Course descriptions Minor Gas Turbines

Term 1

Gas Turbine Theory

2 EC → 56 hours study load

As a gas turbine specialist you'll be working on the design, maintenance and optimization of gas turbine installations in the power or the aircraft industry or perhaps even the Dutch Air Forces and Navy. In the course Gas Turbine Theory, you apply theory and knowledge you've acquired in previous thermodynamics courses on real existing installations by making practical assignments. You will learn how turbines work, how energy is generated and how gas turbines propel aircraft. In the lectures existing plants will be described. Some contact moments will be reserved for you to work (together or individually) on the assignments.
After completing the course, you will be able to size a gas turbine, calculate the efficiency and power of a gas turbine and predict the behavior of gas turbines. Furthermore you will be able to model a gas turbine in an Excel spreadsheet and apply various control philosophies through mathematical experiments. In this way you will be able to make reasonable decisions about the design and operation of gas turbines.

Learning goals :

The Gas Turbine Theory course focuses on the thermodynamic fundamentals of gas turbines. In this context the following learning goals are defined. After completion of the course the student is expected to :
- Model a gas turbine
- Calculate the efficiency and power of a gas turbine
- Predict the behaviour of a gas turbine
- Apply various control philosophies through mathematical experiments

Book : **Gas Turbine Theory, 6th edition, Saravanamutoo, Cohen, Rogers & Straznicky, ISBN 9780132224376**
Plus : PowerPoint slides provided by the lecturer.

Lecture schedule :

Week 1 :
o Introduction. Ideal cycles. Joule-Brayton process. Section 1.1 – 1.6
o Simple gas turbine cycle. Cycle efficiency. Section 2.1 -- 2.2 (a)
o Specific work output. Isentropic efficiency of compressor & turbine.
Week 2 :
o Component losses. Combustion chamber. Fuel / air ratio. Section 2.1 – 2.4
o Non-ideal gas turbine cycle. Increasing cycle work and/or cycle efficiency.
o Heat exchange cycle.
Week 3 :
o Intercooled compression cycle. Reheat cycle.
Week 4 :
o Power turbine. Turboprop engine. Turboshaft engine. Section 3.5 – 3.6
o Twin shaft cycle.
Week 5 :
o Basic turbojet engine. Intake nozzle. Section 2.2, 3.1 – 3.3
o Propelling nozzle. Net thrust. Efficiency / TSFC.
Week 6 :
o Turbofan engine. Bypass ratio. Mixing of exhaust streams. Section 2.2 (b), 3.4 – 3.6
o Polytropic efficiency.
Week 7 :
o Summary, Questions ?
Week 9 : Exam

Maintenance I

2 EC → 56 hours study load

The maintenance of gasturbines is a highly complex task. During this course students will become familiar with maintenance and work scope levels, the repair and overhaul process of engines and the activities required to restore serviceability. The student should acquire a good insight in industry practices with regard to maintenance of gasturbines for aircraft propulsion.
Also the different rulemaking and service bulletin process is described. As is often forgotten, human factors are a key factor for a high quality of maintenance. Therefore also causes and consequences of human behavior, and measures to affect this behavior are discussed. This should help the student to gain a better insight in the human behavior in relation to professional standards and the quality of work.

Learning goals :
After completion of the course the student is expected to
- Know the techniques in maintenance, repair and overhaul of gas turbine engines
- Understand the purpose of thermal coatings and application of such coatings to gas turbine components
- Understand the laws and regulations regarding gas turbine maintenance
- Have insight in the human factors playing a role in maintenance

Week 1 : Introduction gas turbines
Week 2 : Maintenance, repair & overhaul (MRO)
Week 3 : Purpose of repair techniques
Week 4 : Repair techniques
Week 5 : Thermal spraying
Week 6 : Law and regulations
Week 7 : Human factors in maintenance
Week 9 : Exam (One exam with Materials 1)
The order of the lectures in practice depends on availability of KLM lecturers.

Materials 1

1 EC → 28 hours study load

Materials I & II
It is often said that aircraft development completely depends on engine development. And also it can be stated that materials development is essential for engine development, mainly because a lot of improvements in the engine lead to increasing temperatures. For that reason the study of materials is essential.
Lifetime of materials is limited due to several causes. During these two courses the most important failures of the material and the underlying attack mechanisms will be discussed. An overview of relevant and up-to-date inspection methods is given. Preventive solutions like casting technology and protective coatings are studied in detail. In case damage has already been done, corrective solutions like heat treatment, but also application of welding, casting and brazing, are presented.
A future perspective on developments in materials science will be discussed, as well as 3D printing.

Learning goals :
The Gas Turbine Materials course focuses on the materials used and the loads acting on gas turbine components. In this context the following learning goals are defined. After completion of the course the student :

- Knows the basic loads on gas turbine components and materials
- Knows the main physical and mechanical properties of gas turbine materials
- Has knowledge about alloy materials and their microstructure
- Understands phase diagrams of alloys
- Knows about production processes of alloys and crystals

Week 2 : Introduction. Loads and load categories. Material properties.
Week 3 : Superalloys : Strengthening mechanisms and phases. Damages.
Week 4 : Alloy development history. Casting processes. Isotropy / anisotropy. Fe–C phase diagram.
Week 5 : Loads on Gas Turbine components. Design criteria. Materials. Design philosophies.
Week 9 : Exam (One exam with Maintenance 1)

Emissions & Environment

2 EC → 28 hours study load

This item is very important, especially for the following generation who are inheriting a more polluted earth than ever. Majority of the scientists agree that global warming is a fact and that CO2 is the main problem. Within this dilemma we will objectively try to look at these issues regarding gas turbines.

In the course Emissions & Environment you will learn the basics how gas turbines produce emissions, what influence these emissions have on the environment and of course how you can reduce these emissions before, during or after the formation itself. Besides the technical aspect of emissions, you will learn about some environmental bills, regulations and resolutions regarding emissions of gas turbines. Furthermore you will investigate which regulations apply to industrial and flying gas turbines.

After following this course you will be able to guide yourself through the legislation and regulations regarding gas turbine emissions. Furthermore you will have learnt how to assess whether your gas turbine achieves its emission performance and how to correct any problems.

Learning goals :

After completion of the course the student is expected to :
- Know how gas turbines produce emissions, know what influence these emissions have on the environment and how to reduce the emissions before, during or after the formation
- Understand the legislation and regulations regarding gas turbine emissions
- Assess whether a gas turbine achieves the emission performance and know how to correct any problems

This course will not be finalized by a written test. Instead, three assignments are to be made during the course.
Assignment 1: Thermochemistry – modelling (in MS Excel) of stoichiometric non-dissociated and dissociated combustion and actual combustion (equations) for any fuel gas mixture plus literature search on NOx formation.
Assignment 2: Emissions rights and legislation, trades and monitoring.
Assignment 3: Combustion hardware analysis of aero engine, aero-derivatives, and heavy duty industrial combustion systems, low emissions combustors (Emission reduction techniques) etc. in comparison with a base line standard industrial combustion system.

Week 1 : Introduction**,** hand out assignments (planning 2016/2017)
Week 2 : - Hydrocarbon fuels (gases and liquids)
- Elementary combustion thermochemistry of gases and liquids
- HHV and LHV, Tad, stoichiometry, dilution
- Gas laws Avogadro
- Density and Wobbe-index
- Unit conversions
- Combustion air and flue gas analysis

Week 4 : - Incomplete Combustion (Dissociation), Nitrogen Oxides (NOx) / CO, UHC, CO2 etc.
- Emissions : formation mechanisms, reduction, modelling.

Week 5 : Presentation of assignments 1 and 2 at AnsaldoThomassen, Rheden + company visit.
Week 6 : Emissions rights, trading, monitoring.
Week 7 : Combustion systems (hardware) of heavy duty industrial gas turbines, aero-derivatives, aero engines.
No exam. The score for this course is determined by the assignments.

Term 2

Gas Turbine Performance 2 EC → 56 hours study load

It is expected that the students, after attending these lectures, will have learned the typical behaviour of Stationary Industrial and Constant Speed Gas Turbines for Power Generation (heavy Duty and Aero-Derivative Type) and their density influences from environmental conditions and the relatively simple way in which such machines are controlled.
This is done by developing, in the first 4-5 lectures, a simple thermodynamic model of such a machine and showing that once the behaviour of the individual components such as compressor, turbine and combustion system are explained in aerodynamic and thermodynamic formulae, the analysis of its behaviour is remarkably intuitive and can be used without real calculations but just by looking at how parameters change and in which direction.

Learning goals :
The Gas Turbine Performance course focuses on the performance of gas turbines in design and off-design conditions. In this context the following learning goals are defined. After completion of the course the student is expected to :
- Calculate the design point performance of a gas turbine engine.
- Predict the behaviour of gas turbines in off-design conditions.
- Know about the gas turbine control philosophies.
- Discuss the power augmentation options for gas turbines.

Prior knowledge: During the Gas Turbine Performance course students make use of their basic knowledge (and skills) from the courses: Mathematics, Thermodynamics and Gas Turbine Theory.

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Plus : PowerPoint slides provided by the lecturer.

Week 1 : Introduction
Week 2 : Design point performance, selection of size, scaling aero-derivatives. Hand out assignment.
Week 4 : Workshop : Example assignments.
Week 5 : Off-design gas turbine behaviour. Gas turbine control philosophies. Hand in assignment.
Week 7 : Workshop + lecture : Power augmentation options.
Week 8 : Exam.

Materials 2 2 EC → 56 hours study load

Materials I & II
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Lifetime of materials is limited due to several causes. During these two courses the most important failures of the material and the underlying attack mechanisms will be discussed. An overview of relevant and up-to-date inspection methods is given. Preventive solutions like casting technology and protective coatings are studied in detail. In case damage has already been done, corrective solutions like heat treatment, but also application of welding, casting and brazing, are presented.
A future perspective on developments in materials science will be discussed, as well as 3D printing.

Learning goals :
The Gas Turbine Materials course focuses on manufacturing, protection, inspection and repair of gas turbine components. In this context the following learning goals are defined. After completion of the course the student :
- Knows how to manufacture components for use in gas turbines.
- Knows how to protect gas turbine components in high temperature zones.
- Knows how to inspect gas turbine parts.
- Can discuss about the inspection and repair of gas turbine components.

Prior knowledge : During the Gas Turbine Materials course students make use of their knowledge (and skills) from the courses : Materials science, Mechanics and Gas Turbine Materials 1.

Week 1 : Protective coatings
Week 2 : Additive manufacturing (at location of NLR NOP)
Week 3 : Protective coatings, continued
Week 4 : Heat treatments
Week 5 : Inspections
Week 6 : Manufacturing and machining
Week 7 : Repairs, welding and brazing
Week 8 : Exam : Score counts 70 % in final score for Maintenance / Materials 2.

Maintenance 2

1 EC → 26 hours study load

The maintenance of gasturbines is a highly complex task. During this course students will become familiar the repair and overhaul process of engines and the activities required to restore serviceability. The student should acquire a good insight in industry practices with regard to maintenance of industrial gas turbines .
As is often forgotten, human factors are a key factor for a high quality of maintenance. Therefore also causes and consequences of human behavior, and measures to affect this behavior are discussed. This should help the student to gain a better insight in the human behavior in relation to professional standards and the quality of work.

Learning goals :
After completion of the course the student is expected to
- Know the techniques in maintenance, repair and overhaul of (industrial) gas turbine engines
- Understand the purpose of thermal coatings and application of such coatings to gas turbine components
- Understand the laws and regulations regarding gas turbine maintenance
- Understand the effects of human factors in gas turbine maintenance.

Week ? : Guest lecture
Week ? : Guest lecture
Week ? : Guest lecture
Week ? : Lecture(s) during the company visit to E.on Benelux.
Report on one of the lectures according to provided schedule : Score counts 30 % in final score for Maintenance /Materials 2.

Matching & Control

2 EC → 56 hours study load

When designing a gasturbine for aviation or for industry, the first focus is on the design point. That is, the operating point the gasturbine will be on most of the time. For civil aviation this will be cruise. However, a gasturbine also has to function also at points far away from the design point. For example, when starting or stopping the engine. Also at these points performance should be guaranteed. During this course we will design a compressor and turbine for the design point. We will see how the design of the compressor influences the design of the turbine. After that, we will calculate under what circumstances this gasturbine will still function correctly, and under what specific circumstances this gasturbine suffers from choke or stall.

Learning goals :
The Matching & Control course focuses on the conceptual design of turbomachinery parts. In this context the following learning goals are defined. After completion of the course the student can:
1. Determine the blade dimensions, angles and number of stages for a compressor design.
2. Determine the blade dimensions, angles and number of stages for a turbine design.
3. Interpret compressor and turbine characteristics.
4. Determine the equilibrium line of a single-shaft, twin-shaft and a twin-spool engine.
5. Describe how the location of the equilibrium line can be influenced.
6. Give an overview of the assumptions and limits for a compressor and turbine design.

Prior knowledge : During the Matching & Control course students make use of their knowledge (and skills) from the courses: Mathematics, Thermodynamics and Aerodynamics.

Book : **Gas Turbine Theory, 6th edition, Saravanamutoo, Cohen, Rogers & Straznicky,** ISBN 9780132224376
Plus : Presentations by the lecturer.

Week 1 : Introduction, Design point. Dimensionless variables. Buckingham PI Theorem	Section 4.5 – 4.6
Week 2 : Compressor velocity angles. Compressor power.	Section 5.1 – 5.5
Pressure rise. Work done factor. Degree of reaction.	Section 5.7 (Not : Variation of air angles form root to tip.
Week 3 : Turbine velocity angles. Turbine power. Smith chart. Losses.	Section 7.1
Week 4 : Off-design performance. Stage coefficients. Compressor	Section 4.6
characteristics. Choke, stall, surge.	Section 5.11 – 5.12
Week 5 : Equilibrium line. Component matching. Single shaft gas turbine. Load characteristics.	Section 9.1 – 9.2
Week 6 : Twin shaft gas turbine.	Section 9.3 – 9.4
Week 7 : Bleed valves. Variable exhaust. Twin spool gas turbine.	Section 9.6, 10.1 – 10.3
Week 8 : No exam, score is obtained from the **assignments**.	

G. Doornbos, February 8, 2016.