Sigurd Skogestad. Proposed Master specialization projects. Autumn 2019.

KF1. Master Project: Process control Case study at Perstorp

Supervisors: Krister Forsman and Sigurd Skogestad

Krister Forsman is Professor II at NTNU and has given guest lectures in the process control course about industrial control strategies. He leads the control group at Perstorp, which is a Swedish chemical company with many plants all over the world and many interesting control problems. To keep the application current and of interest to Perstorp the specific application will be decided later. The work will generally involve the following (mostly using Matlab):

1. Derive a simple process model (Simulink/Matlab)

2. Match to current operation data

3. Propose an improved control strategy. This will often involve suggestions for moving the throughput manipulator and introducing cascades or simple model-based strategies.

Typically, the project may deal with the modelling and matching with data, and the master thesis will focus on the control part. More information: Krister.Forsman@perstorp.com.

SiS1. Master project: Optimal operation of hot energy storage:

Co-advisor: Cristina Zotica and New PhD student

This is a very relevant topic for saving energy and making use of new energy sources like wind power. The project is in cooperation with HighEFF, which is a large project on energy savings with SINTEF, NTNU and many industrial sponsors.

SiS2. Master project: Systematic design of advanced control structures.

Co-advisor: Cristina Zotica

The objective is to implement optimal operation efficiently, especially when there are changes in active constraints. This is a really interesting project where we expect to find new publishable results. Structures to be considered include split range

control, input (valve) position control, controllers with different setpoints, selectors, cascade, feedforward and physical decouplers.

- **SiS3. Master projects: Machine Learning applied to optimal production of oil and gas**

Co-advisor: Allyne de Machado and Dinesh Krishnamoorthy

This project is in cooperation with SUBPRO and with AkerBP and Equinor as industrial partners.

- **SiS4. Master project/Design project (prosjektering): Techno-economic evaluation of new process at ChemringNobel**

Explosives factory in Sætre, Norway (just south of Asker). Involves non-ideal distillation

Details: See subdirectory more/chemringnobel

Contacts: Erlend.Skjold@chemringnobel.no; 'Terje Halvorsen (terje.halvorsen@resitec.no)'

- **SiS5. Design project and Master project(s) on Waste water treatment for recirculating aquaculture systems (RAS) (Resirkulering av vann i settefiskproduksjon) (Nofitech).**

Industrial Co-advisor: Kari Johanne Kihle Attramadal. Head of R&D. +47 98471328 kari@nofitech.com

She is also Proffesor II in Biotechnology at NTNU.

Co-advisor: Dinesh Krishnamoorthy

More information: See subdirectory more/RAS

Nofitech is a small technological company in trondheimwith about 8 empluees. They specialise in making settefisk. The main process problem is to resireculate and clean the water. It's similar to processes used for wastewater treatment. It's a fast-growing sector in Norway where they now really need process engineers, simulation and control.

- We plan 1 group in "prosjektering". Prosjektering: Techno-economic design. Simulation with Hysys
- We plan 1-2 Design and Master project students. The first part (project) will focus on developing a dynamic model using Matlab or Simulink. The second part will focus on control. There is a lot of resireculation, which makes it necessary to use feedback control in order to stabilize the operation. The following variavbles need to be controlled: O2, temperature pH, Salinity, CO2, ammonia. NO2/NO3, particles.
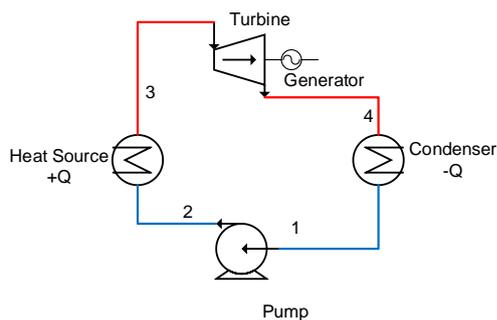
SiS6. Master project / design project: Energy-efficient oil and gas production

Supervisor: Sigurd Skogestad

Co-supervisor: Maryam Ghadran, Equinor

Co-supervisor NTNU: Cristina Zotica

This project is in cooperation with HighEFF and SUBPRO.

SiS7. Master Project: Process control and energy efficiency at Pulp and paper mill, Sweden.

Supervisor: Sigurd Skogestad

Co-supervisor: Andreas B. Volden

Co-supervisor NTNU: Cristina Zotica

BillerudKorsnäs bruk i Frövi/Rockhammar (250 km fra Stocholm). Søknad sommerjobb: 10. mars.

• SiS 8. Optimal operation of heat to power cycles

Coadvisor: Cristina Zotica

About 80% of the electric power in the world is generated by thermal power plants. The scope of this project is to analyze and compare a decentralized control structure (with PID controllers) with model predictive control (MPC) for a simple heat to power Rankine cycle. These types of cycles are used for conversion of thermal energy into electrical power, in a 4-stage process: compression (1-2), heat addition (2-3) in an evaporator, expansion (3-4) in a turbine which drives a generator to produce electricity, and condensation (4-1). The working fluid is commonly water (steam), but recent technological development also include organic fluids, which are more suitable for waste heat recovery processes with low temperatures.

This project will address challenges such as what is the optimal operation that maximizes the energy efficiency under varying heat sources quality (which is the case for waste heat recovery processes), and how to design a control structure that achieves this.

The student should have an interest in operation and control, and knowledge in optimization is recommend (but not required). Experience with Matlab/Simulink or Modelica is a benefit.

For any question or more information, please send an email to cristina.f.zotica@ntnu.no

- **SiS9. Master Project / Design project:** Rigorous modeling and simulation of absorption columns for silver catalyzed formalin plants (Dynea, Lillestrøm)

Supervisors: Sigurd Skogestad

Co-supervisor: Nils-Arne Susort, Dynea

The last step in the production of formalin is to absorb the formaldehyde gas formed in the reactor. The absorbent is particularly a mixture of water, formaldehyde and methanol from the post-reaction gas. Formaldehyde absorption is a heat evolving process because of gas condensation and exothermic reaction between formaldehyde and water, hence absorbers are normally divided into several sections with separate circulations and coolers for better temperature control.

Dynea simulates the absorption tower by combining flash tanks in series and experience data which yields fair results. Nevertheless, this way makes it hard to optimize the absorption tower in terms of column diameter, packing height, no. of packed sections, circulation flow rate, temperature profile etc. The development of a rigorous absorber model is therefore motivated by the potential to look into diverse absorption scenarios in high detail and performing optimization to reduce capital cost, construction costs, operation costs and to increase absorber efficiency.

The absorber model must be created in the simulation program CHEMCAD by Chemstations. Every absorber section should be designated a separate model which could either be a packed column mass transfer model or a tray column mass transfer model where both types must include reactive absorption. CHEMCAD easily deals with reactive absorption models given column design specifications and kinetics for the reactions considered as critical for the absorption.

Before the absorption model can be created there are some issues that have to be solved:

First, the most relevant K-value model for formalin called "Maurer" in CHEMCAD is not possible to use when considering reactive absorption because methylene glycol and poly(oxymethylene) glycol which are formed when formaldehyde and water reacts with each other are not accessible by the user. Neither is the hemiformal or the poly(oxymethylene) hemiformal formed by the reaction between formaldehyde and methanol. However, CHEMCAD provides the user privileges to customize some user-added modules. Amongst all modules is the K-value model "ADDK" readily available where the molar flow rates of all components in both phases and the K-values are passed by reference and therefore easily manipulated. Temperature and pressure are of course passed by value and all other physical properties and ChemCad data are accessible through a wide library of functions. The K-value model must be programmed in C++ and compiled with Microsoft Visual C++. The model must be solved iteratively which in turn relies on a good algorithm to not make it a bottleneck when simulating the process.

Second, an enthalpy model has to be implemented alongside the user added K-value model because new user defined components are created. The principles for programming the enthalpy model are

the same as for the K-value model, but the implementation is far much easier because an iterative solver algorithm is not needed. The calculated enthalpy for every component is only dependent on temperature, reaction enthalpy and evaporation enthalpy, which is solved analytically.

Third, physical properties like density, viscosity, surface tension and thermal conductivity must be included for all user added components.

Once the K-value model, the enthalpy model and the physical properties are well functioning, the modeling of the absorption column can start. There is much literature available which will be absolutely useful in the process of making a good absorption model. Dynea will be supportive in sharing process data and analysis figures from operative processing plants to facilitate the development of a predictive mass transfer model for the absorber sections.

Previous work in this are:

1. **Are Bertheussen, Alexander Leguizamón, Paul Magne Amundsen.** Process design of formaldehyde process in Chemcad using the silver process (with Perstorp). (Spring 2014)
2. **A Comparison of Training Simulators for the Formox Process Keyword (HYSYS vs. CHEMCAD)** Trine Johansen, Anja Johnsen and Ida Christiansen (Spring 2013) (with Perstorp)
3. **Per-Øivind Hanssen, Lars Kåre Andreassen**. Formaldehyd (Spring 2001)
4. **Anne Gry Messenlien (anneme), Steinar Asdahl (steinaa), Christian Asserson (christas), Kjell Øystein Sydnes (kjellsy).** Design optimization of the Dyno process for formaldehyde production. (Spring 1999)
5. **Veslemøy Andersen, Gøran Holten, Elin Salthaug** Formalinproduksjon fra metanol (sølvprosessen; kontakt Dyno: Geir Brustad) (Spring 1998)
6. **Heidi Megård, Sissel Pedersen, Marianne Thorstenson** Formalinproduksjon fra metanol (formoxprosessen; kontakt Dyno: Magnus Schreiber) (Spring 1998)
7. **Tor Arne Johannessen, Karsten Mevassvik, Frode Stenstrøm.** Simulering, dimensjonering of prosjektering av destillasjon av metanol, vann og formalin(samarbeide med Dyno Lillestrøm) (Spring 1997)
8. **Stig Ludvig Selberg. M**odellering av absorbsjonståtn for formalinproduksjon (utført i samarbeide med Dyno Lillestrøm med Lars R. Axelsen som medveileder). (Autumn 1998)