Carburizing of Plane Carbon Steels by Electrolyte Plasma

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Abstract - *In this thesis ASTM A-36 (mild steel) is selected as specimen for testing carburizing by electrolyte plasma and microstructure change. The experiment consists of DC power supply with voltage range 12-36 volt & current 35 A, ASTM A-36 mild steel specimen, electrolyte solution, plastic bicker, thermocouple, stand. The size of specimen is 100 mm length & 20 mm diameter. A plasma treatment apparatus for plasma treating an object to be treated or workpiece by exposure to ions, free radicals and activated gas species generated by a plasma discharge includes a susceptor electrode supposing the workpiece and another electrode facing the susceptor electrode, together constituting a pair of plasma generating electrodes across which an DC voltage is applied.*

ASTM A-36 were carburized by plasma electrolytic carburizing process in a solution, consisting of glycerin and ammonium chloride. After the ASTM A-36 were carburized for 5 and 6 min at 400^0 C, deep 5 mm in electrolytic solution, after plasma formation start the electrical circuit of the system was shut down. Plasma electrolytic carburized layers formed on the mild steel were analyzed for the mechanical properties. The phases formation started around the ASTM A-36 Specimen. The average thickness of the carburized layers for 5- and 10-min samples was 3.4 μm and 5.7 μm, while the average microhardness of the carburized layers was 210 HV and 228 HV. Wear rate and surface roughness of plasma electrolytic carburized samples is decreased.

Key Words: **Heat treatment; ASTM A-36(Mild steel); Microstructure; Universal testing machine; Plasm Electrolyte.**

1. INTRODUCTION

Studies in plasma electrolysis resulted in development of various surface treatments for metal components. These treatments include formation of protective ceramic layers on some metals (e.g. oxide coatings), saturation of metal surfaces with interstitial elements (e.g. nitrogen, carbon and boron), and plasma electrolytic deposition of extrinsic compounds, heat-treatments (e.g. hardening and annealing), surface cleaning and polishing. The main advantages of plasma electrolytic treatments are high processing speeds and low costs. The treatments enable production of surface nanostructures and local area processing. This review examines recent results in plasma electrolytic carburising, nitriding, and nitrocarburizing (as the most common diffusion-based treatments), including treatment modes, electrolyte compositions, structures, and properties of hardened materials. Analysis of the results obtained up to date indicates that pulse plasma electrolytic saturation treatments leading formation of surface Nano-structures appear to be the most promising to advance further this type of electrolytic plasma technology. Moreover, electrolytic plasma treatments provide considerable research interest in terms of fundamental science, for development of models of heat transfer on flat vertically or horizontally oriented surfaces and electrochemical processes occurring in the studied systems. These processes include stages of liberation of saturating components, adsorption of active atoms, and their diffusion into the metal surface; therefore, understanding associated kinetics and limiting factors is important for gaining proper control over these surface treatments [1].

Mild steel is a kind of low carbon steel that is widely used as a tool steel due to its superior mechanical strength and low cost. However, its relatively low wear resistance restricts the use of this kind of steel under high load wearing conditions. Surface hardening such as surface carburizing can be used to improve the surface wear resistance in Mild steel. Plasma electrolytic carburizing (PEC) is a novel method of surface carburizing in which a pulsed discharges applied to the work-piece catholically in an aqueous solution, which provides a super saturated environment called plasma [1].In this process, applied voltage determines the surface temperature of the work-pieces during the treatment [2,3].The temperature should be high enough to form an austenitic phase on the surface to provide an appropriate medium for diffusing carbon atoms. It was also revealed that the final phases are strongly correlated to the process temperature. If the temperature does not exceed the temperature of the two phases in the regions of (a þ g), the formation of the phases other than martensite phase can be predicted [4]. In addition, the applied voltage, duty cycle, and the frequency were affected by temperature during the carburizing process. This played a considerable role in the obtained morphological properties of the treated samples. It was reported that in low melting alloys, higher frequencies lead to a decrease in the size of nanocrystals and the porosity of the compound layer [5]. Furthermore, increase in the frequency improves the diffusion rate of the carbon atoms [6]. The influence of duty cycle on concentration of carbon at the surface layer was also confirmed. Consequently, wear resistance of the treated samples was under influence of frequency and duty cycle [6].

1.1 Detail Description of Apparatus for Plasma heating of steel

Carburizing of plasma carbon steel by electrolyte plasma experimental set up consist of low carbon steel specimen as cathode, thermocouple to measure specimen temperature, electrolyte solution, MS ring as anode, plastic beaker, DC power supply.

Arrange the set up as per given drawing then pour the electrolyte solution in plastic beaker. Make electrical connection with anode & Cathode as per requirement, main DC power supply connected with anode & cathode. Place thermocouple on its place with Specimen. Make sure the power supply connection is as per the drawing connected & emerging depth of the specimen is not more than 10 mm in electrolyte solution.

- Apparatus –

1) Electrolyte Solution- H2O+C3H8O3+NH4CI

   2L 1L 1kg

2) Power Supply- DC Power Supply 300V,24V

3) Electrode – 1) Cathode - ve terminal -Specimen

   2)Anode + ve terminal -Ring

4) Thermocouple- One thermocouple placed with specimen

5) Deep specimen up to 5mm to 8mm only inside the electrolyte solution

- Procedure-

1) Hold the specimen inside the Electrolyte solution.
2) Switch on the DC power supply & gradually increase it up to plasma generate around the specimen
3) After the specimen reaches red hot condition switch off DC power supply.
4) Record total time which required to complete the cycle.
5) Unclamp specimen & stay it inside the same electrolyte solution for quenching.
6) All required readings recorded in observation table.

1.2 Measurement of microstructure & hardness-test results

The specimen ASTM A-36 cut perpendicular to the axis along length. Taken cross section at the carburized portion of specimen. Prepared its surface for microstructure testing & Vickers hardness testing-

Test -1

Specimen 1 exhibits hot roll of ferritic matrix with grains, in elongated as well as equiaxed from grain size found is ASTM no7-8. The Vickers hardness observed is 208,214 HV1.


Magnification at 100 X


Magnification at 500 X

The specimen 1 is original ASTM A-36 material which has low carbon steel (mild steel). The hardness is low for this specimen comparative.

Test -2

Specimen 2 exhibits hot roll of ferritic matrix with grains, in elongated as well as equiaxed from grain size found is ASTM no7. The Vickers hardness observed is 210, 215 HV1. The specimen 2 has small amount of carbon deposition due to bubble formation at the time of increase in voltage. The increased voltage brake electrolyte solution so carbon release into the solution which is deposited on the surface of specimen with these the increased voltage form plasma around the specimen. due to this the harness is increased.


Magnification at 100 X


Magnification at 500 X

Test -3

Specimen 3 exhibits hot roll of ferritic matrix with grains, in elongated as well as equiaxed from grain size found is ASTM no 6-7. The Vickers hardness observed is 214, 220 HV1.

 

Magnification at 100 X Magnification at 500 X

The specimen 3 has more amount of carbon deposition due to sparking formation at the time of increase in voltage. The increased voltage brake electrolyte solution so carbon release into the solution which is deposited on the surface of specimen with these the increased voltage form plasma around the specimen. due to this the harness is increased comparatively more.

Test -4

Specimen 4 exhibits hot roll of ferritic matrix with grains, in elongated as well as equiaxed from grain size found is ASTM no 7. The Vickers hardness observed is 216, 225 HV1.

 

Magnification at 100 X Magnification at 500 X

The specimen 4 has more amount of carbon deposition due to continues sparking formation at the time of increase in voltage. The increased voltage brake electrolyte solution so carbon release into the solution which is deposited on the surface of specimen with these the increased voltage form plasma around the specimen. due to this the harness is increased comparatively more.

Test -5

Specimen 5 exhibits hot roll of ferritic matrix with grains, in elongated as well as equiaxed from grain size found is ASTM no 6-7. The Vickers hardness observed is 228, 235 HV1.

 

Magnification at 100 X Magnification at 500 x

SEM Study of the treated Specimen

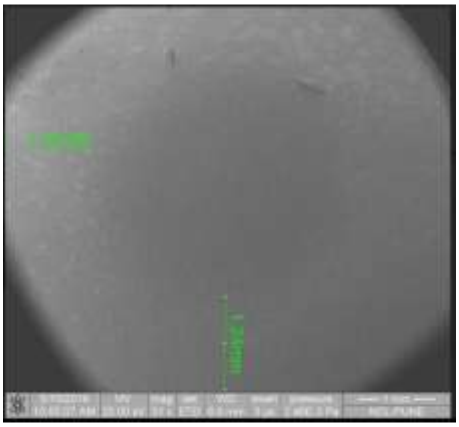

Fig.1 shows the SEM result in which carburizing occurred up to the 1.41 & 1.24 mm from the surface of specimen

2. Observation Table

Specimen	Current	Voltage	Time	Specimen Temp.	Vickers Hardness	Microstructure
Original					208	7-8
Test 1	10	180	5	120	210	7
Test 2	75	230	5	170	214	6-7
Test 3	22	12	30	254	216	7
Final Test	35	12	6	400	228	6-7

Specimen analysis-

Vickers hardness testing- 208 to 228 HV

Microstructure testing- Ferritic matrix with grain size in elongated as well as equiaxed is observed.

Grain size found is ASTM No. 6-7.

Hardness measurement: -

Hardness depending on heat treatment parameters the measured hardness values are shown in Fig. 3. The blue and Purple line represent the hardness of specimens with respective that current, voltage & time also mentioned.

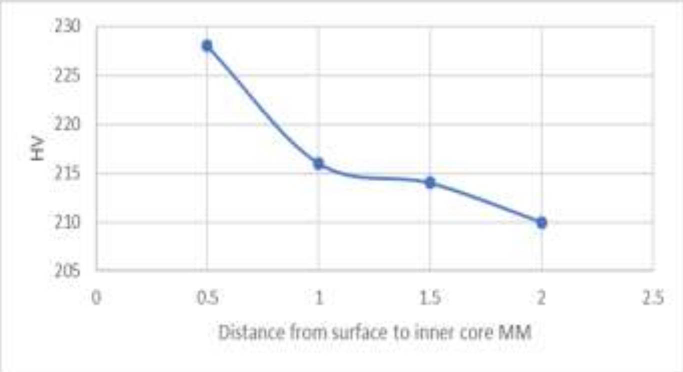

Fig. 2 Vickers hardness (Hardness taken from surface to inner core)

Samples were cut perpendicular to the immersion direction using diamond saw and polished for microhardness measurement. The microhardness of carbon-rich layer formed on the surface of pure iron, and cross-sectional hardness variation from the surface of carburized layer to the interior of the sample was measured by an Instron microhardness tester equipped with a Vickers indentation tests (HV10) with a load of 1 kg.

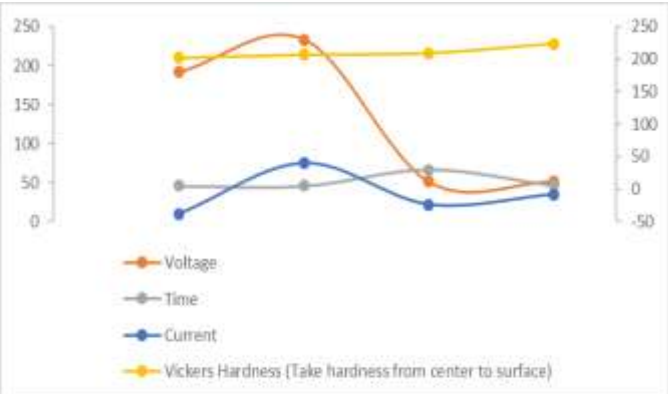

Fig.3 Hardness depending upon different heat treatment parameter

3. CONCLUSION

Modern studies have led to the development of several electrolyte compositions and processing regimes enabling hardness, wear and corrosion resistances of a wide range of steels to be enhanced using PES. Studied carburizing process possible to perform with plasma heating. Performed microstructural result analysis. The mild steel material hardened, hence we proved that by plasma carburizing is beneficial than the conventional carburizing from as well as efficient. This method is so much effective & time saving as compared to the conventional carburizing. Only one thing is required that is the DC power supply which the one-time investment. These results convincingly demonstrate significant potential of Carburizing of plane carbon steel by electrolyte plasma technology for scientific research and various industrial applications.

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