EVALUATION OF VARIOUS MICROSTRUCUTRAL CHARACTERISTICS OF ALLOYS USING IMAGE PROCESSING TECHNIQUES

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ABSTRACT

This paper presents the application of image processing techniques for the evaluation of various microstructural characteristics of alloys. The characteristics like volume fraction, grain size estimation, coating thickness, porosity, nodularity, and sizes of graphite flakes are studied. The image processing techniques simplify the method of evaluation of microstructure characteristics; minimize the time of examination, observation and verification and present the data up to the desired level of decimal points accurately.

Keywords: image processing, volume fraction, grain size, thickness, porosity, nodularity, graphite flakes.

1. INTRODUCTION

Metallography or microscopy consists of the microscopic study of the structural characteristics of a material or an alloy. The microstructure is by far the most important tool of the metallurgist from both the scientific and technical standpoints. It is possible to determine grain size and the shape, size, and distribution of various phases and inclusions, which have a great effect on the mechanical properties of the metal. The microstructure reveal the mechanical and thermal treatment of the metal, and it may be possible to predict its expected behavior under a given set of conditions [1].

Experience has indicated that success in microscopic study depends largely upon the care taken in the preparation of the specimen. The most expensive microscopic does not reveal the structure of a specimen that has been poorly prepared. The maximum magnification obtained with the optical microscope is about 2000x. The principal limitation is the wavelength of visible light, which limits the resolution of fine detail in the metallographic specimen [2].

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The advance in resolving power was obtained by the scanning electron microscope (SEM). Although in principle the SEM is similar to the light microscope, its appearance is very much different. The entire system must be kept pumped to a vacuum since air would interfere with the motion of the electrons.

The present work aims at the evaluation of various microstructural characteristics using image processing techniques. The selected microstructural characteristics are volume fraction, grain size estimation, coating thickness, porosity, nodularity, and sizes of graphite flakes.

2. EXPERIMENTAL PROCEDURE

The microstructural characteristics like volume fraction, grain size estimation, coating thickness, porosity, nodularity, and sizes of graphite flakes were studied using image analysis system for metallography (METAVIS). The microstructural characteristics were computed by using probes. The probes were geometrical patterns, which were imposed on the image of the sample being studied. These probes produce intersections with characteristics being studied. The probes are points, lines, parallel line, line grids, point grids, arcs, cycloids, etc. For an example, an unbiased probe for measuring region volume is point grid, for surface area the probe is a set of lines and arcs [3].

The volume fraction of each phase contained in the microstructure was measured with automatic delineation of each phase. The grain size in the microstructure was studied by intercept method. The coating thickness was measured by plain metric method. Statistics and distribution of the longest caliper on all detected pores were observed. In addition, the count of pores and the standard deviation of the lengths were also reported. Nodularity of the graphites present in the ductile iron was examined with area probes and the perimeter of the nodules was presented. The graphite flakes in the gray cast iron sample were examined for %graphite area, the graphite flake lengths were classified in eight sizes as per American Society for Testing and Materials (ASTM) [4].

3. RESULTS AND DISCUSSION

The microstructure of Al-Si alloy is shown in Fig-1. The histogram of two phases representing the microstructure is given in Fig-2. The statistical report of the microstructure is presented in Table-1. The volume fraction of light area is 47.288% and

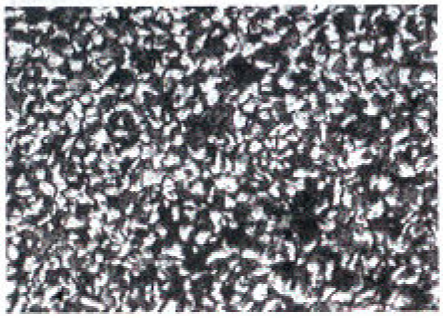

Fig-1 Microstructure of Al-Si alloy

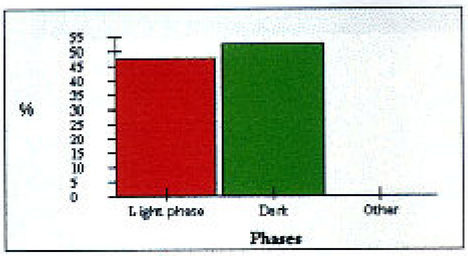

Fig-2 Histogram of Al-Si alloy phases

Table-1: Statistical report of Al-Si alloy

Measurement	Light phase	Dark phase
Volume %	47.288	52.712
Estimated Volume %	47.474	52.526
SD	3.508	3.508
95% CI	3.682	3.682
%RA	7.787	6.986

that of dark area is 52.712%. The volume fraction of light and dark areas measured by the optical microscope are respectively 47.474% and 52.526%. The error in the optical microscope is attributed to the lack of microscope magnification.

The microstructure of brass material is shown in Fig-3. The statistical data of grain size is reported in Table-2. The total area of scanning is 0.37223 mm^2 as per ASTM E1382. The number of intercepts is 163 with mean interception length of 64.32582 µm.

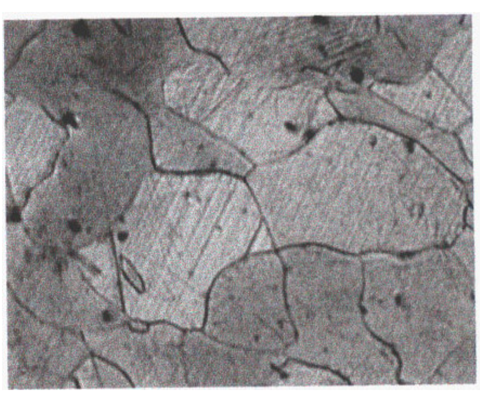

Fig-3 Microstructure of brass metal

Table-2: Statistical data of grain sizes in brass material

Measurement	Value
Grain size	4.6
Intercepts	163
Mean intercept length, µm	64.32582
SD	.002
95% CI	.003
%RA	4.96

The nickel coating given on the steel specimen is illustrated in Fig-4. The thickness values of the coating are given in Table-3. The thickness of the coating was measured at ten different locations across the length of coating. The average thickness of coating is 5.093047 mm. The average thickness of the coating is also measured using conventional Vernier calipers. The average reading of the Vernier calipers is 5. 10 mm. The error is due to the least count (0.01mm) of the Vernier calipers.

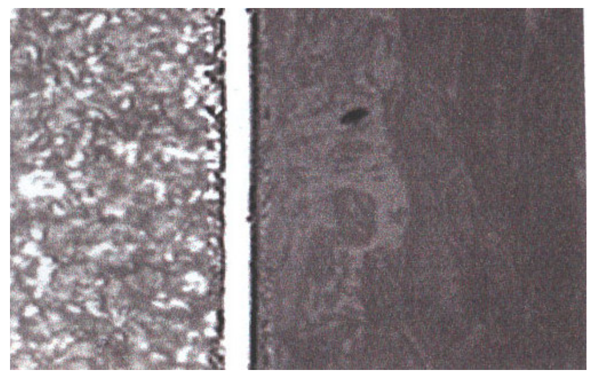

Fig-4 Nickel coating on steel plate

Table-3: Coating Thickness data

Measurement	Thickness
1	4.335385
2	6.503078
3	5.121174
4	4.768924
5	5.202462
6	4.335385
7	5.202426
8	5.470843
9	4.768924
10	5.221875
Thickness (AV)	5.093047
Thickness (MIN)	4.335385
Thickness (MAX)	6.503078

The porosity in the cast metal is due to entrapping of gases released during the solidification process. The microstructure of Titanium alloy is revealed in Fig-5. The area of the specimen examined is 0.66681 mm^2. The statistical data of the porosity present in Titanium alloy is represented in Table-4. The porosity in the Titanium alloy casting is 16.2002%. The density was also evaluated theoretically on the basis of constituents present in the Titanium alloy and measured experimentally using the principle of loss in weight. The theoretical and experimental values of porosity are 15.46% and 15.97% respectively.

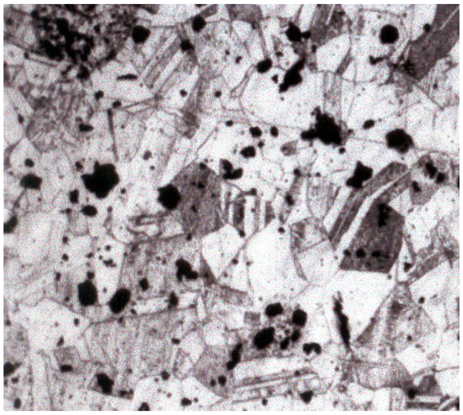

Fig-5 Porosity in Titanium alloy

Table-4: Statistical data of porosity

Measurement	Result	Mean	Min	Max
Porosity %	16.2002			
		19.35663	1.473267	254.8292
Diameter µm		368.6839	4.341205	158717.18
Area sq.mm		.055291	.000651	2.37207
Area %				

The error in the theoretical evaluation of porosity is owing to the loss of constituents during melting of Titanium alloy. The error in the experimental measurement of porosity is attributed to the sensitivity of weighing instrument.

Fig-6 shows the microstructure of ductile iron. The total area scanned to count the number of nodules is 0.88019 mm^2 as per ASTM A-247f. The statistical report of the observation is presented in Table-5. The nodule count is 220. But the number of objects detected by the image processing technique is 261. There are 41 objects, which are not spherical. In fact, this is true as per the microstructure of ductile iron. The lines which may be the scratches on the specimen resulted due to poor polishing are also seen in the microstructure. The image processing technique presents also the type of shapes of nodules. There are some nodules of the shape: flake, vermicular and irregular.

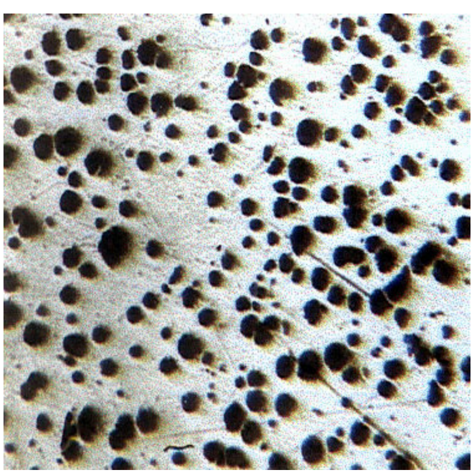

Fig-6 Nodular counts in ductile iron

Table-5: Nodular data of ductile iron

Measurement	Result
Total objects	261
Nodule count	220
% Nodularity	84.29119
Nodule area %	13.97126
Nodules/sq.mm	249.9466
AV size, µm	17.5627
Min size, µm	0
Max size, µm	62.61206
Size1 %	
Size2 %	
Size3 %	
Size4 %	
Size5 %	.455
Size6 %	23.636
Size7 %	33.182
Size8 %	42.727
% Flake	1.149
%Vermicular	2.299
%Irregular	12.261

The graphite flakes in the gray cast iron is illustrated in Fig.7. The histogram representation of the flake sizes is shown in Fig-8. The statistical data of the flakes is given in Table-6. The flake area is 22.39659% of total area examined as per ASTM A-247. As per the standards established by ASTM, the total area of 0.12292 mm2 was scanned for all eight sizes. The maximum flake length is 1147.729 µm. No flakes of size-3 are observed.

Fig-7 graphite flakes in gray cast iron

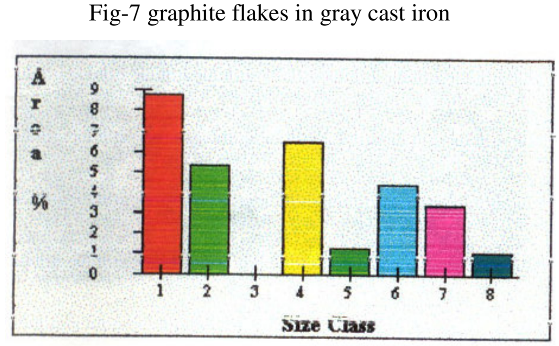

Fig-8 histogram of graphite sizes in gray cast iron

Table-6: Graphite flake size data

Measurement	Result
Flakes area%	22.39659
Max length, μm	1147.729
Size 1%	8.784
Size 2%	5.302
Size 3%	
Size 4%	6.462
Size 5%	1.282
Size 6%	4.417
Size 7%	3.434
Size 8%	1.081

4. CONCLUSIONS

The image processing techniques simplify the method of evaluation of microstructure characteristics; minimize the time of examination, observation and verification and present the data up to the desired level of decimal points accurately. The data of investigation can be presented in the statistical form as well as in the graphical form. Thus, the image processing techniques reduce the complexity of analysis and time of documentation.

The image processing techniques may be extended to the measurement of volumes and distribution of liquid and semi solid phases of emulsions e.g. in cosmetics, food products, pharmaceutical preparations; in biomedicine cancer histopatology e.g. estimation of nuclear volume; in biology e.g. total number of cells in an organ, total distribution of cells and organ cells in space; analysis of bone biopsy material; analysis of dendrite tee length; wound morphology, healing; total gas exchange surface area in lung and effect of AIDS virus on brain volume.

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