TIME TABLE

TIME	Monday	Tuesday	Wednesday	Thursday	Friday
	June 29	June 30	July 1	July 2	July 3
9.00 - 9.45	Registration	Polifke	Sujith	Schuermans	Juniper
9.45 - 10.30	Lieuwen	Lieuwen	Sujith	Schuermans	Juniper
11.00 - 11.45	Lieuwen	Lieuwen	Schuermans	Schuller	Juniper
11.45 - 12.30	Lieuwen	Lieuwen	Schuermans	Schuller	Juniper
14.00 - 14.45	Sujith	Polifke	Schuller	Schuermans	
14.45 - 15.30	Sujith	Polifke	Schuller	Schuermans	
16.00 - 16.45	Sujith	Polifke	Schuller	Polifke	
16.45 - 17.30	Polifke	Sujith	Schuller	Juniper	

ADMISSION AND ACCOMMODATION

The registration fee is of 575,00 Euro + VAT taxes*, where applicable (bank charges are not included).

The registration fee includes a complimentary bag, four fixed menu buffet lunches (Friday subject to numbers), hot beverages, downloadable lecture notes and wi-fi internet access.

Applicants must apply at least one month before the beginning of the course. Application forms should be sent on-line through our web site: http://www.cism.it or by post.

A message of confirmation will be sent to accepted participants. If you need assistance for registration please contact our secretariat.

Applicants may cancel their course registration and receive a full refund by notifying CISM Secretariat in writing (by email) no later than two weeks prior to the start of the course.

If cancellation occurs less than two weeks prior to the start of the course, a Euro 50,00 handling fee will be charged. Incorrect payments are subject to Euro 50,00 handling fee.

A limited number of participants from universities and research centres who are not supported by their own institutions can be offered board and/or lodging in a reasonably priced hotel or students' dormitories, if available.

Requests should be sent to CISM Secretariat by **April 29, 2015** along with the applicant's curriculum and a letter of recommendation by the head of the department or a supervisor confirming that the institute cannot provide funding. Preference will be given to applicants from countries that sponsor CISM.

Information about travel and accommodation is available on our web site, or can be mailed upon request.

* Italian VAT is 22%.

For further information please contact:

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Piazza Garibaldi 18
33100 Udine (Italy)
tel. +39 0432 248511 (6 lines)
fax +39 0432 248550
e-mail: cism@cism.it

ACADEMIC YEAR 2015
The Nieuwstadt Session

Centre International des Sciences Mécaniques
International Centre for Mechanical Sciences

International Union for Theoretical and Applied Mechanics

21th CISM-IUTAM International Summer School on

MEASUREMENT, ANALYSIS AND PASSIVE CONTROL OF THERMOACOUSTIC OSCILLATIONS

Advanced School
coordinated by

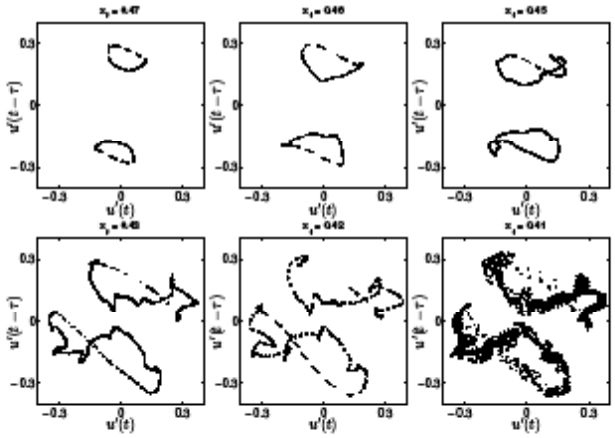
Matthew Juniper
University of Cambridge
UK

IUTAM

Udine, *June 29 - July 3* 2015

MEASUREMENT, ANALYSIS AND PASSIVE CONTROL OF THERMOACOUSTIC OSCILLATIONS

When Yuri Gagarin was launched into orbit in 1961, the probability of a rocket blowing up on take-off was around 50%. In those days, one of the most persistent causes of failure was a violent oscillation caused by the coupling between acoustics and heat release in the combustion chamber. If more heat release than average occurs during moments of high pressure and less heat release than average occurs during moments of low pressure then, over a cycle, more work is done during the expansion phase than is absorbed during the compression phase, causing oscillations to grow. These thermoacoustic oscillations have caused countless rocket engine and gas turbine failures since the 1930s and have been studied extensively. Nevertheless, they are still one of the major problems facing rocket and gas turbine manufacturers today.
The ultimate goal of rocket and gas turbine manufacturers is to eliminate or control thermoacoustic oscillations, either through feedback control or passive control. Feedback control works well in simple thermoacoustic systems but is challenging in industrial systems because the sensors and actuators have to withstand very harsh environments. Furthermore, feedback control is unacceptably risky insome applications, such as aircraft. For these reasons, passive control is preferable, either by good initial design, or by adding a passive device to an existing system.
In order to control a thermoacoustic system passively, it is necessary to understand why the system oscillates. It is well known that acoustic perturbations to the velocity or pressure cause heat release perturbations some time later, and that these lead to the feedback loop described above. Other mechanisms, such as the reflection of entropy waves at a sonic throat, are also known. However, experiments show that even small changes to a system can significantly alter its stability, showing that the details of these processes are very influential.
The aims of this course are: to describe how thermoacoustic oscillations arise, to show the flame dynamics that cause fluctuating heat release, to show how these details are uncovered through experimental measurements, to introduce linear and nonlinear methods of analysis, to introduce methods that can reveal which details of a thermoacoustic system are most influential, and to give examples of these processes in industrial thermoacoustic systems.
The course is aimed at doctoral students in an early stage of a PhD in thermoacoustics; researchers with a background in flow stability who are interested in a new area; and practicing engineers in a closely-related area such as gas turbine or rocket engine research.



Poincaré section showing the Ruelle-Takens-Newhouse route to chaos in a thermoacoustic system consisting of a premixed flame in a tube.

PRELIMINARY SUGGESTED READINGS

Culick, F. Unsteady Motions in Combustion Chambers for Propulsion Systems. AGARD. https://www.cso.nato.int/pubs/rdp.asp?RDP=RTO-AG-AVT-039.

Lieuwen, T. Unsteady Combustor Physics, Chapters 1,2, 11,12. Cambridge University Press.

Haugen, F. Discrete-time signals and systems, Chapters 1 to 8. Citeseer. http://techteach.no/publications/discretetime_signals_systems/discrete.pdf.

Matthew Juniper, Luca Magri Application of receptivity and sensitivity analysis to thermoacoustic instability, Progress in flow instability analysis and laminar-turbulent transition modeling, VKI Lecture Series 2014-05 edited by E. Valero & F. Pinna ISBN 978-2-87516-063-8 (2014) http://www2.eng.cam.ac.uk/~mpj1001/papers/VKI_Juniper.pdf

INVITED LECTURERS

Matthew Juniper - University of Cambridge, UK
5 lectures on: Helmholtz solvers, adjoint sensitivity analysis, applications of adjoint sensitivity analysis to simple thermoacoustic models, applications of adjoint sensitivity analysis to thermoacoustic Helmholtz solvers.

Tim C. Lieuwen - Georgia Tech, Atlanta, GA, USA
6 lectures on: Introduction to thermoacoustic oscillations; Flame Dynamics Modeling (flame kinematics, equiv ratio, swirl effects, laminar & turbulent flames); Disturbance propagation in reacting flow environments; Thermoacoustic Instabilities (linear and nonlinear methods); Entropy waves; Combustion noise. High frequency / Transverse modes; Mechanisms for dissipation of mechanical energy.

Thierry Schuller - Ecole Centrale Paris, France
6 lectures on: Acoustic measurements and diagnostics: Acoustic pressure, density and velocity measurements (Hot wire, LIV, LDV); signal measurement, conditioning and analysis; impedance reconstruction (different techniques 2M, Multi-M, 1M 1V and post-processing); acoustic response of a combustor (modal characterization, end corrections (radiation impedance), damping, burner transfer function). Flow measurement: unsteady flow imaging (Mie scattering, LDV, tomography, PIV); Deconvolution and tomographic reconstructions (Abel, 3D, multi-views); Velocity, vortex dynamics, mixture composition and entropy fluctuation; Characterizations (techniques and post-processing); Two-phase flow diagnostics (LDA, droplets dynamics). Flame measurement: Flame imaging (chemiluminescence, Schlieren, LIF); Heat release rate estimation (chemiluminescence, LIF, emerging techniques); Forcing techniques (loudspeaker, sirens, fuel modulation); FTF and IR reconstruction. Flame Describing Function & frequency domain stability analysis.

Wolfgang Polifke - TU Munich, Germany
6 lectures on: Linear Analysis; Frequency domain/time domain linear analysis; n-tau model and its deficiencies; Transfer functions & its measurement, SISO and MIMO model structures; Transfer matrix; thermoacoustic network analysis; Calculation of growth rates, Nyquist Plots; Non-normality; active control of thermoacoustic systems.

Raman I. Sujith - IIT Madras, India
6 lectures on: Classical Acoustics: Derivation of wave equation; Standing wave and travelling wave solutions; Impedance, eigenvalues; Acoustic Boundary Conditions; Nonlinear time series analysis: Bifurcation diagrams, quasiperiodicity, frequency-locking, routes to chaos; Analysis techniques; Experimental observations and data processing.

Bruno Schuermans - Alstom Power, Baden, Switzerland
6 lectures on: Industrial Thermoacoustics.

LECTURES

All lectures will be given in English. Lecture notes can be downloaded from the CISM web site, instructions will be sent to accepted participants.

MEASUREMENT, ANALYSIS AND PASSIVE CONTROL OF THERMOACOUSTIC OSCILLATIONS

Udine, June 29 - July 3, 2015
Application Form
(Please print or type)

Surname _____

Name _____

Affiliation_____

Address_____

_____

E-mail _____

Phone _____Fax_____

Method of payment upon receipt of confirmation (Please check the box)

The fee is 575,00 Euro + 22% Italian VAT taxes, where applicable (bank charges are not included).

❑ *I shall send a check of Euro _____*

❑ *Payment will be made to CISM - Bank Account No. 094570210900, VENETO BANCA - Udine (CAB 12300 - ABI 05035 - SWIFT/BIC VEBHIT2M - IBAN CODE IT46 N 05035 12300 09457 0210900). Copy of the receipt should be sent to the secretariat*

❑ I *shall pay at the registration counter with check or VISA Credit Card (Mastercard/Eurocard, Visa, CartaSi)*

IMPORTANT: CISM is obliged to present an invoice for the above sum. Please indicate to whom the invoice should be addressed.

Name _____

Address _____

_____

_____

C.F.* _____

VAT/IVA* No _____

(*) Only for EU residents or foreigners with a permanent business activity in Italy.

Only for Italian Public Companies

❑ *I ask for IVA exemption (ex law n. 537/1993 - art. 14 comma 10).*

Privacy policy: I understand that data received via this form will be used only to provide information about CISM and its activities, within the limits set by the Italian legislative decree no. 196/2003 and subsequent amendments.
Complete information on CISM's privacy policy is available at www.cism.it.

I have read the "Admission and Accommodation" terms and conditions and agree.

Date _____ Signature _____