BENEFICIATION OF BOREHOLE IRON ORE SAMPLES THROUGH MULTI-STAGES MAGNETIC SEPARATION

BENEFISIASI PERCONTOH INTI BOR BIJIH BESI MELALUI PEMISAHAN MAGNETIK BERTINGKAT

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ABSTRACT

This study investigates the effectiveness of magnetic concentration techniques for the beneficiation of borehole samples of Arasuko - West Sumatera iron ore. It is a low-grade type of ore sample (±35% Fe) with high silica and calcium content (±36%). Based on the fact, that there are appreciable differences in magnetic susceptibility between the desired iron minerals and the gangue minerals, hence, it was suggested that multi-stages magnetic separation may be useful to concentrate this type of ore. Because of the fine dissemination of the iron minerals and the most abundant gangue mineral, the particles size of ore was set at 80% passing 150 meshes. Rougher tests of magnetic separation produced concentrates with iron content of about 58.2% Fe; the tailing of rougher stage was then scavenged using higher magnetic intensity. Further, the rough and scavenged concentrates were mixed and fed into a cleaner stage with low magnetic intensity. Results indicate that the final iron concentrate assaying of 68.1% Fe at a recovery of about 80% is achieved and reckoned as an iron premium-grade concentrate.

Keywords: iron ore, beneficiation, magnetic separation, iron concentrate

SARI

Penelitian dilakukan untuk mempelajari keefektifan teknik pemisahan magnetik untuk meningkatkan kadar percontoh inti bor bijih besi kualitas rendah asal Arasuko – Sumatera Barat. Percontoh bijih tersebut berkadar rendah yaitu ±35% Fe, mengandung pengotor silika dan kalsium yang tinggi yaitu ±36%. Berdasarkan kenyataan, perbedaan kerentanan magnetik antara mineral besi dan mineral bukan besi cukup besar, sehingga pengonsentrasian cara magnetik bertingkat efektif dilakukan terhadap percontoh bijih tersebut. Percontoh bijih dihaluskan hingga 80% lolos 150 mesh, dilanjutkan dengan uji pemisahan mineral magnetik tingkat penyesah yang dapat menghasilkan konsentrat dengan kadar Fe 58,2%. Ampas dari proses penyesah dibilas secara magnetik pada intensitas magnet lebih tinggi, selanjutnya konsentrat bilasan dicampur dengan konsentrat penyesah untuk dibersihkan lagi secara magnetik pada intensitas magnet yang rendah. Hasil penelitian menunjukkan bahwa kadar Fe pada konsentrat akhir 68,1% dengan perolehan sekitar 80% yang termasuk konsentrat besi kadar premium.

Kata kunci: bijih besi, benefisiasi, pemisahan magnetik, konsentrat besi

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INTRODUCTION

Due to increasing in global demand of iron ores with accordance of the huge requirement of steel all over the world, hence, important iron ore producing countries have increased their production by initiating steps to utilize the low-grade iron ores, fines, and slimes (Ahmed et al, 2012). Indonesia steel industries intensively import the raw materials in the form of iron ore pellet due to the specification of local iron ore is not suitable as raw materials. This condition might induce that the Indonesia steel industries fundamentally unsecure. Competitions among the steel industries in the future are obvious, only the industries that have access to the main raw materials of iron ores will survive. Indonesia actually has iron ores which consists of lateritic ore type, iron sand and primary iron ore with total resources are about 4.92 billion tons, while the measured deposit is around 140 million tons (Armin, 2014). These iron ores chemically and physically are not being yet acceptable for the raw material of steel industries. Therefore, upgrading of the low-grade iron ores is considerably consequential.

Based on the fact that there are appreciable differences in magnetic susceptibility values between the desired iron minerals and the gangue minerals, i.e, hematite is 3586x10-6cgs units, while quartz is 29x10-6cgs units (Reade, 2006). Hence, it was suggested that the multi-stages magnetic separation may be useful to concentrate this type of the ore. However, the main difficulty in processing and utilization of low-grade iron ores is primarily originated from their mineralogical characteristics as well as the soft nature of the lateritic ores and their high impurities. Beneficiating the low-grade iron ores to remove the gangue minerals by fine-sizing of the ore prior to magnetic separation may be an attractive proposition presented in this paper.

Some researchers have conducted the magnetic separation for beneficiating their local minerals such as: Ahmed et al, 2012, undertaken the separation of low-grade iron ore using combination techniques of gravity separation and magnetic separation, the ore originally contains 35% Fe, after separation process they found a final concentrate of 64% Fe with a recovery of 70%. Al-Wakeel and Abdel-Rahman, 2005, studied the slimy iron ore beneficiation, which originally contains 34% Fe and was consecutively processed through screening, attritioning with sodium silicate, classification and magnetic separation. The concentrate with 53.2% Fe and recovery of 83% was achieved. The effectiveness of jigging operation for the beneficiation of Indian low-grade iron ore was undertaken by Das et al, 2007. While Umadevi et al, 2013, established beneficiation for slimy iron ore by combination techniques of such cyclone, wet high magnetic separation and flotation. Dworzanowski, 2012, studied how to maximizing the recovery of fine iron ore, he found that magnetic flocculation method was promising. The most recent research paper for beneficiating low grade fines iron ore was conducted by Sharma and Sharma, 2014. They have done the magnetizing roasting followed by low magnetic intensity separation of fines goethite iron ore. The ore contained of 59% Fe, after roasting at 450°C and magnetized, the grade of concentrate enhanced up to 69.94% Fe with a recovery of 85%.

The magnetic processing method is not new, it has been discussed and applied for the last 50 years; however, it is worth mentioning that the Arasuko iron ore was new borehole samples received at *tek*MIRA mineral processing laboratory and it is no beneficiation studies have been reported concerning this deposit until now.

The main objective of this study is to investigate the amenability of Arasuko low-grade borehole iron ore samples for upgrading by multi-stages magnetic separation technique. The main parameters of the magnetic separation affecting the effectiveness of low intensity rougher stage and lower intensity cleaner stage as well as higher intensity scavenger stage were investigated. The interpretation of separability in terms of chemical content is restricted only to oxides of iron, silica, alumina and calcium, but, separability interpretation based on mineralogical content of the concentrate and tailing is limited to magnetite, bornite, pyrite and gangue minerals.

METHODS

The two boreholes samples of Arasuko (Solok - West Sumatra) iron ores bearing minerals were received consisting of a magnetic sample (MS) and a less magnetic sample (LMS). Those samples were ground to be a size of 80% passing 150 meshes or 100 µm (P_{80},-150#) and then performed the chemical, mineralogical and liberation degree analysis. Chemical analysis used AAS method while mineralogical and liberation degree analysis used optical microscopic method. Both of ground samples were mixed into a composite sample with mixing ratio of MS/LMS = 0.6/0.4 (w/w); The composite sample was mixed with water within 30% solid, and was then tested through a wet multi-stages magnetic separator (feed rate of 25 kg/hour) with adjustable magnetic intensity. During the separation tests, a typical "SLon" vertically pulsating high gradient magnetic separator was used as depicted in Figure 1. Rougher magnetic and cleaner magnetic separations have applied magnetic intensity of 2,000 gauss (0.2 Tesla) and 1,000 gauss (0.1 Tesla), respectively. The tail of rougher stage was fed into a 1st scavenger magnetic separator with applied magnetic intensity of 2,000 gauss (0.2 Tesla), and then the tail of 1st scavenger magnetic separator was fed into a 2nd scavenger magnetic separator with applied magnetic intensity of 4,300 gauss (0.43 Tesla). The magnetic intensities were applied in different strength for different separation steps that are based on the difference of magnetic properties between the ore minerals, i.e., ferromagnetic, paramagnetic and diamagnetic (Wills, 2007). Steps of the multi-stages magnetic separator was conducted in an open circuit as depicted in Figure 2. The tests results were then evaluated based on chemical and mineralogical interpretation. Calculation of magnetic separation results in a closed-circuit with recycling of the cleaner tail into the initial feed is also discussed.

RESULTS AND DISCUSSION

Chemical Composition of Ore Raw Material

Both of ore samples i.e. magnetic (MS = magnetic sample) and less magnetic (LMS = less magnetic sample) have been chemically analyzed to know the grade of the main elements as shown in Table 1. MS samples were obtained from the depth in between 35 m to 45 m, while LMS samples were obtained from the depth in between 21.5 m to 59 m. The ore samples were ground to reach a size of 80% - 150 mesh (100 µm). Furthermore, after analyzing the chemical content, it is known that each sample of MS contains Fe about 36 to 57% with silica content around 5 to 13%, on the other hand, each sample of LMS contains Fe about 20 to 37% with high silica content.

Based on the principle of mining operation, where in the one area of the ore deposits should have

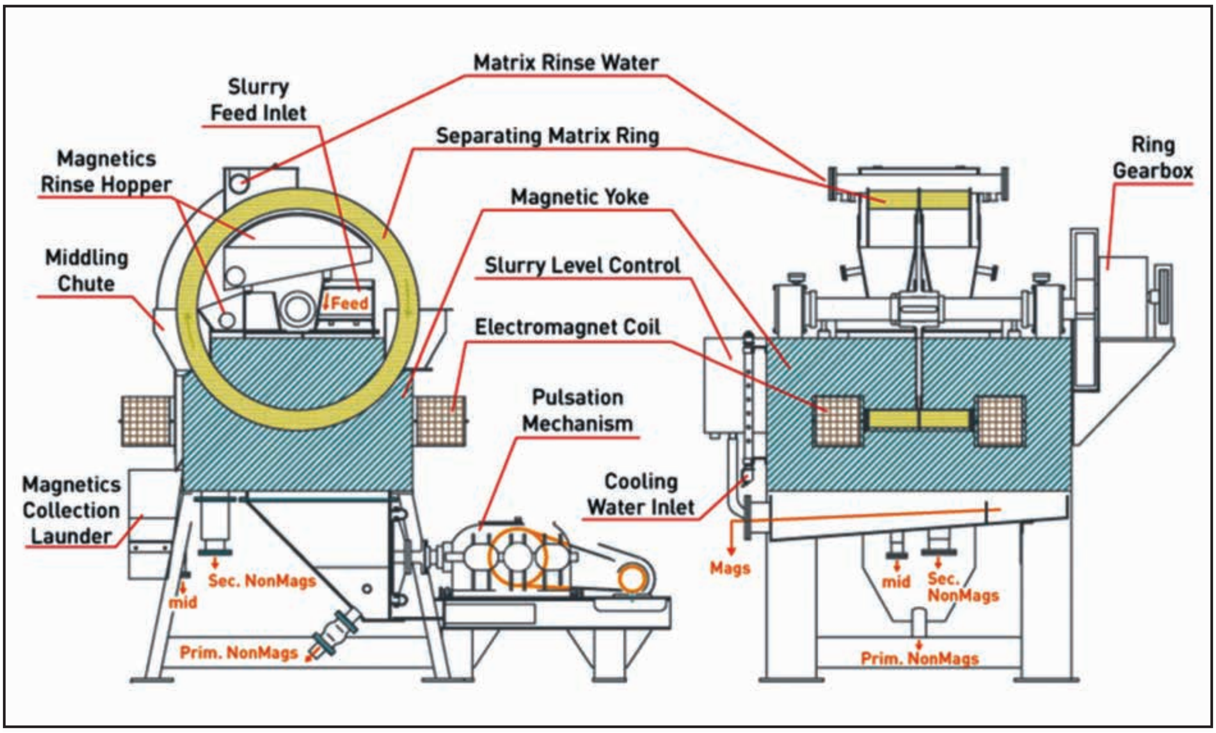


Figure 1. A typical of "SLon" vertically pulsating high gradient magnetic separator (Outotec, 2013)

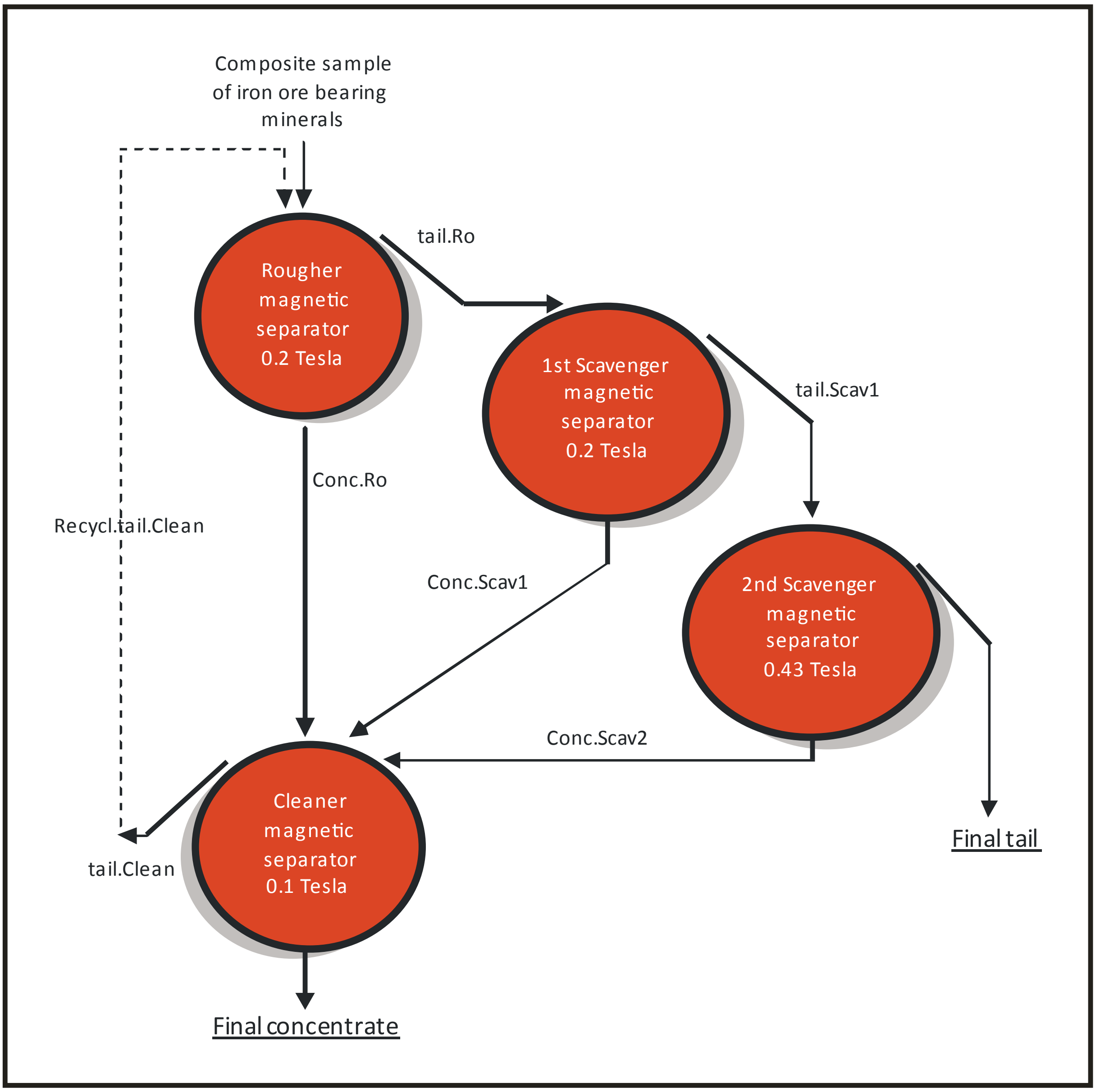


Figure 2. A flow sheet of multi-stages magnetic separation tests

a uniform ore grade, thus, the two drilling core samples were mixed with mixing ratio of MS/LMS = 0.6/0.4(w/w) to obtain a composite sample having calculated grade of Fe around 35%. However, the actual grade of the composite sample obtained from chemical analysis contains 36.56% Fetotal, 20.82% CaO, 15.14% SiO_2, 1.49% S, 6.5% Al_2O_3, 1.32% TiO_2, 0.8% MnO_2 and P_2O_5 is nil (Table 1). The grade of the composite sample used in this study is likely similar to the grade of low-grade iron ore in Egypt studied by Al-Wakeel and Abdel-Rahman, 2005, as well as Ahmed et al, 2012.

Mineral Composition of Ore Raw Material

The ground samples of MS and LMS as well as its composite were also analyzed mineralogically by counting through optical microscopic image. The result as shown in Table 2, clarify that magnetite is the predominant minerals with small amount of native iron. On the other hand, significant amount of sulphide metallic minerals of bornite is found especially in the LMS ore sample. Gangue minerals (non-metallic minerals) content of about 40% may consist of quartz and calcium oxide, which clearly realizes that the present ore samples received are low-grade iron mineral type.

Degree of Liberation

Magnetite as the predominant mineral found in the present iron ore sample was counted for its degree of liberation. Table 3 presents that within particle sizes of passing 150 mesh (100 µm), the liberation degree of magnetite is found more than 93% for MS sample, and also relatively similar is found for LMS sample, where its magnetite liberation degree is more than 92%. As the fact of high liberation degree for magnetite mineral in these ores, hence, the process of magnetic separation would be subjected to be successful.

Referring to all data with respect to chemical analysis, mineralogical analysis and liberation degree analysis of magnetite would be compared

Table 1. Chemical analysis of the borehole samples

No.	MS (Magnetic Samples)									
	Core depth	Weight, g	Fe total,%	CaO, %	SiO_2, %	S, %	Al_2O_3, %	TiO_2, %	MnO_2, %	P_2O_5, %
1	35-40M	8.600	41.8	23.79	10.27	0.80	4.91	0.50	1.58	0
2	40-41M	6.000	41	23.79	11.98	0.80	4.16	0.50	1.27	0
3	40-45M	5.800	39.6	23.79	12.62	0.90	5.67	0.84	1.42	0
4	41-42M	6.600	57.6	7.7	5.78	0	3.40	0.17	0.32	0
5	42-43M	5.600	56.5	8.81	5.35	1	5.29	0.50	0.32	0
6	43-44M	5.800	46	18.47	10.27	0	4.16	0.50	0.95	0
7	33-35M	8.400	36.8	25.89	13.48	1.60	6.05	1.34	1.27	0
8	40-45M	9.200	38.9	23.37	13.69	0.90	4.53	0.84	1.27	0
TOTAL (MS)		56.000	44.03	20.09	10.72	0.79	4.79	0.68	1.09	0
No.	LMS (Less Magnetic Sample)									
	Core depth	Weight, g	Fe total,%	CaO, %	SiO_2,%	S, %	Al_2O_3, %	TiO_2, %	MnO_2, %	P_2O_5, %
1	21,5-22,5M	2.000	36.9	20.43	17.12	3.3	0	1.85	0.47	0
2	47-50M	10.300	23.7	15.53	29.31	2.6	11.34	2.86	0.16	0
3	51-52M	4.000	20	19.45	26.1	2.1	10.2	2.52	0.32	0
4	58-59M	2.200	23.7	13.29	31.24	2.3	10.96	2.86	0.47	0
5	61-65M	2.000	23.1	26.03	19.25	0.9	12.09	1.34	1.11	0
6	33,5-35M	7.600	37.5	25.19	10.91	3.3	7.56	0.84	0.79	0
7	58-59M	10.400	20	27.98	19.25	2.2	7.94	2.69	0.16	0
TOTAL (LMS)		38.500	25.69	21.88	21.58	2.51	8.98	2.25	0.38	0
No.	A composite Sample									
	Composite (0.6/0.4)	Weight, g	Fe total,%	CaO, %	SiO_2, %	S, %	Al_2O_3, %	TiO_2, %	MnO_2, %	P_2O_5, %
1	MS+LMS	94.500	36.56	20.82	15.14	1.49	6.5	1.32	0.8	0

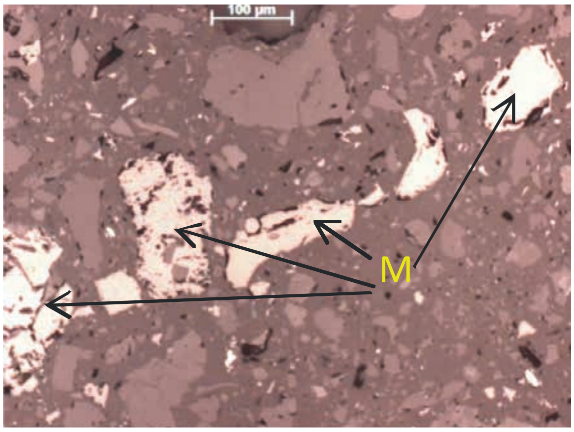
Table 2. Mineral content of the ores samples (%)

No.	Samples	Magnetite, Fe_3O_4	Bornite, Cu_5FeS_4	Pyrite, FeS_2	Chalcopyrite $CuFeS_2$	Native iron, Fe	Gangue mineral
1.	MS	59.56	0.56	0.72	0.15	0.36	38.65
2.	LMS	30.86	16.25	1.22	0.77	0.91	49.99
3.	Composite	47.87	6.95	0.92	0.40	0.58	43.28

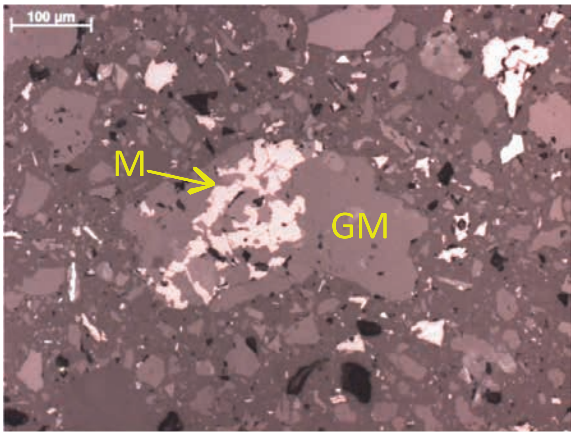
Table 3. Liberation degree of magnetite within ore size of P80, -150 mesh

No.	Samples	Liberation Degree (%)
1.	MS	93.45
2.	LMS	92.73

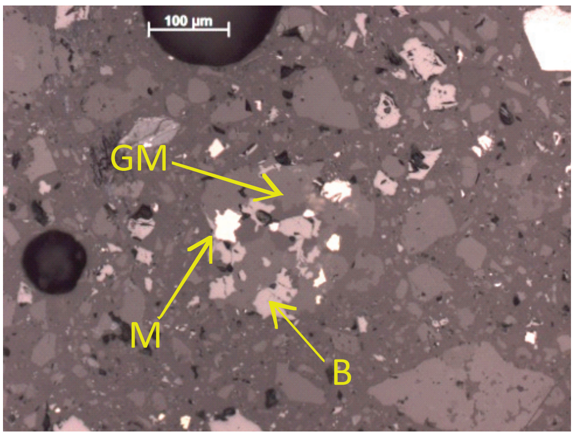
with some Photomicrographs of MS and LMS polished samples as revealed in Photomicrographs 1 to 5. The Photomicrograph 1 presents a drilling core for MS ore sample, which shows free magnetite minerals at particle sizes around 100 to 200 µm. For the similar ground MS ore sample also presents a particle of gangue mineral of size about 400 µm found interlocked with magnetite of size 100 µm as shown in Photomicrograph 2. Further, Photomicrograph 3 shows magnetite and bornite of size about 40 – 50 µm are bound to spread inside of a gangue mineral particle of size 200 µm. The characteristic of LMS drilling core sample, as presented by Photomicrograph 4, is found a liberated magnetite and bornite of size around 50 – 100 µm. While from Photomicrograph 5 is found magnetite of size about 100 µm interlocks with a particle of gangue mineral of size 150 µm. Therefore, from all Photomicrographs confirm that magnetite mineral might be appreciable to be separated through a low-magnetic intensity separator at sizes finer than 150 mesh (100 µm).



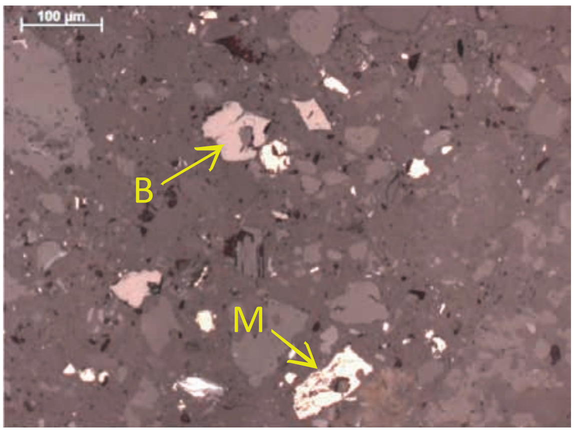
Photomicrograph1. Sample MS, free magnetite (M)



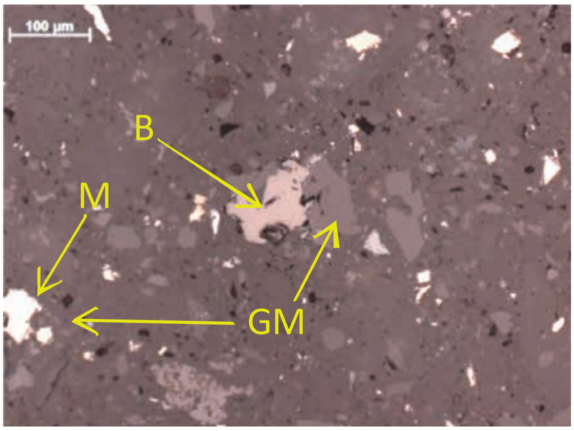
Photomicrograph 2. Sample MS, magnetite (M) interlock in gangue mineral (GM)



Photomicrograph 3. Sample MS, magnetite (M) and bornite (B) interlock in gangue mineral (GM)



Photomicrograph 4. Sample LMS, free magnetite (M) and bornite (B)



Photomicrograph 5. Sample LMS, magnetite (M), bornite (B) interlocked with gangue mineral (GM)

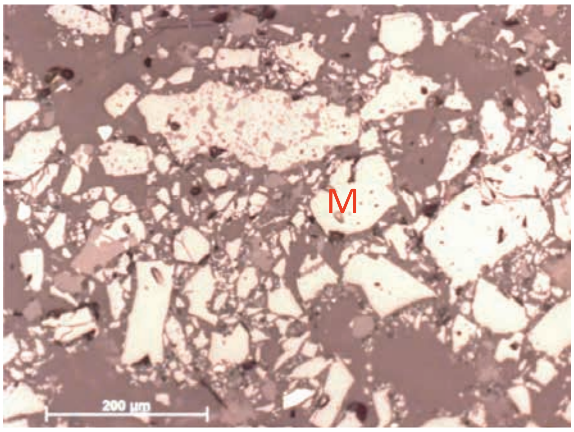
Magnetic Separation Tests

Multi-stages magnetic separations tests have applied to concentrate the composite iron ore mineral of size 80% passing 150 mesh (100 μm). Other experimental conditions were undertaken with feeding rate of 25 kg/hour at 30% solid. The equipment used was “SLon” vertically pulsating high-gradient magnetic separator type of Autotec as shown in Figure 1. This equipment utilizes the combination of magnetic force, pulsating fluid and gravity action to continuously separate magnetic and non-magnetic minerals. The magnetic intensity was adjusted depending on steps of the separation. Figure 2 depicts the separation steps. Prior to the separation tests, it is worth to refer to the mineralogical analysis mentioned above, where the ore is predominated by liberated magnetite mineral with strong paramagnetic properties, and also has a small amount of native iron which has ferromagnetic properties with high magnetic susceptibility. In contrary, the gangue minerals of quartz and calcium-oxide have diamagnetic properties which are repelled magnetic force. Those minerals of ferromagnetic and paramagnetic are appreciable to be concentrated in low-intensity magnetic separator (Wills, 2007). Therefore, the first step of magnetic separator, which is called as rougher magnetic separation was applied in a moderate magnetic strength of 2,000 gauss (0.2 Tesla). Feed of rougher stage used the composite sample containing 34% Fe and 15% SiO_2. After passing the ore through the separating matrix ring of the equipment, then the magnetic minerals were rinsed and collected into a launder as rougher concentrate and then flowed to cleaner stage. Non-magnetic minerals were repelled and flowed to the 1st scavenger stage and so on. Two samples of rough-concentrate and rough-tail were collected to interpret its minerals content as revealed in Table 4, where magnetite is found predominantly spread in rougher concentrate, while, gangue minerals are predominant in rougher tail, but although there presents small amount of fine free magnetite of size less than 50 μm (see Photomicrograph 6 and 7). In general, however, this phenomenon apparently confirms the fruitfulness of the separation.

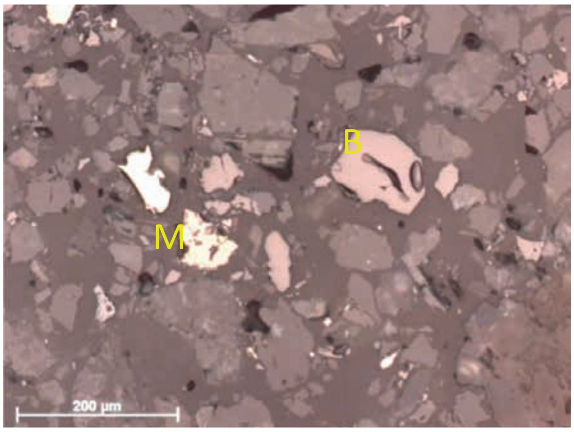
The presence of small amount of free-fine size magnetite particles in rougher tail as depicted in Photomicrograph 7 is likely in accordance with the tests result by Al-Wakeel and Abdel-Rahman, 2005, who stated that fine fraction requires high magnetic intensity. So that in the present tests of rougher stages apply magnetic intensity of 0.2 Tesla, which may be inadequate yet for attracting the fine magnetite particles. Furthermore, The tailing of rougher was then separated consecutively through 1st scavenging process (using magnetic intensity of 0.2 Tesla) and 2nd scavenging process (using magnetic intensity of 0.43 Tesla), whereas, the concentrate of rougher, the concentrate of 1st scavenging and the concentrate of 2nd scavenging were mixed to feed into a cleaning step using low-magnetic intensity of 1,000 gauss (0.1 Tesla). The mixed concentrate is considerably to have high content of iron minerals, so that according to Dworzanowski, 2012, low-magnetic intensity (0.1 Tesla) of the cleaning separation stage had been applied. By conducting multi-stages of

Table 4. Minerals content in rougher concentrate and rougher tail

	Minerals content (Weight,%)					
	Magnetite (Fe_3O_4)	Bornite (Cu_5FeS_4)	Pyrite (FeS_2)	Chalcopyrite ($CuFeS_2$)	Native iron (Fe)	Gangue minerals
Rougher Conc.	86.23	0.80	0.04	-	-	12.93
Rougher Tail	10.38	8.06	1.92	-	-	86.64



Photomicrograph 6. Rougher concentrate contains predominantly magnetite (M)



Photomicrograph 7. Rougher tails contains free small amount of magnetite (M) and bornite (B)

magnetic separation, therefore, the final iron concentrate is obtained containing 68.1% Fetotal with recovery of 81% (Table 5). Other metallic non-magnetic components (i.e., bornite and pyrite at rougher concentrate as presented in Table 4) are distributed in small amount, except for gangue minerals which may be due to fines interlocking with the magnetic particles. However, based on iron content with assumption of limited grade of non-ferrous metals, so the concentrate obtained is considerably as a premium-grade.

Based on the flowsheet of the process as depicted in Figure 2 and a series of experimental data, so that, calculation of the materials balance within the closed-circuit of multi-stage magnetic separation process is solved to understand the reliability of the process, if it would be applied in plant scale in the future. The calculated data of closed-circuit process is presented in Table 6. The flow of the materials is calculated through 4 (four) steps of magnetic separation, i.e., rougher, cleaner, 1^{st} scavenger and 2^{nd} scavenger. Multi-stages separation and recycling of intermediate tail were used to maximize the iron concentration and its recovery (Karmazin et al, 2002). The tail of the cleaning stage is recycled into initial feed, while the concentrate of rougher and 1st scavenger as well as 2nd scavenger are mixed together to feed into the cleaner stage. The weight of overall feed becomes 105.99%, while the weight of final tail obtained from the tailing of the 2nd scavenger likely increases from originally 53.41% (as batch test) to 55.41% (as recycled calculation). The iron content loosed into the final tail increases from originally 8.13% Fe (as batch test) to 12.13% Fe (as recycled calculation). The phenomenon of loosed iron into the final tail may be due to the locked magnetite with gangue minerals, and also there may present some iron based limonite and pyrite loosed into final tail. Therefore, in order to increase the recovery of iron minerals, it might be important to regrind of the rougher tails prior to be fed into the scavenging stages (Karmazin

Table 5. Result of open multi-stage magnetic separators tests

Magnetic Process, Stages and Products	Weight (%)	Grade (%)				Distribution (%)			
		Fe_{total}	SiO_2	Al_2O_3	CaO	Fe_{total}	SiO_2	Al_2O_3	CaO
Conc Cleaner	40.60	68.10	1.62	1.18	2.28	81.04	4.37	7.32	4.46
Tail Cleaner	5.99	35.50	2.30	2.35	3.71	6.23	0.92	2.15	1.07
Tail scv 2	53.41	8.13	26.70	11.10	36.70	12.73	94.72	90.53	94.47
Feed	100	34.12	15.06	6.55	20.75	100.00	100.00	100.00	100.00

Note: Conc = concentrate, Scv = scavenger

Table 6. Calculated materials balance of closed-circuit in multi-stages magnetic separation

No.	Magnetic Process, Stages and Products	Weight (%)	Grade (%)				Distribution (%)			
			Fe_{total}	SiO_2	Al_2O_3	CaO	Fe_{total}	SiO_2	Al_2O_3	CaO
1	Conc Cleaner	44.59	68.10	1.62	1.18	2.28	80.00	4.34	7.50	4.44
2	Tail Cleaner	5.99	35.50	2.30	2.35	3.71	5.6	0.83	2.01	0.97
	F.cl=c.ro+c.scv2+c.scv1	50.58	64.24	1.70	1.32	2.45	85.6	5.17	9.51	5.41
3	ConcScv 2	7.49	40.40	1.37	1.25	2.42	7.97	0.62	1.34	0.79
4	Tail Scv 2	55.41	12.13	26.70	11.10	36.7	17.71	88.95	87.71	88.81
	F.scv2=T.scv1	62.9	15.50	23.68	9.93	32.62	25.68	89.57	89.04	89.60
5	ConcScv 1	5.29	40.00	3.30	1.46	3.91	5.57	1.05	1.10	0.90
6	Tail Scv 1	62.9	14.40	21.60	9.56	29.67	23.86	81.69	85.75	81.51
	F.scv1=Tail rough	68.19	16.39	20.18	8.93	27.67	29.44	82.74	86.85	82.41
7	Conc Rougher	37.8	58.20	3.05	1.27	3.28	57.96	6.93	6.85	5.41
8	Tail Rougher	68.19	23.40	22.70	9.58	31.76	42.04	93.07	93.15	94.59
	Feed (recycle-calculated)	105.99	35.81	15.69	6.62	21.60	100.00	100.00	100.00	100.00
	Feed (initial)	100.00	34.12	15.06	6.55	20.75	-	-	-	-

Note : F.cl=feed cleaner, c.ro=rougher concentrate, c.scv=concentrate scavenger, T.scv=tail scavenger,

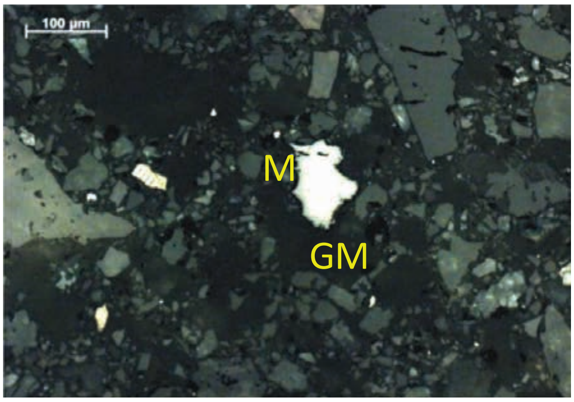
et al, 2002). Whatever the cause is, the data obtained from calculated material balance present final concentrate of iron ore treated in multi-stage magnetic separators, that have had high grade (68.1%Fe) with a recovery around 80 %. This typical concentrate is considered as a premium-grade iron concentrate, which is suitable for blast furnace operation (Al-Wakeel and Abdel-Rahman, 2005). Moreover, concentration ratio of the separation process is found 100/40.6 or 2.46, thus, it is supposed to produce 1 ton iron concentrate with grade of 68% Fe requires 2.46 tons of iron ore with grade around 35% Fe.

Characteristic of Final Tail

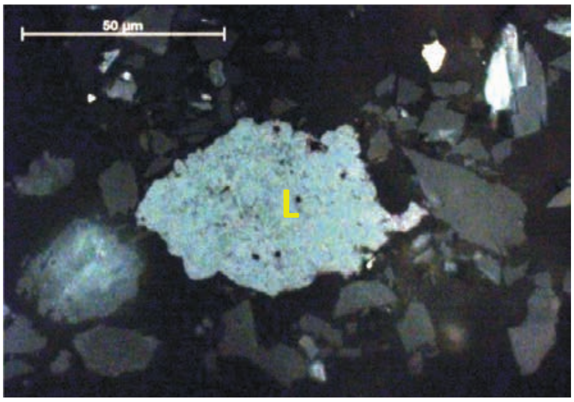
Final tail rejected from 2nd scavenging stage of magnetic separator using high magnetic intensity of 4,300 gauss (0.43 Tesla) contains such minerals as shown in Table 7 and in the Photomicrographs 8 to 11. Small amount of fine magnetite particle (0.76%wt) with size less than 100 µm (see Photomicrograph 8) and having grade about 12.13% Fe is still loosed into the final tails (see Table 6). According to Al-Wakeel and Abdel-Rahman, 2005, who stated that fine fraction requires high magnetic intensity, so that in the present tests of multi-stages magnetic separation, which apply magnetic intensity within 0.1 to 0.43 Tesla may be inadequate yet for attracting the fine magnetite particles. From the photomicrograph 8 to 11, fine magnetite minerals are looked interlock with gangue minerals and also it is shown some iron minerals based limonite and pyrite or chalcopyrite. Those minerals contain iron causing high grade of iron presents in the final tail. Pyrite and chalcopyrite as well as limonite present in free particles condition. In general, however, final tail is predominated by less-magnetic sulphide minerals as well as non-magnetic gangue mineral such as pyrite, bornite, chalcopyrite and gangue minerals of quartz and calcium oxide.

Table 7. Mineral content of final tailing (2nd scavenging tail)

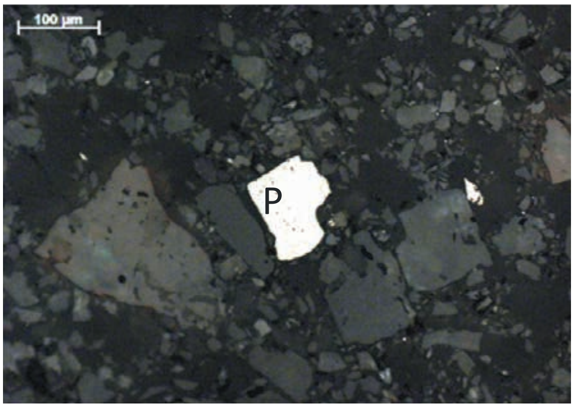
Mineral contents (% Weight)					
Pyrite (FeS_2)	Magnetite (Fe_3O_4)	Bornite (Cu_5FeS_4)	Chalcopyrite ($CuFeS_2$)	Limonite ($FeO(OH)n(H_2O)$)	Gangue mineral
4.44	0.76	10.56	1.87	0.56	94.18



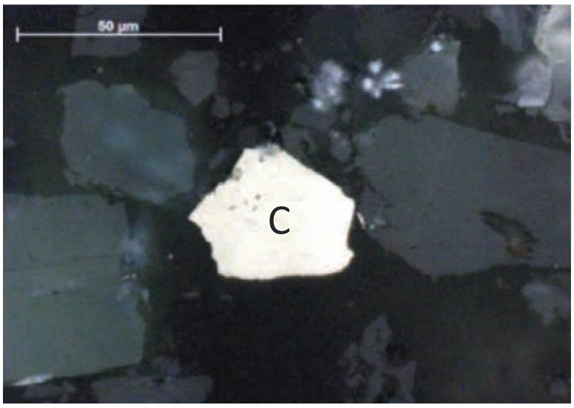
Photomicrograph 8. final tail, magnetite (M),100µm, interlocks with gangue mineral (GM)



Photomicrograph 9. final tail, free limonite (L), ±50µm.



Photomicrograph 10. final tail, free pyrite (P), ±100µm



Photomicrograph 11. final tail, free chalcopyrite (C), ±40µm

CONCLUSION AND SUGGESTION

The beneficiation test results of Arasuko low-grade iron ore using multi-stages magnetic separation method have shown as follows:

The ground composite borehole ore sample of size 100 µm contains 36.5% Fetotal, 20.8% CaO, 15.1% SiO_2, which is considered as a low-grade iron ore. After processing tests, small amount of magnetite is likely loosed into the tailing of rougher stage that is due to the fine size of the magnetic minerals interlock with gangue minerals. Otherwise, small amount of sulphide and gangue minerals join insignificantly to the final concentrate. Anyway, the final concentrate generated from the multi-stages magnetic separation has been considered as a premium-grade of iron mineral containing 68.1% Fetotal with a recovery of 80 % and the ratio of concentration is 2.46;

To increase the recovery of iron and to decrease the non-magnetic component in the final concentrate, it is suggested that regrinding of rougher tail is required prior to be fed into the scavenging stage, as well as, performing the higher magnetic intensity of the separator might be useful.

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