TECHNICAL REPORT

ISO/TR 945-2

First edition
2011-01-15

Microstructure of cast irons —

Part 2:
Graphite classification by image analysis

Microstructure des fontes —

Partie 2: Classification du graphite par analyse d'image

Reference number
ISO/TR 945-2:2011(E)

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Published in Switzerland

Contents

Page

Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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.

ISO/TR 945-2 was prepared by Technical Committee ISO/TC 25, *Cast irons and pig irons*.

ISO 945 consists of the following parts, under the general title *Microstructure of cast irons*:

— *Part 1: Graphite classification by visual analysis*

— *Part 2: Graphite classification by image analysis* [Technical Report]

Introduction

Image analysis, as well as other testing methods, is part of the general or specific assessment of the quality of castings to be agreed between the manufacturer and purchaser at the time of acceptance of the order.

The characterisation of the graphite particle shape in cast irons is often made visually, using the reference sketches of ISO 945-1. The procedure described in ISO 945-1 has an inherent subjective character that can be overcome by using image analysis and appropriate computer software.

Microstructure of cast irons —

Part 2: Graphite classification by image analysis

1 Scope

This part of ISO 945 deals with the two-dimensional characterisation of graphite form and size in cast irons.

A standard method for determining graphite form by image analysis had not been developed at the time of this report, but several methods are in use in the industry. The purpose of this part of ISO 945 is to give an illustration of what is possible and to suggest ways in which the technique might develop in the future.

This part of ISO 945 does not apply to the graphite distribution of grey (lamellar graphite) cast iron as defined in ISO 945-1.

This part of ISO 945 describes procedures used to carry out image analysis of graphite form and size and provides a method of comparison to the results obtained using visual analysis techniques.

It does not specify any particular mathematical description of the graphite forms but provides a means for comparison.

NOTE A mathematical description of graphite form is given in ISO 16112. Other mathematical descriptions of graphite forms and information on technical research are given in the Bibliography.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
maximum Féret diameter
maximum length of an object whatever its orientation

NOTE This dimension applies to all graphite forms.

2.2
roundness
area of the graphite particle divided by the area of the circle whose diameter is the maximum Féret diameter of the same graphite particle (X)

NOTE The calculation of roundness is shown in Figure 1.

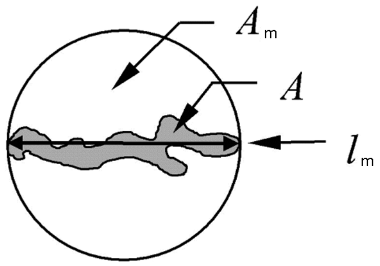

Figure 1 — Roundness

Roundness = $A/A_m = 4A/\pi \cdot l_m^2$

where

l_m is the maximum axis length of the graphite particle in question, which is the maximum distance between two points on the graphite particle perimeter;

A_m is the area of the circle diameter l_m;

A is the area of the graphite particle in question.

2.3
perimeter
P
total length of the object contour

2.4
graphite content rate
graphite content as a percentage of the measured area

3 Designations

3.1 Designation system for classifying graphite in cast irons

When cast iron materials are examined using the image analysis method in accordance with this part of ISO 945, the graphite should be classified by:

a) its form, designated by Roman numerals I to VI, see Annexes A and B (informative);

b) its size, designated by the Arabic numerals 1 to 8, see Table 1.

3.2 Image analysis classification of graphite

The reference images given in Annex A provide a basis for classifying graphite forms. For this purpose, and as examples of actual graphite forms corresponding to these reference images, typical microstructures of graphite in cast irons are arranged in a series of photomicrographs given in Annex B.

The graphite size is determined by measuring the graphite and comparing it with the dimensions and reference numbers given in Table 1.

Because the examined images represent two dimensional cross sections of three dimensional graphite particles, the observed size of any particle will almost always be smaller than its actual size. This fact should be taken into account when evaluating particle size distributions, whether by image analysis methods or by the visual analysis method of ISO 945-1. In ISO 945-1 the determination of graphite size is based on the larger observed particle sizes. Using image analysis, an adjustment to exclude other than the representative larger particle sizes is appropriate.

3.3 Designation of graphite by form and size

3.3.1 Designation by system

To characterise the graphite observed, indications are generally necessary on the form and size of the graphite particles. For this purpose, the following symbols should be used at different positions of the designation:

— Roman numerals of Annex A are used for the graphite form at position 1;

— Arabic numerals of Table 1 are used for the graphite size at position 2.

EXAMPLE 1 For grey cast iron with flake (lamellar) shaped graphite particles of form 1 and size 4, the following designation should be used to describe the structure:

I 4

EXAMPLE 2 For a cast iron with spheroidal graphite particles of form VI and size 4, the following designation should be used to describe that structure:

V1 4

Table 1 — Dimension of the graphite particles forms I to VI

Reference number	Indication of the particle dimension observed at 100 x magnification mm	Actual dimension mm
1	≥100	≥1
2	50 to <100	0,5 to <1
3	25 to <50	0,25 to <0,5
4	12 to <25	0,12 to <0,25
5	6 to <12	0,06 to <0,12
6	3 to <6	0,03 to < 0,06
7	1,5 to <3	0,015 to <0,03
8	<1,5	<0,015

NOTE 1 This table is identical to Table 1 ISO 945-1 except for NOTES 2, 3 and 4.

NOTE 2 For determining size ranges 1 and 2, a lower magnification (25 x or 50 x) may be used.

NOTE 3 For determining size ranges 6 to 8, a higher magnification (200 x or 500 x) may be used.

NOTE 4 For determining size ranges 1 and 2, the largest visible graphite particle size is to be retained.

3.4 Designation of intermediate graphite size

If the graphite observed covers two sizes, reference to both is possible.

EXAMPLE 1 3/4

In a given case the predominating size may be emphasised by underlining.

EXAMPLE 2 3/<u>4</u>

This method can be extended to cover structures where more than two sizes are present.

NOTE Other means of expressing graphite size, such as histograms, can be used.

3.5 Designation of mixed graphite forms and sizes

Graphite structures of mixed form and size can be defined by calculating their percentage proportions.

EXAMPLE For a cast iron with graphite area of 85 % spheroidal graphite particles of form VI, and size 4 and 15 % vermicular graphite particles of form III and covering sizes 3 and 4, the following designation shall be used to describe the structure:

85 % VI 4 + 15 % III 3/4

4 Sampling and sample preparation

4.1 Samples taken from castings or cast samples

The location from which samples are taken should be agreed between the manufacturer and purchaser, taking into account any other requirements in the relevant material standard. If an examination report is required, the location from where the sample is removed shall be recorded.

The sample should be of sufficient size to provide a true representation of the graphite structure in the agreed location from which it is taken.

4.2 Sample preparation

4.2.1 General

Attention should be paid to the careful grinding and polishing of samples, so that the graphite structure appears in its original form and size. Inappropriate preparation can cause unacceptable alteration of the microstructure.

Sample preparation should be carried out in three stages:

— 1. Sectioning;

— 2. Grinding;

— 3. Polishing.

The examination of the graphite should be carried out in the un-etched condition.

4.2.2 Sectioning

The sample should be sectioned in the area agreed between the manufacturer and the purchaser. Care should be taken to ensure that the structure is not altered by the sectioning technique.

4.2.3 Grinding

The sample should be ground in the area agreed between the manufacturer and the purchaser. Care should be taken to ensure that the structure is not altered by the grinding technique.

4.2.4 Polishing

Samples should be repeatedly polished and etched until the true graphite content is revealed and the samples should then be examined in the un-etched condition.

5 Binary image preparation

5.1 General

Once the sample is correctly prepared, appropriate images are taken using a metallographic microscope, a digital camera, a computer image caption program and the image analysis programme. This procedure encompasses several repetitive actions which are listed in chronological order. All these factors can influence the relative exposure of matrix and graphite and the sharpness of the transition zone between both phases.

NOTE It is recommended that a magnification is chosen that enables 20 or more graphite particles to be measured per measured field. The number of particles measurable depends on the pixel resolution of the digital camera. For effective image analysis a higher number of particles can be useful.

5.2 Microscope image light setting

The final picture can be substantially influenced by the intensity of the light on the sample. For un-etched samples containing graphite, a high illumination will remove details from the metal matrix, scratches will disappear and the matrix becomes plain white. At the same time, details in the graphite become visible, as for example, stratifications in graphite spheroids. However, thin graphite details, like thin lamellae or small particles, gradually disappear.

5.3 Microscope filters

Light filters can be present which change the colour composition of the illuminating light.

5.4 Camera

A minimum number of pixels per unit length is needed in order to detect fine details of the graphite structure. The pixel resolution directly influences the number of pixels on the edge of a graphite particle and therefore also the particle perimeter. This parameter appears in some shape factors (for example, the sphericity factor) which are used to classify the graphite particles. Images with a lower total number of pixels can detect the same details on the sample if the magnification of the microscope is increased.

NOTE 1 The image acquiring system should be adjusted to eliminate the background noise.

NOTE 2 Provision should be made to prevent the white and black saturation levels from being reached

NOTE 3 A minimum resolution of 1 pixel/µm should be used.

5.5 Binary image

5.5.1 Brightness setting

The effect of a variation of the illumination by the external light source of the microscope can be obtained in a similar way by changing the programme settings of the image capture programme. By adjusting the exposure time setting, the metallic matrix can be overexposed giving a plain white matrix with less fine graphite details.