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Increasing the Hardness of Developed Low Alloy Steel by Heat Treatment Process and Quenched in Normal Water and Ice

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Abstract: In the present study the hardness values were increased with varying the quenching procedure of the special developed low alloy steel. Austenitization heat treatment was done at 900°C for 2h and quenched in normal water and ice water and then further tempered at 240°C for stabelizing the martensite. After austenitization structure was transformed to martensite and small amount of untransformed austenite. With varying the quenching procedure the structure was varied, at ice water quenching structure shows martensite with small amount of untransformed austente but at normal water quenched the structure shows fully martensitic structure. Micro hardness values were varied with varying the quenching process, Normal water quenched shows higher hardness value then Ice water quenched.
Keywords: Low alloy steel; Heat treatment; Microstructure; X-rd analysis; Microhardness;

I. INTRODUCTION

During the last decays, there has been a great demand for steels with higher mechanical strength, sufficient ductility and toughness. Moreover, the lightness of the steel is attractive, as in the automobile and aircraft applications. These requirements can be achieved by an increase in carbon content in a limited way, but even in the heat-treated condition the maximum strength of alloy steel can reach 700 MPa above this value; the ductility dramatically decreases [1].

The heat treatment is usually carried out to obtain a mainly pearlite matrix, which results into strength and hardness higher than in as-received condition and also used to remove undesirable free carbide present in the as-received sample [2]. Steels are normally hardened and tempered to improve their mechanical properties, particularly their strength and wear resistance and hardness. In hardening, the steel or its alloy is heated to a temperature high enough to promote the formation of austenite, held at that temperature until the desired amount of carbon has been dissolved and then quench in oil or water at a suitable rate. Also, in the harden condition, the steel should have 100% martensite to attain maximum yield strength, but it is very brittle too and thus, as quenched steels are used for very few engineering applications. By tempering, the properties of quenched steel could be modified to decrease hardness and increase ductility and impact strength gradually. The resulting microstructures are bainite or carbide precipitate in a matrix of ferrite depending on the tempering temperature [3]

The objective of the present work is to investigate the effect of heat treatment above Ac1 temperature and quenched in normal water and ice on the microstrucre and harness study. Microstructure was studied by optical microscope; phase analysis was done by X-rd analysis and hardness study by Vickers microhardness study.

II. EXPERIMENTAL PROCEDURE

A. Base Material

Special developed steel with addition of higher amount of Cr is used as a base material for the present study. The chemical composition of the special developed materials are given Table 1.

Element	C	Si	Ni	Cu	Cr	Mo	S	P	Ti	Al	Co	V
Wt.%	0.32	1.51	0.96	0.015	2.28	0.394	0.011	0.026	0.036	0.037	0.006	0.037

B. Heat Treatment

Austenitization heat treatment of the as cast samples performed at 900°C for 2 h holding time. After that the samples were cooling at different condition (cooling in normal water and cooling in ice water) for find out the variation of retained austenite in the samples.

After successfully cooling all the samples were tempered at 240° for 4 h holding time for stabilized the martensite in structure. The tempered temperature was selected based on the martensitic start temperature [4]. The heat treatment cycle was represent in **Fig.1.**
Ms = 550 – 350C – 40Mn – 20Cr – 10Mo – 17Ni – 8W – 35V – 10Cu + 15Co + 30Al................ (1)

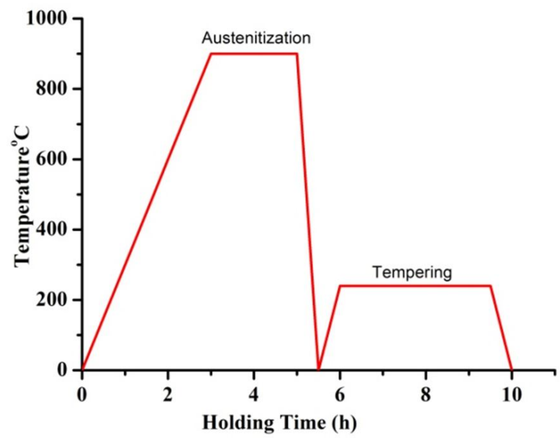

Fig.1: Heat treatment Cycle

C. *Metallography*

The as-cast and heat treated samples were prepared for microstructural study by surface grinding to remove any decarburised skin which could form during the heat treatment. The samples were then mounted, polished in silicon carbide papers (grade 120, 220, 320, 400, 600, 800, 1000 and 1200) followed by cloth polishing using fine 0.05 μn alumina solutions. After polishing all the samples were etched with Kalling's No. 2 (100g Alcohol+100 g Hcl + 5 g $CuCl_2$) solution and micro structures were studied using optical microscope (Carl Zeiss made: AXIO Imager A1m) and photomicrographs were taken at different magnifications (500X, 200X, 100X).

D. *Calculation of Retained Austenite*

X-ray diffraction (XRD) analysis was performed to estimate the volume percentage of retained austenite as well as carbon concentration of the retained austenite using anode Cu – K_α radiation in 1.540 targets with 24 kV and tube current was 40 mA. The specified 2θ range was varied from 30º to 100º with a step size of 0.5º/min. Detailed XRD analysis was performed using integrated intensities of the positions and the integrated intensities for the {1 1 1}, {2 2 0} and {3 1 1} planes of FCC austenite as well as the {1 1 0} and {2 1 1} planes of BCC ferrite. The X-ray diffraction pattern of weld metal at 300°C and 350°C for different holding times are shown in Fig.7. The volume fraction of retained austenite was calculated using the following empirical formula [5]:

$$X_\gamma = \frac{I_\gamma / R_\gamma}{(I_\gamma / R\gamma) + (I_\alpha / R_\alpha)} \text{ .... (2)}$$

Where I_γ and I_α are the integrated intensities and R_γ and R_α are the theoretical relative intensity for the austenite and ferrite, respectively

E. *Microhardness*

Vickers micro hardness tests of as cast and heat treated samples were performed at room temperature using Leco micro hardness tester (Model LM 248SAT) with 100gf load at 10s holding to measure the micro hardness of the as cast and heat treated samples. Micro hardness was taken from the six different positions of samples and average of six hardness values has been considered as representative one.

III. RESULTS AND DISCUSSION

A. *Microstructure*

The optical microstructure of the as-received developed low alloy steel and after austenitization heat treatment cooling at normal water and ice water are shown in Fig.2. In Fig.2 (a) the as-received structure shown ferrite, and pearlite based structure with small amount of bainite was presence. In the Fig. 2(a) the black portion indicates parlite and dark ash colour phase was indicated as bainite. After heat treatment the structure shows martensite with small amount of untransformed austenite. The austenitizing temperature and time plays important rules by indirectly the final microstructure at controlling in normal and ice water which play key parts in the subsequent phase transformatkn during cooling. A very high austenitizing temperature results in a very large grain size. During subsequent quenching the gram size can play an important role in controlling the final transformation products, their distribution and their relative amounts [6]. At the time of austenitizing heat treatment as received developed low alloy steel transformed to marensite and untransformed Austenite. During cooling in normal water and Ice water from 900°C the structure transformed marten site due to rapid cooling system. Martensite is hard brittle structure and it makes the material brittle with increasing strength and hardness. William e. Wood [7] states that during the time of cooling in ice or normal water it was impossible to structure transformed in upper bainite but he also states that lower bainite may also transformed but it was varied in the chemical composition

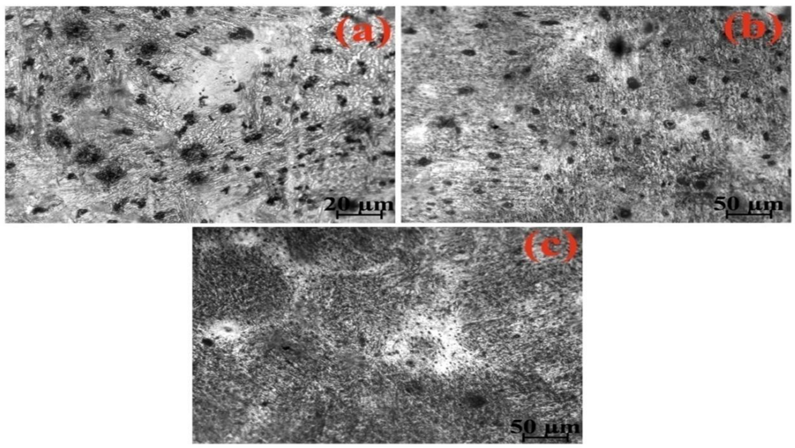

Fig.2: Optical Microstructure of (a) as cast low alloy steel, (b) normal water quenched (c) Ice water quenched

Compare to normal water to ice water quenched the structure shows (Fig. 2(a-b)) more fine but the percentage of austenite is more due to rapid cooling, austenite cannot transformed to fully martensite and therefore small amount of austenite presence in untransformed condition and shows smaller hardness value.

B. Retained Austenite

The volume percentage of retained austenite of the as developed and heat treated low alloy steel sample are calculated by X-rd analyse. The peak- intensity value with respect to 2θ shown in the Fig.3. From the Fig.3 (a) stated that there is no austenite peak was present in the as cast condition and the peak shows fully ferrite base. Similarly at Fig. 3(b) shows that there is small amount of untransformed austenite was present. During cooling from austenitizion temperature to room temperature at ice water and normal water the structure is fully transformed to martensite and small amount of untransformed austenite was present. Therefore, presence of little amount of austenite after heat treatment the materials become hard and ductile. Austenite is soft phase and make the materials ductile to shows the higher impact value and the make the materials for more prominent in practical application.

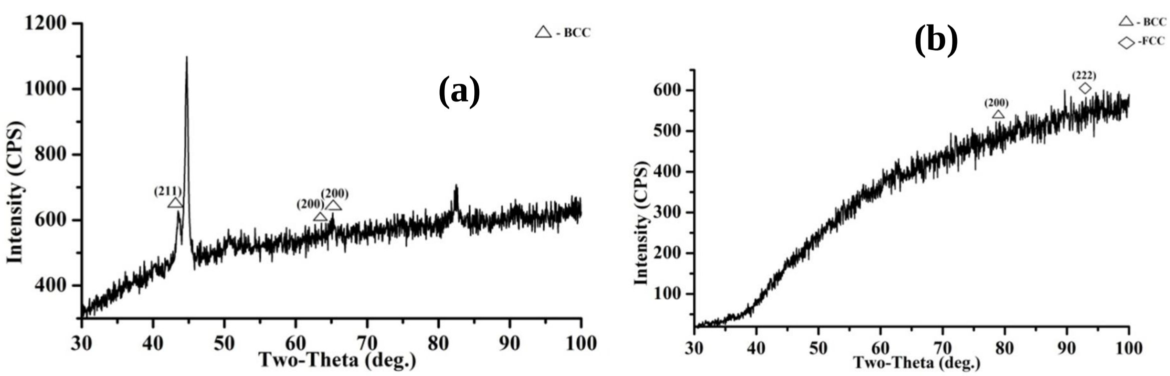

Fig.3: X-rd peak intensity of developed high chrome low alloy steel (a) as-cast material (b) after Ice quenched

C. Microhardness

Vickers microharness test results of the as cast and heat treated low alloy are represented by bar graph in Fig.4

The Fig.4 shows the lower harness value at as cast materials due to presence of ferrite and pearlite based structure. After heat treatment and quenched in normal and ice water the hardness value was increased with changing the microstructure. Compare to ice water and normal water quenched, higher hardness shown at the samples cooling in normal water. Due to relatively slower cooling compare to ice water the structure more or less fully transformed to martensite and make the material hard. But at cooling in ice water the cooling rate is rapid and structure cannot fully transformed to martensite and small amount of untransformed austenite was presence and shows comparatively lower hardness than normal water quenched.

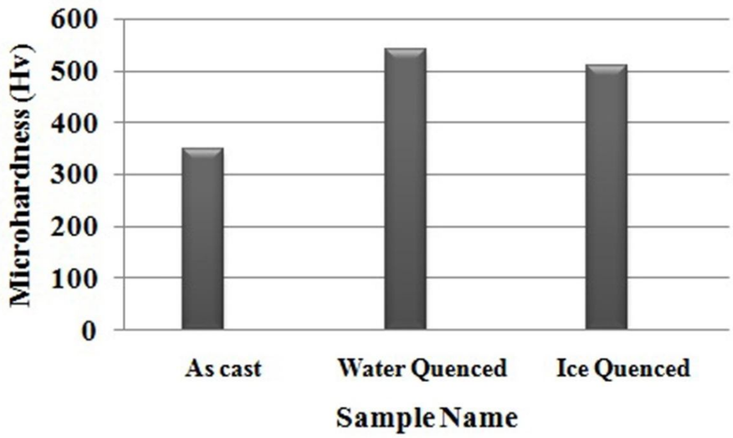

Fig.4: Microhardness plot of as cast, water quenched and Ice quenched developed low alloy steel

IV. CONCLUSION

From the study of the as heat treatment ald quenched in normal and Ice water the following conclusion maybe obtained.

A. Developed low alloy steel was fully respond in austenitization heat treatment and after austenitization samples were quenched at normal water and Ice water. After that further heat treated samples were tempered at below martensite start temperature for stabilizing the transformed martensite.

B. At as cast condition microstructure shows ferrite and pearled based structure with small amount of bainite. After heat treatment the structure was transformed to martensite and small amount of untransformed austenite.

C. Varying the quenching procedure the structure was varied, at ice water quenched structure shows martensite with small amount of untransformed austente but at normal water quenched the structure shows fully martensitic structure.

D. The microhardness values were varied with varying the quenching process, Normal water quenched shows higher hardness value then Ice water quenched.

E. Based on the Microstructure and hardness study it was concluded that normal water quenched is more suitable for increasing the hardness and austenite free structure.

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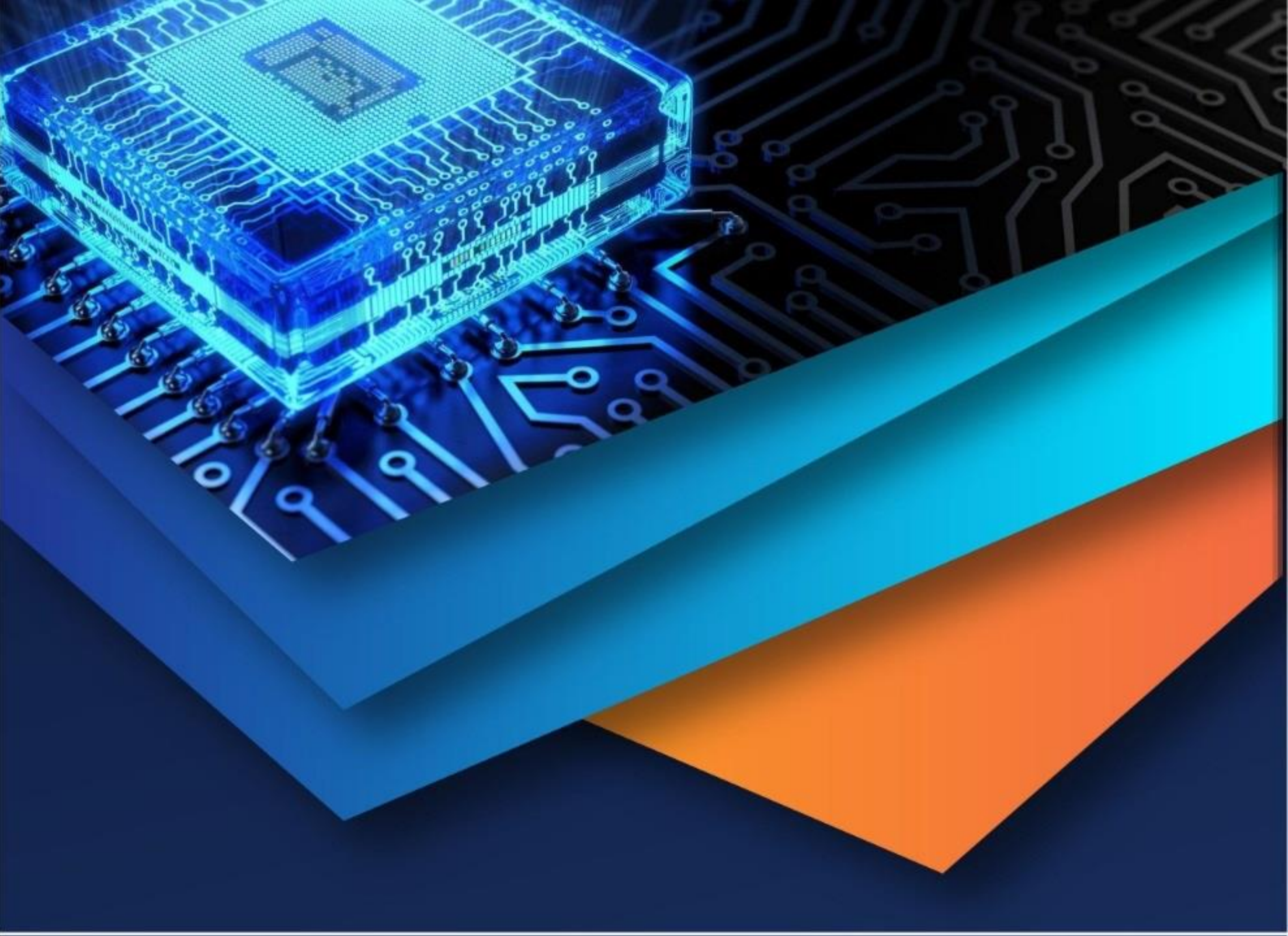

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