

DECREASE OF THE PRESSURE LOSS IN TRANSPORT OF VISCOUS FLUIDS

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Abstract: The problem of pressure loss by friction in pipelines, especially in the case of viscous fluids, has a great influence of the efficiency of the technologic process. The paper discuss two main methods for reducing the frictional pressure loss, and therefore the pump discharge pressure requirement, when transporting viscous, often non-Newtonian, slurries and pastes in pipelines. The first method makes use of boundary liquid (such as water, oil, or polymer solution) which is injected at comparatively small flow rates into the pipe downstream from the pump to form a lubricating annulus adjacent to the pipe wall. The second method involves gas injection into the pipe downstream from the pump to form a slug flow pattern which results in substantial frictional pressure loss reductions for shear-thinning, non-Newtonian slurry, initially flowing in the laminar flow regime prior to gas injection.

Keywords: slurry flow, pressure loss, water injection, injection of air.

1. INTRODUCTION

Many new developments have taken place over the last few years in slurry handling practice and particularly in slurry pipeline technologies. One example of this is the increased tendency for slurries and pastes containing very fine particles to be pumped at increasingly high concentrations. These slurries tend to be pseudo-homogeneous and do not segregate readily under gravity forces. They are often highly viscous and exhibit highly shear-thinning, non-Newtonian flow properties. In addition, it is also possible to pump relatively low moisture, unsaturated (compressible) filter and centrifuge cakes using both reciprocating positive displacement pumps and some classes of rotary pump using bridge breakers and single or double intermeshing, contra-rotating augers at the base of feed hoppers.

There are various techniques to reduce the frictional pressure loss in pipe flow, which is often the major contribution to the pump discharge pressure. These methods also increase the flexibility of existing pipeline systems when there is a requirement to increase slurry concentrations, and therefore slurry viscosities. This technique can be:

- Reduction in the level of particle flocculation through the use of additives to reduce the zeta potential on particle surfaces;
- Injection of water or some other liquid (such as oil or aqueous polymer solution) into the pump discharge pipe using an appropriate injection ring, thus creating a lubricating annulus in the pipe for the viscous slurry;
- Injection of air (or inert gas) into the pump discharge pipe to reduce the proportion of the inner pipe wall wetted by viscous slurry.

The paper describes the last two methods.

2. INJECTING BOUNDARY LAYER LIQUID INTO PIPE

Very highly concentrated slurries can be pumped using either progressive cavity or reciprocating piston pumps by force-feeding the slurry into the pump body using various auger designs and bridge breakers at the base of wedge-shaped hoppers. Even unsaturated solid/liquid/air mixtures such as compressed filter or centrifuge cakes can be pumped in this way.

To reduce the frictional pressure loss in the pump discharge pipe, it is now common for many pump manufacturers to offer boundary layer injection facilities whereby a liquid is injected at three or four points through the pipe wall to generate an annulus that helps to lubricate the flow. The liquid injected is often water but greater reductions in frictional pressure loss can be achieved using aqueous polymer solution, waste or heating oil or polyelectrolytes. Because the central slurry core is so concentrated and viscous, mixing between the annular wall layer of injection liquid and the slurry can be minimal so the friction reduction effect is maintained over a significant pipe length. Figure 1 shows how a lubricating annulus is formed in the pipe.

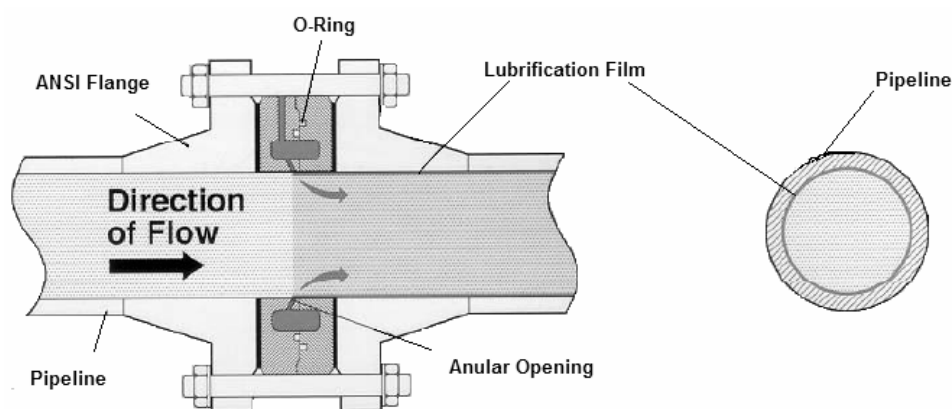


Figure 1 Details of pumps boundary layer injection method

The nature of the boundary layer fluid has a significant effect on the pressure drop reduction on the pipe wall. Table 1 shows the various type of liquids that can be used.

Boundary layer fluids. Table 1.

Bondary layer fluid	Advantages	Disadvantages	Pressure Reduction
Water	Cheap	Mixes with slurry/sludge	20-50%
Heatin oil/waste oil	Greater cost Benefit when used as combination aid	Used only in incineration plan	20-50%
Polyelectrolytes	High efficiency	Mixing station may be required	50-75%
PMLC	Extremely efficient Does not mix with slurry	Mixing station required	70-90 %

Figure 2 shows the substantial effect that either water injection or other special lubricant can have on the pressure gradient.

3. INJECTING AIR DOWNSTREAM FROM PUMP

It has been known for several decades that injecting air (or another gas) into a shear-thinning slurry in laminar pipe flow will result in a reduction in frictional pressure loss.

No such effect occurs for the laminar flow of a Newtonian slurry, or for the turbulent flow of a slurry having any specific laminar flow property

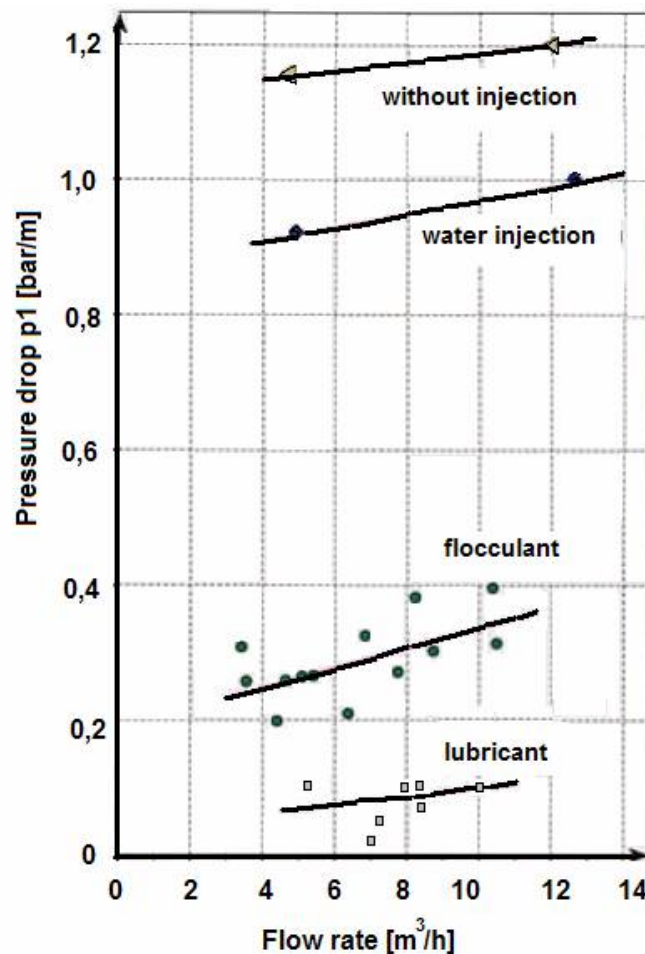


Fig. 2 Data for pressure gradient reduction flow of 37 to 47% sewage sludge

Figure 3 shows some typical data; the drag ratio in this figure is defined as the ratio of frictional pressure gradient along the pipe with gas injection to that with no gas injection, i.e., constant slurry flow rate.

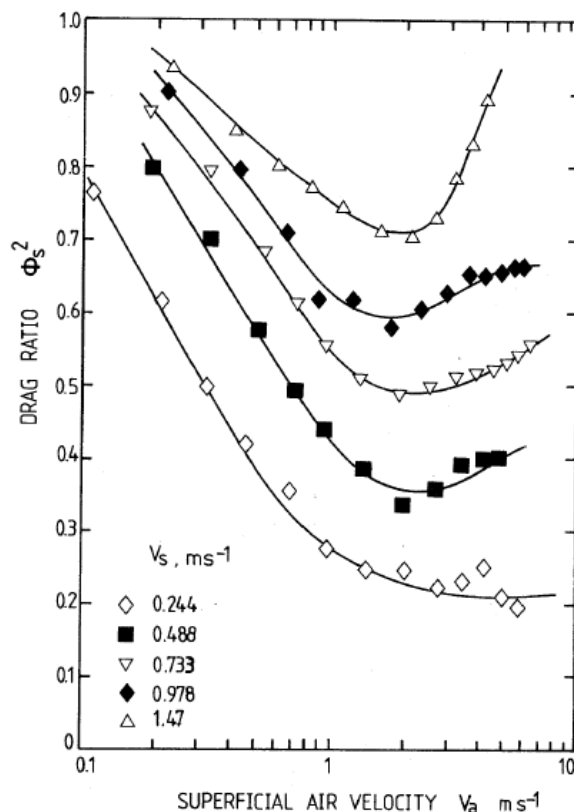


Fig. 3 Reductions in frictional pressure loss for the horizontal pipe flow of shear-thinning slurry at various superficial slurry velocities

The friction reduction effect occurs in both horizontal and vertical slurry pipe flows, and there is the additional advantage of reduced static head in vertical pipe flows.

The gas can distribute itself within the slurry in both pipe orientations, giving rise to six identifiable flow patterns in horizontal pipe flow, and four in vertical pipe flow. In horizontal pipe flow, frictional pressure loss reduction occurs for practical purposes mainly in bubble and plug or slug flow (intermittent flow), but it can occur in stratified flow at low slurry flow rates.

For a given flow rate combination of gas and slurry in a pipe, it is possible to predict the resultant flow model.

This information is often presented in the form of a flow pattern map.

Friction reduction is greater the more shear-thinning the slurry and a maximum effect occurs when the combined gas and slurry pipe flows nears the laminar-turbulent transition for the slurry flow. In this way, the maximum effect can be reliably predicted from knowledge of the slurry rheological properties, the pipe diameter and the gas and slurry flow rates.

The maximum reduction in pipe friction can be correlated using a dimensionless factor, J , which is defined as the ratio of the superficial slurry velocity in the pipe to the critical value for laminar flow breakdown, raised to the power of $(1-n)$. The parameter, n is the exponent in the power law model.

There are many advantages to using air injection:

- reduced discharge pressure requirement for a slurry pump for a given slurry flow rate though a given discharge pipe length;
- increased capacity of an existing pipeline carrying a given slurry while retaining the same pump system;
- extension of an existing pipe run while maintaining the same discharge pressure;
- application of an existing pump and pipeline combination to more viscous, shear-thinning slurry, while maintaining the same discharge pressure.
- reduced pump differential pressure, and therefore reduced slippage in some pump types, with a corresponding reduction in pump wear.

Surprisingly, the advantages of using air injection have still largely been overlooked by industry, like in case of sugar factory when pumping waste molasses. Numerous examples of highly viscous, shear-thinning slurries being pumped through pipe work occur in industry, e.g., red mud waste from alumina production, pulverized fuel ash slurry from power stations, titanium dioxide slurry, chalk and clay slurries, etc. Many of these operations could benefit from the appropriate application of air injection.

4. CONCLUSIONS

This paper has described two alternative methods to reduce pipe friction for highly viscous, often non-Newtonian slurries. In addition to frequent economic advantages to be had by employing one of these methods, other benefits also accrue. These include lower wear rates and therefore maintenance costs for pumps, and reduced instances of pipe blockages. These methods also increase the flexibility of existing pipeline systems when there is a requirement to increase slurry concentrations, and therefore slurry viscosities. It is recommended that each of these methods is considered whenever an existing pipeline needs upgrading, or a new pipeline system is to be designed.

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