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820764 - ICC - Heat Exchangers

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 724 - MMT - Department of Heat Engines
Academic year: 2019
Degree: MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)
MASTER'S DEGREE IN ENERGY ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ECTS credits: 5 Teaching languages: Catalan, Spanish, English

Teaching staff

Coordinator: Carlos David Pérez Segarra

Others: Carles Oliet
Joaquim Rigola
Asensio Oliva

Opening hours

Timetable: The specific timetable is personally agreed on with the student according to his/her availability.

Prior skills

Knowledge of fluid dynamics and heat and mass transfer, necessary to understand the operation of heat exchangers.

Requirements

Knowledge equivalent to having completed the course of levelling the Master's

Degree competences to which the subject contributes

Specific:

CEMT-7. Analyse the performance of equipment and facilities in operation to carry out a diagnostic assessment of the use system and establish measures to improve their energy efficiency.

CEMT-5. Employ technical and economic criteria to select the most appropriate thermal equipment for a given application, dimension thermal equipment and facilities, and recognise and evaluate the newest technological applications in the production, transportation, distribution, storage and use of thermal energy.

Transversal:

CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

CT3. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

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Teaching methodology

Teaching methodology:

The course teaching methodologies are as follows:

- Lectures and conferences: presentation of knowledge by lecturers or guest speakers.
- Participatory sessions: collective resolution of exercises, debates and group dynamics, with the lecturer and other students in the classroom; classroom presentation of an activity individually or in small groups.
- Theoretical/practical supervised work (TD): classroom activity carried out individually or in small groups, with the advice and supervision of the teacher.
- Homework assignment of reduced extension: carry out homework of reduced extension, individually or in groups.
- Homework assignment of broad extension: design, planning and implementation of a project or homework of broad extension by a group of students, and writing a report that should include the approach, results and conclusions.
- Evaluation activities (EV).

Training activities:

The course training activities are as follows:

- Face to face activities
o Lectures and conferences: learning based on understanding and synthesizing the knowledge presented by the teacher or by invited speakers.
o Participatory sessions: learning based on participating in the collective resolution of exercises, as well as in discussions and group dynamics, with the lecturer and other students in the classroom.
o Presentations (PS): learning based on presenting in the classroom an activity individually or in small groups.
o Theoretical/practical supervised work (TD): learning based on performing an activity in the classroom, or a theoretical or practical exercise, individually or in small groups, with the advice of the teacher.

- Study activities
o Homework assignment of reduced extension (PR): learning based on applying knowledge and presenting results.
o Homework assignment of broad extension (PA): learning based on applying and extending knowledge.
o Self-study (EA): learning based on studying or expanding the contents of the learning material, individually or in groups, understanding, assimilating, analysing and synthesizing knowledge.

Learning objectives of the subject

Goals
Acquire basic training in understanding the types and usefulness of different types of heat exchanger.
Acquire a very solid and yet flexible (adaptation to different geometries or phenomenology) in the calculation of heat exchangers by the conventional methods, integrating the knowledge of calculation algorithms with the basics of heat transfer competition.
Know the different levels of calculation of heat exchangers (porosity method, detailed calculation dimensional flows through ducts, solving the Navier-Stokes) and their combination. It aims to provide the tools and criteria to adapt the level of simulation/analysis to the needs of the company or researcher/engineer involved.

Learning outcomes:

At the end of the course, the student:
Consolidation of basic aspects of phenomena of heat and mass transfer (mathematical formulation, analytical techniques and numerical resolution, ...), as part of a technological application of large industrial and social importance are like heat exchangers.

Consolidation of conventional methods of calculation of heat exchangers (F factor methods, e-NTU NTU P, etc.).
Description of the main technical characteristics and peculiarities of calculation of heat exchangers different regarding geometry (double pipe, shell and tube, plates, compact fin-tube) and phenomenology (evaporators, condensers, heat by combustion).
Application of advanced methods of numerical simulation of heat exchangers dimensional fluid analysis, in case of steady state or transient flow and with or without phase change (condenser, evaporator).
Introduce the most advanced methods of calculation of heat exchangers where the fluid analysis is multidimensional, by methods with macro control volumes (porosity type methods) or more advanced methods based on detailed multidimensional solving Navier-Stokes equations.

Study load

Total learning time: 125h	Hours small group:	30h	24.00%
	Guided activities:	10h	8.00%
	Self study:	85h	68.00%

Content

Content 1. Introduction to heat exchangers

Learning time: 9h

Theory classes: 3h
Guided activities: 0h
Self study : 6h

Description:

Definition of heat exchanger, classifying them according to different criteria (current interaction, flow configuration, constructive types, types of fluid/phenomenon, etc.). Examples of application.
General design criteria and considerations. It aims to provide a comprehensive design, introducing constraints of types: thermal, hydraulic, manufacturing, corrosion, vibration, leaks, etc. characteristics of these teams. Also it will give an overview of the limitations inherent in the calculation of heat exchangers: physico-mathematical constraint models for assumed hypotheses, lack of empirical information (operation range, geometry range, measurement errors, etc.), errors in the physical properties, formation of desensitising variables with time, etc.

Related activities:

Theory class

Specific objectives:

- Concept of a heat exchanger and classification. Applications in systems and thermal equipment.
- Provide basic criteria for the design of an integrated heat exchanger.

Content 2. Theoretical basis for thermal and hydraulic designing

Learning time: 19h

Theory classes: 4h
Guided activities: 0h
Self study : 15h

Description:

This content provides the student with a series of basic analysis tools applicable to the majority of heat exchanger configurations. It explains the semi-analytical calculation methodology (NTU method, LMTD method), which shows the potential of this tool to estimate prediction or design in a variety of heat exchangers, interaction of a very efficient form with potential experimental studies. Introduction to more detailed/advanced methods (1D transitions for flow behaviour methods, simplified or complete multidimensional methods based on the resolution of the Navier-Stokes equations) to develop more general and flexible computational tools that integrate with more detail and less prevailing empirical phenomena or the calculation of the performance of characteristic portions of the heat exchanger.

Related activities:

Theory class
Practical class
Reduced scope work
Broad scope work

Specific objectives:

Approach to the resolution of the calculation of a heat exchanger (typology and phenomenology, appropriate formulation, adequate simulation level).
Calculation of heat exchangers using conventional methodologies (NTU method, LMTD method).
Introduction of more advanced methods of calculation: 1D detailed calculation for phase change processes, multidimensional analysis of flow of simplified fluid (porosity method) or more complete (resolution of Navier-Stokes equations).

Content 3. Heat exchangers without phase change: double-pipe, plates, shell and tube	Learning time: 34h Theory classes: 8h Guided activities: 4h Self study : 22h

Description:

Introduction of technological types of heat exchangers used in applications withuot phase change (double-tube, plate, shell and tube). For each variant there will be a detailed geometric characterisation, specific empirical dimensionless information will be provided (heat transfer surface coefficients, friction), and possible methods/special calculation (e.g. analysis method for shell and tube currents) will be described.

Related activities:

Theory class
Practical class
Reduced scope work
Broad scope work

Specific objectives:

Technological introduction of double-tube, plate, shell and tube heat exchangers.
Detailed description of the specific calculation for each variant: geometry, empirical information, calculation methodologies/variants.

Content 4. Heat exchangers with phase change: evaporators, condensers	Learning time: 24h Theory classes: 6h Guided activities: 2h Self study : 16h

Description:

This content is intended to extend the work on content 3, intensifying the analysis of the phase change processes (evaporation, condensation) in the heat exchanger. There will be an introduction to technology type by viewing the most used evaporator or condenser types and in what applications. Basic knowledge on heat transfer will be provided about the boiling/condensation mechanisms on the outside of pipes and bundles of tubes, horizontal or verticle inner tubes. It will complement the design and calculation methodologies presented in previous issues to address phase change processes (semi-analytical methods with phase change, calculating 1D tubes, etc.). Finally, the empirical information on these cases will be complemented (volumetric fraction of vapour, surface heat transfer coefficients and friction) and the design criteria and methodologies for specific situations will be explained.

Related activities:

Theory class
Practical class
Reduced scope work
Broad scope work

Specific objectives:

Introduction of technological condensers and evaporators: variants and applications.
Intensification in foundations of evaporation/condensation processes.
Extending the calculation and design methodologies to situations with phase change.

Content 5. Compact exchangers: fin-tube, regenerators	Learning time: 24h Theory classes: 6h Guided activities: 2h Self study : 16h

Description:

Specialisation of the methodologies outlined in previous topic to the case of heat exchangers with high density surface heat transfer through extended surfaces (fins). Design criteria is provided to proceed to efficiently flap (one/two fluids, density fins) the heat exchanger.
Adaptation of the calculation methodologies to this peculiarity: first to proceed to analyse the performance of the fins and their integration in the calculation process and the other is provide specific empirical dimensionless information for these geometries. Advanced calculation alternatives are presented (detailed models of macro-level volume control, porosity method, etc.). Finally, particular attention is devoted to the specific technology and calculation of regenerative heat treatment which is essentially temporary.

Related activities:

Theory class
Practical class
Reduced scope work
Broad scope work

Specific objectives:

Provide criteria for flapping a heat exchanger efficiently.
Extension of the calculation and design methods to the case of heat exchangers with extended surfaces.
Knowledge of advanced calculation models for these applications.
Analysis of heat recovery.

Content 6. Micro heat exchangers	Learning time: 15h Theory classes: 3h Guided activities: 2h Self study : 10h

Description:
This content aims to introduce students to the world of micro heat exchangers. First the reason for their high performance is explained and the applications that are expanding their use. Second an overview of the types of micro heat exchangers is presented (working range, density of heat transfer, etc.) and manufacturing technologies used. The limits of using the conventional calculation methodologies for these teams are explained. Although the content will focus on single-phase flow in the liquid phase, the main problems in the case of gas flow and phase change (condensation, evaporation) are also introduced. The content is finally complemented with an introduction to biomedical applications of fluidic microsystems (analysers, dispensers, mixers, etc.).

Related activities:
Theory class
Reduced scope work
Broad scope work

Specific objectives:
Understand micro heat exchangers and their state/current application.
Analyse limitations of conventional methods of calculation for the case of liquid flow, and other phenomena (gas phase change) are prospected.
Introduce the biomedical application of fluidic microsystems.

Planning of activities

Theory sessions	Hours: 88h Theory classes: 28h Self study: 60h

Description:
Methodology in large group. The content of the course will follow a model of exhibition class and participation. The material is organised into different groups according to the content areas of knowledge of the subject.

Support materials:
Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:
This activity is evaluated in conjunction with the second activity (problems) through coursework and testing knowledge.

Specific objectives:
At the end of this activity, students should be able to master the knowledge, consolidate them and apply them correctly to various technical problems. Moreover, being a techno-scientific subject, the lectures should serve as a basis for the development of other more technical subjects related to the field of heat, such as refrigeration, or Solar Thermal Engines.

Practical sessions	Hours: 21h Guided activities: 6h Self study: 15h

Description:
Methodology in large group and medium group, as long as the availability of the professor permits it. On each topic there will be some problems in the classroom so that students acquire the necessary guidelines to carry out this resolution: simplifying assumptions, approach, numerical resolution, discussion of results.

Support materials:
Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:
This activity is evaluated in conjunction with the first activity (theory) through coursework and exams.

Specific objectives:
At the end of this activity, students should be able to apply theoretical knowledge to solve different types of problems. Given the methodology, students should be able to:
1.- Understand the statement and analyse the problem.
2.- Propose and develop a scheme of the same resolution.
3.- Solve the problem using proposed equations with a suitable algorithm resolution.
4.- Critically interpret the results.

Guided activities	Hours: 14h Guided activities: 4h Self study: 10h

Description:
Students must perform guided activities. The activities consist in solving small problems, of whcih the data may be the result of a laboratory experiment or proposed data by the professor. The structure to be followed:
Preparation of the activity by a manual of practice.
Groups of 2 or 3 people with a maximum duration of two hours.
Discussion of the results obtained and the problems that have arisen during the course of practice.
Completion of a report on the practice carried out with results, questions and conclusions. This report will be evaluated together with the completion of the practice.

Support materials:
Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:
Reports should follow guidelines given in class.

Specific objectives:
Consolidate the knowledge acquired in theory classes and practices.

Written test	Hours: 2h Theory classes: 2h

Description:
Development of a written test of the course contents 1 and 2. It includes theoretical aspects and development problems.

Support materials:
Recommended references. Notes from the professor (copy and/or ATENEA).

Descriptions of the assignments due and their relation to the assessment:
The exam will be held freely and the statement delivered along with the statement duly filled in with the data required.

Specific objectives:
Demonstrate the level of knowledge achieved in theoretical activities and problems.

Qualification system

Midterm exam: 20%
Final exam: 35%
Works developed individually or in groups throughout the course (TR): 45%

Regulations for carrying out activities

Here are the rules of the system for evaluating the educational activities of the course.

Written test (PE).

There will be a final exam for the course. Students must complete both theoretical questions and problems related to the theoretical and practical content of the course. Reviews and/or claims regarding the examinations will be conducted according to the dates and times established in the academic calendar.

Work done individually or in groups along the course (TR).

Students must follow the instructions explained in class and contained in the file for the work that will be proposed to the student in relation to different teaching content of the course. As a result of these activities, students must submit a report (preferably in PDF format) to the professor, with the deadline to be fixed for each activity. The evaluation work will involve both its realisation and a possible defense.

Attendance and participation in classes and laboratories (AP).

The labs will be assessed both in their implementation and in the implementation of practical exercises that will be proposed; they can begin during the class schedule planned for this type of activity to be completed (if applicable) as an autonomous activity, following the instructions given in class. The results of practical exercises delivered to the teacher must follow the instructions given in class.

The evaluation of the practice will involve both its realisation and a possible defense.

Quality and performance of group work (TG).

The reports of practices and/or group work will be assessed individually on the oral defense if necessary or of any single group on the report.

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Bibliography

Basic:

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Schlünder, Ernst U. Heat exchanger design handbook. New York [etc.]: Hemisphere, 1983. ISBN 0891161252.

Fraas, Arthur P. Heat exchanger design. 2nd ed. New York: John Wiley & Sons, cop. 1989. ISBN 0471628689.

Kays, W. M.; London, A.L. Compact heat exchangers. 3rd ed. New York: McGraw-Hill Company, cop. 1984. ISBN 0070334188.

Kandlikar, S. G. [et al.]. Heat transfer and fluid flow in minichannels and microchannels [on line]. Amsterdam [etc.]: Elsevier, cop. 2006Available on: <http://www.sciencedirect.com/science/book/9780080445274>. ISBN 9780080445274.

Complementary:

Incropera, Frank Paul; DeWitt, David P. Fundamentos de transferencia de calor. 4a ed. México [etc.]: Prentice Hall, cop. 1999. ISBN 9701701704.

Eckert, E. R. G.; Drake, Robert M. Analysis of heat and mass transfer. Washington: Hemisphere Pub. Corp, cop. 1972. ISBN 0891165533.

Patankar, Suhas V. Numerical heat transfer and fluid flow. New York: McGraw-Hill, cop. 1980. ISBN 9780891165224.

Kern, Donald Quentin; Kraus, Allan D. Extended surface heat transfer. New York: McGraw-Hill, cop. 1972. ISBN 0070341958.

Wong, H. Y. Handbook of essential formulae and data on heat transfer for engineers. New York: Longman, cop. 1977. ISBN 0582460506.

Rohsenow, Warren M.; Hartnett, J. P.; Cho, Young I. Handbook of heat transfer. 3rd ed. New York [etc.]: McGraw-Hill, 1998. ISBN 0070535558.

Others resources:

Audiovisual material

Transparencies, proposed problems to be used in class

Resource

Notes made by the professor of the course

Resource