Presentation at the 46th Annual IPLOCA Convention

An Introduction to The Design of Long Distance Slurry Pipelines

Presented by:
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Aims of Presentation

- To provide an overview of some of the issues to consider.
- To show some of the types of slurry that can be transported by pipeline.
- To illustrate how two phase slurry flow behaviour is different from conventional Newtonian systems.
- To briefly discuss the impact of pipe wear on slurry systems.
- To stress the importance of understanding the nature of slurry flow when designing slurry pipelines.
Quick History

- First major long distance ore pipeline system was Consolidation Coal (172 km, 1.3 Mt/a, 1957)
  - Railways reduced tariffs and system was finally mothballed
- President Kennedy promoted the idea of long distance coal pipelines in 1962 to help ailing coal industry
- Black Mesa coal pipeline: 440 km, 4.8 Mt/a, (1970)
- US railways barred slurry pipelines from crossing their servitudes, effectively blocking long distance pipelines in the USA
What can be pumped in a pipeline?

| Thick, viscous, homogeneous | Dilute, settling, heterogeneous |

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Slurry Flow Regimes

- Mixed Regime
- Non Settling
  - 0.1 mm/s
  - 10 µm
- Slow Settling
  - 1 mm/s
  - 32 µm
- Settling
<table>
<thead>
<tr>
<th>Slurry Properties</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse product</td>
<td>Higher velocities</td>
</tr>
<tr>
<td>Fine product</td>
<td>Lower velocities</td>
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<tr>
<td>Low solids concentration</td>
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<td>High solids concentration</td>
<td>Lower velocities</td>
</tr>
<tr>
<td>Fine product at high solids concentration</td>
<td>High velocities = high wear</td>
</tr>
<tr>
<td>Coarse product at low solids concentration</td>
<td>High friction = high power</td>
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An efficient slurry pipeline optimises the trade off between particle size and concentration of the solids.
Pipeline Slurry Flow Behaviour

- Stationary bed with no solids movement
- Part stationary bed with rolling and ripple movement
- Part stationary bed with saltation
- Fully moving bed
- Fully suspended flow

Re-start requirements require an understanding of the flow curve

Operate above this point

Available Flow Area

Pipeline Pressure Gradient

Mean Mixture Velocity

Operate above this point

MIXED REGIME SLURRY FLOW CURVE

WATER

UNSTABLE
NORMAL OPERATION
HIGH ENERGY CONSUMPTION
HIGH WEAR RATES
Stationary Bed Formation

Solids deposition on invert
# Short and Long Distance Slurry Pipelines

<table>
<thead>
<tr>
<th>Short pipelines</th>
<th>Long distance pipelines</th>
</tr>
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<tbody>
<tr>
<td>&lt; 10 km as a guideline</td>
<td>&gt; 10 km, up to 550 km</td>
</tr>
<tr>
<td>Often mine waste (low value)</td>
<td>Concentrate / ore (high value)</td>
</tr>
<tr>
<td>Within mine site lease, no servitude constraints</td>
<td>Route traverses diverse terrain and servitudes</td>
</tr>
<tr>
<td>Wide variation in slurry quality and flow rate envelope</td>
<td>Defined slurry properties and limited variation in flow rate</td>
</tr>
<tr>
<td>High maintenance/tonne (wear and power)</td>
<td>Lower maintenance/tonne (wear and power)</td>
</tr>
<tr>
<td>Includes coarse, dilute settling slurries and viscous paste mixtures</td>
<td>Fine solids, low to medium viscosity</td>
</tr>
</tbody>
</table>
Important Issues to Consider

- Slurry abrasive properties:
  - Affects pump selection and overall system maintenance
  - Requires wear resistant pipe linings to maximise lifetime
  - Due to:
    - Solids mineralogy, hardness, particle shape, solids concentration and pressure

- Slurry corrosive properties:
  - Affects material selection of all equipment
  - Due to chemistry, pH etc.
  - Can be controlled by dosing, e.g. with lime.
Typical Slurries

- Naturally occurring deposit
- Low wear rate

- Milled product
- High wear rate
Wear resistant linings

- The majority of long distance pipelines are lined with high density polyethylene (HDPE)
  - Special flanges / couplings developed to ensure smooth jointing
  - Can be used to line up to 1 km between joints
  - Abrasion and corrosion resistant
- Shorter pipelines can be lined with rubber, basalt, ceramic or polyurethane linings
  - Usually supplied ex factory in standard spool lengths
Slurry Pipe Route Alignment Considerations

- Route selection requires careful consideration of:
  - Maximum gradients along the route to ensure material will not settle in valleys during a shutdown
  - Identification of slack flow sections – during normal, batch and flushing operation
  - Location of choke stations to control slack flow
  - Mechanical requirements
Phosphate Slurry Pipeline, Morocco

Groupe Chérifien Des Phosphates Slurry Pipeline

- Tekfen Construction is the EPC contractor for the entire slurry system
- Throughput: 4400 t/h
- Main pipeline: 187 km
- Nominal diameter: 36 inch
Phosphate Slurry Pipeline, Morocco

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- Throughput: 4400 t/h
- Main pipeline: 187 km
- Nominal diameter: 36 inch
- Lining: 22 mm HDPE
- Average gradient: 0.3 %
- Maximum gradient: 12 %
- Choke station controls slack flow
- Four feeder systems, furthest 22 km away, supply the head station.
Phosphate Slurry Pipeline, Morocco

Groupe Chérifien Des Phosphates Slurry Pipeline

- Head station pumping: 6 x Weir 500 U-HTPP per train
- Installed power: 22 MW
Factors for Successful Slurry System Design

- The slurry properties dictate the pump and pipeline design and overall system economics
- Must select a well graded particle size grading and solids concentration that:
  - Has a low operating velocity
  - Minimises the wear rate
  - Minimises the pipeline pressure loss
  - Is not too fine so as to become too viscous
E J Wasp – on completion of the Black Mesa Coal Slurry Pipeline

“The conviction was that the key to the design of slurry systems which would operate reliably lay, not in the selection of exotic materials or the design of special equipment, but in the understanding and control of the slurry environment”
What needs to be avoided . . .

- The consequence of incorrect material in the pipeline can be severe:
Acknowledgments

- The committee of IPLOCA for inviting me to present at this conference.
- The management of Tekfen Construction for permission to publish photographs of the construction of the Groupe Chérifien Des Phosphates Slurry Pipeline in Morocco.