Gas Dynamics for Internal Combustion Engines (5 hp)
FSG3132

Teachers and Invited Lecturers:

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When and where:

November 7-8
November 28-29
Place: Faxen Room, Gas Dynamics Lab, Plan 2, Teknikringen 8, KTH Campus.

The course covers a broad range of topics from basic thermodynamics and fluid dynamics principles to a detailed description on compressible gas dynamics and flow instability phenomena associated with turbocharging and gas exchange processes in Internal Combustion Engines (ICE). Complex gas exchange systems are characteristic to ICE. In modern ICE, Exhaust Gas Recirculation (EGR) systems are used. Power enhancing technologies like turbocharging will continue to play an important role in the future powertrain systems. Thus, the ICE gas exchange systems are constituted from many components, piping systems with valves and flow regulators, junctions and bends leading to a very complex 3D, intermittent, and unsteady flow. The course content includes discussions on turbulence and turbulent mixing in confined conduits, turbocharger thermodynamics, compressible flows/shocks in exhaust valves and turbomachinery, rotating flows, compressor instabilities, details on experimental and computational methods for assessment of unsteady, pulsating flows in manifolds and turbochargers. For a better understanding of the learned topics, the theoretical part is supported by examples and exercises based on computational modelling/experimental measurements for assessing gas exchange processes and aerodynamics design tools for turbochargers.

After completing this course, the student should be able to:

- explain basic concepts on thermodynamics, turbulence and compressibility and relate them with gas exchange processes and turbocharging flows;
- derive & interpret basic compressible flow relations;
- explain typical flow related instabilities in manifolds and rotational machineries;
- explain different experimental, computational approaches, and models suitable for assessing gas dynamics;
- theoretical design of simple experimental or computational setups used for assessing flow instabilities related to ICE.

Suggested literature:

R.H. Aungier, "Centrifugal Compressors: a Strategy for Aerodynamic Design and Analysis", ASME Press 2000.

J.D. Andersson, "Modern Compressible Flows", McGraw-Hill, 2003.

Moran, Shapiro, Boettner, Bailey "Principles of Engineering Thermodynamics" ISBN 978-470-91801-2. 2012.

Material that will be handed out.

Course content:

1. Overview on thermodynamics
2. Turbulence and turbulent flows (an overview)
3. Overview on compressible flow
4. Introduction to gas exchange in ICE
5. Rotating flows (effects on flow stability) and flow in complex conduits
6. Exhaust Gas Recirculation (EGR) assessment
7. Introduction to centrifugal compressors
8. Turbocharger thermodynamics / centrifugal compressor and turbine maps
9. Compressor Instabilities
10. Assessment of flow related to ICE gas exchanage processes and turbochargers (experimental and computational)

Examination:

The examination consists in an assignment in the form of a project report on a relevant topic that will be submitted and orally presented. The written project report no longer than 4 pages (excluding references) must be submitted for evaluation to the course examiner (e-mail to mihaescu@kth.se). A final project presentation will be given. The assignment can be done individually or in groups of students (recommended not more than 2 students in each group).

The following items have to be approved in order to obtain a pass on the course:

- Compulsory and active attendance during at least 80% of the lecture time.
- Successful completion of the Assignement within given time frame.

- DEL1 – Participation, compulsory & active attendance at least 80% of the lecture time, 1.0 credit, Grading scale: P, F
- INL1 - Assignment, 4.0 credits, Grading scale: P, F

Ethical approach:

- All members of a group are responsible for the group's work.
- In any assessment, every student shall honestly disclose any help received and sources used.
- In an oral assessment, every student shall be able to present and answer questions about the entire assignment and solution.

Course Agenda:

<u>Thu, November 7th, 2019:</u>

09:30-09:45 *Getting together & Coffee*

09:45-10:15 *Course Introduction (MM)*

10:15-11:00 *Overview on Thermodynamics (AD)*
11:15-12:00

12:00-13:00 Lunch Break

13:15-14:00 *Compressible Flows (ML)*
14:15-15:00
15:15-16:00

End of 1st Meeting

<u>Fri, November 8th, 2019:</u>

09:15-10:00 *Turbulence and Turbulence Modeling (LF)*
10:15-11:00
11:15-12:00

12:00-13:00 Lunch Break

13:15-14:00 *Decoding flow instabilities in turbomachinery: Experimental and Computational Efforts (MM)*
14:15-15:00
15:15-16:00

End of 2nd Meeting

<u>Thu, November 28th, 2019:</u>

09:15-10:00 *Gas Exchange Modeling with focus on Engine Efficiency (OB)*
10:15-11:00
11:15-12:00

12:00-13:00 Lunch Break

13:15-14:00 *Aerothermodynamics and exergy analysis for turbomachinery (SML)*
14:15-15:00

End of 3rd Meeting

<u>Fri, November 29th, 2019:</u>

09:15-10:00 *Turbomachinery and Turbocharging – an Industrial perspective (NA)*
10:15-11:00
11:15-12:00

12:00-13:00 Lunch Break

13:15-14:00 *Turbomachinery and Turbocharging – an Industrial perspective (NA)*

14:15-14:45 Concluding Remarks

End of 4th Meeting

Participants: The number of participants is limited to 20. Priority will be given to graduate students in the centres CCGEx, CERC and KCFP. Industry participants (partners in the centres) are also welcome without charge. If there is extra space also other graduate students can apply to participate.