4. SPECIALIZATION IN TURBOMACHINERY AND PROPULSION

The main objective of these specialized courses is to familiarize the students with the main theories and tools for the interpretation of numerical and experimental results and the design techniques for advanced turbomachinery components. The first part provides the basis for the more specialized studies in turbines or compressors in the second part of this course program. The formal lectures are completed with the aero-design of advanced turbomachinery components to put the learned lessons into practice. The targeted courses prepare the student for a position in a turbomachinery research center or the R&D department of a turbomachinery manufacturer.

Flow in Turbomachines (FTM - 8.0 ECTS)

At the end of this course the student should have acquired the necessary background, understand the thermodynamic principles and master the analysis and design methods specific for turbomachines.

He/she should have a good knowledge of: thermodynamic cycles, fundamentals of propulsion and turbopropulsion elements, laws of similitude, prediction correlations. He/she should understand the influence of design parameters on performance maps of turbines and compressors and how they influence compressor and turbine stage matching. He/she should be familiar with design and flow analysis methods of different level of complication for meridional flow and cascades, the effects of boundary layers in turbomachines including curvature and rotational effects. Required is also a good understanding of three-dimensional and secondary flow effects to explain numerical and experimental results. The student should master the novel computerized design techniques based on inverse design and optimization. Viscous and heat transfer effects on boundary layers should be understood.

Evaluation is done by several oral exams measuring the theoretical understanding of the different physical models, the solution techniques and by the outcome of the Design Exercise described in below.

Design Exercise (DE – 5.0 ECTS)

The design of a turbomachine component (Compressor or turbine), required from each student and is meant to be the final hands-on illustration/evaluation of the different turbomachinery lectures (basic and advanced). The component chosen depends on the option chosen for specialization.

Typical geometries to design are: industrial type of compressor such as front stages of an industrial gasturbine, the transonic fan module of a jet engine, the multistage compressor module, turbines for automotive applications and full cells, high pressure turbines for helicopters and counter-rotating turbine stages for space propulsion.

The student is expected to define the aerodynamic path and to specify the bladings in function of the design point using the techniques specified in the courses. The design point has to be complemented by an off design performance prediction. Finally the blades have to be analyzed by Navier stokes solvers to confirm the local energy exchange and verify the optimality of the blade velocity distribution.

The evaluation is based on the design report.

Students making a numerical project may decide to limit the design exercise to 1.5 ECTS and complement their curriculum with the course “numerical methods for Fluid Dynamics, part2” described in the section **Optional Courses for all departments.**

Laboratory Sessions (TU Labs - 3.0 ECTS)
Following lab sessions are defined to provide a better understanding of the flow physics and theories presented in the courses
- Measurement and calculation of the flow in a cascades followed by a computerized design of improved blade sections
- Unsteady flow measurements during surge and stall,
- Heat transfer and gas temperature measurements related to hot turbine blades.

The evaluation is based on the test report.

4.1 Specialization on Turbines

Advanced Course in Turbines (ACT - 4.5 ECTS)
This course is composed of three parts.
At the end of the first part the student should have a good knowledge of the turbine design parameters and their impact on performance, the airfoil design techniques and performance prediction methods, and be able to use them in a practical turbine design.
The objective of the second part is an understanding of the transonic and supersonic blade performance prediction and stage design methods.
A good knowledge of blade cooling concepts and the effect of cooling on the aerodynamic performance of gasturbines are the objectives of the third part. It includes the understanding of the effect of cooling on boundary layer behavior and the modeling of the convective heat transfer.
The evaluation is based on. An oral examination

4.2 Specialization on Compressors

Advanced Course in Compressors (ACC - 4.5 ECTS)
This course is composed of two parts:

Centrifugal compressors
This part provides the background necessary to establish a detailed design and analysis of radial compressors. The objective is to make the student aware of the specificities of radial compressors i.e. the role of radius change on the transformation of energy and pressure rise, the mechanisms governing the flow in vaneless and vaned diffusers and volutes. The student should master the prediction models for surge and stall and understand the specific problems related to the different fields of application (industrial or aeronautic), the impact of Reynolds number or gas composition on performance.
Evaluation is by the design of a radial compressor by means of a computerized design system based on the theory that has been presented and discussion of the different steps that can be taken to improve the performance (design and off-design).

Axial flow compressors

This second part is similar to the first one but oriented towards axial compressors. In addition the student should be aware of the specificities of multistage, transonic and supersonic axial compressors. The impact of flow unsteadiness, the stability criteria and advantages of variable geometry and should be understood.

The evaluation is partly by an oral exam and partly by **Design Exercise** presented before.

4.3 Optional courses in the turbomachinery department

Students following the experimental option have to take following course:
Introduction to Computational Fluid Dynamics LS (ICFD - 1.25 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

Students selecting the **Numerical option** and making the reduced Design Exercise (1.5 ECTS) have to take following course:
Numerical methods in Fluid Dynamics Part 2 (NFMD2 – 3.0 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.