Advanced Control of Batch Reactor Temperature

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Presentation Outline

- Yokogawa Architecture
- Batch Reactor Temperature Control Problems
- Background of Controller Development
- Application Results
- Conclusions

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Batch Reactor Temperature Control Problems

- System Exhibits Integrating Type Response (Open Loop Unstable)
- Dead Time and Long Time Constant
- PID Tuning is Difficult
- PID Control is a Compromise
- Extensive ad hoc PID Override Logic
- Slow Batch Sequence Set Point Ramps
PVC REACTOR using CS1000 and YS170

RS-485

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PVC REACTOR using CS1000

YS170 Client

Brainwave Controller

Brainwave Client

YS170 Controller

OPC Server

Test Function

RS-485
Polyester REACTOR using $\mu$XL

RS-232

RL-Bus
Polyester REACTOR using $\mu$XL
Batch Reactor Temperature Control Problems

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Self Regulating Response

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Slide 9
Integrating Response
Controller Development

- Based on Laguerre Function Series Modeling Method by Zervos/Dumont (University of British Columbia, 1988)
- Developed Controller for Self Regulating Processes in 1989
- Modified Model Structure and Control for Integrating Systems in 1999
- Developed Stochastic Control Equations to Improve Disturbance Rejection
Laguerre Function Series

\[ f_i(t) = \sqrt{2p} \frac{\exp(pt)}{(i-1)!} \frac{d^{i-1}}{dt^{i-1}} \left[ t^{i-1} \exp(-2pt) \right] \]
Laguerre Transient Responses

Combined Model

Component Functions

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Model Identification

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Control Simulation
PVC Reactor

- PVC Molecular Weight is Key Quality Parameter
- Reaction Temperature Affects Molecular Weight
- Existing PID Temperature Controls Adjusted Cooling and Catalyst Feed
- Opportunity for Increased Production and Product Quality
PVC Control Schematic

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PVC Reactor

- Existing PID Control Maintained Temperature +/- 5 Degrees C
- Advanced Controller Configured to Adjust Catalyst Feed Only
- DCS Logic Maintained Cooling at 95% of capacity
- Advanced Controller maintained Temperature +/- 2 Degrees C
PVC Reactor

- Typical Batch Cycle Time for PID Control was 12 to 18 Hours
- Advanced Controller Batch Cycle time was 8.5 to 10.5 Hours
- 100% Cooling Enabled Batch Cycle Time to be Reduced by 35%
PVC Batch Cycle Times

Batch Time (Hours)

PID Control

Advanced Control

Batch Number

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Advanced Controller Setup

- Software Installed on HIS NT PC
- HIS OPC Server to Test Function for Brainwave and YS170 clients
- Initial Models Developed from Historical Data Review and Operations Input
- Controller Completed Entire Batch on First Run
Polyester Reactor

- Polyester Compounds
- “Cook” Ingredients for 18 - 22 Hours
- Exothermic Reactions
- Incinerate Waste Vapors
- Reaction Rate is Temperature Dependent
- Control of Reactor Temperature is Critical
Polyester Reactor Schematic
Manual Control Techniques

- Set Dow Therm Flow to about 15%
- Monitor Rate of Temperature Rise
- Adjust Dow Therm Flow by +/- 2%
- At “High Heat” Set Dow Therm Flow to 0% if Above Set Point
- At “High Heat” Set Dow Therm Flow to 20% if Above Set Point
Manual Control of Reactor
Automation Goals

- Reduce Batch Processing Time
- Improve Product Consistency
- Manage Exothermic Reaction
- Uniform Production of Waste Vapor
- Reduce Operator Task Loading
- Reduce Waste Batches
Advanced Controller Setup

• Software Installed on an NT PC
• Serial Communication to Existing Yokogawa DCS via OPC Server
• Initial Models Developed from Historical Data Review
• Controller Completed Entire Batch on First Run
Automation Benefits

- Batch Sequence Automation Possible
- Exothermic Stage of Process was Controlled
- Manageable Production Rates for Waste Vapors
- Reduced Operator Task Loading
Conclusions

- An Adaptive Model Based Predictive Controller was Developed for Integrating Processes
- Batch Reactor Temperature Control Improved by 60% or More
- Batch Cycle Time and by 35% for PVC Reactor