2SC5210 – Chemical Engineering: application to environment and biomanufacturing

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Department: DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS
Language of instruction: FRANCAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,50

Description

Modern chemical engineering deals with designing, operating, and optimizing environmentally friendly processes for the development of a variety of products and services in many traditional and high-tech sectors (pharmaceuticals, petroleum, fine chemicals, food processing, cosmetics, water and waste treatment, materials, biotechnologies, etc.), and for the production of traditional (nuclear, thermal, etc.) and renewable energies. Chemical engineering methodologies are widely used to ensure the recycling and recovery of numerous products and the purification of liquid and gaseous effluents, thus becoming tools of choice in the strategy of sustainable development on a global scale.
The challenges associated with this environmental issue are numerous: reducing costs, risks and dangers, waste, and energy and raw material consumption. Process intensification is the major lever for taking these challenges up.

This course is an introduction to chemical engineering and its methodologies, allowing students to acquire generalist tools that can be easily transposed to multiple fields, such as biotechnology and the environment. It is fully in line with the environment, energy and health issues. Most of the case studies are focused on bioprocesses used in industrial biotechnology. The development of these bioprocesses is growing rapidly due to the use of living organisms to transform matter and purify polluted systems, and the employment of biomass to replace fossil resources.

Bioprocesses are studied at the industrial bioreactor scale. The description and understanding of biological processes (metabolism, maintenance, etc.) at the cell level are not addressed. The biological agents are thus considered as cellular catalysts transforming raw materials into products according to known kinetic laws.

Quarter number

ST5

Prerequisites (in terms of CS courses)

None.
The case studies conducted involve biochemical or chemical reactions. However, no prior knowledge of chemistry or biology is required.

Syllabus

1. Introduction to chemical engineering; material balance
Case study: Process for the production of 1st generation bioethanol (conversion of renewable raw materials by industrial biotechnology)
2. Ideal reactor models (perfectly stirred and plug flow)
Case study: Design of biological treatment basins of an urban wastewater treatment plant (environmental bioprocess)
3. Thermal energy balances
Case study: Design of a bioreactor for baker's yeast production in batch mode (biomass production by industrial biotechnology)
4. Liquid-vapor equilibria, flash distillation
Application exercise: Flash distillation of ethanol-water mixture (purification of biofuel, alternative to fossil fuels)
5. Multi-stage distillation
Case study: Multi-stage distillation of bioethanol (purification of biofuel, alternative to fossil fuels)
6. Mass transfer: Diffusion and Convection
Case study: Raceway production of Spirulina microalgae (production of nutrients for food and feed by industrial biotechnology)
7. Mass transfer: Permanent Contact Technologies
Case study: treatment of a gaseous effluent with pollutant removal (environmental process)
8. Training for the challenge week
Case study: modeling and simulation of a bioprocess for polymer production (production of added value molecules by industrial biotechnology)

Class components (lecture, labs, etc.)
The course module is organized in lectures (10,5 h), to introduce knowledge and methodological tools, which will be then applied through case studies (13,5 h).

Grading

• Intermediate group exam: Oral presentation by group of a bibliographic project whose topic is an extension of the course (40 % of the grade)
• Individual final written exam: 1.5-hour case study (60 % of the grade).

Course support, bibliography

• **Slideshows**

• Techniques de l'ingénieur :
+ Charpentier J., Génie des procédés, développement durable et innovation – Enjeux et perspectives, 2013
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Transfert de matière – Méthodologie, 2000
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Isambert A., Transfert de matière – Distillation compartimentée idéale, 2001
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Transfert de matière – Autres opérations compartimentées, 2002
+ Buch A., Rakib M., Stambouli M., Transfert de matière- Cinétique du transfert de matière entre deux phases, 2008
+ Sun L.M., Thonnelier J.Y., Perméation gazeuse, 2004
+ Vuillermaux J., Réacteurs chimiques – Principes, 1994
+ Boulinguiez B., Le Cloirec P., Purification de biogaz – Élimination des COV et des siloxanes, 2011

• **General Books:** Perry Chemical Engineer's Handbook, 8th edition, 2007, McGraw-Hill, New York

• **Specific books:**
- *Reactor and bioreactor engineering*
+ Coulson and Richardson's Chemical Engineering – Volume 3A: Chemical and Biochemical Reactors and Reaction Engineering, 4th Edition, 2017, Elsevier. Oxford
+ Fogler H.S., Elements of chemical reaction engineering, 5th Edition, 2016, Pearson Education, Englewood Cliffs
+ Levenspiel O., Chemical Reaction Engineering, 3rd edition, 1999, John Wiley and Sons, New York
+ Villadsen J., Nielsen J., Lidén G., Bioreaction Engineering Principles, 3rd Edition, 2011, Springer, New York
- *Heat and mass transfer*
+ Bergman T.L., Lavine A.S., Incropera F.P., Dewitt F., Fundamentals of Heat and Mass Transfer, 7th Edition, 2011, John Wiley and Sons, New York
+ Coulson and Richardson's Chemical Engineering – Volume 1B: Heat and Mass Transfer: Fundamentals and Application, 7th Edition, 2018, Elsevier, Oxford
+ Cussler E.L., Diffusion Mass Transfer in Fluid systems, 3rd Edition, 2009, Cambridge University Press, Cambridge
+ Treybal R., Mass Transfer Operations, 4th Edition, 1982, McGraw Hill, New York
- *Bioethanol production*

+ Cardona C.A., Sanchez O.J., Gutierrez L.F, Process synthesis for fuel ethanol production, 2010, CRC Press, Boca Raton
+ Naik S.N., Goud V.V., Rout P.K., Dalai A.K, Production of first and second generation biofuels: A comprehensive review, Renewable and Sustainable Energy Reviews 14, 2010, 578–597
+ Vohra M., Manwar J., Manmode R., Padgilwar S., Patil S. Bioethanol production: Feedstock and current technologies, Journal of Environmental Chemical Engineering 2, 2014, 573–584

Resources

• Teaching staff: Irma LIASCUKIENE, Victor POZZOBON, François PUEL, Cristian PUENTES,
• Maximum enrolment in tutorials: 30 to 35 students
• Software, number of licenses required: Excel, Python, MATLAB

Learning outcomes covered on the course

At the end of this course, students will be able to:
• List the type of mass transfer mechanisms and its coupling to heat transfer,
• Identify the different mass transfer mechanisms (diffusion / convection) operating in a given configuration and the potential coupling between heat and mass transfer,
• Write mass balances, taking into account, if necessary, chemical or biochemical reaction kinetics,
• Simplify a seemingly complicated problem, where several transfer phenomena coexist, by taking into account only the main ones,
• Formalize phenomena into equations through elemental balances,
• Size chemical/biochemical conversion and separation technologies based on thermodynamic and kinetic considerations.

Description of the skills acquired at the end of the course

• C1.2. Modeling: using and developing the appropriate models, choosing the correct modeling scale and the relevant simplifying assumptions. Milestone 2.
• C1.3. Solve: solve a problem with a practice of approximation, simulation, and experimentation. Milestone 1.
• C2.4. Produce data and develop knowledge using a scientific approach Milestone 2.
• C7.1. Basically: Structure ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created). Milestone 2.
• C7.2. On the relationship with others: Understand the needs and expectations of his interlocutors evolutionarily. Encourage interactions, be a teacher, and create a climate of trust. Milestone 2.