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A Study to Investigate the Rheological Properties of Coal-oil-slurry at Low Temperatures

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Abstract—*The increase in coal consumption and its limited resources is great challenge to efficiently handle it. The coal-oil slurries (COS) can be easily transported in pipe lines to use in combustion chamber, gasification or liquefaction. Vegetable oil have low viscosity hence high amount of solid particle can be loaded to the slurries.COS is a new kind of fuel suitable for numerous industrial applications. In this paper rheological properties of bituminous class F Assam coal slurry with vegetable oil has been investigated. The sieve test was performed on the sample to obtain 75µm particle size of coal. The whole rheology was performed over 75µm size varying the coal to solvent ratio as 20% and 30%.Further the rheological properties were tested by varying temperatures. It was concluded that coal oil slurry behaves as Newtonian fluid for the tested temperature range and 75µm particle size. It was also found that at high shear rates at 20% loading ratio viscosity decreases by 42%.When the temperature increases from 30°C to 40°C,this gives substantial reduction in the pumping power to pump the slurry.*

Keywords*: Coal-oil slurry, rheology, particle size, temperature, concentration.*

1. INTRODUCTION

Before Designing the pumping system and piping system for power plants to be operated on coal. oil slurry, the variation of flow characteristic of COS is required. Fuel can be stored without danger andtransported in pipeline and incinerated like fuel inbenign manner. Coal organic solvents slurries may provide solution to dispose of some waste organic solvents generated by industries. Coal-water slurries have slightly lower combustion flame temperature leads to less emission but at the same also lower the combustion efficiency [1,6].Since 1990, a new type of oil-based synthetic fuel composed of residual oil, finely pulverized coal and water has been demonstrated to be very promising as a future clean fuel [2].

Coal slurry fuel can be classified into CWS (coal-water slurry), COS (coal-oil slurry), COWS(coal-oil-water slurry),CMWS (coal methanol water slurry) and CMS (coal methanol slurry). In the above mentioned slurries liquid used to be mixed with coal will determine the type of coal slurry.

Viscosity of coal-water slurry increases with solid loading ratio and stability of the suspension becomes poor if the viscosity is reduced[5]. so coal-oil slurry can be taken as substitute to this problem of coal loading ratio. The main advantage of COS is that it can be directly used in furnace which will lead to decrease in running cost of the plant as some equipment which are must for CWS will not be no longer required. The COS have larger no of varieties[4].The viscosity–temperature variation of a Chinese brown coal under high temperature and high pressure was concluded that the viscosity of the brown coal-oil slurry decreases and no peak of viscosity variation appears with increasing temperature[7,8]. In last three decades lot work has been carried out on CWS and COS to economically replace the oil fuels. But these alternatives have their own limitations such as of CWS lower combustion efficiency and COS having high viscosity [9].The properties of COS such as the particles size distribution of coal, solid loading , particle surface charges, pH etc. The amount of loading and size of the coal particles are perhaps the most crusial parameters to control since slurry mixing and size reduction are common operations. The main emphasis is given on particle size of coal and effect of temperature on COS at atm. pressure[3,5].

2. EXPERIMENTAL

2.1 MATERIALS

In proximate analysis Moisture(M), Ash(A), Volatile Matter(VM) are determined. Fixed carbon is obtained from given equation:-

FC=100-[M+A+VM]%.

Moisture is determined by drying 2gm of coal sample at 105°C for 1 hour. Volatile matter is the weight loss obtained by heating sample at 950±5^{o} C for 15 minutes in absence of air. Ash is residue obtained from coal at 950^{0}c. Assam coal samples were collected from Workshop at Thapar University.

Table 2.1

Constituents(Air dried basis)	Assam Coal
%M (Moisture)	3.5
%A (Ash)	35.00
%VM(Volatile Matter)	21.5

%FC(Fixed Carbon)	40.00
TOTAL	100
cv	5064.5

2.2 Particle Size Test

Particle size test is done by using mechanical sieve available in soil testing laboratory. It is done to collect the required amount of fine size coal by dumping the available sample of coal on to the top most sieve of largest pores. An electrical motor is connected to the mechanical sieve which provides the vibrating motion for the sieve to perform particle size distribution. Particle size test is performed Assam coal sample.

Fig. 2.2: Sieve Testing Equipment

Test conducted for 20mins. Assam Coal Sample: Size of coal collected for testing = 75micron (from 300 mesh size sieve)**.**

2.3 RHEOLOGY TEST

Rheology test is conducted to determine the properties of coal oil slurry prepared with different concentration (mentioned in table 2.4) using Rheometer at varying temperatures and hence know the behavior of the fluid. Vegetable oil was selected to make coal oil slurry, with 20% and 30% concentration using Assam coal samples.

The Rheometer used for testing is shown in figure 2.3. The standard Rhoemeter (Rheolab Q-C manufactured by Anton Paar Company Ltd, Germany) was used to determine the shear rate and shear stress relationship of coal samples. The Rheolab Q-C is a rotational viscometer which works on Searle principle. It consists of a high-precision encoder and a highly dynamic electronically commutated (EC) synchronous drive. The waiting time before recording data was set to 4 seconds for each shear rate.

The main purpose of rheology study is that to find out the viscosity variation of fluid with change in surrounding conditions. As viscosity is thermo-physical property it depends upon both temperature and type of body(mainly used for fluid).There for it very important to investigate the variation in viscosity of fluid with other parameters such as shear rate, shear stress etc. In rheology we deal with mainly two types of fluids namely Newtonian and Non-Newtonian. For Newtonian fluid shear stress is proportional to rate change of shear strain. Non-Newtonian fluids do not obey Newton's law of viscosity.

Fig. 2.3: Rheometer

2.4 DESIGN OF EXPERIMENT

Table 2.4

Sr. No.	Coal Sample(gm)	Vegetable-Oil(ml)	Temperature loading(°C)
1.	10	40	30
2.	10	40	35
3.	10	40	40
4.	15	35	30
5.	15	35	35
6.	15	35	40

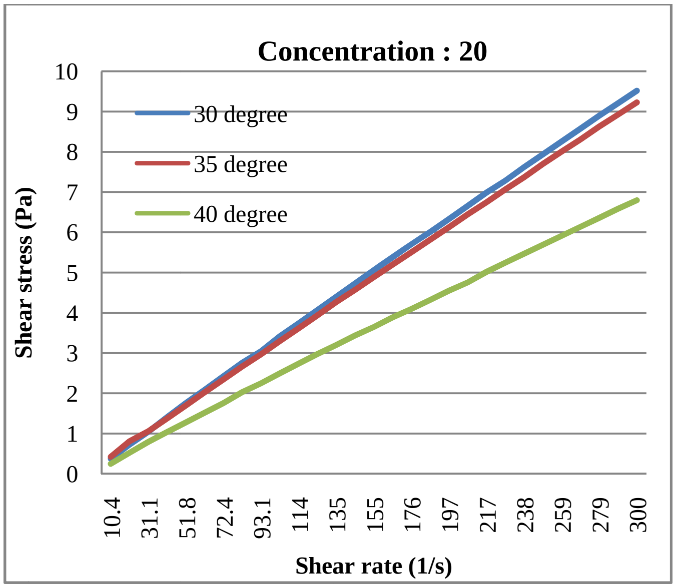
As shown in above table experiment designed for same particle size but at different temperatures in order to study the behavior of coal oil slurry. The 75micron (from 300 mesh size sieve)particle size was used to achieve more accurate results for coal- oil slurry. To make a proper blend of coal and oil was stirred for 15 minute. The vegetable oil having less viscosity was used to make coal slurry.

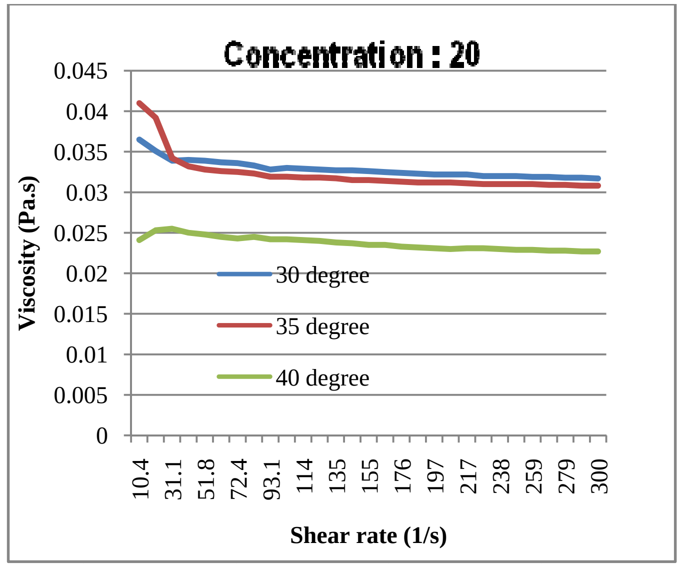
The composition range of coal was varied from 20% to 30% and temperatures were 30°C,35°C and 40°C to investigate the rheological properties of COS.

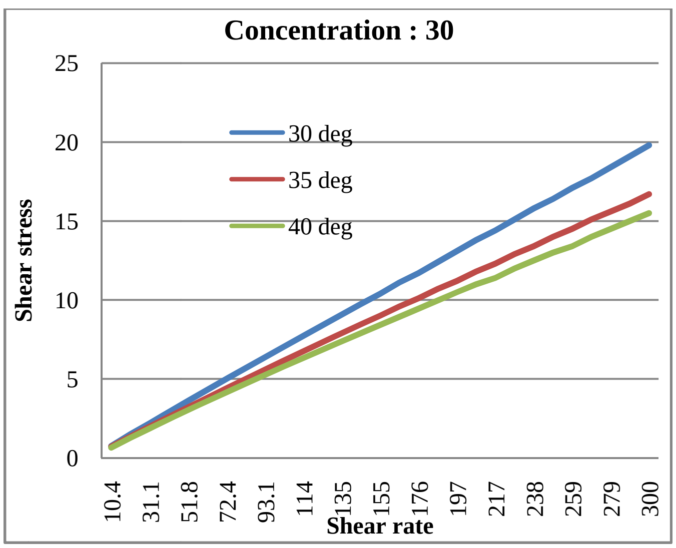
3. RESULTS & DISCUSSIONS

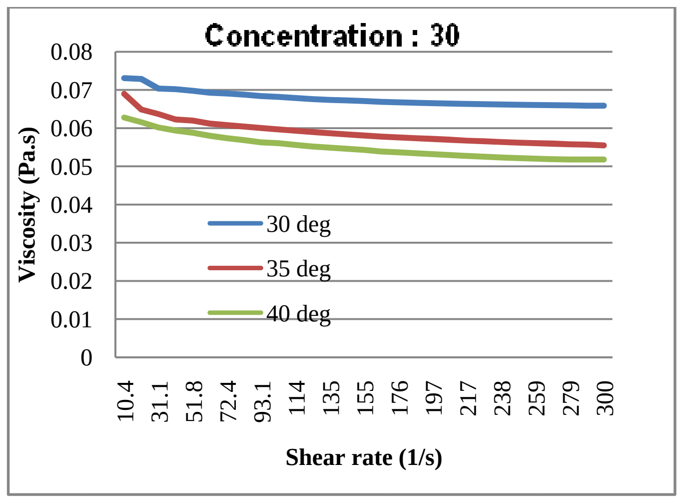
3.1 Variation between Shear stress and Shear rate at 20% & 30% concentration

Coal oil slurry at all temperatures behaves as a Newtonian fluid. The viscosity at 30°C & 35°C is nearly same (4.2% variation).At 5°C increase from 35°C to 40°C ,viscosity decreased nearly29.35%.Due to decrease in viscosity of vegetable oil at 40°C, as the concentration is same.









Coal oil slurry at all temperatures behaves as Newtonian fluid. At 30% Coal-Oil ratio, the decrease in viscosity when temperature change from 30°C-35°C was 13.4%,while at 20% COS ratio, the decrease is 4.2%.. At 30% loading ratio, the decrease of viscosity is 19.19%,when temp. increases from 30°C-40°C,while at 20% loading ratio the decrease was more i.e. 29.35%. Probably due to increased coal-loading ratio.

3.2 Variation between Viscosity and Shear rate at 20% & 30% concentration

Viscosity decreases with increase of shear rate.At higher shear rates the change in viscosity is very small.Up to 51.8 shear strain rate, system was in transient state.The change in viscosity with strain rate at 30°C & 35°C is nearly same.At 217 strain rate, the reduction in viscosity at 30°C to 40°C is nearly 42%.

At 217 shear strain rate, the viscosity at 30°C is 0.0664 Pa-s & at 40°C is 0.0527 Pa-s, i.e. 21.21% decrease. While, at 20% solid loading ratio the decrease is 42%.Decrease in viscosity due to increase of temperature is dominated by increase in viscosity due to more coal percentage in slurry.

4. CONCLUSION

Coal oil slurry behaves as Newtonian fluid at 75micron(300 mesh size sieve) at temperature range of 30°C to 40°C.The increase in temperature, viscosity of coal oil slurry decreases. The higher shear rate, viscosity reduces due to which pumping power is reduced. At 205 loading ratio the viscosity decreases by nearly 42% (30°C to 40°C). For the same temperature (30°C), 20% to 30% coal oil ratio gives an increase of 50.97% while at 40°C this increase is 57.14%. As the coal loading ratio increases the decrease in shear stress in 30% concentration is more than that of 20% concentration for any given temperature in this investigation.

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