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Method for evaluating the nodularity of spheroidal carbides — Steels for cold heading and cold extruding

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Foreword

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This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 4, *Heat treatable and alloy steels.*

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The nodularity of spheroidal carbide is an important characteristic of steel for cold heading or cold extruding. However, the degree of spheroidization is assessed with reference to an agreed series of standard images, which does not exist up-to-now as subject of an International standard. Thus, there has been a continuing debate between supply and demand for the determination of the degree of spheroidization.

This document specifies a test method for evaluating the degree of spheroidal carbide in CHQ wire (Cold Heading Quality wire).

Method for evaluating the nodularity of spheroidal carbides — Steels for cold heading and cold extruding

1 Scope

This document specifies a micrographic method based on comparison charts for determining the degree of spheroidisation of carbides after annealing of wire rod, wire or bars made of non-alloy and low alloy steels intended for cold heading and cold extrusion. The range of carbon content is up to 1,20 % C.

In addition, Annex A includes a method based on machine vision for routine measurements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4954, *Steels for cold heading and cold extruding*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
maximum Féret diameter
maximum length of an object whatever its orientation, as shown in Figure 1

3.2
roundness
area of the carbide particle divided by the area of the circle whose diameter is the maximum Féret diameter of the same carbide particle, calculated according to Formula (1):

$$\text{Roundness} = A/A_m = 4A/\pi \cdot l_m^2 \qquad (1)$$

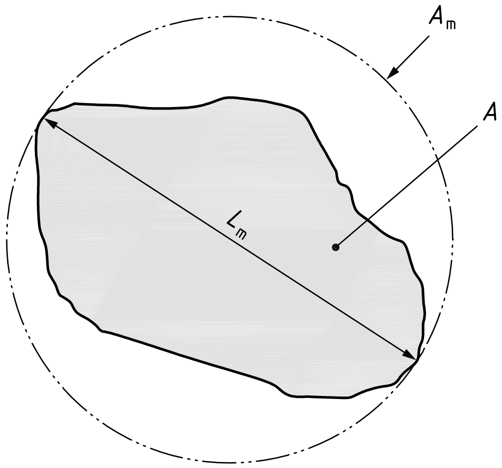


Figure 1 — Illustration of maximum Féret diameter of a carbide particle

where

l_m is the maximum Féret diameter of the carbide particle;

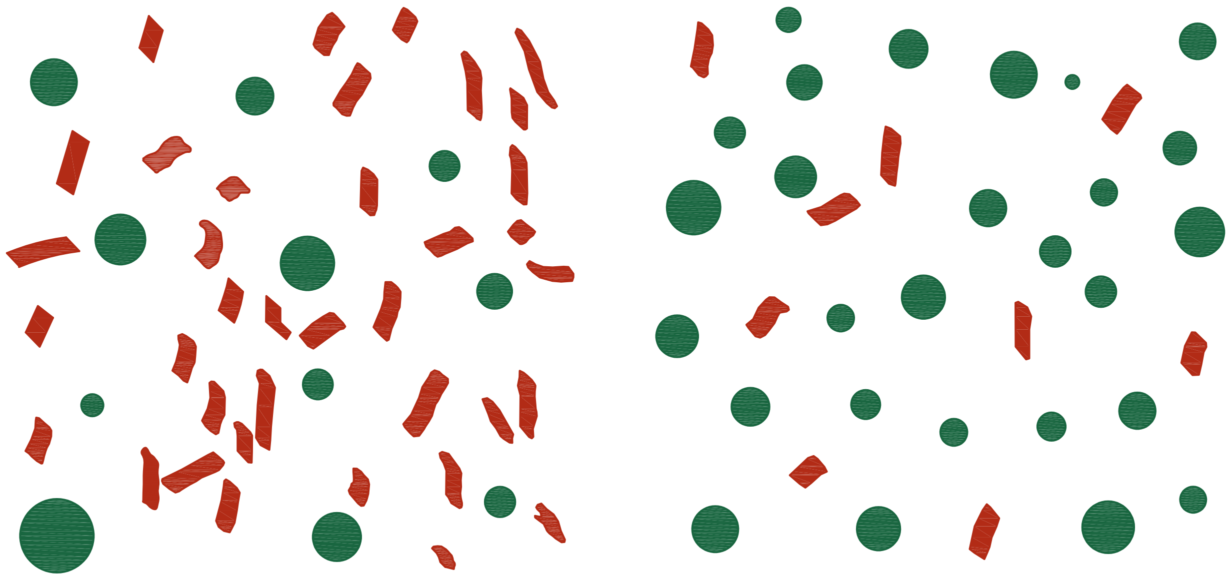
A_m is the area of the circle diameter lm;

A is the area of the carbide particle

3.3
area ratio
accepted/all objects area ratio and describes the relative amount of round objects on the image, calculated according to Formula (2):

$$A\% = \frac{A_{\text{accepted}}}{\left(A_{\text{accepted}} + A_{\text{rejected}}\right)} \quad (2)$$

Note 1 to entry: Round (spheroidized) objects on real images are shown in Figure 2 in green colour (bright) whereas rejected (non-round) objects are drawn in red colour (dark). From class 70 to class 90 the area ratio is increased, so 90 class images contain relatively more round particles.



a) b)

Figure 2 — The ratio of accepted objects to rejected objects on (a) is less than on (b).

3.4
area mean and area standard deviation
objects mean area (A) with its standard deviation (σ_A) describe the particle distribution (see Figure 3) and when considering the particle size from class 70 % to class 90 %, the frequency of inclusions of large particles increases

3.5
spheroidite
characteristic soft microstructure consisting of sphere-like globular cementite particles within a ferrite matrix

Note 1 to entry: see ISO 4885, 3.190.

Note 2 to entry: Carbide particles classified as globular carbide with roundness ≥0,75 to 1,00.

3.6
spheroidizing
annealing just below the A1 temperature of steels with long soaking time to bring the carbides in the form of spheroids

Note 1 to entry: see ISO 4885, 3.191

3.7
nodularity
assessment of the proportion of spheroidal carbide particles in a CHQ Wire (Cold Heading Quality wire) sample, generally expressed as a percentage

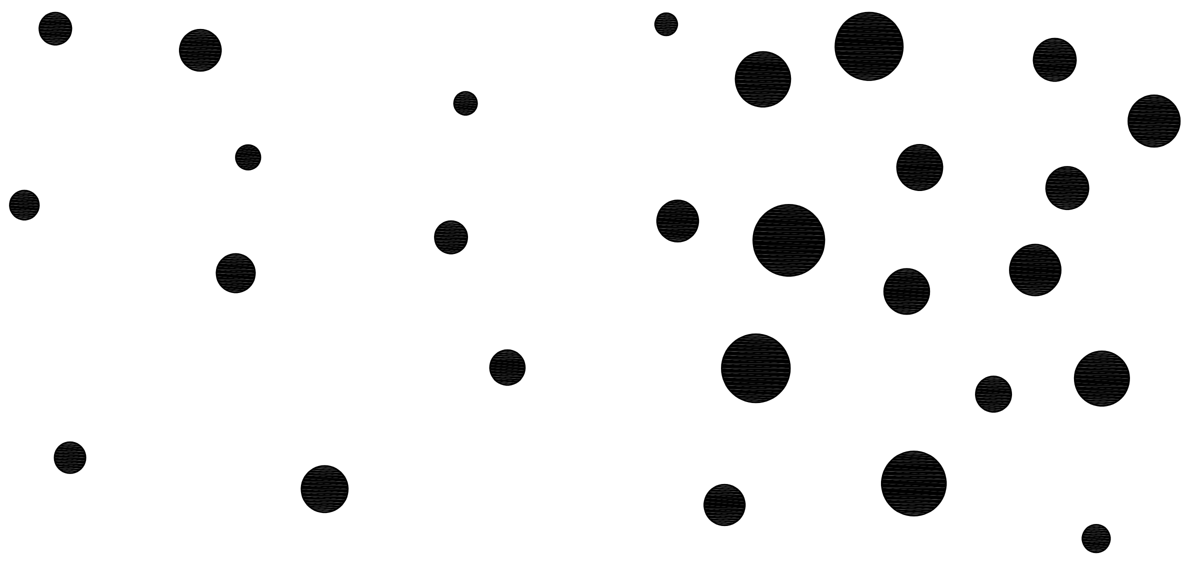


Figure 3 — Round objects area distribution for two different classes

4 Sampling and sample preparation

Sampling and sample preparation are conducted according to ISO 4954. Sampling shall be carried out in such a way that the samples are characteristic of the respective delivery.

The microsection per test piece to be examined shall have a size of 100 mm^2, if possible and practicable. Its position in the cross or longitudinal microsection can differ depending on requirements and should be left to the discretion of the manufacturer.

The test pieces shall be ground and polished. They should be etched in a suitable way, normally with a 2 % Picric acid solution (2 % $C_6H_3N_3O_7$ in C_2H_5OH).

Attention should be paid to a good metallographic preparation to ensure that the microstructure is not altered.

5 Evaluation

5.1 General

To characterize the carbide particles observed, information is generally necessary on the nodularity, the roundness and the distribution of the carbide particles.

5.2 Evaluation methods

This document characterises carbide particles by series of standard images. For routine measurements other methods can be preferred, especially examination by automatized image processing. An example for the automatized image processing is given in Annex A.

In case of dispute, however, the reference method for the characterisation of carbide particles is done by a comparision of images of a test piece under a microscop with a series of standard images.

6 Characterization of carbide particles by means of microscopic examination

6.1 Groups of steel grades and levels of spheroidisation

The volume of carbides depends principally on the carbon content. Other alloying elements of cold heading steel grades have minor influence. The steel grades are classified as presented in Table 1.

Table 1 — Groups of steel grades

Groups of steel grades	Carbon content	
1		≤0,10
2	>0,10	≤0,25
3	>0,25	≤0,40
4	>0,40	≤0,80
5	>0,80	≤1,20

The spheroidisation is characterised as percentage. Partial spheroidisation is for instance ≥70 % and optimal spheroidisation is for instance between 90 % and 100 %. For the spheroidisation four different levels are defined as shown in Table 2.

Table 2 — Different levels of spheroidisation

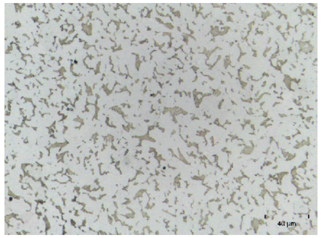
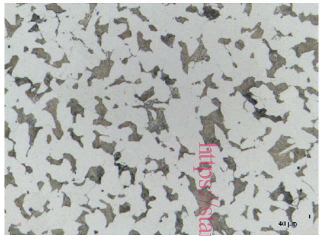
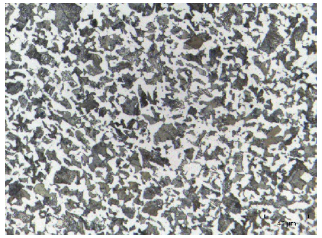
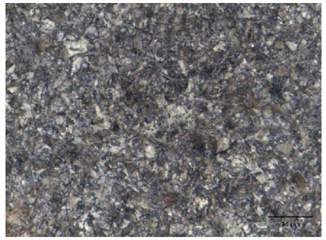
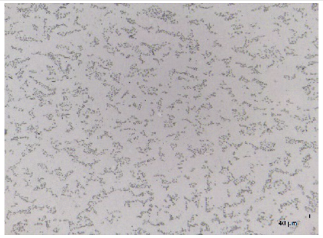
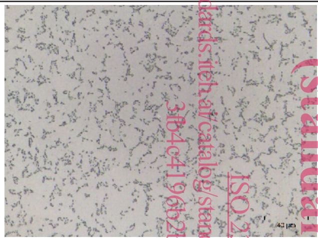
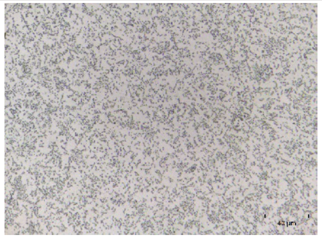
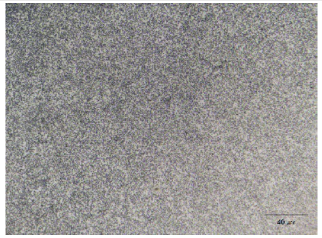
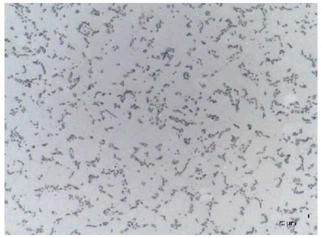
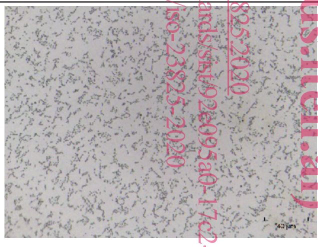
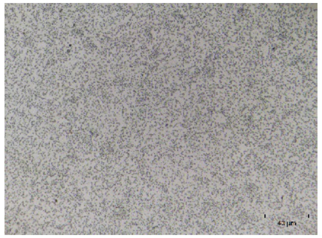
Abbreviation for the level	Level of Spheroidisation	Characteristic	Microstructure level (Example of heat treatement)
0	S around 0 %	initial structure	not soft annealed/not annealed on spheroidized carbides
70	70 % ≤ S < 80 %	partial globularisation	Spheroidisation of more than 70 % ((S)AIP)
80	80 % ≤ S < 90 %	satisfactory globularisation	Spheroidisation of more than 80 % (SAIP)
90	S ≥ 90 %	optimal spheroidite structure	Spheroidisation of more than 90 % (best possible structure of steel after soft annealed/annealed on spheroidized carbides, PSASAIP)

6.2 Series of diagrams

This image series characterizes the microstructure of a test piece by steel groups and the spheroidisation of carbides. The five steel groups represent different carbon contents.

Table 3 shows the microscopic image series with different levels of perlite and globular carbides for steel grades with four different typical carbon contents. Steels with carbon content ≤ 0,1 % C are not shown in the diagrams, because they are mainly ferritic.

Table 3 — Standard images of spheroidal structures of carbides for steels for cold heading and cold extruding

a) Magnification 500:1				
	Steels with 0,10 %< C ≤ 025 % steel group 2	Steels with 0,25 % < C ≤ 0,40 % steel group 3	Steels with 0,40 % < C ≤ 0,80 % steel group 4	Steels with 0,80 % < C ≤ 1,20 % steel group 5
lamellar S around 0 %				
spheroidite S ≥ 70 %				
spheroidite S ≥ 80 %				
Fully spheroidite S ≥ 90 %