hardness values are specified for reasons of increased wear resistance.

[1] See also AD-Merkblatt W3-2 Gusseisenwerkstoffe; Gusseisen mit Kugelgraphit, unlegiert und niedriglegiert (AD Data Sheet W3-2 Cast Iron Grades; Cast Iron with Nodular Graphite, Unalloyed and Low Alloy) March 1968, obtainable through: Beuth Verlag GmbH and Carl Heymanns Verlag KG, both of Berlin and Köln.

Continued on pages 2 and 3
Explanations on pages 3 and 4

3 Shrinkage

The dimensional changes brought about by shrinkage amount to 1.2 % at the most.

4 Sampling

The general principles according to DIN 1605 Part 1 "Testing of materials; mechanical testing of metals; general and acceptance" apply as appropriate also to the sampling and testing of compact castings of cast iron with nodular graphite.

For determining the properties according to Table 1 cast-on test pieces conforming to Fig. 1 with dimensions according to Table 2 are used. Other forms of test piece are subject to agreement.

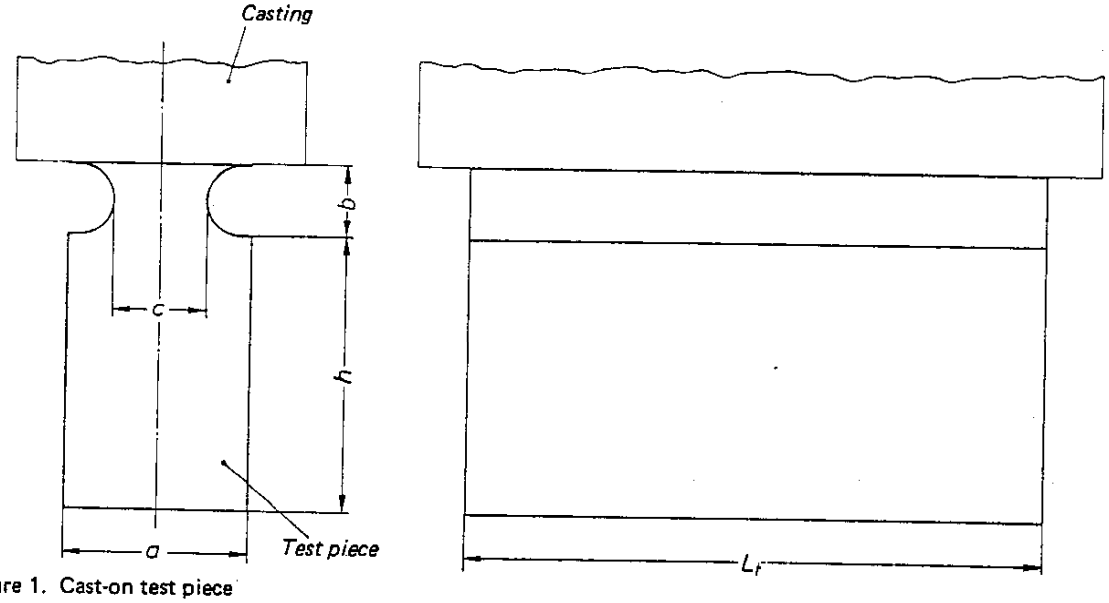

Figure 1. Cast-on test piece

Table 2. Dimensions of the cast-on test piece

Form	Cast-on test piece				
	a mm	b mm max.	c mm min.	h mm	L_t mm
1	40	30	20	40 to 60	125
2	70	52,5	35	70 to 105	125

Factors connected with the design of the casting and with the running and feeding system restrict the possibilities of providing cast-on test pieces. The cast-on test pieces shall not create any additional junctions in the casting which might cause casting defects. Instead, they should preferably be provided as short vertical extensions in the downward direction, for example on flanges and webs. To ensure intimacy of thermal linkage they shall be attached to the casting throughout the test piece length L_t. Any use of explosive cores or mould fillets which is intended to facilitate the detaching process and which goes beyond the arrangement shown in Fig. 1 has to be agreed between manufacturer and purchaser. The ruling dimensions for the necked-in portion are $b = 0.75 \cdot a$ and $c = \frac{a}{2}$. Forms other than this have to be agreed. Unless agreed to the contrary with the purchaser, the decision on position, size and form of the cast-on test pieces will be taken by the casting manufacturer in the light of Tables 1 and 2. The cast-on test pieces shall not be detached until after any heat treatment specified has been carried out. Exceptions to this are only allowed in the case of stress relieving [2] which does not modify the structure.

When the test pieces are cast-on at the side, the specimens shall be taken from the bottom two-thirds.

---

[2] See VDG Merkblatt N 1 „Abbau von Eigenspannungen in Gussstücken aus Gusseisen mit Lamellengraphit" (VDG Data Sheet N 1 "Reduction of Residual Stresses in Castings made of Cast Iron with Lamellar Graphite") obtainable through the library of the Verein Deutscher Giessereifachleute (Association of German Foundrymen), Sohnstrasse 70, 4000 Düsseldorf.

5 Test of properties using cast-on test pieces

5.1 Tensile test

The tensile test is to be performed according to DIN 50 145 using the tensile specimen DIN 50 125 – B 14 x 70.

5.2 Notched bar impact bending test

The notched bar impact bending test is to be performed according to DIN 50 115 on 3 DVM specimens at a test temperature of – 20 °C, see Table 1.

5.3 Number of specimens and test piece dimensions

The number of specimens and the form of the test piece according to Table 2 are to be agreed. At the same time allowance shall be made for specimens for possible repeat tests. In the absence of any agreement the decision is the manufacturer's.

5.4 Repeat tests

5.4.1 If the unsatisfactory outcome of a test is obviously attributable to deficiencies in the testing or to faulty preparation of the specimen, which however must not stem from shortcomings in the material itself, then such result shall be disregarded when reaching a decision on fulfilment of the requirements and the test concerned shall be repeated.

5.4.2 If the results of a proper test fail to satisfy the prescribed requirements a repeat test may be performed. In this case for each unsatisfactory test two further tests are to be carried out on another test piece from the same test unit. Test pieces with unsatisfactory results are to be segregated.

5.4.3 The test unit is deemed to conform to the conditions if both repeat tests turn out satisfactorily. It may be rejected if one of the repeat tests is not good enough.

6 Certificates regarding tests and acceptance

If proof of the tests performed is required, the kind of certification according to DIN 50 049 shall be agreed at the time of ordering.

7 Mechanical strength characteristics in the casting (0.2 % yield limit)

The 0.2 % yield limit values in Table 3 are for guidance purposes when making calculations for castings up to 200 mm section thickness. Where concentrations of material (junction points) occur, the value to be used as the basis for the calculation is not the wall thickness but instead the diameter of the largest inscribable cylinder.

Table 3. **Guidance values for 0.2 % yield limit**

Grade	0.2 % yield limit $R_{p\,0,2}$ N/mm² min. for wall thicknesses			
	up to 50 mm	over 50 up to 80 mm	over 80 up to 120 mm	over 120 up to 200 mm
GGG-40	250	240	230	230
GGG-50	290	280	270	260
GGG-60	360	340	330	320
GGG-70	400	380	370	360

Explanations

It is true that the properties of cast iron with nodular graphite depend less on wall thickness than do those of cast iron with lamellar graphite; from certain casting dimensions upwards, however, and particularly where large hand-moulded castings are concerned, this dependence has to be taken into account.

Thus, where relatively heavy castings and increasing wall thicknesses are involved, the slower progress of crystallization and transformation processes bring about mechanical strength properties which differ from those determined in DIN 1693 Part 1 on separately cast pieces. Various causes account for this:

a) When cooling proceeds slowly the crystallization nuclei arising per unit volume are fewer in number than when solidification is more rapid in areas of smaller wall thickness. This results in relatively large graphite spheres with broader borders of metallic matrix (eutectic cells) surrounding them. In the

regions where these borders are in contact there is a possibility that segregations will occur to a greater extent and will no longer be capable of dispersing sufficiently through diffusion during further cooling. The manufacturer can keep the tendency towards such segregation within limits by choosing a suitable composition and by effective inoculation to increase the number of nuclei, but he cannot avoid this effect entirely.

b) The consequence of the slow progress of the crystallization processes with large wall thicknesses is that the nodular graphite does not always assume the ideal round spherolitic form, instead it often occurs in a form resembling temper carbon or as quasi-flakes. By careful choice of the charge materials and supervision of the treatment process it is possible to keep this technological effect also within limits. Assuming the same kind of basic structure, e. g. ferrite, the consequence of these two effects is that, after transgression of the 0.2 % yield limit which is usually only slightly affected, the ductility of the material is lower. This means that the tensile strength and elongation at break are reduced with increasing wall thickness of the casting.

c) Just as with crystallization, so also is the transformation range traversed more slowly with increasing casting weight and wall thickness. This promotes ferrite formation in the matrix. Pearlite components show a coarser banded structure resulting in reduced hardness and strength. Ferritic basic structures are thus more readily established with the possibility of pearlite borders remaining in the segregation zones. To obtain a predominantly pearlitic matrix it is necessary to use pearlite-stabilizing alloying additions which, however, must not promote cell boundary segregations.

These processes which have to be taken into account in the solidification and cooling of thick-walled and heavy castings call for cast-on test pieces instead of separately cast test pieces. Through the intimate heat linkage with the casting, the cast-on test pieces are better constituted to give information on the mechanical strength properties in the casting. For reasons of standardization, two wall thicknesses, namely 40 mm and 70 mm, are to be used for these cast-on test pieces. The appropriate positioning of these specimens depends on the shape of the castings and on the running and feeding system. Hence only general recommendations can be given for them.

The mechanical strength properties in these cast-on test pieces reflect the properties to be expected in the castings themselves far better than do separately cast test pieces. Nevertheless even they do not necessarily represent the properties of the piece, since it is quite likely that the cooling behaviour of the cast-on test pieces will differ from that of the various regions of the casting.

In a large scale investigation of about 1000 sets of values obtained from specimens which were separately cast, cast-on and taken from the actual castings, the mathematical-statistical method of scatter band analysis was applied for finding relationships which form the basis of this Standard. The objective of this investigation was to disclose guaranteed properties in the casting in relation to those of the cast-on specimen. The amount of material available, however, proved to be still too small to allow guaranteed values of this kind to be defined.

Only for the 0.2 % yield limit, which reveals a relationship with comparatively small scatter in its dependence on section thickness, was it possible to state prospective minimum values in the piece as guidance figures for different wall thickness ranges. They give a 95 % probability of being exceeded and thus provide a useful basis for design. Hence the following alternatives arose:

- delaying standardization until such time as adequate figures for property values are available for defining guaranteed minimum values in the casting;
- or summarizing the present state of knowledge concerning properties in castings made of cast iron with nodular graphite.

The intention is that use of this Standard, which enables the processes of sampling and testing to be unified, will allow experience to be acquired which will facilitate future standardization on a more comprehensive scale.

The following additional information is given regarding the grades quoted in this Standard.

GG-40:

This is a largely ferritic basic grade which makes exacting demands on manufacturing practice. The formation of relatively thick segregation borders has to be prevented for guaranteeing high ductility throughout the casting.

GGG-40.3:

This grade with guaranteed absorbed energy makes exceptionally stringent demands on the charge materials and on melting practice and treatment practice if a largely homogeneous, fine-grained material is to be obtained. When there are large differences in wall thickness in the casting or pearlite components of more than 10 % in the structure, a structure-modifying heat treatment is generally necessary.

GGG-60:

The pearlitic-ferritic basic grade is normally produced in the as-cast condition. It is distinguished by high mechanical strength and good resistance to wear.

GGG-70:

The high 0.2 % yield limit and tensile strength of the GGG-70 grade call for a predominantly fine-banded pearlite matrix in the structure. In view of the slow cooling of thick-section parts in the mould the development of this structure is often only achievable by means of alloying additions with a pearlite-stabilizing action. An alternative approach is subsequent heat treatment at austenite temperatures followed by accelerated cooling through the transformation range. Large wall thicknesses, however, place limits on this method. Sometimes the two methods are also used in combination.

GGG-50:

As regards production practice this grade is not easy to make. With heavy items in particular there may be problems in establishing in different wall thickness regions the same pearlite contents for ensuring both the necessary 0.2 % yield limit and tensile strengths as well as relatively high elongation values. Wherever justifiable from the aspect of casting design, recourse should be had if possible to the basic grades GGG-40 or GGG-60.

The grades GGG-35.3 and GGG-80 have so far not acquired any practical significance where the larger sizes of casting are concerned. They have therefore been left out of account.