International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.3, Issue.1, Jan-Feb. 2013 pp-133-138 ISSN: 2249-6645

Removal of Ash Content from Indian Coal by Using Solvents

Biswajit Saha, [1] Chanchalmondal[2]
1, 2(Department of chemical engineering, Jadavpur University, West Bengal, India

ABSTRACT: *Coal is most important fossil fuel in world. Energy requirement of world is increasing in many fields day by day. The crude oil and coal are the main backbone of energy. Since the reserves of crude oil are decreasing day by day as a result the coal becomes the main sources of fossil fuel. Ash content of Indian coal is very high ranging from 15% to 55% [1]. Ash is an inorganic compound present into the coal defined as a mass of incombustible material remaining after complete combustion of coal as a percentage of the original mass of the coal. It is mainly due to the presence of silicon-di-oxide, Aluminium oxide, Ferric oxide and Calcium oxide. In this paper, the different experiments have been done using different solvents such as N-Methyl-2-Pyrrolidone (NMP), Furfural, Aniline, Acetic Acid and Toluene with different concentration. Comparative study of different solvents show NMP is the best solvent or extractant with respect to the removal of ash content from coal. The maximum reduction of ash content of coal is 72 % at 120^{0}C and 1 atmospheric pressure in presence of NMP as an extractant which has high chemical and thermal stability. NMP is recyclable and biodegradable and it is not a hazardous chemical. 65% of NMP was recovered by thermal distillation at 202^{0}C-206^{0}C and then using hot air oven remaining part of NMP was removed from mixture of NMP and coal dust.*

Keywords: *Coal dust, Extractant, Hot Air Oven, NMP (N-Methyl-2-pyrrolidone), Thermal Distillation*

I. INTRODUCTION

This century coal is the heart in energy field. Global coal consumption grew by 7.6% in 2010 which is the fastest global energy rate since 2003 [7]. Coal represent at present about 70% of world's proven fossil fuel resources. Moreover coal is also a more delocalized resource; it has lower cost among the different fossil fuel [4]. Coal is classified mainly (a) Anthracite (b) Bituminous (c) Lignite. Among them Bituminous and Lignite has high ash contain.

Table-1: Bulk chemical composition of coal ash [5]

Component	Bituminous	Lignite
SiO_2	20-60	15-45
Al_2O_3	5-35	10-25
Fe_2O_3	10-40	4-15
CaO	1-12	15-40
MgO	0-5	3-10

Indian coal has high ash content and is to be fallen into Bituminous and lignite category, so it is very poor in quality compare to other countries.

Table-2: Typical ash characteristics [1]

Compound (%)	India	Australia	Canada	S. Africa
SiO_2	57.0	59.0	53.0	49.0
Al_2O_3	27.0	28.5	30.5	30.1
Fe_2O_3	10.0	3.6	4.8	6.9
CaO	1.7	1.35	3.9	5.5
MgO	0.63	0.75	0.4	1.3
Na_2O	0.35	0.65	0.9	0.8
$S0_3$	0.56	0.9	2.5	3.6

The main utilization of coal is in power plant, currently 71% on India's electricity is generated from coal [13]. But ash content of coal creates a lot of problems including erosion, difficulty in pulverization, poor emissivity, flame temperature [10, 11] and also efficiency of thermal power station as a result the production cost of electricity is high. The low ash coal can reduce erosion rates by 50-60%, maintenance costs by 35% and increase thermal efficiencies as much as 4-5% [9,8] and also reduces amount of emitted fly ash and hazardous air pollutant precursors, improves health and safety and mitigates environmental degradation [12]. Coal purification process first started in U.S.A., Japan and other European countries [13].

The coal extract knows as solvent refined coal which can be used as such for various purposes or further processed

to obtain syncrudes and host of chemicals [2]. Cleaning of coal mainly divided into two processes (a) Mechanical (b) Chemical [1]. In India many researcher work on removal of ash from coal by various chemical and solvents like((a) Mixture of calcium fluoride and sulphuric acid (b) Anthracene oil (c) Sulphuric acid (d) Hydrochloric acid (e) Sodium Hydroxide (f)Mixture of NMP and Ethylene-di-oxide) [1,2,6,14]. But in this experiment a comparative study on performance to remove the ash content from Indian coal is shown among NMP, Aniline, Furfural, Acetic acid, Toluene as anextractant and recovery process of solvent is conducted by thermal distillation process.

II. MATERIAL AND METHOD

2.1 Preparation of samples

Four types of coal samples have been collected from different mines having different percentages of ash. The samples are leveled A, B, C and D and their ash contents are 4.7%, 26%, 37% and51.1% respectively. The samples are properly grinded and have been passed through 72 mesh.

2.2 Experimental procedure

Five solvents such as NMP, Furfural, Aniline, Acetic acid and Toluene have been selected based on literature survey to remove ash from coal samples. Initially four samples, leveled A, B, C, and D are mixed with individual solvents in four different containers having same solvent to coal ratio. The coal added solvents has been heated at 120^{o} C where a mechanical starrier has been used as shown in figure1 to ensure proper mixing for half an hour. After that the mixture has been sent to thermal distillation unit as shown in figure 2 to recover the solvents. Approximately 65% solvent has been recovered by this process the remaining part of solvent of mixture is removed by drying it in hot air oven and again the ash content of solvent refined coal [12] has been determined using proximate analysis. The same procedure has been repeated taking different solvent to coal ratio.

Fig. 1. Mechanical strirrer with continous heating system

Fig. 2. Thermal Distillation column setup

III. RESULT AND DISCUSSION

Several experiments have been done using different solvents such as NMP, Aniline, Furfural, Acetic Acid and Toluene with their different concentrations to remove ash content of coal leveled A , B, C, and D.

3.1. Removal of ash of Sample leveled D.

The experimental results have been tabulated as shown in table 1 where first column shows the concentrations of solvents and remaining columns show the removal of ash contents in the respective solvents. These data have been plotted as shown in figure 3

Table : 3.1 Performance of 5 solvents on removal of ash content of sample labeled D

Concentration Coal: Solvent	Percentage removal of ash				
	NMP	Aniline	Furfural	Acetic Acid	Toluene
1:6	8%	6%	5%	1.2%	1.25%
1:10	18%	8%	7%	1.5%	1.55%
1:15	18%	8%	7%	1.5%	1.55%
1:19	18%	8%	7%	1.51%	1.55%
1:20	17.9%	7.9%	6.98%	1.51%	1.55%
1:22	17.9%	7.9%	6.98%	1.51%	1.56%

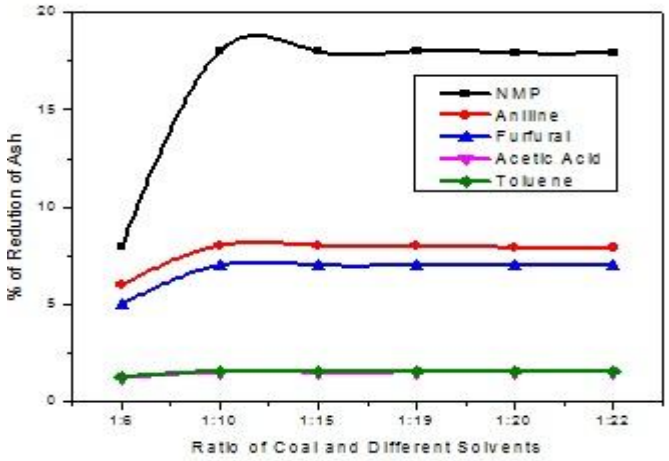

Fig. 3:- performance curve of different solvents on removal of ash of sample labeled D

It is evident from figure3 that NMP has a highest capacity to remove the ash compare to other four solvents. Reduction of ash is increased in case of NMP with increase of solvent concentration at a certain level . After that reduction of ash content is start to decrease with increase of solvent concentration. Maximum reduction of ash is found 18% with 1:10 concentration of NMP. The same trend is followed in case of Aniline and Furfural. But reduction of ash content is 8 & 7% respectively when the coal and solvent ratio is 1:10. It is clear from the figures that Acetic acid and Toluene show the same characteristics for the removal of ash from coal. The maximum reductions of ash are ranges from 1.50% to 1.55% and it is also almost constant at any concentrations of those solvents.

3.2. Removal of ash of Sample leveled C

The experimental results have been tabulated as shown in table 2 where first column shows the concentrations of solvents and remaining columns show the removal of ash contents in the respective solvents. These data have been plotted as shown in figure 4

Concentration Coal: Solvent	Percentage removal of ash				
	NMP	Aniline	Furfural	Acetic Acid	Toluene
1:6	3.5%	5.4%	5%	1.5%	1.30%
1:10	5.4%	6.75%	6.4%	1.86%	1.55%
1:20	11%	8.1%	7.5%	1.86%	1.55%
1:30	13.5%	11.35%	10.8%	1.86%	1.55%
1:40	20%	19%	19%	1.86%	1.54%
1:45	20%	19%	19%	1.85%	1.54%

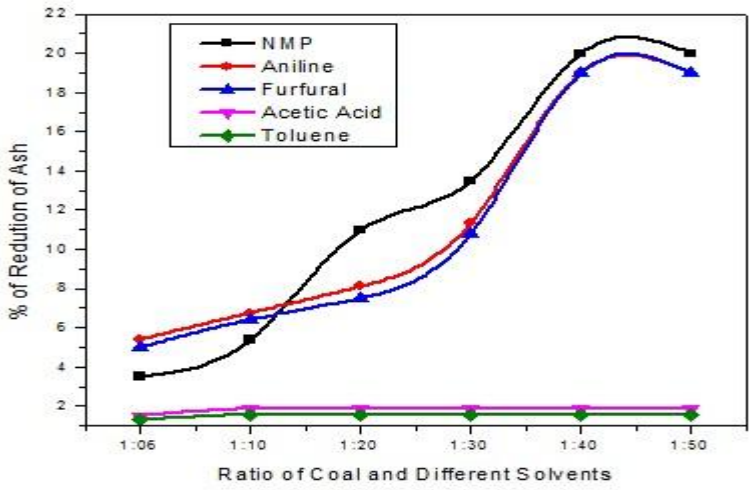

Fig. 4:- :- performance curve of different solvents on removal of ash of sample labeled C

It is evident from figure4 that, reduction of ash is increased in case of NMP with increase of solvent concentration at a certain level. After that reduction of ash content is start to decrease with increase of solvent concentration. Maximum reduction of ash is found 20% with 1:40 concentration of NMP. The same trend is followed in case of Aniline and Furfural.

But reduction of ash content is 19% both when the coal and solvent ratio is 1:40. It is clear from the figures that Acetic acid and Toluene show the same characteristics for the removal of ash from coal. The maximum reductions of ash are ranges from 1.55% to 1.86% and it is also almost constant at any concentrations of those solvents.

3.3. Removal of ash of Sample leveled B

The experimental results have been tabulated as shown in table 3 where first column shows the concentrations of solvents and remaining columns show the removal of ash contents in the respective solvents. These data have been plotted as shown in figure 5

Concentration Coal: Solvent	Percentage removal of ash				
	NMP	Aniline	Furfural	Acetic Acid	Toluene
1:6	9.6%	7.7%	7.4%	1.7%	1.67%
1:10	26%	14.7%	15%	1.8%	1.9%
1:20	26%	19%	18.5%	1.8%	1.9%
1:30	26%	19%	18.5%	1.8%	1.9%
1:40	25.96%	19%	18%	1.78%	1.89%
1:50	25.96%	18.9%	18%	1.79%	1.88%

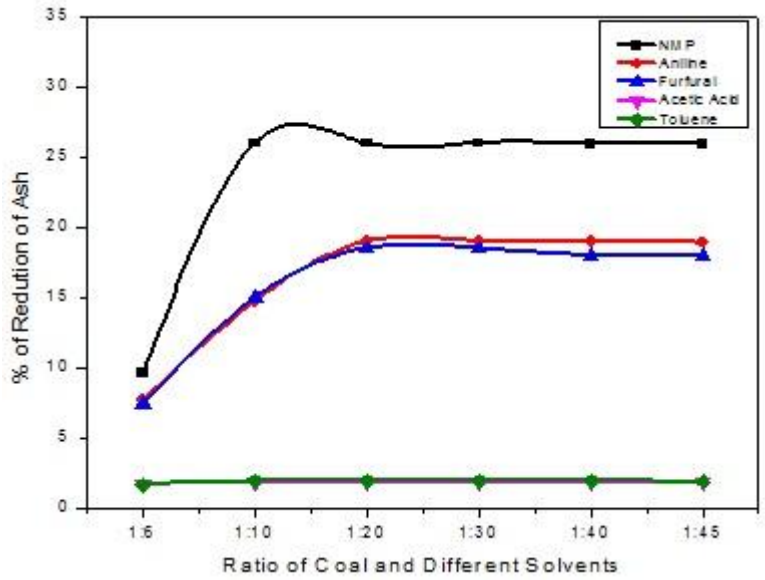

Fig. 5:- :- performance curve of different solvents on removal of ash of sample labeled B

It is evident from figure5 that NMP has a highest capacity to remove the ash compare to other four solvents. Reduction of ash is increased in case of NMP with increase of solvent concentration at a certain level . After that reduction of ash content is start to decrease with increase of solvent concentration. Maximum reduction of ash is found 26% with 1:10 concentration of NMP. The same trend is followed in case of Aniline and Furfural. But reduction of ash content is 14.7 & 15% respectively when the coal and solvent ratio is 1:10. It is clear from the figures that Acetic acid and Toluene show the same characteristics for the removal of ash from coal. The maximum reductions of ash are ranges from 1.8% to 1.9% and it is also almost constant at any concentrations of those solvents.

3.4. Removal of ash of Sample leveled A

The experimental results have been tabulated as shown in table 4 where first column shows the concentrations of solvents and remaining columns show the removal of ash contents in the respective solvents. These data have been plotted as shown in figure 6.

Concentration Coal: Solvent	Percentage removal of ash				
	NMP	**Aniline**	**Furfural**	**Acetic Acid**	**Toluene**
1:6	23.4%	25%	23%	1.75%	1.6%
1:10	72.34%	70.6%	64.46%	1.8%	1.8%
1:20	72.34%	71%	69%	1.8%	1.8%
1:30	72.34%	71%	69%	1.8%	1.8%
1:40	72.34%	69.9%	68.9%	1.79%	1.78%
1:50	72%	69.9%	68.5%	1.78%	1.79%

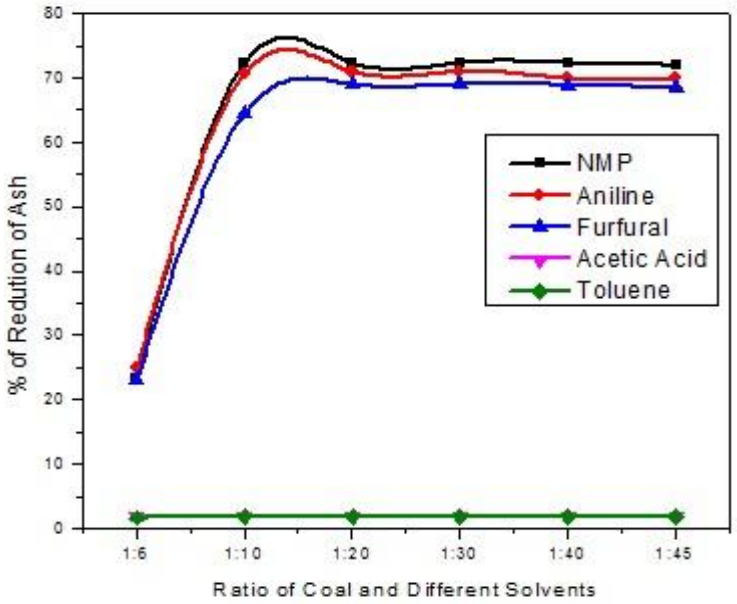

Fig. 6:- :- performance curve of different solvents on removal of ash of sample labeled A

It is evident from figure6 that NMP has a highest capacity to remove the ash compare to other four solvents. Reduction of ash is increased in case of NMP with increase of solvent concentration at a certain level . After that reduction of ash content is start to decrease with increase of solvent concentration. Maximum reduction of ash is found 72.34% with 1:10 concentration of NMP. The same trend is followed in case of Aniline and Furfural. But reduction of ash content is 70.6 & 64.46% respectively when the coal and solvent ratio is 1:10. It is clear from the figures that Acetic acid and Toluene show the same characteristics for the removal of ash from coal. The maximum reductions of ash is ranges between 1.75-1.8% it is also almost constant at any concentrations of those solvents

IV. CONCLUSION

This study shows that NMP is the best solvent to remove ash from coal compare to other four solvents such as Aniline, furfural, Acetic Acid and Toluene. Highest ash removal by NMP is 72.34% when coal and solvent ratio is 1:10. But there is a limitation to increase the concentration of NMP. Experimental result shows that after a certain value of concentration of NMP the ash removal is constant and there is no change in ash removal further increasing the concentration of NMP. So the value of this concentration where the removal of ash is constant is called critical concentration. Every solvent has its own critical concentration.

V. ACKNOWLEDGEMENTS

I greatly thankful to chemical engineering department of Jadavpur University for allocation this valuable project to me and help me by giving financial assistantship for done this project.

I also thank my project guide Dr. ChanchalMondal who gave me his valuable instruction for done this project very smoothly.

REFERENCES

Journal Papers:

[1] Choudhury, R., Bhaktavatsalam, A.K , 1995 "Benification of Indian Coal by Chemical Technique" , Energy Converse anagement" , 38(2): 173-178

[2] Choudhury, S.B., Brahmachari, B.B., Dwivedi S.R., Roy, A.K., Dasgupta, P.K., Chakra borty, M. Haque, R., 1996 "Solvent-refined coal from high ash non-coking coal &washery middling for use in metallurgical coke making part-1. Production, testing & characterisation", Fuel processing technology, 47:203-213

[3] Sato,Y., Kushiyama, S., Tatsumoto, K., Yamaguchi, H., 2004 "Up grading of low rank coal with solvent", Fuel processing Technology, 85(14):1551-1564

[4] Franco,A., Diaz, A.R., 2009 "The future challenges for "clean coal technology": joining efficiency increase & pollutant emission control", Energy, 34(3):348-354

[5] Ahmaruzzaman, M., 2010 "A review on the utilization fly ash", Process in energy and combustion science, 36(3): 327-363 4

[6] Shivaprasad, K.H., Nagabhushana, M.M., Venkataiah, C., 2010 "Reduction of ash content in Raw coal using acid & alkali", E-journal of Chemistry, 7(4):1254-1257

[7] Liang, X.,Wang Z., Zhou, Z., Huang, Z., Zhou, J., Cen, K., 2013 "Up to date life cycle assessment & comparison study of clean coal power generation technology in China", Journal of cleaner production, 39:24-31

Books:

[8] "Impact of Coal Quality and Coal Beneficiation on Utility Boiler", 2005 Coal Preparation Directory and Handbook, Copyright Coal Age and Coal Preparation Society of America. p23-33

Theses:

[9] Hatt, R, 1997 ,"Washed Coal From a Utilization Perspective", World Coal

Proceedings Papers:

[10] Bickelhaupt, R. E. , 1979 ," A Technique for Predicting Fly Ash Resistivity" , The International Conference on Electrostatic Precipitation (ICESP X), pp. 1-10

[11] Hatt, R., 1995, "Correlating the Slagging of a Utility Boiler with Coal Characteristics" Engineering Foundation Conference, Waterville Valley , New Hampshire, USA, pp-16-22

[12] Annual report "Improving Efficiency of Coal Fired Plants in Developing Countries", 2002-2003, Russia, International Energy Agency, (available online at :www.iea.org/media/workshops/2011/platformrussia/Fernandez.pdf)

[13] "World Energy Investment Outlook-2003 Insights", 2006, International Energy Agency, pg 319-323 (available online at : http://www.worldenergyoutlook.org/media/weowebsite/2008-1994/weo2003.pdf)

[14] Meena, N.K., Singh, V.K., Golder, A.K., Chandaliya, V.K., Biswas, P.P., Das, C., 2010 "Improvent of coal properties using organic solvent", CHEMCON-2010