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EFFECT OF CHEMICAL ADDITIVE QUICK LIME ON THE RHEOLOGY OF COKING COAL SLURRY

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Coking coal is in demand for its huge applications in the metallurgical and steel industry. Coking coal is the fine quality of coal that is required for the preparation of coke while manufacturing of steel. When heated in absence of air, metallurgical coke having grayish metallic luster is left. This coke after being checked for chemical and physical characteristics is used by the steel plants. In order to improve the pumping efficiency of coking coal and water slurry, it is required to reduce its viscous forces. This can be achieved by the addition of chemical additives. In this study, Quick lime is used as the chemical additive for shear reduction. Tests are performed at the mass concentrations of 20%, 25%, and 30%. Rheological parameters of the slurry are measured with and without the addition of Quick lime. Quick lime added to the slurry at 0.05%, 0.1%, 0.5%, 1% and 1.5% mass concentrations of solids in the slurry. Most of the samples prepared for the respective concentrations are found to be non-Newtonian in nature and following the Herschel Bulkley model at high shear and Power law at low shear range. A considerable drop in the shear stress and viscosity of coking coal and water slurry has been observed after the addition of Quick lime to the slurry.

KEY WORDS: Coking coal, slurry, quick lime.

1. INTRODUCTION

Solid liquid slurry flow through pipeline is an important advanced method used now a days in the industry. This method is well adopted for more economical, safe and environment friendly transportation of ores and minerals. Coking coal is an important industrial material that needs to be transported on large scale. It is required to make coke in steel manufacturing industries. Bituminous coal with low ash and low Sulphur content is considered as coking coal. Burning of such coal in absence of air gives grey, hard and porous lumps i.e. coke. This high carbon fuel is used in manufacturing of steel.

As a growing economy, there is a huge demand of coking coal in Indian steel manufacturing industry and hence can be transported effectively through slurry pipelines. Determining rheological parameters is important for the modelling of slurry pipeline flow, which helps in estimating the pumping power required for the particular flow. Several efforts till now have been made by researchers in this direction on different types of slurries of various industrial importance. Liu et. al. (2000) used viscosity measurements from the rheological study of ceramic slurry to determine the critical ceramic powder volume concentration which is a helpful criterion in extrusion processes. Bournonville et. al. (2002) investigated non Newtonian suspensions of fly ash obtained from the municipal

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solid waste incinerator for the rheology and the effect of yield stress, concentration and hydrodynamic interaction. Benertem et. al. (2010) discussed in details about the rheology of water phosphate slurries at different solids concentration. Key factors (particle size distribution, particle size and concentration) influencing the viscosity of slurry are analysed and presented in the study. Thixotropic and shear thinning behaviour of the suspension was reported. Assefa and Kaushal (2015) performed an intensive study on the rheology of coal ash slurries. Experiments were performed for the rheological analysis of fly ash with and without addition of bottom ash and vice versa. Where the fly ash slurries found to be showing the Bingham behaviour but bottom ash slurries on the other hand exhibiting the Newtonian nature for the tested concentrations. Further, Assefa and Kaushal (2017) investigated the highly concentrated Bingham slurries with multi-sized particle distribution and proposed a viscosity model predicting the viscosity of high concentration Bingham slurries with more accuracy.

For the efficient transportation of slurry through pipelines, chemical additives are used commonly. Additive can alter the rheological characteristics of slurry by affecting the interparticle interaction and can help in cost reduction by reducing the pumping power. Therefore, effect of different chemical additives on the slurries has been performed by many researchers. Schick and Villa (1983) explains in details the effect of surfactants in coal technology including the coal slurry transportation. Roh et. al. (1995) found that slurryability of coal water slurry can be enhanced after addition of surfactants and performed rheological analysis for different surfactants and concentrations. Pseudoplasticity was found to be increasing with decreasing amount of surfactant.

Decrease in the viscosity of low rank highly concentrated coal water slurry after addition of surface active agents observed by Aktas et. al. (2000). Triton X-405 reduces the viscosity of low ash content slurries but for higher ash content it remains unchanged and exhibits non-Newtonian behaviour. Tiwari et. al. (2004) performed detailed analysis of the effects of various additives in coal water slurry using indian coals. Liu et. al. (2009) performed rheological study for coal water slurry using calcium based additives and figured out the optimum amount of additive for obtaining lesser viscosity. Another study performed by Chandel et. al. (2009) for determining the effect of chemical additives on pressure drop and rheology of fly ash slurries at high concentration. A mixture of sodium carbonate and Henko detergent was used mixed with the slurry and pressure drop in a pilot plant test loop were measured. Measured data is further compared with theoretically calculated pressure drop and reduction in the pressure drop were found.

Sodium bicarbonate and Henko detergent used by Chandel et. al. (2012) as chemical additives to the highly concentrated fly ash slurries for analyzing the performance of progressive cavity and centrifugal pumps. Additives were found to be effectively improving the efficiency of centrifugal pumps. Assefa and Kaushal (2018) used different chemical additives for a detailed rheological study of highly concentrated iron ore slurries. Different concentrations of additives were used and the analysis clearly explains the effect of additives on the rheological parameters and the optimum concentration of additives for minimum stresses was reported.

2. METHODOLOGY

RheolabQC, a rotational type rheometer manufactured by Anton Paar company ltd, Germany, used to perform the rheological tests of the samples. It possess a very high precision encoder along with a highly dynamic EC motor. This whole assembly is connected with a computer system having Rheoplus software installed in it with graphic user interface. Test sample is placed in CC27 measuring cup and ST22-4V-40 sensor systemwith four-bladed van rotor (40 mm length and 22 mm diameter) is used to measure shear stress and shear strain readings from the sample. Tests were performed for two controlled shear rate ranges from 160 to 430 s^{-1} and from 430 to 700 s^{-1}. Shear rate ranges were selected on the basis of accuracy of data obtained. All measurements were repeated three times and averaged to minimize the error. Test samples of 60ml total volume were prepared for all the concentrations and electronic weight balance with a deviation of $\pm 10^{-4}$g used to weigh the samples for required proportion.

3. RESULTS AND DISCUSSION

Sample of coking coal with particle size finer than 500 micron used to perform the rheology tests. Sieve analysis and hydrometer tests performed to obtain the particle size distribution curve and the value of median particle diameter (d_{50}) obtained as 175 micron. Wet sieving of the test sample through 75 micron sieve performed to remove finer particles.

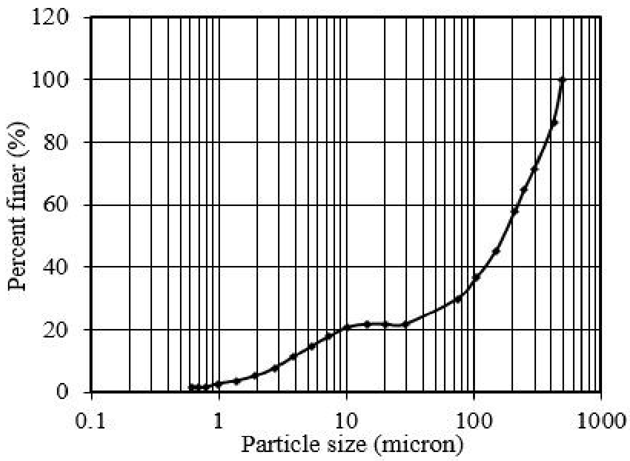

Figure 1. PSD curve for coking coal sample.

pH of the coking coal slurry measured using the digital pH meter for 20% total mass concentration for different additive concentrations as shown in Table 1 is increasing with increase in the concentration of additive.

Table 1

pH of coking coal slurry with different quick lime concentrations.

Additive concentration (%)	pH
0	7.36
0.05	8.11
0.1	10.2
0.5	11.92
1	12.07
1.5	12.05
2	12.09

Coking coal slurry samples are found to be following the Herschel Bulkley model of rheology at higher shear rate range (i.e. 430 s^{-1} to 700 s^{-1}) and Power law model at lower shear rate range (i.e. 160 s^{-1} to 430 s^{-1}). Slope of shear stress versus strain curve (apparent viscosity) increases with increase in shear rate. Hence, the slurry prepared is shear thickening in nature (Figures 2 to 7). Addition of Quick lime to the slurry shows an effective reduction in shear stresses as clearly mentioned in Figures 2, 3, 4, 5, 6 and 7. But further increase in concentration of quick lime increases the stresses inside the slurry. For 20% total mass concentration, minimum shear stress is observed for 0.05% additive concentration which further goes on increasing for up to 1% additive concentration (Figures 2 and 3). Similarly, in case of 25% mass concentration shear stresses are minimum at lower additive concentrations i.e. 0.05% for higher shear rate and 0.5% for lower shear rate as shown in Figures 4 and 5.

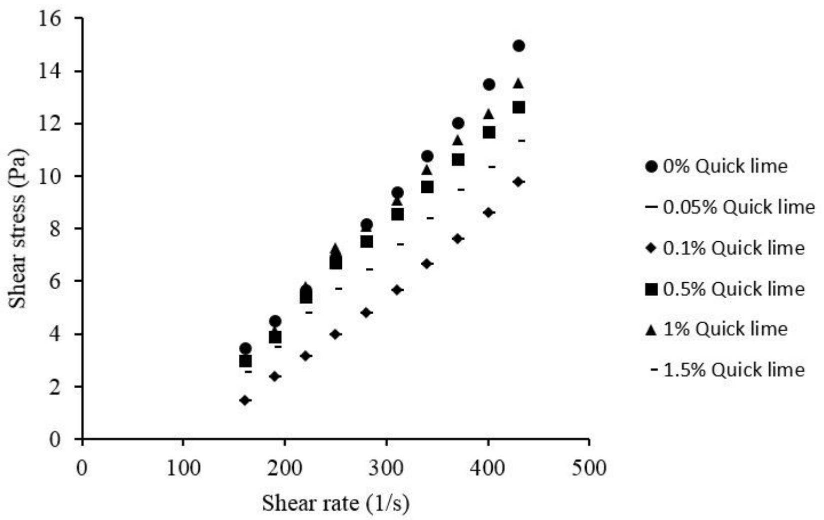

Figure 2. Variation of shear stress with shear rate for 20% total mass concentration for lower shear range.

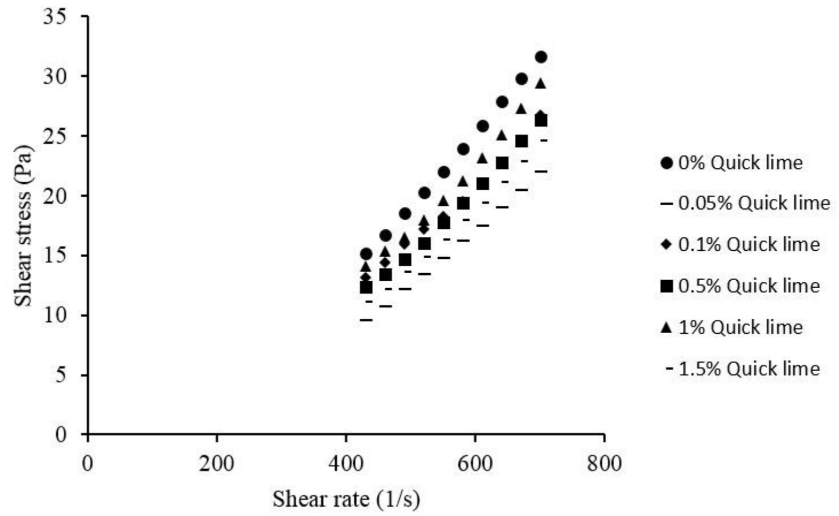

Figure 3. Variation of shear stress with shear rate for 20% total mass concentration for higher shear range.

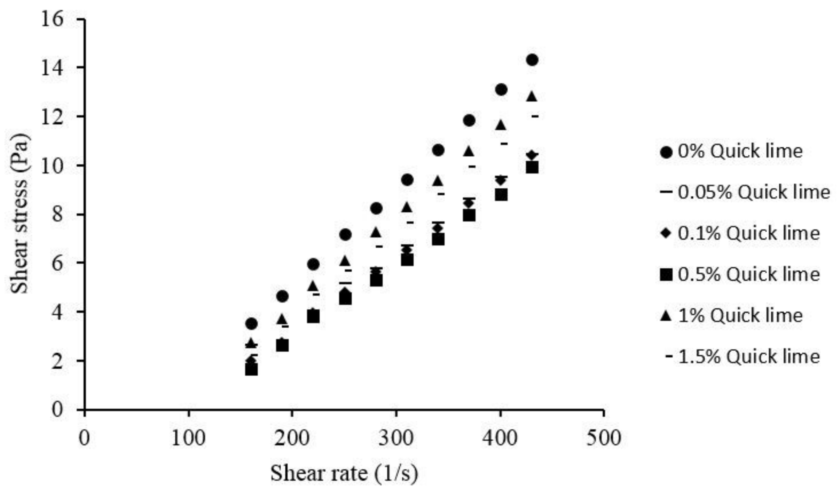

Figure 4. Variation of shear stress with shear rate for 25% total mass concentration for lower shear range.

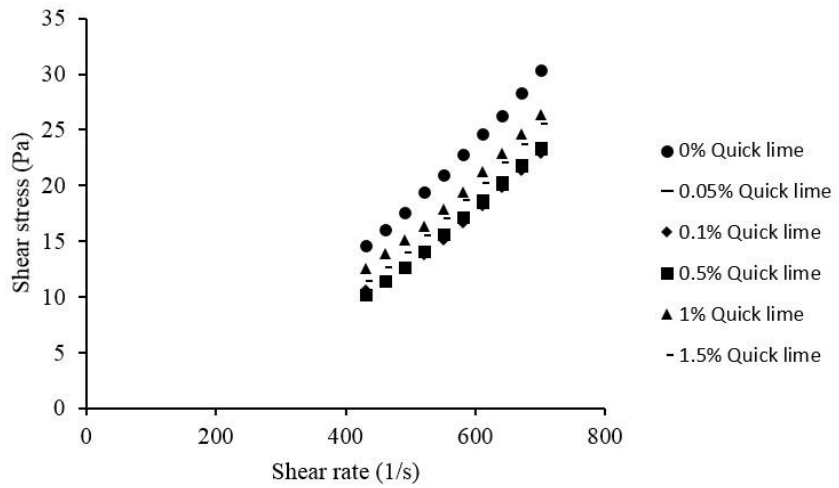

Figure 5. Variation of shear stress with shear rate for 25% total mass concentration for higher shear range.

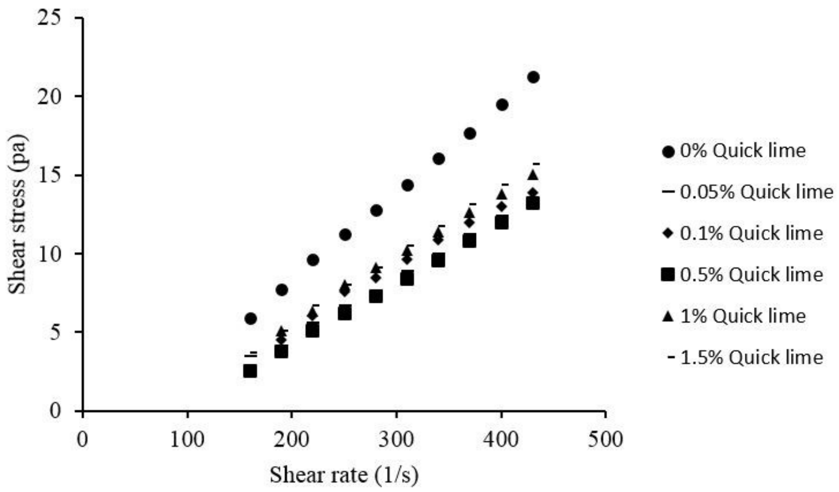

Figure 6. Variation of shear stress with shear rate for 30% total mass concentration for lower shear range.

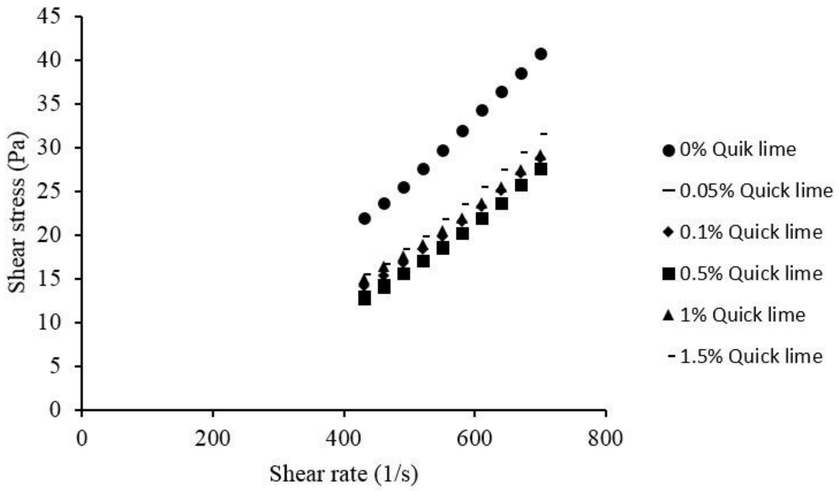

Figure 7. Variation of shear stress with shear rate for 30% total mass concentration for higher shear range.

Stresses for additive concentrations 0.05%, 0.1% and 0.5% are much lesser as compared to additive concentrations 1% and 1.5%. For 30% total mass concentration increase in stresses with increase in additive concentrations is much less as compared to other concentrations (Figures 6 and 7). Shear stresses are minimum at 0.05% additive concentration for higher shear rate and at 0.5% additive concentration for lower shear stresses.

4. CONCLUSION

Addition of quick lime to the coking coal slurry causes considerable reduction in shear stresses. Increase in the amount of quick lime to the coking coal slurry beyond 0.5% leads to further increase in the shear stresses. From the present study, optimum amount of quick lime can be concluded to be 0.5%.

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