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Short Communication

Evaluation of properties of coal slurry from different solvents

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Coal slurries were separately prepared with benzene, ethanol, hexane and water, and the fuel properties of the slurries were examined. The ability of the solvents to dissolve the coal was also evaluated using spectrophotometer in the ultra-violet and visible regions. Some of the slurry properties indicated that the liquid coal have comparable properties to petroleum-based conventional diesel oil. Benzene and hexane were highly flammable and therefore hazardous. The liquid coal can be easily transported in pipelines based on the choice of suitable solvents as evaluated. The coal was extracted with the solvents in decreasing order of ethanol>benzene>water>hexane.

Key words: Coal, properties, slurries, solvents.

INTRODUCTION

Coal is a chemically and physically extremely complex and heterogeneous material (Schobert et al., 1991), consisting of two-phase systems, the organic and the inorganic constituents (Dolinska et al., 2011). Coal is a primary fuel utilized in several countries for generation of electricity, heating and for metallurgical purposes. It is also a feedstock in the making of some chemicals. Coal is found in many countries including United States of America, Nigeria, South Africa, China and Russia. The world's proved international recoverable coal reserves at the end of 2002 from each continent is over 100,000 million tons (World Energy Council, 2004). In Nigeria, as with several countries, coal is grossly under-utilized as crude oil is largely preferred to coal in modern utility. With the increasing crises surrounding crude oil availability and pricing, researches are ongoing for direct replacement of heavy petroleum oil with coal (IChemE, 1983). The conversion of solid coal to liquid form will improve utilization of coal including its transportation in pipelines and usage in engines. The methods of production of liquid fuels from coal are through direct liquefaction and the Fischer-Tropsch (F-T) processes.

Direct liquefaction approach entails hydrogenation while F-T process requires the gasification of the coal and catalytic conversion of the gases generated to liquid products. The conversion of coal to liquids using suitable solvents is attractive as various experiments have given positive prospects for their use in utility boilers, industrial boilers and in blast furnace (Nunez et al., 2010). In this study, coal slurries were separately prepared with benzene, ethanol, hexane and water. The nature of the slurries was examined. These solvents were assessed for suitability in preparation of slurries that can be applied as potential substitutes for conventional petroleum-based diesel oil. This investigation was carried out at the National Center for Energy Research and Development Laboratory, University of Nigeria, Nsukka, between April, 2012 and July, 2012.

MATERIALS AND METHODS

The coal used for this study was from Ogwashi-uku mine, Nigeria and provided by the Nigerian coal corporation. This received coal was ground to a fine powder of 250 microns (60-mesh).

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Table 1. Proximate analysis for Ogwashi-Uku coal, Nigeria.

Parameter	%
Moisture content	35.0
Ash content	6.85
Volatile matter	38.1
Fixed carbon	20.05

Table 2. Slurry properties of the coal with different solvents versus the typical No. 2 diesel.

Properties	Benzene	Ethanol	Hexane	Water	No. 2 Diesel +
Density	0.895	0.927	0.849	1.062	0.952*
Kinematic					
Viscosity (cSt)	1.36	2.46	1.19	1.63	2.6-4.1
Flash point (°C)	<0	18	<0	No flash	74
Boiling point (°C)	25	30	20	86	188 to 343

+ http://www.afdc.energy.gov/afdc/fuels/propertierties.html; *Density of Nigerian commercial diesel oil.

Proximate analysis

Moisture, ash, and volatile matter, fixed carbon: This was carried out on the sample following standard methods (Speight, 2005).

Slurry preparation

Two non-polar solvents (benzene and hexane) and two polar solvents (ethanol and water) were separately used to prepare the coal slurries. The slurries were prepared by measuring 14 g of the coal sample into a beaker. 28 g of benzene was poured into the beaker of coal at 1:2 and the mixture was mechanically agitated with a magnetic stirrer set at high speed for 20 min. This procedure was repeated separately for ethanol, hexane and water. The following tests were carried out on the slurries:

(a) **Viscosity:** This was investigated by using Oswald portable capillary viscometer. This investigation was conducted at room temperature (3℃),
(b) **Density:** The density was measured using a density bottle. The density of the slurry was calculated from the simple relationship between the measured volumes of a fluid and the mass of the fluid. Density = mass/volume.
(c) **Flash point:** This was measured with Pemsky Martin semi-automatic multi flash closed cup flash point tester (Made in Japan),
(d) **Boiling point:** Boiling point was determined with 0-350℃ thermometer and
(e) **Solvent extraction test:** This test was done to determine the ability of the solvents to dissolve the coal. The slurries prepared as described above were dried in an oven to evaporate the solvent and left in an incubator. 0.8 g of each of the dried coal was dissolved in 15 g ethanol. The absorbance of each of the extracts was measured with a UV/Visible spectrophotometer (Jenway, model 6305) in which ethanol was used as a blank at 285 nm.

RESULTS AND DISCUSSION

Proximate analysis

From Table 1, the moisture content of the coal is 35%. This value is appropriate for coal slurry as it is recommended that the moisture content for coal liquid fuel could be as high as 30 to 50%. The ash content at 6.85% is also suitable for coal liquid mixture that can be used for boilers (Vickers and Ivatt, 1983). It could be as high as 10%. In essence, this coal meets the recommended moisture and ash contents for coal slurry fuel. The volatile matter (38.1%) and the fixed carbon (20.05%) contents further shows that the coal is an appropriate fuel whether in solid or in liquid form.

Slurry fuel properties

The densities of the slurries as given in Table 2 showed that the values were within the level for typical No. 2 diesel oil such as the measured commercial diesel (0.952 g/cm^3) which was purchased in a gas station at Nsukka. These values gave an indication of good ignition property for the slurries. Viscosity is a measure of fluid's resistance to flow. Viscosity affects the stability and the atomization of a fuel upon injection into the combustion chamber. The viscosity of the slurries which was measured in centistokes (cSt) showed that the slurries could be pumped and this would ease transportation of the coal in pipelines. The values of 1.36 cSt (Coal-benzene), 1.19 cSt (Coal-hexane) and 1.63 cSt (Coal-water) are lower than the recommended limit for typical No. 2 diesel. But the viscosity of the coal-ethanol slurry was within the limit. Low viscosity of a fuel will not give sufficient lubrication to the engine. The viscosity values of the slurries were low and may not cause any corrosive effect on the internal parts of any compression engine when used as fuels (Knothe and Dunn, 2001).

The flash point is used to assess the overall flammability hazard of a fuel. It also gives indication of

Table 3. Absorbance of the coal slurries in ethanol at 285 nm.

Slurries	Absorbance
Coal-benzene	1.834
Coal-ethanol	1.999
Coal-hexane	1.804
Coal-water	1.813

how easy a chemical may burn. The flash point of coal-benzene mixture and coal-hexane mixture was below 0°C and that of ethanol at 18°C was low. These low flash point values indicate that the slurries are likely to ignite accidentally and within the range to pose extreme fire hazard (Abayeh and Shekarau, 2010). But the coal-organic solvents slurries are easily ignited, while the coal-water slurry did not flash. The boiling point values as given in Table 2, showed that coal water slurry has the highest boiling point of the slurries at 86°C and in decreasing order, ethanol>benzene> hexane.

These values were low compared to standard diesel boiling point at between 188 and 343°C but with blending; it may be possible to raise the boiling point. The boiling point values implied that at ambient temperature, the benzene and hexane slurries will volatilize. The examined slurries except coal-water slurry volatilized at a fast rate. In considering the choice of solvents based on volatility for transporting coal in pipelines so as to subsequently use the coal as solid fuel, then in decreasing order, hexane>benzene>ethanol>water. In this way, the option may be based on the solvent that easily evaporates.

Solvent extraction test

The ability of the various solvents to dissolve the coal, thereby forming a liquid coal was evaluated by the simple solvent extraction test. The solvents dissolved the coal in the decreasing order of ethanol>benzene>water>hexane. This is indicated by the absorbance values as given in Table 3. Solvents with molecules containing unpaired electrons show higher ability to disrupt the hydrogen bonds in coal (Shin and Shen, 2007). This might have accounted for higher dissolution of coal with ethanol.

Conclusion

To improve coal utilization, the liquid form of coal was prepared. The slurries were of low viscosity which is important characteristic for pumping. The flash point and boiling point values indicated that the slurries are volatile and prone to easy ignition thereby posing a fire hazard. From the solvent extraction test, ethanol extracted more of the coal than the other solvents. A high extraction power indicates a high compatibility with coal. This study demonstrated that the coal-solvent slurry is a potential substitute for the conventional petroleum-based diesel oil. More researches are however desirable to improve on some of the characteristics of the slurries.

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