[Hamed* 5(7): July, 2018] ISSN 2349-4506
Impact Factor: 3.799

Global Journal of Engineering Science and Research Management

RECOVERY OF CHROMIUM FROM ELECTROCHEMICAL MACHINING WASTE BY USING ACID LEACHING

Asst. Prof Dr. Saad K. Shather, Dr. Hijran Z. Toama, Shahad W. Hamed*
* Dept. of Production Engineering and Metallurgy, University of Technology, Iraq

DOI: 10.5281/zenodo.1317885

KEYWORDS: Recovery, Leaching, Chromium, Electrochemical machining.

ABSTRACT
The waste from ECM is hazardous solid wastes due to the presence of specific heavy metals such as chromium, iron, nickel, lead and molybdenum. At the same time, some of these metals are valuable and comes in high percentage in the waste such chromium, iron, and nickel. Hence, recovery of these metals has the advantages of financial and economic returns and save the environment from land disposal of heavy metal from the electrochemical machining waste, so recovery of chromium from this waste was investigated.

Chromium was recovered by using hydrometallurgical method via acid leaching by using sulfuric acid (H_2SO_4).The experiments were designed by Taguchi method to determine the optimum conditions for chromium leaching. The optimum leaching conditions were (6 M) sulfuric acid concentration, (60 min) leaching time, and the temperature was (25 C^o).

INTRODUCTION
Electrochemical Machining (ECM) is one of the non-traditional machining (NTM) process belonging to electrochemical category [1, 2]. ECM is widely used in machining jobs involving intricate shapes and to machine very hard or tough materials which are difficult or impossible to machine by traditional machining. The electrochemical machining process produces waste that is hazardous to the environment and contains minerals that can be recovered, thereby reducing the risk of environmental pollution. One of these metals that can be recovered from the electrochemical machining waste is the chromium metal [1, 3]. Chromium is a metallic material with important characteristics which has been used since ancient times and has a major economic and Technological development impact [4]. Chromium used in many metallurgical and chemical industries. Many of these industries, such as; ore processing, stainless steel manufacturing plants, pigments industry, leather tanning, generate a lot of solid and liquid waste containing different proportions of chromium[5,6]. These industrial wastes are considered as important secondary resources to recovery and extraction of chromium metal. These secondary resources are increasingly important due to the depletion of main mineral resources (ores), their scarcity or their presence at very low grade. The continuing need for chromium metal industry makes the recycling of industrial waste and the production of metal a very important task. The process of waste recycling and recovery of metals is not only related to the acquisition of important minerals but also to the conservation of the environment by reducing the percentage of pollutants to the soil, water and air. Industrial wastes containing chromium can be processed recycled and some of which can be used in other industries after treatment such as cement, bricks, glass and paints in addition to environment conservation [7, 8].

EXPERIMENTAL PROCEDURE
Solid samples of waste from the electrochemical industry subjected to leached in acidic leaching solution at atmospheric pressure. Leaching solution used for this process was sulfuric acid (H_2SO_4) CO. (98%). Operation variable temperature, time, leaching solution concentration was chosen as major three controlled factor**.**

Specific weight of a waste from electrochemical machining was mixed with 100 ml of sulfuric acid in round bottom flask (Leaching reactor). The leaching reactor was set on hot plate magnetic stirrer in order agitate and heat the reaction mixture. The agitation speed was 420 rpm and it is fixed for all the leaching experiments. At the end of leaching time, the solution was filtered and analyzed to determine the metal ion concentration in the solution. It should be reported that the leaching efficiency has been calculate using the following equation [9]:

$$LE\% = [\frac{C.V/1000.P}{X/100}]\ 100\%$$

Where, LE% is leaching efficiency, C is the concentration of the metal in the solution (g/ml), V is the volume of the solution (ml), P is the mass of solid sample (g), X is the mass of concentration of metal % (g).

The design of experiment was done by using Taguchi method. Taguchi orthogonal arrays $L9$ (3^3) was established for experiments, The Taguchi design of experiments was done at three variables and three levels: temperature, 25, 30, 45 C°, and leaching time, 30, 45, 60 min, and concentration, 5,6, 7 M. Each experiment was repeated three times and the average was calculated.

RESULTS AND DISCUSSION

All the experiments presented in Taguchi orthogonal array for acid leaching process were executed and the results of the process are shown in Table (1); these values are represented in figure (1).

Table 1. Leaching efficiency of chromium in sulfuric acid solution.

No.	Conc. M	Time min	Temp. C°	Leaching 1, %	Leaching 2, %	Leaching 3, %	Average, %
1	5	30	25	32.5	77.7	51.2	53.80
2	5	45	30	29.4	30.8	26.8	29.00
3	5	60	40	44.6	27.3	25.9	32.60
4	6	30	30	64.2	62.4	83.1	69.90
5	6	45	40	90.5	75.5	75.1	80.43
6	6	60	25	77.5	78.7	84.9	80.36
7	7	30	40	69.4	54.3	91.8	68.83
8	7	45	25	74.5	75.4	92.5	80.80
9	7	60	30	73.4	82.2	90.5	81.93

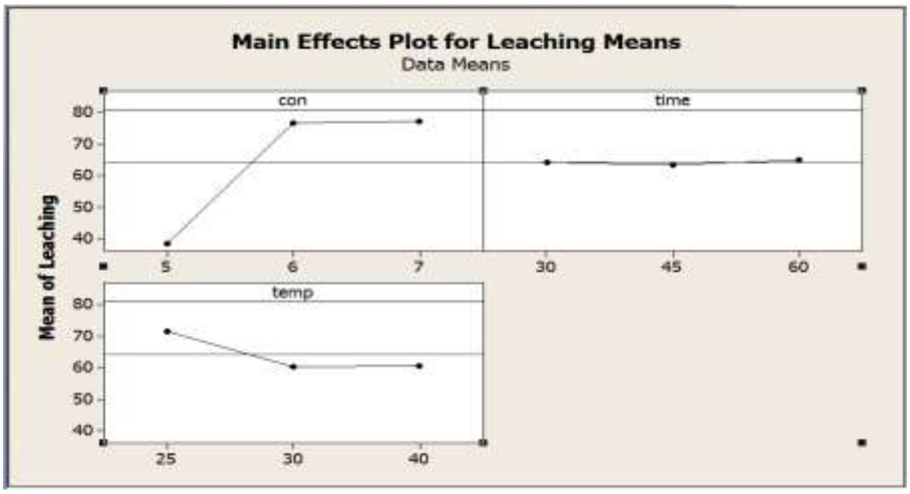

Figure 1. The effect of leaching factors on the leaching efficiency of Chromium

The goal of the leaching process, is to maximize the response i.e. achieving highest degree of leaching efficiency of chromium, the chosen SN ratio was "large the better". Signal-to-noise ratios for each experiment are listed in Table 2. The effect of controlled factors at different levels is shown in Figure 2

***Table 2. Signal-to-noise ratio of acid leaching process*.**

No.	Conc. M	Time min	Temp. C°	Leaching 1, %	Leaching 2, %	Leaching 3, %	S/N ratio
1	5	30	25	32.5	77.7	51.2	33.028
2	5	45	30	29.4	30.8	26.8	29.204
3	5	60	40	44.6	27.3	25.9	29.540
4	6	30	30	64.2	62.4	83.1	36.680
5	6	45	40	90.5	75.7	75.1	38.014
6	6	60	25	77.5	78.7	84.9	38.081
7	7	30	40	69.4	54.3	91.8	35.667
8	7	45	25	74.5	75.4	92.5	38.028
9	7	60	30	73.4	82.2	90.5	38.176

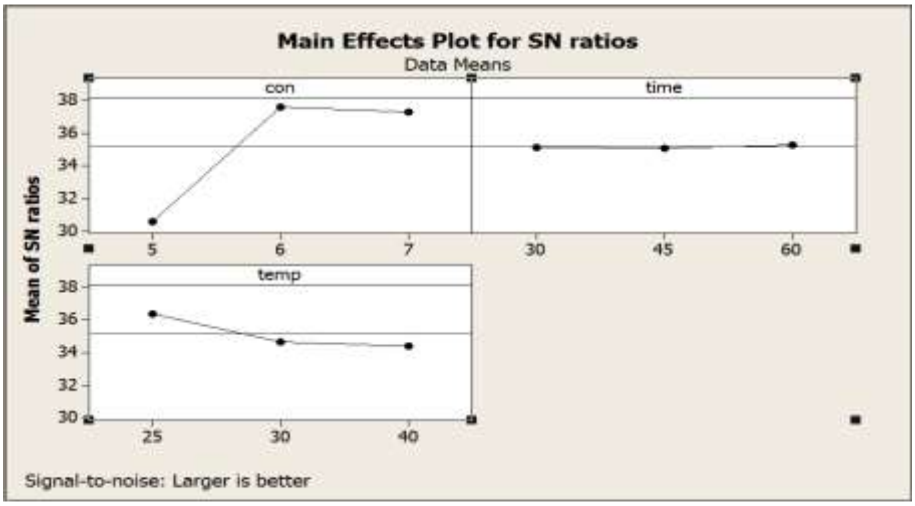

Figure 2. The S/N ratio for leaching factors of chromium.

In order to determine the optimum conditions for the chromium leaching process, a comparison between the leaching efficiency shown in figure 1 And the S/N is ratio given in figure 2 was done in Table 3. Also, the rank of leaching factors is given in Table 4.

Table 3 The optimum conditions values in the leaching process.

Control factor	value	Level
H_2SO_4 concentration (M)	7	3
Time (min)	60	3
Temperature (C°)	25	1

Table 4 The rank of leaching factors for chromium.

Level	Signal – to – Noise Ratio		
Factor	Conc. (M)	Time (min)	Temp. (C°)
1	38.47	64.18	71.66
2	76.90	63.41	60.28
3	77.19	64.97	60.62
Δ	38.72	1.56	11.38
Rank	1	3	2

Table 5 lists the details of ANOVA and the resultant of it, where the variables are ranked in Table 4 are addressed with a value ρ% which determines the percentages of contribution of each controlled factors to have effect on the leaching efficiency of chromium.

Table 5 ANOVA for leaching of chromium.

Controlled factor	DOF_C	SS	MS	F Ratio	% ρ
Concentration (m)	2	93.975	46.9875	12.87	86.894
Time (min)	2	0.056	0.0281	0.01	0.0517
Temperature (Co)	2	6.818	3.4088	0.93	6.304
Error	2	7.299	3.6497	---	6.750
Total	8	108.148	----	---	100

According to the data of Taguchi design experiments, the solution concentration has the largest effect on the leaching process. It can be clearly observed that with increasing the acid concentration the leaching efficiency of chromium was increased. It was found that the 7 M concentration is the best for leaching chromium to 81%.

The result shows the passive effect of temperature on the chromium dissolving. The leaching efficiencies of chromium decrease when the temperature was increased. This may be due to the reaction of waste with H_2SO_4 is exothermal reaction, which means that the reaction creates heat, since with increasing the temperature of exothermal reaction, the solubility decreases. The time has little effect on the leaching efficiency of chromium. Leaching time, as shown in Fig 1 curve, was unstable. The leaching efficiency of chromium decreases when the time was increased until arrive 45 C^o the leaching efficiency will increase. This is because of consumption of the reactant. When the concentration of reactant decreases, the collision among chromium molecule and H+ will be fewer.

According to the above points, it seems that leach time of (60 min) is sufficient in the acid leach process.

CONCLUSION

1) The best conditions for obtaining the highest leaching were 7`M sulfuric acid concentration, leaching time of 60 Min, leaching temperature of 25 ^oC.
2) The effect of concentration on the acidic leaching was positive, increasing the level of the concentration led to increase leaching efficiency of chromium.
3) The temperature effect on the acidic leaching was negative where increasing the temperature led to decrease leaching efficiency of chromium.
4) The leaching time effect on the acidic leaching was unsteady, hence, the optimum value of 60 min leaching time was chosen.

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