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REMOVAL OF IRON FROM FLY ASH FOR CERAMIC AND REFRACTORY APPLICATIONS

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The natural resources of refractory raw materials are declining and at the same time the consumption rate is increasing, particularly in iron and steel industries. Any attempt to identify a new raw material source from the waste dumps could solve the national economy as well as environmental problems. In view of this, fly ash from thermal power plant has been identified for use in the ceramic/refractory industries after suitable beneficiation. For this wet high intensity magnetic separation studies carried out on typical fly ash sample indicate that the non-magnetic fraction (*product*) containing 24% Al_2O_3, 67% SiO_2, 1.7% Fe_2O_3 could be achieved with 63% recovery. This product is acceptable as a ceramic and refractory raw material after the necessary blending.

Keywords: Fly ash; Refractory; Ceramics; Environment; Iron; Alumina; Magnetic separation

INTRODUCTION

Thermal power plants of iron and steel industries are the primary source for the generation of fly ash. The total generation of fly ash in India is around 30 Mt/annum [1]. The utilization pattern of fly ash is limited to the cement mixing, building blocks, embankment and road making. It accounts for 2–3% consumption in India and 5–10% in elsewhere [2–4]. Typical data presented on utilization pattern of fly ash elsewhere is shown in Fig. 1.

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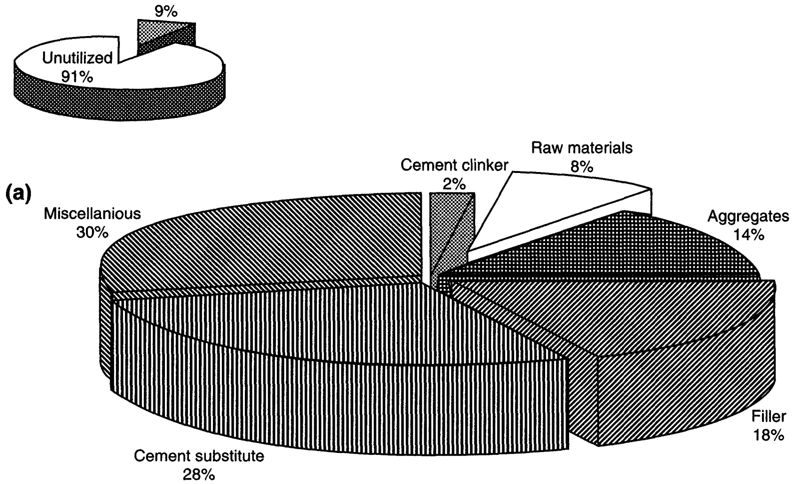

FIGURE 1 Fly ash utilization. (a) Utility pattern of fly ash.

Under the Indian scenario the projected requirement of refractory raw materials for the year 2002 from both indigenous and imported sources of alumina is 0.19 Mt [5], whereas the total estimated resources of refractory alumina raw materials (bauxite, kynite, silliminite) is only 0.10 Mt. Hence identifying any alternate resource is essential. Since fly ash is essentially rich in silica and alumina with certain amount of ferric oxide as impurity it may also find extensive uses in making value added ceramic/refractory raw material/product after the removal of iron [6,7]. Analyses of typical fly ash sample from different sources shown in Table I to indicate that samples contain Al_2O_3 24–36%, SiO_2 54–60% and Fe_2O_3 ranging from 2.7% to 6.4%. Any attempt to reduce Fe_2O_3 from these samples, may be useful to produce raw material for ceramic/ refractory after blending.

Literature reveals that there are many established routes to remove iron from other raw materials. The leaching of iron by using acids is not environment friendly, moreover, filtration of the product is difficult. The alternate process is physical beneficiation either by flotation or magnetic separation [8–10]. In the flotation process, due to reagent addition, the settling of tailings may cause environmental problem. Hence, high intensity magnetic separation is the best approach for the removal of iron from fly ash.

TABLE I The Earlier work on chemical analysis of fly ash (%) of different sources

Constituents	*Visakhapatnam* [5]	*Vijayawada* [3]	*Rourkela* [1,2]	*Manguru* [5]
Al_2O_3	35.9	30.5	24.0	33.2
SiO_2	58.0	53.9	55.0	60.0
Fe_2O_3	2.7	3.5	6.4	2.9
TiO_2	1.4	1.97	1.1	0.05
CaO	0.12	1.85	—	0.45
MgO	0.37	0.63	2.0	
Na_2O		0.46	0.4	
K_2O		0.64	3.4	
LOI		6.58		

In view of the conservation of refractory raw materials for preparation of various ceramic/refractory products and also to introduce fly ash as substitute, a typical fly ash sample from a thermal power plant of the steel plant, Visakhapatnam, Andhrapradesh, India, was chosen for the present investigation. This paper deals only with wet high intensity magnetic separation (WHIMS) studies for the removal of iron and recommendations for the end use of product are made.

EXPERIMENTAL

The fly ash was procured from steel plant Visakhapatnam, Andhrapradesh, India. The size analysis of the fly ash sample was carried out by using standard wet sieves. Magnetic separation studies were carried out on narrow size fractions by using wet high intensity separator (Boxmag Rapid, Type L.H.W; England) with variable magnetic grid and current. The grid is formed by magnetic stainless steel wedge-wires those are spaced apart to form an element. Several elements are spaced apart to form a grid. The grid is inserted into its holder for separation. Standard separating grids with 2 and 1 mm spacing between wires were used for particle size ranges of +500, +50 μm and the stainless steel wool used for particles smaller than 50 μm.

The sample was well conditioned to avoid the presence of agglomerate particles. This dispersed sample was subjected to magnetic separation by using laboratory peristaltic pumps. In the present study the non-magnetic fraction is the product. All the magnetic and non-magnetic fractions were dried and analyzed for alumina, silica and iron. The chemical analysis were carried out by wet chemical methods.

The effect of magnetic intensity was evaluated on the basis of the separation efficiency.

RESULTS AND DISCUSSION

The X-ray diffraction data on fly ash as shown in Table II, represent the minerals present in the order of abundance ($l/l_{0\ max}$ vs $d\theta$). The data indicate that the silicate minerals are more significant followed by the alumina minerals. Mullite, tridymite and glass are the secondary products of combustion. Iron is mostly present as the hematite mineral.

The feed analysis as shown in Table III, indicates that fly ash contains 23.3% alumina, 62.4% silica and 9.6% ferric oxide. The size and elemental analysis shown in Table IV indicate that iron is almost equally distributed in all size fractions. However, the size fraction $-500+50\ \mu m$ contains maximum Fe_2O_3 9.9% accounting for more than 75% of the weight distribution.

TABLE II Minerals present in fly ash in the order of abundance (l/l_{max})

Minerals	*Chemical composition*
Quartz	SiO_2
Orthoclase	$KAlSi_3O_8$
Gibbsite	$Al(OH)_3$
Kaolinite	$Al_4(OH)_8Si_4O_{10}$
Hematite	Fe_2O_3
Mullite	$Al_2O_3:SiO_2=3:2–2:1$
Tridymite	SiO_2
Glass	SiO_2

TABLE III Complete analysis of fly ash

Constituents	*% by weight*
Al_2O_3	23.2
SiO_2	62.5
Fe_2O_3	9.6
TiO_2	0.12
Mn	0.04
CaO	2.2
MgO	0.04
Na_2O+K_2O	1.0
LOl	1.3
Total	100.0

TABLE IV Size distribution and elemental analysis

Size, μm	*Weight*, %	Al_2O_3, %	SiO_2, %	Fe_2O_3, %
−1000 + 500	6.4	24.5	56.5	9.2
−500 + 50	78.3	23.7	63.1	9.9
−50	15.3	21.1	62.8	8.4
Total	100.0	23.3	62.6	9.6

TABLE V Results of magnetic separation on +500 μm size fraction

Details	*Weight*, %	Al_2O_3, %		SiO_2, %		Fe_2O_3, %	
		Grade	*Rec.*	*Grade*	*Rec.*	*Content*	*Removal*
Magnetics	40.0	23.2	37.9	55.5	39.3	19.8	13.7
Non-magnetics	60.0	25.4	62.1	57.1	60.7	2.1	86.3
Total	100.0	24.5	100.0	56.5	100.0	9.2	100.0

Conditions Gap: 2 mm, Mag. Intensity: 1.75 T.

The effect of magnetic intensity on the feed sample indicates that, as expected, with the increase of magnetic intensity, the weight of the non-magnetic fraction as well as the iron content decrease. The overall separation efficiency for the removal of iron also improves with increasing magnetic field. The maximum separation efficiency for the iron removal achieved from the feed sample is 87%.

The results of magnetic separation on +500 μm size fraction shown in Table V indicate that the removal of iron is significant and at the same time a marginal enrichment of alumina and silica is also noticed. It can be clearly seen from the data that the non-magnetic fraction obtained contains 2.1% Fe_2O_3, from the feed containing 9.2% Fe_2O_3, representing 86% iron removal. The Al_2O_3 content has been enriched to 25% with 62% recovery. Similarly the SiO_2 content has been enriched to 57% with 61% recovery.

The results of magnetic separation on +50 μm size fraction are shown in Table VI. The data indicate that the magnetic separation process has achieved a marginal enrichment of alumina and silica content in the non-magnetic product. However, the iron content in the non-magnetic fraction is significantly reduced to 1.8% Fe_2O_3 from a feed containing 9.9% Fe_2O_3 which represent 89% iron removal. The Al_2O_3 content has been enriched to 25% with 63% recovery. Similarly the SiO_2 content has been enriched to 67% with 65% recovery.

TABLE VI Results of magnetic separation on $-500+50\,\mu m$ size fraction

Details	*Weight*, %	Al_2O_3, %		SiO_2, %		Fe_2O_3, %	
		Grade	*Rec.*	*Grade*	*Rec.*	*Content*	*Removal*
Magnetics	39.2	22.4	37.0	56.6	35.2	22.4	11.1
Non-magnetics	60.8	24.7	63.0	67.3	64.8	1.8	88.9
Total	100.0	23.7	100.0	63.1	100.0	9.9	100.0

Conditions Gap: 1 mm Mag. Intensity: 1.95 T.

TABLE VII Results of magnetic separation on $-50\,\mu m$ size fraction

Details	*Weight*, %	Al_2O_3, %		SiO_2, %		Fe_2O_3, %	
		Grade	*Rec.*	*Grade*	*Rec.*	*Content*	*Removal*
Magnetics	39.3	18.3	34.1	53.1	33.2	20.1	5.8
Non-magnetics	60.7	22.9	65.9	69.0	66.8	0.8	94.2
Total	100.0	21.1	100.0	62.8	100.0	8.4	100.0

Conditions Gap: Steel Wool, Mag. Intensity: 1.2 T.

TABLE VIII Summary of the results of magnetic separation on grade and recovery of non-magnetic products

Size, μm	*Product weight*, %	Al_2O_3, %	SiO_2, %	Fe_2O_3, %	*Recovery*, Al_2O_3, %	*Removal*, Fe_2O_3, %
+500	3.8	25.4	57.1	2.1	4	99
+50	47.6	24.7	67.3	1.8	50	91
−50	9.3	22.9	69.0	0.8	9	99
Total	60.7	24.4	66.9	1.7	63	93

The magnetic separation studies on $-50\,\mu m$ size fraction shown in Table VII indicate that magnetic separation has shown marginal enrichment of the grade and recovery of alumina. However, the effect is more pronounced on iron followed by silica. The non-magnetic fraction containing 0.8% Fe_2O_3 and 69% SiO_2 could be achieved from a feed containing 8.4% Fe_2O_3 and 62.8% SiO_2, accounting for 94% iron removal and 67% for recovery of SiO_2.

Summary of the results of magnetic separation is shown in Table VIII. The data indicate that the non-magnetic fraction of $-500+50\,\mu m$ size fraction contains 1.8% Fe_2O_3 and 67% SiO_2. The size fraction below $50\,\mu m$ contains 0.8% Fe_2O_3 and 69% SiO_2. The overall product obtained from the non-magnetic fraction contains 24.4% Al_2O_3, 66.9% SiO_2 and 1.7% Fe_2O_3 with 60% yield and 63% alumina recovery. The overall product may be suitable for use as a ceramic raw material and after suitable blending with bauxite, kynite, silliminite or alumina, this product may also be useful as a refractory raw material.

CONCLUSIONS

Fly ash contains 23% Al_2O_3, 63% SiO_2 and 10% Fe_2O_3. The results of wet high intensity magnetic separation reveal that the overall product containing 24% Al_2O_3, 67% SiO_2 and 1.7% Fe_2O_3 with 63% recovery could be achieved from a non-magnetic fraction. This product is suitable as a raw ceramic material and after necessary blending this material can also be useful for refractory products.

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