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IMPACT OF HYPO AND HYPER EUTECTOID STEELS MICROSTRUCTURES IN THEIR PROPERTIES

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ABSTRACT

Quantitatively a pearlitic structure is characterized by ferrite - pearlite percentage and interlamellar spacing of the pearlite.These parameters vary as a function of the transformation temperature.When the carbon content is below 0.6%, pearlite always degenerate, with low yield strength but good reduction in area. Pearlites containing more than 0.6%C always present normal cementite lamellae with high yield strength but small reduction in area. For 0.6%C steel, fragmented or continuous lamellar structures can be obtained, leading to high yield strength and reduction in area values.

***Keywords: Fatigue Strength, Lamellar Structures, Pearlitic Structure, Transformation Temperature, Yield Strength*.**

I INTRODUCTION

The influence of the carbon content of austenite on the structure of the pearlite was studied in this article. It is pointed out that interlamellar spacing of pearlite and percentage of ferrite decrease with the transformation temperature. It was found that the carbon content in pearlite depends on carbon content of the steel and temperature of transformation, which is both determining the percentage of free ferrite.

The influence of free ferrite has been eliminated by using cooling rates fast enough for obtaining a fully pearliticstructure in steels between 0.45 and 1 %C.

Today heat treatment process is widely used to achieve high mechanical properties. Major requirements of medium carbon steel are high yield strength, high proportional limit, and high fatigue strength. These desirable properties of medium carbon steel can be achieved by adding suitable alloying elements and secondly by heat treatment. Heat treatment is a combination of timed heating and cooling applied to a particular metal or alloy in the solid state in such ways as to produce certain microstructure and desired mechanical properties (hardness, toughness, yield strength, ultimate tensile strength, Young's modulus, percentage elongation and percentage reduction). Annealing, normalizing, hardening and tempering are the most important heat treatments often used to modify the microstructure and mechanical properties of engineering materials particularly steels. Annealing is the type of heat treatment most frequently applied in order to soften iron or steel materials and refines its grains due to ferrite-pearlite microstructure; it is used where elongations and appreciable level of tensile strength are required in engineering materials. In normalizing, the material is heated to the austenitic temperature range and this is followed by air cooling. This treatment is usually carried out to obtain a mainly pearlite matrix, which results into strength and hardness higher than in as received condition. It is also used to remove undesirable free carbide present in the as-received sample. Steels are normally hardened and tempered to improve their mechanical properties, particularly their strength and wear resistance.

II EXPERIMENTAL PROCEDURE

2.1 Materials

In this experiment are used 8 bar steel samples with dimensions d = 15 mm and l = 30 mm. Steels with different percentage of carbon and chemical composition are represented below:

Table 2.1 Sample main characteristics

Sample	Steel with 0.45 % C (1 Sample)	Sample with 60% C (3 Samples)	Steel with 1% C (4 Samples)
Chemical Composition	Unalloyed steels with 0,4- 0,7 % Mn.		

2.2 Heat Treatment

The samples were cylinders 15 mm in diameter and 30 mm long, austenitized as tables follows:

Table 2.2 Treatment procedure for steel with 1% C

Sample (Steel with 1% C)	**Heat Treatment**	**T_A (in ^{0}C)**	**Cooling Method**
C100	Normalizing	790 ^{0} C	Ventilator
C100	Normalizing	790 ^{0} C	Air
C100	Normalizing	790 ^{0} C	Air
C100	Annealing	790 ^{0} C	Furnace

Table 2.3 Treatment procedure for steel with 0.6% C

Sample (Steel with 0,6% C)	**Heat Treatment**	**T_A (in ^{0}C)**	**Cooling Method**
C60	Normalizing	820 ^{0} C	Ventilator
C60	Normalizing	820 ^{0} C	Air
C60	Annealing	820 ^{0} C	Furnace

Table 2.4 Treatment procedure for steel with 0.45% C

Sample (Steel with 0,45% C)	**Heat Treatment**	**T_A (in ^{0}C)**	**Cooling Method**
C45	Normalizing	880^{0}C	Air

2.3 Structural Observation

The structure of the pearlite was studied by thin foil transmission electron microscopy. The interlamellar spacing was determined on the colonies whose lamellae were practically perpendicular to the plane of observation. About 5 measurements were made on each specimen and 40 measurement in total, in order to obtain the average value of the interlamellar spacing S.

2.4 Mechanical Testing

Mechanical characteristics are determined by the strength test. Samples who participated in the experiment were measured for hardness by Vickers apparatus. These samples had the same diameter but are treated in different conditions. Measurement is carried out carefully and hardness measurement is made on the sidelines of the surface of the samples taken for the tests. For each sample three measurements were made, where the measurement of the second and the third is made in the same radius of the sample. Usually the rate of load for Vickers apparatus ranges from 10 mg to 100 kg and is applied for 10 to 15 seconds. Microelement Vickers apparatus used in this test has the form of a of diamond cone – with rectangular base and angles between 136^0. This device can perform measurements on sample surface areas and has the advantage of making the measurements in microscopic areas.

III EXPERIMENTAL RESULTS

It was observed that the lower the carbon content of the steel, the greater becomes the region of cooling rates where the steel presents a pearlitic structure.

3.1 Interlamellar spacing

Table 3.1 shows the values of interlamellar spacing $\bar{S}$ obtained.It is observed that, with decreasing carbon content of steel, S and transformation temperature increase. In the case of the eutectoid steel we also have measured the values of S for several transformation temperatures (obtained by several cooling speeds) as tables below show:

Table 3.1 Interlamelar spacing results on tested samples

Samples I. S (μm)	**S(1)**	**S(2)**	**S(3)**	**S(4)**	**S(5)**	$\bar{S}$
C100 (vent)	0.19	0.16	0.22	0.17	0.2	**0.188**
C100 (air)	0.27	0.22	0.23	0.25	0.26	**0.246**
C100 (furnace)	0.54	0.45	0.46	0.5	1.05	**0.600**
C60 (vent)	0.17	0.15	0.14	0.21	0.15	**0.164**
C60 (air)	0.26	0.18	0.19	0.19	0.16	**0.196**
C60 (furnace)	0.3	0.3	0.27	0.33	0.31	**0.302**

C45 (air)	0.17	0.17	0.25	0.19	0.16	**0.188**

- I.S – Interlamellar Spacing measured in µm.

Table 3.2 Vickers test results for given samples

Samples V.H (µm)	Hv(1)	Hv(2)	Hv(3)	Average
C100 (vent)	281	287	292	**286.67**
C100 (air)	244	245	246	**245.00**
C100 (furnace)	207	199	205	**203.67**
C60 (vent)	266	273	266	**268.33**
C60 (air)	246	242	243	**243.67**
C60 (furnace)	228	228	220	**225.33**
C45 (air)	215	214	220	**216.33**

For every degree of cooling temperature excist the initial and final temperature of microstructure transformation. Samples cooling conditions that are taken in this study have a significant impact on amount of Perlit created in the structure of a sample, and this happens for two main reasons:

- when slow cooling is performed -Ferrite + Perlite (F + P) is observed in hypo eutectoid steels (Fig 1).
- Samples with 0.83% C have a structure completely Perlitike (P); hyper eutectoid steels (Fig 2-7).

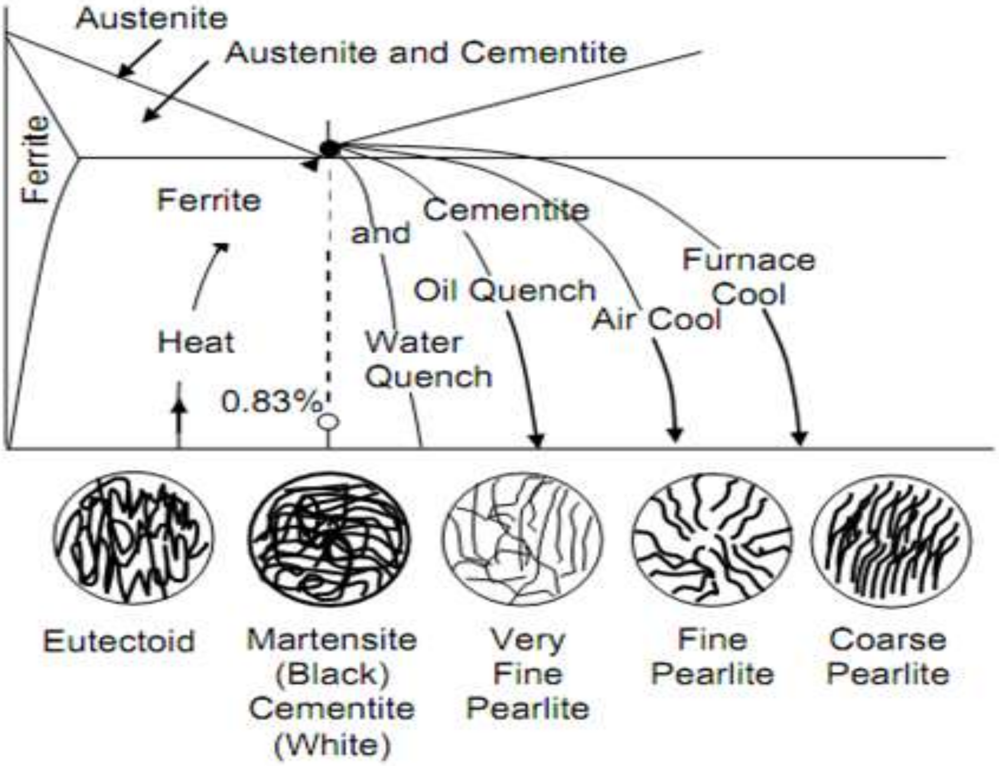

Fig 1: Impact of heat treatment in steel microstructure samples with 0,60 % and 1 % carbon content.

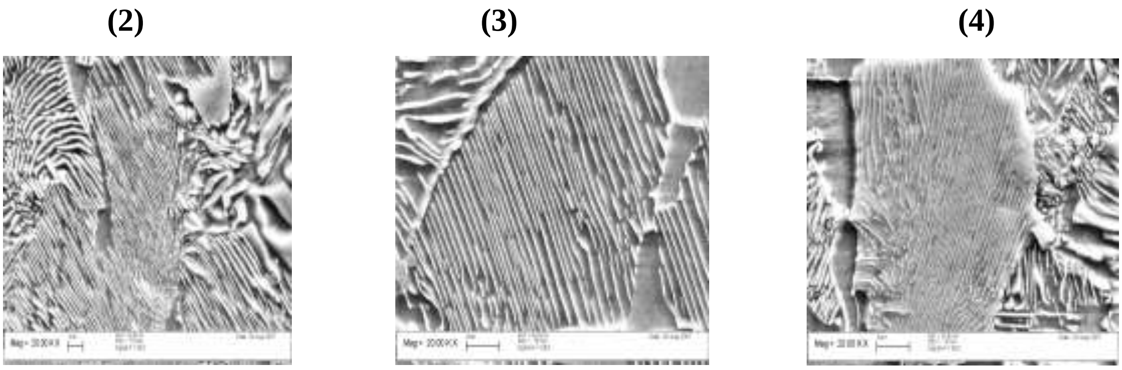

Fig 2,3,4: C60 sample microstructure cooled at (2) ventilator, (3) air, (4) furnace

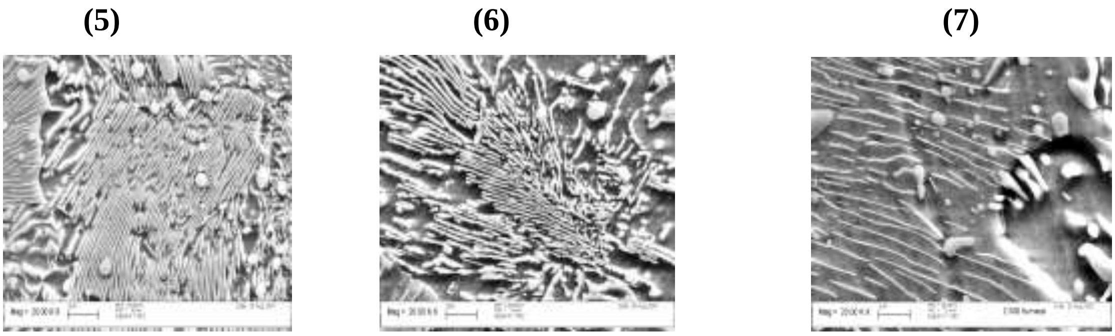

Fig 5,6,7: C100 sample microstructure cooled at (5) ventilator, (6) air, (7) furnace

IV DISCUSSION AND CONCLUSIONS

4.1 Discussion

Pearlite structure is:

$$\gamma_{(0,77\%C)} \rightarrow \alpha_{(0,022\%C)} + Fe_3C_{(6,67\%C)}$$

a mixture of alternate strips of ferrite and cementite in a single grain. The distance between the plates and their thickness is dependent on the cooling rate of the material; fast cooling creates thin plates that are close together and slow cooling creates a much coarser structure possessing less toughness. The name for this structure is derived from its mother of pearl appearance under a microscope. A fully pearlitic structure occurs at 0.8% Carbon. Further increases in carbon will create cementite at the grain boundaries, which will start to weaken the steel.

Steels with Pearlite structures have lower strength compared with those having Bainite and Martensite structures. However, Pearlite structure makes steel more brittle and this properties make those steel more appropriate for avoid catastrophic injuries that occur randomly.

Excist 2 classes of pearlite. Fine Pearlite and Coarse Pearlite. The difference between them lies in the thickness of lamelas. Smaller the distance between lamellas, stronger the steel. Conversely, more thicker the lamellas and greater the distance between them, more brittle will be the steel. Fine pearlite is formed in lower temperatures than coarse pearlite. If we desire to have fine pearlite structure we should take off from furnace and leave it to be cooled at room temperature. While, to form coarse pearlite it is neccessery to treat the sample in furnace in temperature ranging from 600-700 ^{0}C. Although this depend even from carbon content in steel. If carbon content in steel is lower than 0.76%, a part of Austenite is transformed in Ferrite structure in temperature lower than 727^{0}C, and in case of steel containing more than 0.76% carbon, it will transform in cementite. Usually this lead in formation of branches which sorround Pearlite structure. This is called Pearlite in Ferrite matrix (or cementite). Of course if u have 0.8% carbon content in steel we have 100% Pearlite structure. Less carbon content more Ferrite structure will be obtained compared with Pearlite, and in other hand, high carbon content lead to cementite formation. In 6.7% carbon content we have totally cementite structure.

4.2 Conclusions

- Lamellas distance and width is related with cooling rate of sample. Rapid cooling forms fine lamellas which are created close to each ather and in other hand slow cooling makes them thick, making less strong material.
- In samples represented by C45, C60, C100 codes, cooled at the same conditions (samples cooled in air), is observed an inceasement in lamellas distance while having an transformation from Fine Pearlite to Coarse Pearlite. So we can say that the distance between the lamellas is directly related to carbon content in steels (Fig 8-10, 14).
- If we compare samples with the same carbon content but treated in different conditions (example samples represented by C60 code), it is observed that higher the cooling rate smaller the distance betwwen lamellas (Fig 11-13).
- Relationship between Vickers hardness and lamellar distance is linear relation which shows the fact that if distance between lamellas less strong is the steel. This happen due to dislocation presence.

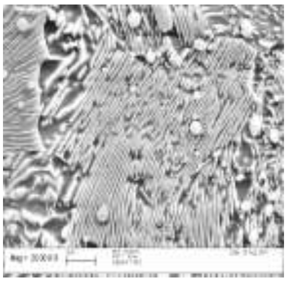

Fig 8: C100 ventilator

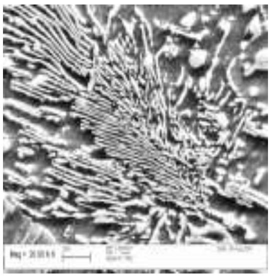

Fig 9: C100 air

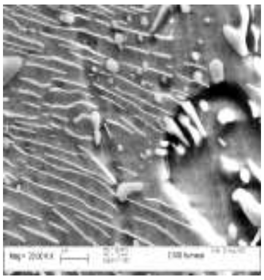

Fig 10: C100 furnace

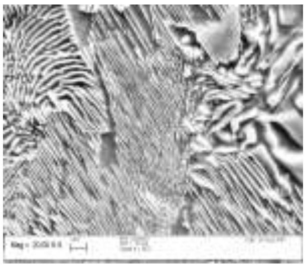

Fig 11: C60 ventilator

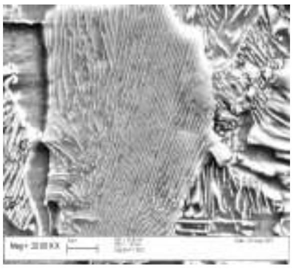

Fig 12: C60 air

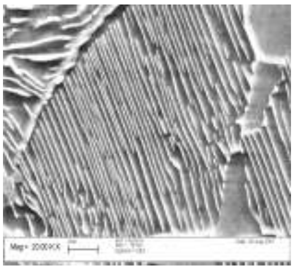

Fig 13: C60 furnace

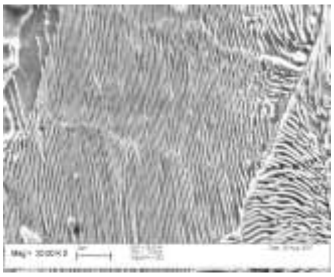

Fig 14: C45 air

4.3 Definitions

Annealing	The steady heating of a metal at a certain temperature above the recrystallization phase followed by a gradual cooling process.
Austenite Phase	The phase at which solid steel recrystallizes and has a face-centered cubic crystal structure. Austenite steel holds a greater amount of dissolved carbon and exhibits increased formability.
Bainite	A combination of ferrite and cementite in ferrous metals that is harder than pearlite. Bainite contains needlelike grain structures, and it requires an initial rapid cooling followed by gradual cooling.
Cementite	A compound of iron and carbon that is very hard and brittle. The presence of cementite hardens steel.
Ferrite Phase	The phase at which solid steel has a body-centered cubic crystal structure. Ferrite steel can hold only a minimal amount of carbon, and it is relatively soft.
Hypereutectoid Steel	Steel that contains more than 0.77 percent carbon. Hypereutectoid steel consists of pearlite and cementite at room temperature.
Hypoeutectoid Steel	Steel that contains less than 0.77 percent carbon. Hypoeutectoid steel consists of ferrite and pearlite at room temperature.
Martensite	A steel that consists of a distorted, body-centered tetragonal crystal structure. Martensite is very hard and brittle.
Normalizing	The steady heating of a metal above the recrystallization phase, followed by a cooling process at a moderate pace. Normalized metals are often cooled in open air at room temperature.
Pearlite	A combination of ferrite and cementite. Pearlite grain structures resemble human fingerprints. Steel with exactly 0.77 percent carbon consists of uniform pearlite at room temperature.
Quenching	The soaking of a metal at a high temperature above the recystallization phase, followed by a rapid cooling process. The quenching of steel creates martensite.

Tempering	The steady heating of martensite steel at a temperature below the recrystallization phase, followed by a gradual cooling process.

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