Simulation and advanced control of transient behaviour in gyratory cone crushers

Pekka Itävuo*, Antti Jaatinen**, Matti Vilkko*

*Tampere University of Technology, Finland
**Metso Automation, Finland
Agenda

• Introduction
• Dynamic model of a gyratory cone crusher
• Simulation results
• Conclusions
Introduction

• Gyratory cone crushers are commonly used comminution equipment in mines and quarries
  – Gyratory cone crusher in this work refers to the secondary and tertiary hydrocone type crushes
• Disturbances like changes in feed material size & hardness and wear of crushing liners cause variation in the crusher output
  – As a result, the process is never in a steady state although modelling is often carried out as if it were
  – Desired performance is only achieved if the effect of occurring disturbances is fully compensated
• Crushers are typically operated with constant closed side setting (CSS) or constant load
• None of the currently existing cone crusher models is truly useful for analytic control system design purposes
  – Modelling in crushers is biased towards process dimensioning and equipment design i.e. steady-state models
Introduction

• Main components of a gyratory cone crusher

• Operating variables of a gyratory cone crusher

CVs have nonlinear & dynamic relationship with associated MVs & DVs
Dynamic model of a gyratory cone crusher

- Modelling principle
  - Combine the existing static nonlinear performance models with simple linear dynamics
  - Hammerstein type system:
Dynamic model of a gyratory cone crusher

Feed material + Material properties:
- Moisture (M)
- Feed grading (FG)
- Crushability (LA)
- Feed rate (Q)
- Specific Gravity (SG)
- Feed flakiness index (FFI)

Material volume in hopper [m^3]

Linear dynamics

Stroke
Cavity geometry

Product size distribution model
Power model
Capacity model

Product Size [mm]
RMS Power [kW]
Capacity [t/h]

y = f(u(t), w(t))
Simulation results

Controllability of product size distribution

- Metso Nordberg GP200M tertiary gyratory cone crusher
  - 25 mm stroke length
  - ~150 t/h capacity
- Feed material, Granite
  - Variations based on realistic data on quarry operation
- Influence of MVs exceed the maximum range of generated disturbances

### Disturbance variables

<table>
<thead>
<tr>
<th>Disturbance variable</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>2.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Crushability, LA-value</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>Feed moisture [%]</td>
<td>0.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Feed Flakiness Index</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td>Feed Grading [mm]</td>
<td>5/32</td>
<td>5/104</td>
</tr>
<tr>
<td>Feed Rate [% of max]</td>
<td>75%</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Manipulated variables

<table>
<thead>
<tr>
<th>Manipulated variable</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closed side setting (CSS)</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Eccentric speed (ES)</td>
<td>250</td>
<td>450</td>
</tr>
</tbody>
</table>

Maximum effect of disturbances

Maximum effect of manipulated variables
Simulation results

-Product size distribution control-

- Metso Nordberg GP200M tertiary gyratory cone crusher
  - 25 mm stroke length
  - ~150 t/h capacity
- Feed material, Granite
  - LA 18.5, SG 2.7 [t/m³]
- Nonlinear CSS actuator
  - Pump up
  - On/off valve down
- Control objective:
  - Maintain the desired product size
- Controller:
  - PID with Ziegler Nichols tuning
Conclusions

• Current operating modes (constant CSS or constant load) cannot provide steady product size
• The effect of every reasonable process disturbance can be cancelled by using advanced feedback control system
• Further investigation and full-scale tests are needed in order to validate these findings