Gas Turbine Technology - MTF171

Aim of the course

Gas turbines are the primary source of propulsion for aircraft and find a widespread use in power generation as well as marine applications. Within the course, aspects ranging from cycle studies and performance calculations to the analysis of individual components are approached. The ambition is that the student shall become familiar with different gas turbine concepts and their operation.

This course allows you to apply what you learned in the thermodynamics course and in fluid mechanics course/courses. Most of the necessary material is revised in the beginning of the course.

Design exercise

A design exercise is part of the course. The exercise is divided into three related subtasks:

1. Engine design point calculation and preliminary design of radial compressor for the W1 engine.
2. Preliminary design of the axial turbine of the W1 engine.
3. Performance simulation of the obtained system for the W1 engine.

The design exercise aims at supporting the learning process, by linking major parts of the theory together through the solution of a large problem. Carrying out the preliminary design and analysis of the W1 jet engine, repeating Frank Whittle's pioneering work - inventor of the jet engine, helps to put the theory in its proper context.

Content and organisation

The course starts with a general overview of the gas turbine system and its field of application. The needs, as given by a jet engine or a power generation system, and the implications by these on the engine cycle are treated. Furthermore, the requirements on the components in order to fulfil these cycle requirements are illustrated. Different design principles for the components, such as compressors, turbines, combustors, nozzles etc., are described and what requirements are most important for the final system performance. Mechanical design constraints are discussed.

Literature

Cohen, Rogers, Saravanamuttoo, Gas Turbine Theory. The book can be obtained at the Cremona bookstore. The 4:th/5:th editions are sufficient for learning the course, but references will only be made to the 6:th edition.

Examination

The student may choose between an oral or written examination. A requirement for attending the oral exam is that the design tasks have been completed. The grades 4 and 5 may be achieved from both examination forms, but are more likely to be obtained from the written examination. Completed design tasks amount to 10 bonus points on the written exam (maximum is 60 credits).

Contacts

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power point documents: http://www.tfd.chalmers.se/~thgr/gas2.html

Schedule - Gas turbine technology - MTF 171

Week 1:
2009-09-01 – ML6, Lec1, 13.15 - 16.00: History of the gas turbine engine, course presentation, revision of thermodynamics, some gas turbine configurations, aircraft propulsion.
2009-09-02 – ML6, Lec2, 10.00 - 11.45: Thermodynamics continued industrial applications, aero-derivatives and large industrial units, closed cycles and outlook for nuclear applications, ideal cycles 1 (Theory 2.1, Theory 2.2).
2009-09-04 - ML6, Lec3, 09.00 - 11.45: Thermodynamics continued, ideal cycles II (Theory 3.1). Real cycles and the inclusion of component losses in the preliminary design process. Jet engine nozzle theory and centrifugal compressors 1.

Week 2:
2009-09-08 - ML6, Exer1, 13.15 - 15.00: Optimal pressure ratio for simple cycle (Theory 2.3). Problem 2.1, Turbojet example. **Hand out of design task 1.**
2009-09-11 - ML6, Exer2, 09.00 - 10.45: Problem 2.9 and exotic combustor cycle.
2009-09-11 - ML6, InvLec, 11.00 - 11.45: Volvo Aero invited lecturer. Future aero engines (Martin Nilsson).

Week 3:
2009-09-15 - ML6, Lec4, 13.15 - 16.00: Ideal cycles III (Theory 4.1), Intercooling and re-heat. Shaft power cycles, current trends. Efficiencies, optimal pressures in intercooled engines.
2009-09-18 - ML6, Lec5, 09.00 - 11.45: Aircraft design performance: performance criteria, intakes, the turbojet (Theory 5.1 and Theory 5.2). Optimization of the turbojet. Engine cycle selection.

Week 4:
2009-09-22 - ML6, Lec6, 13.15 - 16.00: Aircraft engines 2: Indication of thrust, con-di nozzles, thrust reversing and afterburning (Theory 6.1). Turbines: velocity triangles, non-dimensional numbers.
2009-09-22 - ML6, Exer3, 16.00 - 17.00: **Hand in of design task 1. Hand out of design task 2.** Problem 7.1.
2009-09-25 - ML6, Lec7, 08.00 - 10.00: Turbine vortex theory and simplified 3D flow, loss modelling (Theory 7.1) and turbine maps.
2009-09-25 - ML6, Exer4, 10.00 - 11.45: Problem 7.2 and Problem 3.2.

Week 5:
2009-09-29 - ML6, Lec8, 13.15 - 17.00: Centrifugal compressors 2: the diffuser and compressibility effects. Non-dimensional numbers, characteristics and maps. Henrik Ekstrand: aircraft performance.
2009-10-02 - ML6, Lec9, 08.00 - 10.45: Axial compressors: basic operation, velocity triangles (Theory 9.1), diffusion and stage loading, blockage, degree of reaction. Axial compressors: design process, blade design, compressibility, off-design performance, characteristics.
2009-10-02 - ML6, Exer5, 11.00 - 11.45: Problem 5.1. **Hand in of design task 2**.

Week 6:
2009-10-06 - ML6, Lec10, 13.15 - 15.00: Performance: the single shaft gas turbine, the running line (Theory 10.1), gas generator (turbojet and power turbine engines), derivation of the running line. Effect of ambient conditions and variable geometry.
2009-10-06: **ML6, Exer6, 15.0 - 17.00**: Problem 9.1, 9.2 and 9.3. **Hand out of design task 3**.
2009-10-09 – ML6, Lec11, 08.00 – 09.45: Mechanical design of gas turbines: loads and failure modes, gas turbine materials, coatings, design against failure and life estimation, blade design, vibrations.
2009-10-09 – ML6, Exer7, 10.00 – 11.45: Problem 8.1, Problem 8.3 and Problem 8.4.

Week 7:
2009-10-13 - Ryaverken, 13.15 - 15.00: Study visit at Rya-verken CHP plant.
2009-10-14 - ML6, Lec12, 10.00 – 11.45: Combustion systems: operational requirements, types of combustion systems, important factors affecting combustor design, swirl and flame stabilization, performance, fuel injection, starting and ignition, emissions, cheap fuels, coal gasification. Noise pollution.
2009-10-16: **ML6, 08.00 - 11.45**: Reserve time for lectures. **Hand in of design task 3**.

2009-10-24: Written exam ("Väg och vatten"-salar fm V)
2009-10-27: 13.15-15.15 Oral exam

Reading instructions - Gas Turbine Theory

In order to guide you through the reading of the quite extensive course book, a list rating the relevance of the different sections has been compiled. Sections labelled "less relevant" are optional (not included in course).

Section number	Name of section	Relevance
1	Chapter introduction	Important
1.1	Open-cycle single shaft and twin-shaft arrangement	Important
1.2	Multi-spool arrangements	Important
1.3	Closed cycles	Relevant
1.4	Aircraft propulsion	Important
1.5	Industrial applications	Important
1.6	Marine and land transportation	Relevant
1.7	Environmental issues	Important
1.8	Some future possibilities	Relevant
1.9	Gas turbine design procedures	Relevant
2	Chapter introduction	Important
2.1	Ideal cycles	Very important
2.2	Methods of accounting for component losses	Very important
2.3	Design point performance calculations	Very important
2.4	Comparative performance of practical cycles	Very important
2.5	Combined cycles and cogeneration schemes	Important
2.6	Closed-cycle gas turbines	Relevant
3	Chapter introduction	Important
3.1	Criteria of performance	Very important
3.2	Intake and propelling nozzle efficiencies	Important
3.3	Simple turbojet cycle	Very important
3.4	The turbofan engine	Very important
3.5	The turboprop engine	Important
3.6	The turboshaft engine	Important
3.7	Auxiliary power units	Relevant
3.8	Thrust augmentation	Relevant
3.9	Miscellaneous topics	Relevant
4	Chapter introduction	Important
4.1	Principle of operation	Very important
4.2	Work done and pressure rise	Very important
4.3	The diffuser	Very important
4.4	Compressibility effects	Important
4.5	Non-dimensional quantities for plotting compressor characteristics	Very important
4.6	Compressor characteristics	Important
4.7	Computerized design procedures	Relevant
5	Chapter introduction	Important
5.1	Basic operation	Important
5.2	Elementary theory	Very important
5.3	Factors affecting the stage pressure ratio	Important
5.4	Blockage in the compressor annulus	Relevant
5.5	Degree of reaction	Relevant
5.6	Three-dimensional flow	Relevant
5.7	Design process	Very important
5.8	Blade design	Important
5.9	Calculation of stage performance	Less relevant
5.10	Compressibility effects	Relevant
5.11	Off-design performance	Important
5.12	Axial compressor characteristics	Very important
5.13	Closure	Relevant
6	Chapter introduction	Important
6.1	Operational requirements	Important
6.2	Types of combustion system	Very important
6.3	Some important factors affecting combustion design	Important
6.4	The combustion process	Very important
6.5	Combustion chamber performance	Important
6.6	Some practical problems	Important
6.7	Gas turbine emissions	Very important
6.8	Coal gasification	Relevant

7	Chapter introduction	Important
7.1	Elementary theory of axial flow turbine	Very important
7.2	Vortex theory	Relevant
7.3	Choice of blade profile, pitch and chord	Important
7.4	Estimation of stage performance	Less relevant
7.5	Overall turbine performance	Very important
7.6	The cooled turbine	Very important
7.7	The radial flow turbine	Relevant
8	Chapter introduction	Important
8.1	Design process	Important
8.2	Gas turbine architecture	Important
8.3	Loads and failure modes	Very important
8.4	Gas turbine materials	Very important
8.5	Design against failure and life estimation	Very important
8.6	Blades	Important
8.8	Blade and disc vibration	Important
8.9	Engine vibration	Important
8.10	Other components	Relevant
8.11	Closure	Relevant

The sections below are examined through the third hand in task. Thus, any questions on the written and oral exams given on Chapter 9 and 10, will be based on design task 3, i.e. the understanding of how turbojet performance is calculated and used.

Section number	Name of section	Relevance
9	Chapter introduction	Important
9.1	Component characteristics	Important
9.2	Off-design operation of the single-shaft gas turbine	Very important
9.3	Equilibrium running of a gas generator	Very important
9.4	Off-design operation of free turbine engine	Very important
9.5	Off-design operation of the jet engine	Very important
9.6	Methods of displacing the equilibrium running line	Relevant
9.7	Incorporation of variable pressure losses	Relevant
9.8	Power Extraction	Relevant
10	Chapter introduction	Relevant
10.1	Methods of improving part-load performance	Less relevant
10.2	Matching procedures for twin spool engines	Less relevant
10.3	Some notes on the behaviour of twin-spool engines	Less relevant
10.4	Matching procedures for turbofan engine	Less relevant
10.5	Transient behaviour of gas turbines	Relevant
10.6	Performance deterioration	Relevant
10.7	Principles of control systems	Relevant