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Automatic Classification of the Shape of Graphite Particles in Cast Iron

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Cast iron presents graphite particles of different shapes that directly affect its thermo-mechanical properties [1]. Fracture toughness and ductility depend strongly on the shape of the graphite particles. Particles with nodular shapes improve these properties while more elongated particles or with irregular contours are detrimental due to stress concentration points [2]. Thus, cast iron is classified according to the shapes of its graphite particles. The ISO-945 standard presents six classes to characterize the different shapes of graphite particles. Fig. 1 shows the six synthetic reference images that represent these classes.

Traditionally, the classification of cast iron is made by visual comparison of optical micrographs with the reference images from ISO-945. However, a simple visual comparison is subjective and cannot be automated in industrial environment. Thus, a reliable automated approach for the classification of existing classes of graphite shapes is of great interest. Moreover, the visual classification gives only an overall “average” class for a given image, even if there is a wide variation of graphite shapes within the image.

A computer-aided system can automate this process using image analysis (IA). IA provides efficient ways to measure graphite shapes with greater speed and statistical quality. Besides, digital methods allow the application of pattern recognition and artificial intelligence techniques to automate the classification procedure. Once a set of reference images of the different graphite types is provided to the measurement system, the recognition of unknown samples can be made automatically in a typical supervised classification procedure [3].

In this work, an automatic method, based on IA, is proposed to classify graphite particles in cast iron, according to the ISO-945 standard. Using the six reference images as the training set, a supervised classification procedure was developed with the KS400 [4] package. At first, it could be thought that the reference images from ISO-945 represented a limitation to the process because they are composed of synthetic charts that contain a relatively small number of graphite particles. However, they present great variability in graphite shapes within each class, improving their representation. Thus, the reference images used constitute a good training set and the limitation of the process becomes the choice of a parameter set to describe graphite shape.

The challenge is to choose the parameter set that will group particles of the same class, accepting their intrinsic variability and, at the same time, provide maximum discrimination between these classes. In order to represent the graphite shapes, 14 parameters were used, among size measurements, non-dimensional shape factors and contour measurements [5,6]. These parameters were combined in 16383 sets that were then tested in an exhaustive search procedure. The optimal parameter set provided classification rates close to 100% in a validation based on the training set

images. These values are superior to previously reported results [7,8,9]. Results for real samples were consistent with visual examination (Fig. 2). These results indicate that automatic classification of cast irons can be achieved. The procedure can be applied to other materials for which classification is currently done visually. If a training set can be obtained and a parameter set defined, the automatic method should be much faster and more accurate than the traditional one [10].

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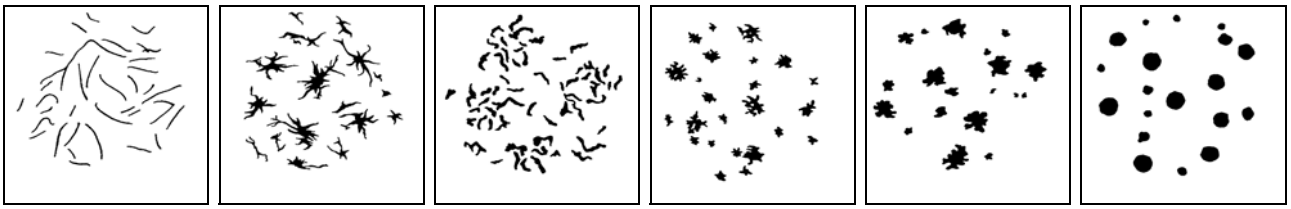
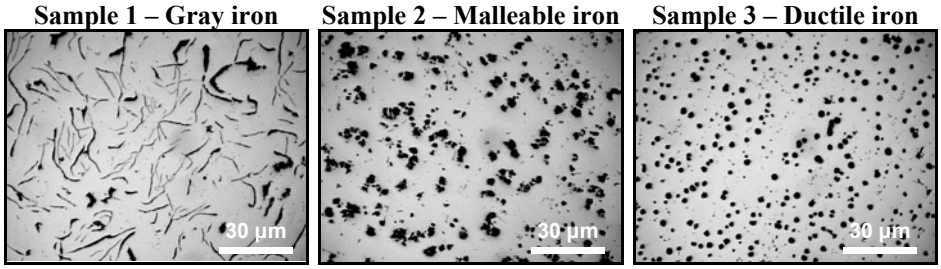


Fig.1 – ISO-945 reference images.



Class	#	%
I	584	42.94
II	180	13.24
III	463	34.04
IV	30	2.21
V	95	6.99
VI	8	0.59
Total	1360	100.00

Class	#	%
I	0	0.00
II	24	1.43
III	163	9.72
IV	264	15.74
V	959	57.19
VI	267	15.92
Total	1677	100.00

Class	#	%
I	0	0.00
II	6	0.22
III	85	3.14
IV	47	1.74
V	789	29.18
VI	1777	65.72
Total	2704	100.00

Fig.2 – Classification of real samples. Results correspond to several fields.

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