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Investigation of Iron Recovery from Filter Dust of Casting Factory

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Abstract

In this study, the possibilities of iron recovering from filter dust of casting foundry was investigated using various physical separation methods. Enrichment studies were carried out using of Falcon Gravimetric Concentrator (FGC), Wet High Intensity Magnetic Separator (WHIMS), Vertical Flow Hydraulic Classifier (VFHC), and Dry Magnetic Separator (DMS). Basic chemical compound of filter dust was determined as 8.68% Fe_2O_3, 7.7% Al_2O_3, 2.1% CaO, 1% MgO, 1.1% Na_2O, 73.5% SiO_2. XRD analysis showed that the dominant peaks of filter dust belong to quartz, iron phosphate, aluminum phosphate, and carbon. Also, density of filter dust was determined as 2.72 g/cm^3.

To recovery of iron, the filter dust was treatment with Falcon Gravimetric Concentrator, Wet High Intensity Magnetic Separator, vertical flow hydraulic classifier, and dry magnetic separator. The best results were obtained by Dry Magnetic separator. According to results, iron can be recovered from filter dust with %60 yield and iron content can be %83 Fe in concentrate of dry magnetic separator. Density of concentrate of dry magnetic separator was measured as 5.73 g/cm^3, so that increasing of density demonstrated to iron enrichment in concentrate. XRD analyses showed that iron in filter dust is in various compound form with carbide, aluminum, manganese, silica and phosphate. As a result of physical separation, it was determined that DMS (Dry Magnetic Separator) concentrate contains same iron forms. According to the metal content analysis, the Fe_2O_3 generally decreases in DMS waste while Al_2O_3 and SiO_2 increases in waste.

Keywords: Iron; Dry magnetic separator; Filter dust; Separation; Enrichment

Abbrevations: FGC: Falcon Gravimetric Concentrator; WHIMS: Wet High Intensity Magnetic Separator; VFHC: Vertical Flow Hydraulic Classifier; DMS: Dry Magnetic Separator

Introduction

Metallurgical wastes contain heavy metals. They are defined as metallic elements that have a high density. At the present day, various metallurgy plants cause to environmental pollution. Although heavy metals are naturally occurring compounds, anthropogenic activities introduce them in excessive quantities in different environmental matrices, which impose severe threats on both human and ecosystem health [1]. There has been reported that an increasing ecological and global public health concern associated with environmental contamination by these heavy metals. Zinc plants [2], blast furnace dusts [3,4], steelmaking dusts [5,6], smelter flue dust [7,8] and slags [9] are mostly caused to heavy metal pollution as metallurgical wastes. Heavy metals in these wastes are not suitable for direct use. Therefore, researchers mostly use chemical methods to remove these wastes and to recover precious metals [10 -14]. However, it is seen in the literature that there has not been much study about recovery of heavy metals from casting filter dusts. The increasing demand for iron in the industry has directed researchers to alternative iron sources [15]. In the melting furnaces, extremely harmful and toxic gases are released during the process. These harmful gases and dusts must be collected and filtered before they are scattered into environment [16]. The collection of these dusts from source is great importance for both energy consumption and employee health. Dust and fumes released during loading, melting, waiting, stripping from the surface and pouring are conveyed to the filter via hoods specially designed to operate in any environment over the induction furnaces. Experiences of the countries most advanced in terms of environmental protection imply that minimization of waste generation, i.e., prevention of waste production, is indeed the most efficient waste management strategy [17].

As can be seen, these filter dusts should not be released into the atmosphere due to the potential of pollution. For this reason, casting foundries have a filter system in their flue such as bag house, electrostatic filter etc. It is important to be aware of the environmental impact of intensive foundry activity [18]. However, considering that an average casting foundry produces 3-10 tons/day of filter dust, the recovery of the iron contained in this dust is both economical and environmentally important. Nevertheless, the biggest problem on recovery of metals in filter dust is that iron (metallic form) has particle size less than 100 µm, and the iron content is low. Therefore, it is not economical to recover the iron from filter dust by chemical methods. It is thought that it would be appropriate to recover of iron in the filter dust by some physical enrichment methods. In this study, filter dust of casting foundry was characterized and investigated to recovery iron using various physical methods.

Materials and Methods

Filter dust (about 10 kg) was supplied from a spheroid casting factory, Elazığ, Turkey. The characterization processes of supplied filter dusts and samples obtained from experimental studies were demonstrated by using various instrumental analysis methods (XRF, XRD, wet analysis etc.). The data obtained through the analyzes were synthesized. Enrichment studies were carried out using of i) Falcon Gravimetric Concentrator (FGC), ii) Wet High Intensity Magnetic Separator (WHIMS), iii) Vertical Flow Hydraulic Classifier (VFHC), and iv) Dry Magnetic Separator (DMS). In all enrichment experiments, a reasonable amount of feed material was fed to the enrichment device through the feed port and taken as a concentrate and waste product. Then, the obtained materials were analyzed. FGC is a semi-continuous centrifuge unit, generally operating at a relatively higher G-forces, 0-50 G. These machines are manufactured in different sizes, from laboratory scale to high-capacity models [19].

WHIMS has been developed aimed at reaching high magnitude field gradients. This enrichment device can achieve a higher magnetic field intensity by using a different matrix and it can be produced in different scales [20]. In VFHC system, feed material enters the top of the unit via with water flow. Simultaneously, process water is injected through an array of pipes located near the bottom of the separation chamber. This water injection causes an upward rising current of water that flows over. Dry magnetic separators possess high magnetic field strength imparted by a permanent magnet or through an induced magnetic field to separate the particles based on their magnetic susceptibility. These devices are used principally for quantitative analysis of paramagnetic mineral samples. Dry separation has its advantage over the wet, such as water consumption, retrieving the water for reuse, tailing pond management, etc [21]. The concentrates and wastes obtained were dried in a 55°C oven for 48 hours before being analysis.

Density measurements of various materials (concentrate, waste, etc.) obtained were performed with a pyknometer. In the density measurements, after weighing the dry sample + pyknometer, 25 mL of distilled water was added and boiled for 3 minutes. Then, it was left in the ultrasonic bath at 40°C for 20 minutes to prevent air bubbles, and dried for 30 minutes, and weighed. According to results of some analyzes obtained, the particle size of filter dust is 63µm (d_{95}), and total loss of ignition is 20% was identified using a laser-scattering technique (Malvern Instruments Master Sizer X) and loss of ignition experiment in porcelain crucible at 1100ºC, respectively.

Results and Discussion

Experimental Results

Recovery studies of filter dust were carried out under different experimental conditions. For FGC, 101 g of filter dust was used for feeding and experiments were performed in range of rotation speed of 20-50 G. 100 g of filter dust as feeding amount was used in WHIMS for 0.10-0.38 Tesla. For DMS, 1000 g of filter dust was used for 0.10-0.12 Tesla. Also, 55 g of filter dust was used for VFHC. The results obtained in the experimental studies are given in Table 1.

FGC

In studies conducted with FGC, it is seen that amount of concentrate increases with increasing G force. Approximately 17% of feed at 20 G rotation speed goes to concentrate, 83% goes to waste, while 53% of feed at 50 G rotation speed goes to concentrate and 47% goes to waste. Considering that density of feed material is 2.72 g / cm^3, the density changing in concentrate obtained from 20 G is approximately + 59%, while density changing of concentrate obtained from 50 G is approximately + 9%.

According to this trend in density changing rates, it can be said that fraction containing the metallic phase in filter dust mostly goes to concentrate, however, the negative density changing indicates that lighter elements (non-ferrous Al, Si etc. in filter dust) go to the waste (Figure 1).

WHIMS

The studies carried out in WHIMS were carried out in the range of 0.10-0.38 Tesla. Despite the increasing magnetic field intensity, it is seen that concentrate/residue waste is almost the same. Amount of concentrate and waste consists of 21% and 79% of feed amount, respectively (concentrate/waste ratio: 0.27) at 0.10 Tesla, while studies at 0.38 Tesla, concentrate and waste amounts are 24% and 76% of feed amount, respectively (concentrate/waste: 0.32). The density changing of concentrate and waste are obtained as in range of + 39-50% and -9-10%, respectively (Figure 2).

VFHC

In the study using VFHC, it is seen that the highest concentrate amount was taken from this group study among all experiments. Accordingly, it is seen that approximately 81% of the feed goes to

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concentrate and 19% to waste. Although a large amount of feed material goes to the concentrate, it is seen that density values of concentrate and waste are 2.84 and 2.48 g/cm^3, respectively. It is also seen that density of concentrate and waste is quite close to the density of feed material (Figure 3).

Table 1: Enrichment results of filter dust.

Sample Gram		Feed Amount	Process Loss	Yield		Density	Density Change	
		%	Gram	%	g/cm3	%		
Feed Sample						2,72		
FGC	20G Concentrate	101,00	0,39	171,898	17,09	4,31	+	58,46
	20G Waste			834,124	82,91	2,53	-	6,99
	25G Concentrate	101,00	0,74	246,608	24,60	3,61	+	32,72
	25G Waste			755,901	75,40	2,58	-	5,15
	30G Concentrate	101,00	0,69	402,565	40,13	3,45	+	26,84
	30G Waste			600,509	59,87	2,37	-	12,87
	35G Concentrate	101,00	0,54	500,170	49,79	3,32	+	22,06
	35G Waste			504,369	50,21	2,40	-	11,76
	40G Concentrate	101,00	0,60	542,647	54,05	3,04	+	11,76
	40G Waste			461,311	45,95	2,34	-	13,97
	45G Concentrate	101,00	0,79	504,479	50,34	2,96	+	8,82
	45G Waste			497,584	49,66	2,48	-	8,82
	50G Concentrate	101,00	0,83	530,737	52,99	2,95	+	8,46
	50G Waste			470,888	47,01	2,47	-	9,19
WHIMS	0.38 Tesla Concentrate	100,00	1,64	239,724	24,37	3,89	+	43,01
	0.38 Tesla Waste			743,904	75,63	2,48	-	8,82
	0.29 Tesla Concentrate	100,00	1,92	247,710	25,26	3,78	+	38,97
	0.29 Tesla Waste			733,077	74,74	2,47	-	9,19
	0.19 Tesla Concentrate	100,00	1,82	207,959	21,18	4,09	+	50,37
	0.19 Tesla Waste			773,859	78,82	2,44	-	10,29
	0.10 Tesla Concentrate	100,00	1,12	207,959	21,03	3,98	+	46,32
	0.10 Tesla Waste			780,792	78,97	2,44	-	10,29
VFHC	Underflow (Concentrate)	55,00	3,52	430,062	81,04	2,84	+	4,41
	Overflow (Waste)			100,592	18,96	2,48	-	8,82
DMS (0.10-0.12 Tesla)	Concentrate 1*	1000,00	4,61	158,64	16,63	5,73	+	110,66
	Concentrate 2*			52,92	5,55	2,60	-	4,41
	Waste			742,35	77,82	2,51	-	7,72

Table 2: Determination of chemical composition of selected parts from experiments [1: Feeding material (filter dust), 2: DMS concentrate, 3: DMS waste].

Sample code	Al	Ca	Fe	K	Mg	Mn	Na	P	Si	Ti
1	4.08	1.49	6.25	0.42	0.6	0.23	0.81	0.09	34.55	0.42
2	0.65	0.21	83	0.13	0.08	-	-	-	4.87	0.03
3	3.98	1.56	2.59	0.42	0.6	0.15	0.74	0.09	36.85	0.42

DMS

According to results of DMS studies, it is seen that 158 g of material goes to concentrate 1[a] and 742 g to waste under condition of 954 g of filter dust feeding. The material collected in concentrate constitutes approximately 17% of the feed material. On the other hand, it was determined that the highest density was reached in this experimental group. The density of concentrate was determined as 5.73 g/cm^3. Accordingly, the density changing

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percentage of concentrate was calculated as + 111%. In addition, density of DMS concentrate decrease with increasing rotation speed. Also, density changing of waste in the same experimental group was determined to be -7.72% (Figure 4).

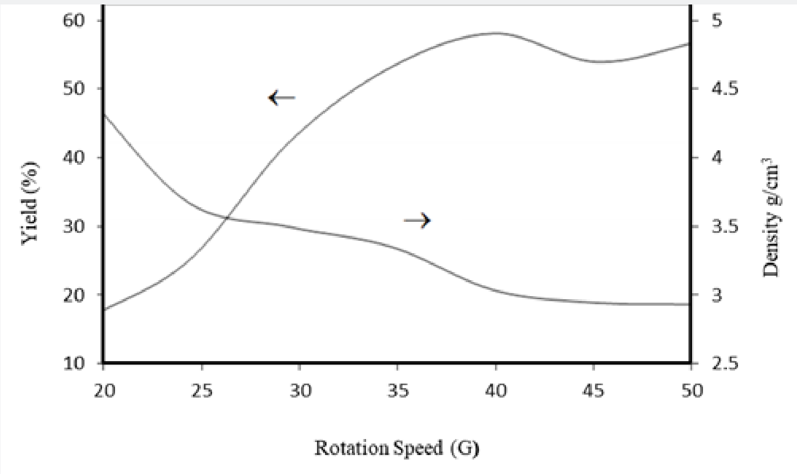

Figure 1: Changing of concentrate amount and density in FGC.

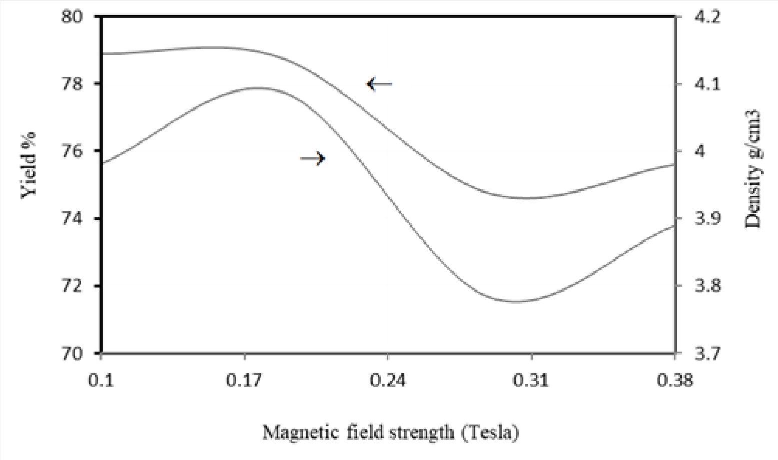

Figure 2: Changing concentration amount and density in WHIS.

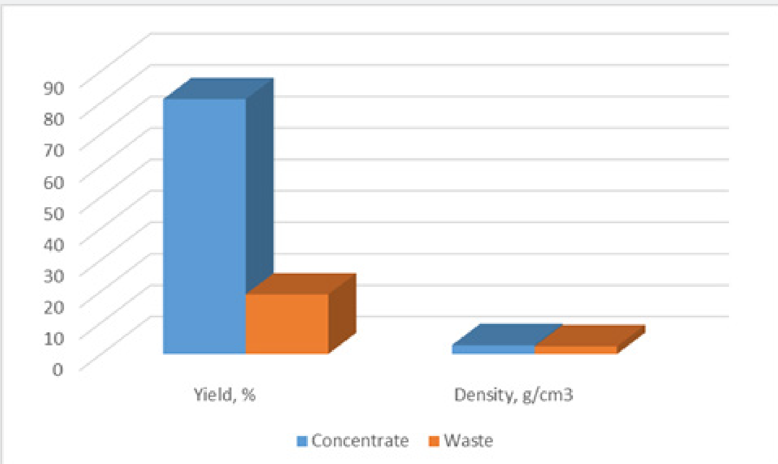

Figure 3: Changing of amount and density in VFHC.

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Characterization

According to results above, various instrumental methods were used to determine the chemical structure and metal contents of the samples with the best results.

It can be claimed that iron should be more in concentrate sections where the highest density values are obtained based on density data of iron. In experimental studies, it is clear that the highest density is achieved with DMS. For this reason, DMS concentrate, DMS waste, and feeding material were chosen to characterization analyses.

The results obtained are shown in Table 2. It is seen that the elemental iron content of feed material is 6.25% Fe so that it is evident that the filter dust is rich in iron. When a factory releases an average of 5 tons of filter dust per day, the monthly loss of metallic iron is about 13 tons. It is seen that iron content in concentrate with DMS is 83% Fe. On the other hand, Al and Si content of the feed material (4.08% Al, 34.55% Si in feeding) decreased to 0.65% and 4.87% in DMS concentrate, respectively. Also, it was determined that iron content in waste obtained with DMS was 2.59% Fe. According to the results of the analysis, the metal recovery efficiency in the concentrate was calculated as 60% for DMS. Optical microscope images of DMS concentrate and waste can be seen in Figure 5. As shown in figure, the concentrate contains bright iron particles. Filter dust also includes dusts that is vacuumed from every section of factory such as CNC machine, spiral cutting, etc. Therefore, the presence of metallic iron particles is actually expected. XRD analysis of feed material and DMS concentrate can be seen in Figure 6. XRD analyses showed that iron which is target metal, is mostly alloyed with other elements in filter dust. Since all the methods used in this study are based on physical separation principles, it is observed that iron maintains its structure in concentrate too.

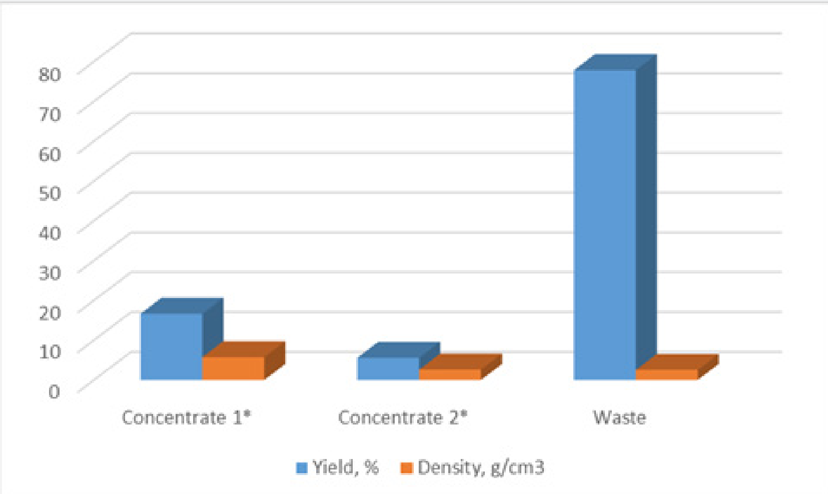

Figure 4: Changing of concentrate amount and density in DMS.

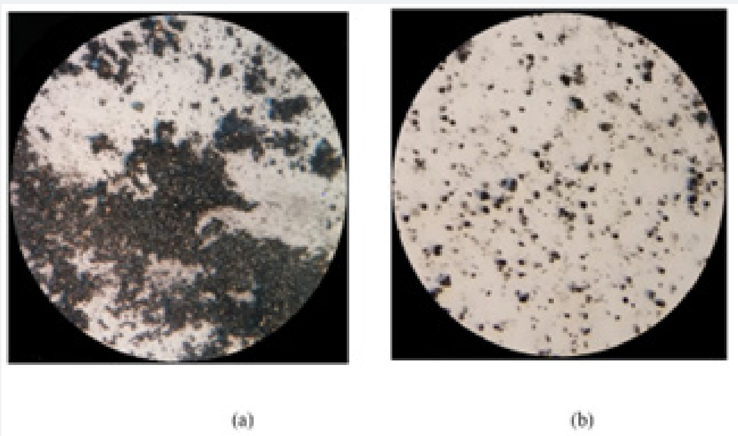

Figure 5: Optical microscope images of DMS, (a) concentrate, (b) waste.

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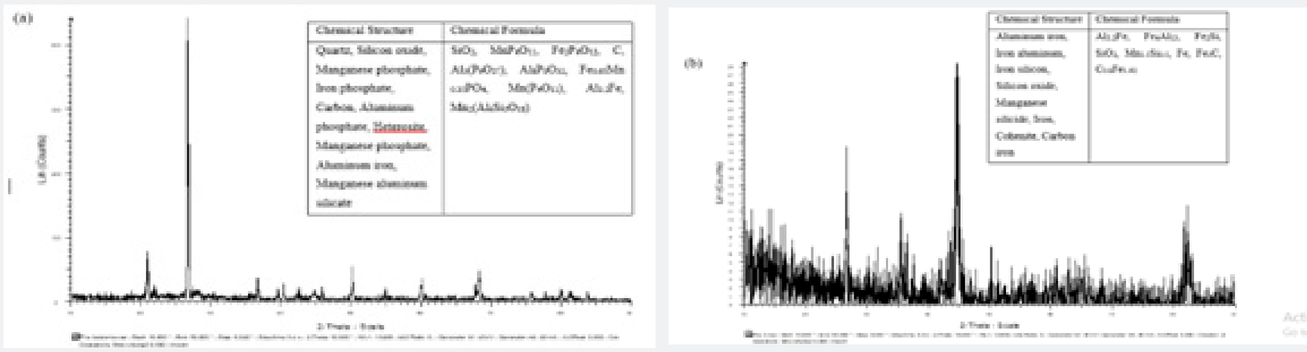

Figure 6: XRD patterns and phase analysis (a) feeding material, (b) DMS concentrate.

Conclusion

The results obtained and some suggestions to recovery of iron from filter dust are given below.

- The recovery of iron from filter dust is considered economically important. However, the biggest obstacle to recovery is that the grain size is very small (63µm).
- According to chemical analysis results of feed material, it was determined that it has a content of 8.68% Fe_2O_3, 7.7% Al_2O_3, 2.1% CaO, 0.5% K_2O, 1% MgO, 0.3% MnO, 1.1% Na_2O, 0.2% P_2O_5, 73.5% SiO_2 and 0.7% TiO_2.
- Enrichment studies were carried out using of i) Falcon Gravimetric Concentrator (FGC), ii) Wet High Intensity Magnetic Separator (WHIMS), iii) Vertical Flow Hydraulic Classifier (VFHC), and iv) Dry Magnetic Separator (DMS).
- The best results were obtained with DMS in 0.10-0.12 Tesla. Results obtained showed that 83% Fe in the DMS concentrate with enrichment efficiency of 60 ± 2%. Also, it was determined that iron content in waste obtained with DMS was 2.59% Fe.
- Optical microscope images showed that the concentrate contains bright iron particles.
- XRD analyses showed that iron in filter dust is in various compound forms with carbide, aluminum, manganese, silica and phosphate. As a result of physical separation, it was determined that DMS concentrate contains the same iron forms.
- According to the metal content analysis, Fe2O3 generally decreases in DMS waste while Al_2O_3 and SiO_2 increases in waste.
- Considering the best results are obtained by DMS with 60% efficiency, it is suggested that recovery yield can be increased with using a constant DMS. DMS experiments were carried out in a rotary drum system. There is a possibility that the non-magnetic parts of iron particles, which is in form of compound-alloy, will come onto the magnetic drum. Therefore, it is predicted that recovery efficiency will be increased by passing it through a fixed magnetic field system, but for a longer period. This system can be a permanent magnet device.

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