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Study the Microstructure and Mechanical Properties of High Chromium White Cast Iron (HCWCI) under Different Martempering Quenching Mediums.

Abstract *This study aims to find the effect of hydroxide mixture as a quenching medium in martempering heat treatment on microstructure and mechanical properties of high chromium white cast iron. This mixture is cheaper and more available than the ordinary nitrate mixture in Iraqi markets. High chromium white cast iron is used in mining, crushing and cement plants as mill liners and it is subjected to extreme conditions of wear and impact that cause failure, reduction in life and raise the cost of repairing. Hence it is important to improve its mechanical properties. In this study, two types of quenching mediums were used:(50% NaOH: 50% KOH) mixture and (50% NaNO3 + 50 % KNO3) mixture. The specimens were austenitized at 950°C for 1 hr then the first group was quenched in nitrate mixture, and the other was quenched in hydroxide mixture both at about 350°C for (1/2, 2,4,6,8) hr. The results showed an increase in hardness and decrease in toughness for both mixtures, and the higher hardness value was found for both of the mixtures at martempering temperature 350°C for 4hr quenching time.*

Keyword: *Hardness, High Chromium White Cast Iron, Martempering, microstructure, quenching mediums.*

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1. Introduction

High chromium white cast irons represent a class of materials commonly used for materials handling, crushing and grinding applications in the minerals and mining industries due to their excellent wear resistance [1,2]. After heat treatment, High chromium white cast irons microstructures are comprised of eutectic carbides and a metallic matrix comprised of secondary chromium carbides, martensite, austenite and in some cases ferrite. During solidification, the eutectic carbides are formed, and they do not undergo a further transformation, but the matrix can be altered. Microstructures in the matrix are affected by three factors: thermal cycle, chemical composition and the initial state of alloy (as-cast or annealed). This will, in turn, affects the hardness and wear resistance of the material. In general, at the end of the solidification process, the microstructure of high-chromium white cast iron is composed of a primary phase (austenite dendrite) and a eutectic compound (M_7C_3) [3]. The reference [4] studied the influence of variables such as holding temperatures and times during aus tempering of High Chromium White Cast Iron (HCWCI). It is found that the best performance of alloy against the abrasion was at austempering at 450 ºC with 6 hours holding time. The reference [5] studied the effects of soft annealing and hardening and tempering on the hardness and microstructure of high chromium cast iron. Their results showed that a proper selection of parameters of heat treatment could control the hardness and composition of phase microstructure of chromium cast iron. Hardening has positive effects on the hardness of castings, but tempering and soft annealing enhance ductile properties. The reference [6] observed the effect of changing the chemical composition and heat-treatments on the microstructure and mechanical properties of high chromium white cast iron. The results revealed marked improvements in mechanical properties and wear performance by adding carbide forming elements .on the other hand, the Destabilization heat treatment employed to obtain the martensitic structure for improving the toughness and abrasion resistance of these irons. In addition, the subcritical (tempering) heat treatments following the hardening are commonly utilized to relieve the internal stresses and to control the final hardness before service. The reference [7] studied the effects of heat-treatment on microstructure and mechanical properties of high chromium white cast iron alloyed with

titanium. The austenitiztion heat treatment with temperatures of 980°C and also 1150°C for 1 hour followed by tempering at 260°C for Two hours have been accomplished, and the effect of these processes on (wear resistance/impact toughness) combination was reported. The results clarify that the maximum tensile strengths were achieved for the (1.31%Ti) irons; also, maximum impact toughness was obtained for the irons without Ti-addition. The wear resistance results were higher for the samples austenitized at (980°C) in comparison to the irons treated at (1150°C). For both treatments, optimum wear resistance was obtained with (1.3% Ti). The current study aims to find cheaper and more available quenching medium than the ordinary nitrate mixture and compare its effect on microstructure and mechanical properties.

2. Materials and Methods

The metal sample of the category (A-532 Class III Type A) is used. The sample is obtained from (Kufa Cement Plant) mill liners. The chemical composition of the sample is investigated via (AMETEK, SPECTRO MAXx) at (State Company for Inspection and Engineering Rehabilitation (S.I.E.R) at Industry and Minerals Ministry, Iraq). The chemical composition of the sample used in this work is shown in the following table (see Table 1). The heat treatment used here is Annealing, quenching and martempering with two types of quenching mediums: (50% NaOH: 50% KOH) mixture and (50% NaNO3 + 50 % KNO3) mixture with differing quenching intervals. All heat treatment processes are illustrated in Figure 1-A. The procedure of martempering heat treatment is illustrated in Figure 1-B.

The samples were prepared to be examined under an optical microscope by polishing using (320 up to 2000) grit papers and using 1µm polycrystalline diamond paste. The specimens were etched using 0.5 g copper (II) chloride in a solution of 11 ml absolute methanol, 11 ml distilled water and 11 ml concentrated HCl (Kalling's reagent)[8]. The specimens were examined under a scanning electron microscope and X ray diffraction spectroscopy. Impact toughness of the specimens was tested using Charpy impact tester(direct readings), and the hardness was tested using Vickers macro hardness tester.

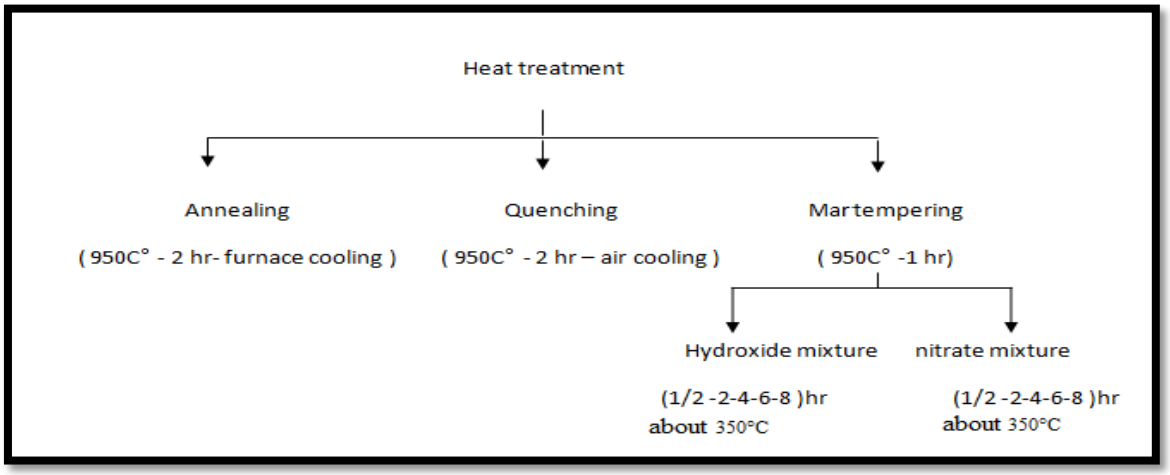


Figure 1-A : heat treatment processes

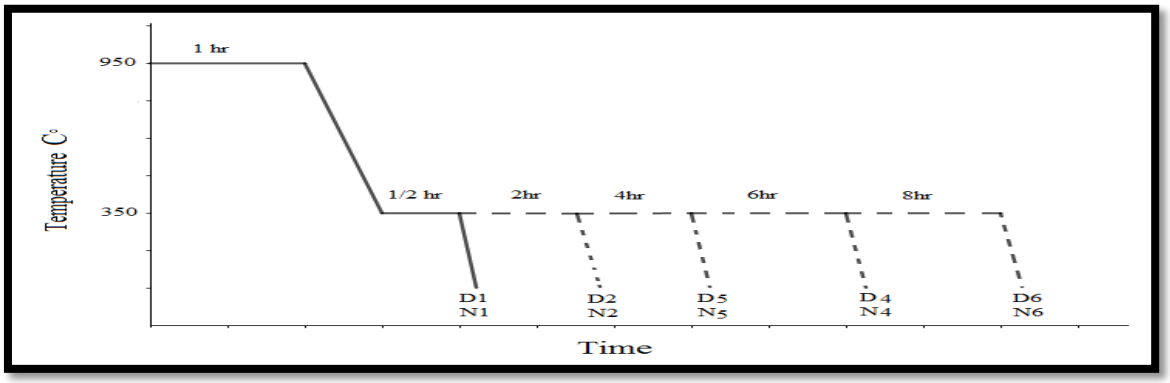


Figure 1-B: Martempering heat treatment procedure

Table 1: Chemical composition of measured sample vs. ASTM

Element	C	Si	Mn	P	Cr	Mo	Ni	Fe
Measured	2.43	0.8	0.7	0.017	27.25	0.014	0.16	Bal
ASTM	2.3 - 3	1 max.	0.5-1.5	-----	23 - 28	1.5 max	1.5 max	Bal

3. Results and Discussion

The results showed that the different heat treatment affects the microstructure and mechanical properties of the specimens in different ways. The results obtained were compared with the as- received specimens, and they showed an increase in hardness of quenched and martempered specimens whereas there was a decrement in hardness values of annealed specimens. The influence of temperature, time can explain this different behavior, the severity of quenching, microstructure type, and second phase particles type in the heat-treated specimens. The hardness values depend on the amount of precipitate of secondary fine carbides and also on the formed martensite [4]. On the other hand, the impact test showed a decrease in toughness of quenched and martempered specimens which is also found by **[**9] also decrease in the annealed ones as illustrated in Table 2.

I-Vickers macrohardness and impact values

From Table 2, it is observed that the highest hardness values were obtained at martempered specimens for (4 hr + quenching) in both molten hydroxide and nitrate mixtures. While the highest impact value was observed in as-received and martempered specimens for (6 hr + quenching) in nitrate mixture.

II. XRD results

From the XRD charts, the microstructure of Figure 2-A(as received specimens) are consisted of ferrite, austenite and secondary carbide [10], while the microstructure of Figure2-B(annealed specimens) consist of ferrite, austenite, martensite, and secondary carbide and the microstructure of Figure 2-C(air-quenched)consist of Martensite, austenite, ferrite and secondary carbides. The microstructures of other specimens (martempered in hydroxide mixture) reveal the appearance of martensite especially at (4,6 and 8) hrs i.e.(Figures 2-D4, D5, D6)while the other microstructures reveal the secondary carbides (Figures2-D1, D2).On the other hand, the mar-tempered specimens (in nitrate mixture) reveal a presence of martensitic phase at(1/2,4,8) hrs , i.e., Figures (2- N1, N5, N6) while other specimens at the remained times (Figures 2- N2, N4) consist mostly of secondary carbides. These microstructures were also found by [4].

Table 2: Vickers microhardness and impact values

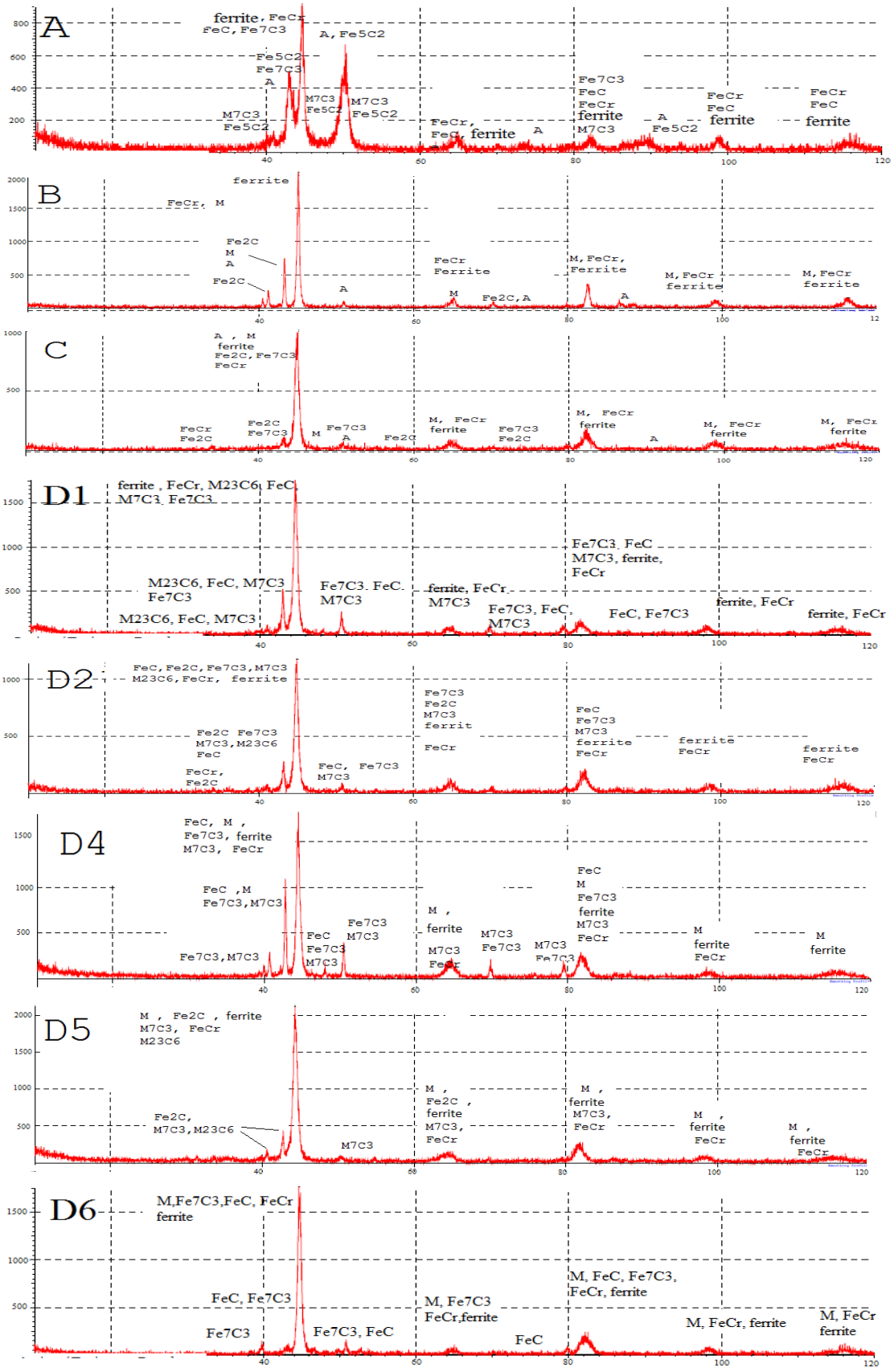
Sample no.	Condition	Vickers Average Hardness	Average Impact Values(J)
A	As-received	857	2.3
B	Annealing	663	1.6
C	quenching	784	1.8
	Hydroxide mixture		
D1	martempered +1/2 hr	789	1.3
D2	martempered + 2 hr	978	1.5
D5	martempered + 4 hr	1051	1.55
D4	martempered + 6 hr	850	1.75
D6	martempered + 8 hr	729	0.96
	Nitrate mixture		
N1	martempered + 1/2 hr	946	1.7
N2	martempered + 2 hr	955	2
N5	martempered + 4 hr	1014	2
N4	martempered + 6 hr	768	2.2
N6	martempered + 8 hr	889	1.6

for the samples

III. Optical microscope images

From Figure 3 it is observed that the microstructures of the specimens martempered at the hydroxide and nitrate mixtures approximately the same. These microstructures consist of (austenitic, ferritic, marensitic) matrix (darker areas) with eutectic and secondary carbides (lighter areas) that are dispersed in these matrixes in approximarely the same shapes and patterns for samples shown in Figure 3(A, B, C, D1, N1, D2, N2, D4, N4, D5, N5) except that for specimens which were mar-tempered in hydroxide and nitrate for 8 hrs (D6 and N6 respectively). The

microstructure of D6 reveals that the carbides circulate the matrix whereas N6 reveal that the carbides were elongated and dispersed in the matrix in almost all directions.



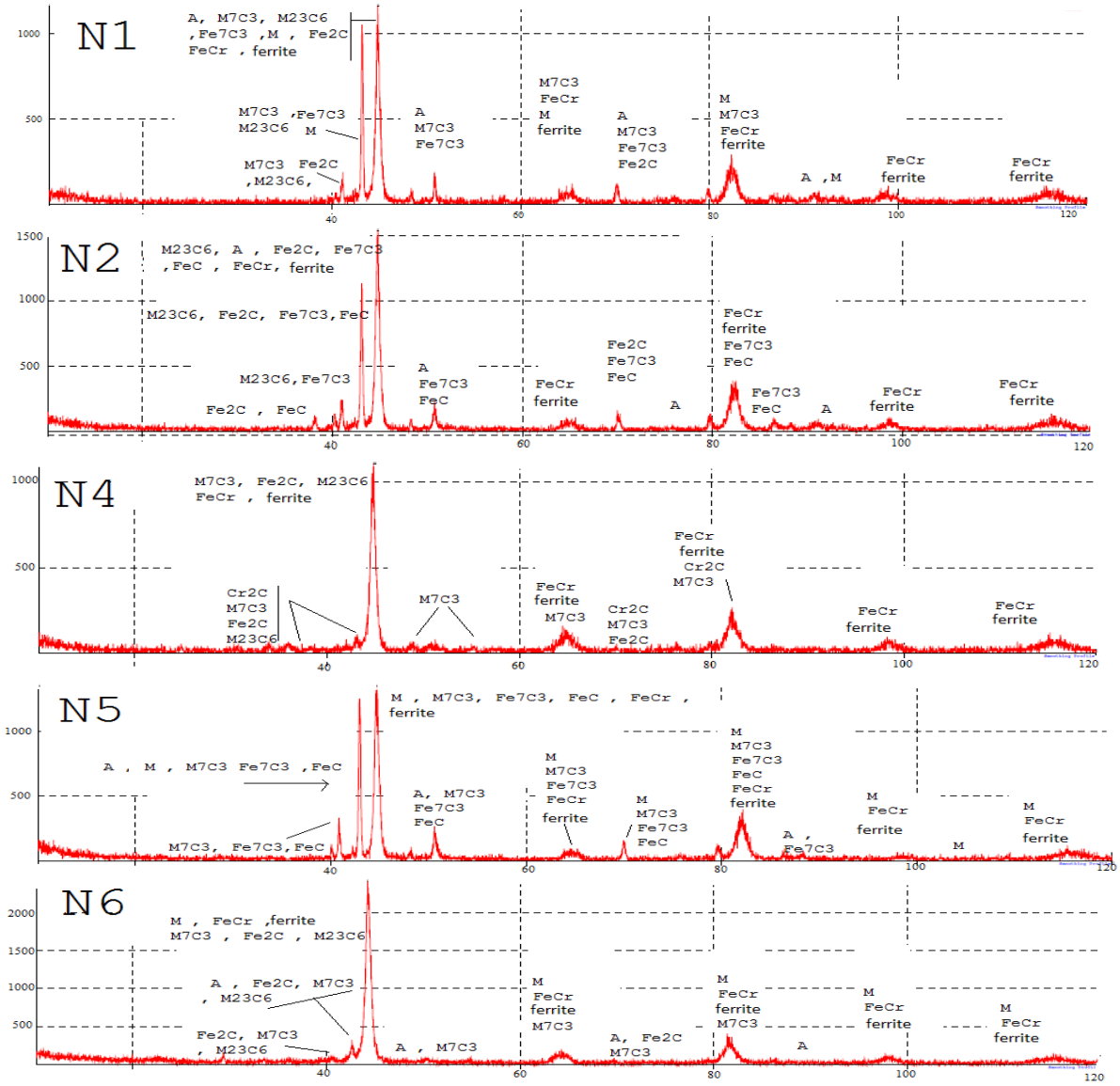
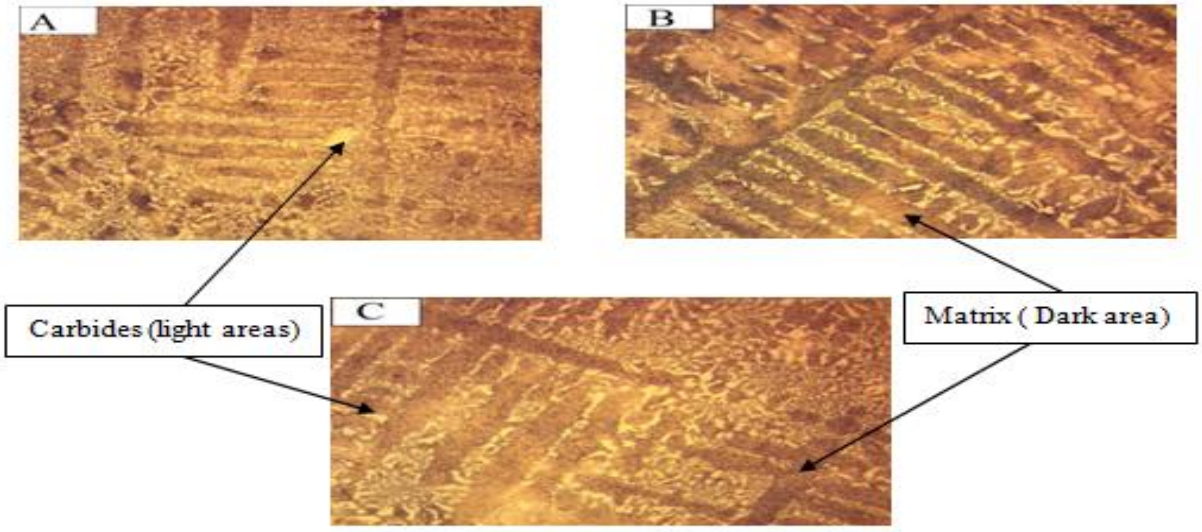


Figure 2: XRD charts of the heat-treated specimens



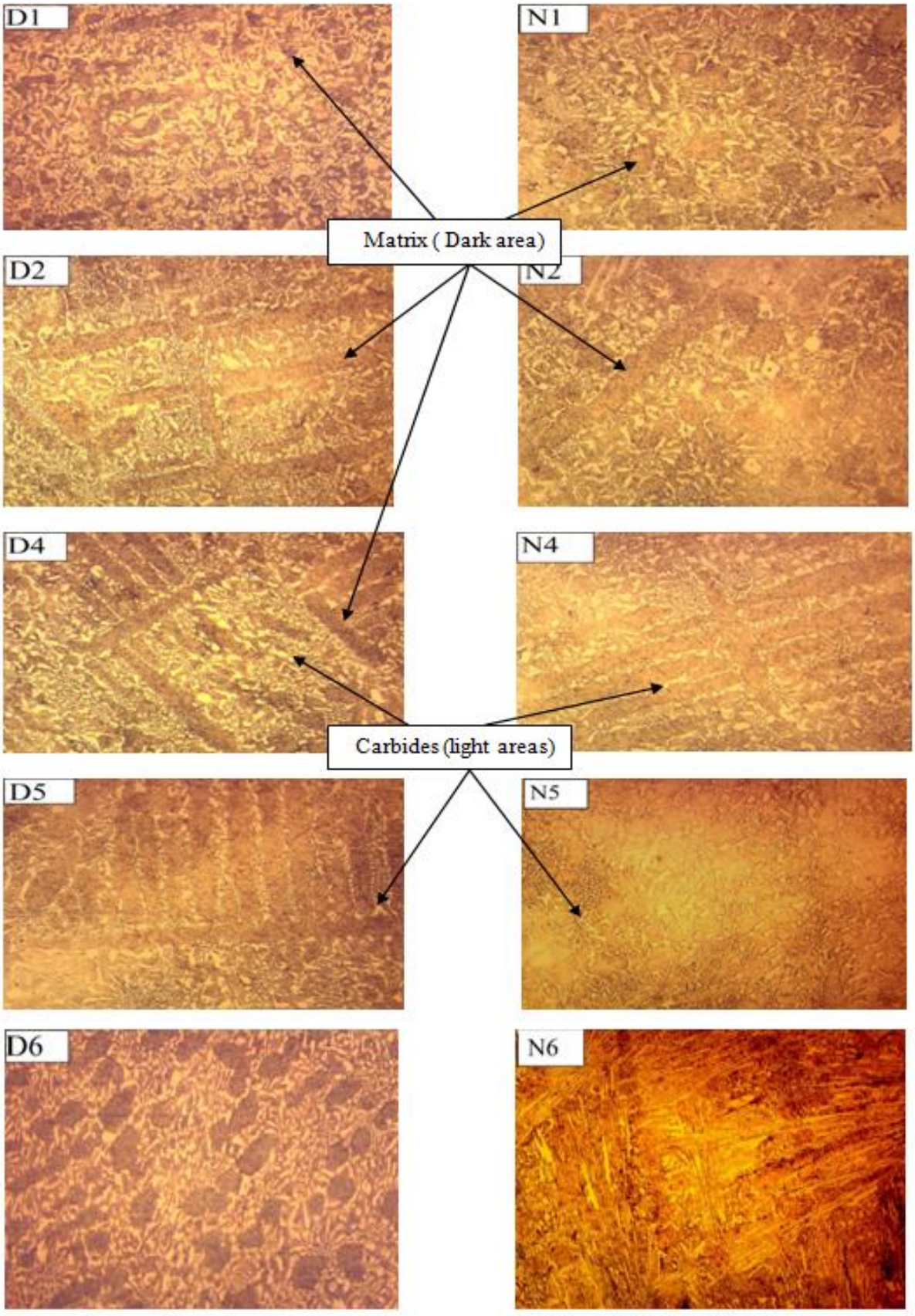


Figure 3: Optical microscope images of the specimens with 20 X magnification

IV.SEM images

SEM image (see Figure 4) were obtained for some of the samples like (A, B, C, D2, D6, N2, N6) at the fractured surface at different magnifications in order to understand the effect of the microstructure developed by different heat treatments on the fracture behavior.

Generally, the fracture has brittle nature in all the samples, but its path is different from one to the other according to the original direction of grain growth during solidification of the original casting.

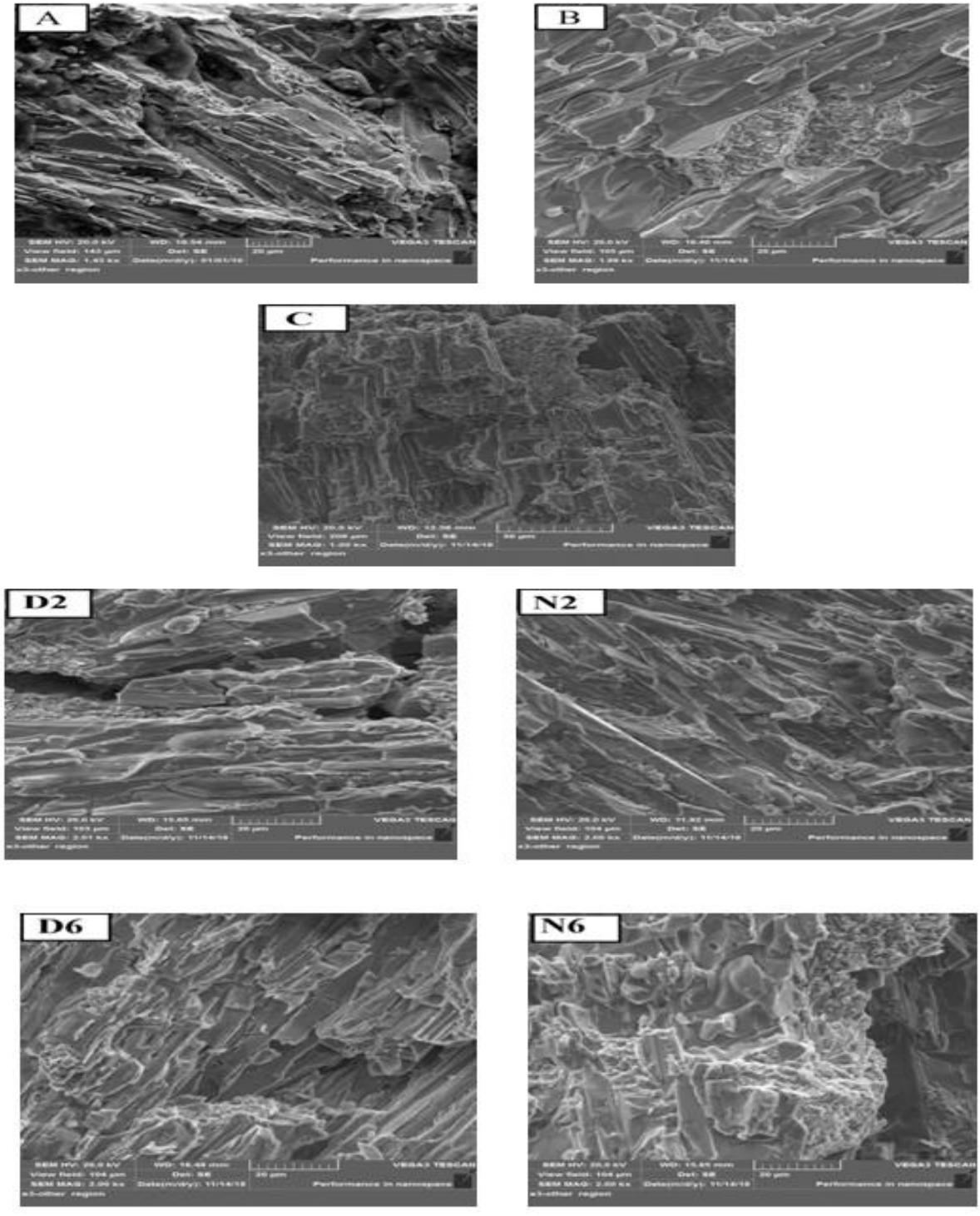


Figure 4: SEM images of different heat-treated samples

4. Conclusions

1- There was an increase in hardness value by 22.64%(hydroxide mixture) and by 18.32% (nitrate mixture) both at martempering about 350°C for 4 hr as compared with as received specimen whereas impact values were gene-rally slightly decreased for both mixtures at all intervals.

2- Martempering process did not lead to a complete transformation of austenite to martensite but produce a mixture of austenite, ferrite, martensite matrixes with eutectic and secondary carbides.

3- The nitrate and hydroxide mixtures have both advantages and disadvantages and can be summarized as follows:

- Nitrate mixture is recyclable, costly,

no emission of gases.

- Hydroxide mixture is cheap, not recyclable, small emission of gases, and corrode some heat treatment equipment (this can be avoided using corrosion resistant equipment).

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