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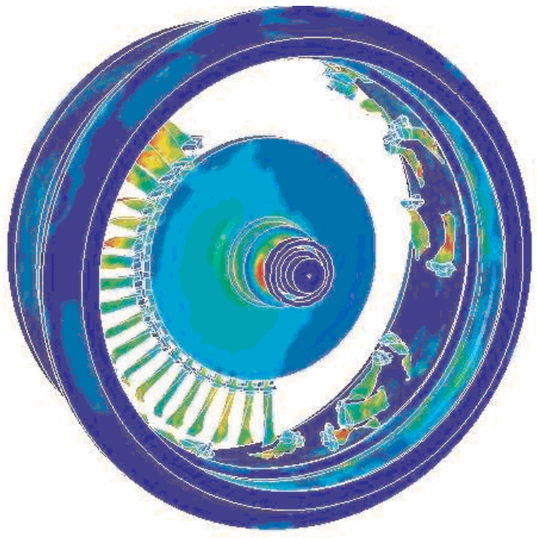
Lecture Series Secretary
von Karman Institute for Fluid Dynamics
72 Chaussée de Waterloo
B-1640 Rhode-St-Genèse
Belgium

von KARMAN INSTITUTE FOR FLUID DYNAMICS

Structural Design of Aircraft Engines: Key objectives and techniques



May 13 - 16, 2008

von Karman Institute for Fluid Dynamics
72, Chaussée de Waterloo
1640 Rhode-Saint-Genèse, Belgium

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E-mail: secretariat@vki.ac.be, TVA BE 0407 185 709
Website: http://www.vki.ac.be

INTRODUCTION

The continuous trend in weight reduction together with novel engine architectures results in large structural and thermal loads, with narrower security margins. The first day addresses the engine global behaviour, the lecture on **aircraft engine** will review the main challenges of structural design of an aircraft engine, and the associated certification constraints. **Whole Engine dynamics** overviews how to model the different elements of the engine to study the dynamic behaviour of the assembled system while respecting design criteria. **Foreign object damage** and **fan blade out** describes the methodologies currently used to perform simulations in compressor blades to predict the integrity of the structure. **Thermal Stresses** reviews the thermo-mechanical analysis as part of the gas turbine design verification process, comprising model construction and development, model validation and the use of the data to support the design process.

The second day is focussed on bladed disk design, from the standard aeromechanical design practices to more complex problems such as aeroelastic stability. The **aeromechanical design** of bladed disks explains the iterative process to find the optimum compromise between aerodynamic performance and structural strength. **Forced response** prediction proposes an alternative approach to estimate the forced response early before the engine testing. The lecture on **flutter** presents a description of the steps in the design analysis process, with examples in fans and low pressure turbines. The airfoils of bladed disks and blisks vary due to manufacturing processes and field usage. This condition is known as "**mistuning**" and has the potential to affect significantly flutter and forced response.

The third day addresses high cycle fatigue, design strategies to mitigate forcing and the state of the art on aeroelasticity research. The **non linear dynamics** lecture will discuss the damping properties caused by friction, aerodynamic viscous and hysteretic dissipation effects on the alternating stresses. The Harmonic Balance Method used for the linearization of friction forces, and the physical interpretation of blade vibrations with friction dissipation at shrouds and on dampers will be taken into consideration. A major goal in the development process of rotating turbomachinery turbine blades is to prevent them from **high cyclic fatigue** (HCF) failure. The Stress-Life method, linear and non-linear hypotheses, and stochastic vibrations will be discussed considering engineering needs. **Design strategies to mitigate unsteady forcing** presents a successful example of resonant-stress reduction through mitigation of unsteady forcing during the aerodynamic design of turbine components. **Experimental research on aeroelasticity** elucidates possible methods for the experimental investigation of aerodynamic damping and forcing, as well as relevant measurement techniques.

The last day is focussed on the mechanic behaviour of material and life estimation. A global overview on material science will be given. Then the process and rules to estimate the life of components versus fatigue and creep will be presented. Two consecutive lectures on **materials** will associate the temperatures of different engine parts with material alternatives from polymer matrix composites in the front end of the engine to the superalloys - carbon matrix composites in the rear parts. The limits related to various parameters will be analyzed: microstructures, grain boundary weakness, and especially the catastrophic influence of stress/strain assisted grain boundary oxidation on hold time fatigue life. The lecture will continue with a description of the general failure mechanisms, fatigue failure mechanisms and mechanical testing to allow life predictions. **Creep life prediction** and **TMF life prediction in turbines** cover the fundamentals of creep and fatigue behaviour from a material point of view.

The Lecture Series directors are E. Seinturier, Turbomeca, and Prof. G. Paniagua, Turbomachinery and Propulsion Department, von Karman Institute.

TIMETABLE

TUESDAY MAY 13, 2008

09:15 **Welcome address**
M. Carbonaro, von Karman Institute for Fluid Dynamics, Belgium

09:30 **Aircraft engine**
E. Seinturier, Turbomeca, France

11:15 **Whole engine dynamics**
F. Thouverez, Ecole Centrale de Lyon, France

14:00 **Foreign object damage and fan blade out**
A. Suffis, Snecma, France

15:45 **Thermal stresses**
S.J. Mills, Rolls Royce, United Kingdom

17:00 **Reception**

WEDNESDAY MAY 14, 2008

09:00 **Aeromechanical design**
E. Seinturier

10:45 **Forced response prediction**
E. Seinturier

14:00 **Bladed disks: flutter**
R. Kielb, Duke University, USA

15:45 **Bladed disks: mistuning**
R. Kielb

THURSDAY MAY 15, 2008

09:00 **Bladed disks: non linear dynamics**
J. Szwedowicz, ABB Turbo Systems Ltd, Switzerland

10:45 **High cycle fatigue**
J. Szwedowicz

14:00 **Design strategies to mitigate unsteady forcing**
J.P. Clark, Wright Patterson AFB, USA

15:45 **Experimental research on aeroelasticity**
D. Vogt,Royal Institute of Technology, Sweden

FRIDAY MAY 16, 2008

09:00 **Material fundamentals**
G. Sjöberg,Volvo Aero Corporation, Sweden

10:45 **Material fundamentals**
T. Hansson, Volvo Aero Corporation, Sweden

14:00 **Creep life prediction in turbines**
S.M. Bagnal, Rolls Royce, United Kingdom

15:45 **Life prediction fatique**
S.M. Bagnal

17:00 **VKI bus departure**

Programme

LECTURE SERIES 2007-2008

VKI LS

- ☐ BASICS OF AERO-ACOUSTICS AND THERMO-ACOUSTICS (3-7 December 2007)
- ☐ INTRODUCTION TO CFD (28 January-1 February 2008)
- ☐ POST-PROCESSING OF NUMERICAL & EXPERIMENTAL DATA (11-15 February 2008)
- ☐ EXPERIMENTAL DETERMINATION OF DYNAMIC STABILITY PARAMETERS (18-22 February 2008)
- ☐ AEROENGINE DESIGN: FROM STATE OF THE ART TURBOFANS TOWARDS INNOVATIVE ARCHITECTURES (3-7 March 2008)
- ☐ LARGE EDDY SIMULATION AND RELATED TECHNIQUES. THEORY AND APPLICATIONS (10-14 March 2008)
- ☐ 35TH CFD / ADIGMA COURSE ON VERY HIGH ORDER DISCRETIZATION METHODS (14-18 April 2008)
- ☑ STRUCTURAL DESIGN OF AIRCRAFT ENGINES - KEY OBJECTIVES AND TECHNIQUES (13-16 May 2008)
- ☐ ATMOSPHERIC BOUNDARY LAYER FLOWS IN AIR POLLUTION MODELLING (19-23 May 2008)
- ☐ OPTIMIZATION AND MULTI-DISCIPLINARY DESIGN (2-6 June 2008)
- ☐ ADVANCES IN LAMINAR-TURBULENT TRANSITION MODELLING (RTO-AVT-VKI) (9-3 June 2008)
- ☐ NON-EQUILIBRIUM GAS DYNAMICS, FROM PHYSICAL MODELS TO HYPERSONIC FLIGHTS (RTO-AVT-VKI) (8-12 September 2008)

OTHER CONFERENCES:

- ☐ XIX BIANNUAL SYMPOSIUM ON MEASURING TECHNIQUES IN TURBOMACHINERY (7-8 April 2008)

COURSE FEE

The fee for the lecture series is 1180 euro, applicable to citizens of NATO countries contributing to the financing of the VKI (Belgium, Czech Republic, France, Germany, Hungary, Iceland, Italy, Luxemburg, Norway, Portugal, Spain and Turkey). For citizens of other NATO countries and of NATO partner countries, the fee is of 1545 euro. For non-NATO citizens, the fee is of 1665 euro. The prices are VAT included (VAT of 21%). The fee includes printed notes, transport between VKI and to the recommended hotels, lunches, beverages, and administrative costs.

FELLOWSHIPS

To encourage greater participation in our Lecture Series programme by university members, the Institute has established a limited number of VKI Lecture Series fellowships for citizens of NATO countries contributing to the financing of the VKI, as well as for citizens of other NATO countries coming from a university in a VKI financing country. The recipient of a fellowship is entitled to attend the VKI Lecture Series at a reduced fee, which will be of 595 € VAT included for assistants not having a Ph.D. degree and for Ph.D. candidates, or 295 € VAT included for undergraduate students. The request to be considered for an award must accompany the application to attend the Lecture Series, and the applicant must provide a recommendation letter from his or her professor; if not done so, the request will not be taken into consideration. All possible alternative sources of funding should be investigated before aid is requested under this scheme, so that those most in need will benefit.

METHODS OF PAYMENT

Payment 2 weeks prior to the beginning of the course (name and course title clearly indicated) by bank transfer to our account Nr 210-0315330-35 at Fortis Bank, avenue de la Forêt de Soignes 322, 1640 Rhode-Saint-Genèse, Belgium, IBAN BE57 2100 3153 3035 (strongly recommended). SWIFT BIC GEBA BE BB

Late registration can be paid cash in EURO, or by VISA or Eurocard at the beginning of the course.

PROCEEDINGS

Lectures will be given in English and printed notes will be distributed during registration. Proceedings of other non-RTO lecture series may be purchased at VKI (by e-mail: vanhaelen@vki.ac.be or by fax : 32 2 359 96 00). Information can be found on http://www.vki.ac.be.

HOW TO REGISTER

It is highly recommended to send the registration/hotel reservation form at the latest 15 days before the beginning of the course. A letter of acceptance and additional information will be sent on receipt of the application form.

ACCOMMODATION & TRANSPORT

Participants are advised to make their reservations as early as possible. VKI secretariat (secretariat@vki.ac.be) can book rooms upon request in the recommended hotels listed below. Daily rates include all charges and continental breakfast. These prices are indicative and could be subject to changes.

Hôtel des Colonies http://www.hotel-des-colonies.com	Single: 110 € / Double: 130 €
Hôtel Vendôme http://www.hotel-vendome.be	Single: 100 € / Double: 130 €
Thon Hotel Brussels City Centre http://www.thonhotels.be/	Single: 135 € / Double: 165 €
Hôtel Le Dôme http://www.hotel-le-dome.be	Single: 120 € / Double: 140 €
Hôtel Orts http://www.hotelorts.com	Single: 200 € / Double: 250 €
Progress Hôtel http://www.progresshotel.be	Single: 200 € / Double: 220 €

However, participants could occasionally find special offers on hotel websites.

A youth hostel, the Sleepwell is within walking distance of the recommended hotels. We invite you to make your own reservation through their website: http://www.sleepwell.be.

The hotels situated in Brussels are all within walking distance from the Gare du Nord and the Place Rogier. A train service links the airport with the Gare du Nord (15' journey). Complete your journey to the hotel/youth hostel on foot or by taxi. Each morning and evening, bus transport will be provided between the Place Rogier and the von Karman Institute, located in Rhode-Saint-Genèse, a suburb south of Brussels.

The following hotel, which is about 1.5 km from the Institute, is also recommended, particularly for those who travel by private car. The hotel is about 12km from the center of Brussels and a high standard of comfort is assured.

Auberge de Waterloo****
e-mail: aubergedewaterloo@skynet.be
Fax : +32 (0)2 358 38 06 - Tel: +32 (0)2 358 35 80
Chaussée de Waterloo 212 -
1640 Rhode-Saint-Genèse

For more information about
the localization of the Institute
and the hotels, please visit
our website on http://www.vki.ac.be.

APPLICATION FOR ADMISSION TO VKI LECTURE SERIES

Lecture Series Title: .....

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Family name: . . . . . Firstname: . . . . . .
Name & full address of organisation, institution or university: . . . . . .
Phone nr: . . . . . Fax nr: . . . . . .
Position or title: . . . . . E-mail: . . . . . .
☐ Asking a reduced fee and joining a recommendation letter as: ☐ undergraduate student ☐ Ph.D. candidate or University assistant
Company / University VAT number: . . . . . Nationality: . . . . . .
VAT of the von Karman Institute: BE 0407 185 709

HOTEL RESERVATION *(if applicable)*

I require accommodation at Hôtel . . . . . for . . . . . person(s)
Single: . . . . . Double: . . . . . Date of arrival: . . . . . .
I shall require transport to and from the Institute ☐☐
I do not require transport to and from the Institute Date of departure: . . . . . .
Please indicate any special needs (e.g. vegetarian, ...):
. . . . . .
Date: . . . . . Signature: . . . . . .

Please mail under-cover to VKI