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OPTIMIZATION OF THE OPERATING PARAMETERS AFFECTING DAVIS TUBE MAGNETIC TESTER USING 2ND FACTORIAL DESIGN

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The current practice of assessing the efficiency for recovery of magnetite by Davis tube tester at a magnetic induction is very important. 2nd factorial design is used for the parametric study of the magnetic separation because the classical approach is a tedious method. Factorial design is the most efficient way to explore the combinations of variables, because it uses every observation and calls only for as many observations as necessary. The results of the factorial experiments were used to identify the variables having a significant effect on magnetite recovery. The main objective of this work is to upgrade the iron ore using the Davis tube magnetic tester. It is also intended to study the most important operating parameters affecting the separation process. Among these are the feed size (µm), current intensity (Amp.), tube oscillation (rpm), tube inclination (degree) and wash water rate (Liter min-1). Consequently, the best fit relation can be expressed mathematically as:

$Y = 58.99 + 7.25X + 4.56I - 1.49O - 2.19W - 1.84S$

KEY WORDS: *Davis tube magnetic tester, 2nd factorial design, Iron ore concentration and MINTAB14*

1- INTRODUCTION

Davis tube is a laboratory instrument designed to separate small samples of magnetic ores into strongly magnetic and weakly magnetic fractions. It has become standard laboratory equipment used for the assessment of the separability of magnetic ores by low-intensity magnetic separators [1,2]. Schulz [1] suggested that a magnetic induction of 0.4 Tesla or greater between the magnet poles should be used. On the other hand, Steiner and Boehm [3] claim that current practice is to conduct the Davis tube tests at a magnetic induction equals to that on the surface of the drum of the magnetic separator.

It has been known for a long time that, the non-magnetic iron ores can be converted to magnetic ones by reduction roasting to achieve concentration by magnetic separation. By controlled reduction roasting in the case of hematite and goethite or by controlled oxidizing roasting in the case of siderite, the iron minerals could be converted into synthetic magnetite. Artificial magnetite has as high magnetic permeability as natural magnetite, but it is more friable. Consequently, higher liberation is to be expected and separation is to be insured [4].

There has been substantial work on the upgrading of El-Baharia iron ore (Egypt). The reduction roasting followed by magnetic separation, for this ore, has shown recovery with high-grade concentrate [5 - 9]. On the other hand, no much effort has been spent to concentrate the Egyptian eastern desert iron ores which include Wadi Kareim locality Bediwi [9] reported some results obtained by magnetic separation for several samples ranging in grade between 37 and 50 percent Fe. He obtained iron concentrates of grade between 49 and 56 percent Fe with recovery ranging between 66 and 73 percent. They were based mainly on gravity separation / or magnetic separation. The obtained concentrates were of grade 55 and 61 percent Fe and iron recovery of 44 and 46 percent respectively and the tailings had 30 and 24 percent respectively. The recovery seemed to be relatively low and the tailings assay is high. Nigm [4] have tried to concentrate this ore using magnetic separation, flotation and combined magnetic separation - flotation techniques and obtained a concentrate of 52 - 58 % Fe at a recovery of 60 - 65 %, 50.5% Fe at a recovery of 78% and 54% Fe at a recovery of 92% respectively.

Two flow sheets were proposed to concentrate Wadi Kareim iron ore by Rizk et al [10]. The first included magnetic separation followed by magnetic roasting of the tailings, while the second included magnetic roasting of the main ore. A concentrate of 46.47% Fe with 92.31% Fe recovery is obtained from the first flow sheet. On the other hand a concentrate of 48.86% Fe with 91.51% Fe recovery is achieved from the second.

Recently, Farghaly [11] succeeded to obtain two main products from El-Bahariya iron ore. He obtained an iron concentrate of 56.33% Fe with a recovery of 81.49% from an iron assay of23.5% Fe. He also, reduced the BaO from 34% to 1.49%, which is less than the allowable for the blast furnace. On the other hand, the barite mineral was concentrated in the tails from 34% to 45.78% BaO at a recovery of 90.22% to represent a second valuable product.

2. EXPERIMENTAL METHODOLOGY

The classical approach to experimentation is to study one variable at a time: varying its level over a certain range, while holding all the other variables constant, and observing the effect on the response variable. From these observations the quantitative relationship and its form can be determined. Having established such a relationship, the effect of the other variables can be examined in the same manner. It is also incapable of detecting interactions: variables acting together may have a greater or smaller effect than individual variables acting alone. If one or two parameters affect the process, it is most easy to investigate their effect, but when the process is affected by many factors, it is important to follow an efficient experimental design to decrease the number of experiments [12].

Factorial design is the most efficient way to explore the combinations of variables, because it uses every observation and calls only for as many observations as necessary.

This method makes it possible to achieve in a short time an optimal interval of parameter values and hence it is of much use in optimization, but it requires a good knowledge of the technology of the process to choose the correct level values.

The essence of the factorial analysis consists in the performance of experiment belonging to one series, changing simultaneously all the tested factors. Each factor is given two values, called levels and then so many experiments are carried out that in each subsequent experiment other combinations of levels of all the factors would occur.

There are several reasons why factorial experiments are taken at only two levels [13].

Primarily, the number of experimental conditions in a factorial experiment increases multiplicatively with the number of levels of each factor thus, if many factors are to be investigated simultaneously, it may be economically impossible to include more than two levels of each factor.

Another important reason for treating $2^{\underline{nd}}$ factorial experiments is that there exist computational short - cuts which apply to this case. Such experiments do have some drawbacks, since each factor is measured only at two levels, it is impossible to judge whether the effects produced by variations in a factor are linear or perhaps, parabolic or exponential. For this reason factorial experiments are often used, which are followed up by experiments involving fewer factors (ordinarily), those found to be "significant" individually or jointly in the screening experiment taken at more than two levels.

3. EXPERIMENTAL WORK

3.1. Material preparation

A sample of iron ore of 3.3 gm/cm^3 density was used in this investigation. The chemical analysis of the head sample is given in Table 1.

The whole well mixed head sample was crushed, and then ground in a porcelain mill to pass from 315µm. The comminuted sample was divided into two parts. While the first part was kept as it is, the second part was further ground to pass from 100 µm.

Table (1) Chemical analysis of the head sample

Element	**Fe**	**O**	**Si**	**Ca**	**Mn**	**P**	**Zn**	**Al**	**Cu**	**Ti**	**K**
%	40.79	35.88	11.58	7.68	1.93	0.67	0.50	0.36	0.27	0.19	0.15

3.2. Equipment

The Davis magnetic tube tester shown in Figure (1) consists of an extremely powerful electromagnet which can generate a magnetic field intensity of up to 4,000 gauss, a glass separation tube and a motor driven agitation mechanism. The tube is positioned between the poles of the magnet at an angle of approximately 45 degrees (the angle can be adjusted).

In the Davis magnetic tube concentrator, magnetic attraction holds magnetically susceptible particles in a magnetic field. Forces due to gravity, inertial, fluid solid friction tend to remove the less susceptible particles from the field.

A dryer was used to dry both the concentrate and tailings of each experiment at 105^0C for 24 hour and the dried concentrate and tailings were accurately weighed.

Figure (1) the Davis magnetic tube concentrator

3.3 Experimental procedures

The experimental runs were planned using factorial design method of two levels for five factors [13]. Thirty two experiments have been carried out to execute the factorial method with the concerned five parameters. It should be noted that values of the upper and lower levels of the studied parameters in Table 2 are chosen with the help of the previous studies [11-16]. The conditions of these experiments are given in Table 2.

Table (2) values of the limits of the studied parameters

Parameter	Symbol	Limits		Units
		Lower	Upper	
Feed Size	X	-100	-315	µm
Current Intensity	I	0.6	1.8	Amp.
Tube Osculation	0	40	70	r.p.m
Wash Water Rate	W	0.5	1.0	Liter min^{-1}
Tube Inclination	S	20	35	Degree

Values of the studied operating parameters at the different experimental conditions as well as their standard order are depicted in table 3.

Table (3) conditions and standard order of the executed experiments

Exp. No.	Studied factors					Values of the studied factors					
	X	I	O	W	S	X	I	O	W	S	Standard order
1	-	-	-	-	-	-100	0.6	40	0.5	20	I
2	+	-	-	-	-	-315	0.6	40	0.5	20	X
3	-	+	-	-	-	-100	1.8	40	0.5	20	I
4	+	+	-	-	-	-315	1.8	40	0.5	20	XI
5	-	-	+	-	-	-100	0.6	70	0.5	20	O
6	+	-	+	-	-	-315	0.6	70	0.5	20	XO
7	-	+	+	-	-	-100	1.8	70	0.5	20	IO
8	+	+	+	-	-	-315	1.8	70	0.5	20	XIO
9	-	-	-	+	-	-100	0.6	40	1	20	W
10	+	-	-	+	-	-315	0.6	40	1	20	XW
11	-	+	-	+	-	-100	1.8	40	1	20	IW
12	+	+	-	+	-	-315	1.8	40	1	20	XIW
13	-	-	+	+	-	-100	0.6	70	1	20	OW
14	+	-	+	+	-	-315	0.6	70	1	20	XOW
15	-	+	+	+	-	-100	1.8	70	1	20	IOW
16	+	+	+	+	-	-315	1.8	70	1	20	XIOW
17	-	-	-	-	+	-100	0.6	40	0.5	35	S
18	+	-	-	-	+	-315	0.6	40	0.5	35	XS
19	-	+	-	-	+	-100	1.8	40	0.5	35	IS
20	+	+	-	-	+	-315	1.8	40	0.5	35	XIS
21	-	-	+	-	+	-100	0.6	70	0.5	35	OS
22	+	-	+	-	+	-315	0.6	70	0.5	35	XOS
23	-	+	+	-	+	-100	1.8	70	0.5	35	IOS
24	+	+	+	-	+	-315	1.8	70	0.5	35	XIOS
25	-	-	-	+	+	-100	0.6	40	1	35	WS
26	+	-	-	+	+	-315	0.6	40	1	35	XWS
27	-	+	-	+	+	-100	1.8	40	1	35	IWS
28	+	+	-	+	+	-315	1.8	40	1	35	XIWS
29	-	-	+	+	+	-100	0.6	70	1	35	OWS
30	+	-	+	+	+	-315	0.6	70	1	35	XOWS
31	-	+	+	+	+	-100	1.8	70	1	35	IOWS
32	+	+	+	+	+	-315	1.8	70	1	35	XIOWS

Samples of the well – mixed head sample weighing 20 grams each were dropped into the water filled tube, while the magnetic unit was switched on. The operating conditions for each experiment were adjusted according to the 2nd factorial method. From preliminary experiments, it was found that five minutes were enough to give clean operation. After the five minutes the tube was stopped and agitated, and constant water current was allowed to flow co – currently in order to wash the samples. The magnetic concentrate and tailings were filtered, dried, and weighed.

4. RESULTS AND DISCUSSION

A set of incremental experiments was done after the results of the factorial experiments were available. In these experiments, one variable was changed over a range of values, or in some experiments this was done while a second variable was set at either upper or lower value. In such experiments, the interaction between the two variables was also examined. The results of all trials in both factorial and incremental experiments are tabulated elsewhere [17]. The effects of each of the five independent variables considered (feed size, current intensity, tube oscillation, tube inclination and wash water rate) on (wt. % recovery) of the concentrate were calculated according to the method given by Davies [18], and the significance levels were estimated by the method of Yates [19].

The results consists of two parts, the first part deals with the effect of the studied factors on the weight recovery of magnetic concentrate as the performance for the magnetic separation process as well as constructing a regression model which correlates the performance with the studied parameters by using Yates' s reduced model. The second part concerns with the optimum values of the studied parameters which give a maximum weight recovery of the concentrate.

4.1 Effect of the studied parameters on the separation performance

The weight recovery of the concentrate is used as a measure for the magnetic separation process. The results of the carried out experiments according to factorial method are given in table 4.

4.2 Results statistical evaluation by (Yates's reduced factorial method)

In $2^{\underline{nd}}$ factorial experimental conditions, since their number can be fairly large, it will be convenient to represent the experimental conditions by means of special notation and listed them in a so – called standard order as given in Table 3.

The Calculations of Yates's reduced method [19-20] can be simplified considerably by using a short – cut as given in Table (5). The upper half of this table is obtained by adding successive pairs of the treatment, and the lower half is obtained by subtracting them, nothing that the first number in each pair is subtracted from the second one. Column (2) is obtained by performing the identical operation on the entries of column (1), and column (3), (4) and (5) are obtained in the same manner from the entries in columns (2), (3) and (4). The general columns (5) give the total effect in standard order.

The results of calculations contained in column (5) denoted:

- In line No. 1, the sum of the results of all experiments.
- In lines numbers 2,3,5,9 and 17 the main effects
- In the remaining lines (interaction effects).

Column (6) contains the sum of squared deviations, indispensable for checking the significance of the respective factors calculated by means of the Eq. 1:

$$m_Z^2 = Z^2 / m \qquad \text{Eq. 1}$$

Table (4) Results of Davis tube magnetic concentration

Exp. No.	Weight of concentrate (gm)	Weight of tailing (gm)	Total weight (gm)	Weight % concentrate	Weight % tailing
1	9.73	10.27	20	48.65	51.35
2	14.57	5.43	20	72.85	27.15
3	10.66	9.34	20	53.30	46.70
4	14.71	5.29	20	73.55	26.45
5	11.39	8.71	20	56.95	43.05
6	14.73	5.27	20	73.65	26.35
7	11.89	8.11	20	59.45	40.55
8	14.43	5.57	20	72.15	27.85
9	8.98	11.02	20	44.90	55.10
10	13.46	6.54	20	67.30	32.70
11	11.38	8.62	20	56.90	43.10
12	14.67	5.63	20	73.35	26.65
13	8.04	11.96	20	40.20	59.80
14	12.14	7.68	20	60.70	39.30
15	10.68	9.32	20	53.40	46.60
16	12.19	6.81	20	65.95	34.05
17	8.60	11.40	20	43.00	57.00
18	14.45	5.55	20	72.25	27.75
19	11.85	8.15	20	59.25	40.75
20	14.46	5.54	20	72.30	27.70
21	11.00	9.00	20	55.00	45.00
22	6.68	13.32	20	33.40	66.60
23	12.10	7.90	20	60.50	39.50
24	14.51	5.49	20	72.55	27.45
25	8.35	11.65	20	41.75	58.25
26	12.77	7.23	20	63.85	36.15
27	19.98	9.02	20	54.90	45.10
28	13.89	6.11	20	69.45	30.55
29	7.97	12.03	20	39.85	60.15
30	11.32	8.68	20	56.60	43.40
31	11.95	8.05	20	59.75	40.25
32	12.00	8.00	20	60.00	40.00

Table (5): calculation of the main effects for weight recovery of the concentrate according to Yates's method

Exp. No.	Recovery %	(X) 1	(I) 2	(O) 3	(W) 4	(S) 5	Z^2 / m 6
1	48.65	121.5	248.35	510.55	973.25	1887.55	111338.91
2	72.85	126.85	262.2	462.7	914.3	232.05	1682.73
3	53.30	130.6	242.45	468.25	145.75	145.95	665.67
4	73.55	131.6	220.25	446.05	86.3	-28.35	25.12
5	56.95	112.2	246.8	73.85	42.85	-47.55	70.66
6	73.65	130.35	221.45	71.9	103.1	-92.45	267.09
7	59.45	100.9	229.95	32.75	-21.85	29.03	26.37
8	72.15	119.35	216.1	53.55	-6.5	38.95	47.41
9	44.90	115.25	44.45	6.35	-8.35	-70.05	153.34
10	67.30	131.55	29.4	36.5	-39.2	18.85	11.10
11	56.90	88.4	38.85	60.95	-20.85	11.44	4.03
12	73.35	133.05	33.05	42.15	-71.6	-47.35	70.06
13	40.20	105.6	42.3	-7.95	-3.95	-24.55	18.83
14	60.70	124.35	-9.55	-13.9	33	41.35	53.43
15	53.40	96.35	36.65	17.45	-2.05	-18.95	11.2
16	65.95	119.75	16.9	-23.95	41	-60,65	114.95
17	43.00	24.2	5.35	13.85	-47.85	-58.95	108.6
18	72.25	20.25	1.00	-22.2	-22.2	-59.45	110.45
19	59.25	16.7	18.05	-25.35	-1.95	60.34	113.44
20	72.30	12.7	18.45	-13.85	20.8	15.35	7.36
21	55.00	22.4	16.3	-15.05	30.15	-30.85	29.74
22	33.40	16.45	44.65	-5.8	-18.8	-50.75	80.49
23	60.50	20.5	18.75	-51.85	-5.95	36.95	42.67
24	72.55	12.55	23.4	-19.75	-41.4	43.05	57.92
25	41.75	29.25	-3.95	-4.35	-36.05	25.65	20.56
26	63.85	13.05	-4	0.4	11.5	22.75	16.17
27	54.90	-21.6	-5.95	28.35	9.25	-48.95	74.88
28	69.45	12.05	-7.95	4.65	32.1	-35.45	39.27
29	39.85	22.1	-16.2	-0.05	4.75	47.55	70.66
30	56.60	14.55	33.65	-2	-23.7	22.85	16.32
31	59.75	16.65	-7.55	49.85	-1.95	-28.45	25.29
32	60.00	0.25	-16.4	-8.85	-58.7	-65.7	100.64

Where:

m the number of all experiments.

z factors or interactions.

The model for system analysis is a five - variable equation having the form in Eq. 2:

$$Y = a_o + a_1 X + a_2 I + a_3 O + a_4 W + a_5 S \qquad \text{Eq. 2}$$

Where:
Y is weight percent recovery of the concentrate.
a_0, a_1, a_2, a_3, a_4, and a_5 are coefficients.
$a_0 = 1887.55/32 = 58.99$
$a_1 = 232.05 / 32 = 7.25$
$a_2 = 145.95/32 = 4.56$
$a_3 = -47.55 / 32 = -1.49$
$a_4 = -70.05 /32 = -2.19$
$a_5 = -58.95 / 32 = -1.84$

Consequently, the best fit relationship can be expressed mathematically as Eq. 3:

$$Y = 58.99 + 7.25X + 4.56\,I - 1.49O - 2.19W - 1.84S \qquad \text{Eq. 3}$$

From the above regression model (Equation 3) the studied parameters affecting the performance of the separation process can be arranged as follows:
X Particle size of the feed, µm.
I Current intensity, Amp.
W Wash water rate, Liter min^{-1},
S Slope (inclination of the tube), degree,
O Tube oscillation, rpm.
From the above mentioned arrangement the following summaries can be drawn:

- The particle size of the feed displays a strong positive value which means that performance of the magnetic separation process increases with increasing the particle size of the feed this behavior may be due to the accumulation of large size particles which leads to the collection of the magnetic field lines.
- Similarly high positive effect characterizes the current intensity, which makes it clear that the current performance increases with increasing the lines of force as the current intensity increases.
- Wash water rate displays a strong negative effect on the performance. This trend may be interpreted by escaping of magnetic materials with the tailing due to the erasing force of the wash water.
- The slope (inclination) of Davis tube displays also a negative effect. This means that the performance of the magnetic separation process decreases with increasing the tube slope. This behavior may be due to the increase of the gravity component as the slope increases which enhance the traveling of some magnetic particles to the tailing's direction.
- Tube oscillation displays the least negative effect compared to the effect of the other factors. This behavior can be interpreted as the oscillation rate increases the chance for cleaning the concentrate increases by getting red of most of tailings in the sample. Another interpretation is no regulation of magnetic lines of force which gives a chance for some magnetic particles to escape from the magnetic field with tailings.

4.3 Confidence level of the predicted regression model

In order to show the degree of significance of the discussed effects using Yates's reduced factorial method, reported Table 3, the following calculations are performed.

The sum of the residual squares (S_r) can be obtained by summing up the sum of squares in column 6 Table 5, except those for experiments 1, 2,3,5,9 and 17.

S_r = 25.12 + 267.09 + 26.37 + 47.41 + 11.10 + 4.03 + 70.06 + 18.83 + 53.43 + 11.22 + 114.95 + 110.45 + 113.44 + 7.36 + 29.74 + 80.49 + 42.67 + 57.92 + 20.56 + 16.17 + 74.88+ 39.27 + 70.66 + 16.32 +25.29 + 100.69 = 1455.52

The corresponding number of freedom = 27
The mean residual squares S^2_r = 1455.52/27 = 53.91
The value of the test function F^0 for checking the zero hypotheses can be calculated by Eq. 4:

$$F = Z^2 / m / S_r^2 \qquad \text{Eq. (4)}$$

For X, function Fx^0 = 1682.73/53.91 = 31.21
For I, function FI^0 = 665.67 / 53.91 = 12.35
For O, function FO^0 = 70.66/53.91 = 1.31
For W, function Fw^0 = 153.34/53.91 = 2.84
For S, function FS^0 = 108.60/53.91 = 2.01

The" F " value is determined for 27 (ϕ_2) degrees of freedom and one (ϕ_1) degree of freedom for the larger mean square by means of Snedeor's table [13] of the distribution of " F " is:

For 1 % of risk of error F 0.01 = 7.68
For 5 % of risk of error F 0.05 = 4.21
For 10 % of risk of error F 0.10 = 2.90

Comparing the values of the calculated test functions F with those obtained from the tables, where the second is less than the first for the rearrange level 1 % with respect to feed particle size and the field intensity as well as for the level 10 % with respect to the rate of wash water and the tube inclination (slope).

Figure (2) illustrate the relationship between parameters standardized on Davis tube tester and standardized effects, its clear from figure that, the feed size is the highest effect, while the tube osculation is the lowest effect on magnetic concentration by Davis tube

Figure 3 showed the statistical processes of results by MINTAB program on Davis tube tester, it's obvious from figure that, there is a good normal probability plot of the residual. Also, Standardized residual approximately variant between -1.3 to + 1.3. This means that all the factors affecting the magnetic separation process using Davis tube are essential to 90 % confidence level.

4.4 Optimization of magnetic separation process.

The previously obtained results can be used to find nearly the optimal values of the parameters; this is possible in two ways:

1- Changing the levels of the factors in the direction indicated in table (signs + and -), i.e. in order to increase the weight recovery of the magnetic tube tester, we must increase the particle size of the feed and the current intensity and decrease the wash water rate, the inclination of the tube and the oscillation.

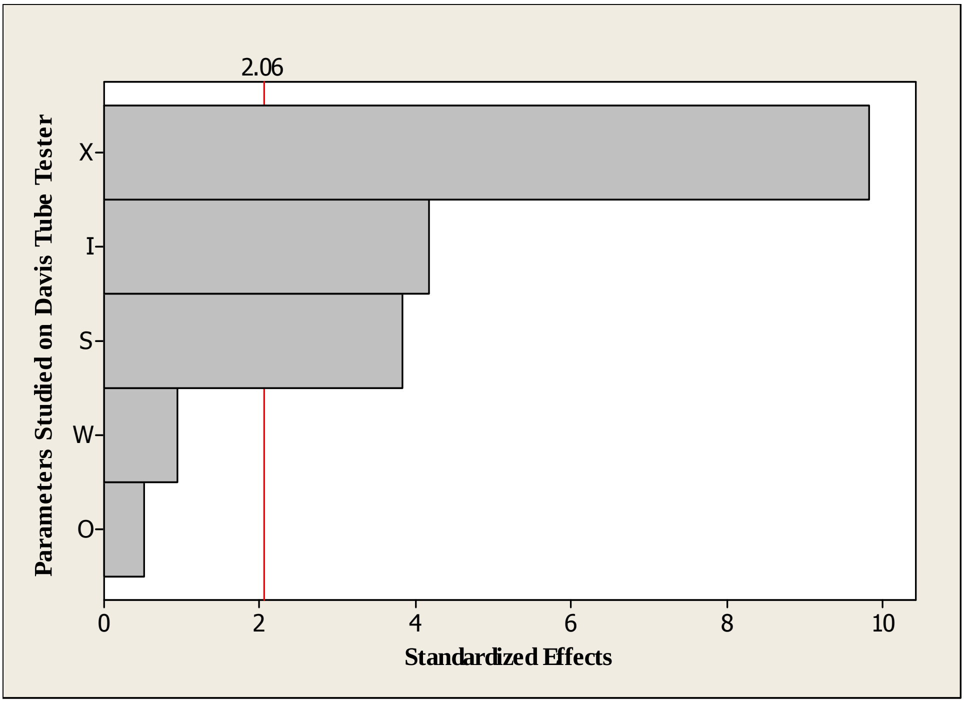

Figure 2 Standardized Effects of Studied Parameters

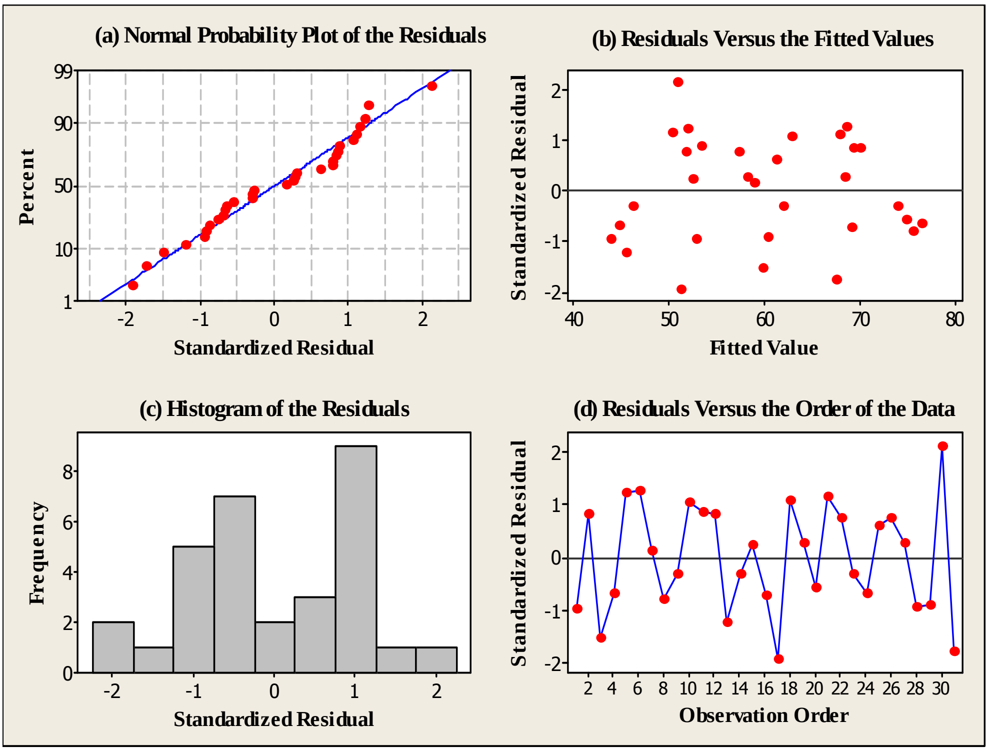

Figure 3 Statistical Processes of Results by MINTAB14 Program

2- Another method indicating changes of the respective parameters is the "gradient method". In this method we make use of the fact that, the main effects concern the parameters of the process. The regression coefficients are calculated basing on the quotient of the main effects of the given factor column (5) Table (5) rows 2,3,5,9 and 17 and the number of experiments.

The values of the parameters for the suggested new experiments are depicted in table (6). It should be noted that these values are slightly adjusted according to the possibility of the used apparatus as well as availability of the laboratory.

Regarding to the results of the new experiments aiming at the optimal condition, it’s found that the weight recovery of the concentrate increases vigoursly from experiment No 33 to experiment No 34, then increases slightly from experiment No. 34 to experiment No 36. Therefore, the values of the studied parameters at the experiment No 36 can be considered as the optimum ones.

Table (6) Procedures of the new experiments aiming at an optimal condition.

Levels and predicted exp.	**X (µm)**	**I (µm)**	**O (rpm)**	**W (Lit./ min)**	**S (degree)**	**Wt. Recov (%)**
Fundamental level	207.5	1.2	55	0.75	27.5	
Interval of variation	107.5	0.6	15	0.25	7.5	
Upper Level (+)	-315	1.8	70	1	35	
Lower Level (-)	-100	0.6	40	0.50	20	
Regression Coefficient	+7.25	+4.56	-1.49	-2.19	-1.84	
Operation Step	+779.38	+2.74	-22.35	-0.46	-16.43	
Reduced operation step	80	+0.3	-2.2	-0.05	-1.6	
Experiment No. 33	287.5	1.5	52.8	0.70	25.9	
Experiment No. 34	367.5	1.8	50.6	0.65	24.3	
Experiment No. 35	447.5	2.1	48.4	0.60	22.7	
Experiment No. 36	527.5	2.4	46.2	0.55	21.10	
Experiment No. 37	607.5	2.7	44.0	0.50	19.50	
Experiment No. 33	315	1.5	54.0	0.70	26	67.0
Experiment No. 34	400	1.8	48.0	0.65	24	77.5
Experiment No. 35	400	1.8	48.0	0.60	23	78.6
Experiment No. 36	500	1.8	48.0	0.55	21	80.5

Table (7) gives the chemical analyses of both the concentrate and tailings of experiment No 36.

Table (7) Chemical analysis of the concentrate and tailing.

Element	Fe	O	Si	Ca	Mn	P	Zn	Al	Cu	Ti	K
Concentrate	48.58	35.91	10.87	3.10	0.26	0.68	0.01	0.42	-	0.09	0.08
Tailing	28.21	36.69	13.53	15.91	1.48	0.86	1.23	0.58	1.12	0.18	0.22

CONCLUSIONS

A regression model has been achieved to correlate the most important operating parameters affecting the magnetic separation process with the weight percent recovery of the concentrate as a performance parameter. This model takes the following form:

$$Y = 58.99 + 7.25X + 4.56\, I - 1.49O - 2.19W - 1.84S$$

From the above mentioned model, the studied parameters can be arranged, according to the significance of their relative effect on the process as follows:

- The particle size of the feed has a strong positive effect while, current intensity, has a moderate positive effect (both of them direct proportionality).
- Both wash water rate and inclination of the tube have reverse proportionality, also, oscillation but with least negative effect

There is a good normal probability plot of the residual. Also, standardized residual approximately variant between -1.3 to +1.3. This means that all the factors affecting the magnetic separation process using Davis tube are essential up to 90 % confidence level.

It is found that, the optimum values of the studied parameters (experiment No. 36) which gives a concentrate of 48.58 % Fe with a recovery of 95.87 % from a head sample of 40.79 % Fe content. This concentrate was not suitable for the production of iron pellets. Decision should be given about the suitability of produced concentrate as a suspension solid for heavy media preparation.

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القيم المثلى للعوامل التي تؤثر في أنبوبة ديفيز للفصل المغناطيسي باستخدام نظرية العوامل لتصميم التجارب

في هذا البحث محاولة لتقييم كفاءة تركيز خام المجناتيت باستخدام أنبوبة ديفيز للفصل المغناطيسي وذلك بتطبيق
نظرية العوامل لتصميم التجارب من الدرجة الثانية والتي تتميز عن الطريقة التقليدية التي يلزمها إجراء عدد كبير
من التجارب وتستهلك كثيرا من الوقت والجهد والمال. إن تطبيق نظرية العوامل من الدرجة الثانية يقلص
عدد التجارب المثلى اللازمة للدراسة من خلال تداخل العوامل المؤثرة في الدراسة وتعطى نتائج ذات درجة ثقة
عالية وتحديد العوامل الأكثر فاعلية في عملية التشغيل.
الهدف الرئيسي من هذا البحث هو رفع درجة نقاوة خام الحديد (المجناتيت) من خلال دراسة العوامل المؤثرة على
أنبوبة ديفيز للفصل المغناطيسي وهذه العوامل هي: حجم حبيبات الخام (مم) – شدة التيار الكهربي (أمبير) – مدى
تذبذب الأنبوبة وحركتها (لفة لكل دقيقة) – ميل الأنبوبة (درجة) – معدل سريان المياه (لتر لكل دقيقة) . وأثبتت
النتائج أن نسبة استرجاع مركزات الخام تتناسب طرديا مع كل من حجم حبيبات الخام و شدة التيار الكهربي
بينما يكون التناسب عكسي بين نسبة استرجاع مركزات الخام و كل من مدى تذبذب الأنبوبة وميل الأنبوبة و معدل
سريان المياه.
من الدراسة السابقة أمكن الحصول علي ركاز يحتوي علي نسبة 48.58% حديد وبنسبة استرجاع تصل الي
95.87% من عينه الخام التي تحتوي علي 40.49% حديد.