THE CONDITIONING OF SOLIDS FLOW FOR PROCESS PRODUCTIVITY

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Abstract

Phase stratification of solids-laden liquid or gas streams increases wear in industrial process piping. This phenomena leads to premature bend, piping and component deterioration. Separation inefficiencies can result from stratification and reduce productivity and increased process costs. Existing technologies address the symptoms of stratification only in treating a two phase process flow as a single phase.

An innovation that redirects the typical flow path of suspended solids in piping and components, results in an improved solids distribution, is described.

An analysis of the current design limitations of two phase process flow systems is provided. The contrasting benefits of the new technology are captured through high speed video of suspended solids flow patterns in a typical partly stratified heterogeneous mixture compared to a pseudo homogeneous mixture resulting from the applied innovation. Test results are presented and discussed.

Process applications, including enhanced additive performance, in both Brown and Greenfield plants are outlined.

1. Introduction

Failure of hydraulic and pneumatic mineral slurry circulation systems due to erosion is a well-documented phenomenon. Typical Industry response to these failures is a Reaction Focused approach, with insertion or application of wear resistant materials such as resin, ceramics, rubber and special hardened metal linings in addition to frequent replacement through costly plant maintenance. Another method used is to increase bend radius from 1.5D to even greater than 6.0D. (D = pipe internal diameter)

Reviewing erosive fluid / solids streams, which are two phase systems, it is generally accepted that the aggressive impact and force of particles on bends is the cause of wear to the internal wall of piping components.

A Cause Focused remedy may therefore be possible if these particles can be redirected through passive zones and away from the typically vulnerable surfaces of piping (at bends and in valves for example). Should this be possible, the need for, or dependence on, high wear resistance materials or contact barrier devices could be reduced. Investigations were undertaken, to focus on methods of reducing the contact between particles in two-phase streams on pipe work components, through a realignment of particulate flow patterns.

The method developed serves to create a changed flow regime. The solids loading against a typical wear / failure area is reduced through creating a more homogenous solids distribution, therefore areas of normally high erosion are eliminated. This approach addresses the cause rather than the symptoms of erosive failures in two-phase systems.

2. Modelling

Preliminary investigations involved the development of bend geometries through 3D CAD and then CFD was applied to understand the flow characteristics of a single phase stream through a typical pipe bend. The next objective was to create bend geometry with a flow pattern exiting the bend equivalent to the inlet flow pattern. The geometry developed established an understanding of the requirements of two-phase flow in bends. Further CFD modelling was then used with the addition of devices (internal to a bend) to establish the optimum size, shape and position the device, to achieve significant changes in the core velocity of the fluid through the bend.

Models were built to evaluate the scale-up parameters, this highlighted that a 10:1 scale up/down for validation testing was appropriate. Due to the complexity of CFD modelling two-phase flows using variable particle size distributions, CFD modelling was not used any further.

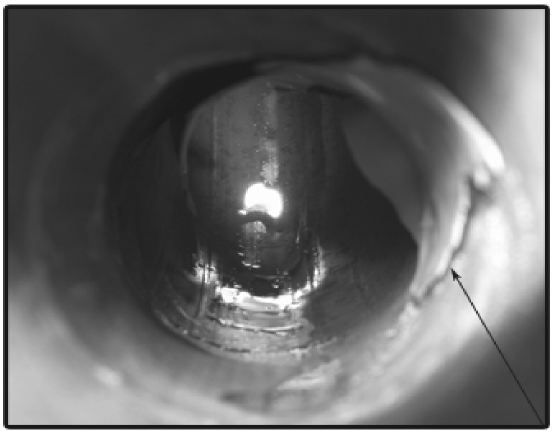
3. Experimental

Pilot plant circuit one

Having established a series of bend geometries, a small test rig was built with a number of bends in series. The test circuit had various bend orientations and inlet conditions and were lined using multiple layers of various coloured two- pack epoxy paints to qualitatively assess internal erosion. Using water as a transport medium, solids were added to a concentration of 17.8% by weight, dry basis. The system flow was monitored using a magnetic flow meter vertically mounted which fed back into a loop set point controlling the system line velocity at approx 2.65 m/sec.

The test bends were removed and photographed at fixed intervals. This showed how the modifications to the bends, in conjunction with a flow conditioning device, affected the erosion of the surface, compared with standard bends. The two photos shown in Figures 1 and 2 are of the internal exit section of two bends, both having been painted using the same procedure, both having experienced the same flow and duration of test. In the standard bend (Fig 1) almost the entire painted surface has been eroded, whereas the new geometry bend (Fig 2) has retained its coating. Testing continued for a total period of 540 hrs with bends being removed at intervals for inspection to determine the degree of paint erosion.

Photo images taken of the internal exit leg of bends - both have seen the same duty



Standard bend - shows remains of coating
Figure 1

New geometry bend - coating not affected
Figure 2

Pilot plant circuit two

A new pilot plant was constructed to handle a high loading of solids, complete with level, temperature, pressure and flow transmitters. Standard and new geometry bends were fitted with differential pressure transmitters, it was determined that the bends were not introducing additional pressure drop.

Overall there were twenty bends in series as a combination of standard and new geometry bends. Bends were not painted, as the object of this trial was to assess the performance of the new bend geometry and solids conditioning device under high solids concentration. Using water as a transport medium, solids were added to a concentration of 56% by weight of washed quartz residue sand, dry basis to create slurry.

Samples were taken at fixed intervals and dried to assess the shape of the quartz. As the particles rounded off, the system was recharged with fresh slurry to the above concentration.

Pilot plant circuit three

This pilot plant circuit was built to enable real time imaging and the effects of solids flow to be viewed in situ in a pipe bend and in alternative designs and configurations. Using CFD to model slurry flow patterns was rejected as the results would have been inconclusive. To achieve an in situ monitoring of solids flow through bends, a transparent section was fabricated using 3D build modelling technology. The pipe bend section was backlit using high wattage studio lighting in conjunction with light blanking side shields this allowed the external video capture of the solid particles in the water.

Hi-speed videos (1000 frames per second) were taken of the solids flow with and without a flow conditioning device. This enabled visual tracking of the solids movement within the bend and assessment of the bias of solids phase distribution towards "the wear area" of a bend. Leaving the bend geometry constant and changing the configuration of the flow conditioning device, the path of the solids could be altered from a dense concentrated solids concentration in the traditional wear areas, to a passive, low impact solids flow through the core of the bend. The video images provided a semi-quantitative evaluation of the performance and identified the flow patterns from Pilot trial 1; and that the conditioning devices extended the life cycle of the component; figures 3 & 4 are images captured from video which highlight the changes in flow patterns.

1000 frame per second video - still frame capture

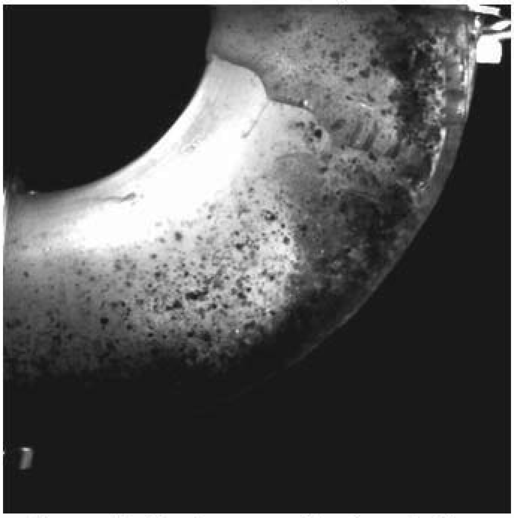


Figure 3 - No flow conditioning device

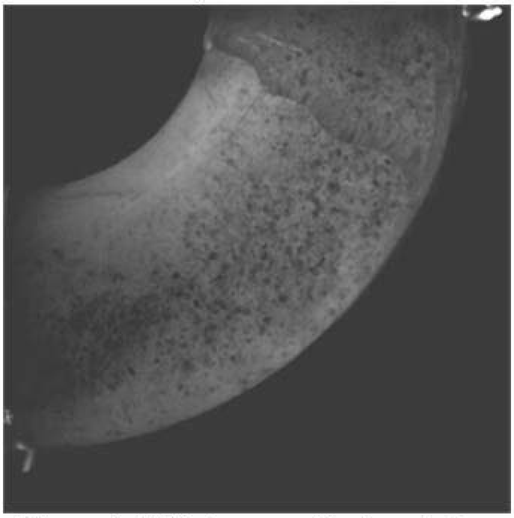


Figure 4 - With flow conditioning device

4. Results and Discussion

The methodology behind the development sought to manipulate the solids phase of a two phase stream are directed away from the component surfaces. This was achieved by interrupting the solids flow path, then dispersing the solids into a greater volume within the stream. Manipulation of solids has many variables including design of the system and its configuration prior to the bend or device. Some of the parameters which must be considered are particle size, settling velocity, solids position, stream velocity, stream viscosity, line size and orientation.

New bend geometry, in conjunction with the conditioning device allows the manipulation of the solids, without change to the system dynamics, thereby negating the need to change pump and power infrastructure.

An important development strategy was the reduction of exit turbulence; this being a significant part of the design as additional costs of downstream erosion can be reduced. Standard bends add turbulence and downstream wear is common, conventional process designs can dictate that up to a 10 times the diameter of pipe length is hard faced to compensate for the problem.

A "symptomatic" approach to the cause of wear and erosion in slurry systems will continue to result in excessive cost, caused by the need for repetitive maintenance programmes and use of coating materials. Concentrating instead on the cause of wear, the subject technology ensures solids no longer flow in a highly erosive heterogeneous pattern. Instead the solids are directed away from surfaces prolonging component life.

5. Conclusions

The ability to change the solids profile of a slurry stream without compromise to the system offers new opportunities in process reliability for components such as; valves, strainers, heat exchangers, distributors and cyclones. Also the performance of process additives can be enhanced by the mid-stream injection into a low shear zone where contact duration is maximised. This technology can be applied to any line size, material and pipe specification which enables retrofit into brown field process plants with relatively minor modifications.

International Patent pending