

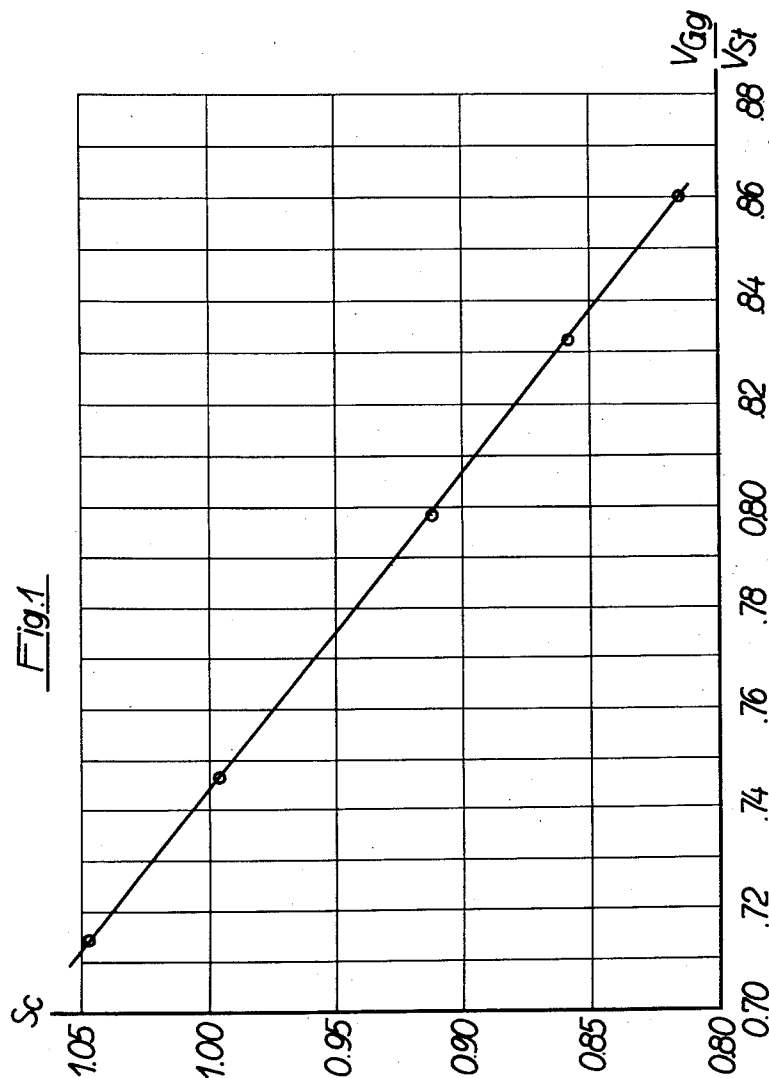
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TESTING METHOD FOR ASCERTAINING THE SATURATION
VALUE OF GREY CAST IRON

3,003,352

Filed Aug. 12, 1957

2 Sheets-Sheet 1



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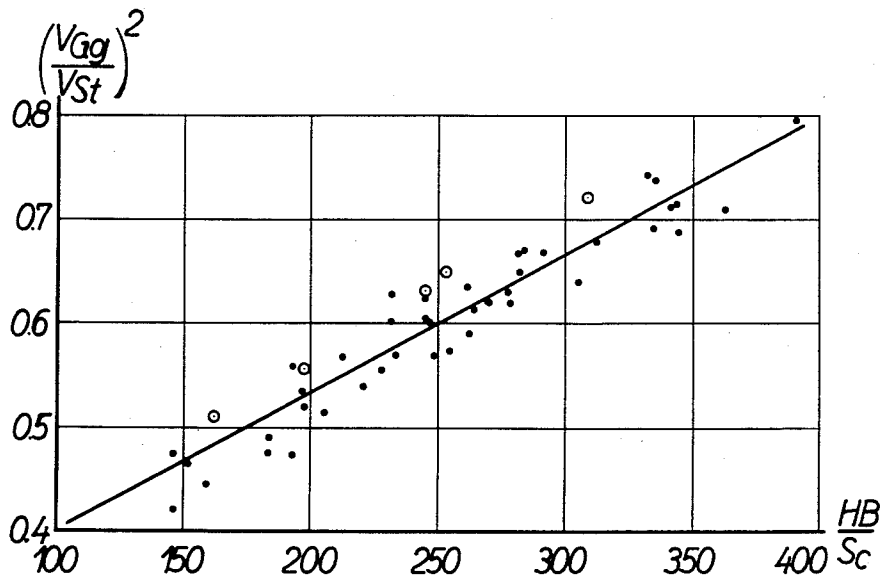
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Fig. 2



• TESTS FOR ESTABLISHING THE GAUGING CURVE

○ CONTROL TESTS

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TESTING METHOD FOR ASCERTAINING THE SATURATION VALUE OF GREY CAST IRON
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The strength properties, the formation of the texture, the segregations and other qualities of cast iron are largely influenced by its chemical composition. The chemical composition is the determining factor whether the cast iron alloys are under-eutectic or super-eutectic or, in other terms, how far the alloy under consideration is remote from the eutectic point. The connection between the chemical composition and the place of the alloy and the corresponding multiple material system is characterized by the so-called saturation value S_c .

$S_c < 1$: under-eutectic alloys

$S_c = 1$: eutectic alloys

$S_c > 1$: super-eutectic alloys

In the case of cast iron the saturation value of the iron commonly known as the carbon equivalent is determined by the contents of carbon, silicon and phosphorus, whilst the other ingredients may be disregarded. The calculation is effected for instance according to the following formula:

$$S_c = \frac{C}{4.23 - 0.312 \cdot Si - 0.275 \cdot P}$$

It is to be ascribed to the comprehensive importance of this coefficient that the metallurgists who have to produce a cast iron type of certain strength properties of a qualified texture formation and a certain behavior of the segregations and pipings or the like have come to prescribing the saturation value on the basis of graphs and values drawn from experiments and expediciencies. Pursuant to this saturation value the analysis is calculated whereby it is indifferent within certain limits whether this saturation value is attained by means of high carbon contents and a low Si-percentage or vice versa.

Maintaining the saturation value prescribed in the course of the melting process gives rise to certain difficulties as the properties of the raw materials are, in general, not exactly known, as furthermore the material during melting is subject to certain modifications caused by carbonisation and by fire loss and the like. It is therefore indispensable to examine the product in order to see whether the saturation value prescribed has really been obtained. For this purpose it is required to carry out a chemical analysis with reference to the elements C, Si, and P for calculation of the saturation value. This proceeding is complicated, costly and time-wasting, requiring a chemical laboratory and some time (more than half-an-hour if the usual implements are used).

The drawback of this long duration of examination is especially disagreeable in the case of the so-called preliminary test. Preliminary tests are supposed to be the tests on materials which are carried out between the tapping of the furnace and casting itself. These samples are ana-

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lysed so as to render possible a modification of the composition of the charge before the definite casting. In the case of cast iron the long duration of analysis would entail unduly long waiting periods causing a heavy cooling down of the charge. This has led to the introduction of wedge samples which are broken and whose fractures permit drawing a conclusion on the saturation value reached. This proceeding of course is far from precise and yields only approximate values.

It is therefore absolutely necessary to develop a process which permits an exact determination of the saturation value within a very short time and which furthermore makes it possible to ascertain the saturation value without having to make use of a chemical laboratory which was hitherto necessary.

In the case of alloys which are only composed of two constituent parts there is an unambiguous connection between the composition and the velocity of sound, so that the velocity of sound permits drawing a conclusion as to the alloy's composition. However this process is not applicable to alloys containing three or four components as one single measuring value, namely the velocity of sound, is not sufficient for determining three or four alloy ingredients. This is the reason why in the case of grey cast iron measuring the velocity of sound will not be sufficient for ascertaining the contents of carbon, silicon and phosphorus.

According to the invention there is a relation between the sound velocity and the saturation value calculated on the basis of the above three components, the said relation depending on the cooling conditions selected.

The advantage of this process consists of the possibility in ascertaining in extraordinarily short time the saturation value which is characteristic for the properties of the cast iron, thus rendering it possible to correct and modify the composition of the cast iron in the course of the melting process.

For the case where the cooling conditions are kept constant the propagation speed of the ultrasonic waves is exclusively dependent on the saturation value. It is therefore possible to establish a graph for a certain cooling method in which their relations are expressed. By means of this graph there is no difficulty in rapidly ascertaining the saturation value of the samples to be examined by simply proceeding to a determination of the ultrasonic speed.

FIG. 1 is a graph of the relationship between the relative ultrasonic speed for grey cast iron and steel and the saturation value, the cooling conditions being constant.

FIG. 2 is a graph of the relationship between the relative ultrasonic speed for grey cast iron and steel and the ratio of the Brinell hardness to saturation value, the cooling conditions being unknown.

A typical example for a process of this kind is given by the following detailed test:

Five cast iron charges of different composition have been cast at a casting temperature of about 1360° in shell moulds for obtaining plates of 85 x 100 x 20 mm. The cooling conditions were kept constant as the casting temperature was constant as well as the mould type and size of the plates.

Three plates were cast from each charge. These plates showed the following charges:

Charge No.	Plate No.	C	Si	Mn	P	S	S _o
1223	1	2.97	1.62	0.62	0.319	0.083	0.816
	2	2.95	1.67	n.b.	0.317	n.b.	0.814
	3	2.96	1.67	n.b.	0.311	n.b.	0.818
	Average						0.816
1226	1	3.05	1.73	0.64	0.317	0.087	0.845
	2	3.08	1.80	n.b.	0.319	n.b.	0.862
	3	3.07	1.77	n.b.	0.319	n.b.	0.854
	Average						0.854
1224	1	3.23	1.65	0.73	0.330	0.093	n.b.
	2	3.30	1.66	n.b.	0.335	n.b.	0.912
	3	3.29	1.69	n.b.	0.330	n.b.	0.911
	Average						0.912
1229	1	3.66	1.52	0.62	0.274	0.087	0.993
	2	3.66	1.55	n.b.	0.271	n.b.	0.997
	3	3.66	1.55	n.b.	0.279	n.b.	0.995
	Average						0.995
1228	1	3.60	2.21	0.63	0.339	0.083	1.043
	2	3.62	2.19	n.b.	0.343	n.b.	1.049
	3	3.60	2.25	n.b.	0.348	n.b.	1.050
	Average						1.047

¹ This sample was taken into consideration not at all as the casting had been defective. N.b.=not calculated.

For determining the propagation speed of the ultrasonic waves, a standard ultrasonic instrument was used. It was an instrument of the type generally used for ascertaining textural irregularities in metals. Additionally this instrument was provided with a measuring device of the wall thickness, said instrument having been calibrated according to the speed of sound in steel.

By means of the measuring device for wall thicknesses, the wall thicknesses of the sample plates were determined. However the value ascertained did not tally with the real wall thickness as the instrument is calibrated to the speed of sound in steel, and as grey cast iron has a different sound propagation speed. Hence the wall thickness is designated as apparent wall thickness. At the same time the real wall thickness at the same point was determined mechanically by means of a calipers. As results from the dependence of the speed of the time and the way in the case of uniform motions the relation of the two propagation speeds is the same as that of the wall thicknesses measured:

$$\frac{v_{Gg}}{v_{St}} = \frac{d_{actual}}{d_{apparent}}$$

v_{Gg} =Sound propagation speed in cast iron

v_{St} =Sound propagation speed in steel

The quotient

$$\frac{v_{Gg}}{v_{St}}$$

represents the relative ultrasonic speed in respect to steel and is easily calculated from the relation between the two wall thicknesses. The relative ultrasonic speed is proportional to the absolute ultrasonic speed and may therefore be used without difficulty for representing the

dependence in respect to the saturation value. The measurements yielded the following results.

Charge No.	Plate No.	Relative Sound Speed $\frac{v_{Gg}}{v_{St}}$
10	1	0.863
	2	0.853
	3	0.863
	Average	0.860
15	1	0.834
	2	0.833
	3	0.829
	Average	0.832
20	1	(¹)
	2	0.799
	3	0.797
	Average	0.798
25	1	0.744
	2	0.746
	3	0.748
	Average	0.746
30	1	0.712
	2	0.717
	3	0.713
	Average	0.714

¹ This sample was not taken into consideration as the casting had been defective.

FIG. 1 shows the average values for saturation and relative sound speed obtained. The dependence of the two values may, in the range investigated, be represented as a straight line with sufficient approximation, this straight line being governed by the following equation:

$$S_c = 2.20 - 1.61 \frac{v_{Gg}}{v_{St}}$$

In order to examine the practical usefulness of the process of the invention sample plates have again been cast out of charges of unknown composition. The saturation value of these plates was first ascertained by means of the ultrasonic instrument and then by chemical analysis. The following is a summary of the results obtained.

Sample No.	Saturation value according to the ultrasonic instrument	Saturation value according to chemical analysis	Deviation
1	0.83	0.83	0.00
2	0.84	0.83	0.01
3	0.87	0.86	0.01
4	0.91	0.90	0.01
5	0.96	0.96	0.00

As is shown by the above, the deviation in the samples between the saturation values determined by the ultrasonic means and by chemical analysis does never exceed the value of .01. This deviation is admissible in any case as experience has proved that the chemical analysis suffers in any case from an irregularity of plus minus .01.

The great importance of the process described consists in the fact that the determination of the saturation value after tapping the melting furnace is carried out in such a short time that the composition of the charge can be carried out before the casting. In this connection it is useful to employ shell molds for casting the preliminary samples as these masks entail the particular advantage that they can be stored for a long time and that they warrant constant cooling conditions. Besides these moulds yield castings of a smooth surface so that the

samples can be subjected to the ultrasonic tests as cast and without having to grind the surface. The dimensions of the sample plates must be selected in such a manner that on the one hand the solidification of the plates takes place within the grey sphere and that on the other hand the wall thickness is not too great so that even with high saturation values the ultrasonic method may be successfully applied.

Determining the ultrasonic speed and calculating the saturation value requires 1-2 minutes. To this space of time should be added the period necessary for casting and cooling the samples which are to be fixed according to the local conditions and are to be taken into account when evolving the gauging curve.

The above described examinations refer to the case of the samples used for determining the saturation value being characterized by the same cooling conditions as the samples which were used for preparing the graph and the same pouring temperature as the known specimens.

In all the cases however in which the cooling conditions are unknown it is necessary to take into consideration a further value permitting drawing a conclusion on the cooling conditions. A value of this kind is for instance the Brinell hardness (HB) which for the same saturation value is all the higher the more rapidly the cast iron has been cooled down.

As described below all these relationships have been subjected to a detailed examination. The plates cast were not only of a different chemical composition but also of a different wall thickness so that the cooling conditions showed great differences. According to the usual casting conditions moulding sand was used for the plates and the casting was effected without drying the moulds. The pouring temperature was maintained constant. Out of 16 charges of different composition 3 plates each were cast of a different thickness which had been formed in a moulding box and which were connected with each other by means of a joint pouring system. These samples were used for ascertaining the chemical compositions, the Brinell hardness HB 30/5 and the relative ultrasonic speeds

$$\frac{v_{Gg}}{v_{St}}$$

The following table is a summary of the results:

Sample No.	chem. analysis					S _c calculated according to formula S.1	Wall thickness					
							6 mm.		15 mm.		35 mm.	
	C	Si	Mn	P	S		HB 30/5	$\frac{v_{Gg}}{v_{St}}$	HB 30/5	$\frac{v_{Gg}}{v_{St}}$	HB 30/5	$\frac{v_{Gg}}{v_{St}}$
1	2.81	1.17	0.57	0.070	0.034	0.73	432	n.b.	426	n.b.	250	0.843
2	2.77	2.32	0.56	0.069	0.034	0.79	272	0.817	242	0.800	209	0.784
3	2.74	3.38	0.56	0.068	0.033	0.87	245	0.803	213	0.792	168	0.753
4	2.71	4.24	0.55	0.067	0.033	0.94	237	0.757	179	0.722	137	0.690
5	2.97	0.86	0.54	0.107	0.024	0.76	488	n.b.	408	n.b.	256	0.860
6	2.94	2.04	0.53	0.106	0.023	0.82	255	0.824	221	0.776	205	0.788
7	2.90	3.27	0.52	0.104	0.023	0.91	238	0.796	194	0.754	167	0.702
8	2.87	4.40	0.52	0.102	0.023	1.01	208	0.717	161	0.665	148	0.591
9	3.13	0.76	0.51	0.109	0.027	0.79	489	n.b.	442	n.b.	287	0.807
10	3.12	1.21	0.50	0.108	0.027	0.82	280	0.845	227	0.793	214	0.767
11	3.08	2.41	0.50	0.107	0.027	0.89	248	0.775	220	0.786	203	0.744
12	3.04	3.53	0.49	0.106	0.026	0.98	234	0.753	217	0.733	180	0.685
13	3.27	0.98	0.55	0.123	0.023	0.84	482	n.b.	329	0.892	195	0.798
14	3.25	1.56	0.54	0.123	0.023	0.87	249	0.818	214	0.778	195	0.776
15	3.19	2.85	0.53	0.121	0.022	0.96	225	0.755	190	0.721	146	0.682
16	3.16	3.82	0.53	0.120	0.022	1.05	207	0.731	158	0.684	150	n.b.

N.b.=samples not taken into consideration, the 6 mm. samples Nos. 1, 5, 9, 13 and the 15 mm. samples 1, 5, 9 had solidified white. The 35 mm. sample No. 16 failed in the ultra-sound experiment.

The exploitation of the measuring results has shown that the relatively simple presentation may be arrived at when plotting the values

$$\left(\frac{v_{Gg}}{v_{St}}\right)^2 \text{ against } \frac{HB}{S_c}$$

as shown in this case the dependence is linear.

For practically applying this methods first

$$\frac{v_{Gg}}{v_{St}}$$

is determined in the manner described above, then the graph according to FIG. 2 is used for ascertaining the value

$$\frac{HB}{S_c}$$

Finally, on the basis of the Brinell hardness measured the value of saturation value is calculated. However the latter calculation may be replaced by adding a suitable nomogram to the graph of FIG. 2.

For checking the graph with reference to samples made from other castings the relative ultrasonic speed was determined by means of the ultrasonic instrument and the quotient

$$\frac{HB}{S_c}$$

was calculated on basis of the chemical analysis and the Brinell values measured. The results have been separately entered in FIG. 2 from which it may be gathered that they do not exceed the spreading sphere. The samples used in this connection had been made under entirely different conditions from the samples which had been used for making the graph, for instance a part of the samples have been cast in shell molds

On account of the flat development of the graph and the lack of precision of the Brinell measurements this determining method is considerably less accurate than the method described above.

Various embodiments of the invention may be employed within the scope of the accompanying claims.

What is claimed is:

1. A method of determining the degree of saturation of grey iron, which comprises forming by casting a plurality of grey iron test specimens of different chemical composition at a constant pouring temperature, cooling said specimens at the same rate, chemically analyzing said grey iron test specimens to determine the degree of saturation of each specimen, subjecting each of said specimens to ultrasonic impulses to determine the apparent thickness of each of said specimens, producing a graph by plotting the quotients obtained by dividing the actual

thickness of said grey iron test specimens as determined by mechanical means by the apparent thickness against the saturation value of said grey iron test specimens and drawing a substantially straight line through the plotted points, and subjecting a grey iron specimen having an unknown degree of saturation to ultrasonic impulses to determine the apparent thickness of said specimen, said

unknown specimen being poured at the same temperature and cooled at the same rate as said grey iron test specimens, said apparent thickness then being divided into the actual thickness of said unknown grey iron specimen as determined by mechanical means and the resultant quotient located on said graph to establish the corresponding saturation value of said unknown grey iron specimen.

2. A method of determining the degree of saturation of grey iron, which comprises chemically analyzing a plurality of grey iron test specimens of different composition for the degree of saturation, subjecting each of said specimens to a hardness testing device calibrated to the Brinell hardness scale to determine the Brinell hardness of each of said specimens, subjecting each of said specimens to ultrasonic impulses to determine the apparent thickness of said specimens, producing a graph by plotting the quotient obtained by dividing the degree of saturation of each specimen into the Brinell hardness thereof against the square of the quotient obtained by dividing the actual thickness of each of said specimens as determined mechanically by the apparent thickness and drawing a substantially straight line through the plotted points, subjecting a specimen having an unknown degree of saturation to a hardness testing device calibrated to the Brinell hardness scale to determine the Brinell hardness of the specimen, and subjecting said unknown specimen to ultrasonic impulses to determine the apparent thickness of said specimen, said apparent thickness then being divided into the actual thickness of said specimen and the resultant quotient squared and located on said graph to determine the saturation value of said specimen using the previously determined Brinell hardness thereof.

3. A method for determining the degree of saturation

of a grey iron specimen, comprising the steps of forming by casting a plurality of grey iron test specimens of varying chemical composition with said specimens being poured at the same temperature, cooling said specimens at the same rate, chemically analyzing said grey iron test specimens to determine the degree of saturation of each, subjecting each of said specimens to ultrasonic impulses to determine the apparent thickness thereof, the degree of saturation of each of said specimens then being related to the quotient obtained by dividing the apparent thickness of each specimen into the actual thickness to establish an empirical relationship between the saturation value and the said quotient, and subjecting an unknown grey iron specimen poured at the same temperature as said test specimens and cooled at the same rate to ultrasonic impulses to determine the apparent thickness thereof, said apparent thickness then being divided into the actual thickness of the unknown specimen and the resulting quotient used in said previously established empirical relationship to determine the saturation value of said unknown specimen.

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