Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

14th International Conference on Applied Mechanics and Mechanical Engineering.

DIRECT METHOD FOR THE ESTIMATION OF GRAIN SIZE MEASUREMENT

By

Ashfaque Ahmed Memon*

Abstract:

Before the manufacturing of any metallic component, to avoid its failure during functional use, the crystalline structure is essential to be studied and the grain size is to be measured for which, several methods are being adopted. Among all, the most recent and advanced is by using computer. But the facility of it is not much explored in the under developed countries, due to its high initial cost and the appropriate training, specifically in the educational institutes.

The most common methods recommended by ASTM that are in use for the measurement of the grain are; Comparison method, Intercept (Heyn) method and Planimetric (Jaffries) method. These methods give approximate values with trial and error using charts and tables. This paper presents the direct method for the estimation/measurement of grain size by direct measurement technique.

In this study, for the measurement of the grain size, a case hardened carbon steel sample was selected, which is most commonly used for gears and shafts manufacturing. The direct method of grain size measurement gives results with very convenience and accuracy in much lesser time. Also, it does not need skill and is free of trial and error.

Keywords: Grain size, Direct method, Estimation

*Mehran University of Engineering and Technology, Sindh, Pakistan

1. Introduction:

Grain size estimation is considered to be one of the most important factors to ascertain the properties of the metal. For which, besides using the appropriate method, the reliability and time factor shall be given equal importance. The grain size and distribution of grains is of prime importance [1], as the properties, both physical and chemical, changes with the structural changes that occurs during the production of the material and the heat treatment process carried after producing component out of it.

This following method describes the evolution of grain size measurement and ASTM standards for it. Due to the different types of grains present in metals, it may influence grain size measurement and some how becomes complicated, although their fundamental shapes are the same [2].

The selected area for the study and analysis was mainly conducted in a large mechanical components manufacturing industry, producing machine tools and automobile components in which, during the manufacturing process various defects were developed, specifically related to grain size, resulting high rate of rejection [3]. For eliminating the identified defects to reduce the rejection rate, comparative microstructure study was conducted [4]. This study does not include the use of all the three basic ASTM recommended methods for grain size measurement.

Sundin et al. [5] suggested to incorporated online, the laser ultrasonic technique to determine direct grain size of commercial low carbon steel production.

For the estimation of grain size there are three basic methods recommended by ASTM:

1. Comparision method
2. Intercept (Heyn) method
3. Planimetric (Jeffries) method

In 1916 E-4 Committee was formed to establishing standard magnifications methods of preparation of micrographs of metals and alloys, was partly devoted to grain size measurement. Two basic approaches to measure grain size were developed, "planimetric" approach, which was further developed/modified by “Jeffries”. By this approach, the grain size was measured in terms of the number of grains that were visible in an area of per square inch at magnification100X. Another “intercept” approach, was given by Heyn in 1904 for measuring grain size. In this method, one or more lines are superimposed over the structure at a known magnification. The basic difference between these two approaches is that, the planimetric, or Jeffries method, considers the grain size in terms of the number of grains per unit area, the average grain area, or the average grain diameter, while the Heyn in its intercept method, considers it in terms of the average intercept length, while using comparison chart that expresses the grain size. The comparison method is most convenient and sufficiently accurate for specimens consisting of equiaxed grains [6]

In order to confirm the reliability of results obtained, this work was supported to conduct the grain size examination as suggested in various issues of ASTM standards [7, 8, 9]. For such

study sophisticated instruments help ensure the effect of the observation, Pan and Fernando [10] used microscope to increase the effectiveness of the examination. Micro structural examination is generally carried out using optical microscope. Modern electronic and scanning electronic microscope can greatly enhance the detail with high magnification results. However, this study is constrained to optical only. A research style project for using grain size analysis of sediments was carried out by Devies[11].

Hence, a quick method, which may not be as precise as an actual measurement is defined in this study, a “Direct method of grain size measurement”. This method does not require much training, equipment, tools, charts, tables, greater time and efforts. With this method of study, the results can be achieved quite reliable, faster and consistent, even if, performed by different persons, the variation in results could hardly be noticed when compared.

2. Methodolgy:

This paper suggests the direct method for the evolution of the grain size measurement. After the preparation of the specimen for the micro structural observation and study under the metallurgical microscope at certain desired magnification, the photograph of the structure revealed from the specimen was taken, also, at the same magnification, photograph of the small steel scale was also taken, this scale is marked/engraved with divisions at an equal distance of 0.001mm, as shown in Figure-1 indicating the size of grains for Plate-1. The value of each division of the scale is standard that remains same at any magnification. This scale acts as a measuring tool for the measurement of the grain size. However, for exact matching, it is very important that, for every value of magnification selected for the observation and snapping the specimen structure, the engraved steel scale must also be snapped at the same value of selected magnification. This consistency would help in the evolution for the estimation of correct size of the grains of average size, while using the photograph of the structure and measuring its grains with the help of the photograph of the scale taken at the same value of magnification. Thus, we can be able to measure the size of the grain directly, quickly and get adequate results of much reliability as compared to the above stated basic standard methods. To understand this methodology, the results of four different plates are elaborated in the section of results and discussion.

Aranzabal et al. [12] have suggested that the study of the microstructure after the heat treatment, influences the mechanical properties of the material. Abbott et al. [13], analyzed a problem of almost similar nature. Results obtained by using this methodology were found quite accurate, easy, consistent, less time consuming and free of error, as compared to, the results obtained by using three basic ASTM standard methods.

Dogines [14] used Image analysis inspection, for greater accuracy and high productivity time analysis, the research adopted methodology obtaining grain image.

In this study, two materials were selected for the grain size estimation which are case-hardened, carbon steel SAE 8620, this material is suitable for gear making and the other selected material is SAE 4320 which is suitable for axle shaft making. Both these components functions under heavy axial, compressive and tensile loads for which, their grain size measurement is of great importance, so as to avoid failure, which may persist during

functional use. To obtain the desired optimum microstructure Babu et al. [15] studied macro and microstructure development in low alloy steel for the inclusion formation and suggested that they should be controlled to prevent failure. Another relevant study on the low carbon steel was carried out by Huang et al. [16].

The simple technique used in this work include following necessary steps;

- Firstly, after the preparation of the specimens of the selected materials, the microstructure was revealed under metallurgical microscope at the magnification of 100X and image was snapped by built-in camera .
- With the help of image photographs, a steel scale under high magnification lens was made with engraved lines, the divisions of these lines were made in accordance to the estimated grain size.
- Both, the specimen and the steel scale were then again brought under the microscope at same magnification of 100X in such a position to match and measure the grain size directly in alignment to each grain to fall between the two division lines of the scale. Hence, measuring the size of the grain.
- The developed steel scale was used as a 'measuring device' for the direct measurement of the grains when ever needed, subjected to the condition, that, for every observation and measurement of the grain size, the scale shall also be snapped at the same varying magnification along with the specimen, so as to use that snap of scale as measuring tool.

This method can easily be understood by observing the figures shown in the section of results and discussion.

3. Results and discussions:

Table-1 shows consolidated results obtained from this study.

S.No.	FigureNo./ Material	Magnification	Structure	Grain Size mm
1	01 SAE 8620	100X	Ferrite and pearlite having uniform fine grain structure	0.03
2	02 SAE 8620	250X	-do-	0.03
3	03 SAE 4320	100X	Ferrite and pearlite in which ferrite is present at the grain boundries.	0.02
4	04 SAE 4320	250X	-do-	0.02

The grains shown in the plates were measured with the plate of the engraved steel scale, both snapped at the same magnification, making the method of measurement so simple. The plates are discussed with the following Figures;

Figure-1:

Pertains to the material SAE 8620 of which the specimen is magnified at 100X, structure shows ferrite and pearlite having uniform fine grains. For reliability, the results obtained with this study were compared with the results obtained by using ASTM standard compression method while using data obtained as, index- 8 and the grain size number n=4, when compared, have given almost the same value **0.03mm.**

Figure-2:
Represents the specimen as that of Figure-1 but with a magnification of 250X, that still gives the measurement of the grain same as **0.03mm.**

Figure-3:
Structure represent material SAE 4321 magnified at 100X. Containing Ferrite and pearlite in which ferrite is present at the grain boundaries. The grain size estimated as **0.02mm.**

Figure-4:
This represent the same material and specimen as that of Figure-3 but with greater magnification of 250X, giving result of grain size as **0.02mm.**

With the above results the reliability of grain size estimation using 'direct method' of measurement confirms the appropriation of the study. Moreover, the convenience of obtaining grain size results has shown consistency and uniformity, even with varying magnification.

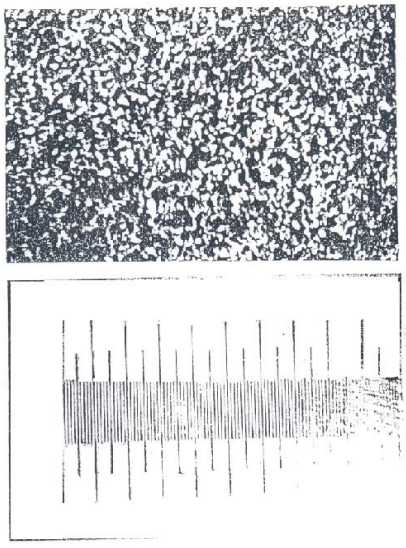

Plate 1. SAE 8620
Structure Compared with the Scale at magnification 100X (below) for Grain Size
Measurement gives Direct Value of the Grain Size: 0.03mm

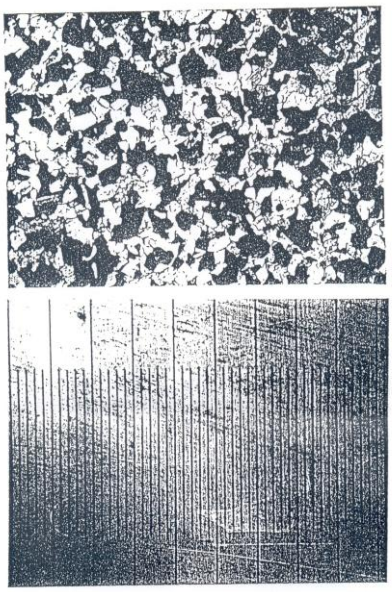

Plate 2. SAE 8620
Structure Compared with the Scale at magnification 250X (below) for Grain Size
Measurement gives Direct Value of the Grain Size=0.03mm

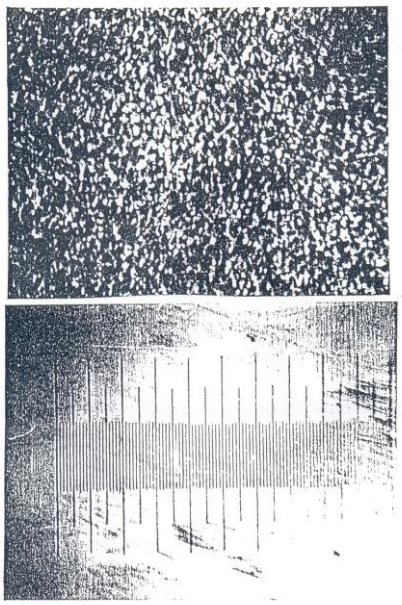

Plate 3. SAE 4320
Structure Compared with the Scale at magnification 100X (below) for Grain Size
Measurement gives Direct Value of the Grain Size=0.02mm

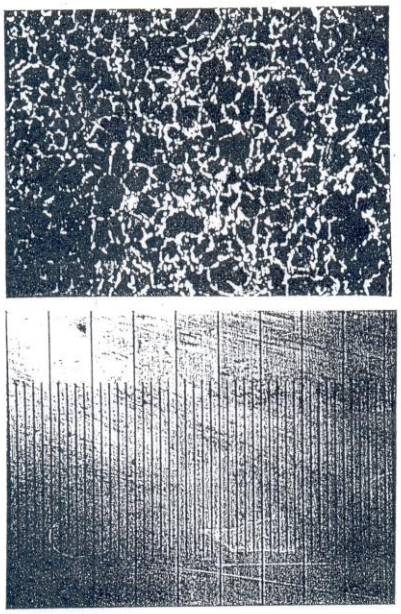

Plate 4. SAE 4320
Structure Compared with the Scale at magnification 250X (below) for Grain Size
Measurement gives Direct Value of the Grain Size=0.02mm'

4. Conclusions:

Following are the conclusions derived from this study;

- An easy and direct method for the measurement of the grain size.
- This method/technique does requires much training, time and cost.
- There is scope for further developing this technique for its extensive application.
- It is suggested that this 'Direct method for the estimation of grain size measurement' shall also be included as standard method for the grain size measurement.
- It can be further advanced by developing software so as to bring at par with this computer age.

References:

1. M. J. Jones, Physical and Fabrication Metallurgy, Proceedings of Ninth Commonwealth Mining and Metallurgy Congress, London 1969, Vol. 4, P-122.

2. Memon A. S., In-charge Metallographic Laboratory, Pakistan Steels Karachi Sindh, Pakistan. March 1999, Personal Communication.

3. Rajput M. S., General Manager, Pakistan Machine Tool Factory Ltd. Landhi Karachi Sindh, Pakistan, May 1999, Personal Communication

4. Memon. A. A, "Study of Surface Cracks in 0.2 per cent Carbon Case Hardened Steel Using 'Image processing Technique", M.Phil. Research Project, August 1999, P-55-56.

5. S. Sundin and D. Artymowicz., Present Address: The Swedish Institute for Metal Research,. S-114 28 Stockholm, Sweden, March 6 2001.
6. Sidney H. Avner; Introduction to Physical Metallurgy, 12th Ed. U.S.A., Mc Graw-Hill Book Company, International Student Edition, 1986. P. 101-104.

7. ASTM Designation E 709-63, Standard Method for Wet Magnetic Particles Inspection. P. 367-377.

8. ASTM Designation E 709-80, re-approved 1985, Standard Practice for Magnetic Particles Examination. P.287-312.

9. ASTM Designation E1444-94a, re-approved 1985, Standard Practice for Magnetic Particles Examination. P. 1-11.

10. Pan Z. J. Fernando U.S., Miller K J and E. R. de. Los RIOS, 'Combined Optical-Acoustic Microscopy for investigation Short Fatigue Crack Prpargation', Mat. Sc. And Tech., April 1994, Vol. 10, P. 265-271

11. Devies-Vollum K., "Using Grain Size Analysis as the Basis for a Research Project in an Undergraduate Sedimentology Course." Journal of Geoscence Education., January 1. 2006.

12. Aranzabal J., Gutierrez I. and Urcola J. J., 'Influence of Heat Treatments on Microstructure of Austempered Ductile Iron.' Mat. Sc. And Tech., August 1994. Vol. 10, P. 728-737.

13. Abbott K., Moskovie R., and Fewett P.E.J., 'Intergranular Fracture in Cleavae Fracture Temperature Range.' Mat.Sc. and Technology. Sept 1994, Vol. 10, P. 813-816

14. Diagenes, Alysson N, Hoff, Eduardo A and Fernandes, celso P., “Grain Size Measurement by Image Analysis”, Proceedings of COBEM 2005 18th International Congrss of Mechanical Engineering. November 6-11, 2005.

15. Babu S. S., David S.A., Vitek J. M., Mundra K., DebRoy T., ‘Development of Macro and Microstructures of Carbon Manganese Low Alloy Steel Welds Inclusions Formation.” Mat. And Sc. Tech., February 1995, Vol.11, P.186-199.

16. Huang, Matsumura O and Furukawa T., ‘Retain Austenite in Low Carbon, Manganese Steel after Inter-critical Heat Treatment’. Mat.Sc. and Tech., July 1994 Vol. 10. P. 621-625.