AGENDA

- INTRODUCTION
- COAL PROCESSES AND CONTROL OBJECTIVES
- SIMULATION RESULTS
- SUMMARY
Fig. 1. The general control problem.
MODEL PREDICTIVE CONTROL

INTRODUCTION

SOLVE FUTURE INPUTS BASED ON PAST INPUTS/OUTPUTS AND OBJECTIVE FUNCTION:

- State-space representation of dynamic model
- Input/output data
- Objective function
- Prediction horizon $N$

Minimise:

$$u_{min} \leq u(t) \leq u_{max} \ \forall t,$$

$$\Delta u_{min} \leq u(t) - u(t-1) \leq \Delta u_{max} \ \forall t,$$

$$y_{min} \leq y(t) \leq y_{max} \ \forall t.$$
COAL PROCESSES AND CONTROL OBJECTIVES
UNIT PROCESSES OF INTEREST:

- Feed bin process
- Dense medium separation process
UNIT PROCESSES OF INTEREST:

- Feed bin process
FEED BIN PROCESS

Inputs:
- $W_{b,i}$ = Feed mass flow rate
- $W_{b,o,3}$ = Bin 3 mass flow rate
- $f_{bf,1}$ = Bin 1 feeder frequency
- $f_{bf,2}$ = Bin 2 feeder frequency

Outputs:
- $W_{bf,o,1}$ = Bin 1 mass flow rate
- $W_{bf,o,2}$ = Bin 2 mass flow rate
- $h_b$ = Bin level

Parameters:
- $\beta_b$ = Bin height ratio
- $\rho_b$ = Bin bulk density
- $A_b$ = Bin base area
- $\tau_{bf,1}$ = Bin 1 feeder time constant
- $K_{bf,1}$ = Bin 1 feeder constant
- $\tau_{bf,2}$ = Bin 2 feeder time constant
- $K_{bf,2}$ = Bin 2 feeder constant

States:
- $m_b$ = Bin mass
- $m_{bf,1}$ = Bin 1 feeder mass
- $m_{bf,2}$ = Bin 2 feeder mass
COAL PROCESSES AND CONTROL OBJECTIVES

FEED BIN PROCESS DYNAMICS

COAL

- Feed bin

\[
\begin{align*}
\frac{dm_b}{dt} &= A \frac{dm_f}{dt} + K_f, \\
\frac{dh_b}{dt} &= \frac{dm_f}{dt} \\
\end{align*}
\]

Fit bin 1: 52.8
Fit bin 2: 48.0
Level fit: 39.8

\[
\begin{align*}
F_i &= m_i + K_i \\
W &= m_W + K_W \\
\end{align*}
\]
FEED BIN OBJECTIVES:

- Ensure bin level between 15% and 85%
- Maintain balance between two feeder mass flow rates
- Maintain bin level at 30%
- Ensure each feeder operates at half the total feed mass flow rate
UNIT PROCESSES OF INTEREST:

- Dense medium separation process
DENSE MEDIUM SEPARATION OBJECTIVES

DMS OBJECTIVES:

- Drum separator
  - Operate yield at 87% or maximise throughput
  - Maximum product ash of 14.5%
  - Operate product ash at 13.5%
- Dense medium cyclone separator
  - Operate yield at 87% or maximise throughput
  - Maximum product ash of 14.5%
  - Operate product ash at 13.5%
SIMULATION RESULTS
LINEARISATION PROCESS:

- Nonlinear state-space representation of dynamic model:

\[
\frac{dy}{dt} = f(x, u)
\]

- Approximate linear model using first order Taylor series expansion around operating point \((x, u)\):

\[
x_{approx} = x + \frac{dx}{dt} \Delta t + \frac{1}{2!} \frac{d^2x}{dt^2} \Delta t^2 + \cdots
\]

\[
u_{approx} = u + \frac{du}{dt} \Delta t + \frac{1}{2!} \frac{d^2u}{dt^2} \Delta t^2 + \cdots
\]

\[
x = x_{approx} - \frac{1}{2!} \frac{dx}{dt} \Delta t^2 - \frac{1}{3!} \frac{d^3x}{dt^3} \Delta t^3 - \cdots
\]

\[
u = u_{approx} - \frac{1}{2!} \frac{du}{dt} \Delta t^2 - \frac{1}{3!} \frac{d^3u}{dt^3} \Delta t^3 - \cdots
\]
UNIT PROCESSES OF INTEREST:

- Feed bin process
SIMULATION RESULTS

FEED BIN

Throughput gain (%) 7.23
UNIT PROCESSES OF INTEREST:

- Dense medium separation process
SIMULATION RESULTS

DRUM SEPARATOR

Yield increase (%) 2.14
Ash improvement (%) 0.38
SIMULATION RESULTS
DENSE MEDIUM CYCLONE SEPARATOR

Yield increase (%) 2.09
Ash improvement (%) 1.20
SUMMARY
MPC IMPROVEMENT RESULTS SUMMARY:

<table>
<thead>
<tr>
<th>Unit process</th>
<th>Improvement</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed bin</td>
<td>Throughput</td>
<td>7.23</td>
</tr>
<tr>
<td>Drum separator</td>
<td>Yield</td>
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<td>Ash</td>
<td>1.20</td>
</tr>
</tbody>
</table>

FUTURE WORK:

- Online measurement of ash content
- Limitation as linearised model applicable to specific operating points
- Future work to apply nonlinear MPC over larger operating regions
Fig. 1. The general control problem.
THANK YOU