KTH Industrial Engineering and Management

MJ2429 Turbomachinery

Course PM 2012

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2012-08-14

Introduction

The course MJ2429 Turbomachinery is taught in periods 1 & 2 at KTH Energy Technology. It is conceived as a basic course serving as preparation for the following more advanced courses:

- Thermal Turbomachinery MJ2430 (period 3)
- Airbreathing Propulsion II MJ2244 (period 3)

The requirements for this course are basic knowledge in thermodynamics and fluid mechanics.

In brief the turbomachinery course is split into two parts; the first part of the course focuses on turbomachines for incompressible fluids (liquids) and takes place in period 1. The second part focus on turbomachines for compressible fluids (gases) and takes place in period 2. Each part is examined separately at the end of the respective periods.

Syllabus

Turbomachines are very widely used in many different applications, be it household appliances, process industry, air transport or power generation. Their area of application is vast ranging from miniature sized cooling fans in computers over modern large bypass ratio turbofans to gigantic steam turbines providing more than one million shaft horse powers for use in power generation. Regardless f size and application, they are based on the same working principle of changing swirl momentum.

The present course will cover the basics of turbomachines, both for use with liquid (incompressible) as well as gaseous (compressible) fluids. It will lead the students from the basic knowledge of fluid mechanics and thermodynamics to being able to perform the preliminary design of such machines.

The course corresponds to 6 ECTS Credits.

Course Overview

The aero-, hydro- and thermodynamic terminology and equations relevant for all these machines are taught and discussed extensively in this course. The fundamental theory is explained in an interactive and animated way. The theory of operating turbomachines at design and off-design conditions is discussed and applied on practical problems. The process of preliminary design is taught and linked to the underlying theory. Calculations and laboratory exercises are performed with the aim to understand the physical relationship between the aero- and thermodynamics of the machine. Throughout the course, a great weight is put to have the practical applications linked to the underlying theory and by this lay out a solid foundation for further studies in this field. Additionally, today's and tomorrow's need for turbomachines as well as future development and research needs are discussed.

Course Objectives

The course aims at giving an overview of different types of turbomachinery used for energy transformation, such as pumps, fans, compressors, as well as hydraulic, steam and gas-turbines. It will focus on applications in power generation, transport, refrigeration and the built environment.

After completing the course the student will be able to:

- Give examples of the main applications of turbomachines
- Recognize typical designs of turbomachines
- Explain the working principles of turbomachines and apply it to various types of machines
- Determine the velocity triangles in turbomachinery stages operating at design and off-design conditions
- Apply the affinity laws to pumps such as to determine their off-design behavior
- Match a pump to a system and discuss various solutions of pump matching from a sustainability point-of-view
- Explain the working principle of various types of hydro turbines and know their application range
- Perform the preliminary design of turbomachines (pumps, compressors, turbines) on a 1-D basis
- Use design parameters for characterizing turbomachinery stages
- Determine the off-design behavior of turbines and compressors and relate it to changes in the velocity triangles
- Explain and understand how the flow varies downstream of a turbomachinery blade row
- Recognize relations between choices made early in the turbomachinery design process and the final components and operability
- Explain the limits of safe operation of compressors
- Recognize and discuss today's and tomorrow's use of turbomachines for enabling a sustainable society

Course Structure

The course is split into two parts; one part covers turbomachines for incompressible fluids such as pumps and hydro turbines, the other one turbomachines for compressible fluids such as compressors and gas/steam turbines. Part 1 of the course takes place in period 1, part 2 in period 2.

The course is largely aligned around solving problems such as to teach the students the subject on a practical background. Each week, a new problem will be made available to the students and solved and discussed in class. The theoretical background for solving these problems is taught via recorded learning units that the students can follow at their preferred pace, time and place. These lecture units are directly accessed from the lecture notes (interactive e-book). The course schedule maintained in KTH Social contains references to the part of the learning material to be followed for a given problem. The problems do not need to be handed in.

In addition, weekly self-assessment tests are made available. These self-assessment tests contain questions and problems that examine the knowledge treated during the respective week. The questions are of similar type as during the exam and thereby prepare the students for the exam in a continuous manner. The self-assessment tests are not compulsory but can give the student one bonus point (one percentage point) for later use in the exam if performed successfully[1]. In addition, they allow the students to stay on the ball.

Two laboratory exercises are performed such as to allow the students to acquire real tests data in an interactive manner and to further analyze this data. The following laboratory exercises are performed:

- Operation of pumps (serial/parallel operation, operation at design and off-design speed)
- Measurements of the flow field downstream of a turbine cascade

The laboratory exercises are performed remotely. Students following the course at KTH on-campus have the possibility to perform the lab on site while accessing the controls through the remote lab interface.

The following persons are involved in this course:

- Main lecturer/examiner: Assoc. Prof. Damian Vogt, damian.vogt@energy.kth.se
- Course assistant: Hina Noor, hina@kth.se
- Lab assistant: Lucio Monaco, lucio@kth.se

[1] A self-assessment test is considered successful if at least 75% of the answers are correct

Requirements to Pass

Exam 1 (TENA), 2 ECTS, turbomachinery for incompressible fluids, grades A-E, FX, F[2]

Exam 2 (TENB), 2.5 ECTS, turbomachinery for compressible fluids, grades A-E, FX, F[2]

Grading scale (for both exams)

From %	To %	Grade
92	100 (+ bonus points[3])	A
80	91	B
68	79	C
56	67	D
50	54	E
40	49	FX
0	39	F

Lab exercises (LAB1), 1.5 ECTS, grades P/F[4]

Criteria for passing the lab exercises:

- Passing of self-assessment test prior to lab (individually)
- Active participation during lab (individually)
- Written lab report submitted on time to Bilda and approved by lab assistant (if not approved, the students will be asked to submit a reviewed report). The lab report is submitted in group.

Language

The language of instruction is English. Reports must be written in English.

[2] Note: grade E and higher means "passed". A grade FX can be raised to a grade E after successful completion of an additional task defined by the examiner. Grade F means "failed".
[3] Bonus points: bonus points can be obtained from for successfully passed weekly self-assessment tests. The bonus points will only be taken into account if the exam itself is passed (i.e. at least 50% correct).
[4] P means "passed, F means "failed".

Webtools

Two KTH webtools are used in this course as are **Bilda** and **KTH Social**. Bilda is accessible at http://bilda.kth.se. The course event is called "MJ2429 (2012) Turbomachinery". If a student does not have access to the event in Bilda, it most probably indicates that he/she is not registered to the course properly. In such case, please contact the course assistant. KTH Social is among others accessible from the KTH main website www.kth.se.

The use of these two tools is organized in the following manner:

Bilda

- Course documents (administrative, lecture notes)
- Administrative actions (confirmation of participation, enlisting for exam)
- Podcasts of lectures (through podcast channel)
- Discussion forum (discussion of technical questions by peers and faculty)
- Online tests (weekly self-assessment tests, exams)
- FAQs
- Submission of lab reports
- Course evaluation

Social

- General course description
- Course schedule containing the information of lecture contents
- Other information of interest

Confirmation of Participation

All students must confirm their participation in the course during the first week of the course. The confirmation is done online (rather than on a list in class) using the course webtool (Bilda), section "Contents". When confirming the enlisting, the students will be asked to give additional information, which is needed for administrative purposes.

Course Literature

Main course literature:

> Vogt, D.M., 2012, "Turbomachinery Lecture Notes", KTH Heat and Power Technology
>
> Interactive e-book containing among other recorded learning units. The e-book is made available through Bilda.

Additional reading:

> Dixon, S.L., Hall, C.A., 2010, "Fluid Mechanics and Thermodynamics of Turbomachinery", 6th edition, Butterworth-Heinemann, ISBN13 9781856177931
>
> This book is recommended to students who would like having additional reading in addition to the lecture notes.

In Case of Missing Lectures

It happens that students miss lectures. In the present course the lectures are recorded (notes on whiteboard, audio) and therefore can be followed afterwards. The recorded lectures are made available through Bilda by means of a podcast channel. Students can subscribe to the podcast using iTunes and follow these on a computer/iPad/etc. Also, the whiteboard notes are stored and made available in Bilda (Document section). Despite these features, students are encouraged to follow the lectures in class.

Course Schedule

Please refer to the course schedule published on KTH Social.

In Case of Questions

If you are uncertain about something, your first checkpoint should be the "FAQ" section in Bilda. If you do not find an answer to your question, please send an email to the course assistant.