Application and Development of Advanced Process Control Schemes in Novozymes Fermentation Pilot Plant

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Stuart Stocks
1. Novozymes at a Glance
2. Fermentation Pilot Plant
3. Structure of Academic Projects
4. Projects
5. Concluding Remarks
Novozymes at a Glance

Geographical distribution of 2011 sales

- Asia: 19%
- North America: 35%
- Latin America: 10%
- Europe, Middle East and Africa: 36%

Sales development in DKK million

- 2010: 9,724
- 2011: 10,510

More than 700 products used in 130 countries

Largest bio product portfolio in the world
Novozymes at a Glance
Fermentation Pilot Plant

Scale-up and transfer of strains from R&D to production

Sample production

Production of material for toxicology characterization

Process optimization

Development and testing of new technology
Fermentation Pilot Plant
Fermentation Pilot Plant
## Structure of Recent Academic Projects

<table>
<thead>
<tr>
<th>Year</th>
<th>Student</th>
<th>Project Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>D. Bonné</td>
<td>PhD</td>
</tr>
<tr>
<td>2006</td>
<td>N. Petersen</td>
<td>M. Sc</td>
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<tr>
<td>2007</td>
<td>N. Faria</td>
<td>Post Doc</td>
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<tr>
<td>2007</td>
<td>M. Villanueva</td>
<td>M. Sc</td>
</tr>
<tr>
<td>2007</td>
<td>J. Rasmussen</td>
<td>PhD</td>
</tr>
<tr>
<td>2009</td>
<td>O. Johnsson</td>
<td>M. Sc, PhD</td>
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</tbody>
</table>
Projects

Optimal and Reproducible Operation of Batch Processes (D. Bonné)

Objective

1. Provide theoretical framework for data driven batch modeling

2. The methodology will be used to achieve optimal and reproducible chemical batch processes

3. Extend the methodology to include design of model-based tools such as the Kalman filter, MPC and iterative learning control
Projects

Optimal and Reproducible Operation of Batch Processes (D. Bonné)

Data preparation

1. Visual inspection to remove outlier batches
2. Data filtered and re-sampled using a Kernel smoother
3. Missing data is reconstructed based on appropriate reference data

Modeling
Projects

Multivariable Modeling for Control of Industrial Fed-batch Cultivations (N. Petersen)

Objective

1. Expand the previous work to industrial fed-batch fermentation process producing an $\alpha$-amylase from A. oryzae

2. Evaluate MPC control using the GoLM framework
Projects

Multivariable Modeling for Control of Industrial Fed-batch Cultivations (N. Petersen)
Projects

Multivariable Modeling for Control of Industrial Fed-batch Cultivations (N. Petersen)
Projects

*Multivariable Modeling for Control of Industrial Fed-batch Cultivations (N. Petersen)*

1. Limitations in the number of batches reduces model quality

2. Too big batch to batch variation explain some of the variation

3. Hence the dataset was not optimal for the purpose

4. Although some variation is needed in the data!
Projects

Fed-batch Process Modeling Using GoLM for Monitoring and Optimizing Control (M. Villanueva)

Objective

1. Generate dataset that can be used to estimate a model using the GoLM methodology

2. Pertubations in the input variables were used to provide additional information in the output data (identification experiment)

3. Implement an MPC scheme and run a batch with the objective to follow a reference batch
Projects

Fed-batch Process Modeling Using GoLM for Monitoring and Optimizing Control (M. Villanueva)

1. Tracking error is based on difference between batch and reference

2. A Kalman filter is used for state estimation
Projects

Oxygen Control for an Industrial Pilot-scale Fed-batch Filamentous Fungal Fermentation (N. Faria)

Objective

Develop high performance oxygen control strategy with optimized setpoint

Evaluate the strategy on an α-amylase A. oryzea process
Projects

**Oxygen Control for an Industrial Pilot-scale Fed-batch Filamentous Fungal Fermentation (N. Faria)**

Poor performance using a standard controller

Biomass and viscosity vary throughout the process

Additional information is available in auxiliary variables like CER and OUR
Projects

*Oxygen Control for an Industrial Pilot-scale Fed-batch Filamentous Fungal Fermentation (N. Faria)*

Inner loop regulates oxygen consumption based on CER and OUR measurements

Outer loop provides set-point for consumption
Projects

Probing control applied to *B. licheniformis* fermentations

(O. Johnsson)

Decision tree type control scheme

A gain factor is used to scale the pulses so that stability is ensured.

The strategy is well known but has here been extended to a Novozymes process and strain.
Projects

Probing control applied to B. licheniformis fermentations (O. Johnsson)
Projects

Probing control applied to *B. licheniformis* fermentations (O. Johnsson)
Concluding Remarks

- The Novozymes fermentation pilot plant has the hardware and software set up to facilitate these types of projects.

- Novozymes and the fermentation pilot plant is very open towards academic collaboration.

- So far, advanced model based strategies have not been so applicable for our types of processes.
Thank you for listening!

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