MASTER OF SCIENCE IN ENGINEERING

Module Description

Process integration and pinch analysis

General Information

Number of ECTS Credits

3

Module code

TSM_ProcInt

Responsible of module

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Language

	Berne	Lausanne			Lugano	Zurich		
Instruction	☐ E 100%	☐ E 100%		☐ F 100%	☐ E 100%	☑ E 100%		☐ D 100%
Documentation	☐ E 100%	☐ E 100%	☐ E %	☐ F %	☐ E 100%	☑ E 100%	☐ E %	☐ D %
Examination	☐ E 100%	☐ E 100%	☐ E 100%	☐ F 100%	☐ E 100%	☑ E 100%	☐ E 100%	☐ D 100%

Module category

☐ FTP Fundamental theoretical principles

☑ TSM Technical/scientific specialization module

☐ CM Context module

Lessons

2 lecture periods and 1 tutorial period per week

Entry level competencies

Prerequisites, previous knowledge

Students should have a keen interest in process engineering and energy engineering issues. Attendance of the module requires prior knowledge of engineering thermodynamics. This includes, in particular:

- reliable application of the first principle (and ideally also the second principle) of thermodynamics for flow processes and energy conversion systems, such as heat engines, heat pumps or cooling systems
- a good understanding of the concept of enthalpy for pure substances
- fundamentals of the theory of heat transfer: fundamental laws of heat conduction, heat transfer and heat transmission; mean logarithmic temperature differential of co-current and counter-current heat exchangers
- the calculation of mass, energy and component balances for common industrial unit operations and processes

Prior knowledge of thermal process engineering and the energy integration of processes is desirable but not absolutely essential for attending the module.

Brief course description of module objectives and content

Against the background of rising energy prices, incentive taxes and ecological requirements, increasing importance is being attached to reducing the energy requirements of industry. The key to higher energy efficiency and cost-efficiency in thermal processes is the energy integration of processes with the aid of pinch analysis. This is characterized by a systematic approach which can be applied to establish the best system design and the optimum energy input from the economic viewpoint. From the results of the analysis, it is possible to derive measures for heat recovery and an improved energy supply in the context of strategic planning.

In this module, students learn the fundamental methods of the energy integration of processes with the aid of pinch analysis. After completing the module, they are in a position to conduct pinch analyses by themselves for "straightforward" industrial processes and to answer the following questions: how large is the energy requirement if an existing plant were to be fully-optimized? Where is the economic optimum for the investment and energy costs? How can this optimum state be achieved? They can then support industrial companies in sustainable development and in the reduction of CO2 emissions, since reducing energy requirements goes hand in hand with increasing cost-efficiency**.**

Aims, content, methods

Learning objectives and acquired competencies

The student

- understands the "nature/philosophy" of process design as well as the energy integration of processes and pinch analysis (onion model, targets before design).

- can complete the mass, material and energy balance for industrial processes with several components and phases and masters the fundamental laws of the thermodynamics for multi-component systems (only ideal two-component systems).
- masters the thermodynamically correct assessment of energy conversion systems and the fundamentals of heat transfer with regard to the energy integration of processes and pinch analysis.
- is in a position to determine the energy targets, heat transfer area targets and cost targets of processes using the fundamental methods of pinch analysis (problem table algorithm, composite curves, grand composite curve and cost curves, etc.).
- is familiar with and understands the "golden rules" of pinch analysis plus the rules for the design of heat transfer networks, and is able to apply these for practical cases. He/she can additionally optimize heat exchanger networks.
- is able to correctly place utilities such as steam and cooling water systems and also energy conversion systems like heat pumps, and combined heat and power generation systems, etc. in a process.
- after completing the module, is in a position to correctly perform the energy modeling of a process and conduct the pinch analysis independently with the aid of software, and to work out measures for increasing efficiency.

Contents of module with emphasis on teaching content

The module contents are divided up as follows (14 semester weeks)::

1. *Introduction*: Energy and Resource Requirements of Industrial Processes, Nature of Process Design and Integration, Fundamentals of Process Engineering, Mass and Energy Balances
2. *Energy Conversion Units (ECUs)*: 1st and 2nd Law of Thermodynamics Analysis in Relation to Pinch Analysis, Heat Engines, Heat Pumps, Mechanical and Thermal Vapour Recompression, Combined Heat and Power (CHP) Generation Systems, Utility Systems
3. *Heat Transfer and Heat Transfer Equipment*: Overall Heat Transfer Coefficients, Temperature Differences in Shell-and-Tube Heat Exchangers, Different Types of Heat Exchangers
4. *Energy and Cost Targets*: Composite Curves CC, Heat Recovery Pinch, “Golden Rules” of Pinch Analysis, Energy Targets
5. *Energy and Cost Targets*: Process Economics, Heat Exchanger Area Targets, Number of Heat Exchanger Units, Number of Shell Targets, Cost Targets, Trade-off between annualized Capital and Operating Costs (Supertargeting), Introduction to Process Analysis and Design Tool PinCH
6. *Heat exchanger Network Design*: Design of Minimum Energy Requirement or Maximum Energy Recovery (MER) Networks, The Pinch Design Method, HEN Design Grid, Stream Splitting, Heat Exchanger Details
7. *Stream Data*: Basic Principles of Data Extraction for Heat Integration
8. *Optimization of Energy Supply Systems*: Shifted Composite Curves, Grand Composite Curve GCC, Utility Selection and Placement (Steam Systems, Furnaces, Cooling Water Systems), Problem Table Algorithm
9. *Integration Energy Conversion Units*: Integration of Heat Pumps and Refrigeration Systems, Mechanical Vapour Recompression (MVR), Thermal Vapour Recompression (TVR)
10. *Integration Energy Conversion Units*: Appropriate Placement Heat Engines, Integration of Combined Heat and Power (CHP) Generation Systems: Steam Turbines, Gas Turbines, Reciprocating Engines
11. *Optimization of Heat exchanger Network Design*: Design for Threshold Problems, Design for Multiple Pinches, Network Optimization (relaxed HEN, Loops, Paths)
12. *Multiple Operating Case (MOC) Analysis*: Challenges and approach for MOC-Problems, Conventional Design Type, Resequence Design Type, Split Grand Composite Curve (Split GCC) and Indirect Heat Recovery (IHR)
13. *Batch Process Analysis*: Time Averaged Models (TAM) and Time Slice Models (TSM), Supertargeting Optimization, Scheduling, Indirect Source and Sink Profile (ISSP)
14. *Batch Process Analysis*: Decision balancing between Direct, Indirect and Utility Heat Exchange, Approach for Batch Process Analysis

Teaching and learning methods

- Classroom Instruction (2 lecture periods per week)
- Exercises/tutorials (1 period per week)
- Individual study from the course script and papers
- Homework (weekly) with subsequent discussion
- Solving case studies with the PinCH software (see www.pinch-analyse.ch)

Literature

A script and additional documents will be made available to students. The following books are recommended for reading:

- Robin Smith: Chemical Process Design and Integration, Wiley, 2007, ISBN 978-0-471-48681-7
- Ian C. Kemp: Pinch Analysis and Process Integration: a User Guide on Process Integration for the efficient Use of Energy, Elsevier Butterworth-Heinemann, 2007, ISBN 978-0-7506-8260-2

Assessment

Certification requirements for final examinations (conditions for attestation)

Successful completion of two exercises to be assigned over the course of the semester.

Basic principle for exams:
All the standard final exams for modules are written exams.
The repetition exams can be either written or oral.

Standard final exam for a module and written repetition exam

Kind of Exam	written
Duration of exam	120 minutes
Permissible aids	☑ Theory Part: closed book, no additional material allowed
	☑ Application Part: open book, permissible material allowed:
	☑ Electronical aids: Calculators
	☑ Hardcopy form: Lecture Material, script (including personal notes)
	☐ ________________________________