

POST MASTERS DESIGNERS COURSE:
PROCESS AND PRODUCT DESIGN
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EINDHOVEN UNIVERSITY OF TECHNOLOGY
CHEMICAL ENGINEERING DEPARTMENT
STAN ACKERMANS INSTITUTE
EINDHOVEN
The NETHERLANDS

WEB-site: www.processandproductdesign.nl

Process- and Product Design – First Year Program

The objective of the study program is to allow trainee design engineers to develop synthesis and interdisciplinary skills, which are characteristic for the professional process and product designer. The emphasis is placed on the acquisition of knowledge and skills while finding technological solutions for the design of products to be manufactured in the process industry, and the processes and constructions for the production of these products.

A process and product designer is expected to have the following skills:

- Ability to work in an interdisciplinary team and to develop technical creativity.
- Working independently and critically in the profession of process and product designer.
- Specifying the requirements a process, product, or system must meet.
- Solving technical and economic core problems of processes.
- Determining the process parameters with boundaries and tolerances.
- Having knowledge of the civil effects of the design.
- Involving the governmental regulations in the design.
- Using a project approach to the design, including planning, throughput time, and taking market developments into account.
- Ability to present the design results in reports, oral presentations, and journal publications.

Study program

To realize a broad interdisciplinary top-level study program, a well-described, coherent program is offered. In the course component, which covers the first year and a small part of the second year, a division is made between the common foundation component and the specialization and elective component (mainly to be followed during the second year project). The common foundation part, which lasts approximately 40 weeks, broadens and deepens the knowledge acquired in the master program.

Most of our courses, including the two major courses “Plant Design and Operation” and “Product Design”, are mainly given by lecturers from industry and some are combined with company visits.

Overview of courses

This document gives an overview of most of the courses that are given in the first year of two-year Post-Master education Process and Product Design. The curriculum is continuously being updated and improved, so some courses may not be given and some other courses may not be listed in this overview.

6V010 Chemical Thermodynamics

2 ECTS

Lecturer: prof.dr. J. Meuldijk (TU/e)

The course Chemical Thermodynamics consists of lectures and preparing solutions of cases related to industrial practice. Trainees present their solutions to the group. Chosen methodologies and if applicable, approximations are discussed by all attendees. The trainees are expected to actively contribute to the discussions. Complex algebraic calculations are carried out with a mathematical software package.

Course material:

- J.M. Smith, H.C. van Ness and M.M. Abott, Introduction to Chemical Engineering Thermodynamics 7th edition, MacGraw-Hill, Singapore, 2005.
- J.M. Prausnitz and J. Gmehling, Verfahrenstechnik-Hochschulkurs III: Thermische Verfahrenstechnik, Phasengleichgewichte, will be distributed during the course
- Lecture notes
- L.P.B.M. Janssen, M.M.C.G. Warmoeskerken, Transport Phenomena Data Companion VSSD Delft (2006) ISBN 978-90-71301-59-9

The course Chemical Thermodynamics aims at making the trainee familiar with thermodynamic calculations frequently encountered during the design of chemical reactors and separation processes.

The following subjects will be treated:

- Heat of reaction, adiabatic temperature rise, also for complex reaction systems
- Fugacity of non ideal gas mixtures. Estimation
 - From experimental density data
 - Using the principle of corresponding states
 - Using the virial equation
 - Using equations of state (van der Waals, Redlich-Kwong, Soave Redlich-Kwong, Peng-Robinson)
- Chemical reaction equilibrium for ideal and real gas behavior, calculation of equilibrium conversion and equilibrium selectivity
- Vapor-liquid and liquid-liquid equilibrium
- Models for calculation of the activity coefficient (Margules, van Laar, Wilson, NRTL, UNIFAC)
- Calculation of P-x,y and T-x,y diagrams using models for activity coefficients
- Polymer solutions: activity of low molecular weight species (monomer, solvent)
- Example of a design study

After the course the trainee should be able to use the outcome of thermodynamic calculations to:

- Make a global selection for reactor types and separation techniques for the production of newly developed chemical products
- Evaluate the safety risks of chemical processes
- Translate phase equilibria into the performance of distillation and extraction processes

Evaluation: Written exam (60%), assignments (40%).

6V436 Emulsion Polymerization

Lecturers: A.M. van Herk (TU/e), J.P.A. Heuts (TU/e), J. Meuldijk (TU/e), D. Mestach (Nuplex Resins, Belgium)

The product of an emulsion polymerization is a latex, a dispersion of submicron polymer particles in water. Applications of latex products are e.g. in paints, adhesives and rubbers. Product properties are governed by e.g. molecular properties (molecular weight distribution, intra- and intermolecular chemical composition distribution), particle size distribution and particle morphology. The course gives the trainees insight into the interplay of aspects (physical) chemistry, process technology and materials science. Subjects of the course: controlled and free radical polymerization, particle nucleation and colloidal stability and surfactant systems, chemical composition control in emulsion polymerization (influence of reactivity of monomers and the phase ratio), aspects of operation and scaling up, recipe development in relation to product properties.

Evaluation: term paper

6V045 Product Design

11 ECTS

Coordinator, lecturer: prof.dr.ir. P. Bongers (Unilever, TU/e)

Course material

- Lecture slides during the course
- Additional reading:
 - Wesselingh, J.A., S. Kill, M.E. Vigild (2007). Design & Development of Biological, Food and Farmaceutical Products. Wiley Ltd.
 - Cussler, E.L., G.D. Moggridge (2001). Chemical Product Design. Cambridge University Press.

Contents

Chemically structured products are ubiquitous in the agricultural, chemical, food and beverage, consumer products and pharmaceutical industries. These complex, multiphase materials include speciality chemicals, granulated powders, compressed or extruded solids, emulsions, suspensions, and other complex solids/fluids. The global marketplace demands a greater rate of innovation and students educated in rapid new product development are needed if developed countries are to compete in the global marketplace. The design and manufacturing of chemically structured products is a formidable task due to the complex effect of chemical formulation, processing and formation on end-use

properties. These products are currently developed through trial-and-error experimental methodologies that are resource intensive and substantially slow the time to market. A structured methodology is needed that allows a more efficient design of chemically structured products and reduces the time for these products to reach the marketplace.

The course will focus on manufacturing technologies, processes and their interaction with product structure and end-use performance. More specific:

- Although most products are judged on their end-use performance, this is often neglected as well as that the consumer preferences are difficult to capture.
- Apart from the composition, the desired product micro-structure determines a number of the key properties. A quantitative specification of the structure, or even a loose description of the structure proved difficult, but a necessity,
- In a number of the products, equivalent micro-structures can be achieved by a multiple combination of ingredients (and their levels) and processes. Thereby it is a necessity to integrate the ingredient selection (product) and processes to maximise the economic potential of the products. Furthermore, compared to classical unit operations, this area involves many atypical processing opportunities for product structuring.
- Especially for fast moving consumer goods, the format of the products play an important role. A similar process can be embedded in different manufacturing technologies to achieve different end-product formats.

The key challenge is to integrate the above activities such that they can be executed concurrently, allowing flexibility for adaptations in the specific activities, and opening a space for novel structures generated by novel processing.

Evaluation: report and presentation/discussion

6V055 Conceptual Process Design and Scale-up

17 ECTS

Coordinator: Dr. ir. M.R. Westerweele (Mobatec, TU/e)

Lecturers: Ir. G. L. B. Thielemans (Shell); Dr. H. Goebel (Fluor)

This course covers all aspects related to the process design of a chemical or petrochemical production unit. From the conceptual design considerations in the earlier phases of a project, such as catalyst selection and testing supported by laboratory experiments, selection of operating conditions, reactor engineering considerations, scale-up issues and economical evaluations, to the actual process design activities in the following stages of the project, such as process simulations with a flow sheeting model (AspenPlus), heat and material balances, process and heat optimization (Pinch), Process Flow Diagrams (PFD) and Piping and Instrumentation Diagrams (P&ID) and cost estimating.

Attention is also given to process engineering design aspects, such as the design of heat transfer equipment (fired and non-fired) and other process equipment, materials of construction, process safeguarding considerations and general facilities such as utilities and other supporting systems. Project review procedures, such as safety analysis (HAZOP) and reliability analysis (RAM), are presented by specialists from industry. In the second part of the course the students will work on assignments during which the technical and economical viability of a process concept is evaluated, making use of the knowledge and skills acquired in the first part of the course.

Evaluation: written exam and design assignment. Report, presentation of results and group discussions.

6V100 Chemical Reactor Development and Process Intensification 3 ECTS

Lecturer: Prof.dr.ir. A. Stankiewicz (TUD, DSM)

The course consists of two parts: "Fundamentals of reactor selection and design" and "Innovative reactor technology for Process Intensification".

In the first part the review of basic chemical reaction engineering concepts will be presented, followed by the methodology for selection of the optimum type of reactor for the given process. Students will learn various criteria, on which the reactor choice must be based and will get an extensive overview of the industrially relevant types of reactors. In the second part general principles of Process Intensification (PI) will be introduced. Various novel reactor technologies for Process Intensification, such as Spinning Disk Reactors or Multifunctional Reactors, will be discussed. Based on the knowledge acquired during the course, the students will work on an assignment to re-design an existing chemical process in an inherently safer way, using the PI-technologies.

Evaluation: final presentation/discussion of case work.

6V430 Mass Transport Phenomena (as to September 2011) 3 ECTS

Lecturers: Prof.dr.ir. P. J.A.M. Kerckhof (TU/e)

The course provides a basic understanding of engineering hydrodynamics and mass transport. The Navier-Stokes equations will be discussed, and some special problems such as inviscid flow, viscous flow, potential theory. Attention is given to flow of gases through tubes and porous systems, including slip flow. This is followed by theory of turbulence, and applications to various flow situations, such as boundary layer theory. The basic elements of Computational Fluid Dynamics are discussed, among which numerical methods for finite differences, finite elements and finite volume methods. A special topic is the flow of polymeric liquids. Multicomponent molecular transport is treated from a general extended Maxwell-Stefan approach. Various limit models are discussed, and attention is given to transport in porous systems, such as membranes and catalyst pores. Included is a short historical flashback to the work of Maxwell, Stefan, Knudsen and many others. Models for multicomponent mass transfer in boundary layers and stagnant films are treated, with applications in distillation, extraction and membrane separations.

Throughout the course exercises are provided for hands-on work.

Evaluation: Case work/Exercises

6V230 Dynamics and control of processes

4

ECTS

Lecturers: dr.ir. E. Zondervan (TU/e), dr.ir. M.R. Westerweele (Mobatec, TU/e)

Process control grew from the requirements of responsible plant operation. The most important drivers are safety, product quality, environment, operational limitations, economic considerations and to account for design errors. In addition to the process modelling course, this course starts with the basic ingredients for controller design, i.e. process dynamics. We will learn what time constants, process gains and transfer functions are. Subsequently we will use these new modelling tools to analyse the dynamics of common systems such as CSTR's (first order, isothermal, equilibrium, consecutive), tubular reactors and separators. In addition we will use process dynamics in the design of controllers. We will get introduced to the principles of feedback and feed forward control and get familiar with the PID controller equations. We will use frequency response analysis and tuning algorithms (such as Ziegler Nichols) to tune the controllers. There will also be an outlook to alternative controller designs such as the Smith predictor (to deal with dead time), Dahlin's controller, Cascaded control, Ratio control and the Relative Gain Array. Lastly we will have a look at a more sophisticated model based control technique, i.e. Dynamic Matrix Control. We will close the course with some thoughts on plantwide control, where we study flowsheet controllability as part of a process design process.

Evaluation: Several case work assignments

6V240 Process Economics

2 ECTS

Lecturer: ir. A. van der Werf (Dupont)

The ultimate goal of any chemical process is to add value to raw (or intermediate) materials. The margin between the Sales Revenue and the Cost of Labor and Materials should make the - usually large - capital investment in a chemical process attractive to the purveyor of (risk!) capital. Operating Cost as well as Capital Cost should be minimized, without compromising either Time or Quality. The various chapters of this course will provide insight in the 'why' and 'how' of the resulting - and significant - economic constraints on the design of chemical processes.

Reading Financial Statements, understanding Cash Flow and Profit, handling the Time Value of Money, as well as Capital Cost Estimating lead to Investment Appraisal and Techno Economic Evaluation. Chapters on Risk analysis, Value Engineering, Planning & Scheduling, and Cost Control complete the picture of the field of Process Economics & Cost Engineering.

6V270 Process Synthesis

2 ECTS

Lecturer: Prof.dr. G. Schembecker (Tu- Dortmund, Process Design Center)

This course introduces participants to the field of process synthesis.

Process synthesis is a structured method that allows systematic identification of the most economical process flowsheets. For new processes it must be applied as early as

possible during the R&D phase because results of a process synthesis project influence the research program and vice versa.

The conventional practice is to improve processes by the optimization of existing designs or smaller stepwise improvements of specific process units (evolutionary design). Although these methods have their added value, the overall process scheme is often not changed. Process Synthesis, also known as Structured Conceptual Process Design, is a technique suitable not only for making a step-change in the existing process but also for synthesizing a process flowsheet from scratch.

Course content

After a short introduction several process synthesis methods will be highlighted. A detailed description of PDC's proprietary heuristic-numeric process synthesis procedure will follow. Applying the method to an extended example will demonstrate how the method can be used for projects with industrial complexity.

The lectures will concentrate on the method rather than on a detailed description of specific design tasks. In order to maximize the transfer of knowledge the example process will be worked out by the participants under the guidance of the instructor.

The course will cover the following topics:

- Introduction to process synthesis
- Process synthesis in the framework of process development
- Process synthesis methods
- Input/output structures
- Flowsheet development
- Energy integration
- Process synthesis example
 - Reactor selection and design
 - Design of the separation system

A course manual is provided as a part of the course.

6V400 Technical Writing and Editing

3 ECTS

Lecturer: drs. D. Breedt (TU/e)

The technical writing and editing course is designed to help you communicate more clearly:

- To become more familiar with the concepts of technical writing and editing;
- To become more comfortable with planning, organizing and producing a variety of texts;
- To polish your writing skills so the final product is of the highest quality in both content and composition.

6V410 Professional Development

3 ECTS

Several lecturers of the STU (TU/e)

Professional development (PD) is spread across the first year and concentrates on the non-technical skills expected from a designer in industry.

Objective:

- Stimulation of the attitude in which you regard professional development as something you can control yourself.
- Development of your social and communication skills.

6V420 Methods and Techniques for Design

3 ECTS

Lecturer: dr.ir. K. van Overveld (TU/e)

Designing technological artifacts requires much more than just the technological knowledge that explains how the artifact functions. Designing starts with understanding who the customers are, what they wish, what the contextual factors are; next, in innovative design, there is a creative phase where solutions alternatives are generated. These phases sometimes have to be iterated over repeatedly. Only in a last phase, definitive decisions are being made that shape the details of the artifact. In the course "Methods and Techniques for Design", a number of techniques for the systematic exploration of context, requirements and solution space are taught. A balance is sought between, on the one hand, clean and structured thinking, and on the other hand unorthodox and creative exploration. The techniques are applied to a more or less realistic design case.

6V431 Applied Statistics for Chemical Engineers

3 ECTS

Lecturers: ir. G.D.Mooiweer (Sara Lee and TU/e, course coordinator), dr.ir. L.T.M.E. Hillegers (CQ consultancy, Leuven)

The condensed course 'Applied Statistics for Chemical Engineers' provides the students with an introduction to the theory and applications of design of experiments (DoE), linear/non-linear regression modelling (curve fitting) and exploratory multivariate data analysis. A large part of the course is used for practical exercises using modern, easy-to-use statistical software, in particular Statgraphics Centurion and The Unscrambler. Moreover, students will work with Statlab, a web-based teaching tool for design of experiments developed at the Eindhoven University of Technology (www.win.tue.nl/statlab).

The course will cover the following topics:

- Uses for statistical models, exploratory data analysis, propagation of errors, basic notions of estimation and hypothesis testing.
- Simple/multiple linear regression, non-linear regression. Model checks. Model selection.
- Design of Experiments (DoE), screening designs, response surface methodology, optimization.
- Exploratory multivariate data analysis using Principle Components Analysis (PCA) and Partial Least Squares regression (PLS).

Examination: Individual written exam, review/presentation of group assigned case studies.

6V435 Project Management

3 ECTS

Lecturers: ir. E. Gerritz (GTI); ir. A. van der Werf (Dupont); prof. dr. ir. J.S. Dhillon (TUD)

This module consists of 3 parts:

1. Prof. Dr J. Dhillon: Description of the innovative approach of the process industry to build future plants faster and more cost effective. Basics of project and contract management will be dealt with. The organization of the implementation phase of projects (Engineering, Procurement, Construction with acronym EPC) is explained including the specific terminology. Also some basics of project definition ("Front End Loading") and technology management will be presented.
2. Ir. E. Gerritz: Presentation of a real life business case. First the business environment is pictured, then a project fulfilling business needs is followed from conceptual engineering through basic engineering and finally the EPC phase in interactive sessions. In these sessions the basics explained by Prof. Dhillon will be applied to an actual executed project. This actual project is also the basis for a larger case where this project is scaled up and relocated, requiring students to exercise with a location study, a contracting strategy, an estimate and a schedule. The results of these exercises will be presented by the students. Also time is reserved for a plant excursion (?).
3. Ir. A. van der Werf: This part will start with a refresher on some items of cost engineering and economics given in the Spring "Economic Evaluations" module. To be followed with a more detailed exploration of scheduling, progress- and cost control and change management.

6V436 Dynamic Modelling and Simulation

3 ECTS

Lecturers: dr.ir. M.R. Westerweele (Mobatec, TU/e), dr.ir. E. Zondervan (TU/e), ir. J.G.Wijers (TU/e)

Models take a central position in all process engineering tasks as they replace the process for the analysis. They represent an abstraction of the process, though not a complete reproduction. Models make it possible to study the behaviour of a process within the domain of common characteristics of the model and the modelled process without affecting the original process. The mapping of the process into a model does not only depend on the chosen theory, but also on the conditions under which the process is being viewed. The mapped characteristics vary thus not only with the applied theory but also with the conditions.

The construction of process models (including testing, initialisation, tuning, etc) is, in general, seen as a difficult and very time consuming task and is preferably handed over to "modelling experts". This does not have to be the case if a clear, stepwise method is adhered to.

Establishing a model, as it is used in a particular application, involves a number of operations, which can be broken down into a number of principle steps. This course will

introduce a systematic modelling methodology, which is based on the hierarchical decomposition of processes into thermodynamic systems.

This course also includes:

| | | |
|--------------|------------------------------------|--------|
| 6V432 | Matlab Beginners Course | 1 ECTS |
| 6V433 | AspenTech Simulation Course | 1 ECTS |

6V170 Industrial Organic Chemistry 3 ECTS

Lecturer: prof.dr. B. Hulshof. (DSM)

After about 1 year of research, at least another 10 years are needed before research on a fine chemical can be put into practice. This traditional approach in process design faces too many drastic changes in route selection to synthesize complicated fine chemical molecules on a large scale. After this explorative route selection phase and before the plant design, research has to be performed in the field of selectivity, optimization of chemistry, technology, economics, process development and scale-up, competitive analysis and QESH (quality, environment, safety and health) – aspects.

Timing and results ('performance') in process R&D and scale-up are hard to estimate in practice. Particularly, pressure of time makes it more difficult to maintain the traditional methodology and way of thinking.

The course will deal with the possibilities of improving the performance in the fine chemical industry by means of solved practical problems in scale-up ('(non)-flyers'). These problems will give lower chemical yields and product quality – loss at first. After some changes and adjustments, results similar or better to those in the laboratory are obtained. These (non) – flyers will help to get insight not only into the ideal approach in process architecture (reaction engineering) but also the ideal concept of the fine chemicals plant of the future.

6V434 Computational Fluid Dynamics 3 ECTS

Lecturer: dr.ir J.G.M. Kuerten. (TU/e), dr.ir. B.P.M. van Esch (TU/e), ir. M. Veenman (DSM)

6V255 Unified Approach to Mass Transfer (OSPT) 2 ECTS

Lecturers: prof.dr.ir. L.A.M. v.d. Wielen (TUD), prof.dr.ir. J.T.F. Keurentjes (Akzo-Nobel, TU/e) and prof.dr.ir. R. Boom (WUR)

This course will teach a method to describe all mass transfer processes. The species are taken to move with respect to each other due to their potential gradients. Their rate of movement is restricted by friction between the species. The method links thermodynamics and transport phenomena in a way, which is easily understood by engineers. It has its origins in the works of Stefan and Maxwell. The course consists of short lectures, followed by computer tutorials. Participants will work out several realistic examples on the computer and discuss how to go on for the least half on the course. Most of the examples are based on realistic practical problems. We will use Mathcad 7.0 for the tutorials. Participants will receive instruction materials for some hour's practice. A reasonable background in thermodynamics and transport phenomena is an advantage.

The course has been designed for PhD and MSc students and for industrial specialists. However, undergraduates who can motivate their choice are also welcome

Polymer Reaction Engineering (as of February 2012)

4 ECTS

Lecturers: prof.dr. J.Meuldijk (TU/e), dr.ir. J.P.A. Heuts (TU/e)

The objective of the course is to provide the trainees with insight into process development for the production of complex performance materials. Topics include polymerization kinetics, process design, modelling of (catalytic) polymerization processes. Product groups to be discussed are: polyolefines, polyesters, polyamides and polymer colloids. In order to enhance the understanding and interaction, the course consists of lectures as well as case studies.

Book: Polymer Reaction Engineering, J.M. Asua, Ed., Blackwell, Oxford (2007)

Evaluation: written exam, assignments, term paper

6V275 Study Tour

1 ECTS