Module Description, available in: EN

Process integration and pinch analysis

General Information

Number of ECTS Credits

3

Module code

TSM_ProcInt

Valid for academic year

2020-2021

Last modification

2018-11-02

Responsible of module

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Explanations regarding the language definitions for each location:

- Instruction is given in the language defined below for each location/each time the module is held.
- Documentation is available in the languages defined below. Where documents are in several languages, the percentage distribution is shown (100% = all the documentation).
- The examination is available 100% in the languages shown for each location/each time it is held.

	Berne	Lausanne			Lugano	Zurich		
Instruction						**X** E 100%		
Documentation						**X** E 100%		
Examination						**X** E 100%		

Module Category

TSM Technical scientific module

Lessons

2 lecture periods and 1 tutorial period per week

Entry level competences

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:

- the first law (and ideally also the second law) of thermodynamics and its application to 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
- the theory of heat transfer: fundamental laws of heat transfer; mean logarithmic temperature difference of co-current and counter-current heat exchangers
- **the calculation of mass, component and energy 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, component 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, e.g. humid air).
- 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 (continuous and non-continuous) 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 exchanger 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, 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, Mass, Component and Energy Balances
2. *Refresher Energy Conversion Units (ECUs)*: 1st and 2nd Law of Thermodynamics Analysis in Relation to Pinch Analysis, Heat Engines, Heat Pumps (HP), Mechanical and Thermal Vapour Recompression (MVR/TVR), Combined Heat and Power (CHP) Generation Systems, Utility Systems
3. *Heat Transfer and Heat Transfer Equipment*: Overall Heat Transfer Coefficients, Temperature Differences in Heat Exchangers (HEXs), Different Types of HEXs
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, HEX Area Targets, Number of HEX Units, Cost Targets, Trade-off Between Annualized Capital and Operating Costs (Supertargeting), Introduction to Process Analysis and Design Tool PinCH
6. *Heat Exchanger Network (HEN) Design*: Design of Minimum Energy Requirement or Maximum Energy Recovery (MER) HEN, The Pinch Design Method, HEN Design Grid, Stream Splitting, HEX Details
7. *Stream Data*: Basic Principles of Data Extraction for Pinch Analysis
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 of ECUs*: Integration of HP and Refrigeration Systems, MVR, TVR
10. *Integration of ECUs*: Appropriate Placement of Heat Engines, Integration of CHP Systems: Steam Turbines, Gas Turbines, Reciprocating Engines
11. *Optimization of HEN 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*: Approach for Batch Process Analysis, Types of Thermal Energy Storage (TES) and Integration

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
- Florian Brunner, Pierre Krummenacher: Einführung in die Prozessintegration mit der Pinch-Methode – Handbuch für die Analyse von kontinuierlichen Prozessen und Batch-Prozessen. Swiss Federal Office of Energy SFOE, 2017 (available from www.pinch-analyse.ch)

Assessment

Certification requirements

Module does not use certification requirements

Basic principle for exams

As a rule, all the standard final exams for modules and also all repetition exams are to be in written form

Standard final exam for a module and written repetition exam

Kind of exam

written

Duration of exam

120 minutes

Permissible aids

Aids permitted as specified below:

Permissible electronic aids

Theory Part: None

Application Part: Calculators

Other permissible aids

Theory Part: None

Application Part: Hardcopy form: Lecture Material, script (including personal notes)

Special case: Repetition exam as oral exam

Kind of exam

oral

Duration of exam

30 minutes

Permissible aids

No aids permitted