

Abstract

Coking coal is an important ingredient used in steel manufacturing industries. It is the type of coal which possess very low ash and Sulphur content and when exposed to very high temperature in the absence of air, a highly carbon rich compound i.e., coke is prepared. This coke is used as a strong reducing agent for the metals or metal oxide in the process of manufacturing of steel. Hence, the transportation of coking coal is required on large scale. In the present study, rheological aspects of the coking coal and water slurry (CCWS) are studied experimentally under different circumstances and a modified model for the coefficient of particle diffusivity for solid-liquid slurry flows is proposed.

Rheological study on CCWS is performed using rotational rheometer for lower mass concentrations 20%, 25% and 30% and for higher mass concentrations 50%, 55%, 60% and 65%. At lower shear rate range shear thickening behaviour is exhibited by the CCWS up to 50% mass concentration and then it starts changing to shear thinning behaviour for higher concentrations. But in case of higher shear rate range, shear thickening behaviour is exhibited up to 60% mass concentration. The slurry behaviour has also been observed to be varying with different time intervals of soaking of CCWS. Sedimentation analysis of CCWS is performed and it was found that the settling of solids is taking place as long as up to 48 hours. Hydrophobic nature of the coking coal particles is clearly visible on the top surface of CCWS after mixing the solids with water in the cylindrical flask. Further absorption of water by the particles take place and the highly porous structure of the coking coal particles influence the solid liquid interaction with time. Hence, the rheology of CCWS is also determined at different time intervals (0 hours, 24 hours, 28 hours, 48 hours, and 72 hours) for the same sample kept in controlled environment. Rheological behaviour of the slurry is found to be changing significantly and the apparent viscosity increase with increasing soaking time interval. Practically such situations can be observed while the non-functioning of pipelines, storage of slurries in sharp vertical bends and slurry storage at different terminals. Slurry mixture follows the Herschel Bulkley model of rheology, for which all the rheological parameters are determined and analysed. Correlations for all the parameters are formulated for which the predicted values are found to be in close agreement with the experimental data.

Transportation of highly concentrated slurries in the industry is required to save time and to make the system more cost effective. Hence, the chemical additives are used to keep pumping

power consumption less and mixed with the slurry which helps in reducing the slurry viscosity. In the present study, chemical additive Calcium Hydroxide is used as additive for the CCWS. Rheological tests are conducted on the samples of CCWS with mass concentrations 20% and 25%. Tests are performed by adding the Calcium Hydroxide to the samples at mass concentrations 0.05%, 0.1%, 0.5%, 1%, 1.5% and 2%. A significant change in the apparent viscosity of the CCWS is observed with the addition of Calcium Hydroxide to the CCWS. CCWS samples with Calcium Hydroxide are also tested at different soaking time intervals i.e., 0 hours, 24 hours, 28 hours, 48 hours and 72 hours. Shear stress and the apparent viscosity decreases with the addition of Calcium Hydroxide to the CCWS. For 20% mass concentration at lower shear rates, at 48 hours and 72 hours soaking time intervals, the shear stresses are found to be minimum for 0.5% additive concentration and for 0 hours, 24 hours and 28 hours soaking time intervals, the shear stresses are found to be minimum for 2% additive concentration. For higher shear rates, at 48 hours and 72 hours soaking time intervals, the shear stresses are found to be minimum for 1.5% additive concentration and for 0 hours, 24 hours and 28 hours soaking time intervals, the shear stresses are found to be minimum for 2% additive concentration. For 25% mass concentration at lower shear rates, at 48 hours and 72 hours soaking time intervals, the shear stresses are found to be minimum for 1.5% additive concentration and for 0 hours, 24 hours and 28 hours soaking time intervals, the shear stresses are found to be minimum for 1% additive concentration. For higher shear rates, at 28 hours, 48 hours and 72 hours soaking time intervals, the shear stresses are found to be minimum for 0.5% additive concentration and for 0 hours and 24 hours soaking time intervals, the shear stresses are found to be minimum for 0.05% additive concentration. Numerical analysis for experimental results obtained is performed and the correlations for the rheological parameters are proposed agreeing well with the experimental data.

In order to optimise and estimate the pressure drop for the slurry flow through pipelines, it is required to model the slurry flows and estimate the concentration profiles more accurately. Many researchers have adopted various methods for predicting concentration profiles in slurry pipeline flows till now. Kaushal and Tomita (2002) found that the particle diffusivity is a varying parameter which depends upon the total efflux concentration and the static settled concentration as well. They obtained single value of the coefficient of particle diffusivity for each of the concentration profile. This model assumes the varying coefficient of particle diffusivity in place of constant particle diffusivity as considered by Karabelas (1977). The modelling approach is based on the diffusion

model and the assumption that gravitational force of the settling particles in a slurry flow is balanced by the upward movement of the particles due to particle diffusion. In the present study, a numerical model for the coefficient of particle diffusivity proposed by Kaushal and Tomita (2002) is modified after taking into consideration the variation of particle diffusivity along the vertical distance from the pipe bottom. Experimental data provided by Matousek et al. (2014) and Krupicka and Matousek (2014) has been used to optimise the coefficient of particle diffusivity at different locations corresponding to the respective particle concentration. Matousek et al. (2014) and Krupicka and Matousek (2014) performed experiments on slurries prepared with glass beads flowing through pipeline and the concentration profiles measured using a highly advanced set up of γ -ray densitometer for different flow parameters. Values obtained for the coefficient of particle diffusivity are found to be increasing with the increase in vertical distance from the pipe bottom. Larger particles possess higher values of particle diffusivity. A mathematical expression for the coefficient of particle diffusivity is proposed which is a function of the vertical distance from the pipe bottom, pipe diameter, total efflux concentration and the static settled concentration. The results from the proposed model are found to be closer to the experimental data as compared to that of the Kaushal and Tomita (2002) model. Standard deviations of concentration profiles from the experimental data for the proposed model are also reduced as compared to that of the Kaushal and Tomita (2002) model.