STUDY OF POLYMETHACRYLATE (PMA) INFLUENCE AS DISPERSANT ON UBCWM PREPARATION

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ABSTRACT

Upgraded brown coal water mixture (UBCWM) is a mixture of coal resulted from upgraded brown coal (UBC) process with water in a certain ratio to form a homogeneous and stable suspension during storage, transportation and combustion. UBCWM can be used as direct fuel as substitute for heavy fuel oil, particularly in industrial boilers. To obtain a UBCWM with high coal concentration and low apparent viscosity as well as good flow characteristics, the addition of additive as dispersant is needed. To study the effectiveness of polymethacrylate (PMA) as dispersant, research on the effect of PMA in the production of UBCWM needs to be carried out. The research was conducted by preparing UBCWM with the addition of PMA of 0.1, 0.3 and 0.5% and also carboxymethyl cellulose (CMC) of 0.01% as stabilizer. Preparation of UBCWM using 0.3% PMA and CMC, xantham gum (S- 60) and ransham gum (S-194) of 0.01% each was also carried out. Flow characteristic of the UBCWM was measured by using a viscometer at various shear rate. Results indicate that the addition of 0.3% PMA in the production of UBCWM is effective as dispersant. The addition of 0.5% PMA did not significantly reduce apparent viscosity. The addition of 0.3% PMA together with 0.01% CMC produces UBCWM with the highest coal concentration of 58.3% with yield stress of 23.22 Pa.

Keywords: polymethacrylate, dispersant, coal slurry, UBCWM

INTRODUCTION

Since the issuance of the government regulation on energy diversification, coal has taken the role as the main alternative energy substituting oil and natural gas. Coal utilization in the form of suspension, i.e. coal water mixture-coal slurry, is interesting due to its flow characteristic that enable the function of liquid fuel as substitution of heavy fuel oil commonly used in oil refinery or industry.

Utilization of coal water mixture (CWM) has several advantages as the followings:
- Diversification of coal utilization;
- No spontaneous combustion hazard;
- Easy to be transported, because its allows the transportation through pipeline;
- Clean environment (dust free); and
- Able to use the existing steam boiler designed for fuel oil with slight modification.

The technology of CWM preparation is quite simple, namely by mixing coal and water at specific ratio. The Indonesian low rank coal if it is used as direct raw material will produce suspension with low coal concentration, thus results in low calorific value (Umar, 2006). To solve the problem, low rank coal needs to be upgraded to decrease the water content of the coal and to produce suspension with relatively high coal concentration. The upgrading technology that has been applied in pilot scale and demonstration plant is by UBC process, namely by heating the coal in 150°C temperature and 3.5 atm pressure (Shigehisa, 2005). The coal water mixture produced from the UBC-proces is called upgraded brown coal water mixture (UBCWM).

In principle UBCWM is similar to CWM, namely having coal concentration as high as possible with relatively low viscosity to enable flowing. Accordingly, additive substance is needed as either dispersant or stabilizer. This paper will describe the influence of polymethacrylate (PMA) as dispersant that was combined with CMC (carboxymethyl cellulose), S-60 (xantham gum) and S 194 (ransham gum)

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as stabilizers towards the flow characteristic of UBCWM. The viscosity measurement and shear stress of UBCWM at some shear rate was measured by using rheometer Scientific SR-5. The result of this research is expected to possibly be used as reference of selection of appropriate additive, so that the UBCWM has good flow and stable characteristics with high coal concentration.

LITERATURE REVIEW

CWM that will be used as fuel has to fulfil the following requirements (Hashimoto, 1999):

- Has optimum yield stress value that UBCWM with good stabilization, in both static and dynamic conditions, will be produced.
- Has the Newtonian fluid flow characteristic when given shear rate with pumping during transportation through pipe or during combustion.
- Has high viscosity during storage, medium viscosity during transportation and low viscosity during combustion.

According to Thambimuthu (1994), the relation between shear stress and shear rate shows the flow characteristic of certain fluid. In general, fluid is characterized into 2 groups, namely:

- Newtonian fluid that conforms to Newton rule/formula, namely fluid with stable viscosity although the shear rate changes.
- Non-Newtonian fluid that does not conform to Newton rule/formula as the fluid has changed viscosity depending on the shear rate.

Non-Newtonian fluid is further classified into 3 parts, namely Bingham plastic, pseudoplastic and dilatant.

The Bingham plastic flow curve does not pass through the start point of shear stress axis, but cuts through it. If the curve is interpolated from its straight part to the shear stress axis at certain point, then the distance between zero point to that point is called yield stress. This thing happens due to the existence of contact among closed particles that needs to be broken before the fluid flows. This yield stress value indicates the level of flocculation energy (Usui, 1997).

Pseudoplastic flow does not have yield stress value as Bingham plastic does. The curve of pseudoplastic flow has a slope with increased shear rate up to certain limit of slope. The viscosity value of Bingham fluid flow and pseudo plastic decrease along with the increase of shear rate. This type is called shear thinning. The dilatants fluid is on the opposite, the viscosity value increases along with the increased shear rate; it is called shear thickening. The dilatants fluid type is not desirable in UBCWM as it will make difficulty for the UBCWM to flow.

Research on the making of CWM by using low rank raw coal from Berau, East Kalimantan, and PMA dispersant has been conducted. (Umar, 2006). Result of research shows that at the coal concentration of 50% and 55%, the apparent viscosity is 2.16 Pa.s and 4.96 Pa.s, respectively. The high apparent viscosity value (> 1 Pa.s) causes difficulty to flow the CWM.

METHODOLOGY

Equipment

Equipments used in this research were:

- 1 unit of UBC process equipment of pilot scale (5 tons/day);
- 1 unit of preparation and coal analysis equipment;
- Ultra fine mill;
- Scale with 2 digit accuracy;
- Magnetic stirrer (500-1.000 rpm);
- Rheometer scientific SR-5 ; and
- Other supporting equipments, like spray bottle, spatula, spindle.

Material

Materials needed were:

- Local rank coal from Berau, East Kalimantan;
- Kerosene;
- Low sulphur wax residue (LSWR);
- Nitrogen gas;
- Polymethacrylate (PMA) made by NIPPON SHOKUBAI Co., Ltd with molecule weight of 40,000-60,000;
- CMC (carboxymethyl cellulose);
- S- 60 (xantham gum);
- S-194 (ransham gum); and
- Other supporting materials, like aquadest, lubricant oil.

Experiment Variable

The experiment of UBCWM preparation was carried out by the following variables:

- Coal concentration in UBCWM: 50, 55, 57,5 and 60%
- PMA concentration: 0,1, 0.3 and 0.5%
- Stabilizer type: CMC, S-60 and S-194 of 0.01% each

Experiment Procedure

- UBC Process
  The UBC process was conducted at Palimanan-Cirebon pilot plant. Coal of -3mm size was mixed with kerosene that contains of 0.5% LSWR (ratio of coal and kerosene is 3:7). The kerosene used in this experiment is the one produced by Pertamina which is usually utilized by industry and households. LSWR is the side-product of the Cilacap oil refinery. The specification of LSWR used can be seen at Table 1 (Umar, 2003).

  The mixture of coal and kerosene was then heated in temperature of 150^0C with pressure of 3.5 atm. Oil residue was added to maintain the water content of coal after the process. After being heated, coal was separated from the kerosene by using decanter and dried by using rotary dryer. The kerosene used in the process was then be separated and can be reused for the next process. The coal produced from UBC process was ground by using ultra fine mill until it gets the size of -200 mesh (Umar, 2001). The result of coal analysis after UBC process can be seen at Table 2.

- UBCWM Preparation
  Coal of -200 mesh size was weighted and put in a 100 ml cup. The coal was mixed with water and PMA additive, as well as the stabilizer at certain ratio according to the experiment variable to produce UBCWM of approximately 50 g. The mixture was stirred by stirring rod until homogeneous. Magnetic stick is put into the

Table 1. Specification of low sulphur wax residue (LSWR)

Analysis	Unit	Result
API gravity 60°F	-	23.35
Ash	weight %	0.003
Residual carbon	weight %	3.9
Density 15°C	kg/m^3	913.3
Flash point PMcc	°C	104.4
Pour point actual	°C	46.1
Sedimentation	weight %	0.01
Specific gravity 60/60°F	-	0.9138
Total sulphur	weight %	0.26
Redwood Viscosity at 140°F	Sec	179
Moisture	volume %	0.1

Table 2. Analysis result of proximate, ultimate and calorific value of upgraded coal

Analysis	Unit, air dried basis	Result
Inherent moisture	%	4.81
Ash	%	3.12
Volatile matter	%	46.69
Fixed carbon	%	45.38
Carbon (C)	%	65.91
Hydrogen (H)	%	6.28
Nitrogen (N)	%	1.03
Sulphur (S)	%	0.48
Oxygen (O)	%	23.18
Calorific value	cal/gr	6,274

cup and stored on the magnetic stirrer. The magnetic stirrer was operated in 1 hour at 750 rpm speed. The flow characteristic of UBCWM was then tested by using rheometer plate-plate at the shear stress started from zero to 10,000 Pa. From this test, it can be obtained the value of apparent viscosity and shear rate.

Flow chart of the test consisting of the UBC and UBCWM preparation, as well as the test on UBCWM flow characteristic can be seen at Figure 1.

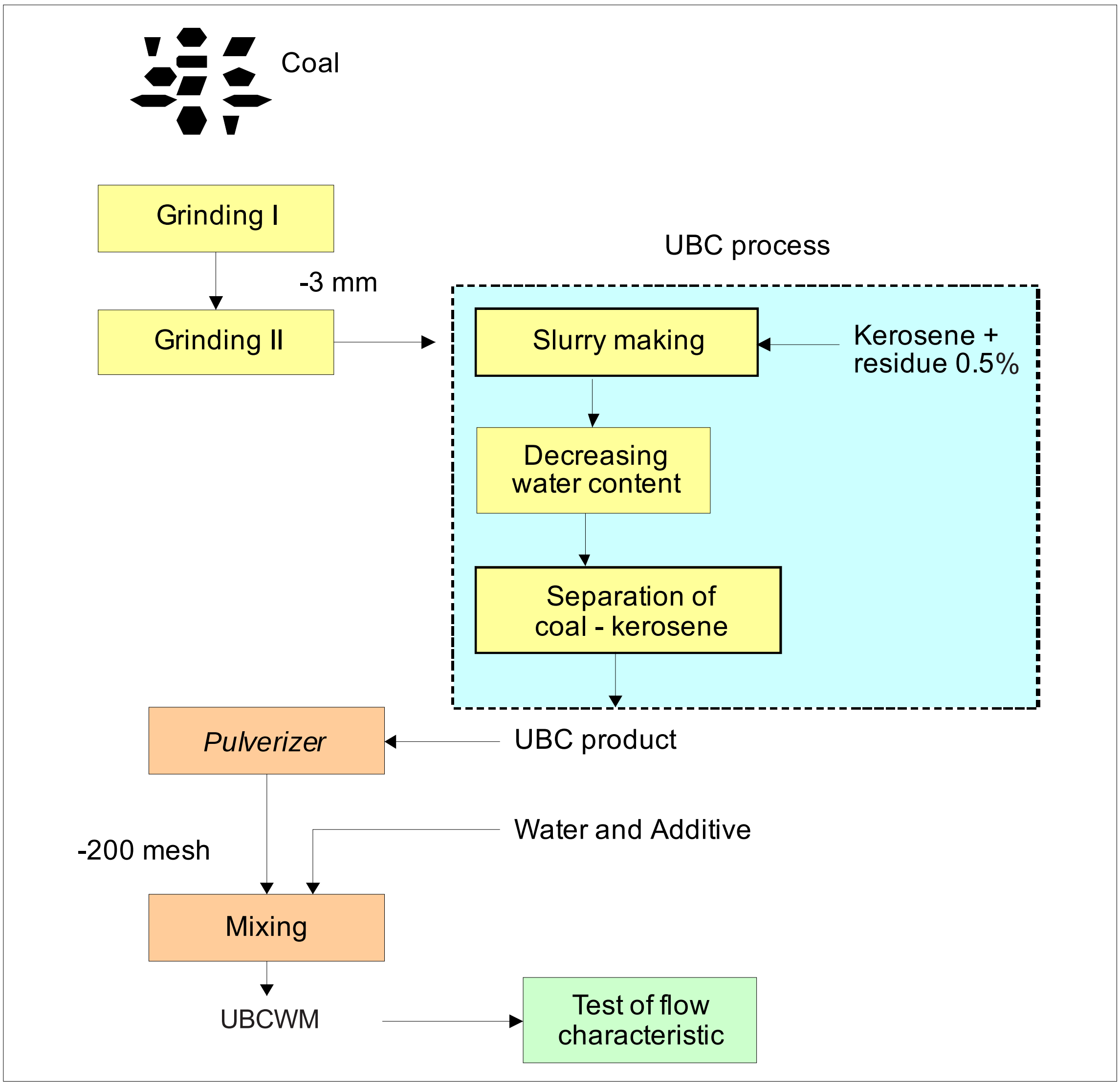

Figure 1. Flow Chart of Experiment

RESULT AND DISCUSSION

PMA influence on various coal concentrations on UBCWM flow characteristic can be seen at Figures 2 and 3 at the shear rate of 100/second. The determination of apparent viscosity at the shear rate of 100/second was considered due to the fact that during CWM combustion, at the shear rate CWM could be completely atomized (Usui, 1997). Figure 3 indicates PMA influence on yield stress at the same shear rate. At this level, the test used CMC stabilizer of 0.01%. As comparison, a research was also conducted on the preparation of UBCWM without the addition of dispersant.

Figure 2 shows that UBCWM without using PMA has the highest apparent viscosity compared to UBCWM that uses PMA as dispersant. It means that PMA is capable of decreasing UBCWM apparent viscosity at the same coal concentration. However, at higher coal concentration (60%), the influence of PMA addition is not significant. According to Usui (1997), good suspension has to have apparent viscosity of 1 Pa.s at the shear rate of 100/sec. Figure 2 shows that UBCWM with 60% of coal concentration has apparent viscosity > 1 Pa.s.

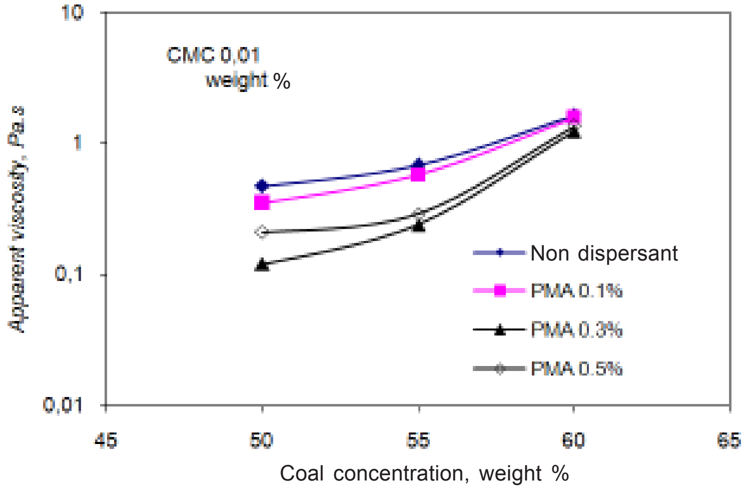

Figure 2. PMA Influence on UBCWM apparent viscosity

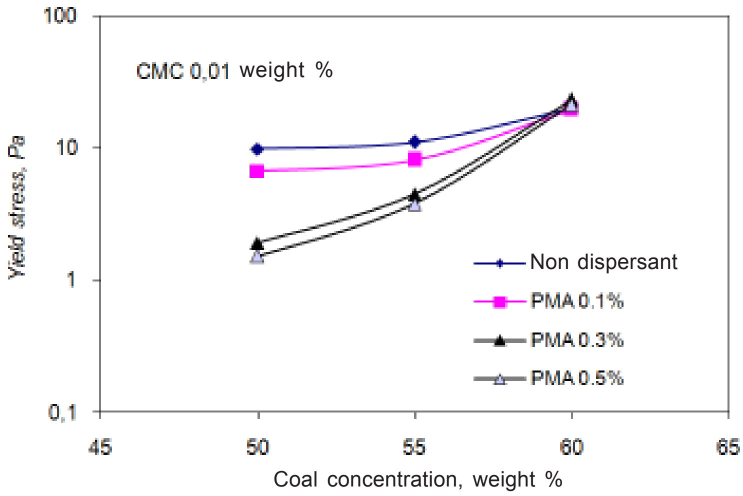

Figure 3. PMA Influence on UBCWM yield stress

The same as the apparent viscosity, UBCWM yield stress will be higher along with the high coal concentration in UBCWM (Figure 3). Yield stress can be used to identify UBCWM static stability. The higher the yield stress is, the better the UBCWM static stability, and the higher the pressure needed to flow it. To know the influence of PMA together with the stabilizer, some experiments were conducted on various stabilizers at the PMA concentration of 0.3%. The results can be seen at Figures 4 and 5.

From Figure 4, it can be seen that the addition of stabilizer S-60 and S-194 was influential to the coal concentration curve – apparent viscosity. While the curve resulted by the addition of CMC stabilizer was similar to the one without stabilizer. As a whole, the increase of coal concentration is followed by the increase of apparent viscosity. However, the UBCWM apparent viscosity that uses S-60 and S-194 stabilizers increases significantly compared to that using or without CMC stabilizer. From the experiment result, it can be con-

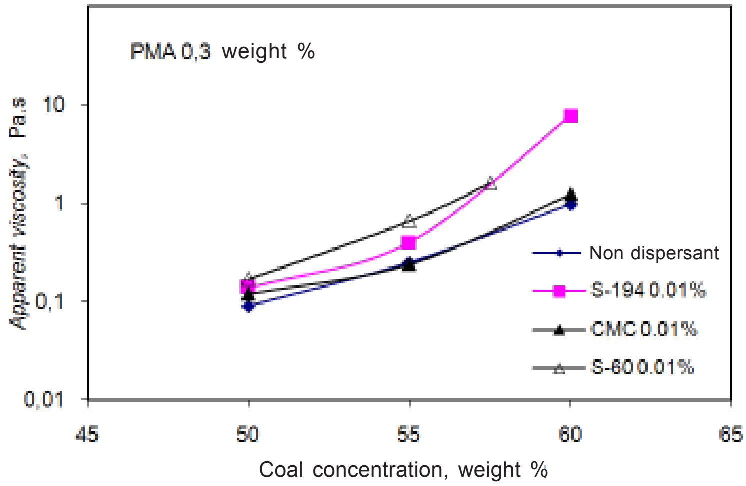

Figure 4. Influence of stabilizer on UBCWM apparent viscosity at 0.3% PMA

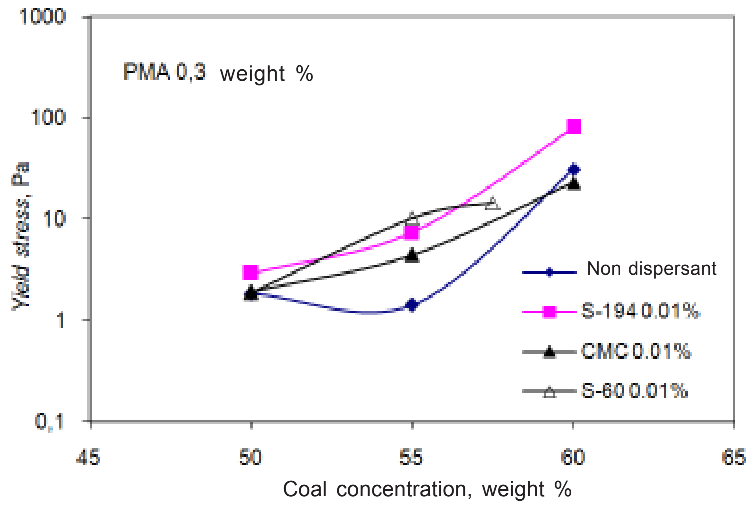

Figure 5. Influence of stabilizer on UBCWM yield stress at 0.3% PMA

cluded that the best stabilizer to be added with PMA is CMC. The addition of 0.01% CMC to the UBCWM with 0.3% PMA shows the optimum apparent viscosity was reached at the coal concentration of 58.3%.

Based on yield stress measurement (Figure 5), it can be seen that the UBCWM of 60% coal concentration with 0.01% CMC has a little bit lower yield stress than that of UBCWM without using stabilizer. However, at 55% coal concentration, UBCWM yield stress without stabilizer addition indicates the lowest value. It shows that with high coal concentration, the UBCWM is quite stable as shown by the following equation (Geankoplis, 1993)

$$V = \frac{(\rho_1 - \rho_2)\ g\ D^2}{1.8\ \mu} \qquad (1)$$

where : V = sedimentation velocity, m/s
ρ_1 = solid density, kg/m^3
ρ_2 = media density, kg/m^3
g = gravity, m/s^2
D = particle diameter, m
μ = viscosity, kg/m.s

According to the equation 1, the higher the coal concentration, the higher the viscosity and the lower the sedimentation velocity or the more stable the UBCWM. In this case, the high coal concentration in UBCWM (60%), the addition of stabilizer was not significantly effect. While to the low coal concentration (50 and 55%), the addition of stabilizer was very important. The experiment result shows that the optimum UBCWM preparation with apparent viscosity of 1 Pa.s was reached at 58.3% coal concentration with the addition of PMA of 0.3% and 0.01% CMC.

Figure 6 shows that UBCWM using 0.3% and 0.01% CMC has non-Newtonian flow characteristics. The apparent viscosity changes by the change of shear rate. The higher the shear rate, the lower the apparent viscosity of UBCWM. It means that the UBCWM was easy to flow when being pressed by pump. Figure 7 shows that the flow characteristic of UBCWM follows the Bingham plastic rheological behaviour that did not pass the start point of shear stress but by crossing it. Besides, if the curve is interpolated from its straight part to shear stress axis at certain point, then there was distance between zero point to that point (yield stress). It means that the UBCWM has the Bingham plastic non-Newtonian flow characteristic. At low shear rate, the apparent viscosity and shear stress are not stable, it was fluctuation. However, the decreasing of viscosity and the increasing of shear stress were quite consistent.

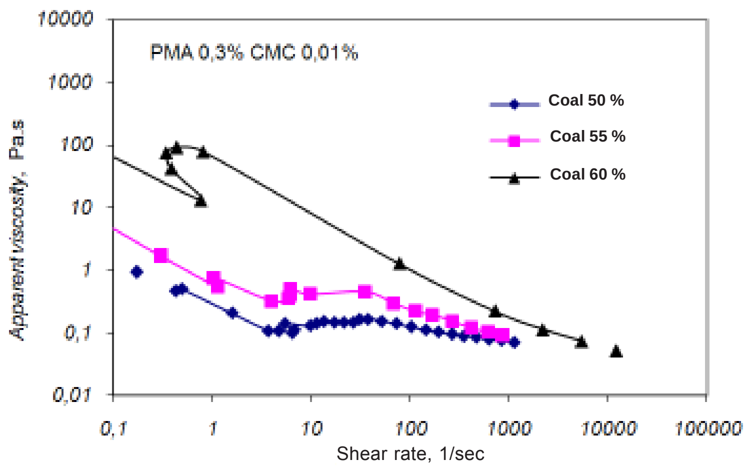

Figure 6. Flow characteristic of UBCWM based on curve of apparent viscosity – shear rate

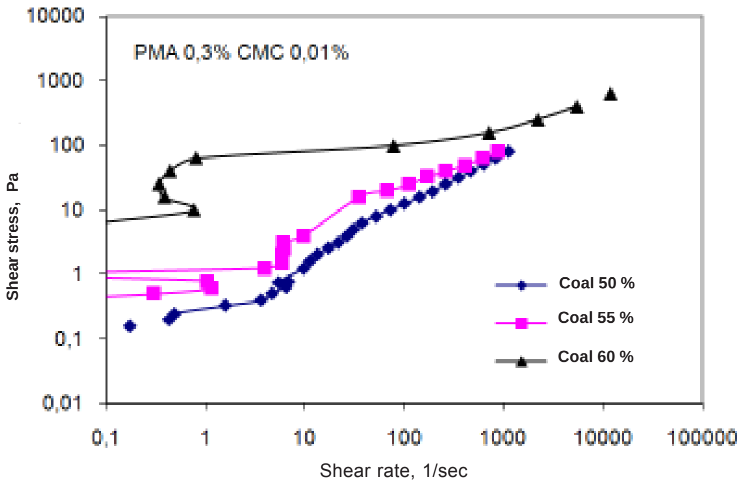

Figure 7. Flow characteristic of UBCWM based on curve of shear stress – shear rate

CONCLUSION

From the experiment result and discussion, it can be concluded that:

– PMA decreases apparent viscosity and increases coal concentration so that the calorific value of UBCWM increases and can easily be used as direct fuel.

– PMA addition was only effective at coal concentration of <60% and optimal apparent viscosity was obtained at UBCWM with 58.3% concentration.

– Addition of stabilizer to UBCWM together with PMA was only effective to <60% coal concentration and the highest yield stress was reached by mixing with CMC stabilizer.

– UBCWM with optimal flow characteristic was obtained by mixture 0.3% PMA and 0.01 CMC, at 58.3% coal concentration.

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