Study of Electrochemical Polishing Applications in Some Alloys for High Surface Finish

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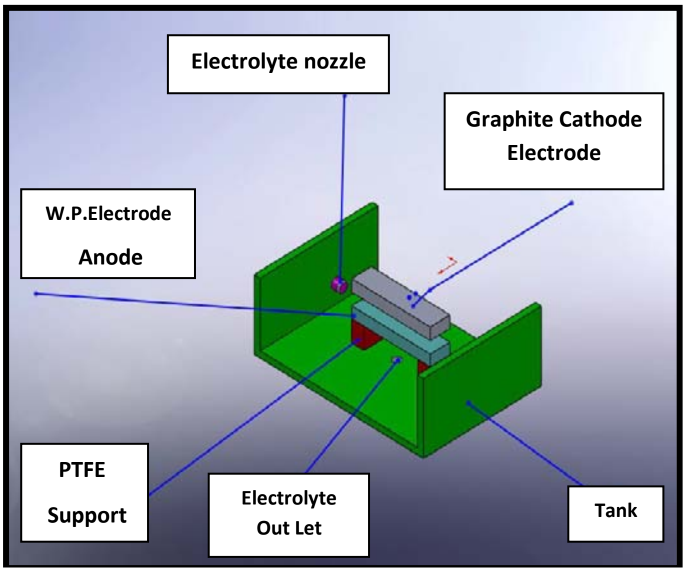
Abstract

Electrochemical polishing with 10% Sodium chlorate electrolyte was used to investigate chemical polishing for three metal alloys used widely in mechanical industries, to obtain high surface finish. The relationships between polishing time – surface roughness, and current density – surface roughness were studied for hot work tool steel, cold work tool steel and dure aluminum. Form which it has been shown that it was possible to obtain surface roughness (2.8μm)for hot work ,(2.5), (2.31 μm), for cold work tool steel and dure aluminum respectively. This study was applied in Nasser state company for mechanical industries / central tool plant to obtain high quality polishing for injection mould cavity, blow mould, spure gear, bevel gear and combustion chamber parts.

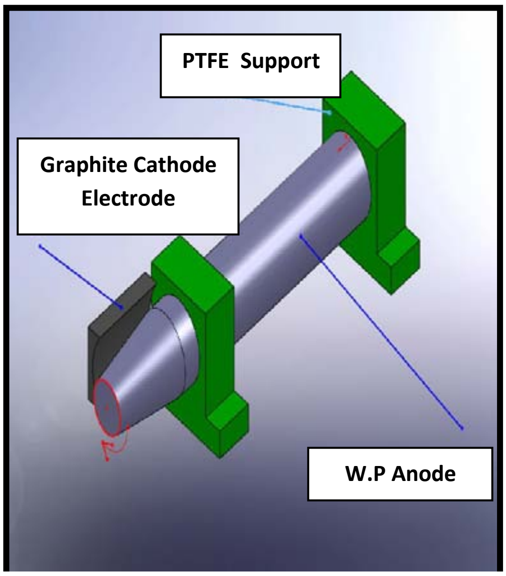
Keywords
Electrochemical Polishing, nonspecular reflection, deburring, surface roughness, industrial operations.

1. Introduction

Electrochemical polishing is a technique which metals are polished and debured by the passage of anodic current through the metal work piece (the anode), across an electrolyte and into a second metal electrode (the cathode) . The rate of metal removal due to cutting is independent to the hardness of the work piece [1]. The process is shown schematically in Figure 1:



a) System represent electro polishing for cavities and flat surfaces



b) System represent electro polishing for circular and tapered parts

Figure 1: Schematic of Electrochemical polishing system

The tool electrode used in the process does not wear and therefore soft metals can used as tools to form fine polishing surface on harder parts, unlike conventional machining methods. The chemical properties of the electrolyte may benefit current distribution. A localization of current flow to smallest dimensions of the anode is desirable to minimize the time required for polishing at a fixed current [2].

Type of electrolytes used in the process affects the quality of surface finish obtained in ECM. Depending on the material, some electrolytes leave an etched finish. This finish results from the nonspecular reflection of light from crystal faces electrochemically dissolved at different rates. Sodium chloride electrolyte tends to produce an etched, matte finish with steels and nickel alloys.

The production of an electrochemically – polished surface is usually associated with the random removal of atoms from the anode work piece, whose surface has become covered with an oxide film. This is governed by the metal – electrolyte combination used. Nonetheless, the mechanisms controlling high – current density electro polishing in ECM are still not completely understood. For example, with nickel – based alloys, the formation of a nickel oxide film seems to be a prerequisite for obtaining a polished surface; a finish of this quality, of 0.2μm , has been claimed for Nimonic (a nickel alloy) machined in saturated sodium chloride solution. Surface finishes as fine as 0.1 μm have been reported when nickel – chromium steels are machined in sodium chlorate solution. The formation of an oxide film on the metal surface is considered the key to these conditions.

Sometimes the formation of oxide film on the metal surface hinders efficient ECP and leads to poor surface finish. For example, the ECP of titanium is rendered difficult in chloride and nitrate electrolytes because the oxide film formed is so passive. Even when higher voltages about 50V are applied to break the oxide film, its disruption is non uniform so that deep grain boundary attack of the metal surface can occur. Occasionally, metals that have undergone ECM have a pitted surface while the remaining area is polished or matte. Pitting normally stems from gas evolution at the anode; the gas bubbles rupture the oxide film. Process variables also affect surface finish. For example, as the current density is raised the finish generally becomes smoother on the work piece surface.

History's first reference to electro polishing occurred in 1912 when the Imperial German government issued a patent for the finishing of silver in a cyanide solution. Further experimentation with the process continued, but the next significant advancement was not made until 1935 when copper was successfully electro polished. This leap forward was followed by other new developments in 1936 and 1937, when Dr. Charles Faust and others discovered solutions for electro polishing stainless steels and other metals.

During World War II, extensive research and process development by both Allied scientists yielded a substantial number of new formulas and results. Data from these projects was published during the post-war period in hundreds of articles describing electropolishing's applications and its theoretical basis. Dozens of new patents were registered between 1940 and 1955. Important applications were developed for the military during World War II and the Korean conflict. Today, electro polishing is being rediscovered as a replacement for mechanical finishing. In addition to making a surface smoother, it is a more visible means of brightening, deburring, passivating, stress relieving and otherwise improving the physical characteristics of most metals and alloys [4,5]. The subject of this study is to develop low impact, low temperature technique to polish and debure injection mould and die casting cavities, press working sheet metals punches and dies and other mechanical machining parts/ Electrochemical polishing was chosen for this application.

2. Experimental Work

The experimental work designed to debure and polish three types specimens, represent hot work tool steel, cold work tool steel and dure alumin. each specimen has gauge length 50mm and rectangular cross- section 20mm in width and 5mm in thickness. Each specimen after degreased and dried was held to the anode of power supply (30 V, 10 Amp), while the cathode is graphite. The anode and cathode were fixed in the electrical cell as shown in Figure 2.

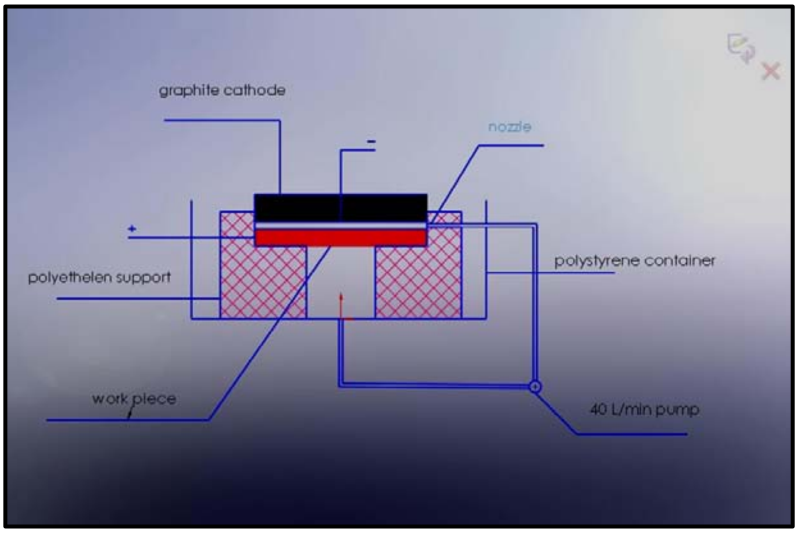


Figure 2: Schematic of electro polishing system

3. Experimental Tests and Results

Three types of alloys were used in the experimental tests. The first one (X40CrMo121) which is hot work tool steel according to (DIN). This alloy widely used in industry of hot forging dies injection mould and die casting dies. Hardness of this alloy between (54-58) HRC the chemical composition of this alloy as shown in Table 1.

Table 1 chemical composition of (X40CrMoV121)

C%	Cr%	Mo%	V%	S&P%
0.4 -0.45	1.0-1.2	0.6-1.0	1	0.04

The second is (X210Cr12) which is cold work tool steel according To (DIN). This alloy is widely used to produce press working sheet metal dies. Hardness of this alloy between (63-65) HRC. The chemical composition of this alloy is shown in Table 2.

Table 2. Chemical composition of (X210Cr12)

C%	Cr%	S&P%
2.1	12	0.03

The third is AlMgCuO5 according to (DIN). This alloy is widely used to produce aircraft parts, ships and blow mould dies [5]. The chemical composition of this alloy is shown in Table 3.

Table 3. Chemical composition of (AlMgCuO5)

Al%	Mg%	Fe%	Cu%
95-96	0.75-0.95	0.4-0.6	2.5-2.65

The relationship between polishing time- surface roughness, and current density – surface roughness was studied for each alloy, the results for each experimental as shown in Figures 3, 4, 5, 6, 7, and 8 respectively.

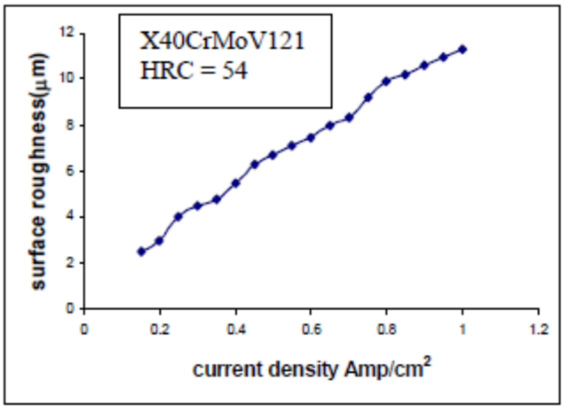


Figure 3: The relationship between surface roughness and current density for hot tool steel

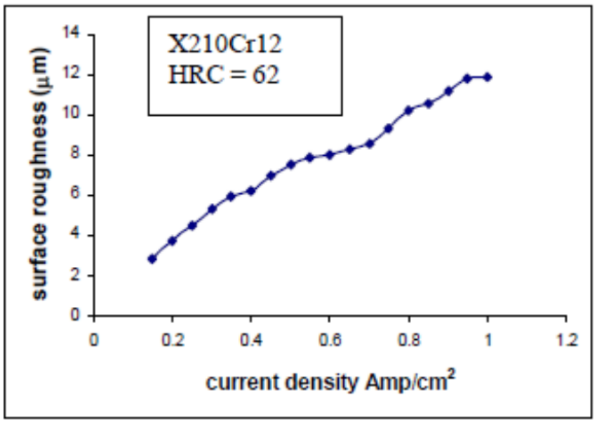


Figure 4: The relationship between surface roughness and current density for cold tool steel

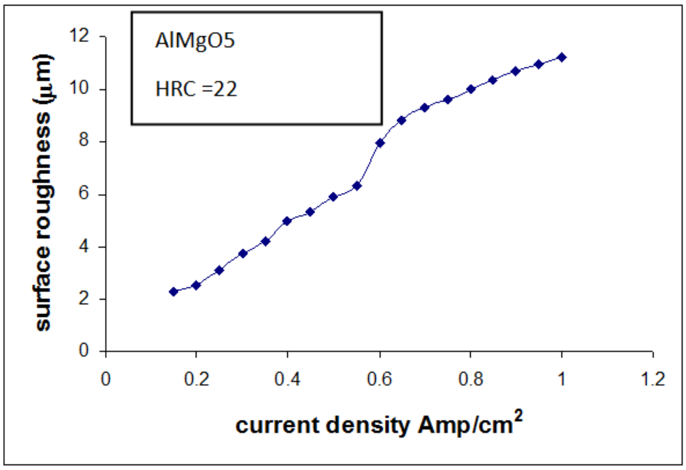


Figure 5: The relationship between surface roughness and current density for dure alumin

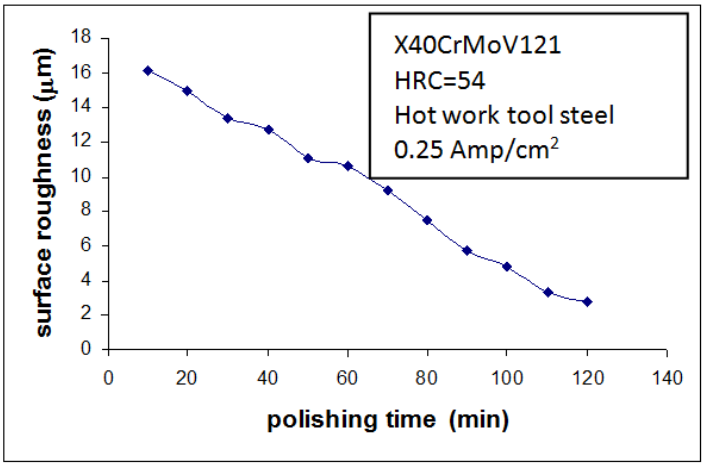


Figure 6: The relationship between surface roughness and polishing time for hot tool steel

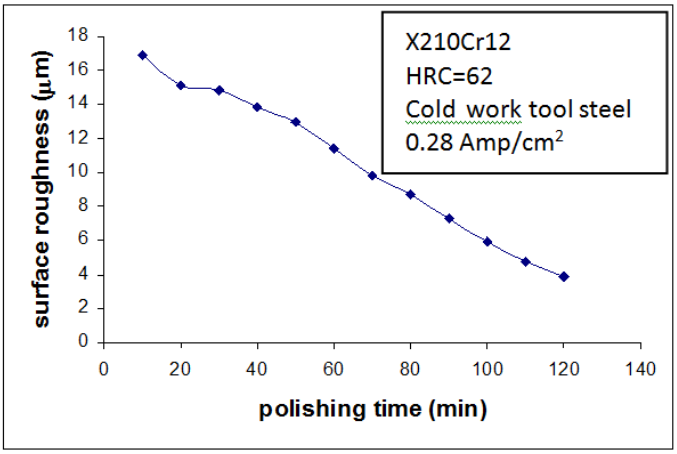


Figure 7: The relationship between surface roughness and polishing time for cold tool steel

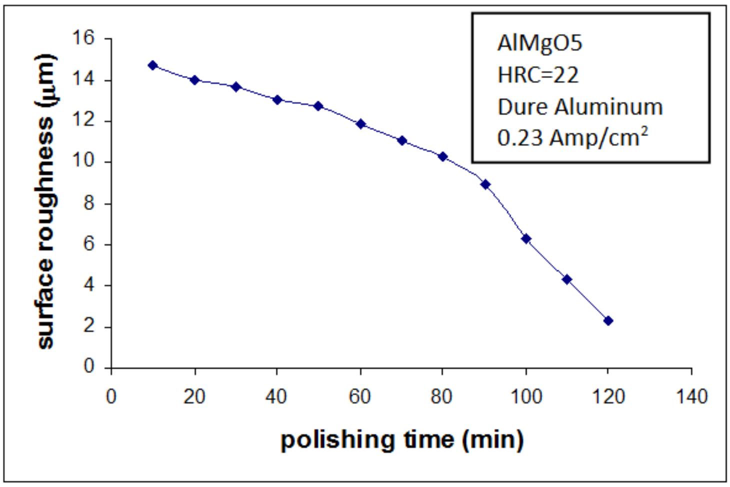


Figure 8: The relationship between surface roughness and polishing time for dure alumin

4. Results and Discussion

The reported experimental with ECP support the use of this technique to debure and polish tool cavity and mechanical parts with goals discussed in the introduction:

1. From Figures 3 and 4 which are represent the relationship between current density and surface roughness of hot and cold work tool steel respectively, we obtain high surface finish (low roughness) 2.5 μm at current density 0.25 Amp/cm2, for hot work tool steel , and 2,8 μm at current density 0.28Amp/cm2, and when current density rise the surface roughness will increase because the cathode and the workpiece (anode) were electrically connected by the conductive electrolyte filled in between the electrodes gap. The oxygen and the viscous layer were formed on the anode and hydrogen from the cathode. The oxygen bubbles that are difficult to escape from the viscous layer near the surface of the anode may cause the non-uniform distribution of the current density. After the process, pittings and flow marks left on the surface will greatly deteriorated the surface quality. There is no different between the results of hot and cold work tool steel because the electrochemical process does not depend on the hardness and chemical composition of the steel alloys[6].

2. From Figure 5 which is represents the relationship between current density and surface roughness of dure alumin we obtain high surface finish (low roughness) 2.3 μm at current density 0.18 Amp/cm2. By increasing the current density, the electropolishing of occurs in the gassing zone. In this zone, the anodic dissolution is accompanied by the evolution of oxygen[7]. The faster formation of the insulating layer and evolution of oxygen will generate more heat on the aluminum surface, which could lead to the deformation of the insulating layer and a non-uniform dissolution, consequently producing a rough surface [8].

3. From Figure 6, 7, and 8 which are represent the relationship between time of machining and surface roughness, we obtain high surface finish (low roughness) at time (120 min), over this time, there is significant change in conductivity of the electrolyte due to the effects of gassing (oxygen) which is occurs during electro chemical metal removal , this time of machining is suitable and economic in industrial operations[9]. The results of this study were applied in ministry of industry and minerals/ Nasser state company for mechanical industries / central tool room plant, to obtain high surface finish for wire drawing guides and tools, as shown in the Figures 9and 10.

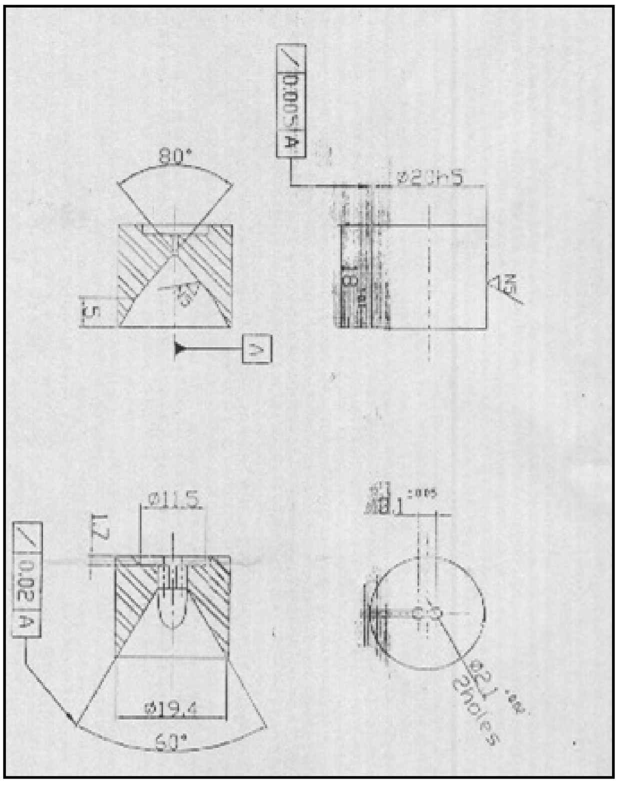


Figure 9: Wire drawing guide

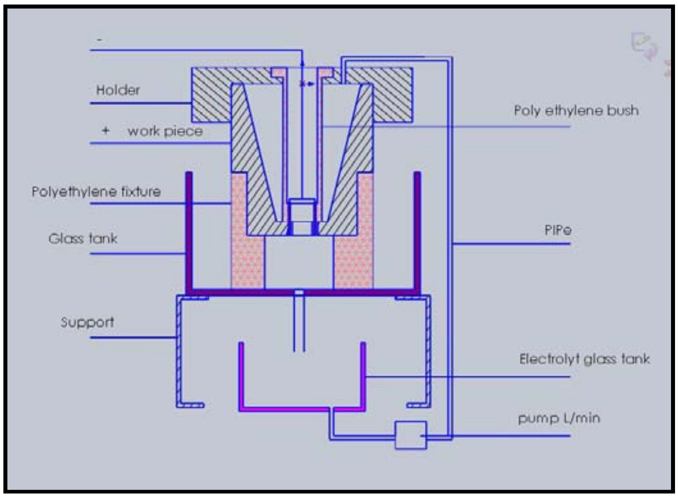


Figure 10: Schematic of electro polishing system to polish wire drawing guides and tools.

5. Conclusions

Electrochemical polishing with 10% sodium chlorate was investigated to polish three types of alloys; hot work tool steel, cold work tool steel, and dure aluminum. The results obtained from this study shown that it was possible to investigate surface roughness 2.8, 2.5, 2.3 for cold work, hot work tool steel and dure aluminum respectively. The choosing of polishing time 120 min because it is suitable and economic in industrial operations.

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