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The Effect of Water Flow Rate on Davis Tube Tests

Davis Tüp Testlerinde Su Akış Hızının Etkisi

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ABSTRACT

The effect of water flow rate on Davis tube tests was investigated in different solid ratios using low and high magnetite content samples. It was found that with increasing water flow rate Fe recovery decreased for each studied solid rate. It has been shown that the chosen solid ratio does not affect the grade regardless of the water flow rate, it has an impact on the Fe recovery.

Keywords: Davis tube, wet magnetic separation, water flow rate, magnetite, iron ore

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INTRODUCTION

An indispensable device in iron ores research, the Davis tube has not undergone any notable modifications since it was patented in 1921 (Svoboda, 2004). With these devices, grinded iron minerals, which can exhibit magnetic properties up to 9000 Gauss, can be separated from their non-magnetic side minerals as much as their liberations allow (Davis, 1955). Although the device which consists of a glass tube and motion motor placed between the electromagnetic poles is called an analyzer, it can also be used as a wet magnetic separator, and the obtained results can be applied to industrial devices with correction factors (Murariu and Svoboda, 2003;

Arol and Aydogan, 2004; Sivrikaya and Arol, 2012). Regardless of the application area, one of the most effective methods of magnetic separation, especially on small amount of samples (<20 g), is again the Davis tube device (Safarik, et al. 2001).

The most comprehensive study on Davis tube working parameters was conducted by Schulz (1964). It was noted that the water flow rate had no significant effect on the magnetic separation characteristic at water flow rates up to 1000 l/min. In subsequent studies, it was again studied in a narrow range and similar results were obtained at low water flow rates (Ahmed, 2010; Haffez, 2012).

In this study, Davis tube studies were conducted with two different type of iron ore, and unlike other studies, the answer to the question of what changes will occur on Fe grade and recovery if there are dramatic changes in water flow rate and solid ratios were investigated.

MATERIAL and METHOD

In the experiments, samples with low and high magnetite content obtained from Gülveren (A) and Bala (B) iron deposits located around the capital Ankara were used. The reason for selecting these deposits is to examine the relation of the change in the magnetite content of the sample with the water flow rate.

Samples A and B contain both magnetite and hematite in their structure, which can show fine hematite-magnetite transition zones. As shown in Table 1, sample A contains 31.85% magnetite, while sample B contains 62.12% magnetite.

The total iron content of the samples (Fe^{2+}+Fe^{3+}) is 55.50% and 45.60% respectively. The satmagan results of the samples show that about half of the Fe content of sample A (31.85x0,72=~23% Fe), and almost all of the sample B (62.12x0.72=~44.73% Fe) may have been caused by magnetite.

Iron analysis of the products obtained in the experiments was performed by aqua regia solution and titration. The magnetite content of the samples was analyzed with the Rapiscan Model Satmagan device.

Mineral liberation analysis (MLA) was performed with FEI Quanta 400 MK2 model SEM; Representative samples of each deposit, were first ground down to -150 µm, and then wet screened to obtain size fractions for SEM-MLA analyses. The modal mineralogical results of SEM-MLA analyses are given in Table 1.

Table 1. SEM-MLA analyses results of the samples A and B

Çizelge 1. A ve B numunelerinin SEM-MLA analiz sonuçları

Modal mineralogy								
Mineral	Mineral Content (%)							
	-150+75 µm		-75+45 µm		-45+20 µm		Average (-150+20 µm)	
	A	B	A	B	A	B	A	B
Magnetite	75,53	9,29	86,19	6,26	87,50	7,51	83,07	7,69
Gothite	10,53	-	7,38	-	6,90	-	8,27	-
Hematite	1,22	-	1,10	-	1,08	-	1,13	-
Mn- magnetite	0,12	59,51	0,12	80,58	0,26	81,41	0,17	73,83
Quartz	5,88	2,30	1,97	0,77	1,26	0,47	3,03	1,18
Garnet	1,09	0,65	0,77	0,23	0,55	0,30	0,80	0,39
Calcite	1,54	5,93	0,58	2,02	0,43	1,64	0,85	3,20
Pyrite	0,10	4,12	0,06	2,60	0,23	2,58	0,13	3,10
Others	3,99	18,20	1,83	7,54	1,79	6,09	2,55	10,61
Total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00

Mineral Liberation						
Mineral	Liberation (%)					
	Sample A			Sample B		
	-150+75µm	-75+45µm	-45+20µm	-150+75µm	-75+45µm	-45+20µm
Magnetite	75,58	80,58	82,49	54,56	50,88	51,04
Mn-magnetite	24,91	56,56	69,95	89,06	89,05	87,49
Hematite	55,67	56,66	55,15	-	-	-
Gothite	31,69	32,32	35,86	-	-	-

Elemental Distribution of Minerals		
Element-Mineral	Sample A Avarage (-150+20 µm)	Sample B Avarage (-150+20 µm)
Fe		
Magnetite	**89,99**	**9,79**
Mn- magnetite	0,16	**84,50**
Others	9,85	5,71
Total	100,00	100,00
Si		
Quartz	**66,65**	**55,55**
Garnet	6,27	6,98
Others	27,08	37,47
Total	100,00	100,00
Ca		
Calcite	**41,50**	**52,63**
Others	58,50	47,37
Total	100,00	100,00

The most remarkable detail in Modal Mineralogy results is to obtain different results with satmagan. The main reason for this is the presence of hematite and geothite in sample A, especially when geothite is eliminated from the sample by 20 μm due to its fine size during wet screening, so that other mineral ratios are detected at a high rate during analysis. This situation shows itself better, especially in the results of elemental distribution. During the preparation phase of the A sample, geothite and hematite are eliminated at -20 μm and the mineral magnetite contributes the most to the Fe content.

This problem, which is frequently encountered in limonite or clay abundant samples in MLA analyses, can be overcome by performing modal analysis on magnetite ores with a satmagan device. In this study, satmagan and Fe analysis values were taken into account.

Sample A and Sample B liberation at -45+20 μm fraction were determined as 82,49% and 87,49%, respectively. For this reason, the samples were milled to be d_{80}:45 μm for Davis tube tests.

The Davis tube device with an internal diameter of 2,2 inches was used in the experiments. Other parameters besides water flow rate were kept constant (agitation frequencies: 72 cycles/min, tube position: 30° from horizontal, stroke length: 50 mm, rotation degrees: 73°). The water flow rate was adjusted by peristaltic pump connected to the water tank. The selected water flow rates are 0,5, 1,0, 2,0, 3,0, 4,0 l/min and 4,5 l/min, which is the upper limit, respectively, and the amount of solids used at each water flow rate is changed from 20 g to 60 g. All experiments were conducted in two sets for a test time of 5 and 10 minutes.

In the experiments, the magnetic field intensity to be applied to the samples was determined by preliminary tests. Experiments were conducted at operating parameters (1000 l/min water flow rate, 10 minutes test time and 30 g solids) in accordance with the device's user manual, and 3000 and 2000 Gauss were selected for the A and B samples, respectively, where the grade and recovery given in Table 2 began to be fixed.

Table 2. Determination of magnetic field intensity to be applied for A and B samples
Çizelge 2. A ve B numuneleri için uygulanacak manyetik alan şiddetinin belirlenmesi

Magnetic Field Intensity (Gauss)	A		B	
	Fe %	Recovery%	Fe %	Recovery%
1000	70,00	5,33	62,65	84,18
2000	70,15	57,69	***62,75***	***86,31***
3000	***69,70***	***70,47***	63,80	86,44
4000	71,25	71,25	62,85	86,85
5000	69,45	69,51	63,00	86,95

RESULTS

The recovery-water flow rate change for sample A with low magnetite content is shown in Figure 1. As the water velocity increases for each solid quantity, the recovery decreases with an exponential function. The reason for the formation of exponential curves is that the recovery values decrease faster than 0,5 l/min to 3 l/min, and the decrease in recovery slows down after 3 l/min. Although a decrease in Fe recovery is expected at high water flow rates, it is noteworthy that increasing the flow rate from 0,5 l/min to 1,0 l/min reduces Fe recovery by up to 5%.

Higher recovery values were obtained in high solid amounts, and lower recovery values were obtained in low solid amounts. Since the recovery change for each flow rate is very close, the recovery-solid ratio curves were parallel to each other at varying water flow rates. As solid amounts increase, the recovery values show linear increases exceeding 7%, regardless of the water flow rate (at each studied flow rate).

The results obtained with the magnetite-dense B sample are given in Figure 2. As the water flow rate increases, the recovery decreases with an exponential function, but this is slower than the A sample with hematite. The increase in recovery values as the amount of solids increases and the formation of curves parallel to each other indicate that the same trend is achieved with the other sample.

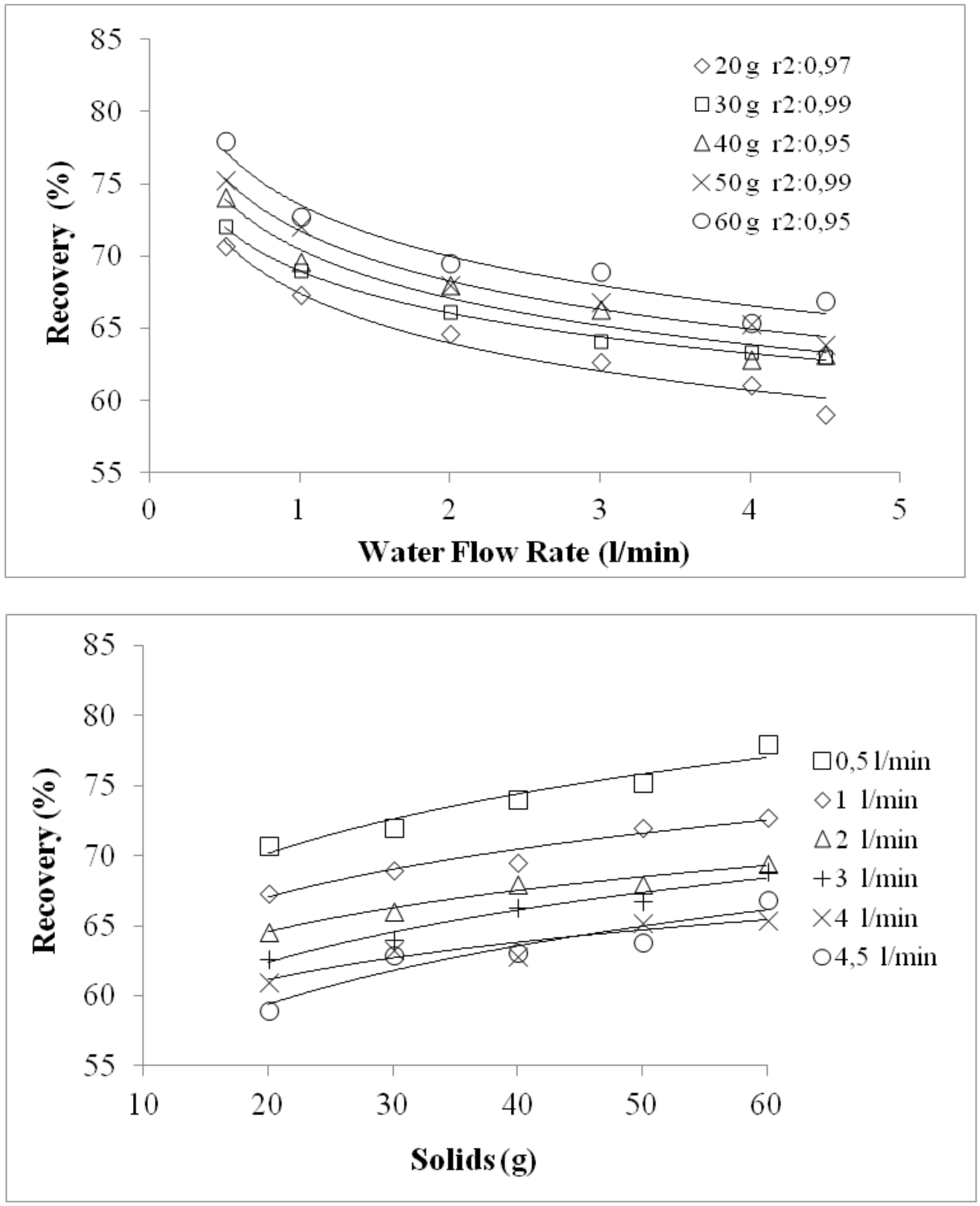
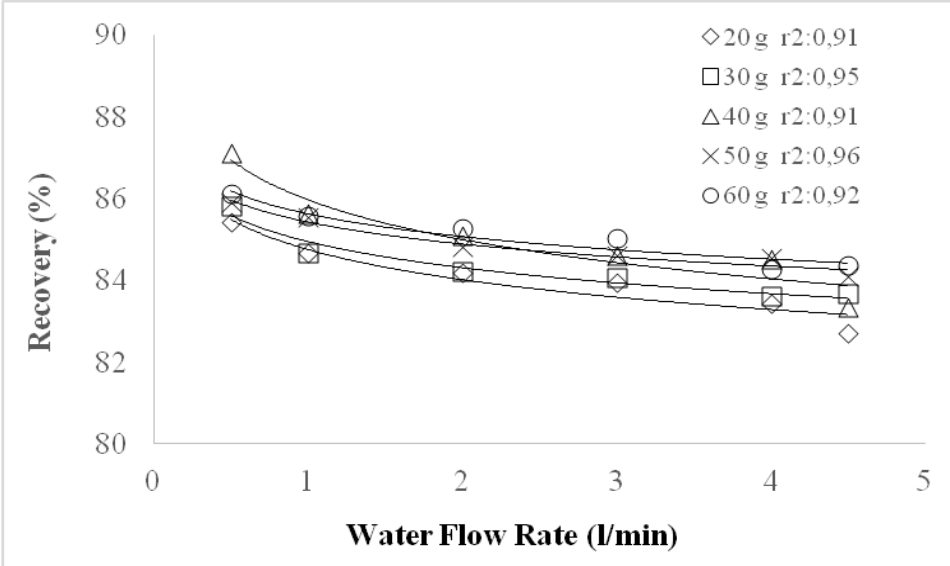


Figure 1- Recovery-water flow rate and recovery-solid changes in increasing solids for sample A

Şekil 1. A numunesi için artan katılarda geri kazanım suyu akış hızı ve geri kazanım katı değişiklikleri



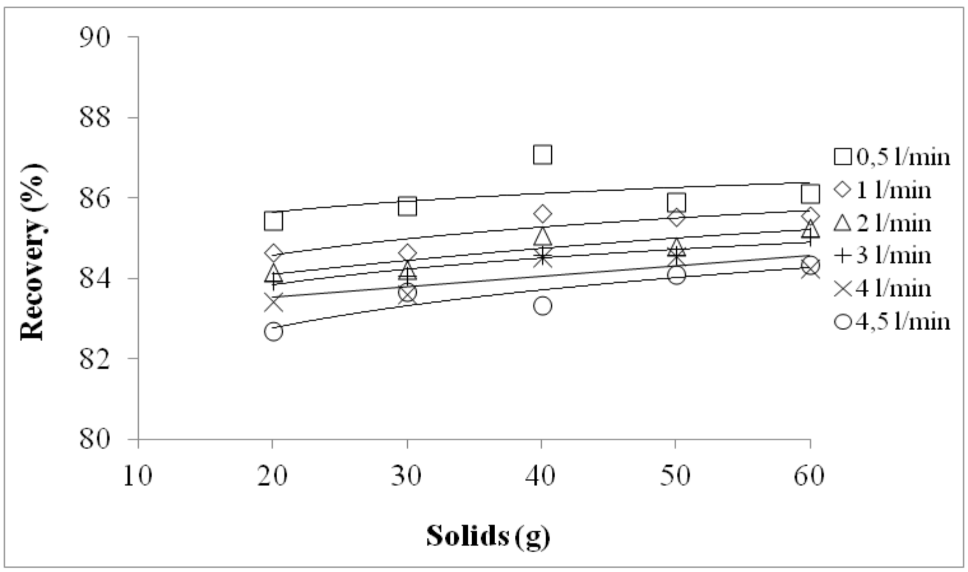


Figure 2- Recovery-water velocity and recovery-solid changes in increasing solids for sample B

Şekil 2. B numunesi için artan katılarda geri kazanım-su hızı ve geri kazanım-katı değişiklikleri

Although a decrease in recovery is expected at high water flow rates for both samples, when the flow rate increases from 0,5 l/min to 1,0 l/min, a decrease in recovery exceeding 5% is observed. Changes in grade values are shown in Figure 3 and Figure 4 for samples A and B. In either way, no significant trend was observed in the grade with the increased water flow rate or the amount of solids, the 70% Fe band for A and the 63% Fe band for B were retained in all cases.

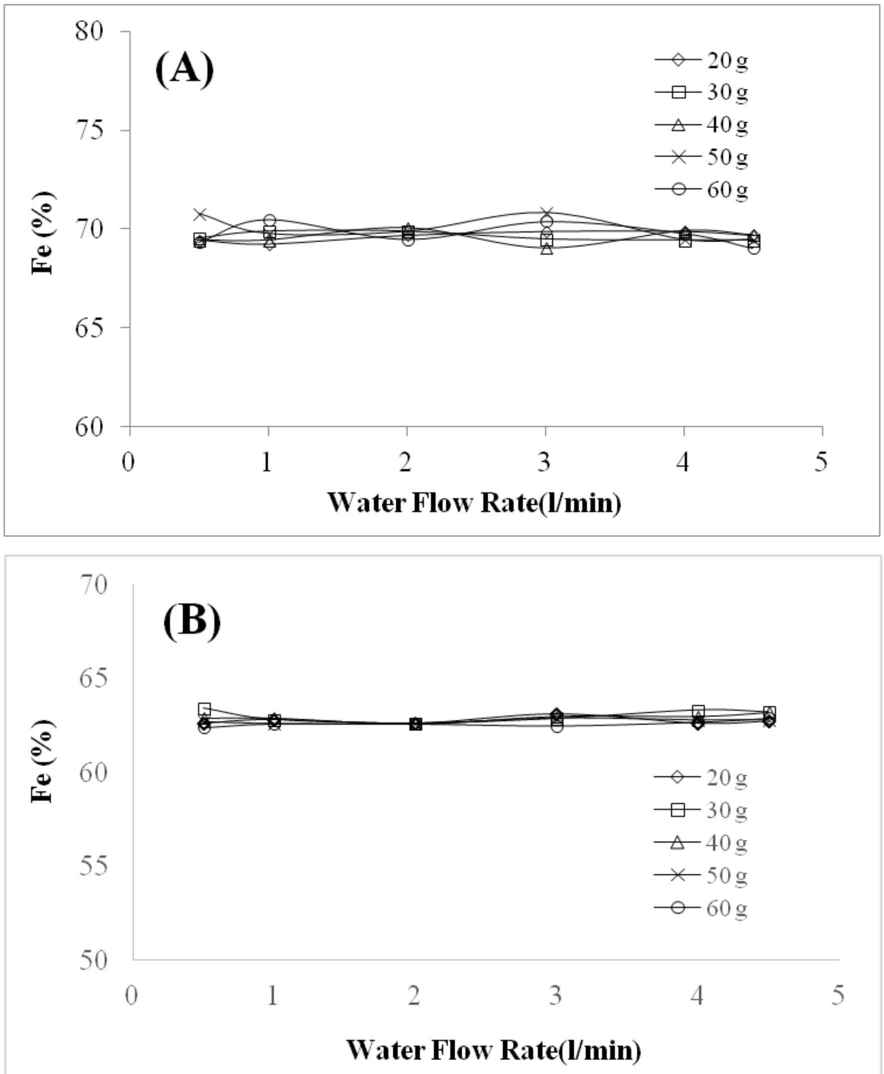


Figure 3- Grade changes for increased water velocity and solid ratios for A and B samples
Şekil 3. A ve B numuneleri için artan su hızı ve katı oranları için derece değişiklikleri

DISCUSSION

The following results were obtained in Davis tube experiments regarding increased water flow rates and solid amounts.

Fe recovery decreases as water flow rate increases:

The decrease in recovery occurs faster between 0,5 l/min and 3 l/min, after this point it decreases more slowly at high water flow rates such as 4-4,5 l/min. Therefore, exponential changes in Figures 2 and 4 are obtained. The decrease in recovery as the water flow rate increases is actually an expected result. The particles normally held in the magnetic field cannot resist the high flow rate and are separated from the magnetic field, thus the solid amount held in the magnetic part decreases, which naturally reduces the recovery of iron.

The same results were obtained in both low and high magnetite samples, but more pronounced in the low magnetite sample (A). Since hematite is also present in this sample, it can be said that the resistance of magnetite to high water flow rates is further reduced by the presence of hematite, or that the particles that first move away from the environment with high water flow rate may be magnetites with hematite. A similar effect is observed in sample B with high magnetite content, but less than in sample A.

The increase in the water flow rate from 0,5 l/min to 1,0 l/min, which is relatively low flow rates without reaching values such as 3 l/min, affects the Fe recovery values. Thus, Davis tube studies show that ensuring constant water flow rate has an effect on recovery rather than grade.

Higher Fe efficiency is achieved in Davis tube experiments as the amount of solids increases:

The relationship between solid amount and recovery is linear and valid for every applied water flow rate, regardless of the water flow rate. As the amount of solid increases iron recovery increases. It is due to the proportional increase in the weight of the magnetic part, and the grade values remains the same. This is related to device capacity, in other words, the region of magnetic concentration.

The grade of the magnetic part does not change:

Although increasing the water flow rate or the solid amount affects the recovery, it does not cause a significant change in the magnetic product grade.

RESULTS

The results indicated that magnetic particles, which can be kept at normal water flow rates in the Davis tube tests, can escape to the tailings when the water flow rate increases. As the water flow rate increases, the Fe recovery decreases, which is observed for every water flow rate increase from 0,5 l/min to 4,5 l/min. However, the increase in water flow rate does not affect the magnetic product grade.

The amount of solid to be used in the Davis tube test must be selected according to the device's magnetic concentration holding capacity. The usage of more or less samples than necessary affects Fe recovery just like the water flow rate, but not the grade.

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REFERENCES

Ahmed M. M. 2010. Statıstıcal design application and analysis of separation efficiency in Davis tube tester, Journal of Engineering Sciences, Assiut University, Vol. 38, No. 4, pp. 1047-1058

Arol A.I., Aydogan A. 2004. Recovery enhancement of magnetite fines in magnetic separation, Colloids and Surfaces A: Physicochem. Eng. Aspects, 232, 151–154

Davis, E.W. 1955. Pioneering with Taconite: The Birth of a Minnesota Industry, 269-283, Minesota Hisstorical Society Press, 2004.

Haffez G.S.A. 2012. Optimization of the operating parameters affecting Davis tube magnetic tester using 2nd factorial design, Journal of Engineering Sciences, Assiut University, Vol. 40, No. 4, pp.1217-1231

Murariu, V., Svoboda, J. 2003. The applıcabılıty of davıs tube tests to ore separatıon by drum magnetıc separators, Physical Separation in Science and Engineering, 12, 1, pp. 1–11.

Safarik, I., Mucha, P., Pechoc, J., Stoklasa, J., Safarikova, M., 2001. Separation of magnetic affinity biopolymer adsorbents in a Davis tube magnetic separator, *Biotechnology Letters* 23: 851–855, 2001.

Sivrikaya, O., Arol, A. I. 2012. Evaluation of low grade iron ore deposit in Erzincan-Turkey for iron ore pellet concentrate production

Schulz, N.F., 1964. Determination of the magnetic separation characteristics with the Davis Magnetic Tube,Trans. SME-AIME, 229, 211–216.

Svoboda, J, 2004. Magnetic Technicues for the Treatment of Materials, Kluwer Academic Publishers