A REVIEW ON THE VARIOUS PARAMETERS OF SLURRY PIPELINE DESIGN

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ABSTRACT
Particulate transport in the form of slurry using pipeline system is continuously gaining popularity as it is economic, ensures real time inventory management, environment friendly and reliable at user’s end. The design engineers have to study the various flow parameters such as flow regimes, critical/settling velocity, pressure drop etc. to design the effective slurry pipeline. The solid-liquid flows are complex flows and the limited correlations are reported in the literature. Also these correlations shows the predicted error in results within the range of 25-35%. The error in the results data that predicted from the available correlations is high that will not acceptable for the design of pipeline.

KEYWORDS: Slurry, Pipeline, Concentration, solid-liquid, two-phase

INTRODUCTION
Hydraulically transport of Bulk Solids in a particle form is a well-known technique accepted by many chemical and mining industries. In general, industries use fluids as a carrying medium to transport material [1,2]. The complete knowledge of principles governing the fluid transportation leads to more efficient and secure system. Slurry transportation is an environment friendly and is economical viable as compared to rail and roadways. Premature studies for slurry transportation were based on low to moderate concentration (upto 25% by weight). Higher concentrations are encouraged and are now in trend [3-4]. Study of the flow with high solid concentration multi sized particulate is very complicated. Slurry system designers should have precise knowledge regarding hold up, critical velocity, pressure drop, flow regimes etc. to enable them to design the pipeline and its associated facilities. Moreover, two-phase or multiphase flows are frequently observed in number of industries as petroleum, chemical, oil and mining industry [5-6]. Multiphase flow can be defined as coterminal flow of number of phases, with two-phase flow to be simplest case. A two-phase flow is simultaneous flow of two distinct phases as gas-solid, gas-liquid, or liquid solid with coexistence in arbitrary field. Generally, in two-phase flow (i.e. liquid-solid or gas-solid), the liquid phase is consistently connected and the solid phase exists as discrete particles. Two-phase flow study is crucial from practical viewpoint applications (e.g. pneumatic and hydraulic particulate flow in pipes) and natural (e.g. biomedical/biological flow, sediment transport in water bodies). Flow in which granular materials are transported in the chemical, mining, petrochemical and food industry [7-8].

Physics of multi-phase flow is more cumbersome than single-phase flow as due to the presence of dispersive phase. Moreover, further fluctuated or continuous contact motion within particulates and turbulence between them increases the degree of complexity. Particularly for these types of cases, solid phase does not follow the flow while interacts and modifies the flow characteristics which results in uncertainty. Turbulence
modulation for multi-phase flow is also important taking into view the industrial applications. Particulate transport in the form of slurry using pipeline system is continuously gaining popularity as it is economic, ensures real time inventory management, environment friendly, reliable at user’s end [9-10]. The slurry raises less dust and is extremely safe. Further, it also broadens the economic ways to reach out to the rich mineral deposit in extremely dangerous areas. Advantages associated with slurry pipeline transportation system are listed below:

- Simplicity of operation and installation.
- Less requirement of man-force to construct, operate and maintain slurry handling system.
- Eliminates logistic bottlenecks and insurance of real time inventory
- Possibility of 100% automation.

Although having number of advantages it has some disadvantages also as:

- Initial investment is high as compared to other means of transportation
- Area of application is solely dedicated to transportation of solid particulate while rail and roadways have wide area of application.
- Transportation in the form of slurry requires carrying fluid as water which is depleting and not easily available at some places.

**SLURRY FLOW**

Slurry is a mixture of fined grinded solid particles and liquids (carrier fluid). The study of slurry flow in pipeline is much different as compared to single phase flow in pipeline. Single phase can be allowed to flow at low flow velocities but for multi-phase flow it is required to overcome deposition critical velocity. The physical properties of slurry is dependent on variety of parameters as particle size distribution, solid concentration, size of pipe, level of turbulence, temperature and viscosity of carrier medium. The pressure gradient or head loss is one of another area in which careful treatment is required as compared for single phase flow. The form dp/dx, pressure gradient or frictional losses accompanied with the flow of slurry in pipeline is unambiguous. The characteristics of slurry are strongly dependent on the settling properties of the solid being conveyed. The measure of settling slurry is done with the application of settling velocity. Settling velocity is the velocity at which single solid particle settles in large volume of carrier liquid. Terminal velocity depends on the liquid and solid properties and particle size Abulnaga (2002).
Figure 1. Schematic layout of a long distance slurry pipeline Abulnaga (2002).

BASIC ELEMENTS OF SLURRY TRANSPORTATION SYSTEM

Solid in the form of fine particulates can be either of two ways by hydraulically or pneumatically. Basic difference between two being the nature of fluid used to provide motion to the solid particles. Slurry transportation system depends upon the type of solid to be transported through pipeline. However, general schematic layout of basic slurry transportation is shown in Figure 1. Three basic sub-system of slurry transportation system namely:

1. Slurry preparation system
2. Main pipeline and pumps
3. Terminal utilization facility

Initial process of the slurry transportation system is being the slurry preparation facility. Firstly, the solid to be transported are crushed to relatively smaller size using crusher so to make solid technically and economically feasible to provide the required power for creating suspension and hence their transportation. Further, the solid particulates are mixed with the carrier fluid and concentration of solid in fluid is maintained
according to optimum transport concentration of transportation system. Finally, the prepared slurry concentration is stored in agitated/non-agitated tank if required. Pumping power required to transport the slurry concentration is met either using one or more pump house. There can be one central pump house or a combination of central and intermediate pump houses to overcome the pressure losses during the transportation depending upon the length of transportation. At the terminal end there is separation facility where ore is separated from carrier fluid. The slurry at terminal end is dewatered, filtered, and dried to meet the requirement of end utilization of solids.

CLASSIFICATION OF FLOW REGIMES

Depending on the specific gravity of solid particles, the flow can be classified into following four categories Brennen (2005).

- Homogenous suspension of very fine particles with size less than 40 μm.
- The partial suspension of the solid particles due to turbulence with particle size range of 40 μm to 0.15 mm.
- The solid particles exhibiting both suspension and saltation motion.
- Solid particles shows saltation motion having particle size bigger than 1.5 mm.

The interdependency between deposition velocity, terminal velocity and solid particle size the above mentioned classification was modified into four flow regimes as shown in Figure 2. Flow velocity, phase material and pipe orientation are the main parameters affecting the two phase flow regimes in pipeline. Generally, particle size and solid concentration are used for classification of mixture nature and flow regimes in solid-liquid flow.

![Figure 2: Flow regimes for slurry flow in a horizontal pipeline.](image)

CLASSIFICATION BASED ON PARTICLE SIZE

The slurry flow is generally classified into broadly two categories: homogeneous and heterogeneous. Due to unavailability of proper distinction between homogeneous and heterogeneous flow the slurry containing solid particle size greater than 50 μm displays heterogeneous properties. The behaviour of heterogeneous slurry
flow is more complicated than that of homogeneous slurries. Due to submerged weight and effects of gravity on coarser particles, sedimentation occurs resulting in non-uniformity in concentration and velocity along the cross-section.

CLASSIFICATION BASED ON SOLID CONCENTRATION

The solid concentration of slurry is used as criterion to distinguish between dilute and dense solid-liquid heterogeneous flow. The mixture is considered to be dilute if the motion of the flow is governed by hydrodynamic forces or carrier medium interactions. Flow is considered to be dense if both particle-particle interactions and hydrodynamic forces govern the flow characteristics. No universal criterion is available in literature to distinguish between dilute and dense phase on basis of solid concentration. The creation varies with material to material and study to study.

CRITICAL VELOCITY AND HOLD UP

Critical velocity is the velocity at which solid form a bed at the lower periphery of pipe from fully suspended solid-liquid flow. It gives a measure of transition of flow from heterogeneous to saltation flow. For the optimizing the slurry through the study of critical flow is crucial and vital step. It represents the lowest velocity at which the system can perform the slurry transportation function with minimum pressure loss. The slurry in pipeline moves in the form of layers moving with different velocities. Holdups are due to slip velocity of layer large particles. Thus hold ups gives rise to a situation when the in-situ solid concentration is larger than the solid concentration delivered. This variation in concentration is known as Hold up. Hold up is key problem for the failure of many empirical relations for prediction of head loss.

HEAD LOSS/PRESSURE DROP

Head loss characteristics in pipe flow are studied for the designing slurry pipeline and pumping system. Numbers of researchers have performed experiments to obtain empirical correlations for the prediction of head loss by estimating the friction factor. The correlation developed depends on the rheological nature of slurry and experimental data of pressure using pilot test loops. Most of the relations developed are for the specific size ranges with very low to moderate solid concentrations. Hence, it is beneficial to study the flow characteristics with the computational scheme resulting lowering the capital cost and time for study.

SOLID CONCENTRATION AND VELOCITY PROFILES

Loss of pipe material due to abrasion and erosion is known as wear. This makes a great impact on initial cost as well as life of component. The wear depends on the particle collisions on the wall, depending on the flow rate and solid concentration. Therefore, in order to understand the wear phenomenon, it need to understand the velocity as well as solid concentration profile in detail. Solid concentration gives us with a detailed view of the solid volume fraction distribution along the plane while velocity profiles are used for prediction of velocity distribution of solids.
CONCLUSION
The design of pipeline is associated with the various flow parameters. The accurate information of these parameters helps to design an economic and reliable slurry pipeline. The critical velocity, flow regimes, solid concentration and pressure drop plays an important role in pipeline design. The transportation of solid particles through pipeline helps to make pipeline more effective and economic way of conveying.

REFERENCES