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Optimization of amount of additives to minimize relative viscosity of coal-water slurry

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Abstract: The transportation of coal or minerals through pipeline is the need of these days. The transportation of materials is already in use in India as well in other countries. Transportation of materials through pipes need power, hence it is required to minimize the power required for transportation the materials in form of slurries/mixtures. The aim of this paper is to find additives/chemicals which will reduce the relative viscosity of coal-water slurries, in turn, the reduction in power for transportation. A number of additives/chemicals were tested which must decrease the relative viscosity as well as settling velocity of slurries. This settling characteristic will be useful to reduce the probability of choking the pipeline during shut down period. The experiment were performed by keeping the facts of reduction of viscosity, minimization of settling velocity and to minimize the resistance of the particles in the cake, which were formed during shut down period. The experimental results show that the best suitable chemicals anionic detergent, mixture of commercial detergent and sodium sulphite, anionic detergent + sodium sulphite. These additives are low cost and don't alter the properties of coal. The maximum amount for minimum relative viscosity required are around 0.4-0.5% by weight of coal. Hence, by using these additives for coal-water slurry through pipeline must be cheaper or comparable with the other modes of material transportation.

I. INTRODUCTION

The transportation of materials through pipeline in slurry form is an industrial reality. For safe and economical operation of pipeline system, it is necessary to consider the char characteristics of the slurry and all other problems, which may arise in the transportation. Choking of pipeline due to settling during the shutdown period, maximum pressure developed by pump during operation, pressure drop per unit length, pipe material and its strength and reactivity or corrosion of the pipe materials with the slurry, are the important factors to be considered during designing the pipeline transportation system.

Among the above factors concerning the pipeline transportation of materials, we shall consider only settling of coal particles and rheology of the slurry. Settling characteristics play important role in this type of transportation. The additives used for the slurry may either increase the settling velocity or decrease the settling velocity. But, for our present problem we have to choose additive/chemicals which will decrease the settling velocity of the particles during transportation or standstill condition. Since coal-water slurry has to be transported at a maximum possible concentration. Therefore, slurry must have minimum settling velocity and also minimum viscosity. This paper has considered developing or finding additives which can decrease the settling characteristics as well as the viscosity of coal-water slurry.

ADDITIVES/ CHEMICALS

The rheological properties of the concerned suspensions are strongly affected by the addition of small amount of any chemical species that influences the degree of particle-particle of fluid-particle interaction. The important action of additives is shear thinning, dispersing, stabilizing, drag reduction and corrosion erosion control. For thick slurries (high concentration and fine particles), shear thinning materials or dispersants i.e., additives, break-up the agglomerates and increase the slurry fluidity by releasing the trapped fluid. The interaction forces may be physical or chemical in nature and can be summarized the the following categories (Darby, 1979).

Physical interaction forces:

- Electrostatic forces, due to surface and ion charges
- London-Vander Waals forces, attributed to temporary dipole interactions.
- Hydrophilic-hydrophobic forces, due to affinity of non-polar organic molecules with water or lack thereof.
- Activation or adsorption, due to linkage of charged species on the surface by a multivalenct ion. (this could be a special case of electrostatic interaction).

Chemical interaction forces

- Chemical bonding forces, by formation of covalent or ionic bonds.
- Co-ordination bonding forces, chelation or complex formation.
- Hydrogen bonding forces, when hydrogen atoms bonded with strong electronegative atoms such as O, S, or N, accept electrons from other atoms and the proton resonates between the two atoms.

A large number of chemical compounds have been used as additives to modify suspension behavior. Most of these may be classified as ionic, surfactant, polymeric, or a combination of these. The most desirable requirements tend to be conflicting; a combination of additives is often employed to achieve optimum properties. The influence of a given additive, not only depends on the physical and chemical properties of the solid, carrier fluid and the additive, but also on the concentration of solids and their particle size.

Corrosion of the pipe surface can be controlled by reducing amount of dissolved oxygen through the addition a suitable agent. Some agents are used to maintain protective layers on the pipe surface, in spite of continuous abrasion by the solid particles, ore, etc.

Selection of additives: Additives are used in the chemical or metallurgical industries for either coagulation or dispersion. Coagulation nature of additives is used to separate the fine particles from the slurries of materials and dispersion type of additives are used to keep the fine particles in suspension. In case of pipeline transportation of coal-water slurry, different types of additives have been used. The additives whose characteristics are of dispersion nature and selection of the additives are made by performing number of experiments by keeping the concentration and particle size distribution constant. The effect of additives has been studied on settling characteristics, to minimize the settling velocity to minimize the choking problem in the pipeline, and rheological characteristics, to lower the viscosity of the slurry which it turn will optimize the power requirement per unit mass for the transportation of the slurry.

RESULT AND DISCUSSIONS

Settling velocity of coal-water slurry: The experiment data are plotted and is shown in Fig. 1.

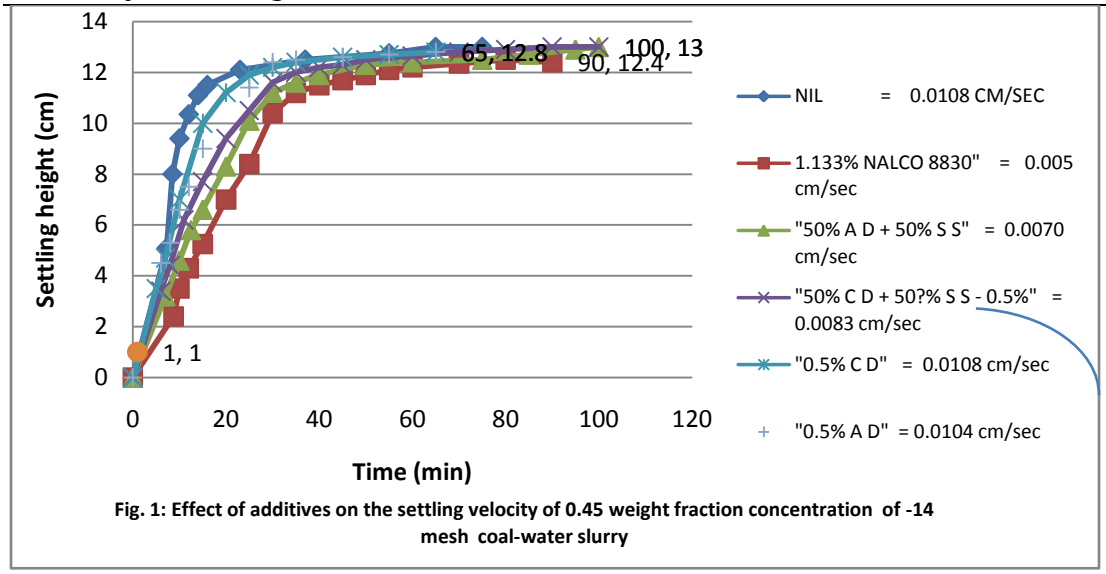

Fig. 1: Effect of additives on the settling velocity of 0.45 weight fraction concentration of -14 mesh coal-water slurry

Main purpose of the study of the effect of additives on coal-water slurry was to characterize the slurry with minimum settling velocity, elimination of floc and coagulation. The experimental results show the elimination of floc and coagulation as well as minimization of the settling velocities in the slurries due to addition of the additives shown the figure.

The reasons for this nature of the additive's effects on the settling velocity, may be summarized as follows:

i) Additives convert the fine particles of hydrophobic properties into hydrophilic nature.
ii) The additives form a layer on the surface of the particles that makes the surface hydroscopic or water loving. Thus, the floc forming particles are minimized after change in surface characteristics due to additives.
iii) The amount considered for the tests is based on the rheological characteristics studythat indicated the amount of additives required to form a monolayer on the surface. The excess amount of additives is neither useful in minimizing the friction force among the particles in the slurry nor in changing the settling characteristics.
iv) These additives make the particles in the slurry of dispersing behavior.
v) The additives also affect the Brownian motion of colloidal particles, Brownian motion randomizes relative motion and orientation and thus counteracts the effect of flow.

The most suitable additives for the minimum settling velocity are mixture of 50% anionic detergent and sodium sulphite, 50% commercial detergent and sodium sulphite. It was observed that the anionic detergent or commercial detergent alone gave more settling velocity and also found foam in the slurry. Therefore, to minimize the foaming characteristics and settling velocity the above mentioned additives were found to be most suitable.

Amount of additives: The maximum amount of additives were determined by varying the amount of different amount of additives added in the coal of fixed size and concentration and then determining the relative viscosity with the help of BROOKFIEL VOSCOMETER (LVF). The results are shown in Fig. 2 and Fig. 3.

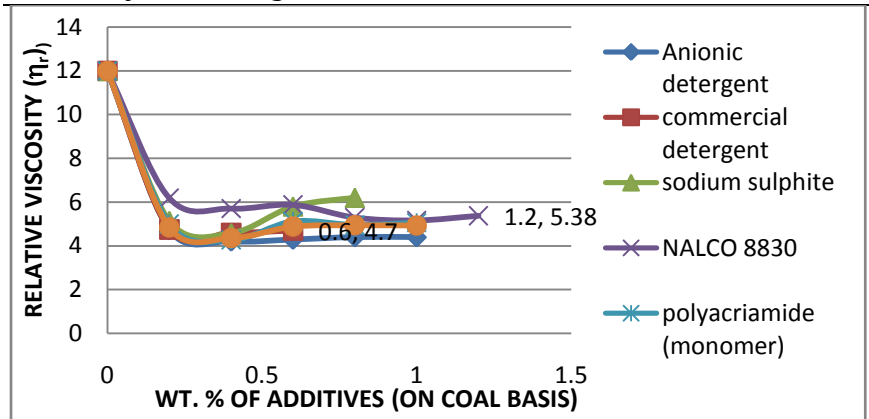

Fig. 2: Effect of addives on the relative viscosity of -120 mesh (d_{50} = 0.065 mm) coal-water slurry of concentration 0.35 weight fraction

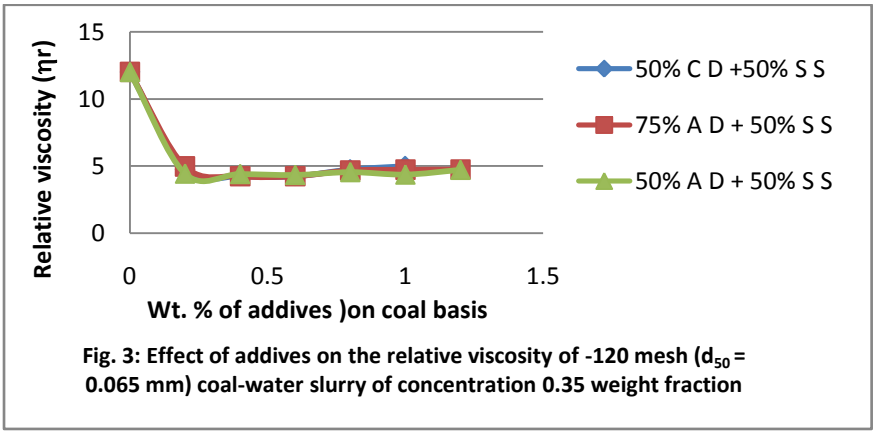

Fig. 3: Effect of addives on the relative viscosity of -120 mesh (d_{50} = 0.065 mm) coal-water slurry of concentration 0.35 weight fraction

From the above results, it is clear that the minimum amount of additives required to minimize the relative viscosity lies in between 0.3 to 0.5 weight percent of coal. Specially, the additives, mixture of anionic detergent and sodium sulphite and mixture of commercial detergent and sodium sulphite, gave minimum relative viscosity and approximately no lather formation.

Relative viscosity: The effects of additives of the optimum amount on relative viscosity were studied in BROOKFIEL VISCOMETER (LVF). The results are shown in Fig. 4.

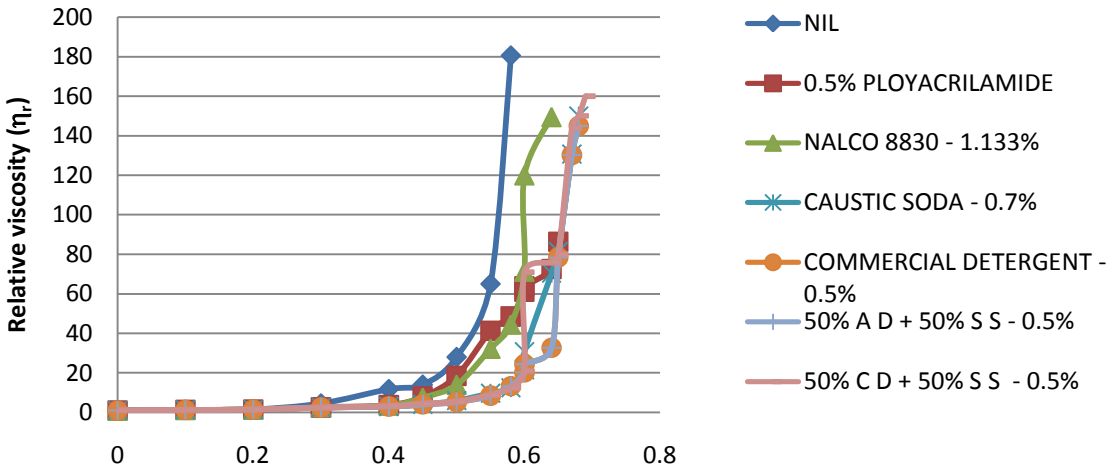

Fig. 3: Effect of additives on the relative viscosity of -72 mesh (d_{50} = 0.080 mm) coal-water slurry

The relative viscosity of coal-water slurries are found to be minimum when the additives are either 50% anionic detergent and 50% sodium sulphite or 50% commercial detergent and 50% sodium sulphite. When there is no additives the slurry are of maximum up to 60% concentration (wt. fraction) and with additives maximum concentration is 70%.

CONCLUSIONS

The effect of additives on the settling and rheological characteristics has been studied experimentally and the followings are the observations of the experimental results:

Among the additives discussed, the mixture of 05% anionic detergent and 50% sodium sulphite and mixture of 50% commercial detergent and 50% sodium sulphite are the most suitable. Mixture of sodium sulphite and commercial detergent is economical and easily available in the market.

The Newtonian nature of the coal-water slurry remains up to 35-38% concentration while the nature is up to 45-50% with treated coal-water slurry. The thixotropic characteristics of coal-water slurry disappear when the coal sample is treated with suitable additives.

The treated coal-water slurries decrease the choking probability, decrease the power requirement for transportation per unit mass of coal and more coal can be transported as the concentration of the slurry can go up to 70%.

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