Digital Image Processing Technique for Microstructure Analysis of Spheroidal Graphite Iron

H.Sarojadevi[1], Ambikashri B. Shetty[2], Apoorva K. Murthy[3]
[1, 2&3]Department of Computer Science
Nitte Meenakshi Institute of Technology
Yelahanka, Bangalore-560064, Karnataka, India
hsarojadevi@gmail.com, ambikashri@gmail.com
apoorvakm@gmail.com

P. Balachandra Shetty[4], Dr.P.G Mukunda[5]
[4 &5] Department of Mechanical Engineering
Nitte Meenakshi Institute of Technology
Yelahanka, Bangalore-560064, Karnataka, India
pbcshetty@hotmail.com, mukundapeegee@yahoo.co.in

***Abstract*— In the present paper the microstructure analysis is done using the digital image processing technique. Digital image processing is a tool that permits fast, complete, and accurate acquisition of information. The processing of microstructure images is to sharpen the microstructure before quantitative analysis. Previously the analysis of the microstructure taken in analog form was performed manually. This procedure is time consuming for numerous set of images. To avoid this problem, Digital Image Processing techniques are being used. In this paper the main emphasis is given on the analysis of microstructure grain boundary, which is detected using various edge detection operators. Here the digital image is converted into a binary image using a threshold value to segment the image. By this procedure we can change the intensity of the image to study the properties of grains more accurately. This also helps for counting the spheroids in the microstructure. Also the image is enhanced by applying filtering technique. The results obtained from this approach are in the form of new microstructure image with smoothed grain areas and precisely detected grain boundary. Such effect allows optimizing further analysis of material structure to perform statistical calculations of average grain size or prepare material model for Finite Element Method simulations. The results of the analysis of microstructure images help us to correlate certain mechanical properties like ductility, malleability, brittleness etc.**

***Index Terms*— Material microstructure, grain boundary, Digital image, Edge detection, Filtering**

I.INTRODUCTION

Analysis of images using the principles of digital image processing is playing an important role in a wide range of applications [1][2][4]. One such field of interest is processing of microstructure from not very clear image arising out of material processing or from imaging equipment. Images can be obtained in various ways using an analog camera or a digital camera. The quality of the images produced by each of these sources varies according to many factors like lighting, the resolution of the camera, noises and many such factors. This brings digital image processing in application which helps in converting unfavorable images into favorable images. It will also facilitate in analyzing the image. The main aim of this paper is to take the images of the spherical graphite iron, irrespective of the medium by which the image is obtained and produce the meaningful results.

Microstructure is defined as the structure of a prepared surface of a given material or a thin foil of material as revealed by a microscope above 25X magnification. The microstructure of a material can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high / low temperature behavior, wear resistance, and many other mechanical properties. The various applications of the materials will definitely depend on the microstructure of the materials[1].

Most of the images captured possess superimposed noise in the form of dark spots originating from various chemical elements (micro inclusions) or scratches inside the analyzed material. Most of the edge detection or image segmentation algorithms do not cope with these problems, giving the unsatisfactory results. This problem can be solved by application of filtering algorithms, which tries to remove additional noise from images[2]. The most commonly used filtering techniques are, Linear filter, Median filter and Weiner filter.

The microstructure in our specimen is revealed by selective etching with the appropriate acid solution and observed using an optical microscope. Microstructure is the "fingerprint" of material processing. Over the past few years, laboratories have increasingly sought to automate these tasks through computerized image analysis systems. An accurate description of the microstructure helps us to find the properties of the alloys in a much effective way which can be simplified to a higher extent using image analysis techniques.

There has been a considerable work performed on measuring the grain size and determine the alloy properties using image processing and using various algorithms to compare it with the existing commercially available algorithms to validate the results.

II. BACKGROUND

A typical image processing system is as shown in figure 1. The input image source I(x, y) is usually a realistic scene or an image. The image source can be an image captured through an analog camera or a pin whole camera or a digital camera. The digitizer converts the input source signal to an electrical signal whose amplitude represents the image intensity. The electrical signal is then digitized using an analog to digital converter, resulting in a two-dimensional discrete signal f(n1,n2). By applying the various image processing techniques, we process f(n1,n2) to obtain g(n1,n2). The result may be then displayed or used as an input to another system [3].

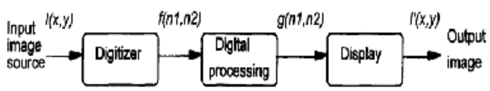

Fig.1. General Image processing system.

Preparing of cast iron specimen for micro structural study is difficult due to the need to properly retain the very soft graphite phase. The specimen preparation consists of sampling, grinding, polishing and etching with a suitable etchant to reveal the microstructure.

III. METHODOLOGY

The image analysis procedure for micro-structure analysis involves the following steps:-

- Melt the Cast iron with added trace of magnesium to obtain Spheroidal graphite.
- Cut and prepare the specimen for metallographic examination
- Acquire digital images of the specimen using an image grabber to apply the principles of digital image processing. i.e., obtain the digital image of the micro-structure.
- Pre-process the acquired images to remove the noise created by structural defects or due to sample preparation during polishing and other chemical treatments using filtering techniques
- Use the edge detection algorithms of various edge detection operators
- Count the regions present in the micro structural image, using the above intermediate results.
- Use the edited image to correlate the mechanical properties of the specimen such as ductility, malleability and brittleness.

The bulky Cast iron with graphite is first cut into a small sample. It is then ground and polished. Specimens have o be prepared with high quality, water proof 220-240 grit silicon carbide paper. It has to be then polished with 9 micro meter diamond paste. Graphite phase retention is better with diamond paste polishing. During grinding the paper must be moistened with flowing tap water and the specimens should be washed with tap water after each step and dried with compressed air. After polishing they were washed with alcohol and dried with hot air from a hair drier.

Capturing of images can be done using pin-hole cameras, analog cameras, video cassettes, or digital camera. In the specimen considered here, digital image is acquired by using a microscope connected to a digital camera. The total magnification achieved by this microscope is 120 times. A digital camera is installed on top of the microscope which has a resolution of 1.3Mpixels and helps in digitizing the microstructure of the specimen. This input image is fed to the computer and further processing is done.

IV. DATA COLLECTION AND ANALYSIS

Often, digital images become corrupted with noise during transmission from other parts of the system. Pre processing the acquired images is necessary to remove the noise created by structural defects or due to scratches obtained during polishing and other chemical treatments using filtering techniques. Using noise filter techniques, the noise can be suppressed and the corrupted images can be restored to an acceptable level. An effective method for removing impulse noise is median filtering. Median filtering is suitable as it does a better job of preserving sharp edges and is shown in figure 2 and 3. Required code snippet for median filtering has been written and implemented.

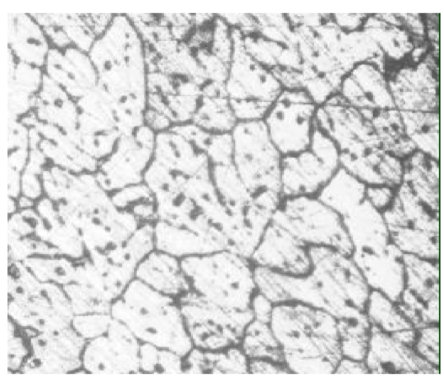

Fig. 2. Spheroidal Graphite Cast iron : Before filtering.

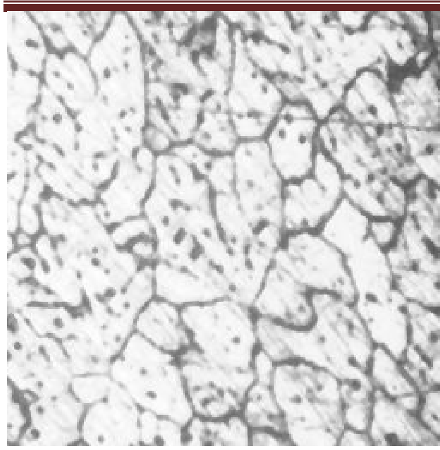

Fig. 3. Spheroidal Graphite Cast iron : After Median filtering.

Image enhancement is aimed at improving the appearance of images or to enhance the performance of an image processing system. It helps us to improve the interpretability or perception of information in images or to provide `better' input for other automated image processing techniques. Image understanding can be regarded as a descriptive process in which an image field or array is analyzed in order to generate some non-pictorial description or representation of the image. The color information can be derived from the digitized image, while the texture information is extracted after transforming the image to a frequency domain. Image enhancement can be achieved by various techniques and one of them is histogram processing. Image histogram is a graphical representation of the number of pixels versus the intensity. It is a valuable tool used to view the intensity profile of an image. It gives an insight into the image composition. The histogram provides information about the contrast and the overall intensity distribution of an image. By looking at the histogram of a specific image a viewer will be able to judge the entire tonal distribution at a glance. Dark images have histograms with pixel distributions towards the left-hand (dark) side. Bright images have pixel distribution towards the right side of the histogram. In an ideal histogram, there is a uniform distribution of pixels across the histogram. We use histograms as this helps us in object identification. Pixels within a grain tend to have similar intensities. By analyzing the peaks and the valleys of a histogram, we can determine what range of pixel intensities belong to the grain, which constitutes the object in the image and the rest which is taken as the image background.

If we take an image and count up how many pixels go into each gray level, putting each one in a separate bin, we have a histogram. In mathematical terms, the histogram is given by applying the relation

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n}$$

where s is the level for every pixel value r in the original image, T( ) is the transform function, n_j is the number of times this level appears in the image, and n is the total number of pixels in the image. Specific code has been written to obtain the histogram and is shown in Fig 4.

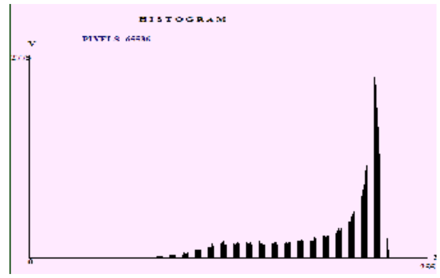

Fig. 4. Image histogram of spheroidal graphite cast iron.

Image thresholding shown in figure 5 is another way of enhancing the images which when used with edge detectors emphasizes the edges. Thresholding emphasizes the strong edges and deemphasizes the weak edges. Thresholding can use one or two levels. Images can use one threshold value to set those above the threshold to the maximum pixel value and those below the threshold to 0. An upper and lower threshold can also be used to alter the pixel values. Values below the lowest threshold are set to 0. Those between the thresholds are left unaltered. Those above the upper threshold are set to 255.

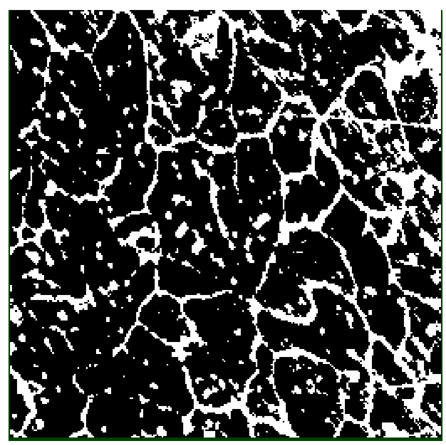

Fig. 5. Single threshold=180

The goal of edge detection is to mark the grain boundary of the micro structural image at which the luminous intensity changes sharply. The edges of an image hold much of the information in the image. The edges tell where the grains are, their shape and size, and something about their texture. By applying edge detection techniques, the important structural properties of an image are preserved while discarding unimportant information.

A grain boundary is the interface between two grains in a polycrystalline material. Grains and grain boundaries help to determine the properties of a material. In the work proposed in our paper, for an input image shown in figure 6, the grain boundary has been detected using threshold and by using Prewitt, Robert, Sobel and Canny's edge detection operators, as shown in figures 7 to 10.

Prewitt is a method of edge detection, which calculates the maximum response of a set of convolution kernels to find the local edge orientation for each pixel. Threshold helps us convert a grayscale image, into binary images. During the threshold process, individual pixels in an image are marked as "object" pixels if their value is greater than some threshold value (assuming an object to be brighter than the background) and as "background" pixels otherwise. This convention is known as threshold above. Variants include threshold below, which is opposite of threshold above; threshold inside, where a pixel is labeled "object" if its value is between two thresholds; and threshold outside, which is the opposite of threshold inside. Typically, an object pixel is given a value of "1" while a background pixel is given a value of "0". Finally, a binary image is created by coloring each pixel white or black, depending on a pixel's label. Lower the threshold, more are the edges detected, and the result will be increasingly susceptible to noise, and also to picking out irrelevant features from the image. Conversely a high threshold may miss subtle edges, or result in fragmented edges[5]. The Prewitt's edge detection operator is simpler to implement than the Sobel's edge detection operator in terms of computation. But Sobel's edge detector has better noise suppression (smoothing) characteristics and hence more preferred. Robert's edge detector calculates the square root of the magnitude squared of the convolution with the Robert's row and column edge detectors. Disadvantage is that spurious noise can affect the Robert's cross operator.

The Canny edge detection algorithm is known to many as the optimal edge detector. The Canny's edge detector first smoothens the image to eliminate noise from the image. It then finds the image gradient to highlight regions with high spatial derivatives. The algorithm then tracks along these regions and suppresses any pixel that is not at the maximum (non maximum suppression). The gradient array is now further reduced by hysteresis. Hysteresis is used to track along the remaining pixels that have not been suppressed. Hysteresis uses two thresholds and if the magnitude is below the first threshold, it is set to zero (made a non edge). If the magnitude is above the high threshold, it is made an edge; And if the magnitude is between the 2 thresholds, then it is set to zero unless there is a path from this pixel to a pixel with a gradient above threshold 2.

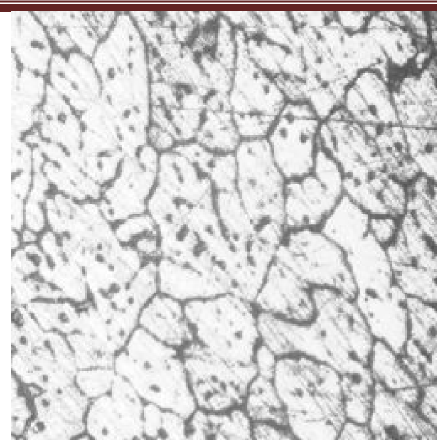

Fig. 6. Captured image

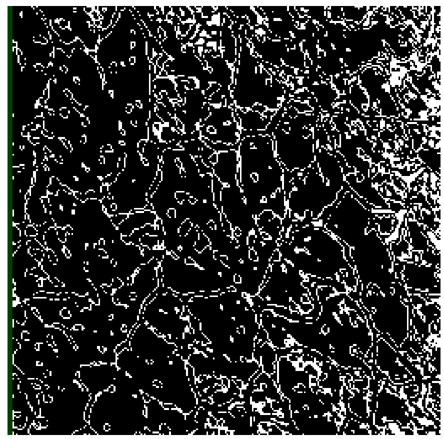

Fig. 7. Prewitt's edge detection operator

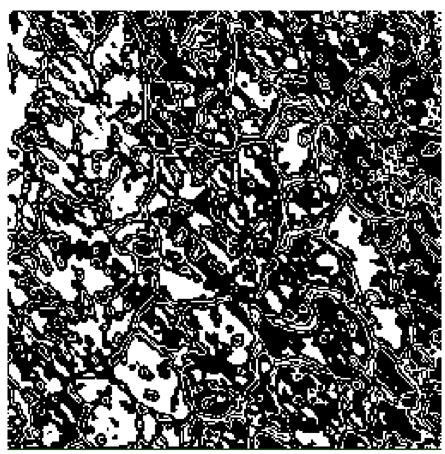

Fig. 8. Sobel's edge detection operator

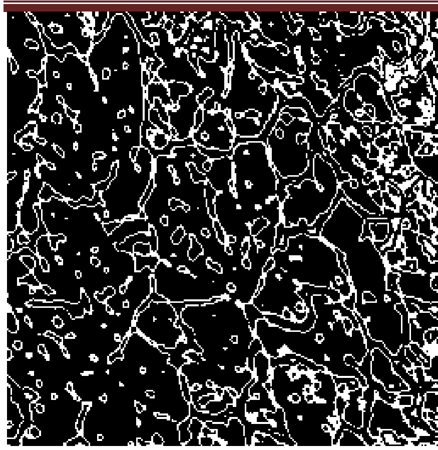

Fig. 9. Robert's edge detection operator

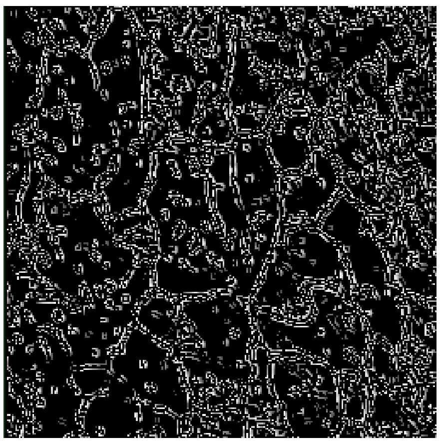

Fig. 10. Canny's edge detection operator

V. DISCUSSION AND RESULTS

The results obtained will help us to count the number of features in the microstructure. For this we can take the images which have passed through the threshold values or in which the region boundaries have been detected using the different edge detection operators. In the case of edge detection operator we choose the best operator which will help us to identify as many regions as possible eliminating the false regions. Region counting can be done by scanning the array of pixels horizontally. As and when we scan, if we find a spike in the intensity levels we label it and detect it as a part of the region. In order to avoid detecting the regions as overlapping, the first spike detected is labeled and as and when we move horizontally in the array we label the intensities belonging to a region with a single color and other regions with other colors.

VI. CONCLUSION

All this processing helps to find out various properties of the alloy such as the ductility, malleability, brittleness, wear properties etc. The result obtained by the algorithm is comparable with the commercially available software like Metalite. Many of the mechanical properties can be correlated with the grain sizes for e.g. like, the coarse-grained structures will give better electrical conducting property and the fine-grained structures are tougher and harder.

ACKNOWLEDGEMENT

The authors are indebted to Dr. N.R.Shetty, former Vice Chancellor, Bangalore University for the constant encouragement to Research work at Educational Institutions.

REFERENCES

[1] S.G. Lee, Y. Mao, A.M. Gokhale, J. Harris, and M.F. Horstemeyer (2009), Application of digital image processing for automatic detection and characterization of cracked constituent particles/inclusions in wrought aluminum alloys, Elsevier, Materials Characterization, 60(9), pp.964-970.

[2] D. Deb, S. Hariharan, U.M. Rao, and Chang-Ha Ryu (2008), Automatic detection and analysis of discontinuity geometry of rock mass from digital images, Elsevier, Computers & Geosciences, 34(2), pp.115–126.

[3] Zhanfeng Shen, Jiancheng Luo, Chenghu Zhou, Guangyu Huang, Weifeng Ma, and Dongping Ming (2005), System design and implementation of digital-image processing using computational grids, Elsevier, Computers & Geosciences, 31(5), pp. 619–630.

[4] D.W.Moolman, C. Aldrich, J.S.J. Van Deventer, and W.W. Stange (1994), Digital Image Processing as a tool for online monitoring of froth in flotation plants, Elsevier, Minerals Engineering, 7(9), pp. 1149-1164.

[5] S.Vandenberg and C. F. Osborne (1992), Digital image processing techniques, fractal dimensionality and scale-space applied to surface roughness, Elsevier, Wear, 159(1) , pp.17-30.