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Effect of Mechanical Surface Treatments on Impact Strength for Low Carbon Steel AISI 1020

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Abstract. Objective of this paper is to study the influence of some mechanical surface treatments on impact strength stress for low carbon steel AISI 1020 AISI. Several specimens were subjected or encountered to for impact test were equipped agreeing to ASTM E23 and then were encounter to surface treatment Such as shot peening which was implemented on some specimens using steel balls having diameter of 1.25mm and hardness= 55HRC for (10,20,30) min. Some another's specimens were treated with using laser peening pulse in notch zone of impact specimen at (5,10,15) laser CO₂ pulse. and Plasma also used for surface treatment of impact specimens by using plasma beam for 2,5,10 sec. The results showed that the mechanical surface treatment contributed in improvements of toughness fracture for low carbon steel comparing with base metal. It was found that when increasing shot peening time finding decreasing in the impact strength decreased impact stress because of increase in hardness which generating from heat shot which generated residual stress and the best time was 10 min. and laser pulses and plasma beam were in contributed in increasing impact strength stress for the same reason above and the number of 5 pulse give gave the best result and also the plasma for 5 sec.

Keywords: Shot peening, laser peening, plasma, Impact toughness

1. Introduction

The mechanical properties of carbon steel are the most important because it affects the selection of these materials for using in the various industrial fields. Some of these applications are structures of buildings, ships, bridges and oil tanks were the steel is exposed to different stresses. Therefore, many methods are employed to improve the mechanical properties of steel.

These procedures include mechanical surface hardening, such as shot peening, laser peening, hot& cold rolling and plasma beam. All mechanical surface hardening methods are designed to produce heterogeneous plastic deformation and a compressive stress [1, 2].

Shot peening is a cold working method in which bullet bangs the surface of components to generate film of compressive enduring stress at the face that leads to the hardening of the outer layer with a depth not exceeding 5μ [3, 4,5]. The effective factors on the shot-peening method are extent and form of the shots, time of peening, stream with speeds of 20-100 m/s. It expelled versus throw face, air compression on the peened component, distance from nozzle to material face and spout angle peening [6].

The second mechanical surface hardening is laser beam, which used in surface treatment of metals, especially steel, in order to increase surface hardness. Laser is a one-wave length package of electromagnetic beam absorbed through surface layers of the metal, so laser technologies enjoy the most important features. These features include:



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- 1 - Chemically clean,
- 2 - The possibility of adjusting the depth of thermal penetration in the surface and then the possibility of reducing the deformation caused by the thermal effect of the laser beam,
- 3 - Control the shape and location of heat - affected area,
- 4 - The possibility of remote operation, especially places that are difficult to access to achieve heat treatment,
- 5 - Heat treatment is generally aimed at controlling the mechanical properties of metal parts without causing any change in their shape or chemical composition.

The laser beam occurs very quickly for a thin surface of the steel segment higher than the AC_3 on the surface and gradually decrease as we move away from it to reach higher than AC_1 at a certain depth and cooling with water contributes of the leadership of surface hardness [7,8].

The plasmas also express a distinct state of matter that can be described as an ionized gas in which the electrons are free and unrelated to the atom or molecule. The plasma can be classified as the fourth state on which the substance can be found. Ionization causes one or more electrons to exit when heat or energy is given. This electrical charge makes the plasma connected to electricity and therefore responds strongly to the electromagnetic field. Ionization α is necessary for plasma formation, which defends the amount of atoms that have lost or accumulated electrons, and the temperature is the dominant factor controlling it. If a part of the gas, equivalent to 1% of the molecule. α is defined by the equation:

$$\alpha = \frac{n_i}{(n_i + n_a)} \quad \text{----- (1)}$$

Where: n_i expresses the density of ions and n_a expresses the density of non-ionized atoms (neutral) electron density is linked to ionization $\langle Z \rangle$ by the state of the average charge of the ion during the following equation (2):

$$n_e = \langle Z \rangle n_i \quad \text{----- (2)}$$

n_e As it symbolizes the density of the electrons.

Many researchers are studied the subject such as: -

Abdullahi K. Gujba [9] studied the influence of many factors on surface hardening in laser peening of diverse materials using a Q-switched pulsed beam action laser on residual stress. The method is contrast with ultrasonic influence peening (UIP) & ultrasonic shot peening (USP) [10]. In this method, the surface micro and Nano hardness, elastic modulus, tensile yield strength and refinement of microstructure, that converts to improved fatigue life, troubling fatigue life, and stress corrosion cracking (SCC). It was found that Laser peening method has been viewed to persuade pressure remaining stresses attainment near 4–5 times more profound. The greater strength with evenness across material surface than the conventional shot peening system [11]. Though, the SP takes not been substituted using the laser peening particularly in requests coatings to apply. Several academics are of the view that both methods have their separate qualities and defiance.

In another study Leshchinskiy and Samotugin [12] studied the influence of surface hardening using a very focused plasma pour on the construction and mechanical qualities of 5 Cr-0.5 Mo-0.15 V (0.20 C) sediment and a comparison of microstructures, fracture, X-ray diffraction mechanical examinations of sediment alloy in the original and later plasma external hardening. Rise in hardness deprived of a reduction in dynamic fracture toughness due to the great displacement density and mosaic chunk extent decrease.

Mallesh & Suresh kumar [13] studied the mechanical conduct and tribological qualities on AISI 1018 and AISI304 steel before and after shot peening. The diverse mechanical examinations such as Brinell Hardness Examination, tensile examination, 3- point bending examination and wear examinations show that the face qualities and wear resistance were improved with the rise in the shot peering period. Further, the microstructure topic displays that numerous effects of shot peening on the surface rectitude and impact ultra-fine crystalline layer thickness.

2. Experimental work

The practical aspect included the following steps:

2.1. Material selection

Low carbon steel AISI 1020 was chosen in the form of a rod with a square section (12) mm. The chemical composition of the steel is exposed in Table (1). This analysis was conducted at the Institute of Engineering Industries using a spectrometer.

Table 1. Chemical analysis of the metal used

Wt % element	C	Si	Mn	Cr	Mo	Cu	W	Ni	P	s
Actual value	0.2	0.00	0.65	0.01	0.00	0.04	0.00	0.01	0.0	0.0
		9		1	4	1	3	2	9	5
Standard value	0.18- 0.23	0.01	0.3-0.6	-	-	-	-	-	0.0	0.0
									4	5

2.2. Manufacture of test samples

A number of impact test specimens were manufactured according to ASTM E23 standard with dimensions are shown in Figure 1 below.

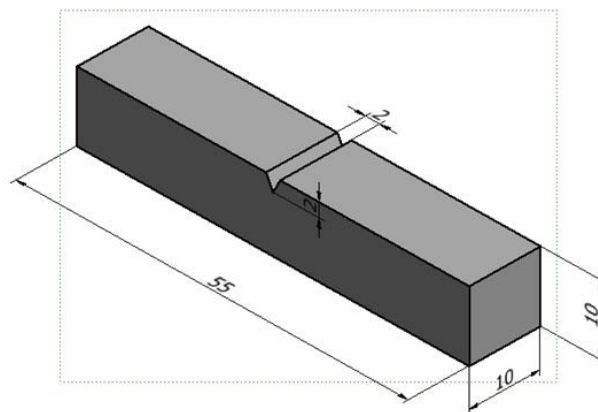


Figure 1. Impact specimen dimensions in mm

3. Classification of test samples

After completion of the manufacturing process, the samples were encoded into four groups as shown in Table (2).

Table 2. Classification of test sample

Symbol	State
A	As received
B	Shot peening by steel ball has diameter 1.25mm
C	Surface hardness by leaser peen
D	Surface hardness by Plasma peen

4. Shot peening with steel balls

This test was applied on a set of samples using steel balls with a diameter of 1.25 mm and hardness of 55 HRC. The machine rotates with a fixed speed of 40 m / min, a different time of (10, 20, 30) min., and an ejection angle of 10 degrees. The distance between the entry hole and the sample surface is 120 mm. The rotate shot type STB-OB was used as shown in Figure 2.



Figure 2. shot peening device

5. Laser peening

This method was applied to the set of samples in Table (2) using the laser device shown in Figure 3. The laser beam has a wavelength of nm1064 and a variable number of pulse (5, 10, and 15) pulses.



Figure 3. Device of laser peen

6. Plasma hardening

It was implementing on the same set of samples in Table (2). An electric arc was created between the heating gun and the working piece with a current of 18 amp and a voltage of 240 volt. Then, the air pressure of a compressor was applied with 5 bars using advice shown in Figure 4.



Figure 4. Plasma device

7. Examination of microstructure

The specimens were prepared in order to identify the microstructure of the entire sample in table (2). The preparation stages included grinding by emery sheet with grades from 180 - 240 - 320 - 500 - 800 - 1000, a fine polishing process with a special alumina polishing and granular size $0.5\ \mu$. Then, chemical treatment of the surface using nital solution consisting of 2% nitric acid and 98% methyl alcohol and finally, examined and photographed the microstructure and as explained in Figure 5.

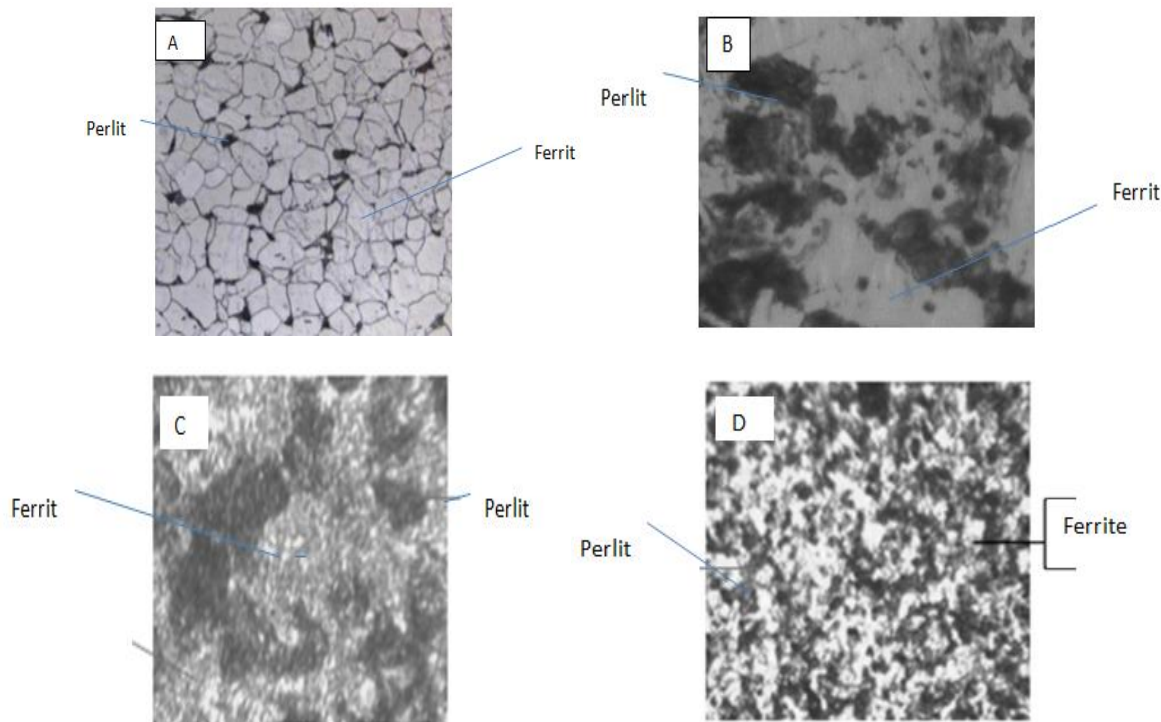


Figure 5. The microstructure of test specimens at the best result. (All magnification 40x)

8. Hardness Test

The Hardness test was performed on all samples in Table 2 using the HRC method. Three readings were taken for each sample and the mean was adopted. The results are shown in Table3.

9. Sharpe Impact Test

Using the sharpe device and calculate the Impact stress of the samples by applying the equation below:

$$\sigma_a = E / A \text{ ----- (3) Joule / cm}^2$$

σ_a = Impact stress in (Joule / cm^2), E = Energy in (Joule)

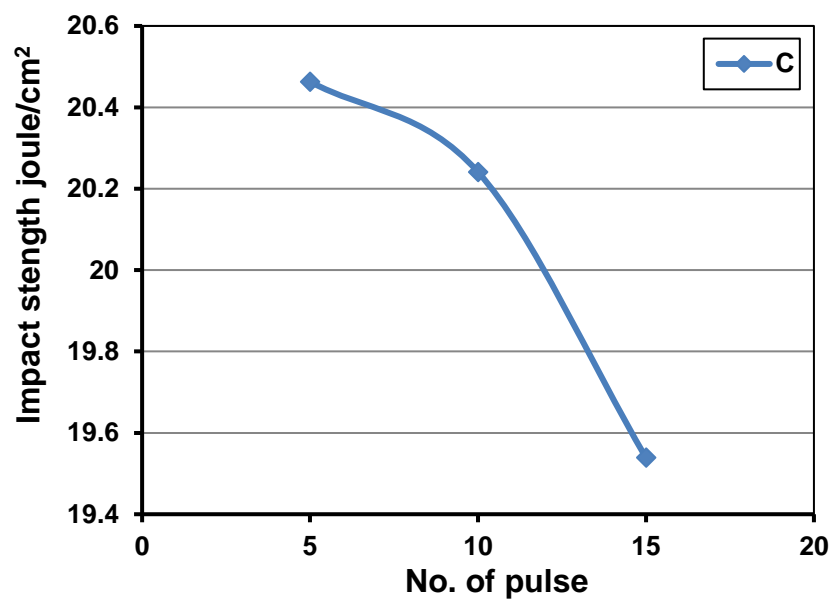
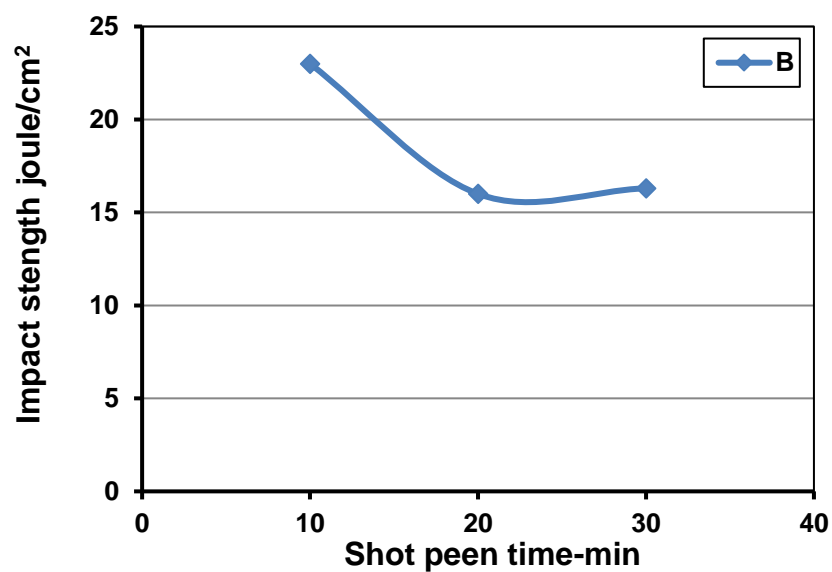
The energy of the fracture is calculated from the relationship below:

$$E = w * L (h_1 - h_2) \text{ in (kg.m) ----- (4)}$$

w = pendol weight (25.5kg), L = pendol length (75 cm), A = cross section area in (cm^2). The results of the test are shown in Table (3) & Figure 6.

Table 3. Result of mechanical properties

Specimens	Impact Strength Joule/cm ²	Impact strength Joule/cm ²	Impact Strength Joule/cm ²	Rockwell Hardness HRC kg/mm ²
A	14.437	-	-	30
B	23.019 for shot time (10) min.	15.9025 for shot time (20) min.	15.9024 for shot time (30) min.	39
C	(20.463) for (5) pulses.	(20.241) for (10) pulses.	19.5387 for (15) pulses.	40
D	20.888 for (3) sec.	21.8390 for (5) sec.	21.7513 for (10) sec.	38



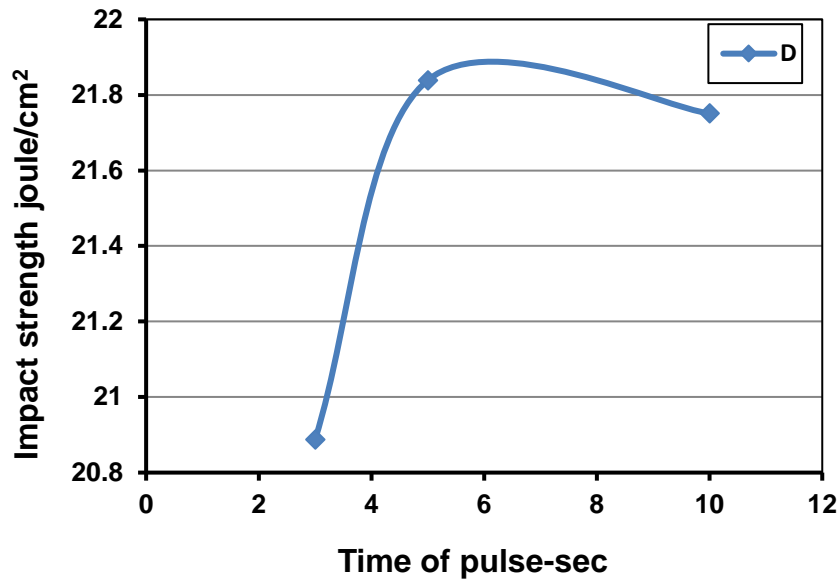


Figure 6. Relation between impact strength and surface hardening of the three methods.

10. Discussion

Figure (5A) represents the microstructure of the metal without surface treatment and it has been found that the main phases are the ferrite and little amount of perlite, the chemical analysis which is shown in Table (1) noted that the carbon is low than 0.2% therefore the control phase is the ferrite which caused a small increase in the hardness of the metal after the surface hardening and little change occur in grain size due to the low percentage of carbon source of the phase transformations and the increase in the hardness of the samples (B) which subjected to shot peening and sample (C) which exposed to laser peening was occurred due to shot peening form high density of dislocation lead to refinement of grain in surface layer after shot which improve hardens properties in addition to plastic deformation, shot peening then it was decreased at the time was increased to 30 min. due to the stress in this time reach to fullness and hardens was decreased due to shot peening generating high temperature then subjected to low cooling rate causes in this decreases Figure (6 B) and table (3) show the values of hardness for all specimens compared to the base metal, which contributed to improve the impact strength and the best value was at the shot time of (10) minutes also the laser peening contributed to improve the impact strength The best result was at (5) pulse because of the greater number of shocks causes the greater of plastic deformation. Low laser shock or the stresses have been relaxed due to increase in number of shocks. Moreover, the absorbent layer may have been destroyed during multiple shocks [4,5]. The increase in the number of pulses led to high temperature and the low cooling rate led to this decrease. (6C) plasma radiation for 5 seconds gave the best results compared with 10 sec because increasing the time of exposure would cause the change in sample dimensions but decreases time to 3 sec causes in decrease hardens due to decreases in plastic deformation (6D). Finally, the increase in the number of pulses led to high temperature and the low cooling rate led to this decrease. Improved fracture strength. Exposure to plasma radiation for 5 seconds gave the best results because increasing the time of exposure would cause a distortion in the sample dimensions.

11. Conclusions

- 1-Surface hardening methods contributed to improve the impact strength of the low carbon steel at different conditions.
- 2- The strength depends on the case of mechanical surface hardening treatment.
- 3- Shot peening, laser peening gives the high value of strength at low shot time and number of laser pulses but increases in plasma time increases impact strength.

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