

# EXTRACTION OF ALUMINA FROM COAL FLY ASH

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**Abstract** - The Coal Fly ash is one of the by-products of coal combustion process. Although coal fly ash disposal is of environmental concern the quality of residues can be improved with respect to high value applications. Fly ash is considered as a potential source of aluminium and other strategic metals. Instead of disposing Fly ash directly it is used for metal extraction by leaching process. Although this extraction process is not efficient compared to extraction of aluminium by bayer process, it helps to reduce the volume of Fly ash disposal. Leaching and metal extraction behaviour of fly ash collected from Sree Rengaraj Ispat Industries Pvt Ltd have been thoroughly studied using sulphuric acid as Leaching agent. The chemical and mineralogical compositions of post-leached samples have been determined. Alumina extraction by direct leaching at low acid concentration and ambient temperature is not suitable for high recovery. The extraction efficiency of aluminium increases significantly at a higher solid: liquid ratio. It is evident that the leachability of metals from fly ash depends on the nature of leaching medium, solid: liquid ratio, temperature and leaching time.

**Key Words:** Alumina, Fly ash, Leaching, Sulphuric acid.

## 1. INTRODUCTION

Solid wastes are those organic and inorganic waste materials produced by various activities of the society, which have lost their value to the first user. Improper disposal of solid wastes seriously spoiling the environmental conditions in developing countries. The solid waste generated through domestic and commercial activities is classified as municipal solid waste. The solid waste generated by industries is known as industrial solid waste. Among them there has been a significant increase in industrial waste generation in India in the last few decades. Management of industrial wastes have generally remained somewhat neglected in India. Due to rapid growth of industries, as well as constraint in resources, the management of solid waste poses a difficult and complex problem for the society and its improper management gravely affects the public health and degrades environment.

Fly ash is one of the industrial waste products from thermal power plants have been utilised about 1-2% of fly ash by cement industry. The disposal of huge fly ash has always remained a big headache in India which pollutes the environment. In this thesis, Aluminium is extracted from coal fly ash by Leaching process which is one of the metal extraction method.

In view of the use of coal of relative high ash content made available to thermal power projects. The amount of fly ash generated from 69 thermal power stations in 1998 was estimated to be of the order of 60 million tons. The estimate was updated to 90 million tons from 82 thermal power stations, having aggregate capacity of 60,000 MW in the year 2000, 125 million tons in year 2005 to generate 1,15,000 MW and it is estimated to be 150 million tons in year of 2010 to generate 1,40,000 MW electricity, which is expected to go up every year, with increase in production of electricity from coal-base thermal plants. The coal used in India is predominantly bituminous, which gives rise to low-lime fly ash. Sub-bituminous lignite coal, used in some power plants gives high-lime fly ash. In view of their large scale availability, low-lime fly ashes are mainly used in India and elsewhere.

## 2. MATERIALS AND METHODOLOGY

### Fly Ash

The Fly Ash material used throughout this study was provided by Sree Rengaraj Ispat Industries Pvt Ltd which is one of the leading industry in SIPCOT Industrial Growth Center, Perundurai. The collected samples were dried at 105 °C for 24 h and the particle size distribution (PSD) of fly ash was obtained by physically screening the samples using 200 and 75 µm screens.

### Reagent

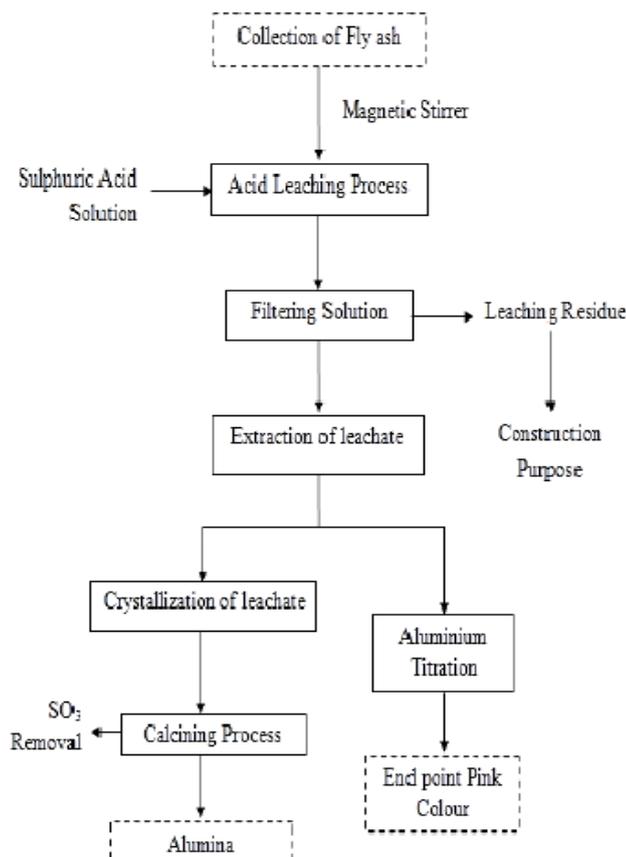
All reagents used in this study were of analytical grade (AR). Analytical grade reagents are chemical substances of sufficient purity fit for laboratory and general use according to International standards (ASTM, 2012; Grades of chemicals, 2008). The main reagent used for the Leaching purpose is Sulphuric Acid (H<sub>2</sub>SO<sub>4</sub>) and distilled water is used for acid dilution.

The reagents required were made up as follows:

4.5 M Sulphuric acid: 250 ml concentrated H<sub>2</sub>SO<sub>4</sub> was added to 750 ml of de-ionised water in a beaker.

### Methodology

The step by step Procedure for the extraction of alumina from fly ash is represented as Flow chart in the Fig 1.



**Fig 1:** Flow Chart for the Extraction of Alumina from Fly ash

Steps involved in this process are,

1. Initially the fly ash is collected from Industry and analyse the Chemical Composition and sieve them for 200µm sieve.
2. By adding diluted H<sub>2</sub>SO<sub>4</sub> with raw fly ash, the solution is stir in magnetic stirrer and heated for making slurry in which water content is removed.
3. Then the slurry is filtered and using diluted water the residue is washed to neutralize the acid content.
4. The solution extracted from the slurry is crystallized and complexation titration of determining aluminium content is done.
5. The crystallised leachate is calcined to remove the SO<sub>3</sub> content and Aluminium oxide is extracted.

### 3. EXPERIMENTAL PROCEDURE

#### Acid Leaching Process

An acidic leaching test was performed using sulphuric acid. The H<sub>2</sub>SO<sub>4</sub> indirect leaching test was adapted. Varying concentrations of H<sub>2</sub>SO<sub>4</sub> (2 M, 4 M, 6 M, 8 M, 10 M) were mixed with 100 g CFA. The mixture was taken in a one-litre flask and boiled on constant stirring.

It was then stirred at 200 rpm while heating on a hotplate Magnetic stirrer at 30°C-85°C. The reaction was allowed to proceed until all the liquid evaporated. The reaction vessel then remained on the hotplate at that temperature for a further 30 minutes then the mixture normally became slurry due to loss of water.



#### Filtration of Residue

Once cooled, de-ionised water was added to the CFA residue in a solid: liquid ratio of 1:6. The mixture was stirred rapidly at a temperature range of 85 - 90 °C for 30 minutes. The purpose of this secondary step was to separate the leached Al in the form of Al<sub>2</sub>SO<sub>4</sub> from the CFA matrix. Finally, the mixture was extracted with 500-ml hot distilled water, filtered through a G3 Buchner funnel using suction pump. The residue was washed twice with hot distilled water to reduce the acid content present in residue.

#### Calcining Process

The Leachant obtained after the crystallisation taken in a crucible and heated in muffle furnace for extraction the alumina in solid form is finally extracted. The calcination temperature range is 500-1000°C. After certain of calcination time, take out and cool to room temperature. In this process the Sulphur trioxide is removed and hence to obtain the solid alumina (Al<sub>2</sub>O<sub>3</sub>). The Calcining process of leachate liquor in the muffle furnace.



### 4. RESULT AND DISCUSSION

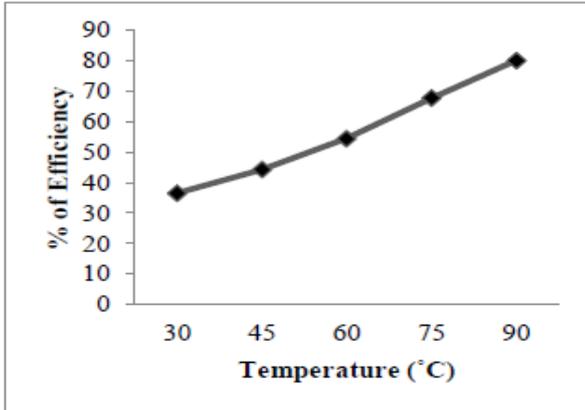
CFA is directly leached by H<sub>2</sub>SO<sub>4</sub> according to the orthogonal test below. The effect of temperature, time, acid concentration and ratio of solid and liquid are estimated. However, liquid/ash has little effect on the alumina extraction rate. It can be seen that in CFA, mullite, quartz and glass phase can't be destroyed by sulphuric acid. The leaching efficiency was based on the weight of alumina in CFA and the weight of alumina in the leach solution:  $\eta = \frac{W_l}{W_s} \times 100$  where  $\eta$ ,  $W_l$ , and  $W_s$  are the leaching efficiency, the weight of alumina in the leach solution, and the weight of alumina in CFA respectively.

#### Effect of temperature

Fixed experiment condition is setting acid leaching time as 4h, concentration of H<sub>2</sub>SO<sub>4</sub> as 6M and ratio of solid and liquid as 1:4. Given the demand of low energy of experiment, the experiment conducting five single factor analyses in the temperature below 100°C, obtains the result as following graph as shown in Fig 2. The Table 1 shows that the increase of reaction temperature, the extraction efficiency also rises and the maximum efficiency occurs at temperature of 90°C of about 80.05%.

**Table 1:** Effect of temperature

Temperature (°C)	30	45	60	75	90
% of Efficiency	36.5	44.23	54.4	67.7	80.05



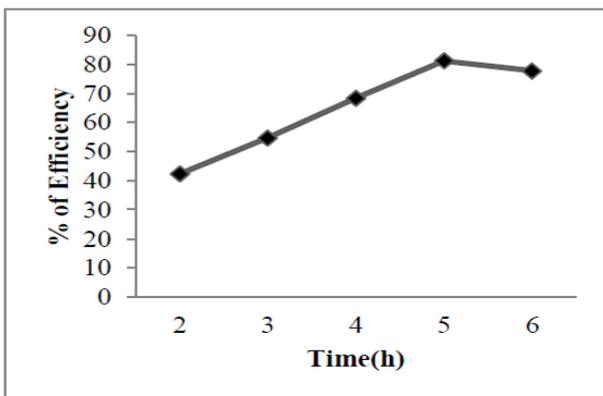
**Fig 2 :** Effect of Temperature

**Effect of time**

Fixed experiment condition is setting acid leaching temperature as 60°C, concentration of H<sub>2</sub>SO<sub>4</sub> as 6M and ratio of solid and liquid as 1:4. Given the demand of low energy of experiment, the experiment conducting five single factor analyses in the time as 2h-6h, obtains the result as following graph as shown in Fig 3. The Table 2 shows that the increase of reaction temperature, the extraction efficiency also rises and the maximum efficiency occurs at time 5h of about 81.2%.

**Table 2:**Effect of time

Time(h)	2	3	4	5	6
% of Efficiency	42.3	54.7	68.4	81.2	77.8



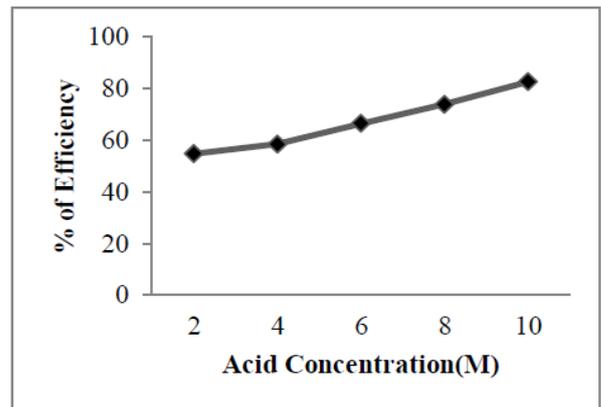
**Fig 3 :** Effect of time

**Effect of Acid Concentration**

Fixed experiment condition is setting acid leaching temperature as 60°C, leaching time as 4h and ratio of solid and liquid as 1:4. Given the demand of low energy of experiment, the experiment conducting five single factor analyses in concentration of H<sub>2</sub>SO<sub>4</sub> as 2M, 4M, 6M, 8M and 10M, obtains the result as following graph as shown in Fig 4. The Table 3 shows that the increase of reaction temperature, the extraction efficiency also rises and the maximum efficiency occurs at acid concentration of 10M of about 82.4%.

**Table 3:** Effect of Acid Concentration

Acid Concentration (M)	2	4	6	8	10
% of Efficiency	54.6	58.32	66.35	73.8	82.4



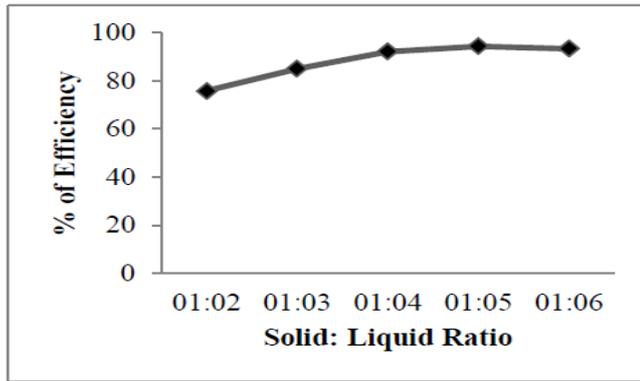
**Fig 4 :** Effect of Acid Concentration

**Effect of solid and liquid Ratio**

Fixed experiment condition is setting acid leaching temperature as 60°C, leaching time as 4h and concentration of H<sub>2</sub>SO<sub>4</sub> as 6M. Given the demand of low energy of experiment, the experiment conducting five single factor analyses in the ratio of solid and liquid as 1:2, 1:3, 1:4, 1:5 and 1:6, obtains the result as following graph as shown in Fig 5. The Table 4 shows that the increase of reaction temperature, the extraction efficiency also rises and the maximum efficiency occurs at S/L ratio of 1:5 of about 94.3%.

**Table 4:** Effect of S/L ratio

Solid/liquid ratio	1:2	1:3	1:4	1:5	1:6
% of Efficiency	75.8	85.01	92.1	94.3	93.9



**Fig 5 : Effect of S/L ratio**

## 5. CONCLUSION

Leaching of CFA in sulphuric acid resulted in simultaneous extraction of alumina. Under such conditions, total extraction efficiency of 94.2% alumina was obtained. Through a direct leaching process, amorphous and crystal phases of aluminium in coal ash were leached under atmospheric pressure. For effective separation impurities other than Al<sup>3+</sup> need to be removed through a suitable process. It is concluded that direct acid leaching at low concentration and ambient temperatures is not satisfactory for high recoveries of these metals from this fly ash. The concentrations of the acids were varied from low to concentrated reagent. Hence, low to moderate recoveries of metal values from fly ash by direct acid leaching is not surprising. The leachability of metals from fly ash depends on the nature of leaching medium, solid: liquid ratio, temperature and leaching time. The following conclusions can be drawn:

- By varying temperature with 6M sulphuric acid at 90°C in 4 h and an S/L of 1:4, alumina extraction  $\eta_1$  from raw CFA reached 80.05%.
- By varying time with 6M sulphuric acid at 60°C in 5 h and an S/L of 1:4, alumina extraction  $\eta_2$  from raw CFA reached 77.8%.
- By varying acid concentration with 10M sulphuric acid at 60°C in 4 h and an S/L of 1:4, alumina extraction  $\eta_3$  from raw CFA reached 82.4%.
- By varying ratio of solid and liquid with 6M sulphuric acid at 60°C in 4 h and an S/L of 1:5, alumina extraction  $\eta_4$  from raw CFA reached 94.3%.
- By removing alumina content from the fly ash can be used for the extraction of SiO<sub>2</sub> and CaO and Ga contents.

From the above four results the conclusion of the report in the extraction efficiency of alumina increases with the increase of solid and liquid ratio.

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