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THE EFFECT OF CURRENT AND VOLTAGE ON MECHANICAL PROPERTIES OF LOW CARBON STEEL PRODUCTS

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ABSTRACT

This study presents an evaluation of the effects of electrical energy on the most important properties of low carbon steel such as yield strength, ultimate strength, hardness, and impact strength. These properties are the most important parameters of design and manufacturing of machine parts and structures. A36 is one of the low carbon steels which are widely used in different industries. The chemical composition of this steel includes carbon between0.17 and 0.2 (% wt).Present work focuses on the relationship between the change of mechanical properties of steel and electrical power passing through its products. Experiments show that increasing current or voltage passing through products made of this type of steel results in decreasing of their mechanical properties.

Key words: Low Carbon Steel; Current; Voltage; Mechanical Properties; Manufacturing.

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1. INTRODUCTION

Low carbon steel is the most common form of steel as its price is relatively low while it provides material properties that are acceptable for many applications [1].

In manufacturing operations, many parts and components made of low carbon steel are formed into various shapes by applying external forces, mechanical properties of materials are the most important parameters taken into account in design and manufacturing of products [2, 3].

Mechanical properties of metals determine the range of usefulness of a material and establish the service life that can be expected. Mechanical properties are also used to help classify and identify the material. The most common properties considered are strength, ductility, hardness, impact resistance, and fracture toughness [4].

The mechanical properties of a material are changed as a function of temperature, loading, and other conditions. For example, temperatures below room temperature generally cause an increase in strength properties of metallic alloys; while ductility, fracture toughness, and elongation usually decrease. Temperatures above room temperature usually cause a decrease in the strength properties of metallic alloys [5].

Ductility may increase or decrease with increasing temperature depending on the same variables in manufacturing processes especially in metal forming such as bulk deformation processes which include forging, rolling and extrusion, also in sheet metal forming operations, the formability depends on mechanical properties of manufactured metals[6].

A36 steel has the following applications:

- It is used in bolted, riveted or welded construction of bridges, buildings, and oil rigs.
- It is used in forming tanks, bins, bearing plates, fixtures, rings, templates, jigs, sprockets, cams, gears, base plates, forgings, ornamental works, stakes, brackets, automotive and agricultural equipment, frames, machinery parts.
- It is used for various parts obtained by flame cutting such as in parking garages, walkways, boat landing ramps and trenches.

Due to high industry importance and wide application of A36 steel, this experimental study was carried out to get the effect of passing the electrical current through steel products during manufacturing, Arc and spot welding, or maintenance. Which can help us to improve the quality and reduce the cost of manufactured products.

Chemical composition and mechanical properties of low carbon steel are shown in Tables 1.and 2. [7]

Table 1.Chemical composition of A36 steel

Element	Wt (%)
Carbon, C	0.25
Phosphorous	0,040
Sulfur, S	0.050
Copper, Cu	0.20
Manganese, Mn	1.03
Silicon, Si	0.280
Iron, Fe	98.0

Table 2 mechanical properties of A36 steel

Yeild Stress	Ultimate Strength	Elongation	Hardness
(Mpa)	(Mpa)	(%)	(HB)
250	400	24.5	155

2. MATERIALS AND METHODS

Experiments were carried out using specimen's of A36 steel, by applying current and voltage with variable values for thirty seconds, using DC power supply with controlled output then measuring the mechanical properties according to each value [8].

Three specimens were used for each value of current and voltage applied, then the average results were taken. The voltage values were from 20 to 32V and for current from 100 to 160 A. A tensile test to measure yield and ultimate strength, HB hardness test, and Izod impact tests were carried out for all specimens, and the average values were tabled. Brinell hardness tester under a static load of 500 kg, with a ball indenter of 2.5mm diameter, was used to determine the hardness of the specimens at a dwell time of 15 s. The diameter of indentation on the specimen was measured with the aid of a calibrated microscope and determined. Tensile test specimens were tested according to ASME standard [9]. Ultimate tensile strength and yield strength of the specimen were determined. A specimen of low carbon steel A36 with dimensions and shape according to ASME standard shown in fig (1) and table .3 was used.

Izod test was carried out for samples with 55 by 10 by 10 mm dimensions and using impact tester with pendulum weight of 22kg, and pendulum length of 80 mm [10].

Microstructure Test was carried out using an optical microscope to observe the characteristics of the microstructure, specimens were prepared and polished using a diamond paste of 1 micron, then etched, washed and dried. Optical microscope with camera and Magnification of 500 was used [11].

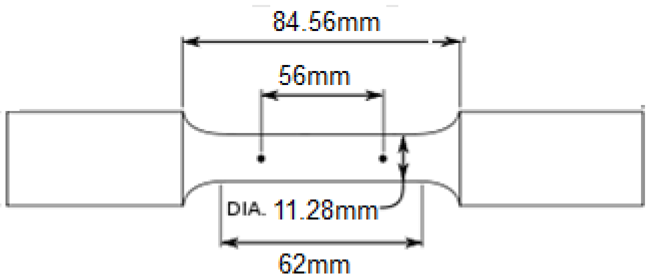

Figure 1 schematic illustration of tensile specimen.

Table 3 tensile specimen dimensions.

Dimension (mm)	Gauge length	Diameter	Radius of fillet	Reduced section	Distance between shoulders
	56	11.28	10	62	84.56

Table 4 Mechanical properties at deferent values of volta.

Voltage (v)	Hardness (HB)	Yield strength (Mpa)	UTS (Mpa)	Impact strength (joule)
20	153	248	366	66
22	150	244	360	63
24	147	239	357	53
26	145	227	355	50
28	144	220	352	48
30	138	217	350	45
32	129	211	348	40

Table 5 Mechanical properties at deferent values of current.

Current (A)	Hardness (HB)	Yield strength (Mpa)	UST (MPa)	Impact strength (joule)
100	151	246	388	64
110	148	238	383	55
120	142	233	380	51
130	139	227	378	49
140	133	222	375	45
150	126	219	372	36
160	118	213	368	30

3. RESULTS AND DISCUSSION

3.1. Hardness

In table 4. are given the results of hardness test for each value of voltage and Fig (2) shows the effect of voltage on the hardness of low carbon steel samples. It is noted that the hardness of the samples changed slightly with changes in voltage values between 20 V and 32 V and it was decreased about 16.7% as compared with a normal sample. In table 5. are given the results of hardness test after applying current to samples, results were plotted in Fig.(3) which shows that increase in the current from 100 A to 160 A, resulted in a decrease in hardness about 23.8%. This is similar to the effect of the voltage. Which means that by applying current or voltage, the heat generated affects the microstructure by the growth of grains and burning of some additives which causes a great chance of formation defects [12].

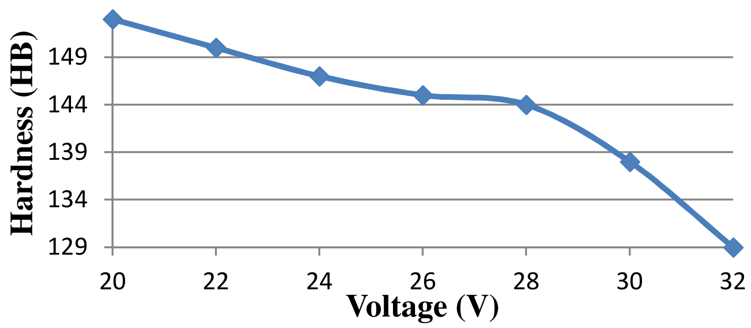

Figure 2 Hardness at deferent values of voltage.

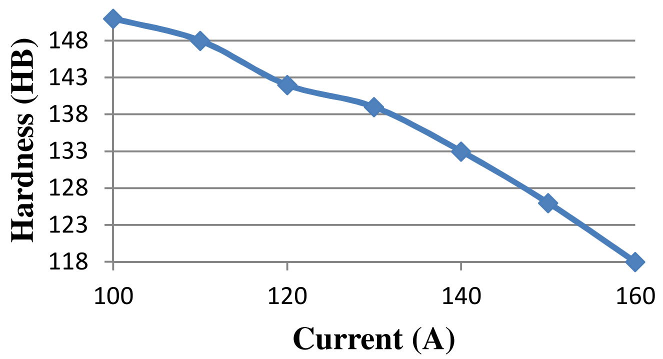

Figure 3 Hardness at deferent values of current.

3.2. Impact toughness

In Table .4 shown the results of impact test of the specimens affected by voltage [13].

The impact toughness values of all specimens are lower than that of the normal specimen which was 70 Joules. Also in table.5 are the results of impact tests after applying current, results are plotted in figures (4) and (5). Figures show similar profiles and in both cases, Impact toughness decreases with the increase of current and voltage.

A decrease of impact toughness at 32 V was 42 % and at a current of 160A was 57%.

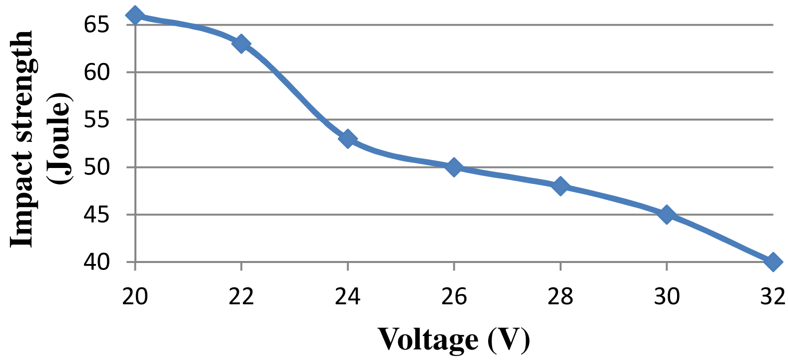

Figure 4 impact strength at deferent values of voltage.

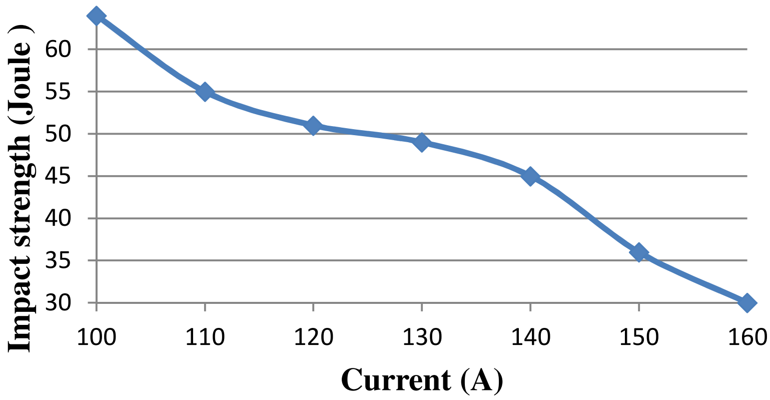

Figure 5 impact strength at deferent values of current.

3.3. Yield stress and ultimate strength

Results of the tensile test in table .4 show the changes of yield and ultimate stresses by changing the voltage, the results are plotted in figures (6) and (7) and show the decrease of these properties by increasing voltage. At 32V the yield stress decreased by 15.6% and ultimate strength decreased by 11.25%.

Results of the tensile test according to applied current also tabulated in table.5. Fig.8 shows the effect of increasing current on yield stress; the decrease of yield stress at 160A was 14.8%, also in Fig.9 shown the decrease of ultimate strength by increasing current which was 8% at 160 A. which means that by increasing voltage or current the steel becomes more ductile [14].

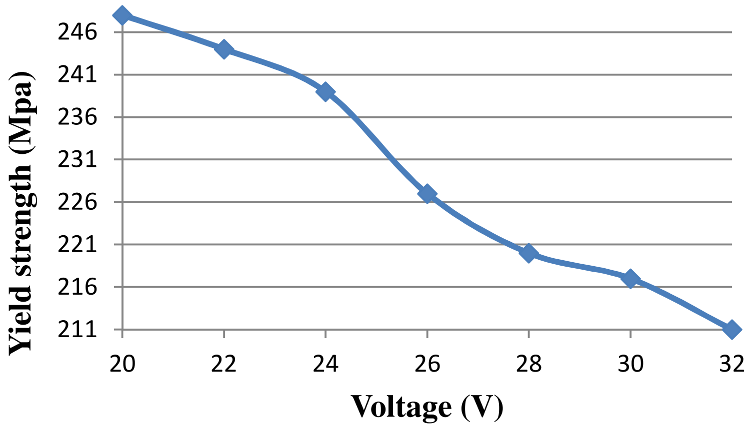

Figure 6 yield strength at deferent values of voltage.

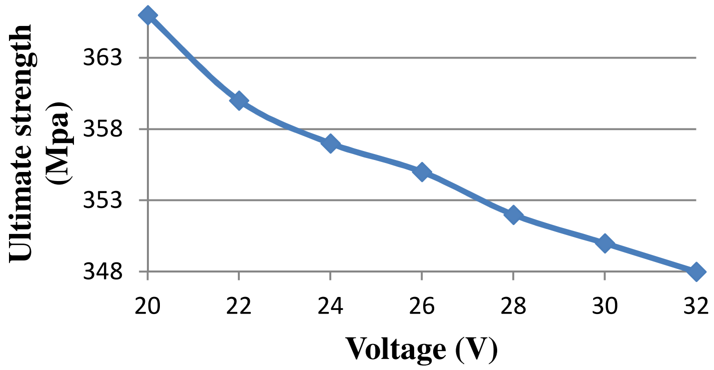

Figure 7 ultimate tensile strength at deferent values of voltage.

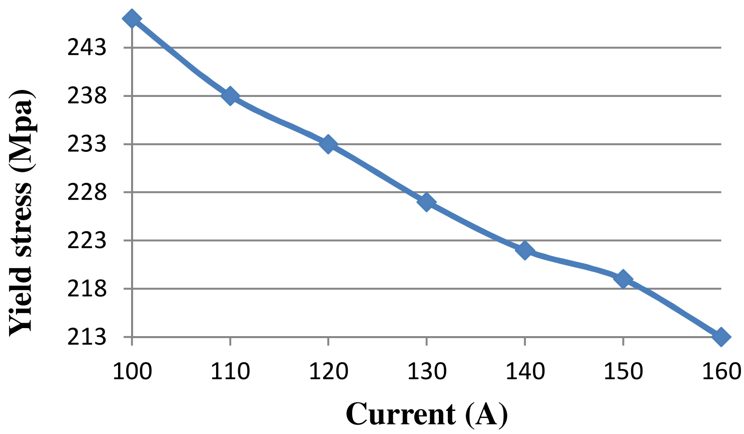

Figure 8 yield strength at deferent values of current.

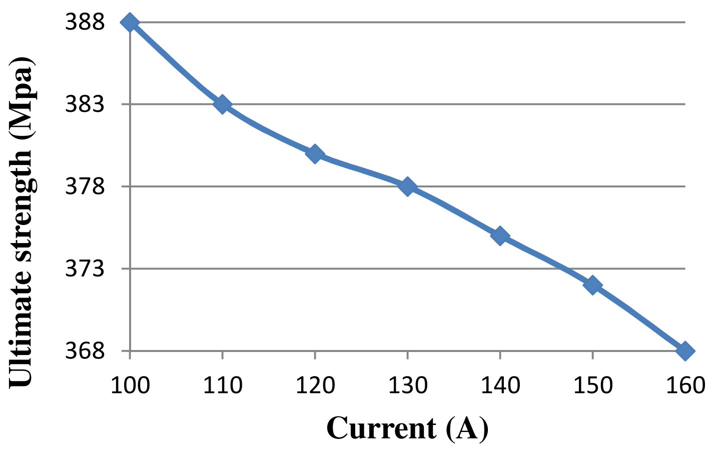

Figure 9 Ultimate tensile strength at deferent values of current.

3.4. Microstructure

A microscope with camera and magnification of 500 was used to observe the change of grain size according to increasing of current values, figures (5,6.7.8.9.10) show the grain size with applied current, they show that the grain size increases by increasing current As the current increases, the heat input also increases. The microstructure becomes more coarse as the current increases, Coarse-grain in the microstructure indicates lower hardness and low strength.

Figure 10 Microstructure at 100A

Figure 11.Microstructure at 120A

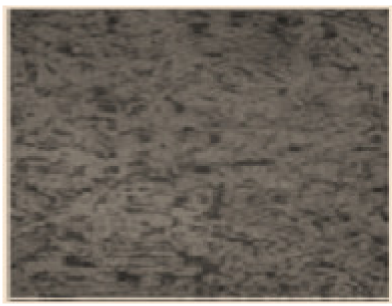

Figure 12 Microstructure at 140A

Figure 13 Microstructure at 150A

Figure 14 Microstructure at 160A

From results shown in tables (4) and (5) and plotting these results as it was shown in figures we can note that increasing of voltage or current will increase the heat generated in these specimens, and cool in air resulted in softening of the metal through the removal of dislocations. Recrystallization results in the new strain-free grains that replace those deformed by dislocations .Grain growth results in the coarsening of the microstructure of the metal, which cause a loss of strength if the metal is not hardened [15].

The thermodynamic process of stress relieving is spontaneous, but occurs slowly at room temperatures, prepares the metal for further work, such as cutting, shaping or forming. Non-ferrous metals, such as copper, silver, and brass, can be cooled quickly by quenching in water, while ferrous metals must be cooled slowly in still air and as a result decrease the values of yield strength, ultimate strength, hardness, and impact strength.

4. CONCLUSIONS

As a conclusion, an increase of current or voltage will increase the heat which will affect the microstructure of steel parts and cause a decrease in their mechanical properties so we advise the following:

1. Machines and structural parts must be avoided from current or voltage during their work or maintenance .to keep their properties that they were designed for to avoid their failure.
2. n metal forming industry in many operations we need to reduce mechanical properties of stocks as in forging, extrusion, rolling, cutting ,and sheet metal forming, so dies or molds can be suited to apply suitable current or voltage to parts according to their volumes and required heat instead of using furnaces for this purpose.

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