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Effect of Al, Ni, Mo, Ti, Nb and temperature on grain size number in low carbon high alloyed steel

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Abstract: Usually steels for manufacturing are purchased on the basis of chemical composition. This can affect its properties. In this study chemical composition and temperature effect on grain size number has been observed carefully. Three steels with different chemical composition as well as heat treatment temperatures at 920°C and 1100°C respectively with holding time of 30 minutes in the oxidization atmospheric laboratory based furnace, to know the influence of both factors composition and temperature, microstructures of these three different steels have been obtained by conventional metallography methods. Grain size of each steel sample has been calculated as indicated by Higginson, R.L. and Sellars C.M. The ASTM grain size number. The data has been plotted at both observing temperatures. In the light of above experiments and observations it was concluded that chemical composition and temperature has definitely effect on ASTM grain size number. Al, Ni, Mo, Ti, Nb has significant effect on forming the microstructure and grain size can be affected by the presence of these elements in the steel composition. Also as the austenizing temperature is increased the grain size number is decreased. Aluminum can hinder the grain growth and nickel is austenite stabilizing element which can affect the grain size number.

Keywords: Grain size number, steel composition, heat treatment etc.

1. INTRODUCTION

The ASTM grain size number, g, was originally defined from the number of grains per square inch at a magnification of x100, (Higginson and Sellars 2003), but is now related to the number of grains per millimeter squared (N_A) measured at any appropriate magnification as

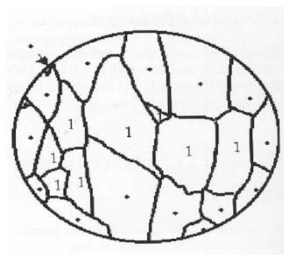
$$g = -2.954 + 3.322\log(N_A)$$

To determine the value of N_A the number of grains in appropriate areas must be counted.A circle of diameter 79.8mm (area = 5000mm^2) has been drawn on the micrograph. The grains that are fully enclosed within the circle are marked with a '1' and those that intersect the circle are marked with a '.'All the grains marked **'.'** are counted as 1/2.

The number of grains per mm^2 is computed using the equation: (Mager, 1952) (Goodenough, 1954).

$$N_A = M^2 / 5000 [n_1 + (n_2/2)]$$

where M is the magnification of the photographic image, n_1 is the number of grains completely in the inscribed area and n_2 is the number of grains intersecting the perimeter of the test area. (Bozorth, 1951). (Adler, and Pfeiffer, 1974) (Degauque, *et al.*,1982) Calculation of grain size number is the measurement of mechanical properties which can be analyzed to reveal the microstructure. These quantitative metallography methods are adopted by many researchers and scientist working in the steel industry.



2. EXPERIMENTAL PROCEDURE

Commerciallyany kind of steel is purchased on the ground of chemical composition which indicates the harden ability of that steel. Alloying elements on the other hand have influence on mechanical properties of the steel. Heat treatment of the steel in solid state can play a versatile role for controlling mechanical properties by forming grains either small or coarse depending upon the required properties by end user. Grain size number is the reference number for any steel microstructure and size of grains produced by heat treatment. (Bertotti, *et al.*,1991) (Taeko, *et al.*, 2006) (ASTM 2004), with increasing temperature in the austenitic range can affect the grain size number of the steel. Grains either grows as a coarse or reduce by refining. To know the effect of chemical composition and temperature four different steel compositions has been observed. The chemical composition is shown in the following **(Table1).**

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Table.1. Chemical Composition of the Experimental Steels

#	C	Al	Ni	Mo	Ti	Nb	N_2
1	0.2	-	0.25	0.104	0.02	-	0.079
2	0.2	0.02	-	-	0.024	0.048	0.005
3	0.2	0.042	-	-	0.025	-	0.0061

Four different steel samples were then heat treated at two different temperatures at 925°C and 1100°C respectively with same holding time of 30 minutes each sample. After soaking samples were then cooled in water as shown in the **(Fig.2).**

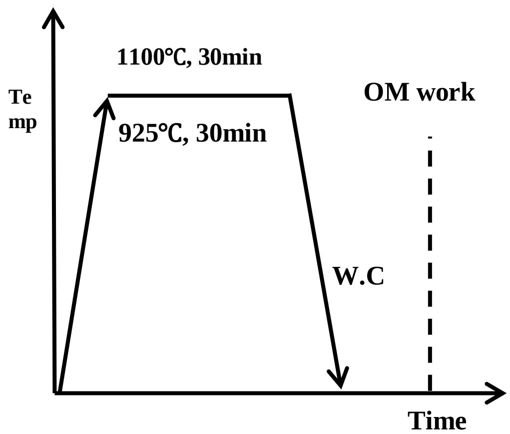
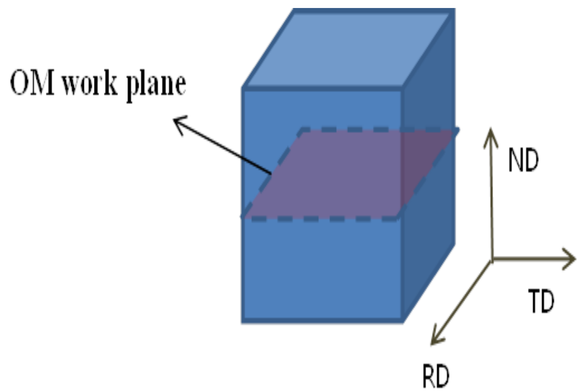


Fig. 2. Heat treatment cycle for the experimental steels.

As shown below in the Immediate after cutting samples were prepared for conventional metallography i-e grinding, polishing followed by etching in LePera solution for revealing the prior austenite grain boundaries. The etching time was applied from 10sec to 60sec. Olympus metallurgical microscope was then used with different magnification to watch the prior austenite grain boundaries.

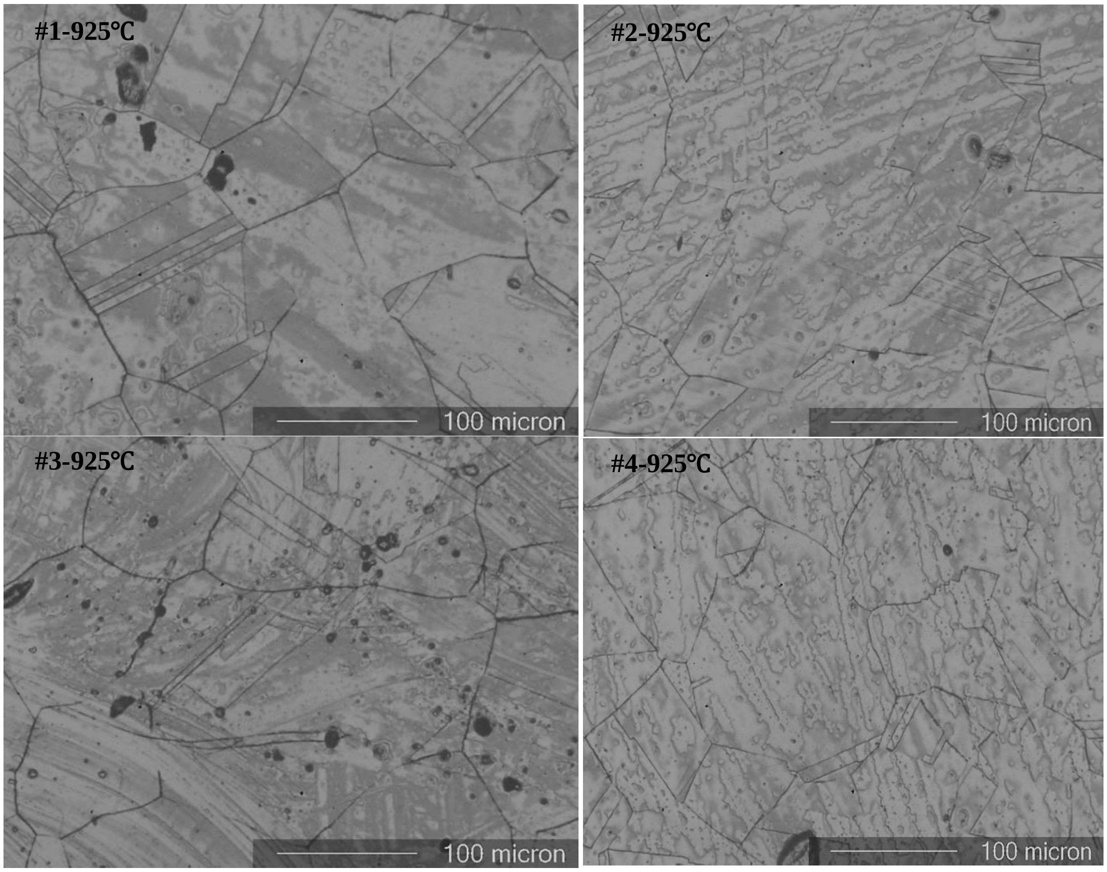


(Fig.3)All the samples after heat treatment were cut 10mm cube size.

3. <u>RESULTS</u>

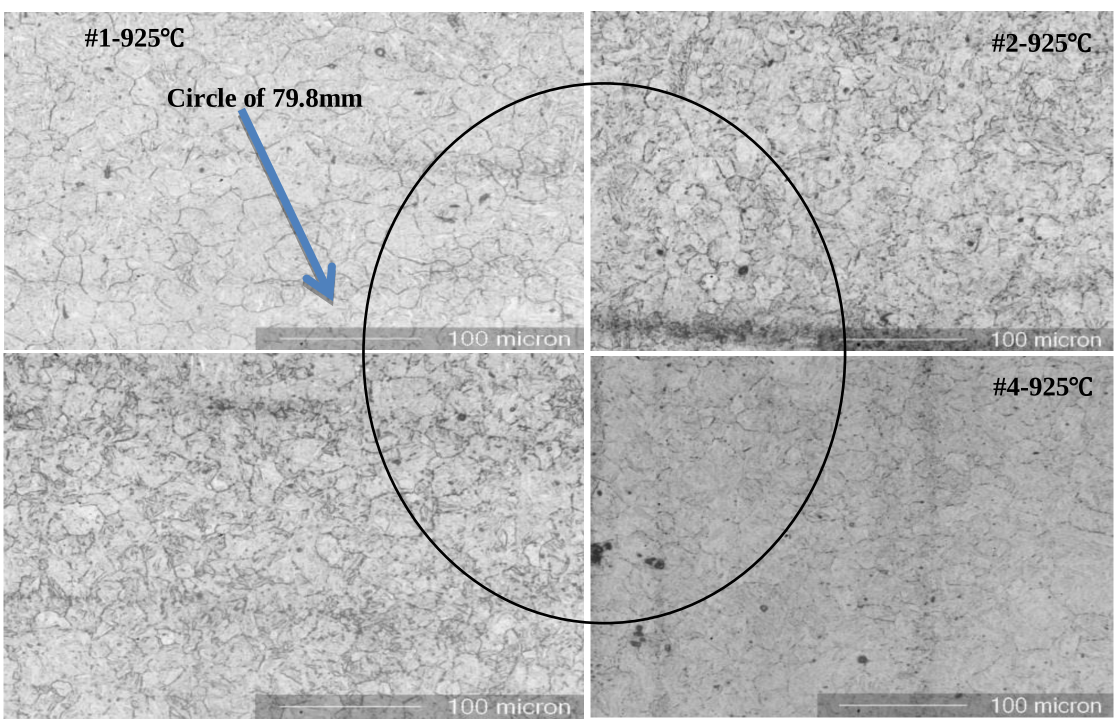
3.1 Scanning Electron Microscopy

To observe the surface topography of the four steels used in this research an SEM microscopy was taken just after etching the samples in heat treated condition at 925°C for 30 minutes holding. Grain size number (GSN) is taken on the optical microscopy pictures of the samples, this was a highly dedicated and time consuming work which involves the long time grinding, polishing, etching work, an attempt was made to reveal the prior austenite grain boundaries by the SEM analysis to make sure that p-austenite grain network is reveal able or not this act was done to save the time for further metallography. SEM micrographs are shown in **(Fig.4).**

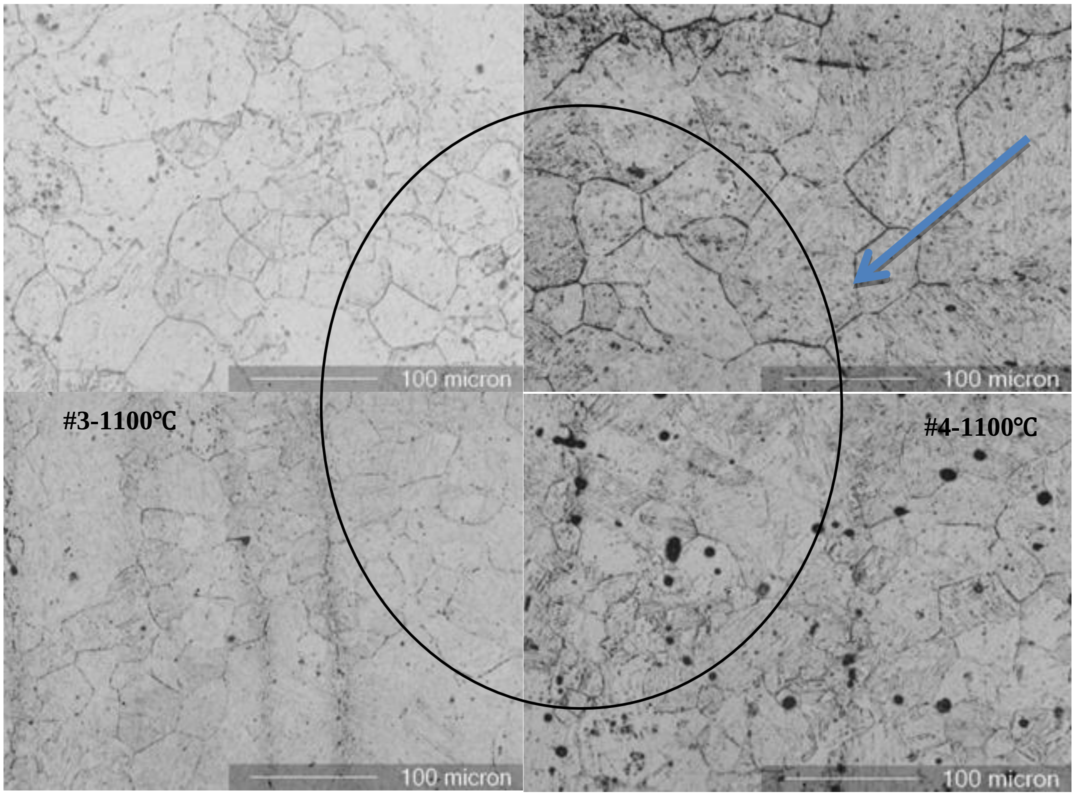


3.2 Micro structural Features at 925C.

Microstructure for four steels has been taken at 925°C with holding time of 30 minutes. Optical microscope was used. Lepera etching reveals the prior austenite grain structure successfully there is nothing dithering in the all microstructure.



3.2 Microstructural features and grain size number at 1100C (30minutes holding).

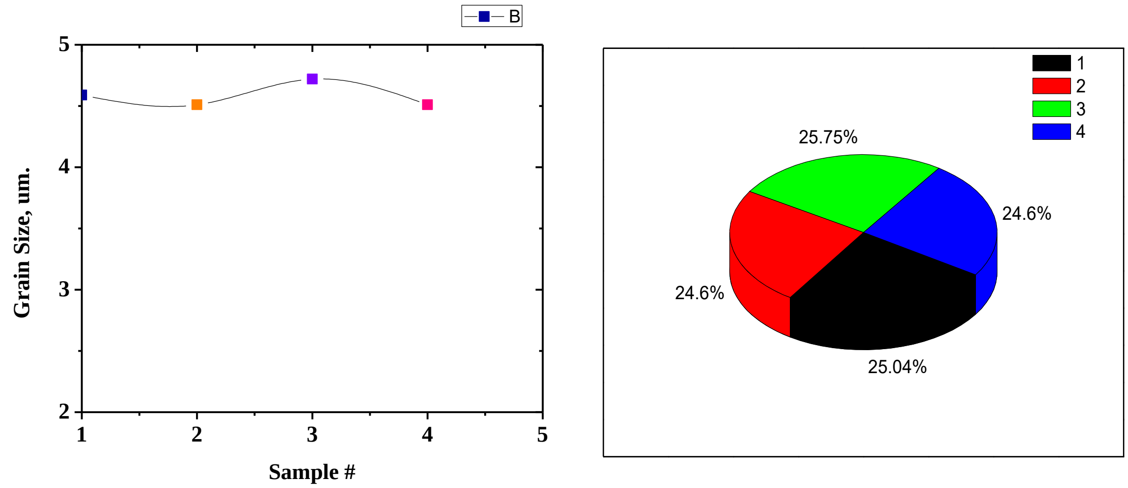


3.4 Calculation of grain size number, g.

The ASTM grain size number, g, was calculated from the number of grains per square inch at a magnification of x100, related to the number of grains per millimeter squared (N_A) measured as:**$g = -2.954 + 3.322\log(N_A)$**(Hall, 1960).To determine the value of N_A the number of grains in appropriate areas has been counted by using the metallography images taken by optical microscope. A circle of diameter 79.8mm (area = 5000mm^2) has been drawn on the micrographs and calculate the results as shown in **(Table.2)**.

Sample #	925℃	1100℃
1	**4.59 ± 0.20**	**2.20 ± 0.50**
2	**4.51 ± 0.20**	**3.73 ± 0.20**
3	**4.72 ± 0.20**	**3.98 ± 0.20**
4	**4.51 ± 0.20**	**4.06 0.20**

The data as received from calculating the grain size number was then plotted as shown in **(Fig.5a** and **Fig5b)**.
Fig5a. Grain Size No. at 925°C.



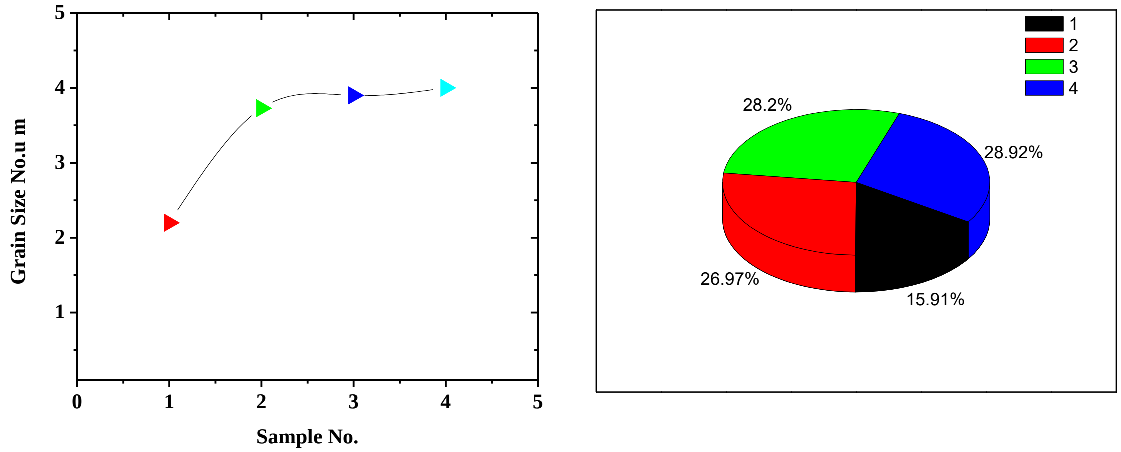


Fig. 5b. Grain Size No. at 1100°C.

4. CONCLUSION

It was concluded that chemical composition and temperature has definitely effect on ASTM grain size number.Al, Ni, Mo, Ti, Nb has significant effect on forming the microstructure and grain size can be affected by the presence of these elements in the steel composition. Also as the austenizing temperature is increased the grain size number is decreased. The driving force for increasing the grain size number is the increasing temperature during heat treatment. Aluminum can hinder the grain growth and nickel is austenite stabilizing element which can affect the grain size number.

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