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Demineralization of Indian Coal by Using Solvents

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Abstract

Coal is most important fossil fuel in the world. Availability of coal is three times greater than that of the crude oil. Ash content of Indian coal is very high ranging from 15% to 55% [1]. High ash Indian coals are unsuitable for efficient use in carbonization, combustion, gasification, liquefaction etc purpose. Demineralisation is process of coal upgrading. The extraction yield depends strongly on the coal particle size, solvent and extraction conditions. This study shows maximum removal of ash content of Indian coal by using two solvents Dimethylformamide (DMF) & Dimethyl sulfoxide (DMSO). This study also highlighted how ash removal of coal by using solvents increased with decreasing particle size due to the liberation of ash particles from lump [15]. Comparative studies between DMF and DMSO solvent have been done and experimental results shows that DMSO is best solvent for a particular size of coal particle. It is maximum reduction of ash is found to be 26.93%.

Keywords: Coal particle size; coal upgrading; Dimethylformamide (DMF); Dimethyl sulfoxide (DMSO).

Introduction

Coal is one of the most important sources of energy in India and nearly 70% of the commercial energy produced in India is met by coal [2]. Coal generally incorporates various amounts of mineral matter as impurity. The presence of mineral matter adversely affects most aspects of coal utilization and processing. Coal generally incorporates various amounts of mineral matter as impurity. The presence of mineral matter adversely affects most aspects of coal utilization and processing. Burning low-quality, high-ash coals also creates problems for power stations, including erosion, difficulty in pulverization, poor emissivity and flame temperature, low radiative transfer, excessive amount of fly ash containing large amounts of unburned carbons etc [3,4]. Therefore, removal of mineral matter from Indian coal is desirable. The use of beneficiated coal can reduce erosion rates by 50-60%, maintenance costs by 35% and increase thermal efficiencies 4-5% on existing PC boilers with an accompanying reduction of CO2 emissions by up to 15%[5,6]. The removal of mineral matter from coal by conventional physical separation techniques is not so effective. So, chemical leaching is incorporated which involve treatment of coal with different chemicals that are effective for removing mineral matters [7]. It has been proposed that the volatile matter measured by the ASTM standard depends on particle size [8,9] and data from a few studies [10–13] imply that particle size also has a significant influence on the content of ash and fixed carbon. Jayaweera et al. [14] studied the effect of particle size on the percentage weight loss of a low quality bituminous coal during combustion in air by thermal analysis. The influence of reagents on the coal carbonaceous matrix is required to determine the extent of dissolution of the matrix for leachants [15].

Grinding the coal sample to a finer fraction is necessary for increasing the surface exposed to the leachant. As the coal sample is ground to finer fractions, the minerals scatted through the matrix become exposed to the reagent and therefore able to react into soluble compounds.

Material and Method

Preparation of samples

Coal sample have been collected from market having high percentages of ash. It has been crushed by using Jaw and Roll crusher. The crushed sample has been separated in three fractions by passed through Tyler Standard Mesh Sieves stacked vertically in descending order of mesh of 30,36,60,90,100 and 200 respectively with a collector pan at the base and it have been sieved for 15 min using a vibratory shaker.

The volume surface mean diameters (D) of the samples have been calculated by taking different fraction from different sieves. The volume surface mean diameter of the first is 0.1131mm and it has been levelled sample A. Similarly the volume surface mean diameter of second cut is 0.2142mm have been levelled sample B. Final volume surface mean diameter of third cut is 0.3046mm has been levelled C.

Solvent Classification Based on DN and AN

A solvent can be quantitatively characterized in terms of two parameters, donor number (DN) and acceptor number (AN). The donor number characterizes the nucleophilicity of the solvent while the acceptor number characterizes the electrophilicity of the solvent. Marzec et al modelled solvent extraction of coal as a series of replacement reactions of coal, coal-coal electron donor- acceptor bonds by the coal solvent electron donor acceptor bonds [14]. A good solvent for extraction is one which forms bonds with coal that have higher energies than that of bonds present in the original coal and in the solvent [17]. (Gadam 1990)

Solvents with electron donor number (DN) greater than 19 and electron acceptor number (AN) less than 21 would be effective solvents for extraction. DMF has DN=26.6 and AN=16.0 and DMSO has DN=29.8 and AN=19.3 explain are an effective solvent.

DMF & DMSO are a dipolar aprotic solvents termed as super solvent which dissolve large fraction of organic material in coal [18] (Stiller et al 1981). Extraction yield depends upon the different specific solvents different boiling point. In comparison with boiling point DMSO has a higher boiling point than DMF. With higher boiling point solvent greater extraction yield is generally expected [19]. (Dryden, 1951

Table 1
Classification of solvents based on their donor and acceptor numbers (Marzec et al., 1979)

DNs	ANs	Solvents	Extraction Yield	
			Expected	Stated
⩾19	<21	Dimethylsulfoxide, Ethylenediamine, Dimethylformamide, diethyl ether, tetrahydrofuran, pyridine, N-methylpyrrolidone	High	10-20 %
17-19	<21	Acetone, dioxane	Low	1-2 %
⩽14	<21	Hexane, Benzene, Nitromethane, Acetonitrile	No extract	0.1 %

3. Experimental procedure

1 gm of sample A has been taken in beaker. It has been well mixed by mechanical stirrer at a speed of 980 rpm with solvent with different ratios. The leaching time has been selected for 30 minutes at about 106°C and 1 atmospheric pressure. After the completing the leaching process the mixture of coal and solvent is placed in a thermal distillation column. Approximately 70% solvent has been recovered by using thermal distillation process. The remaining residue has been heated in hot air oven to dry up the sample. The ash content of the residue of coal after the process has been determined using proximate analysis.

Results and Discussion

Many investigations have been conducted with respect to ash reduction of coal fractions levelled Sample A, Sample B and Sample C having their different particle sizes. Two solvents have been used for ash reduction of coal of Sample A, Sample B and Sample C.

Removal of ash content of Sample A

The experimental results have been tabulated in table 1 and experimental data have been shown in figure 1. It has been observed from figure ash reduction of sample A is increased with increase of coal- solvent ratio upto1:40 where maximum ash reduction has been detected to16.81% in case of DMF. But in case of DMSO the ash reduction is increased sharply with increase of coal-solvent ratio upto 1:50. The maximum and constant reduction has been observed 26.93%. It is clear from figure 1 reduction in ash content of coal is more in case of DMSO with respect to DMF for a particular size of coal particle of Sample A.

Table 1: Performance of DMF & DMSO solvents on removal of ash content of sample A

Coal: Solvent	Temperature °C	Time of leaching Minutes	Percentage of ash removal	
			Dimethylformamide	Dimethyl sulfoxide
1:7	106	30	7.23	9.47
1:10	106	30	9.65	11.86
1:20	106	30	12.81	17.59
1:30	106	30	15.34	23.62
1:40	106	30	16.76	26.78
1:50	106	30	16.81	26.93
1:60	106	30	16.81	26.93

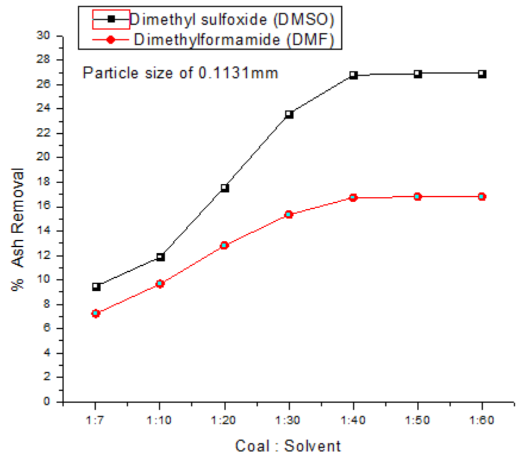

Figure 1:-Performance of DMF & DMSO solvents on percentage of ash removal for sample A

Removal of ash content of Sample B

The experimental results have been tabulated as shown in table 2 and it results have been plotted as shown in figure 2. It is clear from the figure reduction of ash content is still higher in case of DMSO with respect to DMF for a particular size of coal particle for sample B. The trend of the figure in case of DMSO & DMF is parallel upto coal-solvent ratio 1:7 to 1:10. After that concentration the reduction of ash content in case of DMSO sharply changes and reduction rate is much higher than that of DMF. Maximum ash reduction in case of DMF & DMSO are 15.12% and 25.76% respectively.

Table 2: Performance of DMF & DMSO solvents on removal of ash content of sample B

Coal: Solvent	Temperature °C	Time of leaching Minutes	Percentage of ash removal	
			Dimethylformamide	Dimethyl sulfoxide
1:7	106	30	5.23	8.42
1:10	106	30	7.92	10.70
1:20	106	30	10.93	16.21
1:30	106	30	13.74	21.96
1:40	106	30	14.91	25.76
1:50	106	30	15.12	25.76
1:60	106	30	15.12	25.76

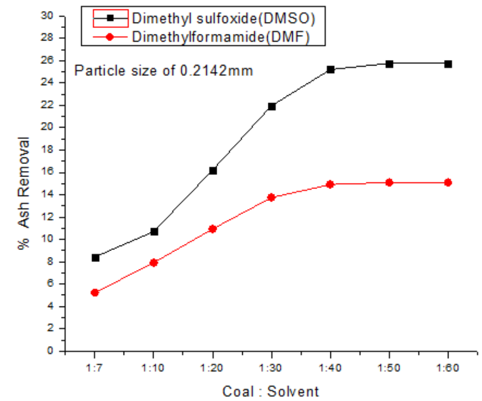

Figure 2:-Performance of DMF & DMSO solvents on percentage of ash removal for sample B

Removal of ash content of Sample C

The experimental results have been tabulated as shown in table 2 and it results have been plotted as shown in figure 2. Increasing coal- solvent ratio from 1:7 to 1:10 the figures shows that ash removal rate for DMF & DMSO are parallel in nature. At coal-solvent ratio 1:20 sharp removal of ash content removal has been observed in case of DMSO with respect to DMF for particular coal Sample C. Maximum ash content has been observed in case of DMF & DMSO are 12.93% and 24.16% respectively at 1:50 coal-solvent ratio. Further increase of concentration the nature of the lines in case of DMSO & DMF becomes constant and parallel to each other.

Table 3: Performance of DMF & DMSO solvents on removal of ash content of sample C

Coal: Solvent	Temperature °C	Time of leaching Minutes	Percentage of ash removal	
			Dimethylformamide	Dimethyl sulfoxide
1:7	106	30	4.12	7.38
1:10	106	30	6.93	9.81
1:20	106	30	9.83	14.89
1:30	106	30	11.84	20.17
1:40	106	30	12.93	23.89
1:50	106	30	12.93	24.16
1:60	106	30	12.93	24.16

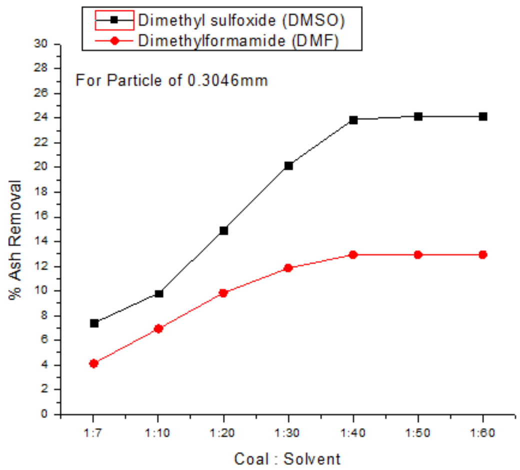

Figure 3:-Performance of DMF & DMSO solvents on percentage of ash removal for sample C

Variation of ash reduction in case of DMSO & DMF with particle sizes

Three experiments have been conducted for different sizes of coal of each sample. Experimental results have been shown in table 4 and it has also been presented graphically as shown in figure 4. From experimental results it is evident that reduction of ash content of coal gradually increases as the particle size of coal is decreased. For every particle sizes the reduction of ash content is much higher in case of DMSO with respect to DMF. That may be due to the increase of surface area of coal particle which increases the leaching rate. The trends of the lines are nearly linear for both the solvent.

Table 4 Variation of ash reduction in case of DMSO & DMF with particle sizes

Average Particle size(mm)	Maximum Ash Removal Percentage	
	Dimethylformamide	Dimethyl sulfoxide
0.1131	16.81	26.93
0.2142	15.12	25.76
0.3046	12.93	24.16

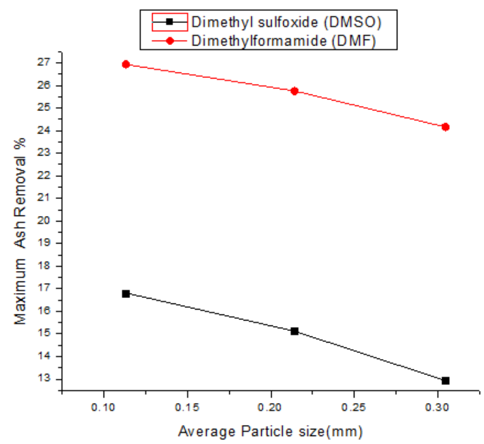

Figure. 4:- Variation of ash reduction in case of DMSO & DMF with particle sizes

Conclusion

Though various physical methods are available for reducing ash content of coal but chemical methods have more advantages over physical methods. In this study two solvents have been chosen for the reduction of ash content of coal. On the other hand effect of coal particle size on ash removal from high ash content of Indian coal is investigated by proximate analysis. The ash removal rate is increased as the particle size decreased. However, the drawbacks of grinding of coal sample to a finer size are the amount of extra energy required. The most favourable option based on achieving a balance between the advantages of a finer coal particle size and disadvantages from higher energy requirements.

The solvent DMSO reduces maximum ash content of coal are 26.93%, 25.76% and 24.16% with particle sizes of 0.1131mm to 0.3046mm respectively. On the other hand DMF reduces maximum ash content of coal are 16.81%, 15.12% and 12.93% under same operating condition. So, it can be concluded that DMSO is considered the best solvent than DMF with respect to beneficiation on Indian coal.

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