Application of Electrochemical Process as Inner Holes Cleaner

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Abstract: **Electrochemical process is a relatively important method for removing unwanted scales by anodic dissolution. In this work an Electrochemical process was used to remove the corrosion from the inner holes of the work pieces (medium carbon steel 0.35% C) by immersing it in electrolyte sodium carbonate, Na_2CO_3. The tool used was made from brass. This work focuses on surface roughness of the work pipes.**

Keywords: Electrochemical Process, Electrolytic Cell, Surface Finish

1. Introduction

Electrochemical process is a removing rust by anodic dissolution method and it has no cutting forces and stresses because the process depends mainly on electrical conductivity of materials and chemical reaction between the electrolyte and the workpiece (Alwan, 2011). No thermal damages occur to the workpiece structure which produces surface stresses. Thus, high surface finished is obtained (Singh, 2008). There are various methods for rust removal, but they are unsuitable for being old or due to their being old techniques, they tend to be destructive in use. Dissolving the rust with acids such as phosphoric acid or even vinegar can produce good results, but this process can remove surface features which may have been preserved in the rust. These methods were considered inappropriate. also known as electrolysis, which involves using the passage of an electric current in an alkaline solution, or electrolyte, to do the job of trying to convert some of the corrosion products into a more stable form, whilst loosening the remaining corrosion by converting it into a loosely bound, easily removed deposit (Westcott, 2010).

Electrochemical cleaning has a working mechanism that is similar to that of electro polishing. Unlike the electro polishing, the electrochemical method of cleaning is deemed far more portable, and it can also be applied locally. One would not be wrong in saying that the electrochemical method of cleaning is indeed more advantageous than other methods such as electro polishing, acid cleaning or even mechanical cleaning. When it comes to electro cleaning, you don’t have to deal with the annoying problems of dirt, buffing compounds (Eliyan, Mahdi & Alfantazi, 2012). Bicarbonate ($HCO3^-$) plays a critical role in the dissolution reactions of internal and external sides of pipeline structures. Many works were reported on the electrochemically-enhanced stress corrosion cracking when bicarbonate-saturated ground water is in contact with pipeline surfaces. It was reported that bicarbonate is a major agent in the dissolution of pipeline steels although of the reported controversy on its role in acidic CO_2^-saturated flows. In another study, bicarbonate was also proposed to contribute in formation of complexation of iron carbonate. In most pipeline corrosion studies, the mechanisms conventionally involved a solution of H_2CO_3 in driving the cathodic reactions in deoxygenated media (Harle & Beavers, 1993).

Bicarbonate was reported to be a key corrosive agent involved in anodic and cathodic reactions. More specifically, the determining steps were found to be fundamentally associated with bicarbonate as they are, for example, reduced directly to produce adsorbed hydrogen atoms and/or hydrogen gas represented by Eqs. (1)–(3) as:

$HCO_3^- + e^- \rightarrow H_{ads} + CO_3^{2-}$ (1)
$HCO_3^- + H_{ads} + e^- \rightarrow H_2 + CO_3^{2-}$ (2)
$2HCO_3^- + 2\ e^- \rightarrow H_2 + 2CO_3^{2-}$ (3)

The corrosion rates and polarization characteristics were found dependent on bicarbonate content (Videm & Koren, 1993).

2. Procedure

2.1 Cathode tool

The material used for Electrochemical tools should be electrically conductive and easily Machin able to the required geometry. The tool used in the process is made from brass metal as cylinder shape with diameter Ø13 mm.

2.2 Anode Work Piece

For this work, the work piece is a cylinder pipe medium carbon steel (0.35%) with the chemical composition show in table (1a,b)

Table (1a): The material specification

Material standard	DIN system
Material of the workpiece	Medium carbon steel (Ck35)
Steel group	Special structural steels
Designation symbol	Ck35
Material number	1.1181
Density of the alloy	7.85 g/cm^3

Table (1b): Composition of the alloy

Element	Wt%	Density (g/cm^3)	Atomic weight	Valence
C	0.35	2.26	12.011	4
Mn	0.81	7.84	54.938	4
Si	0.19	2.33	28.086	4
P	0.011	2.93	30.97376	3
S	0.023	1.819	32.066	2
Ni	0.3	8.92	58.693	2
Cr	0.07	7.19	51.996	6
Mo	0.01	10.22	95.94	3
Cu	0.02	8.97	63.546	2
Al	0.05	2.71	26.98	3
Remain	98.436	7.86	55.845	2

2.3 Electrolytes

Na_2CO_3 is used with water as an electrolyte with weights (250g) and (1 litter) of water.

2.4 Electrochemical cell

The electrochemical process was done by placing the workpiece in the cell with fixture to oscillate the workpiece during the process. The tool is made of brass having a cylinder shape and fixed in the tool holder using drilling machine. The gap between the tool and the workpiece is controlled manually. After that the negative pole of the power supply is connected to the tool and the positive pole to the workpiece. Then both tanks are filled with the electrolyte. During the process and after power supply is turned on, the electrolyte with the sludge is sending out to the storage tank. From the other side of the storage tank the electrolyte is send to a filtration unit to remove the sludge and is pumped to the reaction zone (Alwan, 2011).

In this work, the experiment is focused on the roughness and the surface cleaning of the workpiece.

3. Result and Discussion

The free anodic dissolution can involve OH^- to form iron (2) hydroxide:

$$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 2e^- \quad (4)$$

The cathodic reactions involve the simultaneous reduction of bicarbonate and dissolved oxygen:

$$HCO_3^- + e^- \rightarrow \tfrac{1}{2} H_2 + CO_3^{2-} \quad (5)$$

$$HCO_3^- + e^- \rightarrow H_{ads} + CO_3^{2-} \quad (6)$$

OH^- involvement in the dissolution processes results in a defective hydrous film capable of

decelerating the current densities.
The film, could be hydroxide-based developed within a short potential range, which was illustrated in a Fe–H–C–O Pourbiax diagram, (Hirnyi, 2001) as:

$Fe + 2OH^- \rightarrow Fe(OH)_2^-$ (7)

$Fe + HCO_3^- \rightarrow FeHCO_3$ (8)

$Fe(OH)_2 + OH^- \rightarrow FeCO_3 + H_2O + e^-$ (9)
$3FeCO_3 + 4OH^- \rightarrow Fe_2O_3 + 2HCO_3^- + H_2O + 2e^-$ (10)
$4Fe(OH)_2 + O_2 \rightarrow 2Fe_2O_3 + 4H_2O$ (11)

The results of the effect of gap size on the surface cleaning is gaven in table (2) at operation time of T = 10 minutes and current density 2.856 Amp/cm^2.

Table (2): The surface Cleaning & the gap size before and after the operation

Gap size (mm)	Workpiece Roughness Before the operation (μm)	Workpiece Roughness After the operation (μm)
1	5.21	2.6
1.5	5.97	3.05
2	5.09	3.22
2.5	5.89	4.32
3	6.01	4.88

Fig (1) shows the effect of increasing the gap between the tool and the workpiece causing the surface cleaning rather poor after Electrochemical process due to the increase in the distance between the tool and the work piece that causing dicrease in the conductivity of the electrolyte (increase in ohmic resistance) causing unequal distribution of the current density on the surface which cause unequal anodic dissolution on the machining surface of the workpiece.

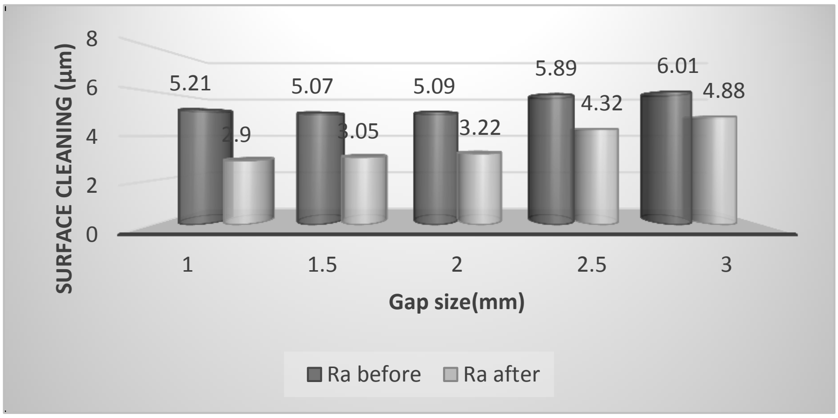

Fig (1): The relationship between the gap size on the surface cleaning

The increasing of the surface roughness and efficiency of cleaning indicate at gap size (3mm) reaching to (46.7%) compared with gap size of (1mm). The poor cleaning of workpiece surface as shown in fig (2) and table (3), these due to the increase in the distance between the tool and the work piece which causing increasing in Ohmic resistance of the electrolyte reducing the amount of the current and decreasing the amount of anodic dissolution.

Table (3): Surface cleaning & the gap size on the dissolution rate

Gap size (mm)	Workpiece Weight Before the operation (g)	Workpiece Weight After The operation (g)	MRRs $x10^{-2}$ (cm^3/sec)	Dissolution rate$x10^{-5}$ (cm/sec)
1	149.5	140.5	0.191	7.79
1.5	113.6	104.8	0.186	7.59
2	157. 4	148.9	0.179	7.3048
2.5	152.8	144.8	0.169	6.8967
3	190.2	182.6	0.16	6.5294

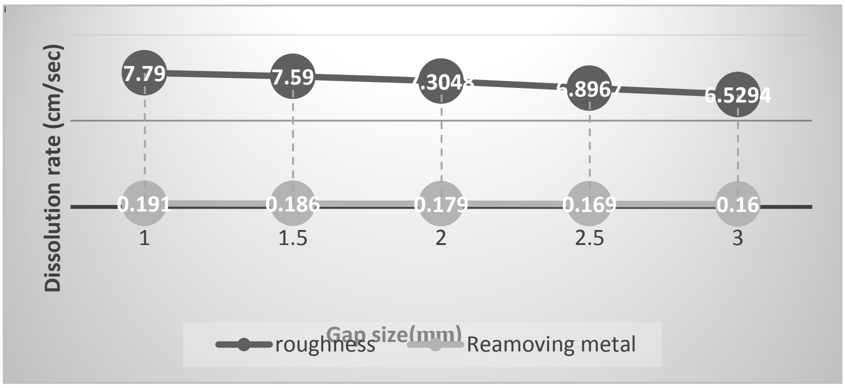

Fig (2) the relationship between the gap size on the dissolution rate

The dissolution rate decreases with the increases of the gap size, and the best result for the high dissolution rate is at the small gap sizes. For this reason (1 mm) gap size has been chosen as a best size for the tests.

The results of surface roughness at different current values are given in the table (4). These are at time of operation T = 10 min and the gap size between the tool and the work piece = 1 mm.

Table (4) surface cleaning & the current density before and after the operation

Current density (Amp/cm^2)	Workpiece Roughness before the operation (µm)	Workpiece Roughness after the operation (µm)
2.4485	3.677	2.687
2.856	3.59	2.49
3.2647	3.55	2.08
3.6728	3.48	1.855

Fig (3) shows that the effect of the current density on the cleaning surface increases at increasing the value of current density, while the roughness decreases rapidly arriving at the value of (1.8 µm) that decreased (31%) as shown in table (5) with a current density is (3.6728 Amp/cm^2) that is because the high value of current causes a better decrease in the peaks of the workpiece surface and good surface cleaning and high current density distribution at all the machining surface of the work piece.

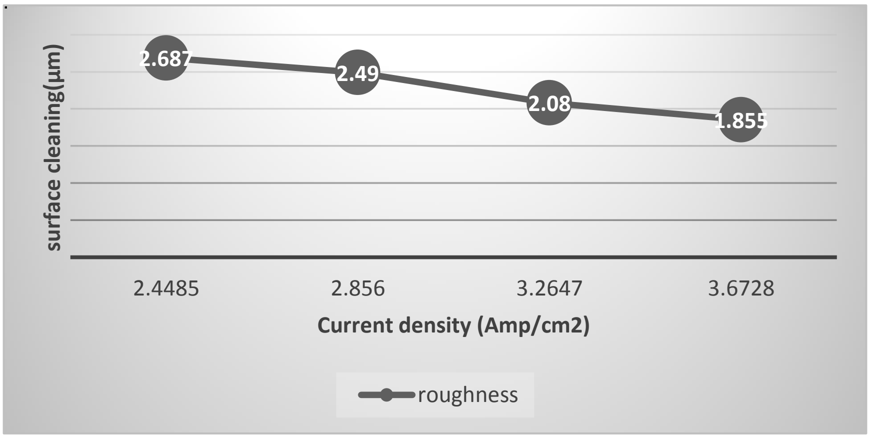

Figure (3) the relationship between the current density on the surface cleaning

Table (5): The MRRg

Current density (Amp/cm^2)	Workpiece Weight before the operation (g)	Workpiece Weight after the operation (g)	MRRg (g/sec)
2.4485	639	632	0.0116
2.856	674	665	0.015
3.2647	684	673	0.0183
3.6728	648	634	0.0233

The better declining of these values was at high current values so the value (3.6728 Amp/cm^2) gives the best decreases of the surface roughness and metal rust arrived to (46.69%) when compared with the surface roughness before the operation. Fig (4) shows that the theoretical surface is cleaning a increasing with current density arrived to (93.9%) at a gap size of (1mm). The high value of current is rushing the chemical reaction in the medium of operation which gives the best results.

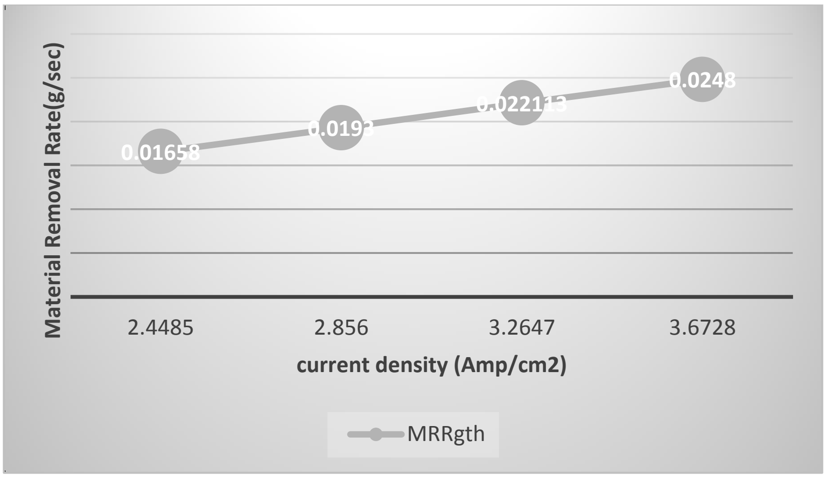

Figure (4) The effect of current density on MRRg

Figure (5): The Workpiece before the operation

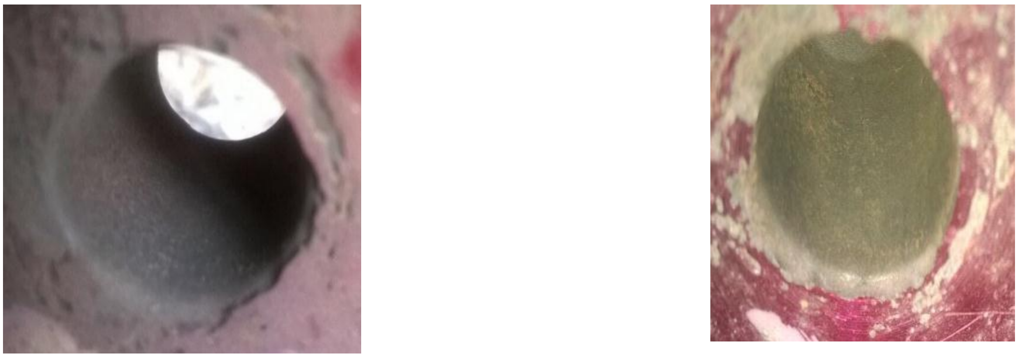

Figure (6): The workpiece after the operation

6. Conclusion

The following points can be concluded:

1- Poor surface cleaning is due to larger distance between tool and workpiece.

2- The dissolution rate decreases with increasing in the distance between the tool and the work piece.

3- The gap size has an effect on the efficiency of the process. The best value that gives a high efficiency (77.7%) is at the (1 mm) gap size.

4- Dissolution rate increases with increasing a current density and the best results were at (3.6728 Amp/cm^2). The efficiency arrived to (93.9%).

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