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Study of Annealing, Hardening and Tempering on Hardness and Microstructure of Mn-Fe Alloy

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Abstract:

In this study, the effects of heat treatments annealing ,hardening and tempering on the microstructure and hardness of Mn-Fe Alloy were investigated. The Mn-Fe alloy samples were annealed at 900◦C for 20 min then cooling inside furnace and hardened treatment at 900◦C for 20 min with cooling by water, oil, and salts solution. The specimens were subsequently tempered at temperatures of 100 ^{o}C, 290 ^{o}C, 350 ^{o}C and 500^{o}C. The microstructures, and hardness properties of these samples were analyzed and compared with samples without treatment. The microscopic examinations showed that difference in grains size for samples before and after heat treatments. The result showed that tempering of Mn-Fe Alloy samples (0.3%C) significantly exhibited better hardness as compared with that of Mn-Fe alloy without treatments .

Keywords: annealing , hardening , tempering

1. Introduction

The optimization of alloying contents in the iron-carbon alloy system combined with different mechanical and heat treatments lead to immense opportunities for parameter variations and these are continuously being developed [1].

The applications of steels for engineering components require a complete understanding of material properties and design requirement. Quenched and tempered microalloyed steels are most likely candidate material for the next generation of high strength steel sheets. For a given alloy content, quenched and tempered microalloyed steel exhibits good combination of strength and toughness[1,2].

Traditionally, quenched and tempered steels sheets are being employed in automotive industry in the areas of structural members, power transmission and impact resistance systems. With the advent of dual-phase heat treatment, the possibility of introducing dual phase treated sheets are becoming attractive proposition in those areas. Dual-phase microalloyed steel consists of martensitic islands in a ductile ferrite matrix [1]. Their potential as superior strength and formability substitutes for current automotive steels was recognized and has provided an incentive for their rapid development acceptance in this role . However, the microstructural evolution and mechanical properties of tempered dual phase steels is also of interest but has received little attention [3].

The objective of this work, therefore, was to study and compare the effect of variation of hardening tempering temperatures on the microstructure and hardness properties of quenched and tempered of Mn-Fe alloy.

The study of mechanical properties is important to know the stress durability. These are also of great importance in connection with the corrosion resistance that are directly influenced by mechanical factors such hardness, tensile, applied stress, …, etc.

2. Annealing , Hardening and tempering of Mn-Fe alloy

Annealing includes the heating of steel to an appropriate and enough temperature to transform steel to austenite, i.e. above the temperature of (**A_3**) for hypo-eutectoid steel, by about (**30 – 50 ^oC**), and keeping steel at this temperature for an enough period of time to completely transform steel to austenite (equals to about one hour for every **25 mm** thickness of piece under treatment). Then, this is followed by cooling steel extremely slowly (inside a furnace) to room temperature. Hypo-eutectoid steel types are hardened by heating to temperatures above (**A_3**) as shown in figure (1) by (**30 – 50 ^oC**) for a time period long enough to transform the steel into austenite, and then cooled quickly by quenching in water. While types of hyper-eutectoid steel are hardened by heating to temperatures above (**A_1**), i.e. below (**A_{cem}**), then they are cooled quickly by quenching in water. At these temperatures, the steel microstructure will consist of austenite and cementite grains. Therefore, the resulting structure after hardening will consist of martensite and cementite. Cementite is very hard, whose hardness may reach about(**70 RC**) Rockwell hardness which exceeds that of martensite whose hardness is less than (**70 RC**) Rockwell hardness, therefore, the resulting structure will have extreme hardness after the hardening treatment [4].

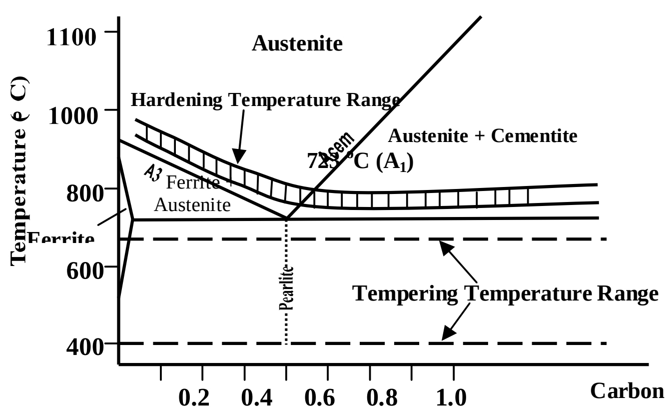

Figure (1) Temperature Range for Tempered And Hardened Types of Carbon Steel [4]

Usually, tempering is carried out by heating hardened steel at temperatures below the lower critical temperature (**A_1**), within the range (**450 – 700 ^oC**), as shown in Figure (**1**). This treatment can be conducted at lower temperatures i.e. within (**100 – 300 ^oC**), but in this case, it will not achieve all the required objectives; it only leads to a stress relief and remove retained austenite [4].

In any case, tempering treatment can be carried out on many stages, depending on temperatures used; and these stages are called tempering at low, medium, and high temperature tempering, noting that these stages might overlap between each other [5].

3. Experimental Procedure

3.1 Chemical Composition

The chemical compositions of material used in this study have the following composition (in wt.%): 0.3% C, 1.5% Mn, 0.06% P, and 0.06% S, Fe for balance, where, samples are cutting from circular bar used in traditional manufacturing process with chemical compositions illustrate above.

3.2 Heat Treatments Procedure

The heat treatment which was used in this study for cylindrical specimen 0.7 Ø × 0.7 cm of Mn-steel alloy and 17 min remaining in an electric muffle furnace at the temperature illustrated in Table (1) below:

Table (1) Heat treatments operation.

Heat treatments	Austenizing temperatures	Cooling media
Annealing	900^{o}C	Inside furnace
Hardening	900^{o}C	Water and oil quench
Tempering	For sample quench in water, 100^{o}C ,290^{o}C, 350^{o}C and 500^{o}C	Air cool

3.3. Hardness Test

The (Eqno-Tip type D, Swiss made) hardness machine used for this test was Vicker's diamond pyramid indenter, as the hardness measurements were made for the samples before and after treatments, [5]. The Vickers hardness test uses a square based diamond pyramid as the indenter which gives geometrically similar impressions under different tests. The angularity of the pyramid is 136° and loads ranging from 5 to 120 kg can be used (in this work 10 kg are using). The diamond pyramid hardness number (DPH, or alternatively, the Vickers hardness number, VHN) is determined by dividing the load by the indented surface area [6].

3.4. Metallurgical Microstructure

For preparing the specimens to the metallographic .evaluation are as follows:

I. Wet grind using 240, 320, 400 and finally 600 grit SiC paper.

II. Rough polish using 6 micron diamond on a nylon cloth.

III. Fine polish using 0.05 micron alumina on a flocked cloth.

IV. Etch in a Nital solution. The microscope examination was done by using optical microscope (Olympus-Japan made, 1989).[7]

4. Results and discussion

Increasing the hardness of steel is, sometimes, considered to be one of the main objectives of the hardening treatment for the equipment and machine parts which are exposed to friction during service, hardening treatment leads to increase their tensile strength. Microstructures formed as a result of rapid cooling by quenching in water, is characterized by good mechanical properties like, hardness and tensile strength, but at the same time, it lacks a number of important properties such as ductility and toughness. The main objectives of tempering hardened steel are justified in removing these flaws or minimizing their negative effect on the properties of steel.

The diameter of indentation of hardness testing results are presented in Table (2) for three readings of each specimens, these readings show the surface of specimens in non homogeneous therefore we are taking the mean value. The results of Vicker's Hardness tests are presented in Table (3) and Figure (2) which showed that hardness decreases in annealing while increasing hardness in water , oil and salt solution quenching as respectively, these results refer to an increase in hardness as a result of heat.

Annealing treatment, leads to the removal of crystal dislocations and decreasing in hardness. This process results from the diffusion which takes place easily during the heating and the following slow cooling.

Cepus, E., Liu, CD. and Bassim, N.M., [8] appears that for medium carbon steel Vicker's hardnes equal to 185.7 VHN without treatment, changing to 330.0 VHN at 315°C quench tempered, 323.3 VHN at 480°C quench tempered ,and 214.7 at 650 °C quench tempered.

In this work appears that for Mn-Fe Alloy Vicker's hardnes 142 VHN without treatment, changing to 277 VHN at 350°C quench tempered, Vicker's hardnes 149 VHN without treatment changing to 314 VHN at 290°C quench tempered, and Vicker's hardnes 168 VHN without treatment changing to 217 VHN at 500°C quench tempered.

Microstructure has influence on the cooling rate and treatment type , this has been clearly observed in the present investigation as shown in Figures(3,4,5,6,& 7)

Cepus, E., Liu, CD. and Bassim, N.M., [3] appears that any heat treatment responsible for the increase in ferrite of the sample will correspondingly increase its ductility. Ferrite, since being the softest of the phases studied here will deform preferentially over either pearlite or martensite. If the pearlite is sufficiently coarse, the lamellar spacing will be great enough such that the ferrite between the cementite layers will be in great enough proportion to deform, giving rise to a homogeneously deformed shear band. In the case of martensitic microstructures which can be resulted from hardening treatment, the deformation is uniform until the amount of ferrite is increased through tempering, at which point the ferrite will deform preferentially while the martensite remains virtually un deformed.

Table (2) diameter indentation (d (mm)) in Vicker's hardness test

Samples No.	1	2	3	4
Diameter of indenter before treatment	4.5	4.3	4.2	3.8
	4.3	4.3	4.2	4.1
	4.3	4.4	4.3	4.1
Treatment	Annealing cooling inside furnace	Hardening cooling in oil	Hardening cooling in salt solution	Hardening cooling in water
Diameter of indenter after treatment	4.8	4.1	3.1	2.6
	4.85	4	3.1	2.6
	4.75	4	3.2	2.6
Treatment	Tempering at 100°C quench in water	Tempering at 290°C quench in water	Tempering at 350°C quench in water	Tempering at 500°C quench in water
Diameter of indenter after treatment	2.6	2.9	3.1	3.6

Table (3) Results of Vicker's Hardness tests

Number of sample	1	2	3	4
Vicker's Hardness (HV) before treatment	132	144	151	185
	144	144	151	159
	144	138	144	159
HV mean value	140	142	149	168
Treatment	Annealing cooling inside furnace	Hardening cooling in oil	Hardening cooling in salt solution	Hardening cooling in water
Vicker's Hardness after treatment	116	159	278	395
	113	167	278	395
	118	167	261	395
HV mean value	116	164	272	395
Treatment	Tempering at 100°C quench in water	Tempering at 290°C quench in water	Tempering at 350°C quench in water	Tempering at 500°C quench in water
HV mean value	395	314	**277**	**217**

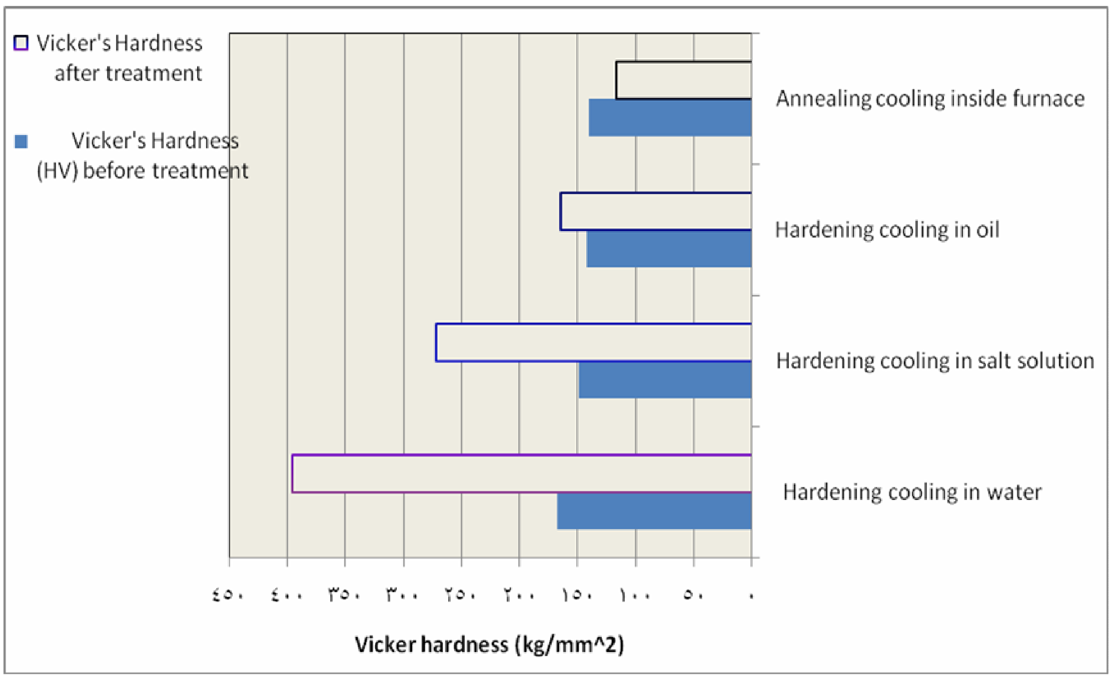

Figure (2) Mean of Vicker's Hardness tests

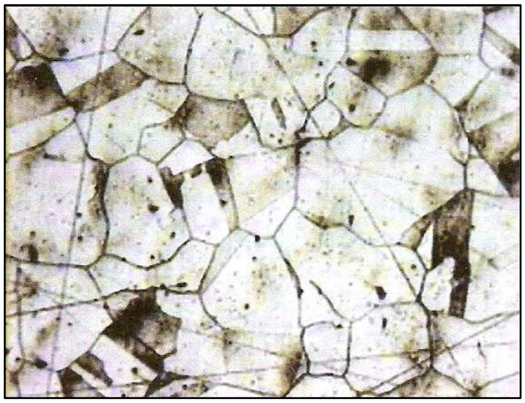

Figure (3) Microstructure of carbon steel before subjected to annealing treatment

Figure (4) Microstructure of carbon steel before subjected to hardening treatment

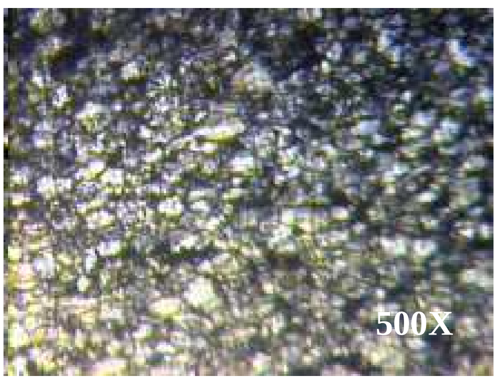

Figure (5) Microstructure of carbon steel after subjected to hardening treatment cooling in salt solution

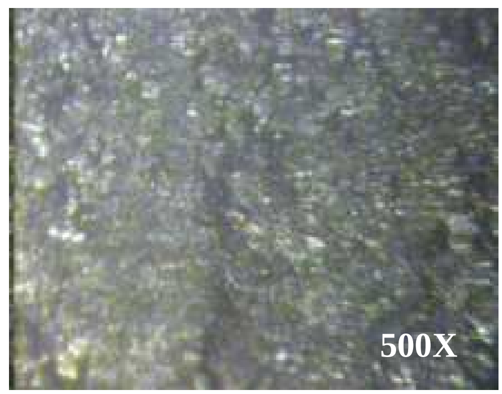

Figure (6) Microstructure of carbon steel after subjected to hardening treatment cooling in oil solution

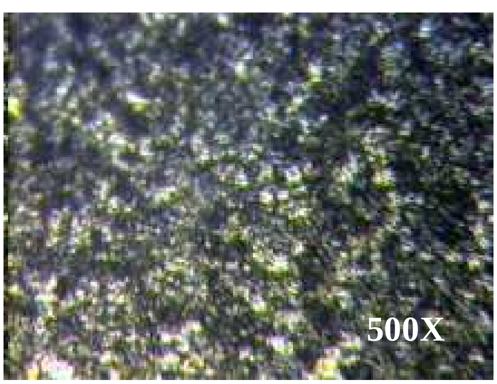

Figure (7) Microscopic of carbon steel sample hardening by quenched in water.

5. Conclusion

From the results of the investigation carried out in this work, it can be concluded that:

I- The tempered Mn-Fe alloy samples are characterized by a comparatively high hardness than the sample without treatment.

II-The increase in tempering temperature in the range of 200-350^{o}C shows small significant variation on the hardness of the tempered 0.3% C steel.

III-It appears that the hardening treatment causing granular.

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دراسة تأثير التلدين ، التصليد والمراجعة على الصلادة والبنية المجهرية في سبيكة Mn – Fe

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الخلاصة:

في هذه الدراسة ، تم التعرف على تأثير المعاملات الحرارية :التلدين، التصليد والمراجعة على البنية المجهرية وخاصية الصلادة في سبيكة Mn – Fe. عينات سبيكة Mn – Fe لدنت بدرجة حرارة 900◦C لمدة 20 min وبردت داخل الفرن وعوملت بالتصليد بدرجة حرارة 900◦C لمدة 20 min وبردت في الماء والزيت ومحلول ملحي. بعدها تم مراجعة العينات في درجات الحرارة من 100 ^{o}C, 290^{o}C, 350 ^{o}C و 500^{o}C. تم تحليل البنى المجهرية وخاصية الصلادة لهذه السبيكة ومقارنتها مع عينة من دون معاملة ، تم فحص البنى المجهرية للعينات قبل المعاملة الحرارية وبعد تغيرها . واظهرت النتائج ان معاملة سبيكة(0.3%C) Mn – Fe يؤدي الى الحصول على أفضل الخصائص الميكانيكية بما في ذلك ارتفاع الصلادة بالمقارنة مع سبيكة Mn – Fe بدون معاملة.