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Study of the effects of heat treatment on reinforcing bars Which is produced by the Libyan Iron and Steel Company

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Abstract

This research paper aims to study the effects of heat treatment on 14 mm reinforcing bars that are produced by the Libyan Iron and Steel Company. These operations were conducted in the quality control laboratory, and it was found that there are two types of 14 mm reinforcing bars: (G-40) and (G-60). The difference between them is the percentage of carbon present in their chemical composition, as the percentage of carbon in the variety (G-40) ranges between 0.25% and 0.38%, and as for the variety (G-60), it ranges between 0.35% and 0.45%[1]. In this research paper, three different heat treatment processes were carried out: hardening, neutralization and fermentation at a constant temperature of 850°C and for a constant period of 30 minutes on 14 mm reinforcement bars with American specifications (ASTM A615 G-40 and G-60)[5]. After performing these operations, a change occurred in the internal structure of the material and its phases, which led to a change in the mechanical properties of these bars. To know and determine this change, mechanical tests (tensile test and hardness test) and microscopic examination were performed.

Keywords: Chemical composition , Heat treatment, Harding ,Neutralization

Introduction

The various engineering alloys, especially ferrous alloys known as steel, are one of the most important fruits of the industrial revolution in the middle of the eighteenth century AD, and these alloys have represented the cornerstone in technical progress and material renaissance and modern urban and structural development, but the secret of their importance is their properties superior to their basic metals alone It is known that improving the properties of the material mechanical or chemical is not unique to the alloying industry only, but This superiority can also be achieved through thermal and surface treatments, as Although heat treatments were an ancient art observed by man from trial and error, they have recently turned into a science of metallurgical physics with its scientific basis and accepted explanations[2].

<u>The effect of carbon</u> on the properties of steel: The structure of steel, as we mentioned, consists of two phases, namely fritite and commentate, and is directly proportional to the increase in the percentage of carbon, and commentate raises the hardness and brittleness of the steel clearly, as its presence leads to an increase in the resistance to the movement of dislocations and thus the resistance of formation rises and decreases the plasticity and ductile steel. Inside the steel leading to a decrease[2]

<u>Increasing</u> the carbon content of steel also leads to a decrease in both the density and quality of electrical conductivity and heat as well as a decrease in magnetic permeability...Thermal equilibrium

diagram of an iron carbon system: The following figure shows the thermal equilibrium diagram of an iron-carbon system.[3]

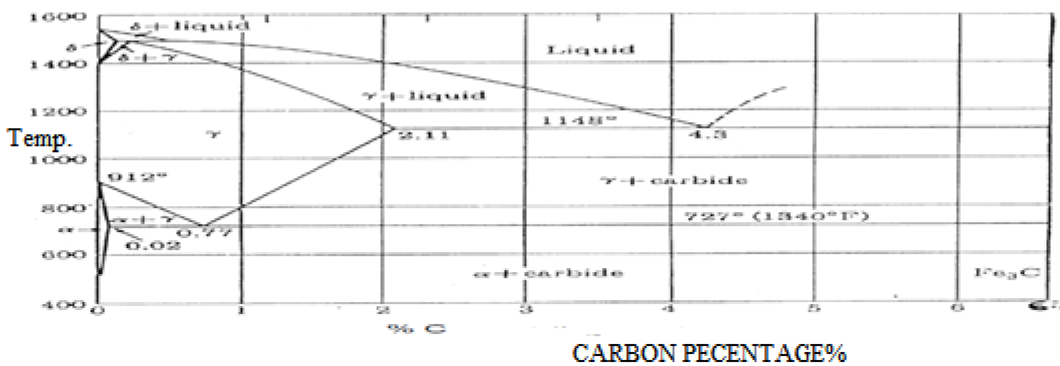

Figure (1) Thermal equilibrium diagram of an iron-carbon system[4]

Engineering materials testing: 1. Destructive tests of materials: in which the sample is damaged and its integrity is not maintained, such as breaking, bending and scratching. The most important are: 1- Tensile test.2- Pressure test.3- Hardness test.4- Impact test.5- Torsion test

Non-destructive material tests: The sample is tested without destroying it and maintaining its integrity. The most important of which are: 1- Visual inspection test .2- Fluid penetrating test.3- X-ray test.4- Ultrasound test.

The relationship between stress and strain: When testing a sample under the stress test, we get a relationship between stress and strain

Heat treatment steps: The first step of heat treatment is heating, which is of course the same step followed when treating steel thermally, where the steel is heated to a certain temperature, and the processing temperature in this case, in the critical temperature range or slightly higher than it in order to ensure the formation of ostonite. , thus leading to their deformation, and sometimes to their splintering-.In the case of cold forming steel with high internal stresses processing, it must be heated slowly compared to stress-free steel to avoid deformation or warp, because the first type is fast-acting with thermal stresses. The temperature of thermal impregnation determines the quality of the transformation in the structural structure of the treated steel, and it also determines the completeness or incompleteness of equilibrium .Necessary. The cooling rate must also be controlled because it is the main factor affecting the final structural structure, and thus determine the properties, and the basic cooling rate is determined according to the type of properties required, and the cooling rates are as follows -:A very slow cooling rate, which is important and essential to reach the equilibrium state, and this is required in the case of annealing, and the cooling process is carried out in the furnace or in the casings, and it is also carried out in the case of thermal revision treatment, and cooling is then carried out in the air[3].

Types of heat treatments for steel: 1.Hardening: The hardening process is used for all tools and some parts of machines, exposed to complex working conditions and parts of machines made of alloy steel, and the main purpose of hardening the number is to obtain high hardness, while the parts of machines made of steel constructions with a crystalline composition pearlite they harden in order to increase their tensile strength and yield strength and the hardening process follows the equalization process usually in order to obtain better mechanical properties. The hardening process is divided into 1- Hardening by watering: the aim is to raise hardness and resistance ,Mechanical steel of carbon steel and alloy steel by heating to above the upper critical temperature and keeping it for a period of time at that temperature (according to thickness) followed by cooling in one of the quenching media (air, oil, water) and in this process the cooling was done in the oil, and the output is pearlite if the cooling rate is slow, when the cooling rate is increased is converted to martensite, which is a single phase and has high hardness, strength and brittleness, meaning that it is not formable on Launch, to achieve hardening of steel by quenching and obtaining the values of hardness and strength in a satisfactory manner, three basic conditions must be met.1 :Appropriate carbon content in alloy steels for martensite composition. 2- Heating to the correct temperature and appropriate for the hardening process while giving the treated piece the correct appropriate time to reach the correct thermal impregnation, where the entire structural structure turns into the Estonian state.[6]

1. Appropriate carbon content in alloy steels for martensite composition. 2- Heating to the correct temperature and appropriate for the hardening process while giving the treated piece the correct appropriate time to reach the correct thermal impregnation, where the entire structural structure turns into the Estonian state.[6]

Disadvantages of hardening by quenching: -1- Change in dimensions.2- The occurrence of cracks.3- Oxidation and decarbonization.4- The presence of some soft points.5- non-conformity of mechanical properties of specifications.

2. Surface hardening: - In many cases of ferrous or non-ferrous metal materials, their outer surface is treated, and surface treatment is represented in the formation of a very thin layer compared to the thickness of the material or the addition of an outer layer to the original material, and the treatment of the outer surface aims to: - 1- Improve the resistance of the outer surface to corrosion, improve the external resistance and compared to the entire body and thus increase the resistance of the surface to induction and wear. The material acquires an attractive external appearance[2].

<u>Equation</u>: The equation process of steel, whether it is a superetotuid steel or sub-yotectoid steel, is heated to (A3) for steel before yotectoid, and is heated to (A_c m) for super eutectoid steel by (30-50) ° C and then cooling in air. The equation process is similar to the annealing process in terms of heating temperature, except that it differs in the cooling rate, as it is faster in the case of equation. The equation process is performed on steel with weak structural structure and non -Objectives of the equation process: 1. Increase maximum tensile strength.2. Reduce internal stresses. 3- Improve the workability of the steel.1- Disposal of the cementite network surrounding the perlite in the steel above the toxoid.

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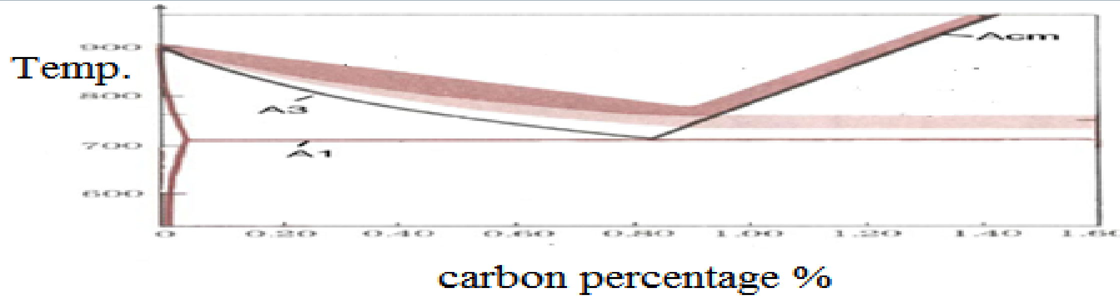

Figure (2) shows the temperature range of heat treatment processes[5]

3. Fermentation (annealing): Fermentation is usually done by heating the material to relatively high temperatures and there are two types of fermentation in steel: 1- Subcritical fermentation: in which the steel is heated under the lower critical temperature, which is the temperature of the eutectoid, and the main purpose of this type of fermentation is usually to remove internal stresses resulting from cold forming processes and previous cooling processes or operation processes[4].
4. Total fermentation: in which the steel is heated in the furnace to a temperature higher than the upper critical temperature A3 as in Figure (1) if the steel composition is below the eutectoid (carbon content less than 0.77%) or between the lower and upper critical temperature (ACM) if the steel composition is above the eutectoid. After a period of time, it is slowly cooled in the furnace and the purpose of this process is to give the steel plasticity[4].
5. Normalization: Normalization can be defined as heating steel hardened by quenching or subjected to thermal revision, at a certain temperature under the transformation range, and then keeping it for an appropriate period at that temperature, and this method is used
6. Sample processing: At the beginning of the practical aspect, eight (8) samples of 14 mm reinforcing bars of American specifications (ASTM A615 G-40 & G-60), four G-40 samples and

<u>Chemical analysis of samples</u>: in chemical analysis in order to know the chemical composition of each sample and determine the proportion of chemical elements inside each sample. In this to test and then pressure the two samples (G60, G40) to increase the diameter of the sample to become 20 mm to suit the position of fixing the sample inside the examination device (spectroscopy), then operate the device and examine the two samples (G40, G60) file respectively and then obtain the results shown in the following table

Table (1) shows the chemical composition of the samples[1].

NO	Steel Grade	%FE	C	Mn	Si	P	S	Cr	Mo	Ni
1	G-40	98.59	0.3570	0.7120	0.1500	0.0121	0.0058	0.0360	0.0070	0.0250
2	G-60	98.05	0.4170	1.1630	0.2730	0.0170	0.0026	0.0300	0.0040	0.0110

NO	Cu	Sn	AL	Co	Nb	Ti	V	Zr	B	Zn
1	0.0919	0.0020	0.0001	0.0040	0.0001	0.0015	0.0027	0.0002	0.0001	0.0001
2	0.0268	0.0001	0.0004	0.0030	0.0001	0.0019	0.0043	0.0005	0.0001	0.0001

Through the results of this analysis and then determine the percentage of carbon in each sample and the percentage of other elements, and the following table shows the chemical composition of reinforcing bars according to the standard specifications ASTM A615[4]

Table (2) Standard specifications for reinforcing bars.[3]

Steel Grade	Limit	C %	Si %	Mn %	P %	S %	C.E %
ASTM A615 G-60 L	Min	0.35	0.20	1.10	-	-	0.63
	Max	0.39	0.40	1.20	0.04	0.04	0.69
ASTM A615 G-60 M	Min	0.39	0.20	1.20	0.04	0.04	0.69
	Max	0.43	0.40	1.30	0.04	0.04	0.76
ASTM A615 G-60 H	Min	0.40	0.20	1.40	0.04	0.04	0.75
	Max	0.45	0.40	1.56	0.04	0.04	0.84
ASTM A615 G-40 L	Min	0.25	0.15	0.60	0.04	0.04	0.40
	Max	0.30	0.25	0.70	0.04	0.04	0.48
ASTM A615 G-40 M	Min	0.30	0.15	0.70	0.04	0.04	0.48
	Max	0.35	0.25	0.80	0.04	0.04	0.55
ASTM A615 G-40 H	Min	0.36	0.20	0.80	0.04	0.04	0.56
	Max	0.38	0.30	0.84	0.04	0.04	0.59

By comparing the results obtained in the standard specifications table, it was found that the sample (G-40) whose carbon content was 0.357% matches the specifications of the average steel (G-40 M) and the second sample (G-60) carbon content 0.417%.[6]

Since the percentage of the sample G-60 is higher than the standard specifications of steel, the carbon equivalent of the sample is determined according to the following equation: carbon equivalent (C.E %) = (manganese value / 4) + carbon value. 0.70% = (1.163/ 4) + 0.417

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Through this equation, the carbon equivalent of the sample corresponds to the specification of the average steel (G-60M).[6]

Heat treatment: The purpose of conducting heat treatment operations for samples is to obtain different mechanical properties and change the microstructure of the samples. Three different heat treatment processes are carried out on the samples: 1- Tempering process.2- Equalization process.3- Annealing process. In four different cooling modes (oil, water, air, oven), samples are collected and numbered according to the test, tensile test samples are numbered from 1 to 10, as well as hardness test samples are numbered from 1 to 10, for the purpose of distinguishing each sample according to the process of treatment and the method of cooling [3]

After the numbering process has been carried out by (numbering pen) for each sample, the heat treatment furnace is turned on and set to a temperature of 850 ° C, then samples are taken from 2 to 5 for steel (G-40) (for tensile and hardness test samples) and placed inside the furnace and left inside the furnace for 30 minutes, and at the end of the period, the samples are taken out of the oven and each sample is placed in the cooling medium allocated to it according to the previous table (Table (2)), and for sample No. (5) it is left to cool inside Furnace for a full day (annealing process) and the same steps are performed on samples 7 to 10 for steel (G-60)[1]

Hardness test: The purpose of conducting hardness testing on samples is to determine the hardness of the original samples of each steel (G-40 & G-60) and compare them with samples that have been heat treatment operations, and the ROCKWELL device is used to test and measure the hardness of each sample, and a tempered steel cone is used, a fixed load of (150 kg) in the case of measuring the hardness of highly hardness materials and symbolized by the symbol (HRC 100) .(kg) in the case of less hardened materials and symbolized by the symbol (HRB) and when testing samples from 1 to 10 you get hardness values for each sample, and the following table shows the hardness of each sample:

Table (3) shows the hardness of samples.

Harden	Cooling method	Type of steel	Samp.no
HRC5	Org.	G-40	1
HRC32	oil	G-40	2
HRC53	water	G-40	3
HRB87	air	G-40	4
HRB79	even	G-40	5
HRC17	ˡorg.	G-60	6
HRC42	oil	G-60	7
HRC54	water	G-60	8
HRB92	air	G-60	9
HRB88	even	G-60	10

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The following diagram shows the hardness of each sample and its comparison with other samples, where the x-axis represents the number of samples and the y-axis represents the hardness value in units (HRC & HRB).

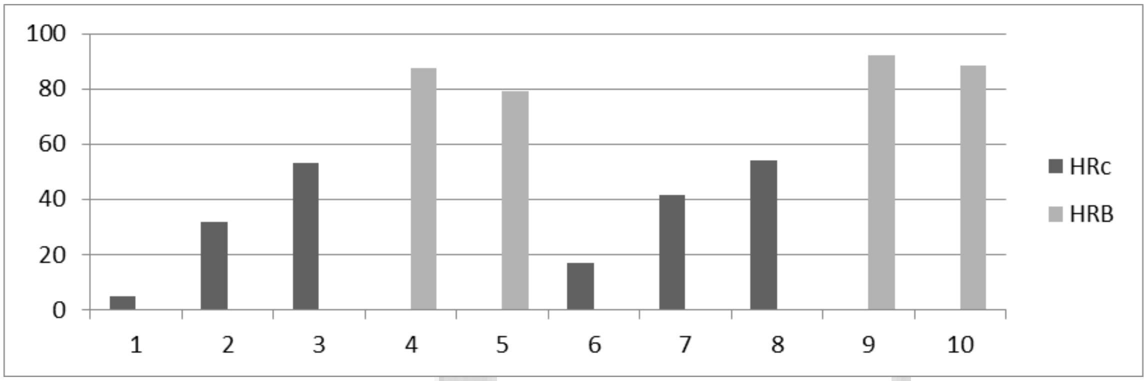


Chart (1) shows the hardness of the samples

Tensile tests for samples: The purpose of this test is to know and determine the following specifications for each sample: 1-The relationship between stress and strain- 2- Subject point3- Maximum stress bearing force 4- Ductility

The following tools and devices are used in tensile testing: 1- Measuring ruler.2- Lily or shankra tool.3- Hammer.4- Tensile testing machine.

The tensile testing machine is used to perform tensile tests on samples from 1 to 10.In this test, a standard sample is taken, so that it is easy to install between the jaws of the tensile machine. The original length is equal to ten times the diameter of the sample (L = 10D). The original length is determined on the sample using a measuring ruler with a hammer and a lizard, then the sample is fixed on the testing machine and the test machine is gradually loaded until the fracture is completed. When the sample is broken[1],

you get the stress and strain relationship curve [1]

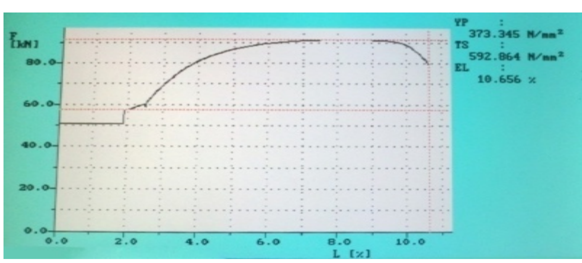


Figure (3) Strain and strain curve of sample (1)

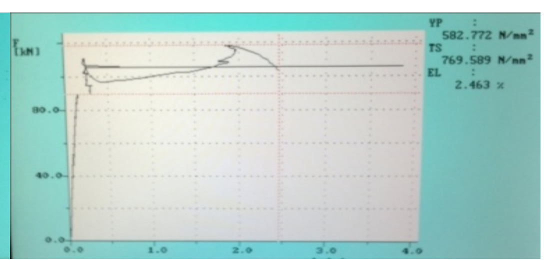
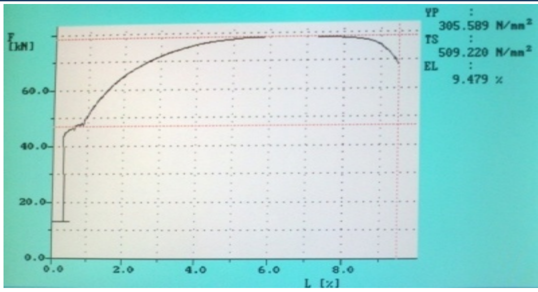


Figure (4) Strain and strain curve of sample (2)



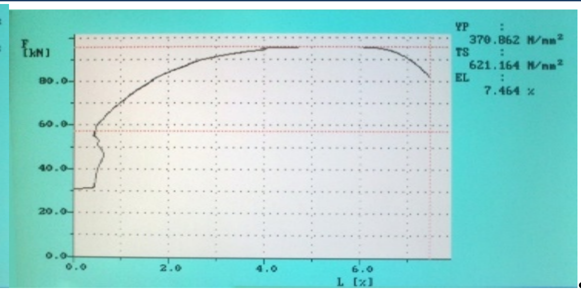
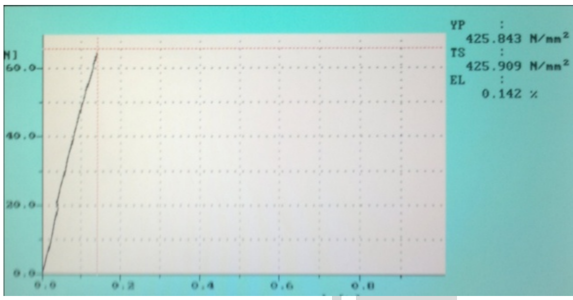


Figure (5) Strain and strain curve of sample (3) **Figure (6) Strain curve of sample (4)**



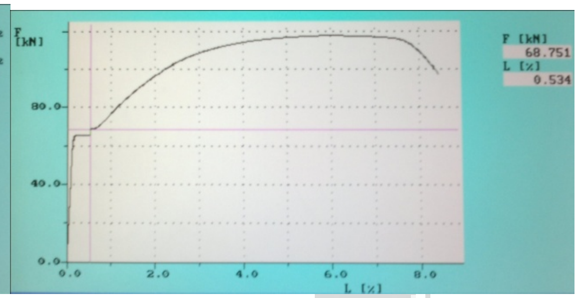
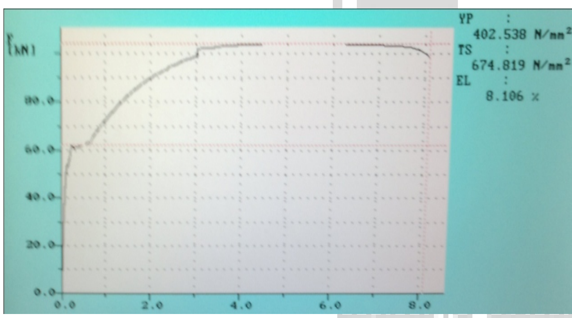


Figure (7) Strain and strain curve of sample (5). **Figure (8) Strain and strain curve of sample (6)**



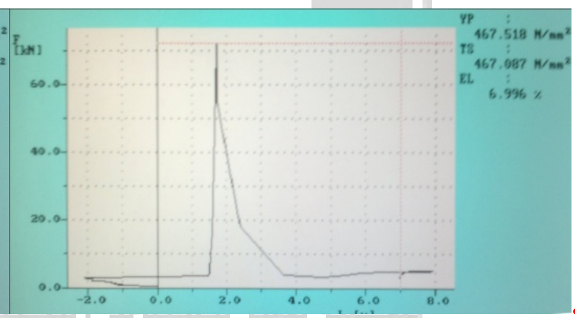


Figure (9) Strain and strain curve of sample (7). **Figure (10) Strain and strain curve of sample (8)**

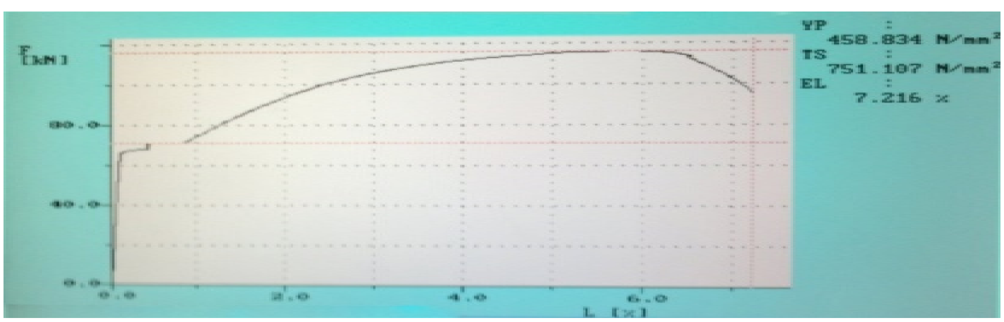


Figure (11) Strain and strain curve of sample (9).

From this test, the yield point, the maximum tensile strength and the amount of elongation can be obtained by following the following laws :Yield point voltage = load at yield / cross-sectional area (Kg/mm²)،Tensile strength = Max load/cross-sectional area (Kg/mm²)

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Elongation = (New Length – Original Length) / Original Length X 100(%)

The following table shows the values of the yield point, the maximum tensile strength and the elongation of each sample :Table (4) Tensile strength, yield and ductility of samples. The following diagram shows the value of the yield point and the maximum tensile force for each sample, where the x-axis represents the sample number and the y-axis represents the value of the applied stress in Newton's/mm²

Table (4) Tensile strength, yield and ductility of samples[1].

NO	Area	Diameter	Length	Yield Point		Ultimate		Elongation	
	A	D	L	Load	Y. S	Load	U.T. S	New Length	E
	(mm)²	(mm)	(mm)	(Kg)	(N/mm²)	(Kg)	(N/mm²)	(mm)	%
1	154	14	140	5808	370	9749	621	169	21
2	154	14	140	9136	582	12072	769	143	2
3	154	14	140	4600	293	4600	293	140	0
4	154	14	140	5855	373	9309	593	170	21
5	154	14	140	4788	305	7990	509	174	24
6	154	14	140	7001	446	12009	765	166	19
7	154	14	290	14725	938	18226	1161	293	1
8	154	14	140	6687	426	6687	426	140	0
9	154	14	140	7190	458	11789	751	155	11
10	154	14	140	6311	402	10596	675	171	22

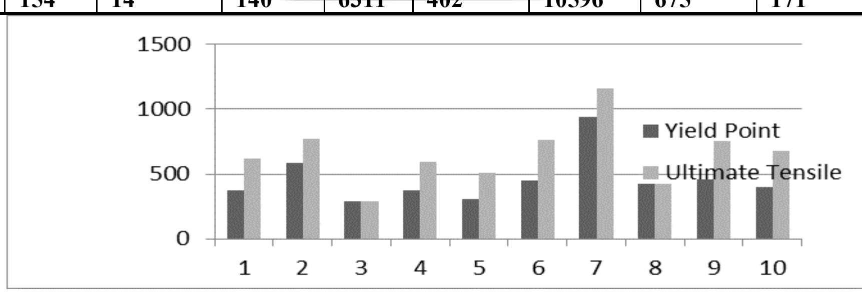

Chart (2) Maximum tensile strength and submission of samples

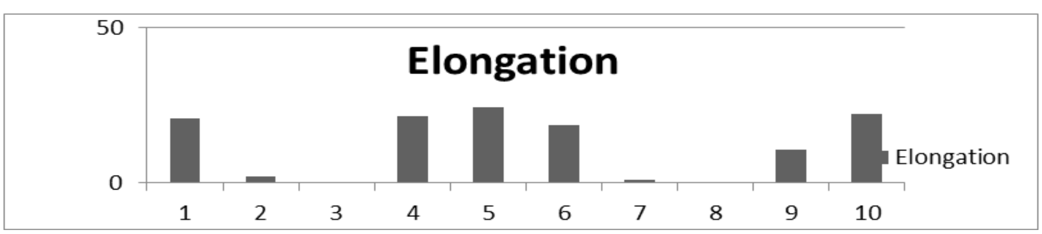

Chart (3) Ductility of samples

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The following diagram shows the difference in ductility for each sample, where the x-axis represents the sample number and the y-axis represents the elongation in percentage.5. 4- Metallography[3]: Metallography is the science of studying the composition of the structure of metals and alloys, including their properties and features using a microscope and through which it is possible to detect the components of the internal structure of metal. Microscopic examination is used for multiple purposes, the most important of which are: detecting the components of the microstructure of the metal, knowing the chemical composition of the steel, knowing the impurities in the metal, and it has been proven that success in obtaining a good and reliable reading when microscopic examination depends on the good preparation of the examined sample, so you must know the proper way to prepare the sample[6]. Through This research was noted that: 14 mm reinforcing bars are classified according to carbon percentage as follows: 1-1 reinforcing bars 14 mm class (G-40 mm reinforcing bars class (G-60).

Carbon content: 14-. The main differences between the two varieties are 14 mm (G-60) reinforcing rods contain a greater percentage of carbon.

-1Reinforcing bars 14 mm class (G-60) stronger bladder and stiffer.

Reinforcing rods 14 mm class (G-40) are more elongated and amenable to formation and bending.

The percentage of perlite in the reinforcing rods of 14 mm class (G-60) are more rigid .

-the microstructure (G-60) is greater than that in (G-40). By conducting tensile testing on samples before and after the treatment processes, it was noted that:

The maximum tensile strength increases after the hardening process and decreases after the neutralization and fermentation processes of the two varieties (G-40 and G-60).

Also, the yield point increases after the hardening process and decreases after the neutralization and fermentation processes of the two varieties (G-40 and G-60).

Ductility decreases at the hardening process, as there is no ductility for hardened and water-cooled samples for the two varieties.

Obtaining maximum tensile strength after the hardening and cooling process in the oil for the two varieties.

the fermentation process of the two varieties. Obtaining the greatest ductility and formability after Fragility increases after the hardening process, and is highest when cooling in water after the hardening process

The maximum tensile strength is equal to the point of yield after the process of hardening and cooling in water so that there is a fracture of the samples without any elongation.

The fracture limit of the sample is level whenever the hardness is high.

1. Through conducting hardness testing for samples before and after the treatment processes, it was noted that:

2. The hardness of the two types of reinforcing rods 14 mm rises after the hardening process and decreases after the neutralization and fermentation processes.
3. The hardness of the cooled sample in water after the hardening process is higher than the hardness of the cooled sample in the oil after the hardening process.
4. The hardness of the sample after the neutralization process is higher than the hardness obtained after the fermentation process and is close after these two processes.
5. The hardness of the original samples of the two varieties and the samples on which the hardening process is carried out is high and measured in units (HRC), while the hardness of the samples on which the neutralization and fermentation processes are carried out are low and measured in units (HRB)
6. The difficulty of marking with a hammer and a lizard on the samples on which hardening operations are carried out due to their high surface hardness.
7. Through microscopic examination of the original samples and the samples for which the treatment operations were performed, it was found that:
   a. The internal structure of the samples changes after heat treatment operations.-1The internal structure of the original samples of the two varieties (G-40 and G-60) consists of the ferrite and perlite phases with a slight increase in the percentage of pearlite in the (G-60) class than in the (G-40) class.-1The martensite phase is formed after the hardening process.-2After the equation process, we get a little bit of the austeonite phase.
   b. The crystal size increases after counting the neutralization and fermentation processes.

Accordingly: it is preferable to use 14 mm reinforcing bars class (G-60) with relatively high loads and diligences due to their high resistance to stress.

Conclusion

There are two types of 14 mm reinforcing bars: (G-40) and (G-60). The difference between them is the percentage of carbon present in their chemical composition, as the percentage of carbon in the variety (G-40) ranges between 0.25% and 0.38%, and as for the variety (G-60), it ranges between 0.35% and 0.45% Through This research was noted that: 14 mm reinforcing bars are classified according to carbon percentage as follows: 1 reinforcing bars 14 mm class (G-40 mm reinforcing bars class (G-60).

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