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Effect of Some Heat Treatment Processes on the Mechanical Properties of Medium Carbon Steel

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ABSTRACT: *Steel alloys could possess with specific mechanical properties, in some extent by adding metal elements to steel in different percentage like chromium, nickel, vanadium, …etc., and also by applying heat treatment on steel alloys as well. In this paper, heat treatment applications, like full annealing, normalizing, and hardening has been carried out on medium carbon steel alloy, AISI 1040. The change in mechanical properties has been checked via hardness and impact tests. Micro-structure photos of steel samples taken out to obtain the change in grain structures after the heat treatment. All results are checked and modeled by SPSS statistical software version24. It's obvious that, the throng correlation factors between the heat treatment levels in one hand, and samples surface hardness, impact energy, in another hand. Moreover, the best internal grain structure has gotten in normalizing heat treatment samples.*

KEYWORDS: *Heat treatment , Surface hardness, Impact energy, grain structure.*

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I. INTRODUCTION

Steeland other alloys have a large number of applications in engineering practice under varying conditions, requiring different properties in them. At one place they may be subjected to bending while at the other to twisting. They may be required to withstand various types of stresses and, as tool materials, they may be required to have hardness, specially red hardness, combined with toughness, along with a non-brittle cutting edge. They may be required to bear static or dynamic loads, revolve at extremely high speeds, operate in highly corrosive media, carry an extremely hard skin with a tough core, subjected to fatigue and creep,… etc. such varying conditions of their applications require these materials to possess specific properties of the required order to successfully serve under these conditions. But, a material may lack in some or all of these properties either fully or partially. These deficiencies are made good though the process of Heat Treatment.

II. HEAT TREATMENT PROCESS

The process of heat treatment involves heating of solid metals to specified temperatures, holding them at that temperature, and then cooling them at suitable rates in order to enable the metals to acquire desired properties to the required extents. All this takes place because of the changes of size, form, nature and the distribution of different constituents in the micro-structures of these metals.

Heat treatment processes carried out in this paper

1- Full annealing.

It is known as High temperature annealing.In this process complete phase recrystallization takes place and, therefore, all imperfections of the previous structure are wiped out. The main objectives of this process are to soften the metal, relieve its stresses and refine its grain structure. This involves heating of steel to a temperature of about 30^0 C to 50^0 C above the Higher Critical temperature for **hypoeutectoid steels** (as our tested steel AISI 1040, has 0.413 % Carbon constituent), near about 840^0 C, holding it at that temperature for sufficient time (approximately 3 to 4 minutes time at elevated temperature per mm thickness of specimen) to allow the internal changes to take place and then cooling slowly in the furnace itself by allowing a fall of temperature at the rate of 10 to 30^0 C per hour. This fall of temperature is allowed to continue till the metal temperature comes down to about 30^0 C below the lower critical temperature (723^0 C). The metal piece is then air cooled down to room temperature. This process results in a coarse pearlitic structure which is quite soft and ductile.

2- Normalizing.

This process is similar to annealing in sequence but differs a lot in holding time and rate of cooling. In this process steel is heated to a temperature 40^0 C to 50^0 C above the higher critical temperature, held at that temperature (840^0 C)for relatively shorter period of time (about 15 minutes) and then cooled down to room temperature in still air. Thus austenite is ultimately transformed into ferrite plus pearlite for hypoeutectoid steels (our case). The main objectives achieved through this heat treatment are : internal stresses caused during previous operations are removed, internal structure is refined to fine grains, and mechanical properties of steel are improved.

3- Hardening.

It the process of heating steel to a temperature within the hardening range, which is 30^0 C to 50^0 C above the higher critical point for Hypereutectoid steels, holding it at that temperature for sufficient time to allow it to attain austenitic structure and then cooling it rapidly by quenching in suitable medium like water. This process is widely applied to all cutting tools, all machine parts made from alloy steels, dies and some selected machine parts subjected to heavy work.

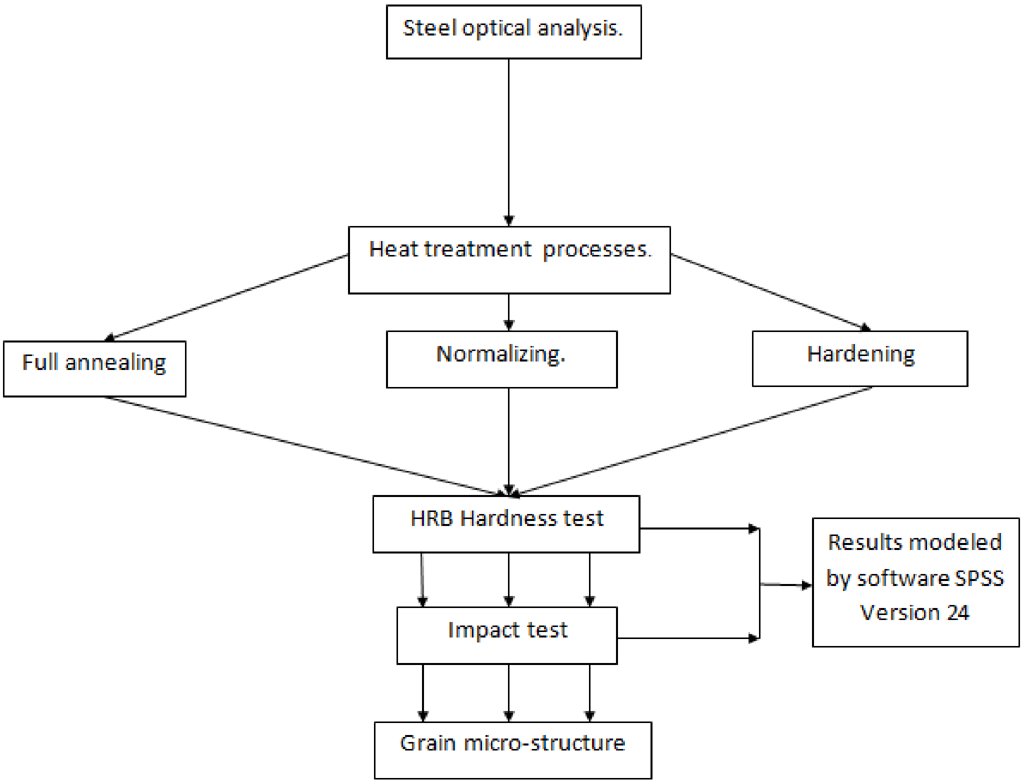

Fig.1. Experiments flow chart.

The type of steel used in experiments

The chemical compositions of tested steel have been identified via optical analysis device and, the results come out as the following table.

Element	Fe	C	SI	Mn	TI	S	Cr	ZN	NI
Percentage	98.1	0.417	0.245	0.606	0.0028	0.0077	0.172	0.002	0.157
Element	P	MO	AL	CU	PB	BI	V	TI	SB
Percentage	0.505	0.008	0.014	0.161	0.100	0.001	0.002	0.0008	0.016

The steel classified as a medium carbon steel alloy (AISI 1040). Three groups of samples have prepared of the same steel, each group consists of three samples, each sample has the following shape and dimensions.

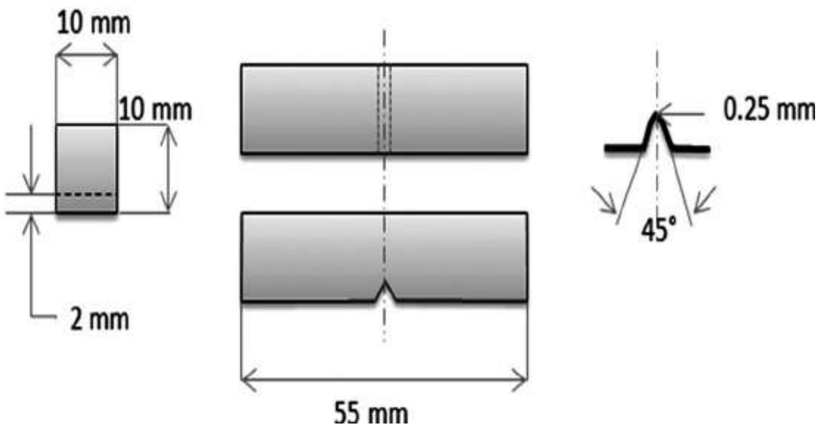

Fig.2. The shape of the sample used in the study.

- **Heat treatment processes carried out**

One group of samples utilized in full annealing heat treatment, second one in normalizing, and third one in hardening. The furnace used in the three processes is (POK71), made in Polonia**.**

Fig.3. The furnace used (POK71).

Heat treatment levels

The heat treatment levels shown in the following table.

Full annealing	Slow cooling	1
Normalizing	Medium cooling	2
Hardening	Fast cooling	3

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- **HRB Hardness test**

The hardness of each sample has been identified and tested via Rockwell hardness tester device made in Turkey.

Fig.4. Rockwell hardness device.

The reading come out summaries in the following table.

Samples	HRB	HRB	HRB	Mean value
Full annealing	91	87	90	89.3 HRB
Normalizing	83	83	84	HRB83.3
Hardening	106.68	119.38	111.76	HRB112

The reading modeled in statistical software programmer (SPSS – 24), the results come out as the following**.**

Correlations

		Heat treatment level	Surface hardness-HRB
Heat treatment level	Pearson Correlation	1	.750
	Sig. (2-tailed)		.460
	N	3	3
Surface hardness-HRB	Pearson Correlation	.750	1
	Sig. (2-tailed)	.460	
	N	3	3

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	72.167	21.639		3.335	.185
	Heat treatment level	11.350	10.017	.750	1.133	.460

a. Dependent Variable: Surface hardness-HRB

Model Summary and Parameter Estimates

Dependent Variable: Surface hardness-HRB

Equation	Model Summary R Square	F	df1	df2	Sig.	Parameter Estimates Constant	b1
Linear	.562	1.284	1	1	.460	72.167	11.350

The independent variable is Heat treatment level.

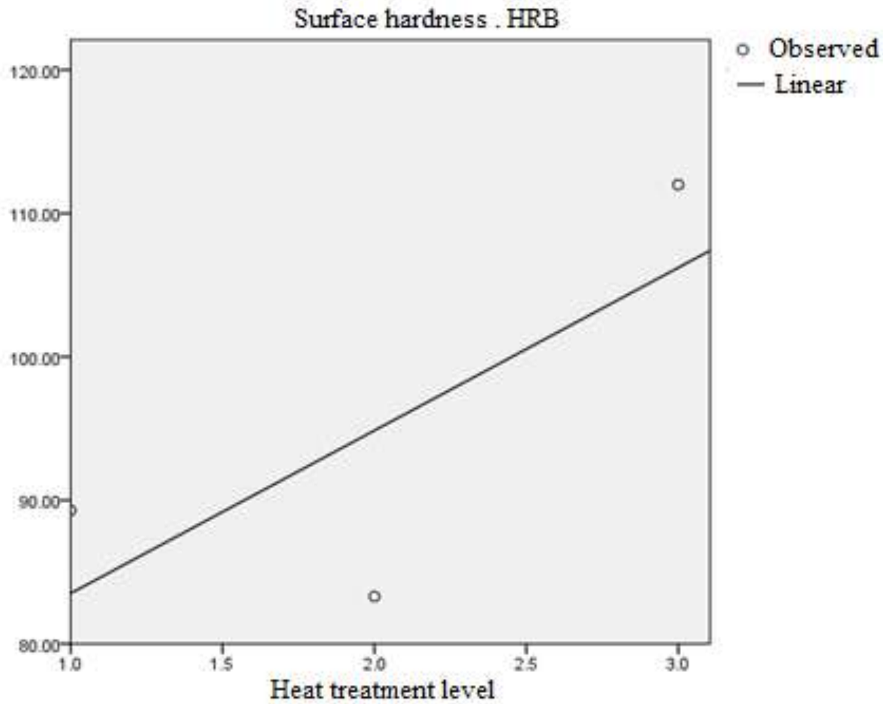

Fig.5. Regression curve.

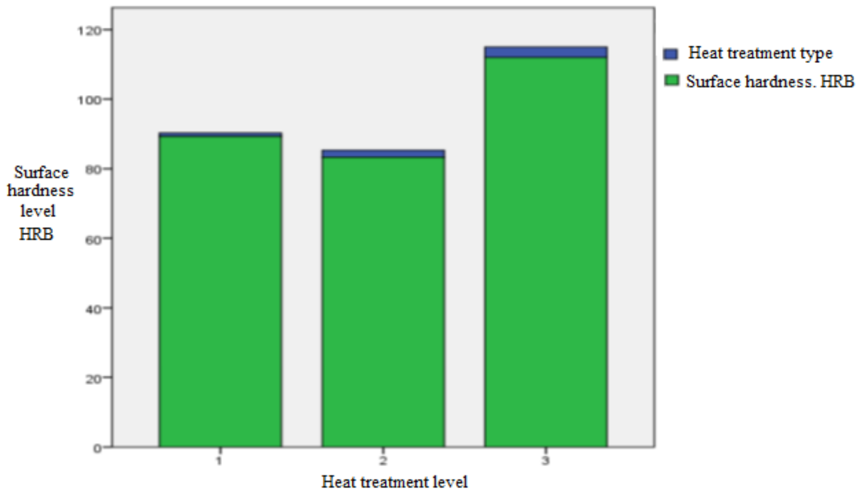

Fig.6. Relationship diagram.

- **Impact test**

The toughness of each sample has been identified and tested via charpy impact tester (ZWICK), the reading come out summarized in the following table.

Samples	Joule	Joule	Joule	Mean value
Full annealing	160	180	175	171 J
Normalizing	133	110	123	122 J
Hardening	17	16	10	14 J

The reading modeled in statistical software programmer (SPSS – 24), the results come out as the following.

Correlations

		Heat treatment level	Impact energy-Joule
Heat treatment level	Pearson Correlation	1	-.977-
	Sig. (2-tailed)		.136
	N	3	3
Impact energy-Joule	Pearson Correlation	-.977-	1
	Sig. (2-tailed)	.136	
	N	3	3

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.245	.321		10.114	.063
	Impact energy-Joule	-.012-	.003	-.977-	-4.609-	.136

a. Dependent Variable: Heat treatment level

Model Summary and Parameter Estimates

Dependent Variable: Impact energy-Joule

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.955	21.243	1	1	.136	259.333	-78.500-

The independent variable is Heat treatment level.

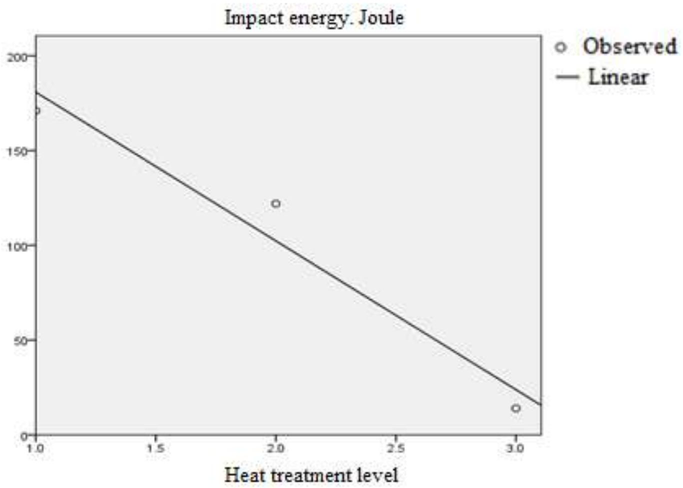

Fig.7. Regression curve.

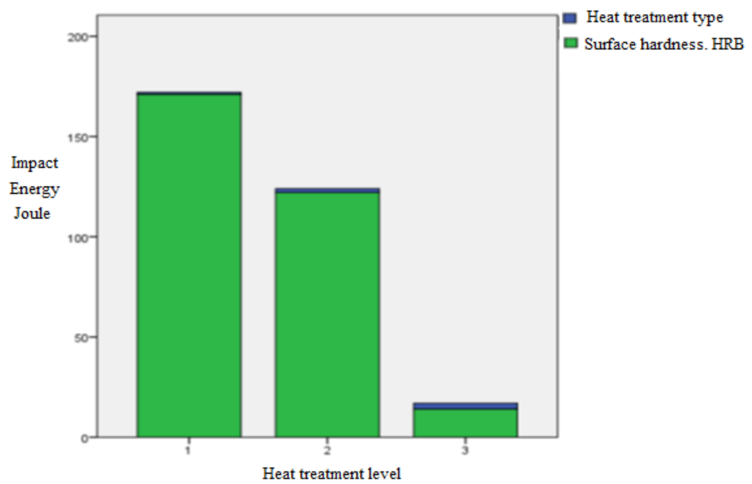

Fig.8. Relationship diagram.

- **Micro – structure inspection of samples.**

After Honing, Buffing processes of the tested samples, they have been inspected by Compound optical microscope connected with computer, and the following photos come out.

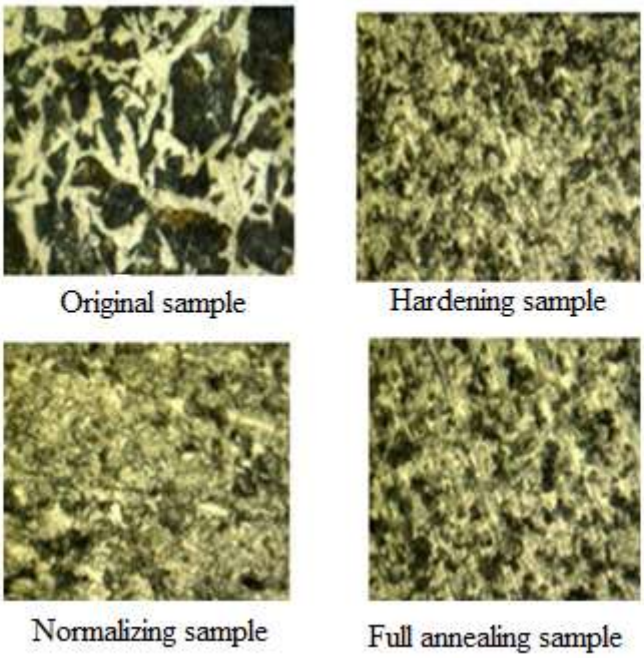

Fig.9. Microstructure inspection of samples.

III. CONCLUSION

The study revealed that, in common trend the hardness of treated steel is directly proportional to the rate of cooling level related to the particular heat treatment process, as it is clear from correlation factor (0.750) and regression curve. Secondly, the toughness of samples gained by heat treatment processes as a function of impact energy is inversely proportional to the rate of cooling level related to the particular heat treatment process, as it is clear from correlation factor (- 0.977) and regression curve. Finally, the best homogenous , equally distributed and finely grain size structure as it is clear from photos, is the photo related to the normalizing heat treatment process..

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