

MAGNETIC TESTING OF STRUCTURE OF THE CAST-IRON PRODUCTS: POSSIBILITIES AND RESULTS

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This report considers the problem of non-destructive testing in metallurgy. In the paper, the problems of controlling the structure of casting products are analyzed, which can be solved using magnetic parameters of the casts. Recommendations on application of the testing means are provided.

Introduction.

Cast-iron is one of the most widely used and promising technological casting materials. Disruptions of the technological processes in production lead to unacceptable variations in the properties of casting products. To guarantee the conformance of the casting structure with the demanded one, the non-destructive testing methods can be employed. Diversity of the cast-iron structures leads to a great number of tasks and methods for the structural testing.

The aim of this work is to generalize the basic principles of magnetic testing of structure of the cast-iron products.

Magnetic testing of cast-iron products is based on the differences in magnetic properties of structural components of the cast-iron. The results of investigations [1, 2] of the variation ranges of the coercitive force H_C , residual magnetization M_R , and saturation magnetization M_S for white (WC), gray (GC), malleable (MC), and high-strength (HC) cast-irons at different structures of metallic matrices are summarized in the Table.

Table

Magnetic properties of structural components of the cast-iron.

Type of cast-iron	Type of metallic basis	H_C , kA/m	M_S , kA/m	M_R , kA/m
White cast-iron (WC)		1.04 – 1.28	1035	400 – 440
Gray cast-iron (GC)	Ferrite	0.2 – 0.4	1433	240 – 440
	Perlite	0.56 – 1.06	1393	320 – 560
High-strength cast-iron (HC)	Ferrite	0.12 – 0.2	1513	240 – 480
	Perlite	0.4 – 0.88	1473	400 – 640
Malleable cast-iron (MC)	Ferrite	0.12 – 0.2	1433	440 – 560
	Perlite	0.4 – 0.88	1393	480 – 600

The elaborated methodology [3] allows to calculate the residual magnetization M_d of a casting product, magnetized in an open magnetic circuit by the field of intensity H_e , using H_C , M_S and M_R of the material, and the demagnetization factor N .

An overview of the published data reveals that there is no relationship between the amount of carbon and the magnetic properties of cast-iron, because not the amount, but the state of the carbon in the cast-iron has the deciding influence on the magnetic properties.

GC has the highest H_C and the lowest μ_m and M_S . At increase of graphitization, H_C drops and μ_m grows, especially at decomposition of the last residua of the cementite. This can be accounted for by the increased soft magnetic component in the cast-iron structure (the ferrite) and the decreased inner tension due to smaller structural microtensions induced by graphite than by cementite. Investigations of the influence of the shape of magnetic inclusions have revealed [1, 2] that compact inclusions lead to magnetically softer cast-iron. For this reason GC and MC, which have spherical or flaky shape of graphite inclusions, have larger μ_m and smaller H_C compared to HC with the same metallic base. Diversity of the chemical compositions of cast-irons causes fluctuations of their magnetic characteristics. Nevertheless, we can establish an unambiguous dependence of H_C and μ_m on the degree of graphitization.

Discrimination of cast-irons with different structures by measuring their magnetic properties can be recommended in the following basic cases.

The white cast-iron can be reliably distinguished from cast-irons of all other types by measuring either H_C or M_d . These parameters of the white cast-iron and ferrite cast-irons of other types differ by a factor 3 to 10, which practically excludes their confusion at testing. Differences in H_C and M_d of WC and perlite MC and HC are also sufficient for their reliable sorting (factor 1.2 - 3.0). Practice of the magnetic testing of quality of annealing the products from WC to MC is one of the most successful and reliable applications of the magnetic non-destructive testing [3, 4, 6]. Moreover, in the magnetic fields not bringing the casting products with a high N to the technical saturation, we observe a higher (by 20-30%) sensitivity of M_d of the products to the structure of their material, than at magnetization to saturation [8] (Fig.1).

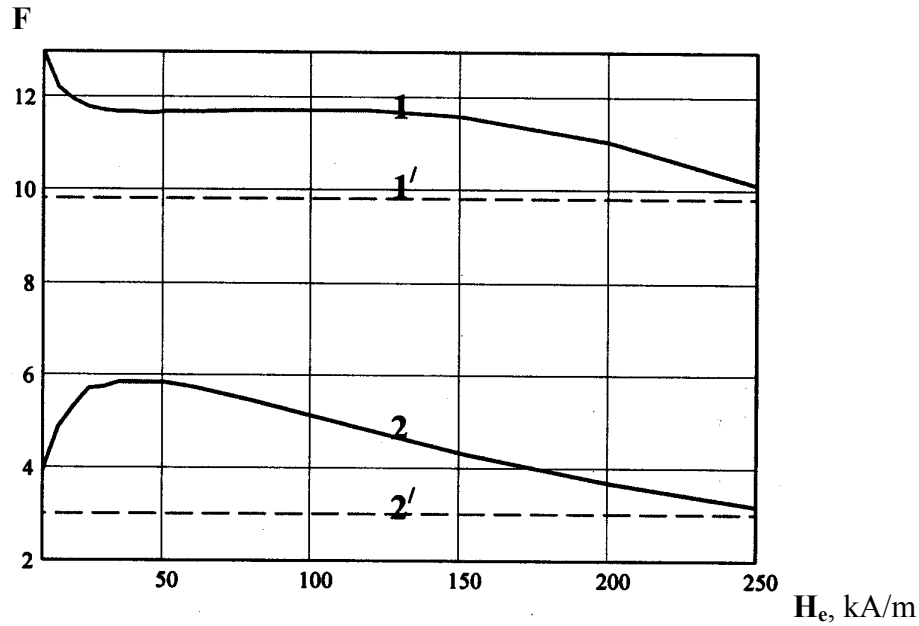


Figure 1. Computations outcome [8] for dependence of the ratio F of residual magnetization M_d of casts "nippel 1¼" of WC to M_d of the same casts of ferritic MC (1) and HC (2) (magnetic parameters are average values from the Table) on the intensity H_e of magnetizing field. 1', 2' -- F after magnetization of the casts in the field $H_e = 1000$ kA/m.

Based on variations in H_C or M_d , the perlite or ferrite cast-irons of all types can be separated from each other. The problem of determining the quantitative ratio of the perlite to ferrite content in casting products with high N is solved in the device MAKSI based on measuring M_d (Fig.2) [9].

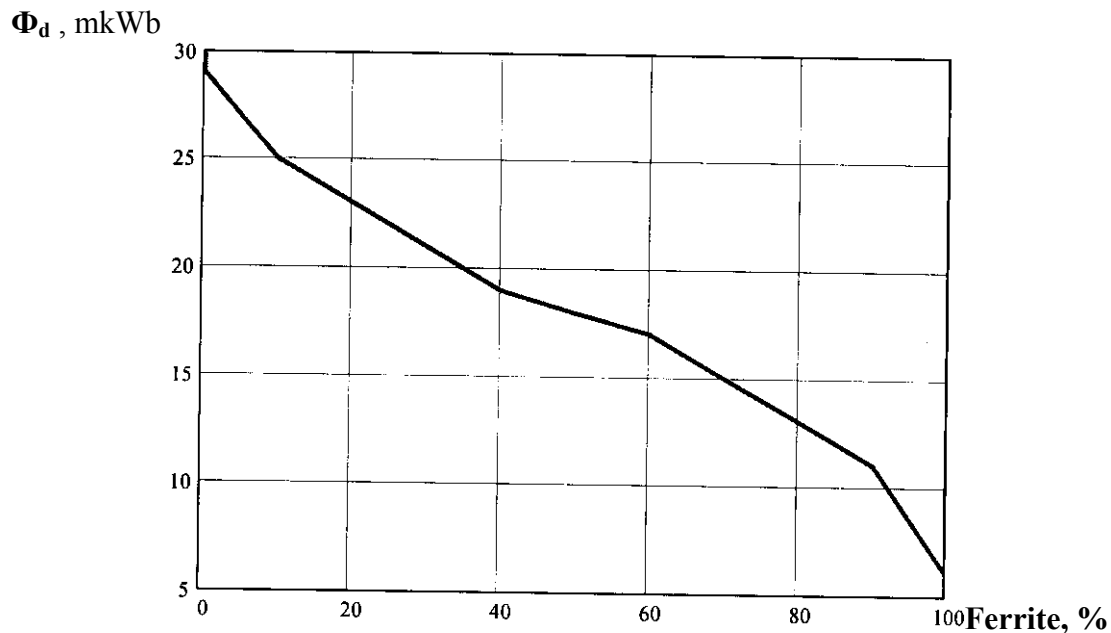


Figure 2. Dependence of residual magnetic flow Φ_d in an annealed cast "nippel 1¼" of MC after magnetization in a field 46 kA/m on the ferrite content in the metallic matrix of the cast.

When solving the task of assessing the quantitative ratio of perlite to ferrite content in HC, one must take into account [1 – 3], that increase in H_C , characteristic for increase of perlite content in the metallic matrix of a cast-iron, can also be caused by increase of the percentage of lamellar ferrite inclusions in the cast-iron with globular graphite. In [10] it is shown that at the same shape of the graphite inclusions, the variation of the perlite content in the metallic matrix of HC and GC from 0 to 100% leads to a factor 2.8 increase in indications Φ_d and ∇H of the devices MAKSI and MS [3, 4, 6, 7], which are proportional to M_d of the casting products. The values of the parameters Φ_d and ∇H for the samples with an HC structure are on average 1.6 times smaller than for the products with a GC structure at the same ratio of perlite to ferrite. The obtained results, along with the data summarized in the Table on the possible ranges of variation of the magnetic parameters of cast-irons with different structures, allow to provide the presented on the Fig. 3 estimation of variation of the H_C for the casting products made of HC (1) and GC (2) at variation of the perlite to ferrite ratio in their metallic matrix.

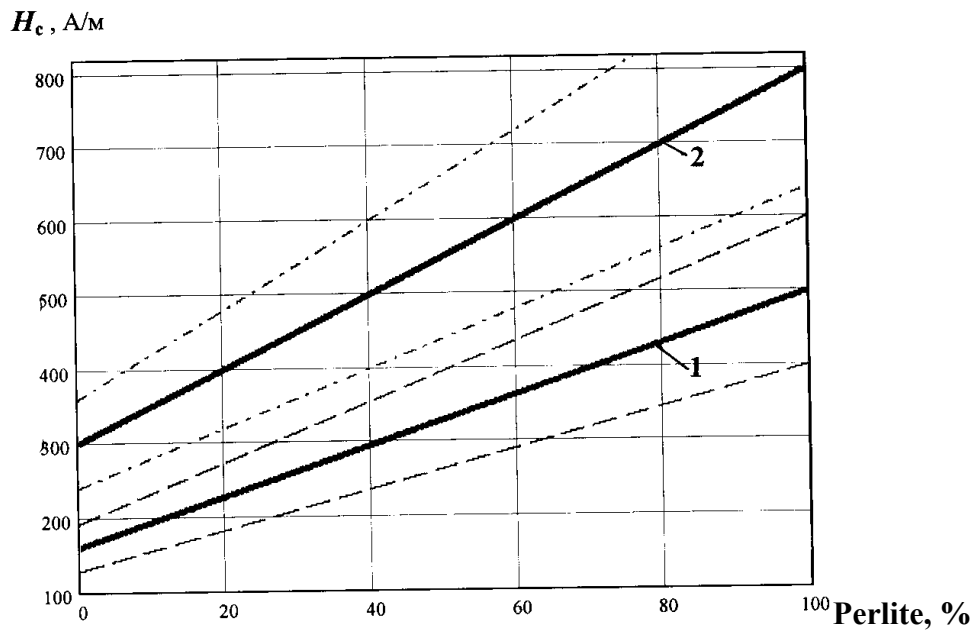


Figure 3. Dependence of the coercive force H_C of GC (1) and HC (2) on the pearlite content in the metallic matrix. Estimation is based on the results of the former investigations [10]. Dash and dot-dash show the ranges of the possible H_C variation on the basis of the data in the Table.

If the spherical shape of the graphite inclusions is guaranteed, the measurement of the coercively dependent magnetic parameters Φ_d and ∇H can be used to grade the casts of GC upon quantitative content of pearlite in their metallic matrix, as has been shown in production. The pearlite content is known

to effect the machinability [11-13] and hardness [14] of the casts (Fig.4).

Measurement of the coercively sensitive magnetic parameter ∇H also guarantees [14] the quantitative control of hardness of casts of HC without surface cleaning (Fig. 5).

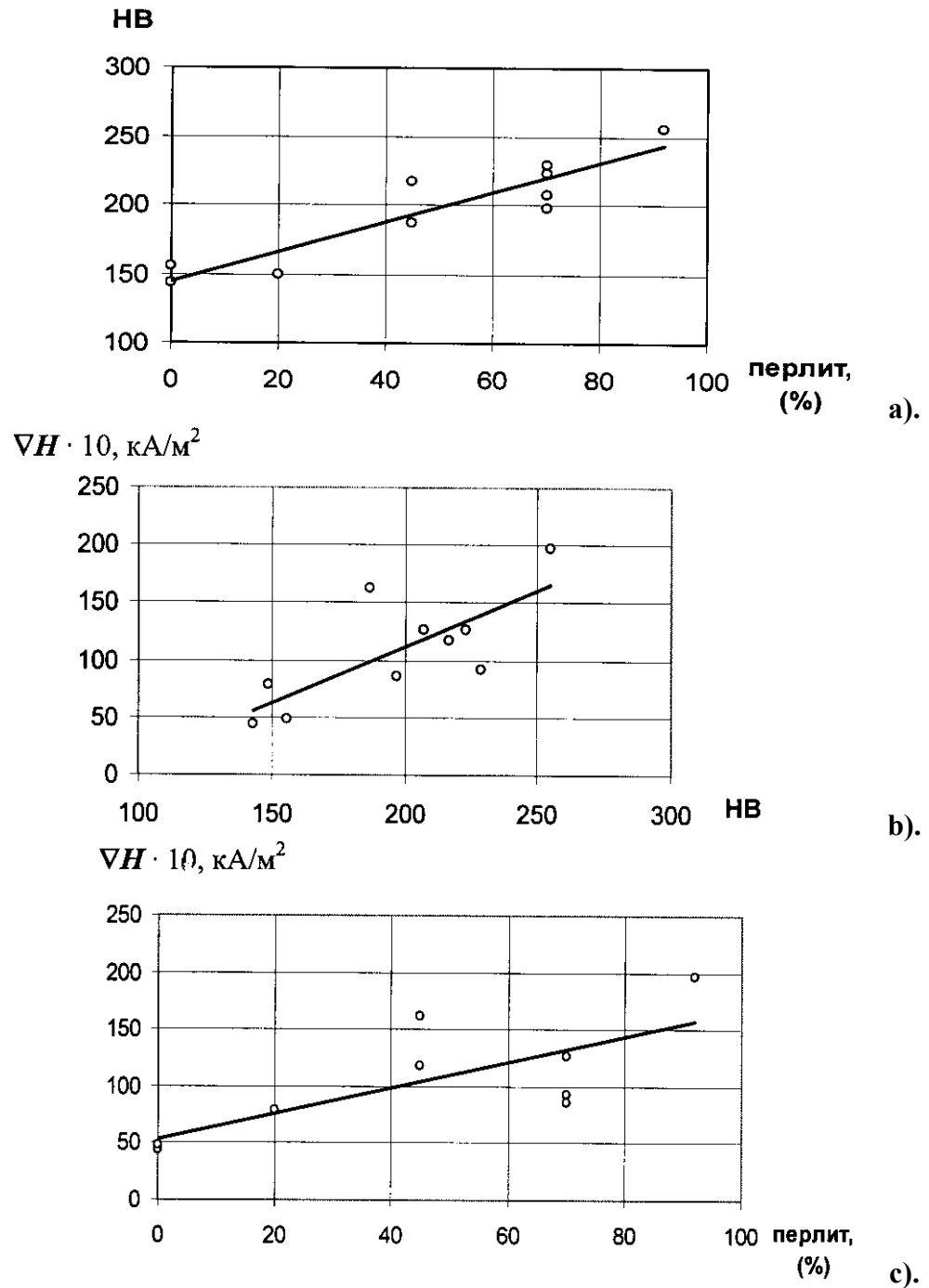


Fig.4 Interdependence between the hardness HB and perlit content in casts of GC (a), and dependence of the display ∇H of the device “Sorter magnetic MS” on hardness HB (b) and perlit content (c) in casts with GC structure.

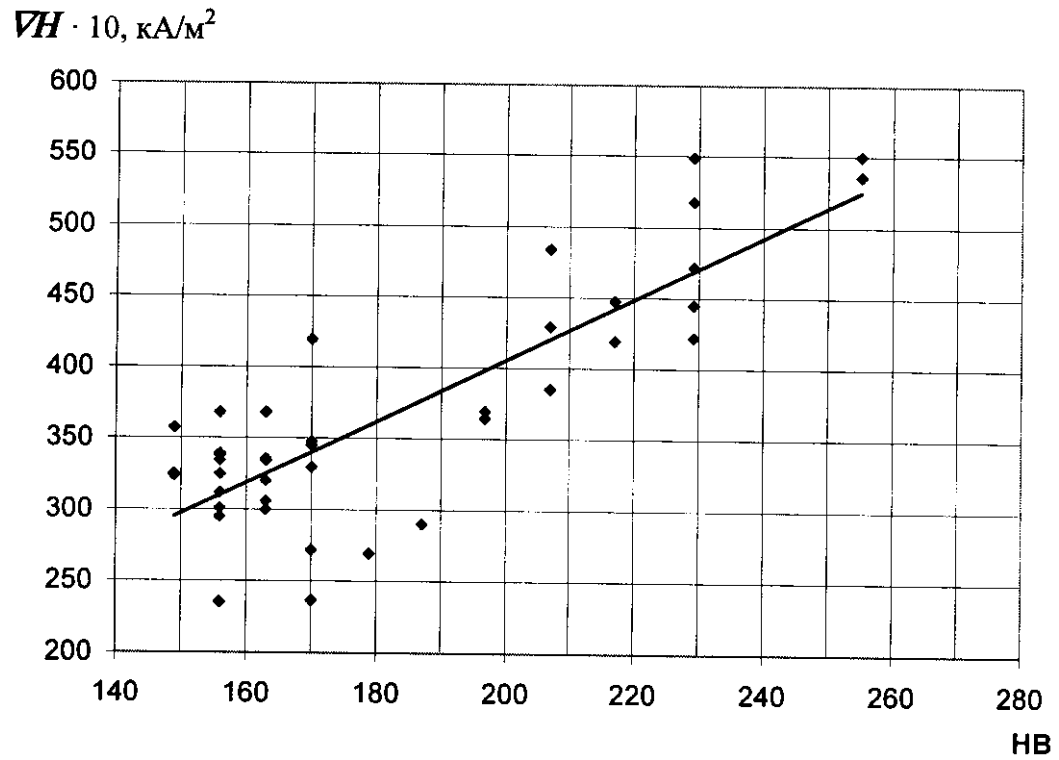


Fig.5 Dependence of display ∇H of the device “Sorter magnetic MS” on hardness HB of the casts of HC.

Recommendations on use of the testing means. Magnetic testing of structure of cast-iron foundries in many cases can be based on the difference of their coercive force H_C . Devices are widespread which employ indirect measurements of H_C : using the demagnetization current in attached magnetic devices [15], the field of the residual magnetization after magnetizing the products according to the "point pole" method [16], the residual magnetic flow Φ_d in the product [17].

A recent realization of the "point pole" method is put into practice in the device “Sorter magnetic MS-1” (Fig.6) [14, 18, 19].



Fig. 6 Appearance of the device “Sorter magnetic MS”

For testing mass lots of small-sized cast-iron foundry products, highly-productive devices must be used, which are based on measuring the residual magnetic flow Φ_d in the controlled casts during their motion. Optimal for the testing is the device «The magnetic analyzer of quality of steel items MAQSI-P (portable)» (Fig.7) [3, 4, 6, 7, 9, 11 – 13, 17], which is used at the Minsk plant for heating equipment and a number of iron foundry and machine building enterprises in Russia.

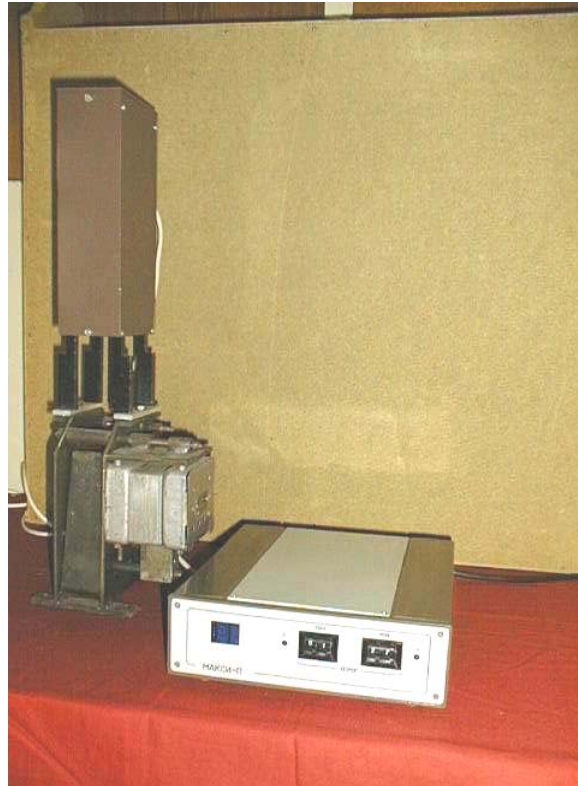


Fig.7 Appearance of the device MAQSI-P (portable).

Conclusions. Sorting of cast-iron foundries with different structure based on measuring their magnetic parameters can be recommended for:

- sorting WC from cast-irons of all other types (including quality control of annealing WC to MC, control of presence of chill on the surface of HC casts);

- grading perlite and ferrite cast-irons of all types from each other (the possibility exists to qualitatively estimate the relation of perlite to ferrite content in MC and GC);

- control of the shape of graphite inclusions in cast-irons at a fixed structure of the metallic matrix. As a simultaneous change in the structure of the metallic matrix and the occurrence of lamellar graphite are possible in GC, a confident separation of ferrite GC from HC is feasible. To grade the perlite GC from the ferrite HC, a simultaneous measurement of H_C and of the sound speed have to be

performed.

- for control of the local structure of sections of big-volume casts, recent modifications of coercimeters of different types can be recommended, for instance the device “Sorter magnetic MS-1”, and for structural sorting of mass lots of small-sized cast-iron foundry -- the device “MAQSI-P (portable)”.

The scientific state of the arts allows to forecast the possibility to apply the magnetic methods for the non-destructive control of heat treatment regimes, of the chemical, structural and phase composition, mechanical properties of cast-iron products. The instrumental implementation of the methods allows to conduct the monitoring in the factory workshops and laboratories.

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