Training our upcoming chemical engineers
by simulating an industrial setting: a classroom case-study on waste cellulose valorization

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some numbers:

- Founded in 1817
- 11 faculties with a total of 41,000 students
- 3,600 PhD students
- 1,400 professors
chemical engineering at Ghent University

common for all majors

bachelor

master

Year 1

Year 2

Year 3

Year 4

Year 5

ΔU = Q − W

ΔU = \frac{1}{\kappa} \left( \Delta x^2 \right)

\frac{2}{\pi} \cos(\theta) \left[ \frac{4}{\pi^2} \frac{4}{\pi^2} + 0 \right]

\text{cross-course project}
cross-course project: how it used to be

\[ SO_2: 43.4 \text{ kmol/hr} \]
\[ O_2: 73 \text{ kmol/hr} \]
\[ O_2: 0.4 \text{ kmol/hr} \]
\[ SO_2: 43 \text{ kmol/hr} \]
\[ H_2O: 43 \text{ kmol/hr} \]
\[ H_2SO_4: 43 \text{ kmol/hr} \]
\[ O_2: 51.5 \text{ kmol/hr} \]
\[ SO_2: 0.4 \text{ kmol/hr} \]

**OXIDATIE**

\[ q_{el} = \left( 3.44 \frac{\text{mol}}{s} \cdot 147 \frac{J}{\text{mol} \cdot K} + 64.39 \frac{\text{mol}}{s} \cdot 147 \frac{J}{\text{mol} \cdot K} \right) \frac{1}{51.5 \text{ kmol/hr}} (313K - 343K) \]

\[ q_{el} = -256269.33 \frac{J}{s} = -0.26 \text{MW} \]

\[ q_{o_2} = \frac{J}{K \cdot \text{mol}} \cdot 1.73 \frac{-\text{mol}}{s} \cdot 770K - 873K + 29.41 \frac{J}{K \cdot \text{mol}} \cdot 15.51 \frac{-\text{mol}}{s} \cdot 473K - 873K \]

\[ = -187700 \frac{J}{s} = -0.19 \text{MW} \]
cross-course project: how it is now

Project starts with a question from industry or an industrial problem.

Typically, unconventional projects are proposed: no one knows how the project will turn out, the students steer the project!
cross-course project: typical activities

Experiments

Kinetic modelling and regression

Process design and simulation
What do the students learn?

Learning objectives:

- Searching, processing and interpreting (scientific) literature
- Applying theoretical knowledge from previous courses
- Working in a team, communicating effectively and planning the workload
- Being critical about their findings

Grading:

- Report
- Presentation: oral presentation and poster presentation
- Daily work (commitment, planning, critical attitude)
- Peer evaluation and self-evaluation.
the new cross-course project: well received!

Industrial partnerships established

- internships
- master theses
- PhD research

International Student Research Conference (SRC)

Students

Learning effect

Organization

Guidance

Global evaluation

Your score

Fac. Ref.

Academic year 2010 - 2011
Poll participation: 58 %

2008 - 2009
case study: cellulose waste stream valorization

± 1000 kg per day (dry)

bioethanol

Figure courtesy of waterschap Noorderzijlvest
from waste cellulose to ethanol

Measuring concentration of glucose: UV-VIS analytical method
Kinetic modeling and determining parameters

Michaelis-Menten kinetic model construction and experimental data regression

\[ E + S \overset{k_1}{\underset{k_{-1}}{\rightleftharpoons}} ES \overset{k_2}{\rightarrow} E + P \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Optimal estimate</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k ) (1/s)</td>
<td>( 3.08 \times 10^4 )</td>
<td>-</td>
</tr>
<tr>
<td>( K_s ) (mol/l)</td>
<td>( 2.67 \times 10^1 )</td>
<td>([2.53 \times 10^1; 2.81 \times 10^1])</td>
</tr>
</tbody>
</table>

Cellulose → Glucose

\( V_E = 120 \ \mu l \)

\( V_E = 80 \ \mu l \)

Glucose → Ethanol

\( T = 30\ ^\circ C \)

\( C_S = 0.056 \ \text{mol/l} \)

\( C_E = 0.09 \ \text{mol/l} \)
Aspen Plus® process simulation

hydrolysis:
T = 40°C
P = 1 atm

flash vessel:
T = 30°C
P = 1 atm

fermentation:
T = 30°C
P = 1 atm

distillation:
number of plates = 28
reflux ratio = 2

23.2 ton/h total:
1.24 m% cellobiose
1.17 m% glucose
97.5 m% water

1,21 ton/h ethanol
0.205 ton/h water

Conclusion: positive impact of course reforms!

• Fruitful results from collaborations with industrial partners
• Successful participations in the SRC competition
• Students learn to work on a project without well-defined boundaries
• … and they seem to like the challenge!
Acknowledgments

Thank you for your kind attention!

Questions or comments?