**CHEM-E7160 - Fluid Flow in Process Units**

**General**

This course gives tools to design chemical processes from fluid flow point of view. First previous knowledge related to mechanical energy balances and how pumps and piping systems should be designed based on them is revised. Although it is expected that pump and piping design is already included in BSc level education, many practical fluid flow related problems can be solved with straightforward application of mechanical energy balances. Therefore, these tools cannot be overemphasized. After this, more modern tools using momentum balances and computational fluid dynamics are introduced, first for single phase flow and then for multiple phases. Along with introducing rigorous numerical tools, traditional correlation based design for the same problems are also covered.

**Learning Outcomes:**

After the course the student

* Knows technical solutions for typical mixing problems
* Can solve fluid flow problems based on material, energy and momentum balances
* Can use modern simulation tools to solve fluid flow problems numerically
* Understands how fluid flow affects process performance and can design processes to ensure proper fluid flow
* Understands the nature of non-Newtonian and multiphase fluid flows

 **Content:**

* Navier-Stokes equations and computational fluid dynamics in single and multiphase systems
* Fundamentals of mixing: stirred vessels (gassed, slurries), static mixers, mixing in reactors
* Multiphase flow in pipes and process units, settling, fluidization
* Fluid flow in porous materials
* Practical design of unit operations for controlled multiphase flow
* Non-Newtonian flow, rheological property models
* Fluid flow measurements

**Workload and** **grading (% of total points)**

* Lectures 24 h
* Exercises 36 h (15%)
* Project work 35 h (30%)
* Laboratory exercise 10 h (10%)
* Other independent study and exam 30 h (45%)

One additional point will be given by answering the official course feedback. Additional points may also be given if you find significant mistakes in the course material or propose a very good exam question.

Grading is built so that it corresponds to the workload as well as possible. Workload related to the lectures and part of the exercises are included in the final exam grade. Exercise grading shown in the list refers to participation points (see description later). No specific part of the course is compulsory for passing, but 50 % of total points are needed for passing and at maximum 85 % for the highest grade. If less than 5 % of the registered students would get the highest grade, then the limits may be lowered.

If all the graded assignments are done during the same year, they remain valid with the earned points. If you have finished only parts of the course, e.g. have points only from pre-exam and exercises but wish to continue next year with home assignments, earlier completed tasks may be recognized upon agreement but only with reduced points.

**Lectures**

* Lectures will be held twice a week. There are typically small activating tasks during the lectures, so be prepared with pen, paper and a calculator. On 2021, all lectures will be given remotely via Zoom.

**Exercises**

* Twice a week. By actively participating in the exercises, the student gets a point from each exercise; no returned answers are expected. On 2021, all exercises are held in Zoom. Active participation is controlled by simple MC quizzes, which will be opened during the exercise and closed soon after the exercise ends. You will get the participation points based on these quizzes. During the exercises, there will be various breakout room arrangements, so you can work either alone or in small groups according to your preference.
* If you cannot attend, you can get the point by returning a report how you did the exercise (one page) and the answers **before the exercise session**. The report must contain answers and a short written description. You should ask for any help if needed. The idea is that you should get the same advice as in the computer class. Workload for this alternative is expected to be higher than in the corresponding normal exercise. This is only a substitute for normal practice in special cases!
* Answers will be uploaded to MC either at the end of each session or immediately afterwards. You are expected to go through them and ask for any clarifications irrespective if you are at the computer class or doing exercise remotely.

**Laboratory exercise**

* The course has one laboratory exercise where the students make themselves acquainted with a small-scale agitation apparatus with aeration by making a set of measurements in the laboratory and making a report of the main observations of the experiments. This is done in a group of 2 students. At the moment (per 29.1.2021) the laboratory work is allowed at Aalto University taking into account the Covid -19 regulations given by the university, school and Finnish government. This part is subject to changes if the Covid -19 situation changes.

**Seminar work**

Seminar work will be done in groups of two or three persons. Further advise is given when the number of registered people to the course is confirmed. In some special cases, a group of one can be accepted. This is mainly intended for post-graduate students who wish to carry out a topic related to their research. Contact the teachers in such a case. The workload of the work is adjusted accordingly.

Mark your selection and group members in a list in MyCourses. Each group should have own topic.

The workload per person should be 35 h, so the total work should reflect the number of students in the group. Each person is responsible for equal workload in each group (no free riders!). Do not either use excessive amount of time, just do the best you can in the given time. Ask for help when needed but think yourself first. Sharing your work is done electronically, but the process follows traditional seminar day: you should prepare written report and a presentation. Each written report will be commented carefully by two other students, and each student should see all presentations and ask questions, similarly as you would do in the normal seminar. Each group should respond to comments / questions related to their work.

**Follow this list for a successful assignment completion:**

1. Start by looking briefly about the relevant literature (not only Wikipedia!), 3-5 references is typically enough here, depending on the case
2. Build the model and run it. If your topic is a Comsol tutorial you must progress from the given example into a relevant direction that you can (and should) propose yourself. You can ask comments related to your ideas for this. Please note that when you modify the case, you can get advice from other tutorials (e.g. combining fluid flow with chemistry).
3. Analyze the results from a perspective that you find interesting, but focus on the course topic (Fluid flow). Try to analyze critically whether the results obtained with the tool you have been using are correct.
4. Upload a description of the work progress to MC before stated deadline for this progress report. Half a page of general description is sufficient. Note that simulations may take time even if you know what to do, so start the work early!
5. Write a final report and upload it to MC. The total report should not be very long, 3-4 pages of text (with relevant model equations), and some illustrative figures is enough.
6. Prepare a video presentation of the work (5-10 min, outside this range affects grading). It does not have to be a video clip of your group talking, but any format including animations, pictures, and whatever material you feel appropriate to support the written report. It could also be a PP presentation with voice. You can also refer to the written report in the video. Note size limit (less than 200 MB!) for any file in MC.
7. Upload both written report and the video to MC in your own folder.
8. Act as an opponent two written reports and all videos (individually). Prepare comments and questions of them and upload to MC. Mark your own name clearly for each question / comment and mark that you have been assessing the whole work: “O”, for Opponent. Select such reports that have not yet been commented by many so that each report will be commented equally.
9. Look at all the other presentations (no need to assess written reports) and ask questions if you have any. This should be similar activity than during a normal seminar. Mark your questions and comments with “P”, for Participant.
10. Each group should answer to the questions raised by other students and by teachers who comment the work after students’ comments. Continuing high quality academic discussion is an additional merit for both teams.
11. Read responses to your own comments / questions.

**Evaluation is based on the following aspects:**

* quality of the work (simulation model and analysis of the results)
* quality of the report
* quality of the video (mastery of the topic and clearness of presentation)
* keeping the schedule for intermediate and final reports, commenting and responding
* activity and diligence in commenting peer group’s work both for report and for video (“thank you very nice” is not a sufficient comment), and answering to the comments

**Tools**

Besides normal tools (pen, paper, calculator, Excel…), this course uses Comsol software to demonstrate numerical tools that can be used in computational fluid dynamics problems. Comsol is not specifically aimed for fluid flow problems (there are other more specific software for that), but it is a general-purpose modeling tool that is relatively quick to get familiar with, and it is available for download also to Aalto students. It is also relatively straightforward to add other physical models to fluid flow problems in Comsol, which is typical in Chemical Engineering problems. Some other commercial tools, such as Aspen Plus, may be used as well. It is strongly recommended that you install Comsol to your own computer in the beginning of the course, as it helps you to carry out the exercises. For Aspen, a VDI connection to Aalto is needed for the license.

**Final exam**

For advice how to prepare for the final exam, see separate instruction text.