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STUDY OF ADDITIVE, SIZE FRACTION AND COAL CONCENTRATION FOR COAL WATER FUEL

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ABSTRACT

Coal Water Fuel (CWF) is one of energy diversifications. It enables the coal to substitute fuel oil by existing installations because CWF could flow similar to the flow of liquid.

Selections of additive, coal size fraction, ratio coal and water of CWF were studied in laboratory scale. Arutmin coal, processed with Upgraded Brown Coal (UBC) technology, was grouped to -60 and -200 meshes and then are mixed with water and small quantities of additive. Size fraction, coal concentration and additive type were varied to investigate their effects on CWF behavior.

Results from concentration and penetration tests show that the best additive for CWF with size fraction - 200 mesh is DBS (Doacely Benzene Sulfanat) with optimum coal concentration is 51% using size - 60 mesh indicate, that the most stable CWF was resulted from CWF using DBS with optimum coal concentration 55 %.

Results of using different size fraction that show the decrease of concentration and penetration rate from CWF with size fraction - 200 mesh is relatively constant compared to the CWF with size fraction – 60 mesh.

Keywords: Coal water fuel, additive, concentration, penetration

INTRODUCTION

Indonesian coal reserves are expected to be an intermediate between energy from conventional energy (gas and oil) to a renewable energy (solar, wind, water etc.). At the beginning, coal is only used as a direct fuel and in the next stage coal is expected to be converted into synthetic fuel such as oil and gas or in the form of suspension.

Indonesian coal reserve is dominated by low-rank coal (lignite to sub-bituminous). The fuel has a comparatively low heating value because its high moisture content (Daulay, 2006). Consequently the transportation cost is expensive.

Coal Water Fuel (CWF) is a mixture of fine coal, water in a certain ratio, and small quantities of additive that has slurry stable and homogeneus. Combustion of coal in the form of powders has many shortcomings such as the dust emission, spontaneous ignition and explosion. Since the CWF properties are similar to the liquid fuel (oil), it is expected to solve the problem in the direct use of coal and the use of fine coal. Since the CWF properties are similar to the liquid fuel (oil), CWF is free from those shortcomings. CWF also does not require large handling facilities (Hashimoto, 1999). It is expected to solve the problem in the direct use of coal and the use of fine coal.

Coal and water have a tendency to separate because they have different density. Coal and water separation will occur rapidly if the CWF consists only of coal and water, without the aid of other components. Therefore, it is necessary to add additive in CWF which function is to make the separation of coal and water slower (Saeki, et. al., 1999).

Coal type is important to create a good CWF. The coal is preferable have a high heating value, ignition stability and chemical reactivity to overcome the detrimental effects of a high concentration of

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inert moisture on fuel combustion. All of these properties are usually found in bituminous coal. Low rank coal (LRC) have high moisture content, volatile content and fuel reactivity, on the other hand they have low heating values. Therefore LRC is needed to be upgraded first to reduce moisture content to be equal with a high rank coal, so it can significantly produce a good characteristic of CWF (Usui et al, 1999).

The most important factor in the application of CWF technology is the stability of coal particles solid phase dispersed in the liquid phase. CWF tend to be stable when the coal particles in a given time interval was dispersed in water and not having sedimentation (Umar, 2007). The undesirable condition, if precipitation occurs before CWF is used, it will cause problems in storage and transport. Therefore the period of deposition of coal particles try to work as long as possible.

Factors that influence the stability of CWF are as follows:
- surface properties of coal;
- distribution/size of particle;
- quantity/content of coal in the mix;
- quantity and type of additives used.

The use of coal in the form of CWF has several benefits as the followings :
- diversification of energy;
- diversification of coal;
- fossil energy savings (oil and gas);
- no spontaneous ignition;
- easy transportation as enabling transporting through pipes;
- cleaner fuel and cleaner environment because the raw materials selected from coal with relatively low ash and sulfur content; and
- utilizing the existing boiler which is designed for fuel oil with a little modification.

The CWF properties are controlled by slurry stability, pumpability and combustibility. They are strongly influenced by coal characteristics. The objective of this study is to produce good properties of CWF. The effect of coal concentration, coal size fraction and additive type were investigated.

METHODOLOGY

Research conducted at Coal Technology Research Laboratory *tek*MIRA with experimental methods. Process stages for making CWF are as follows:
- coal preparation;
- CWF preparation;
- stability analysis of CWF.

The evaluation is stressed to the main factors that determine best additive, the optimum coal concentration and coal size fraction.

Coal preparation

The coal for study came from PT Arutmin, South Kalimantan that had been through the UBC process performing size fraction of -60 mesh and -200 mesh.

CWF preparation

- Coal composition
  In this experiment, composition of coal is above 50% of CWF to find the expected viscosity. Overall weight of CWF is 400 gram. It has been adjusted to the condition of the existing equipment in the coal laboratory.

- Water composition
  Water in this experiment came from reservoirs through pipes into Coal Laboratory. Water composition for CWF depends on coal composition, if coal composition is 50%, water composition is 50% (plus the amount of additives); if coal composition is 52%, then water composition is 48% (plus the amount of additives), and so on, until coal composition with water equal to 100%.

Stability analysis of CWF

To ascertain the relationship between additive and CWF stability, the relationship between coal size fraction and properties of CWF were used by penetration and concentration test.

RESULTS AND DISCUSSION

Coal Characteristics and Additives

Characteristics of raw materials were determined in the Laboratory for Mineral and Coal Technology (*tek*MIRA). Analysis and test include proximate analysis (inherent moisture, ash, volatile matter and fixed carbon), ultimate analysis (carbon, hydrogen, sulfur, and oxygen). Analysis results are presented in Table 1.

Table 1. Proximate and ultimate analysis results of Arutmin coal

Analysis	Raw Coal	UBC Coal
Proksimat		
Inherent Moisture, adb %	29.47	1.32
Ash, adb %	0.98	1.54
Volatile Matter, adb %	37.8	52.36
Fixed Carbon, adb %	31.75	44.78
Ultimat		
Carbon (C), daf %	50.69	69.56
Hidrogen (H), daf %	6.6	4.63
Nitrogen (N), daf %	0.49	0.7
Total Sulfur (S), daf %	0.17	0.22

Note : adb = air dried basis
daf = dry ash free

There are 8 types of additives used in this experiment, namely:

- CMC (Carboxyl Methyl Cellulose);
- KOAL150 (Nephthalene sulfonate Formaldehyde Condensat);
- wheat starch;
- PSS (Poly Styrene Sulfanat);
- PEG I (Poly Ethylene Glycol I);
- TEA (Tri Ethanol Amine);
- DBS (Doacely Benzena Sulfanat);
- PEG II (Poly Ethylene Glycol II).

Selection of above additives is based on previous studies (Umar, et al., 1992). All additives are soluble in water and can be well dispersed by coal. This property makes CWF stable within a certain timeframe. Additive used in each experiment was 0.5 wt% of CWF slurries or 2 gram.

Concentration Test Results

Concentration test represent coal content with CWF. The decrease of coal concentration in CWF during storage shows that the CWF is unstable. CWF stability is reached if coal concentration in CWF is constant during storage. The period of CWF can be calculated by performing calculations in the coal concentration.

Results of concentration tests and penetration tests with CWF coal size fraction of 200 mesh and 60 mesh can be seen in Table 2, Figure 1 and Figure 2.

Figure 1, shows the late decrease of concentration is CWF with optimum coal concentration of 51% and using DB Sadditive. The decrease of concentration is relatively constant namely 48.09%, 42.64%, 42.43%, 41.1% and 39.91%.

Table 2. Concentration test results

No	Coal (wt%)	Water (wt%)	Additives	Stability Coal Consentrations (% solid) week - 1	2	3	4	5
coal size fraction 200 mesh								
1	50	50	PEGI	46.03	35.31	22.07	13.50	5.66
2	62	38	Wheat starch	61.05	30.00	18.42	12.00	4.83
3	63	37	PSS	60.10	42.70	37.40	31.90	26.50
4	51	49	DBS	48.09	42.64	42.43	41.10	39.91
5	59	41	CMC	56.80	35.82	21.50	8.70	3.53
6	61	39	COAL 150	59.40	37.30	20.50	10.31	1.60
7	51	49	TEA	46.70	33.75	32.20	28.01	23.60
8	50	50	PEGII	47.60	35.40	34.35	33.20	27.70
coal size fraction 60 mesh								
1	56	46	PEGI	50.64	36.40	26.50	16.43	4.83
2	60	40	Wheat starch	58.23	23.60	16.21	3.20	0.81
3	68	32	PSS	65.69	23.38	20.54	10.31	2.95
4	55	45	DBS	54.47	40.96	39.91	32.60	28.64
5	58	42	CMC	56.25	28.64	17.14	4.47	1.54
6	68	32	COAL 150	67.50	23.07	16.80	4.40	0.81
7	60	40	TEA	58.40	25.00	20.00	11.10	6.71
8	60	40	PEGII	58.09	20.54	15.39	7.25	0.89

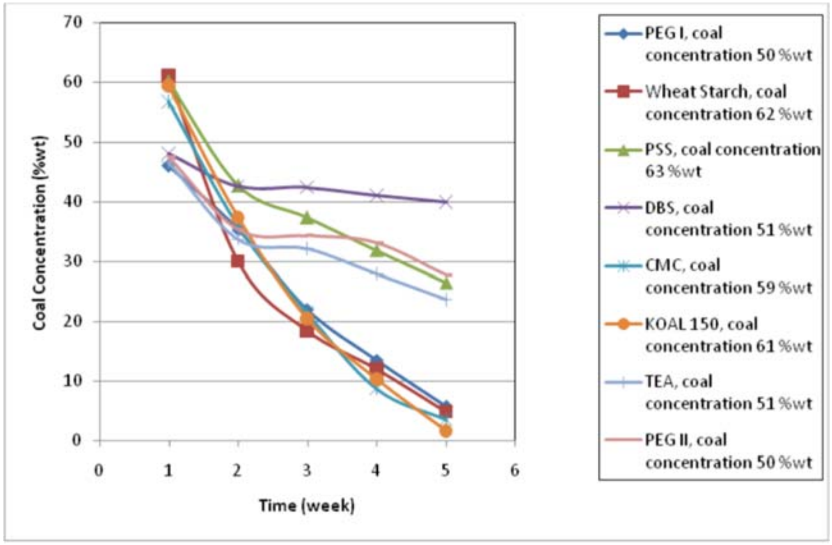

Figure 1. Concentration test graph CWF with 200 mesh size fraction

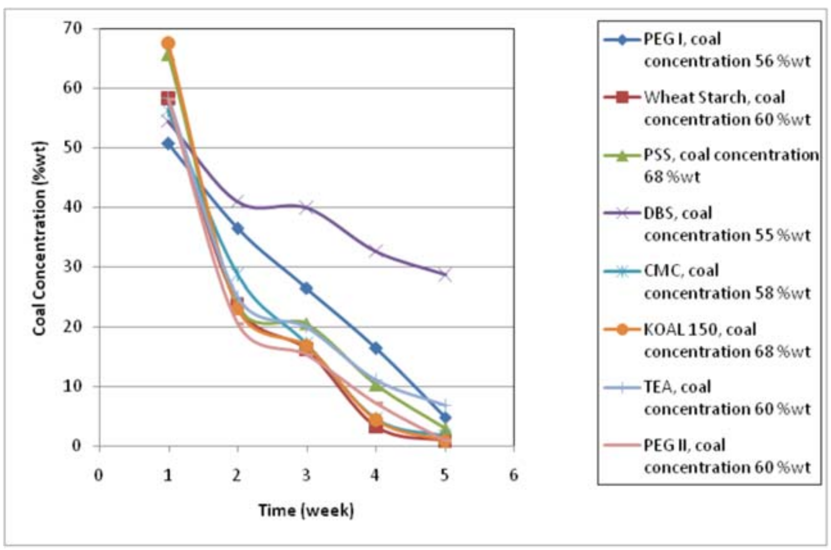

Figure 2. Concentration test graph CWF with 60 mesh size fraction

Meanwhile CWF with 60 mesh size fraction (Figure 2), shows the late decrease of concentration is the CWF with optimum coal concentration of 55% produced using DBS additive. Relatively constant decrease in concentration are 54.47%, 40.96%, 39.91%, 43.6% and 28.6%.

Penetration Test Results

CWF tend to be stable within a certain time when the penetration rate is still fast (stable), or in other words coal in the CWF is not sediment. This penetration test has a limit: testing conducted prior to the hardening at the base of the tube or prior to the deposition. In this experiment the penetration test was conducted until the fourth week.

Figure 3 shows that CWF with coal particle size of 200 mesh is most stable if using DBS additives with optimum concentration of 51% coal. It can be ascertained from penetration rate that are relatively constant namely 0.14 seconds, 0.2 seconds, 0.26 seconds, 0, 28 seconds, and 0.3 seconds.

Figure 4 shows that CWF with coal particle size of 60 mesh is most stable if using DBS additives

Table 3. Penetration Test Results

No	Coal (wt%)	Water (wt%)	Additives	Penetration Rate (second) week -				
				1	2	3	4	5
coal size fraction 200 mesh								
1	50	50	PEG I	0.11	0.39	0.59	1.52	-
2	62	38	Wheat Starch	0.18	1.45	2.41	-	-
3	63	37	PSS	0.20	0.29	0.47	1.12	1.35
4	51	49	DBS	0.14	0.20	0.26	0.28	0.30
5	59	41	CMC	0.21	1.38	2.59	-	-
6	61	39	COAL 150	0.25	2.15	2,55	-	-
7	51	49	TEA	0.15	0.51	1.12	1.33	1.55
8	50	50	PEG II	0.10	0.31	0.49	1.15	1.39
coal size fraction 60 mesh								
1	56	46	PEG I	0.11	0.21	1.14	3.21	-
2	60	40	Wheat Starch	0.49	2.55	-	-	-
3	68	32	PSS	0.29	1.59	2.55	-	-
4	55	45	DBS	0.10	0.31	0.42	1.12	1.48
5	58	42	CMC	0.11	1.29	2.45	-	-
6	63	32	COAL 150	0.31	2.45	-	-	-
7	60	40	TEA	0.20	1.47	-	-	-
8	60	40	PEG II	0.12	1.36	2.19	-	-

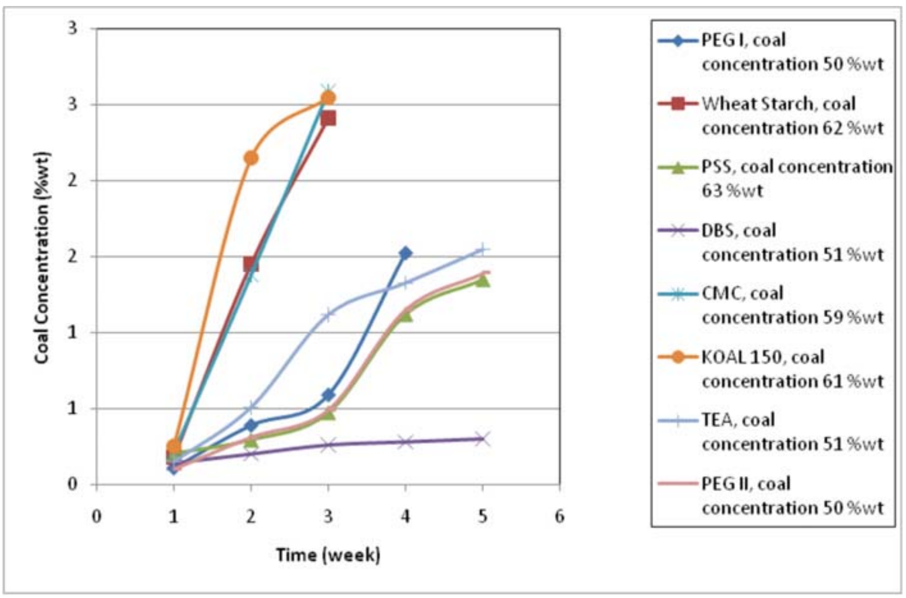

Figure 3. Penetration test results with 200 mesh size fraction

with the optimum composition of coal is 55% because its penetration rate are relatively constant: 0.1 seconds, 0.31 seconds, 0.42 seconds, 1.12 seconds, and 1.48 seconds.

The fact that CWF are stable and not easy to settle rapidly in a gravity field is a goog characteristics. CWF stability can be indicated by the steady decline in concentration, while the minimum sedimentation can be indicated by the constant penetration rate. Concentration test which shown in Figure 1 and Figure 2 shows the late decrease of concentration is CWF that uses DBS additive. Penetration test which is shown in Figure 3 and 4 shows

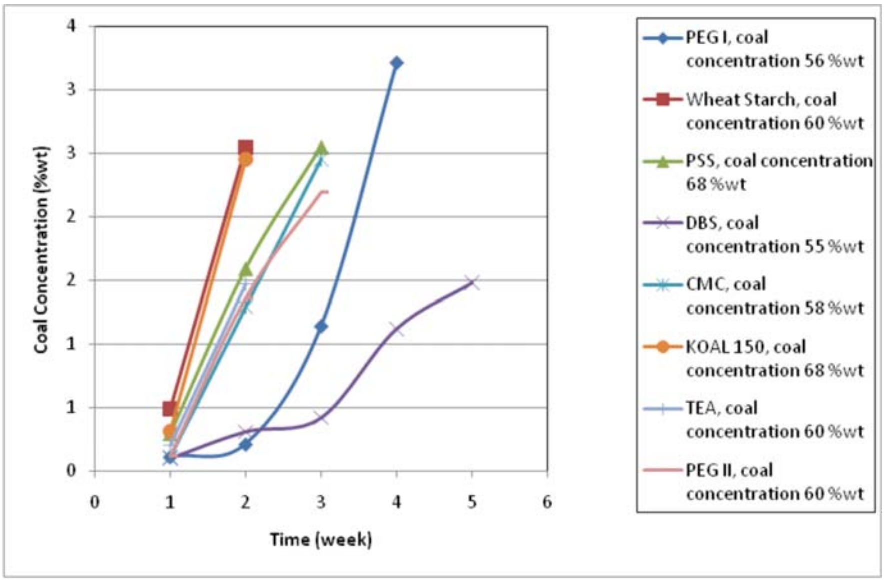

Figure 4. Penetration Test Results With 60 mesh size fraction

the constant penetration rate is CWF that uses DBS additive also. It means that DBS additive is the best additive compare to other 7 (seven) additives for both of size fraction of 60 mesh and 200 mesh.

Preparation of CWF was as substitute for heavy oil as energy source. So, it is necessary to maintain the energy from CWF as similar to those of oil which can be achieved by maximize solid content or coal concentration in CWF. However, the increase of coal concentration in CWF will cause an increase in viscosity which will make CWF difficult to flow. Thus it is important to find out the optimum coal concentration in CWF. Results of experiments above shows that optimum coal concentration in CWF that uses additive DBS is 51 to 55%.

In CWF with 200 mesh size fraction, the decrease rate of coal concentration (Figure 1) is relatively constant compared with CWF with 60 mesh size fraction (Figure 2). The penetration rate of CWF with 200 mesh size fraction (Figure 3) is relatively constant compared to CWF with 60 mesh size fraction (Figure 4). It is in accordance with Stokes law for calculating terminal velocity which states that in order to obtain a stable CWF particle diameter / size fraction of coal should be as small as possible (Wikipedia.org). The optimum mean particle size for CWM prepared for use in heat engines is generally in the 10-15 µm range (Davis and Maxwell, 1991).

CONCLUSIONS AND SUGGESTIONS

Conclusion

Quality of CWF depends on specific additive types, certain coal size fraction and limited coal concentration. The best characteristic of CWF in the experiment results from combination DBS additive, 200 mesh size fraction and 51% coal concentration.

Suggestions

It is suggested that:

– experiment with more various variables is necessary, including raw material from different locations and different types of additives.

– additives should be economically less expensive and easier to obtain.

– for low rank coal, it is endeavored to do the first UBC.

– rheology test needed to be done with more specific tool, in order to obtain results more accurately.

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