Process integration and pinch analysis

General Information

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<th>Number of ECTS Credits</th>
<th>3</th>
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<tr>
<td>Module code</td>
<td>TSM_ProcInt</td>
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<tr>
<td>Valid for academic year</td>
<td>2020-21</td>
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<td>Last modification</td>
<td>2018-11-02</td>
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<tr>
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<td>Beat Wellig (HSLU, <a href="mailto:beat.wellig@hslu.ch">beat.wellig@hslu.ch</a>)</td>
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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.

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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 fundamentals of the thermodynamics of 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):

3. Heat Transfer and Heat Transfer Equipment: Overall Heat Transfer Coefficients, Temperature Differences in Heat Exchangers (HEXs), Different Types of HEXs
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
7. Stream Data: Basic Principles of Data Extraction for Pinch Analysis
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)

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:

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 resit exams are to be in written form

Standard final exam for a module and written resit 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: Resit exam as oral exam
Kind of exam
oral
Duration of exam
30 minutes
Permissible aids
No aids permitted