KTH Mechanics

SE-100 44 Stockholm, Sweden

Activity Report 2003

Contents

1. Introduction

2. Personnel

3. Laboratory facilities and computers

4. Economy

5. Teaching activities
5.1 Undergraduate courses
5.2 Master theses ('examensarbeten')
5.3 Graduate courses

6. Research areas – short project descriptions
6.1 Theoretical and computational mechanics
6.2 Biomechanics
6.3 Fluid mechanics
6.4 Education didactics

7. Research activities
7.1 Doctoral theses
7.2 Licentiate theses
7.3 Publications 2003
7.4 Seminars

8. The Faxén Laboratory
8.1 Introduction
8.2 Management and organization of the Centre
8.3 Research performed at Faxén Laboratory
8.4 Financial status
8.5 Miscellaneous

Preface

This report was compiled to a large extent from information in our data base that forms the platform for our web-pages. Special thanks go to Jerome Hoepffner and Yuan Lin for extracting this information from the data-base and to Henrik Alfredsson for editing, proof reading etc. The report reflects the activities of the eleventh budget year of the (new) department of mechanics in education, research and other areas.

Stockholm, April 2004

Arne Johansson, department chairman
Gustav Amberg, department vice chairman

1 Introduction

This is the eleventh annual activity report of the new mechanics department and covers the year 2003. The mechanics department (web address: http://www.mech.kth.se) has about 80 employees and a yearly turnaround of about 65 MSEK. It is also host department for the Faxén Laboratory, a VINNOVA competence centre for the fluid dynamics of industrial processes.

The head of department ('prefekt') is professor Arne Johansson and vice *ditto* ('proprefekt') is professor Gustav Amberg. The study rector ('studierektor') is Hanno Essén.

The department board consists of: Nicholas Apazidis, Fritz Bark, Dan Henningson, Arne Johansson (chairman), Lars Thor, Ingunn Wester, Peter Gudmundsson (prof. Dept of Solid mechanics, external board member), Johan Gullman-Strand (grad. stud. repr.) and an undergraduate student representative.

The teaching activities comprise courses in basic mechanics at almost all parts of KTH, and a large number of higher level and graduate courses on many different aspects of mechanics of solids as well as of fluids.

A new International Master Program in Engineering Mechanics was started during 2003. This is a joint effort with the Department of Solid Mechanics and is coordinated by Jean-Marc Battini.

The new basic mechanics course for the micro-electronics program at KTH-Kista and a new Vehicle Aerodynamics course were given for the first time during 2003.

In general the teaching activities showed a positive trend during 2003 with new courses increased volume and a balanced economy.

The research activities can essentially be classified into major areas of "Fluid mechanics", "Theoretical and Computational mechanics", and "Biomechanics", although no strict boundaries exist between them. During 2003 there were more than 45 active graduate students at the department (about a third of which are associated with the Faxén Laboratory) and more than ten external graduate students in industry and research institutes. Ten doctoral thesis defences and eight licentiate seminars were held during 2003.

The Faxén Laboratory (started July 1995) is directed by Professor Fritz Bark. The centre comprises activities at five different KTH departments, viz. 'Kemiteknik', 'Materialens Processteknologi', 'Mekanik', 'Pappers- och Massateknik' (now included in the Polymer and fibre technology department) and 'Hållfasthetslära', and 19 industrial partners. The activities are divided into the program areas of Electrochemistry, Material process technology and Paper technology (for details see section 8).

KTH Mechanics has the coordinator role for the Nordic ERCOFTAC Pilot Centre. The coordinatorship is held by Professor Gustav Amberg. A number of partners from the different Nordic countries are members of the centre.

KTH mechanics has gradually broadened its research profile. The aim is to have a strong basis in fundamental research in the general area of engineering mechanics and to have a good flexibility and width of application areas. The area of Biomechanics was defined as a strategically important area for the department, where we seek to expand the activities.

The external funding has developed well during the last three years. The past year has been exceptionally strong and we have seen a number of new contracts in new areas. For 2004 we see a substantial decrease in e.g. the VR-funding, but the economy still appears to be in balance. In the pipeline we see substantially increased EU-funding with several new contracts presently being negotiated, and new proposals being submitted.

The broadened range of research applications is signified well by the fact that KTH Mechanics had project cooperation (with 'exchange of money') with 11 other departments at KTH, with five other universities in Sweden and with more than 20 companies in Sweden and several other countries.

Personel related matters 2002 and miscellaneous

Jean-Marc Battini was appointed as assistant lecturer ('biträdande lektor') in Structural mechanics.

Gunnar Tibert and Geert Brethouwer were appointed as research associates ('forskarassistenter') with funding from VR.

Stefan Wallin was appointed as adjunct lecturer ('adjungerad lektor') in Fluid Mechanics with turbulence model applications.

Alessandro Talamelli was appointed as 'guest lecturer'.

Ardeshir Hanifi was awarded the Docent degree.

Nine new graduate students started.

Prof. em. Bengt Joel Andersson passed away on May 27, 2003 at an age of 84 years. Bengt Joel Andersson was a docent, at that time a position, of Hydrodynamics 1950-1955, associate professor ('laborator') of Mechanics 1955-1958 and professor of Hydrodynamics during the period 1958-1985. In 1992, the Hydrodynamics department was merged with the departments of Gasdynamics and Mechanics.

The department board met on Jan. 28, Feb. 05 and Dec. 16.

A number of the 'ledningsgruppsmöten' and 'samverkansgruppsmöten' were also held.

Department meetings followed by dinner were held towards the end of the spring and fall semesters.

2 Personnel

Professors

- Henrik Alfredsson, PhD in mechanics, KTH 1983 and Docent there 1985. At KTH since 1977. Extra professor 1986 and professor in Fluid Physics 1989. Dean of KTH 1999 – Feb. 2003. Research in fluid mechanics, in particular laminar-turbulent transition.
- Gustav Amberg, PhD in fluid mechanics, KTH 1986, Docent at KTH 1990. Professor in fluid mechanics 1999. At KTH since 1982. Research in fluid mechanics and heat and mass transfer, in particular with application to materials processes. Department vice chairman.
- Fritz Bark, Ph.D. in Applied Mechanics at KTH 1974. Extra professor in Applied Mechanics 1979, professor in Hydro-mechanics, 1985, all at KTH. Research in fluid mechanics, in particular convection in electrochemical systems and processes in paper technology. Director of the Faxén Laboratory.
- Anders Eriksson, PhD in steel structures, KTH 1981 and Docent there 1988. At KTH since 1976. Professor in structural mechanics 1992. Research in non-linear structural mechanics, in particular computational modelling of instabilities. Vice president of KTH.
- Dan Henningson. M.Eng. MIT 1985, Ph.D. KTH 1988, Docent KTH 1992, Ass. Prof. Appl. Math. MIT 1988-1992. Adj. Prof. Mechanics (20 %) KTH 1992-1999. Professor in fluid mechanics, 60 % 1999-2003, 80% 2003- . Research on flow control, linear and non-linear hydrodynamic stability and numerical simulation of transitional flows.
- Arne Johansson, PhD in mechanics, KTH 1983 and Docent there 1984. At KTH since 1977. Extra professor 1986 and professor in mechanics 1991. Research in fluid mechanics, in particular turbulence and turbulence modelling. Department chairman.
- Martin Lesser, Ph.D in Aerosp. Eng. 1966 at Cornell; Bell Labs 1966–71; Inst. Cerac in Lausanne 1971–75; 1975–84 docent and prof. at LuTH; 1984–87 Chairman and full prof. at Dept of Mech. Eng. & Appl. Mech. at Univ. of Penn.; 1987 professor in Mechanics at KTH; research on multibody mechanical systems and the use of computer algebra in mechanics.

Adjunct professors, guest professor and 'Biträdande professor'

- Said Zahrai, PhD in Mechanics 1992, Docent KTH 1998, Employed 20% as Adj. Prof. in Fluid Mechanics at KTH (from April 2002) and 80% at ABB Corp. Res. Research on Mechatronics and Fluid Mechanics
- Per-Olof Thomasson, PhD in 'Stålbyggnad' 1978, Docent KTH 1978, Employed 20% as Adj. Prof. in Applied Structural Mechanics at KTH (from October 2002) and 80% at TYRÉNS AB

- Laszlo Fuchs. Ph.D. in Gasdynamics KTH 1977, Docent KTH 1980. Adj. prof. Applied CFD (50 %), KTH 1989–1994 IBM Sweden (50 %) 1989-1992. Prof. Fluid Mechanics LTH 1994–. Guest Prof. (20%) at the Mechanics Dept, KTH 1994– Research in CFD methods and models, with application to compressible flows and combustion in engines and furnaces.
- Bengt Enflo, PhD and Docent 1965 in theoretical physics, Univ. of Stockholm. Two years at Nordita and one year at CERN. 'Biträdande professor' at KTH since 1996. Research in theoretical acoustics, nonlinear waves, acoustic diffraction. 'Biträdande professor' since 1996. Retired in 2000.

Senior Lecturers (in Swedish: lektorer)

- Nicholas Apazidis, PhD in mechanics, KTH 1985, Docent at KTH 1994. At KTH since 1977. Research in two-phase flow and shock wave focusing in fluids.
- Anthony Burden, PhD in applied mathematical physics, Univ. of Göteborg 1984. Research on two-point closures for turbulence and computational models for turbulent combustion.
- Ian Cohen, PhD and Docent 1982 in theoretical physics, Univ. of Stockholm. Research in general relativity and computer algebra applications in physics.
- Anders Dahlkild, PhD in mechanics 1988 and Docent 1992 at KTH. Research on two-phase flow. Scientific secretary of the Faxén Laboratory.
- Hanno Essén, PhD in theoretical physics Univ. of Stockholm 1979. Three years in England and Canada. Docent 1986. At KTH since 1988. Research on general relativity and on non-holonomic systems.
- Richard Hsieh, PhD in mechanics 1978, Docent at KTH 1980, at KTH since 1973. Research on continuum mechanics and mechanics of materials.
- Arne Karlsson, TeknL.
- Göran Karlsson, PhD in quantum chemistry 1970 Univ. of Uppsala. Canada and US 1971. At KTH since 1973. Research on education didactics, computer aided learning, distance eduction, computer information systems.
- Erik Lindborg, PhD in Mechanics KTH 1996, Docent at KTH 2001. Senior Lecturer in 'fluid mechanics with geophysical applications' since July 2002. At KTH since 1991. Research in turbulence and fluid mechanics with geophysical applications.
- Arne Nordmark. PhD in mechanics 1992. At KTH since 1984. Docent 1999. Senior lecturer 2001. Research in the dynamics of mechanical systems with discontinuous or impulsive forces.
- Christer Nyberg, PhD in mechanics 1979 KTH. Research in acoustics.
- Lars Söderholm, PhD and Docent 1970 in theoretical physics, Univ. of Stockholm. Two years at Nordita. At KTH since 1980. Research on relativity and continuum mechanics: Klein-Alfvén cosmology, relativistic temperature, material frame indifference, constitutive relations and kinetic theory.

- Anders J Thor. TeknL in mechanics, KTH 1964. At KTH since 1956. Work on standards for quantities and units. Retired 2001, but continues work on standards and some teaching.
- Lars Thor, PhD in mechanics at KTH 1973. At KTH since 1965. One semester of teching in Australia 1990.
- Karl-Erik Thylwe, PhD 1981 in theoretical physics, Univ. of Uppsala. Four years at Univ. of Kaiserslautern and Manchester. Docent 1987. At KTH since 1988. Research on Regge-pole theory and semi-classical phenomena of atom-molecule collisions, nonlinear phenomena of dynamical systems, asymptotic methods.

Lecturers and researchers (in Swedish: biträdande lektor, forskarassistenter, förste forskare, adjunkter, 1:e fo.ing.)

- Jean-Marc Battini ('bitr. lektor'), PhD in Building Mechanics 2002, at KTH since 1994. Research in non-linear finite elements and instability
- Geert Brethouwer, PhD in Fluid Mechanics, TU Delft 2001. Research associate ('forskarassistent') from January 2003, Research on turbulence and combustion.
- Pär Ekstrand, Responsible for the department's computer system
- Barbro M. Klingmann, PhD in Fluid Physics, KTH 1991. Postdoc at EPFL Lausanne and Novosibirsk 1992-94 and at Volvo Aero. 1994-1996. Docent at KTH 1996, Research on transition and turbulent separation.
- Gunnar Maxe, ('adjunkt')
- Galina Shugai, PhD 2000 at KTH, 'Forskare', Research in fluid mechanics
- Gunnar Tibert, PhD in Structure Mechanics, KTH 2002. Research associate ('forskarassistent') from January 2003, Research on structure mechanics.
- Nils Tillmark, TeknD 1995, Responsible for the department's lab. facilities. Research on shock waves and compressible flow.
- Michael Vynnycky ('förste forskare'), PhD Univ. of Oxford, Lecturer at Univ. of East Anglia, Norwich 1991-92, Extended research visits in Japan 1992-96, Docent at KTH 2002, at KTH from 1997.

Adjunct Lecturers (20% of full time position)

- Daniel Söderberg, PhD in Fluid Mechanics 1999. Adjunct lecturer in fluid mechanics with paper manufacturing application, since December 2002.

- Stefan Wallin, PhD in Fluid Mechanics 2000. Adjunct lecturer in fluid mechanics with turbulence modelling application, since January 2003.

Guest researchers, post-docs

- Prof. Harry Dankowicz, Virginia Polytechnical Institute and State University, Blacksburg, VA USA
- Prof. Alessandro Talamelli, Univ. of Bologna, Italy
- post-docs: Dr Philippe Brunet, Dr Shuya Yoshioka

Technical and administrative staff (in Swedish: TA-personal)

- Lars Bjernerstam
- Marcus Gällstedt
- Ulf Landén
- Katti Lindfors
- Anne-Mari Olofsson
- Hans Silverhag (chefsadm./ekonomiansvarig)
- Stefan Skult
- Viviana Wallin
- Ingunn Wester (chefsadm./personalansvarig)

Professors emeritii

Bengt-Joel Andersson (passed away on May 27, 2003)
Stig Hjalmars

Graduate students (in Swedish: doktorander)

Daniel Ahlman
Anders Ahlström
Kristian Angele
Karl Erik Birgersson, Faxén Laboratory

Karl Borg
Luca Brandt
Arnim Brüger
Carl-Ola Danielsson
Minh Do-Quang
Veronica Eliasson
Johan Eriksson
Luca Facciolo
Jens Fransson
Monica Fällman, Faxén Laboratory
Olof Grundestam
Johan Gullman-Strand
David Hammarström, Faxén Laboratory
Astrid Herbst
Jérôme Hoepffner
Richard Holm
Claes Holmqvist, Faxén Laboratory
Thomas Hällqvist
Nulifer Ipek, Faxén Laboratory
Goto Kazuya
Robley Kisitu
Ori Levin
Darja Ljubimova
Irina Loginova
Fredrik Lundell
Ola Lögdberg
Olivier Macchion, Faxén Laboratory
Davide Medici
Niklas Mellgren, Faxén Laboratory
Gustaf Mårtensson, Faxén Laboratory
Sofia Nilsson
Filli Nurhussen
Jan Pralits
Henrik Sandqvist
Junichiro Shiomi
Timmy Sigfrids
Erik Stålberg
Olle Törnblom
Walter Villanueva
Roland Wiberg, Faxén Laboratory
Tom Wright
Jan Östlund

External graduate students (not employed by department of mechanics)

Mattias Chevalier, FOI/FFA
Jan Eriksson, Vattenfall Utveckling AB, Älvkarleby (FLA)
Marco Hyensjö, Metso Paper (FLA)
Hans Moberg, Alfa Laval, Tumba
Andreas Möller, FOI/FFA
Federica De Magistris, STFI

There are further graduate students associated with FLA but employed at other departments at KTH (see section 8).

3 Laboratory facilities and computers

3.1 Laboratory facilities

The department has a laboratory with several experimental facilities for research and student laboratory exercises. Students do laboratory exercises in most fluid dynamics courses and during 2003 almost 200 laboratory exercises were made by groups of 3 to 4 students.

Among the larger research facilities the following are of interest for the present project:

- MTL subsonic wind tunnel, 7 m long (1.2 m × 0.8 m) test section, max. speed 69 m/s
- BL subsonic wind-tunnel, 0.5 m × 0.75 m test section, max. speed 48 m/s
- plane Couette flow apparatus with and without system rotation
- asymmetric diffuser facility for studies of turbulent separation and control
- plane Poiseuille flow apparatus (2m×0.8m) for transition and control studies, etc. (not operational at present)
- two-dimensional contraction for studies of turbulence undergoing strain and also relaminarizing boundary layers
- Maragoni convection set up for studies of stability and control in an annular geometry (flow cell has diameter of 6 mm).
- rotating pipe flow apparatus (6 m long, 60 mm diameter) for studies of rotation effects of pipe flow and swirling jets
- shock-tube for experiments on focusing shock waves

A major facility is the MTL wind-tunnel, which is a low-turbulence wind-tunnel with outstanding flow quality - the turbulence level is as low as 0.02 %. It is and has been used for a variety of long-term research projects on hydrodynamic stability and laminar-turbulent transition, flow separation, turbulence structure and control. Ten PhD-theses, where the experiments were made in the tunnel, have been completed since the tunnel became operational in the beginning of the 1990's and several projects are presently active in the tunnel. The tunnel has also been instrumental in attracting guest researchers and post-docs to the department from various countries (e.g. Germany, Italy, Japan, Russia, USA, England, France Uruguay).

A smaller wind tunnel (BL wind-tunnel) based on the same concept as the MTL-tunnel was taken into operation during 1999 both for research and education purposes. This tunnel is especially suitable for optical measurement techniques since it allows easy optical access. It is also possible to fit with various test sections, and has been used for studies of separating turbulent boundary layers.

The department also shares a continuously running supersonic wind-tunnel, 0.1m×0.1m test section, with ‘continuously’ variable Mach number (0.3–2.5). The wind-tunnel is located at KTH Energy Technology.

A new shock tube became operational in 2003 and will be used to study the stability of focused shock waves and the high pressure gasdynamics in the focus region. Schlieren technique and pulsed laser is used to visualize the flow.

The measurement techniques used in the laboratory comprise most fluid mechanics measurement techniques. The laboratory has developed the hot-wire anemometry technique systematically, especially regarding probe manufacturing and miniaturizing. Recent development work deals with using hot-wires also in transonic and supersonic flows.

Development has also been made regarding temperature sensitive paint for determining surface temperature distributions in connection with heat transfer measurements. Recently work has started in order to evaluate the use of pressure sensitive paint.

In terms of optical measurement techniques the laboratory has access to Laser-Doppler Velocimetry (LDV) and Particle Image Velocimetry (PIV). PIV has since its introduction in the laboratory found its use in many different projects ranging from large wind-tunnel studies to very small measurement volumes. A significant amount of development work has been ongoing both for seeding techniques and data evaluation. The results from PIV have been extremely valuable and could not have been obtained with other methods.

A new laboratory room is under development to become a “wet”-laboratory, mainly for research on fiber suspensions. Among other things the development of ultrasonic techniques for measurements of the velocity field in fiber suspensions are underway.

3.2 Computers

The department has a computer system consisting 38 AMD Athlon 2400+ and 2000+ workstations and 4 AMD Opteron 144 workstations running Debian Linux. There are also around 70 PC:s/Mac:s. The Department has built a linux cluster consisting of 16 dual cpu AMD Athlon MP 2400+ nodes conected with a fast low latency SCI interconect using 16 Dolphin Wulfkit D234 cards. The nodes are also conected with gigabit ethernet. The cluster is controlled from an aditional dual cpu AMD athlon MP 2400+ computer. Every node has 2 Gb memory. The Department has Compaq AlphaServer ES40 to serve as a number cruncher. It has four EV6 500MHz processors and a total of 3 GB shared memory. Eight Debian Linux servers and two Windows 2000 servers provide services for the Department like mail server and file storage.

The department also has an active role in the Kallsup consortium that has access to a large IBM SP-machine with 36 Nighthawk II nodes.

4 Economy

A brief overview of the different categories of incoming resources to the department is given below for 2003. The FLA sum does not inlude in-kind contributions.

INCOME (in Mkr)

	Dept. total
Education (GRU)	**15**
Research (FOFU)	**20**
External	**21**
FLA (external)	**10**
Σ	**66**

The external funding is mainly composed of grants from VR, STEM, VINNOVA, EU, SSF, MISTRA, BIMAC, The Göran Gustafsson Foundation and private industry. The strong external funding is a key factor behind the presently strong economical situation for the department.

5 Teaching activities

5.1 Undergraduate courses

Basic courses mechanics(grundkurser)				
School	Year	Course no.	Credit	Name
K, E , OPEN	1	5C1102	4	Mechanics, Smaller Course
VBI, F , V , I	1	5C1103	6	Mechanics, Basic Course
D	2	5C1105	4	Insights in Mechanics; Modelling and simulation
ME	1	5C1106	4	Tillämpad fysik, mekanik
BD, T , E	2	5C1111	4	Mechanics, Continuation Course
M, BD	1	5C1112	6	Mechanics, Continuation Course
F	2	5C1113	4	Mechanics, Continuation Course
T, M , BD , P	1	5C1130	6	Mechanics 1
Basic courses structural mechanics				
V (All)	3	1C1103	5	Structural Mechanics III
V	2	1C1109	5	Structural Mechanics I
V	2	1C1115	5	Structural Mechanics II
Basic courses fluid mechanics				
T	2	5C1201	8	Fluid Mechanics with Thermodynamics
F	3	5C1202	4	Fluid Mechanics, Introductory Course
M	3	5C1921	4,5	Fluid Mechanics for Engineers
Advanced courses mechanics (högre kurser)				
	3	5C1121	4	Analytical Mechanics
	4	5C1122	4	Continuum Mechanic
	4	5C1123	4	Math. Methods of Mechanics, General Course
VBI, V	4	5C1125	2	Math. Methods of Mechanics, Intermediate Course
	4	5C1400	5	Nonlinear Dynamics in Mechanics
	4	5C1902	4	Advanced Dynamics of Complex Systems
	4	5C1904	4	Advanced Modern Mechanics
	4	5C1980	4	Applied Mechanics
Advanced courses structural mechanics				
V	4	1C5032	5	Structural Dynamics, Advanced Course
	4	5C1840	5	Structural dynamics
	4	5C1850	5	Finite element methods
	4	5C1860	5	Finite element method modelling
Advanced courses fluid mechanics				
	4	5C1211	4	Vehicle Aerodynamics
	4	5C1212	5	Computational Fluid Dynamics
	4	5C1213	2	Applied Computational Fluid Dynamics
	3	5C1214	5	Fluid Mechanics, General Course
	4	5C1215	5	Compressible Flow
	4	5C1992	4,5	Turbulence

5.2 Master thesis projects ('examensarbeten')

- 03/01: Jayaweera, Jayani "Numerical approaches for phase-field simulation of iso-thermal binary alloy solidification (Advisor G. Amberg)
- 03/02: Månsson, Johan & Söderqvist, Johan "Finite element analysis of thin membrane wrinkling" (Advisor A. Eriksson)
- 03/03: Gårdstam, Johannes "Simulation of self piercing riveting of the austenitic stainless sheet steel EN 1.4301 in 1+1 mm sheet thickness (Advisor A. Eriksson)
- 03/04: Ocuneva, Inna "Parameter dependencies in phase field simulations of dendritic solidification (Advisor G. Amberg)
- 03/05: Picard, Cyril "Visualisation of two-phase flow in the anode of a direct methanol fuel cell (Advisor M. Vynnycky)
- 03/06: Papadopoulos, Dimitrios "Fluid mechanics of convective heat transfer for multiple short cylinders in axial and cross flow" (Advisor F. Bark)
- 03/07: Pettersson, Christian & Svensson, Staffan "Development of an on-line forming analyser: measurement of fibre orientation and design of a light-in-blade module (Advisor D. Söderberg)
- 03/08: Ålenius, Martin: "Finite element modeling of composite bridge stability" (Advisor A. Eriksson)
- 03/09: Wingstrand, Dag: "Simulation of ductile fracture in tool steels" (Advisor A. Eriksson)
- 03/10: Abrams Björnsdotter, Alicia "Modelling of two-phase flow in the anode of a direct methanol fuel cell" (Advisor M. Vynnycky)
- 03/11: Bengtsson, Greger: "Topographic steering in a stratified ocean" (Advisor F. Bark)
- 03/12: Korinth, Leo & Moradbakhti, Yashar "Simulation of rigid bodies" (Advisor A. Nordmark)
- 03/13: Svedung, Lars "Multi-body dynamics of vehicle suspensions" (Advisor H. Essén)
- 03/14: Unckel, Carl-Gustav "Calculations of separated laminar boundary layers" (Advisor D. Henningson)
- 03/15: Lin, Yuan "Phase-field simulation of Ni-Cu binary alloy solidification in shear flow" (Advisor G. Amberg)
- 03/16: Brandt, Märta-Karin & Törnquist, Tobias "CFD studies of heat transfer during gas quenching of metals" (Advisor S. Zahrai)
- 03/17: Tegengren, Åke M. "Mixing of high consistency pulp in streaming water" (Advisor F. Bark)

5.3 Graduate courses

During 2003 the following graduate courses ('forskarutbildningskurser') were given (some of which were given in combination with the corresponding undergaduate course). In addition several reading courses were given.

- 5C5112 Turbulence
- 5C5113 Compressible Aerodynamics
- 5C5114 Numerical Methods in Fluid Mechanics
- 5C5130 Micro fluid flows
- 5C5135 Free boundary problems
- 5C5001 General and analytical mechanics
- 5C5045 Non-linear oscillations and dynamical systems
- 1C5049 FEM modelling
- 1C5020 Finite Element Methods, Advanced course

6 Research areas - short project description

6.1 Theoretical and computational mechanics

Diffraction of sound by noise barriers

Researcher(s): Bengt Enflo

Graduate student(s): Henrik Sandqvist

Sponsor(s): BFR, KFB

Noise from traffic, fans, motors etc. is often shielded by barriers. In normal design the top edge of a noise barrier is straight. The edge may act as a string of highly correlated point sources. The effectiveness of the barrier is reduced by the coherence of these secondary sources. Experiments at The University of Texas show that the effectiveness of the barrier can be increased if it is made irregular. The project aims at understanding of these phenomena by theoretical methods. It will continue with theoretical and experimental investigations of possibilities of increasing the effect of sound barriers.

Nonlinear wave propagation in fluids

Researcher(s): Lars Söderholm

Sponsor(s): KTH

Nonlinear acoustics usually includes terms to second order in the Mach number as well as the product of the Mach number and the Knudsen number (the Knudsen number is the mean free path divided by the wavelength). The basic equations there are due to Burgers and Kuznetsov. The focus in this project is on the study of higher order effects in non-linear wave propagation. Such effects are behind the phenomenon of autoreflection, the emergence of a wave propagating in the direction opposite to the original wave. The building up of the autoreflected wave particularly takes place when a shock has developed. But when a shock is present, kinetic effects (second order in the Knudsen number) are expected to be as important as terms to third order in the Mach number. To meet this, a set of equations has been derived, which is correct to second order in the Knudsen number. They are related to the Burnett equations. The evolution of the acoustical wave is studied numerically.

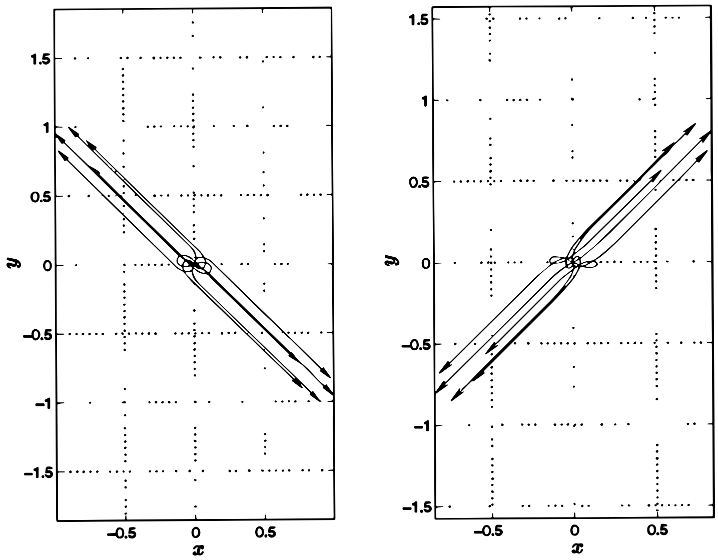
Dynamics of moderately and highly rarefied gases

Researcher(s): Lars Söderholm

Sponsor(s): KTH

When the size of a body in a gas approaches that of the mean free path, the continuum description of the Navier-Stokes equations no longer holds. In particular, in the limit where the body is small compared to the mean free path, the physics of the flow is very different from ordinary fluid dynamics. An example is that a thin thread, which in the continuum regime will be cooled by the flow, in the opposite regime instead is heated. Such threads are used to measure the speed of flows.

Small particles in a gas move slowly relative to the flow. It is well-known that a temperature gradient causes such a transport, called thermophoresis. A related phenomenon, named shearing phoresis, has been discovered. It is a transport which occurs when the gas is shearing. The motion of rotating spherical bodies is also studied. The Magnus force is responsible for the curvature of a spinning soccer ball. We have found that in a rarefied gas, the Magnus force is in the direction opposite to that in the continuum limit.



Figur 1: *Shearing gas flows in the horisontal direction. The transport of particles in the gas – shearing phoresis - is shown for particles of two different shapes.*

Dynamic simulation of wind power plants (VindSim)

Researcher(s): Anders Eriksson

Graduate student(s): Anders Ahlström

Sponsor(s): STEM

The project aims at developing and evaluating simulation models for complete wind power structures. The objective is to use these models for evaluation of strength and stability aspects of the structures, giving an improved understanding of estimated life spans and safety margins. The simulation models should utilize common modelling descriptions, typically finite elements, in order to allow different building paradigms. For the utilization of results from stochastic simulations, the modelling must be balanced in accuracies. The project is expected to give an improved understanding of the structural mechanical aspects of wind power structures, thereby improving the possibilities for quantitative descriptions of final or suggested configurations. This can eventually lead to optimization methods for the structures, under given assumptions on position and environment. A few examples will be shown in the project.

Buckling and collapse behaviour of optimised thin-walled structures

Researcher(s): Anders Eriksson

Graduate student(s): Daria Lioubomova

Sponsor(s): VR

Consideration of non-linear phenomena is a necessary consequence of structural optimisation. Coupled with resulting instabilities and dynamic phenomena, a pronounced sensitivity with respect to initial imperfections, and to parametric variations will normally be present. Basic numerical procedures for treatment of structural non-linear problems have been developed in previous and the ongoing project. The proposed continuation project aims at the verification of the numerical models, when compared to performed experiments on failure behaviour of optimised, thin-walled aeronautical structures. The main parts of the work will be directed towards the inclusion of more relevant material descriptions in the developed finite elements, the dynamic and static instability investigations of the structures, and the further improvement of the unique numerical algorithms for the parameterised response description of the structures. The project will be closely connected to the main lines of development within the group.

Active and passive damping with applications in manufacturing.

Researcher(s): Göran Karlsson

Sponsor(s): Swedish Institute

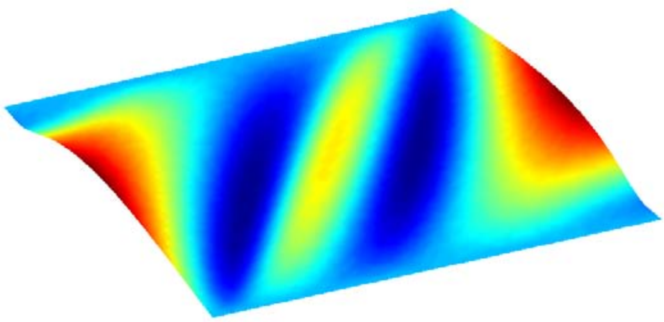
Sponsor: Swedish Institute Project 2657/2001. This project is a three year project in cooperation between Dept. of Mechanics, Dept of Industrial Production, KTH,Stockholm (Mihai Nicolescu) and Institute of Solid Mechanics of the Romanian Academy, Bucharest. The project started in September 2001 and it objectives are: (i) Development of passive and active vibration control based on damping technologies to substantially improve the dynamic behavior of manufacturing systems. (ii) Theoretical studies and practical applications of damping materials, such as viscoelastic and piezoelectrics, for increasing dynamic stability of manufacturing systems. (iii) Modelling and analysis methodologies and tools for viscoelastic and piezoelectric materials. (iv) Establish a reference base on the subject. (v) Organize common workshop, conferences or meetings. (vi) To facilitate the access of young researchers from Romania to KTH/facilities that are essential for high quality research. (vi) To improve the scientific and technological level and to contribute to attainment of a general level of scientific excellence (PhD courses, workshops and meetings). (vii) To give the opportunity to young Romanian scientists to work at their doctor's thesis at KTH.

Simulation of Flexible structures

Researcher(s): Gunnar Tibert

Sponsor(s): VR

Using the concept of deployable structures, and in particular inflatable space antennae, as a background target area, a few basic areas of computational structural modelling are studied. The specific objective for the space structures is to create minimum weight, minimum volume solutions for transport into and deployment to operational form in space. The simulation of these structures demand several computational analyses of dynamic and instability behaviour. The main work in the proposed project is the development of computationally accurate and efficient elements, primarily for thin membranes, using theories for large rigid deflections, and small but finite elastic deformations. Also, the control mechanisms for the deployment, are of major computational interest. The project parts will, together with previous and ongoing work in the group, give basic simulation tools, presently not available in commerical software, and an improved phenomenological understanding of the mechanical behaviour of these structures. Although primarily aiming at space structures, the studies are also highly relevant for many other types of optimized structures, including robotics, and the mechanical studies of biological tissues, but also for medi-technical small-scale applications.



Figur 2: *Wrinkle formation in a thin membrane in shear.*

New measurement techniques of complex attractors of mechanical systems

Researcher(s): Arne Nordmark, Annika Stensson

Graduate student(s): Johan Eriksson

Sponsor(s): VR

The objective of this work is to develop devices for the measurement of the dimension of attractors of mechanical systems. This is intended as an analytical tool for determining the causes of seemingly random behaviour in actual mechanical systems such as vehicles. The main idea is to develop definitions of dimension that connect with the measurement process and retain a close relation to more classical dimension concepts like correlation dimension.

Modelling, simulation and control of nonsmooth dynamical systems - SICONOS

Researcher(s): Arne Nordmark, Annika Stensson, Lars Drugge, Jenny Jerrelind, Anders Klarbring

The purpose of the project is to develop algorithms and software for the simulation and feedback control of dynamical systems which are nonsmooth, and more specifically so-called complementarity dynamical systems. Nonsmoothness is usually introduced into the system either by some nonsmooth control action or by the presence of nonsmooth events at a macroscopic level (such as impacts or switchings). Nonsmooth models abound in many engineering systems such as sliding mode or hybrid control and rigid body mechanics such as rattle of automotive components and other mechanical freeplay, and switching circuits in power electronics.

The research will tackle two fundamental issues head on. Firstly, that smooth numerical methods fail on nonsmooth systems. Algorithms need to be developed that deal with hit crossings, impacts, complementarity problems, sliding and chatter in a robust and easily applicable way. Secondly, the qualitative understanding of the dynamics including the design of feedback and robust control algorithms requires specific methods and cannot be solved with simple adaptations of known techniques for smooth linear or nonlinear dynamical systems.

6.2 Biomechanics

Biomechanical modelling of eye accomodation

Researcher(s): Anders Eriksson

Graduate student(s): Darja Ljubimova

Sponsor(s): KTH

The project deals with the mechanical modelling of accommodation of a human eye. Using clinical and experimental data concerning the behavior of an eye as a background, and combining this with technical shell modelling knowledge, a few basic areas of computational structural modelling are studied. The background knowledge is used to accurately describe the geometry of the lens and its parts, but also to develop relevant and efficient numerical models.

The main work in the proposed project will be done in the context of a general mechanical simulation, using non-linear analysis and considering small but finite elastic deformations. Material data of the constituent parts are an important part of work. Aspects of presbyopia and its relation to age will also be considered in the project. Special interest in the simulations will be directed towards the influence of the vitreous and its effects on the force-movement relations in the model.

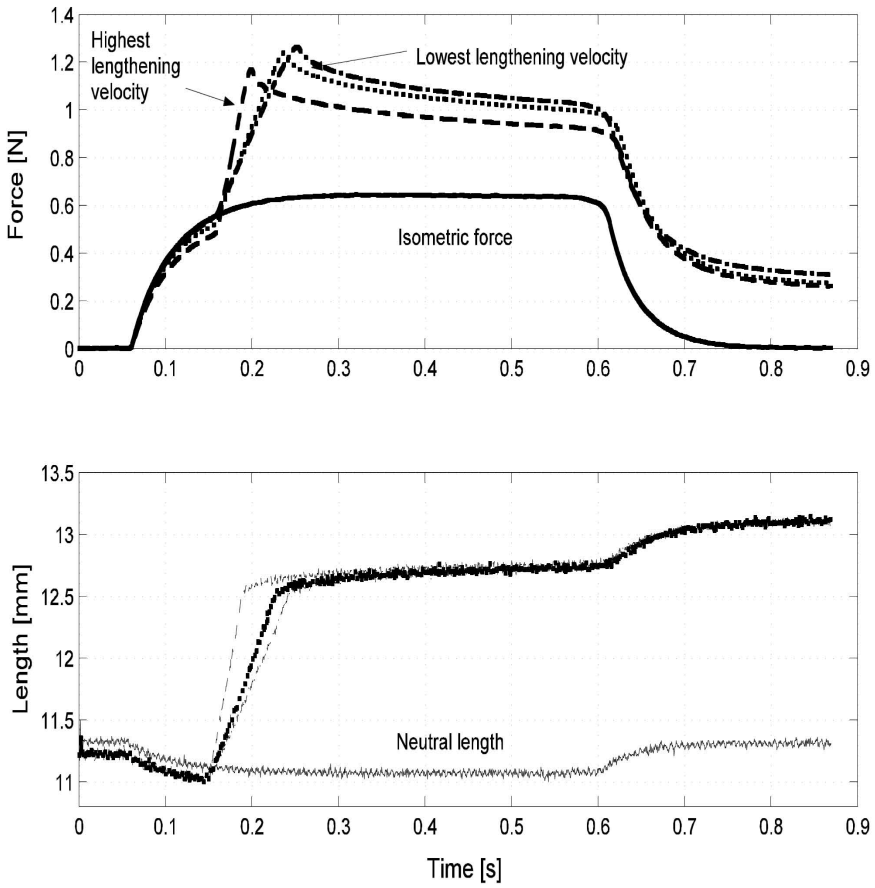
The project will lead to an improved phenomenological understanding of the mechanical behavior of the structure and will give improved knowledge on the process of accommodation. In addition to developing the framework of a general simulation algorithm, the aim is also to give at least some results of clinical interest concerning the process of accommodation in connection to the reversal of presbyopia and the prevention of glaucoma and cataract.

Biomechanical simulations of the skeleto-muscular system

Researcher(s): Anders Eriksson

Sponsor(s): KTH

This trans-disciplinary project aims at an improved modelling of the skeleto-muscular system in the human body. It takes as its background clinical and experimental knowledge on the behaviour of muscles and muscle cells, and connects this to the computational modelling of elasto-mechanical systems. In a simulation context, the focus is on the description of dynamic loading and movement situations. The project will primarily study the behaviour of muscles, to give improved descriptions for the human system, when subjected to impact or sustained high loading conditions. As one special objective, the improved modelling of muscle behaviour will allow more accurate consideration of the instantaneous response in a pre-recruited muscle, e.g. in vehicle crash simulations. This approach will lead to new development in the mechanical understanding of human muscular behaviour, but also to new demands on the physiological experimentation. The project will therefore be based on experiments and numerical modelling in parallel. By improving the muscular models, the project will give further improvement of existing bio-mechanical simulation models, and thereby lead to results of clinical interest on the damage or injury of a human joint, or a body part.



Figur 3: *An example of eccentric contraction experiments on EDL (Exensor-Digitorum-Longus) muscle stimulated with 120 Hz., different shortening velocities and pre-activation time of 0.15 s. Upper panel illustrates the isometric force produced during stimulation and the increasing of such a force with the active lengthening. The lengthening velocity was estimated to1.5-3.8 cm/s. Lower panel shows the length of the muscle.*

Simulations of post-surgical upper limb capacity

Researcher(s): Anders Eriksson

Graduate student(s): Sofia Nilsson

Sponsor(s): KTH

This trans-disciplinary project aims at an improved modelling of the capacity of the upper limb, with a primary application to post-surgical capacity after restorative surgery, including only a subset of original muscles. This modelling can be assumed to be a useful planning tool for surgeons, in the treatment of more or less fully paralyzed patients. The project essentially consists of three parts, where the development of a kinematical description of upper limb movement patterns and algorithms for the distribution of forces between synergistic muscles are the two theoretical, numerical parts. The third part of the project is a clinical, experimental verification of the developed model.

Modelling of muscle mechanics

Researcher(s): Anders Eriksson, Håkan Westerblad

Graduate student(s): Goto Kazuya, Filli Nurhussen

Sponsor(s): VR

This trans-disciplinary project aims at an improved modelling of the skeleto-muscular system in the human body. It takes as its background clinical and experimental knowledge on the behaviour of muscles and muscle cells, and connects this to the computational modelling of elasto-mechanical systems. In a simulation context, the focus is on the description of dynamic loading and movement situations. The project will primarily study the behaviour of muscles, to give improved descriptions for the human system, when subjected to impact or sustained high loading conditions. As one special objective, the improved modelling of muscle behaviour will allow more accurate consideration of the instantaneous response in a pre-recruited muscle, e.g. in vehicle crash simulations. This approach will lead to new development in the mechanical understanding of human muscular behaviour, but also to new demands on the physiological experimentation. The project will therefore be based on experiments and numerical modelling in parallel. By improving the muscular models, the project will give further improvement of existing bio-mechanical simulation models, and thereby lead to results of clinical interest on the damage or injury of a human joint, or a body part.

Optimization of middle ear replacement device

Researcher(s): Martin Lesser

Graduate student(s): Tom Wright

Sponsor(s): KTH

Despite intensive study since the time of Helmholz the middle ear still defies our complete understanding. This linkage of three small bones that join the ear drum to the cochlear is normally treated with linear one degree of freedom models fitted to available data. Yet the system clearly undergoes more complex motions and has active components. The first stage of this project has concentrated on the gathering and analysis of available data that describe the anatomy and dynamic parameters. Also several preliminary models have been postulated to encompass the more complex behavior with as much simplicity as possible. One of the primary goals is to determine the actual active degrees of freedom in middle ear motion and to develop models susceptible to more complete analysis and understanding of the nonlinear dynamics. This is in contrast with current attempts at full scale finite element models of the middle ear bones which are difficult to interpret.

6.3 Fluid mechanics

Experiments on wall bounded shear flows

Researcher(s): Henrik Alfredsson, Nils Tillmark, Alessandro Talamelli, Shuya Yoshioka

Graduate student(s): Fredrik Lundell, Jens Fransson, Luca Facciolo, Timmy Sigfrids, Davide Medici

Sponsor(s): VR, STEM, Carl Tryggers stiftelse, KTH

This research area deals in various ways with wall bounded flows and the research is mainly experimental.

One part deals with the transition to turbulence in laminar boundary layers, and various methods to control and hopefully delay the transition process. Several studies in our laboratory have dealt with the receptivity of the laminar boundary layer to free stream turbulence, through detailed velocity measurements in the MTL wind tunnel, where free stream turbulence is generated by different grids. Both flow visualisation and hot-wire measurements (one and two-point) have shown that the interaction with the boundary layer gives rise to elongated structures of high and low velocity. The streaks are susceptible to secondary instabilities and will subsequently break down into turbulence. In the doctoral thesis of Lundell (March 2003) a succesful attempt was made to control the breakdown process by an active control method, where hot-wires mounted at the wall detected low velocity streaks and control was made by localized suction through small holes.

Another way to control boundary layer flows is to use distributed suction over a large surface. This is done in an experiment where the asymptotic suction boundary layer could succesfully be obtained (maybe for the first time in an exepriment). The effect both on wave disturbances and free stream turbulence induced disturbances are investigated and in the doctoral thesis of Fransson (Dec 2003) it is shown that suction may have a strong stabilizing effect. Presently the effect of both suction and blowing on a turbulent boundary layer is studied.

The effect of axial rotation on the structure of rotating pipe flow as well as the emanating jet from a rotating pipe is studied in a newly constructed apparatus (Licentiate thesis of Facciolo, Nov, 2003). The final goal of the study is to investigate the structure in the near wall region of a swirling impinging jet, with focus on the resulting heat transfer.

Boundary layers in transonic flow may be affected by shock boundary layer interaction. Work has been done in the VM100 tunnel using hot-wire anemometry and Particle Image Velocimetry. A calibration technique for hot-wires in compressible flow has also been developed (Licentiate thesis of Sigfrids, June 2003).

The development and interaction of wind turbine wakes in wind farms is an important reserach area and may determine how close wind turbines can be placed in a wind farm. The research aims at actively controlling the turbine yaw and thereby avoiding interference between turbines (Licentiate thesis of Medici, March 2004). This may enhance the total power output of the wind farm as well as avoiding turbulence approaching individual turbines which could cause fatigue.

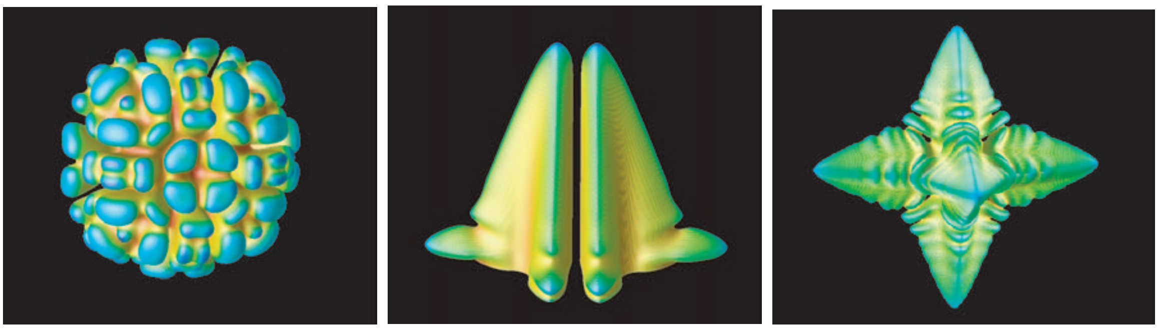
Diffuse interface methods for computations in materials science

Researcher(s): Gustav Amberg

Graduate student(s): Irina Loginova

Sponsor(s): VR

The structure of materials is changed by phase transformations during synthesis and processing. Many phase transformations involve diffusion and/or heat transfer and the rate of such a phase transformation may often be evaluated quite precisely by solving a diffusion problem. The growth or dissolution of a secondary particle in a parent phase is a classical problem. When there are several diffusing species the problem becomes quite complicated. The phase diagram becomes multidimensional and thus the operating compositions at the moving phase interface cannot be read directly from the phase diagram. At present such multicomponent systems have only been solved by assuming very simple geometries, e.g. spheres, plates, etc. A drawback is that the shape of a growing particle is not predicted by the calculation. Diffuse interface methods have been used increasingly to study the dynamics of phase boundaries over the last ten years. In this approach a new field variable, the order parameter, is used to track the phase boundary. A value of 0 or 1 designates the two phases, and transition regions are identified with the phase boundary. Over the last ten years a number of phase field simulations of thermal solidification have appeared in the litterature. However, until now no simulations for truly multicomponent transformations in two or three dimensions have been reported. It is proposed to develop diffuse interface methods that can treat multicomponent phase change. The numerical methods that have been used so far must be improved significantly in order to do such simulations efficienty.



Figur 4: *Examples of different morphologies in a solidifying crystal, simulated using the phase field method.*

Computational Phase Transformations

Researcher(s): Gustav Amberg

*Graduate student(s):*Walter Villanueva

Sponsor(s): SSF

Properties of materials depend on their structure, which is changed by phase transformations during synthesis and processing. The purpose of this multidisciplinary project is to bring microstructural modelling to a new level by developing the necessary mathematical models and computational techniques, such as reliable and efficient solvers and adaptive methods for deterministic and stochastic PDEs. Close collaboration between material scientists, mathematicians and numerical analysts will result in the next generation of models and computational tools that will be able to treat complex microstructures including three-dimensional shapes with important features on several length scales. The project involves the departments of Mechanics (Gustav Amberg); MSE, Materials Science and Engineering (John Ågren); NADA, Numerical Analysis and Computer Science (Anders Szepessy, Gunilla Kreiss), and Mathematics (Anders Szepessy), at KTH. The project is funded primarily by the Swedish Foundation for Strategic Research (SSF) as a *Ramanslag i tillämpad matematik* project in applied mathematics on Mathematical theory and simulation tools for phase transformations is materials". The project is administered by the Department of Mechanics.

Control of oscillatory thermocapillary convection

Researcher(s): Gustav Amberg, Henrik Alfredsson

Graduate student(s): Junichiro Shiomi

Sponsor(s): VR

In many solidification processes in materials technology, thermocapillary convection in the liquid metal is crucial for the properties of the finished product. Examples of such processes are all the various techniques for crystal growth, and welding where the flow in the weld pool determines the penetration of the liquid pool (i.e. 'weldability'). Often it is technically important to avoid oscillatory flow, and thus it is important to understand the stability characteristics of thermocapillary convection in general. In the project, experimental techniques have been developed that allow us to study onset of oscillatory thermocapillary convection in detail. Quantitative velocity measurements have been carried out using PIV. Active control has been introduced in the experiment and it is found that oscillations can be at least partially suppressed.

In the doctoral theses of J. Shiomi, presented in Dec. 2003, the possibility to stabilize thermocapillary convection was explored further.

Numerical simulation of weld pools

Researcher(s): Gustav Amberg

Graduate student(s): M. Do-Quang

Sponsor(s): PSCI

The possibility of simulating reasonably complete mathematical models of welding is explored in this project. These simulations are characterized by complex physical phenomena such as surface tension driven convection, electromagnetic forces, heat and mass transfer, solidification and melting, etc. The surface tension must be modelled realistically, including the solution of convective diffusion equations restricted to the melt - gas interface, for surface concentrations of surface active substances. The Reynolds numbers that are encountered are such that the melt flow is between a rapid laminar flow with thin boundary layers, up to transitional unsteady or even turbulent flow. There are also different timescales in this problem, since the timescale for the melt flow is much shorter than the timescale for melting/solidification. These simulations would typically be either time dependent axisymmetric or steady three-dimensional. The main effort in this project will be to improve the modelling to make predictions of weldability for realistic steels. The aim is to make this sufficiently reliable to be used as a tool for predicting welding properties of new materials. The knowledge that is generated should eventually be made available to industry as improved expert systems or small simulations that can be done online. Apart from development of the physical models, a significant development of the numerical techniques must be carried out in order to deal with the somewhat nonstandard mathematical models in an efficient way. There will be a close coupling between simulations made at KTH and corresponding experiments at Avesta Sheffield.

Higher-order finite difference methods for DNS/LES in complex geometries

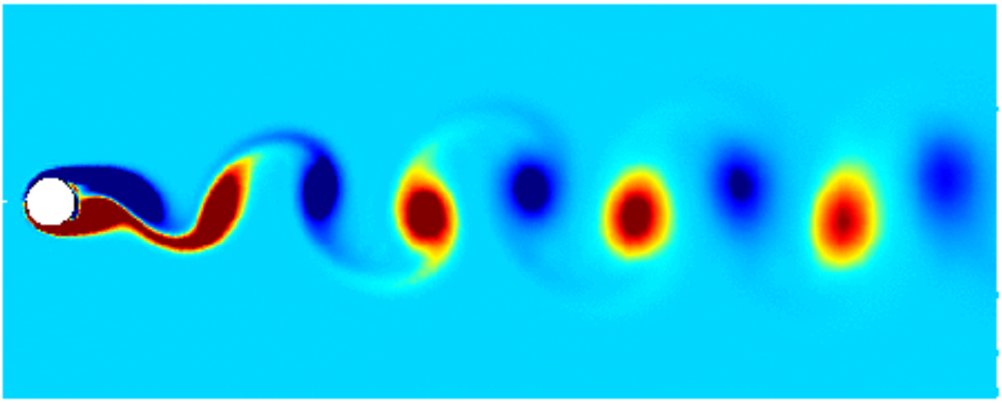
Researcher(s): Dan Henningson, Arne Johansson, Bertil Gustafsson, Per Lötstedt, Jonas Nilsson

Graduate student(s): Arnim Brüger, Erik Stålberg

Sponsor(s): NGSSC, Uppsala Univ., VR

The aim of this project is to perform direct numerical simulations (DNS) of turb ulent flow phenomena in complex geometries. A so far unique discretisation method of the incompressible Navier-Stokes equations will be used. It is based on higher-order difference methods which allow for the use of curvilinear, staggered meshes. The compact higher-order stencils make it more efficient and less memory demanding than the standard second-order methods routinely used today.

The final goal is to simulate turbulence phenomena on a wing profile geometry. This is an important step towards realistic applications of a DNS method. Another important issue is to simulate turbulent flow separation in an asymmetric diffuser, a case where ongoing experiments is performed at the department of Mechanics. In a further step the DNS code will form a basis for inclusion of large eddy simulation (LES) models. The research will build on the compact higher-order finite difference methods developed in an ongoing cooperation project between the department of Mechanics, KTH and TDB, Uppsala University.



Figur 5: *DNS of the Karman vortex street downstream a circular cylinder*

Boundary layer transition - Theory and DNS

Researcher(s): Dan Henningson

Graduate student(s): Luca Brandt

Sponsor(s): FOI, VR

This project involves research to determine the maximum growth possible of disturbances evolving according to linear theory, as well as to investigate the importance of this growth when non-linearity comes into play. Several shear flow types have been considered. The results show that non-modal growth, i.e. growth not associated with individual eigenmodes but inherently dependent on their superposition, can cause large transient amplification. This growth is mainly associated with streaky structures in the streamwise direction. Non-linear calculations have shown that when the optimal disturbances from linear theory are used as initial conditions, the threshold amplitudes required for transition to turbulence is lower than for general disturbances. Recent calculations have also shown that these results carry over into the spatial development of disturbances in boundary layers.

Another part of the project involves direct numerical simulations (DNS) of transition to turbulence where these transient growth mechanisms play a major role. This bypass of the traditional Tollmien-Schlichting instability waves is involved in many shear flow transition scenarios. Previously transition associated with localized disturbances have been investigated, and at present the transition in boundary layers starting with a pair of oblique waves is investigated. These waves generate elongated streakss in the streamwise velocity which rapidly grow due to the non-modal mechanism. The secondary instability of these streaks has also been studied, both using DNS and secondary instability theory.

A new direction in the project is to simulate transition in a boundary layer subjected to free-stream turbulence, where the turbulence is initiated close to the leading edge by a random distribution of continuous spectrum modes.

Active control of boundary-layer transition

Researcher(s): Dan Henningson, Martin Berggren

Graduate student(s): Mattias Chevalier, Jérôme Hoepffner

Sponsor(s): NGSSC, FOI, VR

Study and design of active control strategies for transition in boundary layer flows is done within this project. The control strategies are designed using the optimal-control approach to control of the Navier-Stokes equations and use the adjoint-equation technique for associated gradient computations. Linear optimal control techniques based on the Riccati equation are also explored, where spatially localized convolution kernals have been obtained for both control and estimation. The strategies are applied to control or delay of bypass transition as well as other flow instabilities. The performance of these control laws is quantified in direct numerical simulations by computing transition thresholds. We have shown that the threshold values can be increased by about 500% for random perturbations. By using a physically motivated modification of the objective function we have shown that the linear controllers are also able to relaminarize a low Reynolds number turbulent flow. A new direction of this research is to calculate and evaluate these controllers and estimators for more complicated boundary layer flows such as Falkner-Skan and Falkner-Skan-Cooke flows.

Modern stability prediction methods and control

Researcher(s): Dan Henningson, Martin Berggren

Graduate student(s): Ori Levin

Sponsor(s): KTH, STEM, FOI

The project concerns a new transition prediction tool which is being developed in cooperation with DLR in Gottingen. The code uses the parabolized stability equations (PSE) and is so far based on the linearized equations. The method uses a wave ansatz with a slowly varying amplitude function and wave number, similar to the WKB method. In addition an auxiliary condition is introduced which ensures uniqueness of the solution so that the traditional WKB expansion can be avoided. This method has proven to be effcient and to produce accurate stability results for complicated glows. It has been carefully checked against existing solutions and will be extended to handle non-linear interactions between wave components.

Applications motivating the development of this method is the hypersonic transition research carried out within the ESA FESTIP program and laminar wing design carried out in the CEC EUROTRANS and ALTTA programs.

Another direction in this research is to use optimization methods to predict the transition location in flows with high free-stream turbulence levels. This is done using adjoint methods, similar to those used in the active control project, and parabolic approximations for the stability problem. A new transition prediction method has been proposed. The later stages of transition induced by high free-stream turbulence levels have been studied using secondary stability analysis.

Direct numerical simulation of turbulent separation and separation control

Researcher(s): Dan Henningson

Graduate student(s): Astrid Herbst

Sponsor(s): PSCI, STEM, FOI

Multidisciplinary issues are increasingly affecting performance and complicating the aeronautical design process. There are advanced ideas of use flow control to improve performance, in particular in conditions when inherent sensitivities or instabilities in the flow could be utilized to accomplish large effects by small controls, e.g. flows with substantial regions of separated flow. In addition, correct modeling of turbulence is one of the most crucial areas for design computation of flow around aircraft configurations, including wings and air intakes. Current models are not accurate enough for many common flow cases, especially when they contain zones of separated flow.

Direct numerical simulations (DNS) of turbulent boundary layers with adverse pressure gradients and separation have been performed, including some very larg supercomputer simulations. The data has been used to evaluate models of separated turbulent flow.

A new direction in this project is aimed at control of flow separation in diffusor flows with application to modern engine air intakes. The objective is to obtain a numerical implementation of a complete flow control system for separated flow in a diffusor. This includes DNS/LES flow solvers, modelling of flow sensors and actuators and active flow control algorithms.

Optimal design of vehicles with low drag

Researcher(s): Dan Henningson

Graduate student(s): Jan Pralits

Sponsor(s): SSF, IVS

The project aims at developing methodology needed for optimal design of vehicles with low drag. The general objective is to link aerodynamic computational tools with optimization techniques to create a more automated flow design process in order to improve flow efficiency. The sensitivity of the predicted drag, say, on the design parameters chosen can then effectively be determined by the use of so called adjoint methods. The aim is to automatically incorporate a transition prediction method into the design process of low-drag vehicles. This chosen problem should be seen as one interesting example where these optimal design methods can be applied. The techniques developed in the project are general and once mastered could be applied in a number of other design applications.

Active control of flow separation in an asymmetric plane diffuser

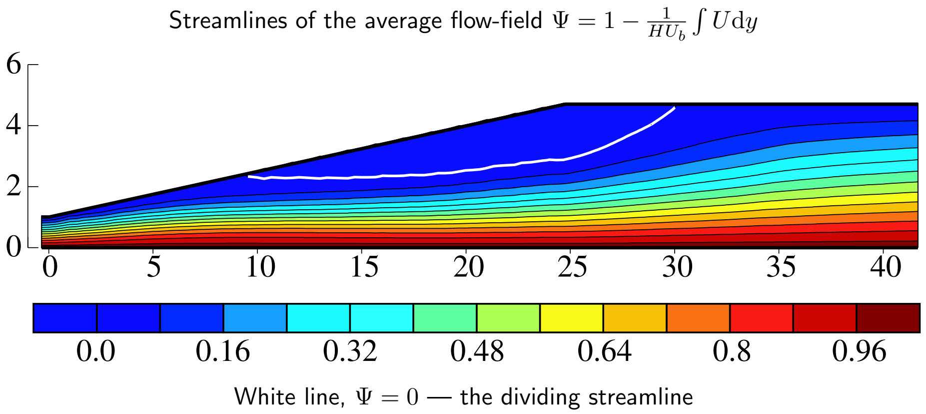
Researcher(s): Arne Johansson, Björn Lindgren

Graduate student(s): Olle Törnblom

Sponsor(s): TFR, STEM, VR

Measurements of the three velocity components and their fluctuations have been carried out in the spanwise symmetry plane of a plane asymmetric diffuser. A data-base with the experimental data has been created and it has been extensively used both to characterize the flow in the diffuser, with special attention to the separated region, and to evaluate turbulence model predictions. The main measurement techniques used are Laser Doppler Velocimetry for the spanwise velocity and its fluctuation and Particle Image Velocimetry for the other two velocity components and their fluctuations. Along with these measurements static wall pressure measurements have been performed to characterize the pressure loss in the diffuser both with separating flow and with attached flow. The attached flow is obtained by use of vortex generators bringing in high momentum fluid into the separated near-wall region and thereby preventing the flow separation.

The work has been documented in three papers focusing on the flow characteristics, comparison with model predictions and a description of the experimental procedure respectively. The two first papers have been included in a doctoral thesis (Björn Lindgren) and all three in a licentiate thesis (Olle Törnblom). The work has also been presented at three conferences (Southampton and Lisbon 2002 and at TSFP3 in Sendai 2003). A study have also been made to investigate the possibility of describing the flow control effects of vortex generators by means of time-resolved RANS-computations. In the two-dimensional description only the effects of wall-normal and transverse mixing by the vortex generators are accounted for, but it was shown that much of the control aspects were captured in this relatively simple way. The future focus on this work will be to complement the data-base with further near wall measurements and to implement separation preventing control other than the vortex generator method described above. This addition to the data-base will further improve the possibilities to perform important model prediction comparisons.



Figur 6: *Streamlines and velocity magnitudes from PIV measurements*

Measurement, modelling and simulation of turbulence

Researcher(s): Arne Johansson, Stefan Wallin, Björn Lindgren

Graduate student(s): Johan Gullman-Strand

Sponsor(s): KTH, FOI, IVS, VR

The aim of the project is to develop and critically evaluate models for statistical description of turbulent flows. The main methods used within the present project for gaining further knowledge of the physics of turbulence are experimental studies and direct numerical simulations of turbulent flows. The models so far investigated belong to the realm of one-point closures for the turbulent stress tensor and turbulent heat flux vector to be used for computational fluid dynamics. The main emphasis is laid on closures based on the transport equations for the turbulent stresses. Particularly, our efforts have been focused on the modeling problems of flows exhibiting strongly anisotropic turbulence. Especially the modelling of the inter-component transfer terms have been studied and models for the pressure strain-rate have been proposed. New formulations of explicit algebraic Reynolds stress models have been derived and tested with considerable success in a number of test cases including complex cases such as a Mach 5 turbulent boundary layer with shock induced separation. Generalizations of such models in order to take into account effects of strong streamline curvature and rotation have also been develepod within this project. Also formulations of explicit algebraic Reynolds flux models have been derived and tested against experiments and direct numerical simulation of passive scalar transport in a turbulent channel flow. In conjunction with this modelling work also a DNS study of turbulent channel flow with heat transfer has been carried out.

A new versatile tool for testing and calibrating turbulence models in general 2D geometries has been developed to the stage where several different types of models have been tested. Eddy-viscosity based two-equation models and explicit algebraic Reynolds stress models have been used for the computation of asymmetric diffuser flow. The model tester is based on finite element methods with extensive use of highly automated code generation.

Turbulent boundary layers at high Reynolds numbers and new wind-tunnel design techniques

Researcher(s): Arne Johansson

Graduate student(s): Björn Lindgren

Sponsor(s): Göran Gustafsson's Foundation, VR

For turbulent boundary layers typical Reynolds numbers are in most applications very high, whereas most laboratory experiments have been carried out at low to moderate Re. In the present project boundary layer measurements have earlier been carried out in the MTL wind tunnel at KTH, on a 7 m long boundary layer plate and with free-stream velocities up to 50 m/s. This gives Reynolds numbers based on momentum loss thickness of up to 20,000 or roughly 20 million based on x, which is realistic for practical applications. Hot-wire anemometry was used with miniaturized probes to measure the velocity components. New results concerning the overlap region of turbulent boundary formed an important part of the doctoral theses of J. Österlund, presented in Dec. 1999. The results contradicted some new proposals of a power-law for the mean velocity in the overlap region, and instead cofirmed a classical log-law, although with new values of the constants involved. It was also concluded that the universal overlap region starts further out from the wall than previously assumed. The results of the boundary layer measurements have been put into a data-base that has been further analyzed concerning the evaluation of new scaling laws that have been derived by use of Lie group symmetry methods. The most striking result is the verification of an exponential law for the velocity defect in the outer reion of the turbulent boundary layer. These results can be found in the doctoral thesis of B. Lindgren (theis defence in Dec. 2002) and are now accepted for publication in J. Fluid Mech. This thesis also contains experimental parts related to wind-tunnel design and flow in an asymmetric diffuser.

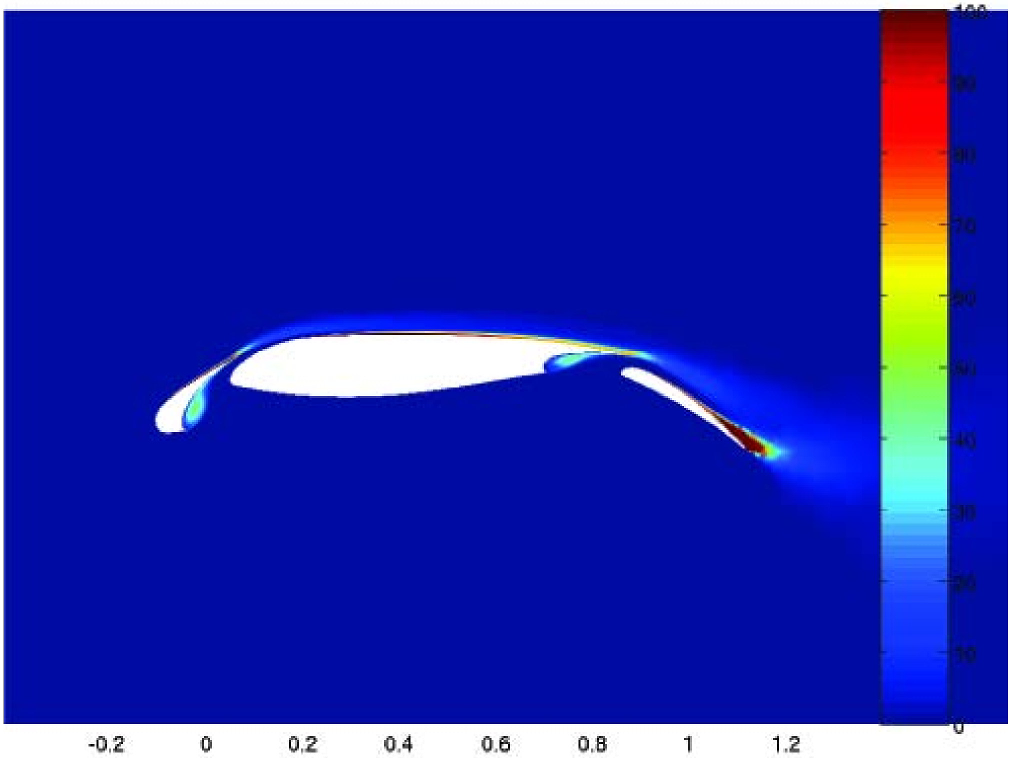
High level modelling for high-lift aerodynamics

Researcher(s): Arne Johansson, Stefan Wallin

Graduate student(s): Olof Grundestam

Sponsor(s): EU

This project is part of a research program (HiAer) funded by EU, with partners also in Finland, Germany, England, Italy and France. It is aimed at one of the big challenges for future generations of European transportation aircraft, namely the development of new and unconventional high-lift devices leading to substantial improvements in both cruise efficiency and landing and take-off performance. The goal of HiAer is to contribute to lowering the industrial cost and risk in design of new high lift systems by improving the flow modelling state-of-the-art CFD tools, and (in the part that concerns this project) to develop new turbulence models and with the aid of these demonstrate accurate prediction of 3D high lift flows. The turbulence modelling work is focussed around explicit algebraic Reynolds stress modelling (EARSM), which is a rational approximation of a full differential Reynolds stress model (DRSM) at a two-equation level. The development work is directed into four different strongly interacting routes:
* Effect of strong streamline curvature will be considered by rational extensions of terms from the DRSM.
* The choice of basic 'length-scale determining' equation in EARSM will be studied and optimised by the use of rational constraints. The near-wall treatment is closely connected to this work. Adaptive 'wall-function' kind of boundary conditions, for optimal grid-point distribution in 3D cases where resolution is critical, will also be considered.
* The choice of basic quasi-linear pressure-strain rate model will be optimised and a reduced functional basis in 3D mean flow will be searched for.
* Finally, a strongly non-linear, realisable DRSM will be tested and possibilities to include such ideas at the EARSM level will be investigated.



Figur 7: *The turbulence kinetic energy predicted by a nonlinear DRSM for a three element high-lift configuration*

Development of 3D LDV measurement techniques with applications to wall bounded shear flows

Researcher(s): Rolf Karlsson

Graduate student(s): Jan Eriksson

Sponsor(s): NUTEK, Vattenfall Utveckling AB

The aim of the project is to develop a practically useful methodology for making simultaneous 3D LDV measurements with high spatial and temporal resolution, and to apply this technique to obtain detailed 3D turbulence data in the plane turbulent wall jet. In a longer perspective, such data will be used to improve near-wall Reynolds stress turbulence modelling. The first phase of the project has now been successfully completed, and measurements in an enclosed circular jet with a measuring volume as small as 0.035 mm have been made. The second phase of the project is to supplement an earlier (2D) experimental investigation of the turbulent wall jet with simultaneous 3D measurements of the total velocity vector. In particular, attention will be focussed on the equation for the turbulent kinetic energy and on the limiting behaviour of the Reynolds stresses near the wall. The 3-component LDV measurements of phase 2 have now been concluded, and a thorough analysis of the results is performed. A paper describing the 2-component measurements has been published in Exp. Fluids. This experiment has also been used as a test case at the ERCOFTAC/IAHR Workshop on Refined Flow Modelling, Paris April 1996 and in Delft June 1997. Together with Prof. W.K. George, USA, and a group at Chalmers Univ. of Technology, the work on a similarity theory of the plane wall jet is just concluded, and a paper will be submitted.

Investigation of turbulent flow separation using PIV

Researcher(s): Barbro Muhammad-Klingmann

Graduate student(s): Kristian P. Angele

Sponsor(s): VR

Flow separation occurs as a result of flow deceleration over the surface of bodies such as lifting wings, turbomachinery blading or diffusers. In most cases flow separation causes severe performance reduction, and it is therefore of great interest to predict. The objective of the present project is to provide experimental data for a well-defined test case, which can be used to develop accurate CFD models. Flow separation can be controlled to some extent by introducing longitudinal vortices in the boundary layer. The effect of such vortex generators on the turbulence structure will be studied experimentally.

The experiments are performed on a flat plate mounted vertically the test section of a low speed wind tunnel. The test section wall opposite to the plate can be expanded to an arbitrary shape, so that the pressure distribution can be varied at will. The boundary layer is removed from the expanding surface by means of suction, forcing the flow to decelerate on the flat plate.

The boundary layer development is studied using LDV and PIV. The PIV technique has been tested in both decelerating and non-decelerating boundary layers, and it has been possible to obtain accurate near-wall measurements of both mean and fluctuation velocities - in fact, PIV gives better near resolution for v‘ and u‘v‘ than both hotwire and LDV. But the most interesting use of PIV is maybe the possibility to investigate sublayer streaks. In non-decelerating flow, the sublayer is much thinner than the light sheet, but in decelerating flow the viscous scale increases, making it possible to perform PIV measurements within the sublayer. This becomes all the more interesting in connection with the study vortex generators and their effect on turbulent flow separation.

Supersonic flow separation

Researcher(s): Barbro Muhammad-Klingmann

Graduate student(s): Jan Östlund

Sponsor(s): VR, Volvo Aero Corp.

A new generation of rocket engine nozzles using Flow Separation Control (FSC) is about to be developed. The idea is to allow flow separation during sea level operation, in order to increase performance during flight. Such nozzles have a high potential to increase payload, which eventually means increased capacity to launch satellites. Within the European space programme, an engine based on this concept is planned to be launched 2005, provided that reliable methods can be developed for simulation of the fluid dynamics and associated side load phenomena. Success in this development will immediately reflect on the future competitiveness of VAC on the space craft market, and strengthen Sweden's position as a partner in technical co-operation programmes directed by ESA, as well as the evolving technology co-operation with Russia and USA.

The present research is expected to give
(i) validated turbulence models to be applied in CFD codes for computation of supersonic flow fields with separation
(ii) a method for treating the coupling of fluid flow and structural response.

Apart from their immediate aim, the results will also be directly applicable in military aircraft, e g in the design of afterburners in RAM and SCRAMjets, air-breathing engines, and vectored nozzles used to increase aircraft manoeuvring capabilities.

Activities include
- analysis of data from full and subscale tests,
- developing appropriate CFD-methods for studying the observed phenomena, and
- deriving methods for scaling and engineering correlation.

The CFD program includes turbulence modelling of 3-dimensional time-dependent flow with combustion, requiring heavy computation on parallel machines. The project is mainly performed at VAC, and is closely related to test activities and concept studies for future European spacecraft.

Simulation and modelling of turbulent flow and combustion

Researcher(s): Geert Brethouwer, Arne Johansson

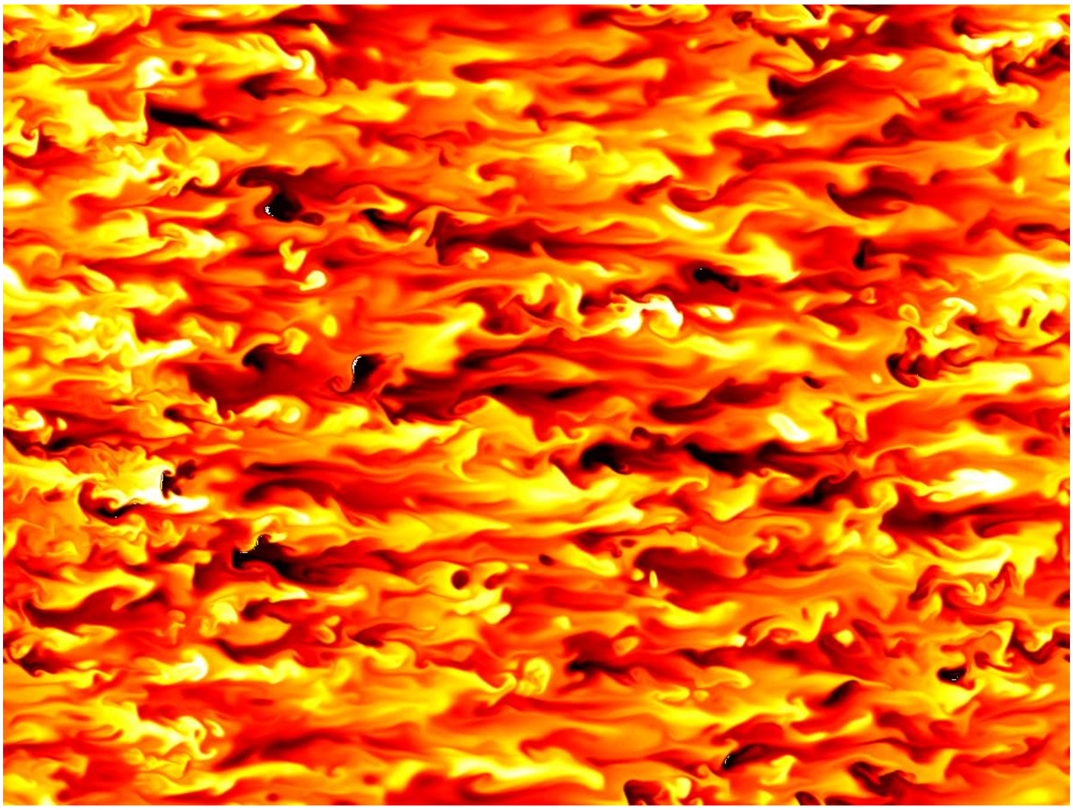
Graduate student(s): Daniel Ahlman

Sponsor(s): VR, STEM, The Göran Gustafsson Foundation,

The aim of the project is to study the effect of rotation and buoyancy on turbulent shear flows and turbulent mixing using DNS and to proceed the modeling work of the KTH-mechanics group. The aim is in particular to extend the recently developed Reynolds stress models and scalar flux model with the description of the effects of rotation and buoyancy on turbulence and turbulent mixing so that the models are applicable for a wider range of problems.

Walls have a significant influence on the combustion process in many practical applications like car engines and gas turbines. One of the important reasons is that the walls are in general much colder than the burning mixture. The heat transfer to the wall leads then to a relative low temperature of the fuel-oxidizer mixture near the wall. Due to the relative low temperature the combustion rate in the near wall region is slower than in the rest of combustion chamber and it is even possible that the fuel is not completely consumed which leads to pollution. The goal of this project is to study combustion in the near wall region by means of highly accurate direct numerical simulations (DNS).

The system that will be simulated is combustion in a compressible turbulent channel flow with cold walls. In this channel a simple reaction takes place between a partly premixed fuel and oxidizer. In addition to the simulation work a model for turbulent combustion will be developed. The recently developed EARSM (explicit algebraic Reynolds-stress model) and EASFM (explicit algebraic scalar flux model) will be extended so that they can take into account the density variations in a non-isothermic turbulent flow. In a later stage the EARSM and EASFM will be combined with a model to describe the reaction of the fuel and the oxidizer. The developed turbulent combustion models will be validated with the DNS data. A DNS code is being developed for this purpose. Compressible round and plane jet flows were first tested to validate the code. The code is now adapted for cmpressible wall-jet flow with a passive scalar. The results for this case will be presented at the 10th European Turbulence Conference, June 2004. The project is part of the STEM-financed CECOST program.



Figur 8: *The instantaneous fluctuations of a scalar in a turbulent shear flow, extracted from a direct numerical simulation.*

Nonlinear interactions between internal gravity waves

Researcher(s): Erik Lindborg

Sponsor(s): VR

The project will study the dynamics of a strongly stratified fluid, with special emphasis on non-linear interactions between internal gravity waves. Theoretical and numerical investigations will be combined with statistical analyses based on data from MOZAIC data base, consisting of wind, temperature and ozon records from a large number of commercial air flights.

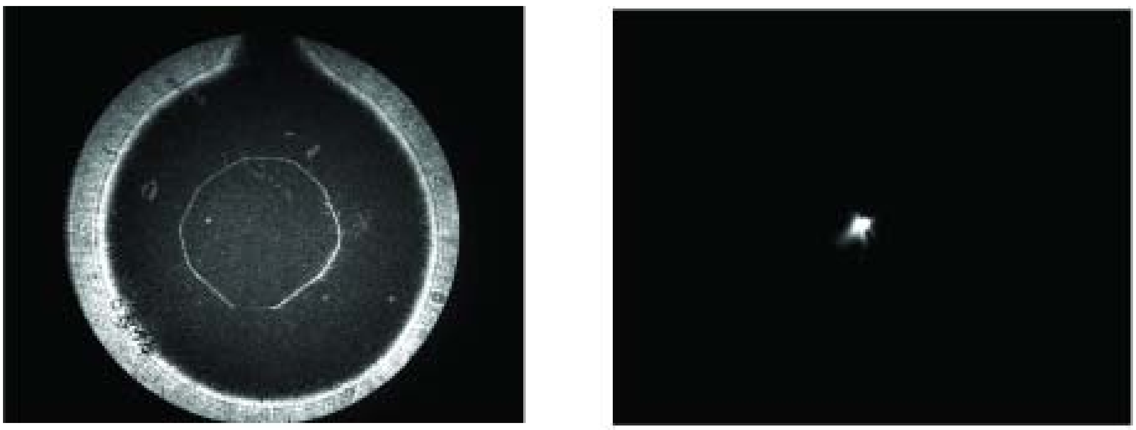
Shock enhancement of sonoluminescence

Researcher(s): Nicholas Apazidis, Nils Tillmark, Martin Lesser, Hanno Essén

Graduate student(s): Veronica Eliasson

Sponsor(s): VR, The Göran Gustafsson Foundation

The main objective of this project is to investigate experimentally and theoretically the possibility of enhancement of bubble collapse and sonoluminescence by action of strong, highly symmetrical and stable polygonal shocks. Generation and stable behavior of this type of converging shocks has been investigated experimentaly and theoretically by the members of the group. The experimental study will be conducted by means of a new type of a shock tube.



(a) (b)

Figure shows experimental results obtained by means of a new shock tube with a specially constructed chamber. (a) A strong stable converging shock with a polygonal shape.
(b) Luminescence spot at the center of the chamber observed at the final stages of the shock convergence.

Paper structure control through boundary layer flow

Researcher(s): Henrik Alfredsson, Daniel Söderberg, Bo Norman,

Graduate student(s): Richard Holm

Sponsor(s): BiMaC, KTH

The objective of the project is to develop the appropriate equipment for the study of fibre flows near phase boundaries in order to be able to affect fiber anisotropy in the manufacture of paper or board sheets. This anisotropy is only a function of the sheet forming process. and anisotropy variations in the plane of the paper sheet as well as throughout the sheet thickness can cause defects in the final product. However, if fibre anisotropy could be controlled it would open new possibilities, through i.e. headbox design, to actively control the structure of paper products. Based on earlier findings there seems to be a large potential to use boundary layers to control fibre orientation and flocculation in papermaking suspensions.

The focus of the project has so far been to develop methods to quantify fiber anisotropy in a flowing suspension close to a solid boundary. The equipment is based on image capturing hardware and image processing techniques that are being developed. Presently the hardware is functioning and the software is being further developed. This is performed as a project at UBC, Vancouver, Canada and especially the gravitational settling of a fiber suspension has been studied.

Two-phase modelling of dilute fibre suspensions.

Researcher(s): Anders Dahlkild, Marko Hyensjö, Jari Hämäläinen

Sponsor(s): VR, Metso Paper

It is known from experiments that flocs of fibre networks may form or disrupt in certain flows. In the project we try to increase the knowledge how the flocs are formed and disrupted from theoretical considerations. The properties of the final paper are to a large extent influenced by the way the fibre suspension is treated and dewatered in the so called forming unit. An important part of the forming unit is the head box which ejects the suspension into the dewatering stage of the process in form of a wide jet. Two critical components of the headbox is the turbulence generator, which acts to disperse the fibres uniformly in the water, i.e. without flocs, and the following converging channel which produces the thin jet of fibre suspension that will become the final paper sheet. In the converging channel, after the turbulence generator, there is a tendency of the reformation of flocs which will appear as a non-uniformity of the produced paper sheet . For paper manufacturing the increased knowledge of how these two components work and interact is of fundamental importance, and the project therefore focuses on this. The goal is to refine existent fibre flocculation models and to develop a computational tool that can be validated against experiments and predict the flocculation process in a headbox. The work is expected to result in a doctoral degree.

Modelling of concentrated fibre suspensions

Researcher(s): Anders Dahlkild, David Hammarström, Jari Hämäläinen, Kenneth Eriksson

Sponsor(s): Faxén Laboratoriet

Handling of high consistency fibre suspensions has become increasingly important in the paper making process industry. The objective of the present project is to improve the techniques for computational simulation of flow of high consistency fibre suspensions. Different methods/models will be tested and refined, such as non-Newtonian rheological models and multi-phase models. Computational results will be validated against experimental data as far as they are or become available for these complex flows.

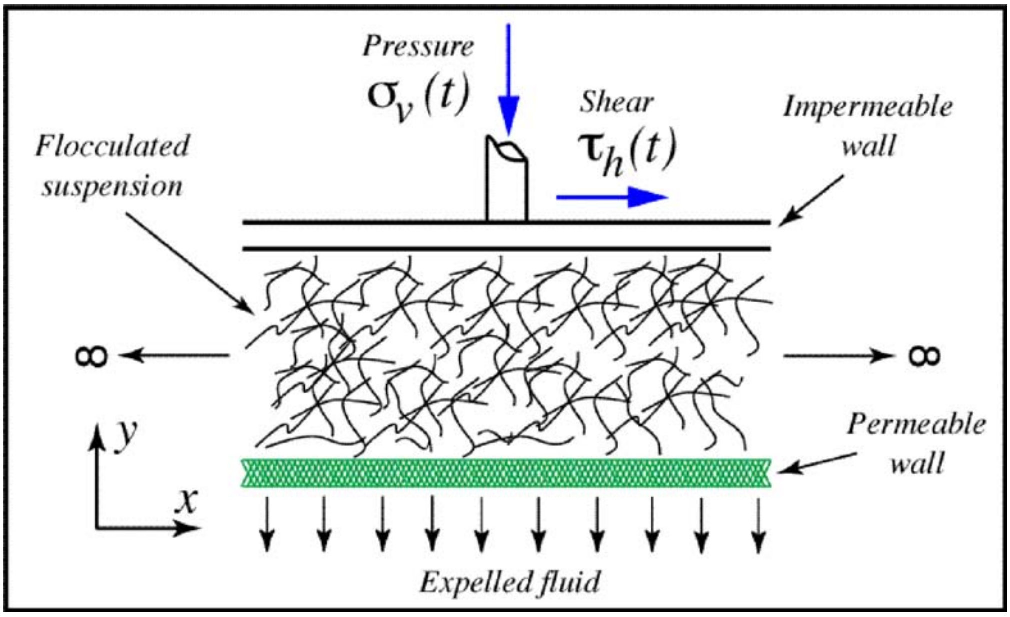
Numerical methods for the flow at multiple blade twin-wire forming of paper

Researcher(s): Anders Dahlkild

Graduate student(s): Claes Holmqvist

Sponsor(s): Faxén Laboratory

The fundamental aspects of dewatering between two wires is to a great extent known, but presently not accurately quantified for dewatering over multiple blades in a series. Detailed knowledge of the involved mechanisms, e.g. wave propagation on free wires, facilitates controll of dewatering and straining of the fiber suspension, which in turn can be used for control of flock distribution and fibre orientaion. The latter factors determine the quality of the paper.



Figur 9: *Sketch of dewatering of a floculated fibre suspension*

Development of an electro-dialysis cell for continuous removal of nitrate from ground water.

Researcher(s): Anders Dahlkild, Göran Lindbergh, Anna Velin, Mårten Behm

Graduate student(s): Carl-Ola Danielsson

Sponsor(s): Faxén Laboratoriet

In this project, a specific water filtration device an electrodialysis-type cell that incorporates grafted non-wovens as ion exchange textile is developed. The equipment is to be used for waste treatment and is to be suitable for treating effluents that already have low concentration impurities, but need to be purified further to a ppb level. The objectives are to design equipment that has large surface area for the ion exchange material per unit volume of cell, to develop mathematical models for the velocity, pressure field and the current-potential distribution inside the designed cell, and to construct and validate the equipment in the field of effluent treatment.

Cold gas quenching

Researcher(s): Noam Lior, Fritz Bark, Arthur Rizzi

Graduate student(s): Roland Wiberg, Olivier Macchion

Sponsor(s): Faxén Laboratoriet

Previous researchs have shown that cold gas flow nonhomogeneities create distortions of the metal parts during quenching. This project aims at defining which parts of a furnace should be optimized in order to minimize those disortions.

6.4 Education didactics

National training center for educational management in Moldova

Researcher(s): Göran Karlsson

Sponsor(s): EU

Project initiated by Institute for Continuing Education at State University of Moldova to create a National Training Center for Educational Management in Moldova to meet the needs of educational professionals functioning in senior management roles in national and provincial governments, universities and other higher education institutions, colleges and schools, by assisting them to develop their understanding and skills in respect of current educational management law, theory and practice and to prepare them for leadership roles at national and international levels. EU-project: IB_JEP-22056-2001 Partners: (1)State University of Moldova: Institute for Continuing Education (Chisinau), (2) University of Alicante, (3) Ministery of Education and Science (Chisinau) Moldova (4) Kungl. Tekniska Högskolan [KTH] (Stockholm) Sweden (5) Centrinity AB (Uppsala) Sweden.

7 Research activities

7.1 Doctoral theses defended 2003

Fredrik Lundell

Thesis title: Experimental studies of bypass transition and its control
Date: March 14 , 2003
Faculty opponent: Prof. Kwing-So Choi, University of Nottingham
Evaluation Commitee: Prof. Ulf Ringertz, KTH, Prof. Håkan Gustavsson, Luth, Prof. William George, Chalmers
Main Advisor: Prof. Henrik Alfredsson

Luca Brandt

Thesis title: Numerical studies of bypass transition in the Blasius boundary layer
Date: May 20 , 2003
Faculty opponent: Prof. Ulrich Rist, Stuttgart University, Germany
Evaluation Commitee: Prof. Arthur Rizzi, Aeronautics, KTH, Prof. Lennart Löfdahl, CTH, Dr Johan Westin, Hägglunds AB
Main Advisor: Prof. Dan Henningson

Karl Borg

Thesis title: Dynamics of bodies small compared to the mean free path in gases
Date: June 11 , 2003
Faculty opponent: Prof. Kazuo Aoki, University of Kyoto
Evaluation Commitee: Docent Johan Grundberg, Mälardalens högskola, Docent Alexei Heintz, Department of Mathematics, Chalmers, Prof. Bo Thidé, Swedish Institute of Space Physics, Uppsala
Main Advisor: Docent Lars Söderholm

Kristian P. Angele

Thesis title: Experimental studies of turbulent boundary layer separation and control
Date: June 12 , 2003
Faculty opponent: Prof. Per-Åge Krogstad, NTNU, Trondheim
Evaluation Commitee: Prof. William George, CTH, Docent Said Zahrai, ABB CR, Dr. Carl Häggmark, Alfa Laval
Main Advisor: Docent Barbro Muhammad-Klingmann

Henrik Sandqvist

Thesis title: Theoretical studies of acoustic waves with consideration of nonlinearity, dispersion, dissipation and diffraction
Date: June 13 , 2003
Faculty opponent: Prof. Oleg Rudenko, Moscow
Evaluation Commitee: Docent Claes Hedberg, Blekinge Tekniska Högskola, Docent Börje Nilsson, Växjö Universitet, Prof. Mats Åbom, Farkostteknik, KTH
Main Advisor: Prof. Bengt Enflo

Jan Pralits

Thesis title: Optimal design of natural and hybrid laminar flow control on wings
Date: October 7 , 2003
Faculty opponent: Prof. Patrick Huerre, LadHyX - Ecole Polytechnique, France
Evaluation Commitee: Prof. Jesper Oppelstrup, KTH, NADA, Prof. Per Lötstedt, TDB, Uppsala University, Dr. Yngve Sedin, Saab Aerospace, Saab AB, Linköping
Main Advisor: Prof. Dan Henningson

Irina Loginova

Thesis title: Phase-field modeling of diffusion controlled phase transformations
Date: October 31 , 2003
Faculty opponent: Prof. Ryo Kobayashi, Hokkaido University, Sapporo
Evaluation Commitee: Dr Peter Hansbo, Tillämpad Mekanik, Chalmers, Dr Malin Selleby, Materialvetenskap, KTH, Dr Ingvar Svensson, Högskolan i Jönköping
Main Advisor: Prof. Gustav Amberg

Jan Eriksson

Thesis title: Experimental studies of the plane turbulent wall jet
Date: November 14 , 2003
Faculty opponent: Prof. Ronald Adrian, Univ. of Illinois
Evaluation Commitee: Prof. Håkan Gustavsson, LTU, prof. Tor-Göran Malmström, KTH, Prof. Poul Scheel-Larsen, DTU, Lyngby
Main Advisor: Prof. Fritz Bark

Junichiro Shiomi

Thesis title: Control of oscillatory thermocapillary convection
Date: December 5 , 2003
Faculty opponent: Prof. Diedrich Schwabe, Giessen Unviersity
Evaluation Commitee: FD, Martin Berggren, TDB, Uppsala Univ., Dr T. Carlberg, Dr. Per Elofsson, Scania
Main Advisor: Prof. Gustav Amberg

Jens Fransson

Thesis title: Flow control of boundary layers and wakes
Date: December 12 , 2003
Faculty opponent: Prof. Frans Nieuwstadt, Delft University of Technology
Evaluation Commitee: Prof. Håkan Gustavsson, LTU, Prof. Torsten Fransson, KTH, Dr. Stefan Szepessy, Alfa Laval
Main Advisor: Prof. Henrik Alfredsson

7.2 Licentiate theses presented 2003

Olle Törnblom

Thesis title: Experimental study of the turbulent flow in a plane asymmetric diffuser
Date: January 15, 2003
External examiner: Prof. Rolf Karlsson, Vattenfall Utveckling AB
Main Advisor: Prof. Arne Johansson

Karl Erik Birgersson

Thesis title: Modelling of transport phenomena in direct methanol and proton exchange membrane fuel cells
Date: February 27, 2003
Main Advisor: Docent Michael Vynnycky

Thomas Hällqvist

Thesis title: Numerical study of impinging jets with heat transfer
Date: May 28, 2003
External examiner: Prof. Lars Davidsson, Chalmers
Main Advisor: Prof. Laszlo Fuchs

Timmy Sigfrids

Thesis title: Hot wire and PIV studies of transonic turbulent wall-bounded flows
Date: June 2, 2003
External examiner: Prof. Richard Gebart, LTU
Main Advisor: Prof. Henrik Alfredsson

Federica De Magistris

Thesis title: Combined shear and compression analysis using a modification of the losipescu shear test device
Date: September 3, 2003
External examiners: Prof. Myat Htun, Mitthögskolan and Prof. Ola Dahlblom, LTH
Main Advisor: Prof. Anders Eriksson

Luca Facciolo

Thesis title: Experimental study of rotating pipe and jet flows
Date: November 20, 2003
External examiner: Prof. M. Sandberg, HiG
Main Advisor: Prof. Henrik Alfredsson

Minh Do-Quang

Thesis title: Parallel computations on fusion welding and floating zones
Date: December 8, 2003
External examiner: Prof. Lars-Erik Lindgren, LTU
Main Advisor: Prof. Gustav Amberg

Ori Levin

Thesis title: Stability analysis and transition prediction of wall-bounded flows
Date: December 17, 2003
External examiner: Docent Ardeshir Hanifi, , FOI
Main Advisor: Prof. Dan Henningson

7.3 Publications 2003

7.3.1 Papers published in archival journals and books

Referenser

[1] Amberg, G. 2003 A semi-sharp phase field method for quantitative phase change simulations. *Phys. Rev. Lett.* **91**, 265505.

[2] Apazidis, N. 2003 Focusing of strong shocks in an elliptic cavity. *Shock waves* **13**, 91–101.

[3] Battini, J.M., Pacoste, C. & Eriksson, A. 2003 Improved minimal augmentation procedure for the direct computation of critical points. *Comp. Meth. Appl. Mech. Eng.* **192**, 2169–2185.

[4] Borg, K., Söderholm, L. H. & Essèn, H. 2003 Force on a spinning sphere moving in a rarefied gas. *Phys. Fluids* **15**, 736–41.

[5] Brandt, L., Cossu, C., Chomaz, J.–M., Huerre, P. & Henningson, D.S 2003 On the convectively unstable nature of optimal streaks in boundary layers. *J. Fluid Mech.* **485**, 221–242.

[6] Brethouwer, G., Hunt, J.C.R. & Nieuwstadt, F.T.M. 2003 Micro-structure and Lagrangian statistics of the scalar field with a mean gradient in isotropic turbulence. *J. Fluid Mech.* **474**, 193–225.

[7] Di Bernardo, M., Kowalczyk, P. & Nordmark, A. 2003 Sliding bifurcations: A novel mechanism for the sudden onset of chaos in dry friction oscillators. *Int. J. Bifurcat. Chaos* **13**, 2935–2948.

[8] Ferrari, J., Lior, N & Slycke, J. 2003 An evaluation of gas quenching of steel rings by multiple-jet impingement. *J. Mat. Proc. Technol.* **136**, 190–201.

[9] Fransson, J. H. M. & Alfredsson, P.H. 2003 On the disturbance growth in an asymptotic suction boundary layers. *J. Fluid Mech.* **482**, 51–90.

[10] Fransson, J. H. M.& Alfredsson, P.H. 2003 On the hydrodynamic stability of channel flow with cross flow, *Phys. Fluids* **15**, 436–441.

[11] Fransson, J. H. M. & Corbett, P. 2003 Optimal linear growth in the asymptotic suction boundary layer. *Eur. J. Mech. B/Fluids* **22**, 259–270.

[12] Högberg, M. Bewley, T.R. & Henningson, D.S. 2003 Linear feedback control and estimation of transition in plane channel flow. *J. Fluid Mech.* **481**, 149–175.

[13] Högberg, M., Bewley, T.R. & Henningson, D.S. 2003 Relaminarization of $Re_\tau = 100$ turbulence using gain scheduling and linear state-feedback control. *Phys. Fluids* **15**, 3572–3575.

[14] Högberg, M., Chevalier, M. & Henningson, D.S. 2003 Linear compensator control of a pointsource induced perturbation in a Falkner-Skan-Cooke boundary layer. *Phys. Fluids* **15**, 2449–2452.

[15] Inasawa, A., Lundell, F., Matsubara, M., Kohama, Y. & Alfredsson, P. H. 2003 Velocity statistics and flow structures observed in bypass transition using stereo PTV. *Exp. Fluids* **34**, 242–252.

[16] Kron, J., Bellet, M., Ludwig, A., Wendt, J., Pustal, B. & Fredriksson, H., 2003, Cooperation within MEBSP on the subject of air gap formation during a casting process, *Adv. Eng. Mat.*, **5**, 78–79

[17] Levin, O. & Henningson, D.S 2003 Exponential vs algebraic growth and transition prediction in boundary layer flow. *Flow, Turbulence and Combustion*, **70**, 183–210.

[18] Loginova, I., Odqvist, , Amberg, G., & Ågren, J. 2003 The phase-field approach and solute drag modeling of the transition to massive gamma to alpha transformation in binary Fe-C alloys, *Acta Materialia*, **51**, 1327–1339

[19] Lundell, F. & Alfredsson, P.H. 2003 Experiments on control of streamwise streaks. *Eur. J. Mech. B/Fluids* **22**, 279-290.

[20] Lundell, F. 2003 Pulse–width modulated blowing/suction as a flow control actuator. *Exp. Fluids* **35**, 502–504.

[21] Sachdev, P.L., Enflo, B.O., Rao, Ch.S., Vaganan, B.M. & Goyal, P. 2003 Large-time asymptotics for periodic solutions of some generalized Burgers' equations. *Stud. Appl. Math.* **110**, 181–204.

[22] Shiomi, J., Kudo, M., Ueno, I., Kawamura, H. & Amberg, G. 2003 Feedback control of oscillatory thermocapillary convection in a half-zone liquid bridge. *J. Fluid Mech.* **496**, 193–211.

[23] Söderberg, L. D. 2003 Absolute and convective instability of a relaxational plane liquid jet. *J. Fluid Mech.* **493**, 89–119.

[24] Vynnycky, M. & Birgersson, K. E. 2003 Analysis of a model for multicomponent mass transfer in the cathode of a polymer electrolyte fuel cell. *SIAM J. Appl. Math.* **63**, 1392–1423.

[25] Vynnycky, M., Ferrari, J. & Lior, N. 2003 Some basic analytical and numerical solutions to inverse problems, with application to phase-transformation-tracking-optimized gas quenching. *J. Heat Transfer* **125**, 1–10.

[26] Österlund, J. M., Lindgren, B. & Johansson, A.V. 2003 Flow structures in zero pressure-gradient turbulent boundary layers at high Reynolds numbers. *Eur. J. Mech. B/Fluids* **22**, 379–390.

7.3.2 Papers published in conference proceedings

Referenser

[35] Angele, K.P. 2003 Streamwise vortices for turbulent boundary layer separation control. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 151–155.

[28] Borg, K., Söderholm, L. H. & Essèn, H. 2003 The transversal force on a spinning sphere moving in a rarefied gas. *Rarefied Gas Dynamics*, **23** (on CD).

[29] Brethouwer, G. 2003 The effect of rotation on a rapidly sheared homogeneous turbulent flow with a passive scalar. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 311–316.

[30] Dahlberg, J.-Å. & Medici, D. 2003 Potential improvement of wind turbine array efficiency by active wake control (AWC). *Proc. European Wind Energy Conference*, Madrid, June 16-19, 2003 (on CD).

[31] Do-Quang, M. & Amberg, G. 2003 Modeling of time-dependent 3D weld pool flow due to a moving arc. *Proc. High Performance Scientific Computing*, Hanoi, March 2003.

[32] Enflo, B.O., Hedberg, C.M. & Rudenko, O. 2003 Nonlinear standing waves in a layer excited by the periodic motion of its boundary. *Proc. 16th International Symposium on Nonlinear Acoustics*, Moscow, pp. 49–52.

[35] Facciolo, L., Tillmark, N. & Talamelli, A. 2003 Experimental investigation of jets produced by rotating fully developed pipe flow. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 1217–1222.

[34] Grundestam, O., Wallin, S. & Johansson, A.V. 2003 A generalized EARSM based on a non-linear pressure-strain rate model. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 69–74

[35] Gullman-Strand, J., Amberg, G. & Johansson, A.V. 2003 Numerical study of separated flow in a plane asymmetric diffuser. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 251–256

[36] Gurbatov, S.N., Enflo, B.O. & Cherepennikov, V.V. 2003 Old-age stage evolution of intense cylindrical and spherical acoustic noise. *Proc. 16th International Symposium on Nonlinear Acoustics*, Moscow, pp. 341–348

[37] Hammarström, D., Hämäläinen, J. & Dahlkild, A. A. 2003 CFD simulation of fiber suspensions. *Proc. 8 th Finnish Mechanics Days,* 12-13 June 2003, Espoo, Finland, pp. 71–77.

[38] Johansson, A.V., B. Lindgren & Österlund, J.M. 2003 Experimental tests of mean velocity distribution laws derived by Lie group symmetry methods in turbulent boundary layers. In *Reynolds Number Scaling in Turbulent Flow*, pp. 257–264. (Ed. A. J. Smits), Kluwer Academic Publishers, (Proc. of the IUTAM Symposium on Reynolds Number Scaling in Turbulent Flow, September 11-13, 2002, Princeton, NJ, USA).

[39] Macchion, O., Lior, N. & Rizzi, A. 2003 Computational study of velocity distribution and pressure drop for designing gas quench chamber and furnace ducts. *Proc. of the International Conference on Advances in Materials and Processing Technologies* 8-11 July 2003, Dublin, Ireland, pp. 155–158.

[40] Molotkov, V.I. & Enflo, B.O. 2003 A more precise equation for sound beams in dissipative fluids. Effect shock-shocks, *Proc. 16th International Symposium on Nonlinear Acoustics*, Moscow, pp. 57–60.

[41] Nilsson, J., Gustafsson, B., Lötstedt, P. & Brüger, A. 2003 High order difference method on staggered, curvilinear grids for the incompressible Navier-Stokes equations. *Proc. of Second MIT Conference on Computational Fluid and Solid Mechanics* MIT, USA 2003.

[42] Shugai, G. A. & Yakubenko, P. A. 2003 Heat transfer processes during the production of XLPE insulated cables. *HT2003-40382, Proc. 2003 ASME Summer Heat Transfer Conference*, July 21-23 2003, Las Vegas, Nevada, USA.

[43] Söderholm, L. H. & Borg, K. 2003 Phoresis in a shearing gas. *Rarefied Gas Dynamics*, **23**, pp. 242–249

[44] Tibert, G. & Pellegrino, S 2003 Deployable tensegrity masts, *Proc. 44th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics, and Materials Conference*, Norfolk VA, April 7-10, 2003, AIAA-2003-1978

[45] Tibert, G. 2003 Optimal design of tension truss antennas. *Proc. 44th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics, and Materials Conference*, Norfolk VA, April 7-10, 2003, AIAA-2003-1629

[47] Tsuji, Y., Lindgren, B. & Johansson, A.V. 2003 Invariant assumption of PDF and mean velocity profile in high-Reynolds number turbulent boundary layers. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 135–138.

[47] Törnblom, O., Lindgren, B. & Johansson, A.V. 2003 Experimental investigation of the turbulence in the separating flow in a plane asymmetric diffuser. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 245–250.

[48] Wallin, S., Hellsten, A., Schatz, M., Rung, T., Peshkin, D. & Johansson, A.V. 2003 Streamline curvature corrected algebraic Reynolds stress turbulence modelling. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 45–50.

[49] Warren, J.A., Loginova, I., Granasy, L., Börzsönyi, T. & Pusztai, T. 2003 Phase field modeling of alloy polycrystals. *Proc. Modeling Casting and Advanced Solidification Processes X* (Eds. D. Stefanescu, J. A. Warren, M. Krane & M. Jolly

[50] Wiberg, R. &Lior, N. 2003 Convection heat transfer coefficientsfor axial flow gas quenching of a cylinder. *Proc. 4 th Intl Conference on Quenching and the Control of Distortion,* 20-23 May 2003, Beijing

[52] Wiberg, R. & Lior, N. 2003 Error causes and magnitudes in thermochromic liquid crystal thermometry. *Proc. of IMECE'03 2003 ASME International Mechanical Engineering Congress & Exposition,* 16-21 November 2003, Washington, D.C., USA.

[52] Yoshioka, S., Fransson, J. H. M. & Alfredsson, P.H. 2003 Evolution of disturbances in a boundary layer with wall suction. *Third Int. Symp. Turbulence and Shear Flow Phenomena*, Sendai, June 25-27, 2003 (Eds. N. Kasagi et al.), pp. 489–494.

7.4 Seminars

January 14 David Haviland, Nanostructure Physics, KTH
Charge and flux solitons in superconducting circuits

January 23 Gustav Amberg, KTH, Mekanik
Simulations of phase change

January 30 Astrid Herbst, KTH, Mekanik
Influence of periodic excitation on a turbulent separation bubble

February 6 Kristian P. Angele, KTH, Mekanik
Streamwise vortices in separation control

February 11 Carlo Cossu, LadHyX - Ecole Polytechnique, France
The stabilizing role of boundary layer streaks on Tollmien-Schlichting waves

February 13 Tom Wright, KTH, Mekanik
Newton's Fluid Dynamics

March 13 Kwing-So Choi, University of Nottingham
Opposition control of near-wall turbulence for drag reduction

March 20 Thomas Hällqvist, KTH, Mekanik
Numerical simulation of steady and unsteady impinging jets with heat transfer

April 24 Ori Levin, KTH, Mekanik
A numerical and experimental study of the Blasius wall jet

May 8 Luca Brandt, KTH, Mekanik
Simulations of transition in boundary layers subjected to free-stream turbulence

May 19 Ulrich Rist, Stuttgart University, Germany
DNS studies of boundary-layer transition and control at University of Stuttgart

May 27 Mikhail Dzugutov, Nada, KTH
Structural and dynamical anomalies in supercooled liquids

June 10 Kazuo Aoki, University of Kyoto
Monte Carlo simulation of rarefied gas flows between two coaxial circular cylinders

June 16 Anthony Sayers, University of Cape Town
Aspects of sports engineering

August 20 Laurent Brodeau, KTH, Mekanik
Development of a Reynolds Stress Model by means of automated code generation

August 26 Cyril Picard, KTH, Mekanik
Visualisation of two-phase flow in a direct methanol fuel cell

September 11 Ola Widlund, KTH, Mekanik, Faxén Laboratory
Modeling of magnetohydrodynamic (MHD) turbulence

September 18 Ardeshir Hanifi, FOI
Docent lecture: Modern transition prediction

October 2 Silke Günther, University of Technology, Darmstadt
Shear free turbulent diffusion: Classical and new scaling laws

October 6 Patrick Huerre, LadHyX - Ecole Polytechnique, France
Self-sustained states in shear flows

October 7 Anders Bodare, Soil and Rock Mechanics, KTH
A simple model for train-induced ground vibration

October 9 Jérôme Hoepffner, KTH, Mekanik
Estimation of wall bounded shear flow

October 9 Michael Vynnycky, KTH, Mekanik
Modelling of two-phase flow in the anode of a direct methanol fuel cell

October 16 Mattias Chevalier, KTH, Mekanik
Turbulent flow estimation

December 11 Frans Nieuwstadt, Delft University of Technology
Some recent development on the transition in cylindrical pipe flow

December 17 Carl-Gustav Unckel, KTH
Calculation of separated laminar boundary layers

8 FaxénLaboratoriet

A short description of FaxénLaboratoriet (web address: http://www.faxenlaboratoriet.se) is given below for 2003. The text in this section is an extract (with some modifications) of the Report to the internaional Evaluation Group 2003. The Department of Mechanics is the host institute for FaxénLaboratoriet.

8.1 Introduction

FaxénLaboratoriet, below referred to as FLA, is a VINNOVA Competence Centre with the goal of making research results and methods in experimental, numerical and theoretical fluid mechanics practically useful for the participating industrial partners. It also has a goal to broaden the multidisciplinary knowledge base of fluid mechanics in industrial process technology by means of a research program leading to Licentiate and Doctoral degrees. The costs of this centre are shared equally between KTH, VINNOVA, and the following industrial partners:

ABB Group Services Center AB/CRC

ABB Power Technology Products AB

ABB Process Industries AB

Albany International AB

Alfa Laval Tumba AB

Borealis AB

Eka Chemicals AB

Ipsen International GmbH

Linde Gas AG

Metso Paper Inc.

M-real

Outokumpu Copper Partner AB

Process Flow Ltd Oy

SAPA AB

SCA Packaging Research

Stora Enso Research

Vattenfall Utveckling AB

The following contribute financially as non-signatory partners:
University of Tokyo
University of Pennsylvania
MISTRA (Stiftelsen för Miljöstrategisk Forskning)
STFI (Svenska träforskningsinstitutet.)

Staff from the following departments of KTH are involved in the activities of FaxénLaboratoriet:

- Alfvénlaboratoriet
- Dept. of Chemical Engineering & Technology
- Dept. of Materials Processing
- Dept. of Mechanics (host department of FaxénLaboratoriet)
- Dept. of Pulp and Paper Chemistry & Technology
- Dept. of Solid Mechanics

The inter-disciplinary character of the work at FLA is well illustrated by the names of these departments.

8.2 Management and organisation of the Centre

Major decisions about the activities of FLA are made by its Board. The present members of this are:
Lars Hanarp (Albany Nordiskafilt AB)
Fredrik Herlitz (Eka Chemicals AB)
Torsten Holm (Linde Gas AG)
Rolf Karlsson (Vattenfall Utveckling AB (Chairman))
Arne Johansson (Dept. of Mechanics, KTH),
Anders Wigsten (Stora Enso Research)
Carl Zotterman (Metso Paper, Inc)

The operative leadership at FLA consists of the following:
Professor Fritz Bark, Dept. of Mechanics, KTH – Director
Dr. Anders Dahlkild, Dept. of Mechanics, KTH - Deputy Director
Dr. Michael Vynnycky, Dept. of Mechanics, KTH - Scientific Coordinator

Ingunn Wester, Dept. of Mechanics, KTH - Administrative Head

The research efforts of FaxénLaboratoriet are aimed at three main areas:

Electrochemical Processes
Materials Processing
Paper Technology

These are all disciplines where fluid mechanics has been traditionally neglected and where, from the FaxénLaboratoriet's initial standpoint, the interdisciplinary intersection of each of these fields with fluid mechanics could in itself be considered a new approach to those fields.

8.3 Research performed at FaxénLaboratoriet

Relevant publications are listed in section 7.3. FaxénLaboratoriet arranged a number of seminars, listed in section 7.4.

8.3.1 Electrochemical Processes

Industrial partners: ABB Group Services Center AB/CRC, Eka Chemicals AB, Vattenfall Utveckling AB.

Other parties: University of Pennsylvania.
Graduate students: Erik Birgersson, Carl-Ola Danielsson, Jan Eriksson, Nulifer Ipek, Niklas Mellgren, Linda Nylén.
Supervisors: Fritz Bark, Mårten Behm, Anders Dahlkild, Göran Lindbergh, Noam Lior, Michael Vynnycky, Anna Welin, Said Zahrai.

General description:
Attention is focused on a better understanding of the fluid mechanics prevalent in several different processes in the electrochemical industry, ultimately with a view to improving current efficiency in electrode reactions, evening out current distribution in multiple-electrode reactors and decreasing energy consumption. A common characteristic of the projects is that flows, usually of electrolyte, are often turbulent and occur in the presence of evolved gas, such as chlorine, oxygen or hydrogen. During the period 2000-3, there has been less focus on gas-evolving electrodes in the chlorate process and effects of turbulence, following the examination of the three students mentioned above; however, new efforts are focused on

- complex electrode kinetics in the presence of electrolyte flow;
- multi-phase flow in the porous backing material of proton exchange membrane fuel cells;
- electrolyte flow through a porous ion-exchange material for the purification of water by electrodialysis.

Whilst the first of these follows on from earlier work on the chlorate process, the latter two are more recent additions to the research programme. The second involves the development of validated mathematical models for the polymer electrolyte fuel cell within the Swedish MISTRA Programmes Fuel Cells for a Better Environment"(1998-2002) and Fuel cells in a sustainable society"(2003-2006), whilst the third is a PhD project that is implemented as an integral part of Vattenfall Utveckling AB's own industrial development of this process. At presently, there are 5 projects in the Electrochemical Processes programme, engaging 6 students in total. For nearly all of the projects, mathematical modelling and numerical simulation is required to describe turbulent and/or multiphase flows. Existing sedimentation models have been developed to account for the flow of small, electrochemically generated bubbles in the narrow gap of a vertical electrochemical cell. An in-house computer code has been developed for Large Eddy Simulation of turbulence in one project, whilst the commercial fluid dynamics software, CFX and the multipurpose commercial software FEMLAB, has been added to and implemented in several of the others. In 3 of the projects, experiments using Laser Doppler Velocimetry (LDV), hot wire anemometry and microelectrodes have been used in tandem with developed theory. In the fuel cell project, models are validated against experimental results of a fuel cell with segmented electrodes developed in a parallel project within the MISTRA programme. Fuel cells have been identified as one of the target areas for FaxénLaboratoriet in the road map for activities into period 4. To strengthen this research area, the search for incremental funding via large multi-partner EU projects has been intensified. In 2003, FaxénLaboratoriet has been

- 2 Integrated Projects (IP)
- 1 Networks of Excellence (NoE)
- 1 Specific Targeted Research Project (STREP).

In addition, FaxénLaboratoriet has coordinated a 9-partner Cooperative Research Project (CRAFT) proposal entitled Development of novel, efficient and validated software-based tools for PEM fuel cell component and stack designers". The proposal (with acronym PEMTOOL) received a favourable evaluation, and FaxénLaboratoriet has entered into negotiations with the EU, with anticipated start of the project being January 2004. In tandem with that project, which will engage two post-docs for two years, a one year post-doc position will also be installed for numerical implementation of fuel cell modelling, to be financed by MISTRA.

8.3.2 Materials Processing

Industrial partners: ABB Group Services Center AB/CRC, ABB Power Technology Products AB, ABB Process Industries AB, Alfa Laval Tumba AB, Borealis AB, Ipsen International GmbH, Linde Gas AG, Outokumpu Copper Partner AB, SAPA AB.
Other parties: University of Pennsylvania, University of Tokyo
Graduate students: Jenny Kron, Olivier Macchion. Gustaf Mårtensson, Lorent Olasz, Roland Wiberg.

Supervisors: Fritz Bark, Hasse Fredriksson, Peter Gudmundsson, Torbjörn Hellsten, Bo Häggblad, Hans Moberg, Arne Johansson, Noam Lior, Galina Shugai, Michael Vynnycky, Petr Yakubenko, Said Zahrai.

General description:
In this research program the focal points are to secure a good overall understanding of two important industrial processes: the continuous casting of steel and copper, and the gas quenching of steel. Other projects deal with the development of turbulence models for use in MHD flows and flows in rapid rotation. A new project, in collaboration between the Departments of Solid Mechanics and Mechanics, concerns the manufacturing of cross-linked polymer (XLPE) high voltage cables in a process that has superficial similarities both to continuous casting and quenching. At present, there are 5 projects engaging 5 students. Numerical simulation, using both in-house and commercial software (CFX and FEMLAB), has been employed in all of the projects to date. It should be noted that the use of CFD for continuous casting and gas quenching, particularly for the latter, is a recent phenomenon in industry, and the progress so far has yielded many new insights. Foremost amongst these has been the optimization of gas quenching chamber design. Whilst, in the main, already-existing turbulence models have been employed for these projects, work done in tandem has been concerned with developing new turbulence models, for instance for continuous casting with electromagnetic braking. Experimental work has also been carried out, for quenching at Diploma level and casting at Ph.D. level.

8.3.3 Paper Technology

Industrial partners: Albany Nordiskafilt AB, Metso Paper, Inc, M-Real, Process Flow Ltd Oy, SCA Packaging Research AB, Stora Enso Research AB.

Graduate students: Roger Bergström, Monica Fällman, Richard Holm, David Hammarström, Claes Holmqvist, Marko Hyensjö, Jordan Ko, Krister Åkesson.
Supervisors: Henrik Alfredsson, Anders Dahlkild, Jari Hämäläinen, Bo Norman, Daniel Söderbergh, Hannes Vomhoff, Said Zahrai.

General description:
In this research program the projects complement each other in that they each investigate, theoretically and experimentally, different stages of the early forming part of the papermaking process, with a view to improving the control of the process, and thence the paper quality per unit cost of raw materials. During the past 3-year period, the overall focus of the projects have generally gone from the simplified assumption that regards the fibre suspension as pure water towards considering different flow phenomena involving fibres. The effect of this change is an intensified interest from industry. This has, for example, resulted in a paper technology seminar at KTH, initiated by the industrial partners. At present, there are 6 projects active, engaging 7 students. The slender geometry present in paper manufacturing has ensured that significant analytical progress has been made in modelling certain stages of the process. In one project, an in-house numerical code was

written to extend such modelling to cover cases of industrial interest. In Sweden, the use of CFD in papermaking is also somewhat new, and this has been done in four of the projects; in one case these simulations have been directly compared with in-house air-flow experiments, which have given important information both about turbulence modelling and machine design. The other CFD projects deal with fibre separation, fibre flocculation and the validation of non-Newtonian models for the flow of concentrated fibre suspensions. An experimental model of the initial stages of the forming section of a paper machine, the KTH-former, has been constructed to perform investigations on flow details that it would be impossible to perform in a working paper machine: for example, the behaviour of a fibre floc passing through a pressure pulse along the wire path has been visually observed with this experimental model former. Recently, experiments for the investigation of the effects of fibres on turbulence using the ultra sound velocimetry probe technique (UVP) and Laser Doppler Velocimetry (LDV) have also been started. The flow here is of a more generic type than that in the KTH-former. A technique to detect fibre orientation in shear flows using particle image velocimetry (PIV) is also under development.

8.4 Financial status

The total cash (in MSEK) contributions for 2003 from the three major parties amounted to:

KTH	4.6
Industry	3.2
VINNOVA	6.0
Other	1.0
Total	14.8

In addition to this, there are also in-kind contributions, totalling roughly 6.6 MSEK (according to budget), from industry and KTH.

8.5 Miscellaneous

The year 2003 at FaxénLaboratoriet: a sample of events

February 27: Lic.Eng. defence, Erik Birgersson
March 11: FLA Board Meeting at KTH
June 11: FLA Board Meeting at KTH
June 13: Lic. Eng. defence, Roger Bergström
November 14: PhD. Defence, Jan Eriksson
November 24 : FLA Board Meeting at KTH
December 11: FLA Board Meeting at KTH