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Performance Study of Ash Slurry Disposal System of a Thermal Power Station

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Abstract
Centrifugal slurry pumps are the most commonly used pumps used for ash slurry disposal system. The present work is based on study of properties of ash contents present in slurry at different concentration of water. The performance of centrifugal slurry disposal pump would be studied at different concentration of ash present in slurry. The amount of ash content in the mixture of coal-ash and water will be varied to see the effect on the performance of ash disposal system in centrifugal pumps.

Keywords
Ash Slurry; Centrifugal Pump; Wear; Rheology

I. Introduction

A thermal power station is a power plant in which the prime mover is steam driven. Large amount of ash is produced in central stations, as much as 10 to 20% of the total quantity of coal burnt in a day. Theoretically whole of the ash from the furnace should get deposited in the ash hoppers, but actually from 5 to 40% of it leaves with the outgoing gases. Ash handling comprises of operations such as removing the ash from the furnace ash hoppers, conveying this ash to storage by means of conveyors and disposal of the stored ash. To handle huge amounts of ash per day, mechanical means are employed. The ash handling and disposal system can work continuously [1].

Discharge pressure and the abrasive wear are the two key factors for selecting an ash disposal pump. The centrifugal pump works on the principle of forced vortex flow. The rise in pressure head at any point of the rotating liquid is proportional to the square of tangential velocity of the liquid. Thus at the outlet of the impeller, the rise in pressure head will be more and the liquid will be discharged at the outlet with high pressure head. Hence the liquid can be lifted to a high level.

Centrifugal Pumps are used for Transportation of Slurry because of its Simplicity of design, easy installation, low maintenance, lower weight, handles suspensions and slurry easily. Centrifugal slurry pumps are best suited for short distances and for in-plant slurry pipe line systems. These pumps are used for over 97% of all short distance slurry pipelines.

Fig. 1: Centrifugal Slurry Pumps in Series

A centrifugal pump design for slurry handling system needs special consideration to ensure that the flow passage are such as to offer no restriction to the passage of solids. The abrasive nature of solids cause wears in the pumps [2]. Centrifugal slurry pumps used in thermal power station is shown in figure 01.

II. Literature Survey

Parida et al. [3] have established the pressure loss in horizontal pipes for transportation of fly ash up to 60% concentration (by weight) by correlating it with the rheological behavior of the slurry. The pressure loss could be estimated reasonably well using pressure loss models developed for Newtonian fluids in the range of 20-25% concentration by weight.

Ghanta et al. [4] using two different solids namely coal and copper ore having different surface characteristics. They found that coarse size coal-in-water slurry exhibit lower viscosity compared to fine size coal-in-water slurry, whereas copper ore behaves in a reverse way due to its opposite surface characteristics. The studies reveal that mixing fines particles with coarse slurry could reduce the viscosity of the suspension. For copper ore-water system 40:60 weight proportion gave maximum reduction and for coal water system 60:40 gave maximum reduction.

Lei L et al. [5] studies the pipeline transportation of dense fly ash –water slurry. Rheological characteristics and sedimentation stability of the slurry with the addition of four kinds of stabilizing additives were measured. Using usui's thixotropy model the relationship between flow rate and pressure drop has been estimated for the transportation of slurry. A feasibility study of new transport system was also performed.

Slatter et al. [6] studies the turbulent flow phenomena of non-Newtonian slurries in pipes and found that the rheology derived from laminar pipe flow is most useful for the prediction of the pipe flow head loss in laminar and turbulent flow.

Vlasak et al. [7] has highlighted the use of peptizing agent to decrease the viscosity and yield stress depressing the strong non-Newtonian behavior of the slurry due to presence of colloidal particles. Tests were performed on Kaolin water suspensions for laminar and turbulent regimes using an experimental test loop of 17.5 mm inner diameter and rotational rheometer.

Knezevic D et al. [8] presents the influence of ash concentration on change of flow and pressure in slurry transportation. The results show that the transport should be accomplished with ash and bottom ash concentration below 50% but above 40% of solids. In this concentration range there is decrease of both flow (per volume) and pressure. This decrease is considerably small regarding quantity of fly and bottom ash transported during the time limit.

Kumar et al. [9] have carried out the measurements for concentration profiles in mid-horizontal and mid-vertical planes at 50D, 25D and 6D downstream of a conventional 90o horizontal circular pipe bend using equi-sized silica sand slurries in a 50 mm NB re-circulating pilot plant test loop having total 30m length. The concentration profile just downstream of the bend is more uniform in the mid vertical plane as compared to the mid horizontal plane. For the flow to be fully developed, the re-adjustment length required for the slurry flow through the bend is of the order of 50 diameters from the bend exit as the concentration profile at 50D and thereafter showed no sign of effect of the bend.

Rudman M et al. [10] performed extensive experiments to explore the behavior of non- Newtonian fluids at transition to turbulence or in a weak turbulent pipe flow situation and compared the behavior with the behavior of Newtonian fluids. The Operation in the transitional regime may be advantageous for suspension transport with the intermittency of such flows being useful in re-suspending solids that have settled but still operating at lower pressure gradient than fully developed turbulent flow.

Mosa et al. [11] examined the effect of chemical additives or reagents on rheological characteristics of coal water slurry. Apparent viscosity and flow properties of coal water slurry are sensitive to the use of chemical additives. Sulphonic acid recorded the best performance in modification and reducing slurry viscosity. The best dosage of all tested dispersants was found to be as 0.75 % (by wt.) of solids. The stabilizer Na-CMC recorded better performance than xanthan gum. Best dosage of investigated stabilizers was found to be as 0.1 % (by wt.) from total solids.

Branganca et al. [12] finds that the coal ash transportation as high solids content (68% by weight) pastes are feasible. Viscosity showed significant variations depending on the particle size distribution, chemical composition, concentration of fine particles and medium pH. When water content ranged from 30% to 35% (by weight), the paste fluidity was found very well. The wetted ashes did not show any pozzalanic behavior; particle interaction in the pastes is due to electrostatic forces. Viscosity of the pulps tends to be high when they are motionless, but it diminishes under stirring (thyxotropic behavior) and becomes stable after a short period.

Senapati et al. [13] studied the modeling of viscosity for power plant ash slurry at higher concentrations and effect of particle size, solid volume fraction and hydrodynamic forces in a non-Newtonian laminar flow regime. A model has been developed to predict the viscosity incorporating maximum solids fraction (m), power law index (n), median particle size (d50), co-efficient of uniformity (CU) and shear rate (γ).

Chandel et al. [14] described the effect of additive on pressure drop and rheological characteristics of fly ash slurry at high concentration (above 60% by wt.). There is reduction in pressure drop when additive like soap solution is added to the fly ash slurry at higher concentrations. Fly ash Slurries at these concentrations show a Bingham behavior. The Bingham viscosity and yield shear stress increase with increase in concentration. The addition of soap solution as additive to the fly ash slurries reduces the rheological parameters and result in substantial decrease in energy parameters.

Naik et al. [15] observed the effect of drag reducing additives on the rheological properties of fly ash water suspensions at varying temperature. The distinctive reduction of surface tension on colloidal disperse characteristics of the resulting slurry was observed in the presence of surfactants. The additive has the capability to keep the fly ash particles water borne during its transportation in pipelines. The treated slurries exhibited the shear thinning or/and Newtonian flow properties with zero yield stress.

Mishra et al. [16] have measured the pressure drop across 90o bends in horizontal plane namely 90o mild steel commercially available pipe bend (100mm NB diameter having a radius ratio of 4) and two diverging converging bends having an area ratio of 1.5 and 2 up to middle plane with inner curvature same as commercial bend using zinc tailing slurry. Result shows higher pressure drop for diverging-converging bends compared to the conventional bends, but the extent of increase of pressure droop for bend with area ratio 2.0 over the conventional bend was only marginal.

Steward et al. [17] tested the pipe flow behavior of fly ash and water mixtures in a closed loop pipe system at solids concentrations ranging from 51% to 74% (by mass), in three different pipe sizes; 40, 50 and 65 nominal bore. The flow behavior has been presented on pipe flow curves and the laminar flow data have been used to characterize the material as viscoplastic using the Herschel-Bulkley rheological model. Anomalous transitional flow behavior is reported in that the results appear to fit the Newtonian laminar to turbulent transition model as opposed to the more widely accepted Slatter transition model.

III. Rheological Behavior of Ash Slurry

One of the most important input data needed for the design of the slurry transportation system is the rheological behavior of the slurry at various concentrations and flow conditions. Rheological parameters also help in determining the power requirement in agitating the slurry in the agitation tank. Knowledge of suspension rheology is also important to ensure a stable/energy efficient pipeline transportation system. The rheological characteristics of slurry depend on parameters such as shape, size distribution of particles, carrier fluid properties, solids concentration etc. By suitably particle size distribution, it is possible to obtain a stabilized slurry suspension. If the solids are coarse then the cost of dewatering is less but the flow becomes more heterogeneous whereas if the particles are fine then the flow is homogenous but the slurry becomes non-Newtonian and the cost of dewatering also increases. Thus in a slurry transportation system, a compromise has to be made between the particle size and the cost of dewatering. The rheological behavior of the slurry is also required to predict the head requirement for pumping the slurry. In addition, surfaces of the impeller and the walls of the casing wear more rapidly due to solid particles. The characterization of rheological behavior of slurry is complicated due to the fact that a large number of factors influence it. Non- Newtonian slurries make the principles of fluid mechanics more complex since the resistance to flow 'viscosity' now must be defined through a physical model reflecting process conditions.

IV. Conclusion

The slurries of solid materials are generally Newtonian at relatively lower concentrations but at high concentrations non-Newtonian behavior is experienced. The size distribution of particles has significant influence on the rheological behavior of the slurries. Maximum concentration of solid is a useful parameter to account for the effect of size distributions. But the difficulty in determination of the maximum concentration accurately for solids having wide particle size distribution limits the use of this parameter for the determination of the rheological properties of slurries. Maximum static settled concentration of solids account for various parameters like size and size distribution of particles, solid's specific gravity and the shape of the particle. It also reflects the crowding of particles in the carrier liquid. Correlations based on reduced volumetric concentration, for the predictions of rhelogical parameters of fine particulate slurries following Bingham model, have been found to give satisfactory results.

The presence of solids in the slurry has a great effect on the performance of centrifugal slurry pumps. The heads developed and the efficiency of the pump decreases while the input power increases with the increase in solids concentration. NPSH, in meters of slurry column, required for centrifugal pumps handling slurries is lower than that required with water. The head ratio is found to decrease with flow rate at high discharges and at higher concentration of solids. For low concentrations, it is independent of flow rate. Head ratio decreases linearly with solids concentration. The efficiency and head ratios of any given pump appear to be weakly dependent on the magnitude of rheological parameters of the coal slurry over the range tested. The efficiency ratio decreases slightly due to increase in the power input. In case of slurries of heavier solids where the rheological effects are relatively small, the deterioration in the pump performance is more pronounced in the rubber lined pump as compared to the metal closed impeller pump. Materials properties such as size, size distribution, specific gravity and concentration of solids have significant influence on the pump performance with slurries. For solids having wide particle size distribution, the mean particle diameter is a better choice as the representative particle size as compared to the average or median diameter of particles.

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