Analysis of Low Velocity Dense Phase Pneumatic Conveying System to Extend System Conveying Capability

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  - Standard pipe
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MODES OF PNEUMATIC CONVEYING

Moving bed
Fluidised dense phase
Dune flow

Design Point
Under Performance

Further optimisation

Lines of constant $m_a$

Pressure
Minimum Curve

Decreasing air mass flow rate

Direction of material flow

$\Delta P$ (Pa)

$m_a$ (kg/s)
Bypass Pneumatic Conveying System

(a) schematic diagram

(b) bypass pipe

(c) pressure transducer taps arrangement
## Test material

<table>
<thead>
<tr>
<th>Material</th>
<th>$d_p$, µm</th>
<th>$\rho_p$, kg/m$^3$</th>
<th>$\rho_b$, kg/m$^3$</th>
<th>$P_f$, $\times 10^{-7}$m$^2$/(Pa·s)</th>
<th>$v_{mf}$, mm/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash</td>
<td>14.65</td>
<td>2093</td>
<td>775</td>
<td>6.55</td>
<td>84.7</td>
</tr>
</tbody>
</table>
High speed camera visualization

(a) bypass flutes position

(b) moving bed

(c) Dune
Specific energy

\[
\text{Specific Energy} = 2RT \frac{M_a}{M_s} \ln \left( \frac{P_1}{P_2} \right)
\]
Specific energy for fly ash

Specific energy, kJ/kg

Air mass flow rate, kg/s

- Conventional pipe
- Bypass pipe
Case Study
Ash Disposal - Positive pressure blow tank system

• System Performance
  • Is it achieving design capacity
  • Is there opportunity to improve capacity using existing system components

• Analyse existing system:
  • Explore optimisation of conveying cycle
  • Investigate opportunities to increase capacity through:
    • Air supply management
    • Feeding techniques

• Systematically Implement improvement opportunities
Case Study: Improvement to existing flyash system
Power Station Details

• Built 1957 – 4 x 30MW units
• 1976 – upgrade to 2 x 500 MW units
• Ash Handling System:
  • ESP Collection
  • Positive Pressure Blow-tanks – 8 x 1m³
  • 500 m conveying length
  • 5” (250 mm) – 6” (300mm) diameter pipe
Case Study: Improvement to existing flyash system
Pipeline components – Straights and bends
Discharge
Analysis of current system: Conveying cycle pressure

<table>
<thead>
<tr>
<th>Pressure number</th>
<th>Length from start of pipeline (m)</th>
<th>Location from bend (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>1.0</td>
<td>1.0 m after blowtank</td>
</tr>
<tr>
<td>T2</td>
<td>4.4</td>
<td>3.4 m after blowtank</td>
</tr>
<tr>
<td>T3</td>
<td>7.4</td>
<td>1 m before LR bend</td>
</tr>
<tr>
<td>T4</td>
<td>11.6</td>
<td>middle of LR bend</td>
</tr>
<tr>
<td>T5</td>
<td>13.6</td>
<td>1 m after LR bend</td>
</tr>
<tr>
<td>T6</td>
<td>68.6</td>
<td>1 m before T bend</td>
</tr>
<tr>
<td>T7</td>
<td>70.9</td>
<td>1 m after T bend</td>
</tr>
</tbody>
</table>
Analysis of current system: Conveying cycle pressure

Blowtank conveying cycle

Estimated time that 90-95% of flyash is removed
Load cell installation
System Analysis: 20 minutes
Blow tank discharge – fill cycle

- Blow tank emptying cycle
- Slow fill region
- Fast fill region
- Blow tank pressure venting region
- Blow tank line valve closed
- Blow tank line valve opened

[Chart showing time, pressure, and load changes during blow tank discharge and fill cycle]
## Optimisation – Flow rates

### Flyash Flow Rates

<table>
<thead>
<tr>
<th>Region</th>
<th>[kg/s]</th>
<th>[t/hr]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blowtank Refill</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow refill</td>
<td>1.14</td>
<td>4.09</td>
</tr>
<tr>
<td>Fast refill</td>
<td>27.1</td>
<td>97.6</td>
</tr>
<tr>
<td><strong>Blowtank Discharge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full 100% of discharge</td>
<td>7.67</td>
<td>27.6</td>
</tr>
<tr>
<td>First 90% of discharge</td>
<td>13.13</td>
<td>47.3</td>
</tr>
<tr>
<td>Last 10% of discharge</td>
<td>1.62</td>
<td>5.82</td>
</tr>
</tbody>
</table>
Optimisation – Flow rates

average discharge = 27.6 t/hr

average discharge = 5.82 t/hr

average discharge = 47.3 t/hr

first 90% of material discharged

last 10% of material discharged

90% discharge weight

start Blow tank weight

final Blow tank weight

T1 [kPa]

load [kg]
Improving initial pressurisation

• It is clear from the analysis that the current flyash material has a conveying rate below 270 kPa which is well below the current pre-pressurisation setting of 400 kPa. It is recommended that the pre-pressurisation is reduced to 300 kPa in order to save energy and also to provide a faster pre-pressurisation time of approximately 5 seconds.
• This recommendation assumes that the grade of flyash will not vary significantly.
Improving tonnage

• changeover time between blow tank discharge into the main pipeline is 10 s, which appears to include the pre-pressurisation time.
• total conveying time was 73 seconds.
  • average cycle time of approximately 83 seconds (or 43 cycles per hour).
  • tonnage rate for the 100% conveying time was 27 t/hr over a 73 second period.
  • effective tonnage rate will be 24 t/hr.
• The 90% discharge rate occurs over a 41 seconds
  • flow rate of 47 t/hr.
Improving tonnage

• For the 90% discharge rate and taking into account the extra 10 s for cycle changes
  • a new cycle time of 51 seconds (or 70 cycles per hour)
  • provides an effective discharge rate of 38 t/hr.
  • This effective discharge rate increases output capacity by 58%.

• Lastly, it is important to note:
  • from a life cycle and maintenance issue, you will also have a 58% increase in the operation of the valves over the same time period.
  • A larger blow tank size would reduce valve cycle rates.
Final improvement 2011-2102
Original Control of feed air into blow-tank

40% air bypass tank into main line

60% air to fluidise ash
Final improvement 2011-2012
Improved Control of feed air into blow-tank

90% air into top of tank

5% air bypass tank into main line

5% air to fluidise ash

Increased effective tonnages 40 – 45 t/hr
(originally 27 t/hr)
Summary

• System Design
  • Determine ash properties
  • Define minimum transport conditions

• Post installation - Analyse existing system:
  • Explore optimisation of conveying cycle
  • Investigate opportunities to increase capacity through:
    • Air supply management
    • Feeding techniques

• Systematically Implement improvement opportunities
QUESTIONS?