Department of Mechanics

KTH, SE-100 44 Stockholm, Sweden

Activity Report
2000

Contents

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 Jan Pralits and Jesper Adolfsson for building this new system that also allows us to compile a report of this nature in a semi-automatic manner. The report reflects the activities of the eighth budget year of the (new) department of mechanics in education, research and other areas.

Stockholm, February 2001

Arne Johansson, department chairman
Martin Lesser, department vice chairman

1 Introduction

This is the eighth annual activity report of the new mechanics department and covers the year 2000. The mechanics department (web address: http://www.mech.kth.se) has about 80 employees and a yearly turnaround of about 50 MSEK. It is also host department for the Faxén Laboratory, a NUTEK competence centre for the fluid dynamics of industrial processes.

The head of department ('prefekt') is professor Arne Johansson and vice *dito* ('proprefekt') is professor Martin Lesser. The study rector ('studierektor') is Hanno Essén.

The department board consists of: Gustav Amberg, Fritz Bark, Arne Johansson (chairman), Martin Lesser, Lars Thor, Ingunn Wester, Bo Norman (prof. Dept of Paper and Pulp Technology, external board member), Fredrik Lundell (grad. stud. repr.) and an undergraduate student representative.

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

The research activities can essentially be classified into two major areas, *viz.* "Fluid mechanics" and "Theoretical and applied mechanics". In January 2000 there were altogether 40 graduate students active at the department (12 of which are associated with the Faxén Laboratory) and 7 external graduate students in industry and research institutes. Seven doctoral degrees and eight licentiate degrees were awarded during 2000.

The Mechanics department together with fluid dynamics researchers at other KTH departments and at FFA has received the status of Nordic ERCOFTAC Pilot Centre (coordinator: Dan Henningson). A number of partners from the different Nordic countries have joined the centre.

The Faxén Laboratory was formally started July 1995 and is directed by Professor Fritz Bark. The centre comprises activities at four different KTH departments ('Kemiteknik', 'Materialens Processteknologi', 'Mekanik', 'Pappers- och Massateknik') and 19 industrial partners. The activities is divided into three program areas:

- Electrochemistry
- Material process technology
- Paper technology

Altogether 23 doctoral students are active in the program activities (for details see section 8).

Personel related matters 2000

Professor emeritus Olof Brulin died September 9, 2000.

Viviana Wallin was employed 1 January 2000 as administrative assistant.

Katti Lindfors was employed 28 August 2000 as administrative assistant.

Michael Vynnycky was employed 1 January 2000 as scientific coordinator of FLA.

Six new graduate students started.

Ian Cohen started part-time retirement (65%).

Professor Bengt Enflo reached retirement age in June 2000, but continues on a part-time basis (15%).

Jan Ströman retired after some 40 years of service at the department and was replaced in the Gru administration by Katti Lindfors.

Professor Arne Johansson was elected member of the Royal Academy of Sciences (KVA).

Department meetings and miscellaneous

The department board met on Feb. 18, 2000.

A department meeting followed by a Christmas dinner at Hotel Anglais was held December 6, 2000.

A 'samverkansgrupp' consisting of Arne Johansson (chairman) and Ingunn Wester as representatives for the employer, and three representatives for the employee organizations, *viz.* Marcus Gällstedt (SF), Jan Ströman (ATF), and Anders Thor (SACO) has been active. The tasks include, *e.g.* MBL negotiations. Also present during the meetings has been Karl-Erik Thylwe ('skyddsombud').

The department has a contract one hour per week at 'KTH-hallen' for 'innebandy'.

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. Research in fluid mechanics, in particular laminar-turbulent transition. Dean of KTH.

- 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.

- 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. Department vice chairman.

- 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.

- 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- . Research on linear and non-linear hydrodynamic stability and numerical simulation of transitional flows.

'Biträdande respektive gästprofessor'

- 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.

- 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. (30%) at the Mechanics Dept, KTH 1994– Research in CFD methods and models, with application to compressible flows and combustion in engines and furnaces.

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 and docent at KTH.
- 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.
- 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.
- 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 researcher (in Swedish: adjunkter and 1:e fo.ing.)

- Gunnar Maxe
- Pär Ekstrand, Responsible for the department's computer system
- Nils Tillmark, TeknD, Responsible for the department's lab. facilities
- Michael Vynnycky, PhD Univ. of Oxford, Lecturer at Univ. of East Anglia, Norwich 1991-92, Extended research visits in Japan 1992-96, at KTH from 1997.

Research associates (in Swedish: forskarassistenter)

- Barbro M. Klingmann, PhD in Fluid Physics, KTH 1991. Postdoc at EPFL Lausanne and Novosibirsk 1992-94 and at Volvo Aero. 1994-1996. Research on transition and turbulent separation.
- Erik Lindborg, TeknD KTH 1996, Research in turbulence.
- Arne Nordmark. PhD in mechanics 1992. At KTH since 1984. Research in the dynamics of mechanical systems with discontinuous or impulsive forces.

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

- Lars Bjernerstam
- Marcus Gällstedt
- Ulf Landén
- Katti Lindfors
- Anne-Mari Olofsson
- Hans Silverhag
- Jan Ströman
- Ingunn Wester (chefsadm./intendent)

Professors emeritii

Bengt-Joel Andersson
Sune Berndt
Olof Brulin
Stig Hjalmars

Graduate students (in Swedish: doktorander)

Jesper Adolfsson
Krister Alvelius
Kristian Angele
Erik Birgersson (FLA)
Karl Borg
Luca Brandt
Arnim Brüger
Gitte Ekdahl
Luca Facciolo
Jerome Ferrari (FLA)
Jens Fransson
Franck Gregoire
Johan Gullman-Strand
Francois Gurniki (FLA)
Torkel Hambreus (also at FFA)
Richard Holm (FLA)
Claes Holmqvist (FLA)
Carl Häggmark
Marcus Högberg
Nulifer Ipek (FLA)
Bo Johansson
Arif Kalifa
Jukka Komminaho
Anders Lennartsson
Ori Levin
Mats Lind (FLA)
Björn Lindgren
Irina Loginova
Fredrik Lundell
Gustaf Mårtensson (FLA)
Per Olsson
Mehran Parsheh (FLA)
Ivan Pavlov
Petri Piiroinen
Jan Pralits
Henrik Sandqvist
Junichiro Shiomi

Timmy Sigfrid
Martin Skote
Daniel Söderberg (FLA)
Tadahisa Terao
Olle Törnblom
Ruben Wedin (FLA)
Ola Widlund (FLA)
Christian Winkler
Thomas Wright
Jens Österlund

External graduate students (not employed by department of mechanics)

Leonard Borgström, Alfa Laval, Tumba
Mattias Chevalier, FFA
Jan Eriksson, Vattenfall in Älvkarleby
Koji Fukagata (FLA) ABB Corp. Res.
Jan-Erik Gustafsson, STFI
Peter Löfgren (FLA) ABB Corp. Res.
Jonas Gunnarsson, Adtranz
Hans Moberg, Alfa Laval, Tumba
Torbjörn Nielsen (FLA) ABB Corp. Res.
Johan Persson (FLA) Vattenfall Utveckling AB
Roland Rydén. Volvo Aero Corporation in Trollhättan.
Lars Tysell, FFA
Stefan Wallin, FFA
Ulrike Windecker (FLA) ABB Corp. Res.
Jan Östlund, Volvo Aero
Pedro Olivas, INPG, Grenoble

The graduate students with (FLA) after their names are associated with the Faxén Laboratory. Five other graduate students are associated with FLA but employed at other departments at KTH (see section 8).

3 Laboratory facilities, computers

3.1 Laboratory facilities

3.1.1 Wind tunnels

The department has a laboratory with several permanent experimental facilities.

- MTL subsonic windtunnel, 7 m long (1.2 m × 0.8 m) test section, max. speed 69 m/s
- Subsonic wind-tunnel, 0.4 m × 0.5 m test section, max. speed 50 m/s
- New subsonic wind-tunnel (1998), 0.5 m × 0.75 m test section, max. speed 48 m/s
- Shock tube for research and student laboratory exercises

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 used for a variety of long-term research projects on turbulence and laminar-turbulent transition, flow separation and turbulence structure.

A smaller windtunnel based on the same concept as the MTL-tunnel was inaugurated in october 98. The new windtunnel was calibrated and taken into operation during 1999 both in research and education. The tunnel is powered by a frequency controlled 15 kW AC-motor and has the special design feature of expanding corners ($\frac{A_{out}}{A_{in}} = 1.32$) to reduce the overall length.

The department also has access to a continuously running supersonic wind-tunnel, 0.1m×0.1m test section, with 'continuously' variable Mach number (0.7–2.5). The wind-tunnel is stationed at the Department of Energy Technology, KTH.

3.1.2 Other flow facilities

There are also a number of smaller experimental apparatus for research and student demonstration purposes:

- miniature convection cell for study of thermocapillary convection
- model of a headbox for distribution of fiber suspension in paper manufacturing applications
- plane Couette flow apparatus with and without system rotation
- curved or straight rotating channel flow apparatus for studies of instabilities due to centrifugal and rotational effects
- plane Poiseuille flow apparatus (2m×0.8m) for transition studies

- a small water table for student demonstrations
- Hele-Shaw cell and Taylor-Couette apparatus
- a pipe-flow facility for student exercises

3.1.3 Measurement equipment

The PIV system purchased by the Department of Mechanics consists of a Nd:YAG double pulse laser, a high resolution CCD camera capable of storing two consecutive frames at a minimum time separation of 1μs, and a processing unit for crosscorrelation of the two images. The system (laser and camera) runs at a frequency of 15 Hz.

The department has two Laser-Doppler Velocimetry (LDV) equipments. One of the LDV systems is a two-component fibreoptic system from Aerometrics, with a high power Ar laser. The other system is a low energy fiberoptic one-component "FlowLite" system, from Dantec, which is easy to use and to adapt to different measurement situations, including student exercises.

Hot wire techniques are extensively used and constantly developed at the laboratory. Many different types of probes are designed and made 'in-house'. The smallest wires used have a diameter of 0.6μm and a typical length of 0.1 mm. Data sampling is carried out mainly with Macintosh computers.

3.1.4 Other laboratory equipment

The laboratory also has some equipment for flow visualisation

- Schlieren system with possibility for short duration double flash exposure
- High speed camera (up to 500 frames per second) for flow visualisation
- Digital video camera recorder
- Smoke generators both for flow visualisation and particle generation in PIV and LDV.

3.2 Computers

The department has a computer system consisting of 36 SUN workstations running Solaris 2.5.1, 5 IBM-RS6000 workstations running AIX 4.2, (>)55 Macintosh computers and (>)20 PC's running Windows 95,98,NT or Linux. Pär Ekstrand (pe@mech.kth.se) is responsible for the computers, with help from Arne Nordmark. Jesper Adolfsson is responsible for maintaining the departments web pages with help from Jan Pralits.

The system is mainly managed by three servers. A SUN sparc 4 called eiger for central services like mail, printers and DNS. The department has it's own AFS cell and Kerberos realm. There is 54 GB of disk storage in the AFS filesystem distributed on six 9GB disks with two wide SCSI controlers on each server. The disks are placed on two dedicated AFS file servers, a SUN sparc 10 called pollux and a SUN sparc 20 called castor. Both fileservers are dual processor machines. There is an aditional dedicated WWW and FTP server, a SUN Spark 5 called

nadelhorn. The official part of the departments web pages is hosted on an PC running Windows NT.

A PC called vulcan running Linux has been set up as a small modem service with four modems currently connected it also acts as a printer server for the PC's using Samba.

The department has four IBM-RS6000 workstations serving as numbercrushers, a model 590, a model 390, a model 375 and a model 370. They are setup in a DQS batch system. They where acquired 93-95 with grants from the Göran Gustafsson Foundation.

To complement the IBM's the department invested in a Compaq AlphaServer ES40 to serv as a new numbercruncher. It has four EV6 500MHz processors and a total of 3 GB shared memory. It was acquired with grants from the Göran Gustafsson Foundation.

There is also two SUN Ultra2's shared by the department. One called dom for for interactive jobs and one called ask for batch jobs.

A significant amount of computer time has also been granted to some of the research groups within the department from international supercomputer centers.

The department has signed a license agreement for Microsoft software as a part of a central agreement between KTH and Microsoft. It implies that we will have a continuous supply of upgrades, new versions etc of, *e.g.* Word and Excel. Also manuals will be supplied through this agreement (contact person: Lars Thor). The department also has licenses for a number of other softwares products.

4 Economy

A brief overview of the different categories of incoming resources to the department is given below for 2000. The FLA sum does not inlude in-kind contributions.

INCOME (in Mkr)

	Dept. total
Education (GRU)	**10**
Research (FOFU)	**16**
External	**12**
FLA	**11**
Σ	**49**

The external funding is mainly composed of grants from TFR, STEM, SSF, NUTEK, The Göran Gustafsson Foundation, NFR, BFR and KFB.

5 Teaching activities

5.1 Undergraduate courses

Basic courses (grundkurser)

School	Year	Course no.	Credit	Name
K	1	5C1102	4	Mechanics, Smaller Course
VBI , M , T	1	5C1103	6	Mechanics, Basic Course
B, F , V , I	1	5C1103	6	Mechanics, Basic Course
D	2	5C1104	4	Insigths in Mechanics; Orbits and Robots
E, B , T	2	5C1111	4	Mechanics, Continuation Course
M	2	5C1112	4	Mechanics, Continuation Course
F	2	5C1113	4	Mechanics, Continuation Course
VBI, V	2	5C1114	4	Mechanics, Continuation Course
T	2	5C1201	8	Fluid Mechanics with Thermodynamics, for T
F	3	5C1202	4	Fluid Mechanics, Introductory Course

Advanced courses (högre kurser)

School	Year	Course no.	Credit	Name
B, M , T	3	5C1121	4	Analytical Mechanics
T, F , B , M	4	5C1122	4	Continuum Mechanic
T, F , M	4	5C1123	4	Mathematical Methods of Mechanics, General Course
M, T , F	4	5C1125	2	Mathematical Methods of Mechanics, Intermediate Course
T, F , M	4	5C1400	5	Nonlinear Dynamics in Mechanics
F, T , M	4	5C1902	4	Advanced Dynamics of Complex Systems
M, F , T	4	5C1904	4	Advanced Modern Mechanics
M, F , T	4	5C1980	4	Applied Mechanics
T, F	3	5C1203	4	Fluid Mechanics, General Course
F, T , M	4	5C1205	4	Compressible Flow, General Course
M, T , F	4	5C1207	5	Boundary Layer Theory and Thermal Convection
T, M , F	4	5C1208	2	Fluid mechanics, continuation course
T, M , F	4	5C1209	2	Compressible flow, continuation course
M, T , F	4	5C1210	4	Experimental Methods in Fluid Mechanics
M, I	3	5C1921	4,5	Fluid Mechanics for Engineers
T, F , M	4	5C1940	4	Computational Fluid Mechanics
M, T , F	4	5C1992	4,5	Turbulence

6 Research areas - short project description

6.1 Theoretical and applied mechanics

Shock wave propagation in fluids

Researcher(s): Martin Lesser, Nicholas Apazidis

Sponsor(s): TFR

This project deals with propagation of shock waves in liquids and liquid impact problems. Generation, reflection and convergence of shock waves in confined chambers of various forms is investigated on the basis of Whitham‘s non-linear theory of geometrical shock dynamics. This theory has been extended by a new theoretical and computational method, developed by Apazidis & Lesser (1996). The method can be applied to the propagation of shocks arbitrary in strength and form into a medium with no-homogeneous flow conditions. Calculations based on the new approach have been applied to the problems of shock reflec- tion and convergence in various types of confined chambers. It is shown that by an appropriate choice of the form of the reflector boundary one may obtain reflected shock waves having desirable shapes, for example a near-square shape. Also reflectors with parabolic geometry are considered. A cylindrical wave is generated at the focus of the parabolic cross-section. It is shown that con- trary to the linear case the reflected wave is no longer planar. Experimental investigations of shock focusing in a thin confined chamber with a reflector boundary in the form of a slightly perturbed circle have been carried out. Experimental results confirm the possibility of producing polygonally- shaped converging shocks. Technological and medical applications of the project may be found within the fields of shock wave propagation, shock induced collapse of cavities, erosion, disintegration of kidney and bladder stones by means of a shock wave attenuation in lithotriptor devices.

Human and machine locomotion

Researcher(s): Harry Dankowicz, Arne Nordmark

Graduate student(s): Jesper Adolfsson, Anders Lennartsson, Petri Piiroinen

Sponsor(s): TFR, SSF, Volvo Research Foundation

The inherent dynamics of a bipedal, kneed mechanism are studied with particular emphasis on the existence of stable three-dimensional gait in the absence of external, actively regulated, control.

Suitable modifications of geometry and mass distributions are suggested to afford implementation of walking in complicated and potentially changing terrain. Originating in the pioneering work by McGeer and others, the approach is based on the assumption that satisfactory walking motion under actuation can be achieved more efficiently once the mechanism‘s natural dynamics have been accounted for. Thus, the need for actuation is minimized by controlling the system about a motion dynamically achievable by the passive system, rather than imposing a behavior far from such a motion.

Publication(s): (2), (60)

Propagation and diffraction of sound in fluids

Researcher(s): Bengt Enflo, Sergey Gurbatov, Oleg Rudenko, Zbigniew Peradzynski

Sponsor(s): TFR, Göran Gustafsson's Foundation, KVA

In the project basic problems of nonlinear acoustic wave propagation are studied. Burgers' equation and its generalizations are studied by analytical and numerical methods. Applications are found to propagation of shocks and signals in the sea and in the atmosphere. Examples of problems studied by use of equations of Burgers' type are: studying the decay of plane wave pulses with complicated structure, finding asymptotic waveforms originating from spherical and cylindrical sine waves and short pulses, nonlinear acoustic wave propagation in dispersive and layered media and nonlinear propagation of sonic boom waves.

Publication(s): (17)

Diffraction of sound by noise barriers

Researcher(s): Bengt Enflo

Graduate student(s): Ivan Pavlov

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.

Mechanics of The Vasa Steering System

Researcher(s): Martin Lesser

Graduate student(s): Jesper Adolfsson, Gitte Ekdahl, Anders Lennartsson, Tom Wright

Sponsor(s): Internal Funds

The steering mechanism of the Vasa, known as a "whipstaff" was of the type used in ships for a thousand years. It is the only surviving example of this device which for the most part has gone undocumented. A number of issues concerning the way the mechanism has been reconstructed, how it was used and the possible problems of physical damage to the steersman in carrying out his task are at issue. The project, in cooperation with the Vasa Museum and the Science Museum in London is designed to answer these questions. As part of the work we are preparing a simulation of the mechanism which will be placed in the Vasa museum. The simulation is partly an actual copy and partly a servo steered mechanism run by a computer program. Users will get some of the sense of what was involved in steering the ship.

Theorectical acoustical investigations with applications in musical acoustics

Researcher(s): Christer Nyberg

Sponsor(s): KTH

The purpose of this project is to investigate nonlinear generation of combination frequencies in cavities. The tone generation in musical instruments is often described in terms of a clearly defined nonlinear element which can excite the rest of the instrument, treated as a linear, passive, multi-mode cavity. However, linear theory, which requires small amplitudes, seems to be inadequate for describing the sound field in a cavity close to a resonance, as finite amplitudes are predicted even with dissipative effects included. If the sound field is excited by two frequencies close to resonance, nonlinear interaction is therefore expected to become important. Starting with a nonlinear generalization of d'Alembert's wave equation together with appropriate boundary conditions, the acoustic wave field in the cavity is calculated and can then, in the case of periodicity, be decomposed into its Fourier-components.

Dynamics of Moderately and Highly Rarefied Gases

Researcher(s): Lars Söderholm

Graduate student(s): Karl Borg

Sponsor(s): TFR

The kinetics of gases is studied in two regions. Firstly, the region where characteristic lengths are larger than but approach the mean free path. In air at normal conditions, this is the case for flow in channels of diameter of the order of $10^(- 4)$ mm, say. The Burnett equations are reformulated as a hyperbolic system to eliminate the instabilities.

Secondly, the dynamics of gases is also studied in the free molecular flow limit, for flow around bodies with a length scale small compared with mean free path. The effects of the non-Maxwellian character of the distribution function in a nonuniform gas are considered. Axially symmetric bodies are studied. In the case with a temperature gradient, thermophoresis and in the case of shearing the equilibrium temperature is determined. - The influence of wall roughness on the heat exchange of a rarefied gas flow in narrow channels is an example.

Relativistic dissipative dynamics of gases

Researcher(s): Lars Söderholm

Relativistic fluid dynamics has to be applied when macroscopic or thermal speeds are comparable to the speed of light.There is a rather straightforward relativistic generalization of the compressible Navier-Stokes equations, which is often used. It is, however, unsatisfactory in the sense that it is non-causal. The system of equations is partly parabolic. Shear disturbances propagate with infinite speed in the rest frame of the gas, which means backward in time in other frames. To overcome this problem, equations closely related to a truncated Grad system for the Boltzmann equation have been constructed by Müller, Israel and Stewart and later developed into a mature mathematical theory by Hiscock, Lindblom and others.

As, however, a truncated Grad system is not correct even to first (Navier-Stokes) order in the Knudsen number, a first step in the present investigation was to derive from the Boltzmann equation a modified 14 moments system, which is correct to first order. For this system, all modes propagate as waves. A next step is the study of the nonrelativistic limit of the Müller-Israel-Stewart equations. A kinematic concept is introduced, related to Fermi-Walker propagation, which considerably clarifies the nonrelativistic limit of the equations. A basic object of the continuing investigation is to determine the physical accuracy of the different equations.

Nonlinear continuum mechanics

Researcher(s): Lars Söderholm

The equations of continuum mechanics are formulated in arbitrary coordinate systems by means of a Maple program. In particular, the program handles mixed objects like the deformation gradient, with one leg in the present configuration and one in the reference configuration. The manipulation of tensor fields is also made possible.

Nonlinear wave propagation in fluids

Researcher(s): Lars Söderholm

The focus in this project is on the study of higher order effects in nonlinear wave propagation. Such effects are responsible for many important wave phenomena. One example is that of the generation of a wave propagating in the direction opposite to the original wave. This is an effect, which particularly takes place at a discontinuity. A further phenomen is that of the generation of a constant component, related to acoustic streaming. An equation for nonlinear acoustics has been derived from the compressible Navier-Stokes equations. It is exact in the Mach number and correct to first order in the dissipative (Knudsen) number. Terms of the order of Mach number times the Knudsen number are neglected. When the Mach number is of the order of the Knudsen number, the derived equation reduces to the well-known Kuznetsov equation of second order nonlinear acoustics. The equation is applicable to any equation of state. This equation is the basis of the continuing study. Within the same range of approximation, waves propagating in one direction are being studied.

Publication(s): (16)

6.2 Fluid mechanics

Experiments on stability, transition, separation and turbulence in boundary layer flows.

Researcher(s): Henrik Alfredsson, Johan Westin, Nils Tillmark, Masahara Matsubara, Bakchinov, Talamelli, Michael Katasonov

Graduate student(s): Per Elofsson, Fredrik Lundell, Carl Häggmark, Jens Fransson

Sponsor(s): TFR, Göran Gustafsson's Foundation, KVA, KTH

This project 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. Formation of elongated structures may also occur through the interaction between two finite amplitude oblique waves. This, so called, oblique transition scenario has been investigated in a laminar boundary layer in the MTL-wind tunnel where the waves have been generated through a spanwise slot connected to up to six different loudspeakers. This research was included in the doctoral thesis of Elofsson, which was succesfully defended in May 1998. An new experiment has been designed in order to model the streaky structures which are seen in the boundary layer flows and then to develop active control methods. This model experiment uses a channel where the streaks are formed through regularly spaced suction holes and where secondary in stability can be forced. Tests show that this set-up mimicks many of the features of free stream turbulence induced transition and preliminary control experiments are underway. Control will be applied through local (in time and space) suction/blowing at the wall. Transition often occur when a laminar boundary layer separates. One project deals with this type of transition in the MTL-tunnel, where a pressure gradient is imposed by an adjustable bump mounted at the upper wall, forcing separation at the test plate. Hot-wire measurements and flow visualizations showed that the front part of the separation bubble induced on the plate was 2D and steady whereas in the reattachment region an unsteady 3D vortical shedding motion appeared. Flow visualizations further revealed a spanwise periodicity of these vortices. So far experiments on the response of the bubble to the natural wind tunnel disturbances (low level disturbances), controlled disturbances in form of TS-waves as well as grid generated free stream turbulence (FST, level 1.5 conditions frequency spectra from the shear layer show a quite distinct peak from the wave packets indicating that there is a strong wave frequency selection in the shear layer. These waves can be studied in more detail by introducing two-dimensional deterministic waves upstream of the separated region. In the negative pressure gradient boundary layer upstream of the bubble the waves are damped while in the separation region they are strongly amplified (several orders of magnitude). The influence of excitation amplitude and frequency of the waves on the mean flow has been investigated. FST was found to have a significant effect on the structure of the separation bubble and reduced the size of the separated region. Initially the disturbance growth was found to be exponential for the 2D waves and linear in the FST-case, but seemed to saturate at the same level in both cases. A related study of numerical simulations of separated flows is carried out by Prof. Henningson. In connection with the separation experiments a new three wire probe has been developed. The three wires are parallel and in the same plane. The centre wire is run as a conventional hot-wire whereas the two outer wires are run as temperature sensors thereby feeling the temperature wake of the centre wire. These two wires are coupled as two legs of a Wheatsone bridge, thereby giving a signal which directly gives the flow direction. It has been shown that this wire can distinguish reversed flow and thereby increase the accuarcy for measurements in the separated region. Another experiment to better understand the interference between an X-wire and the wall has also been undertaken. An X-wire configuration was set up from two slanted wires which could be moved relative to each other. The measurements were made in a fully developed turbulent channel flow. It was shown that the presence of the wall displaces the effective cooling position of the wires and thereby gives erroneous results close to the wall. A correction method was deviced and it was also found that by intentionally separate the wires it is possible to determine some correlations which otherwise cannot be mea- sured with traditional hot-wire configurations. In cases where body forces affect boundary layer flows other types of instability may be dominating. For instance a boundary layer flow along a wall in a rotating system will be affected by a Coriolis force which can give rise to instabilities in the form of longitudinal vortices. For plane Couette flow with system rotation, the Coriolis force will either be stabilizing or destabilizing across the full channel width. Linear stability theory shows that the critical Reynolds number is as low as 20.65. Our experiments have verified the linear theory and also shown that the flow exhibit a number of interesting secondary instabilities which occur on top of the primary roll cell structure. The experiments show furthermore that rotating plane Couette flow exhibits a rich variety of flow phenomena, some of which has not been observed in other flow situations, such as relaminarization for stabilizing rotation. PIV and LDV measurements are underway to study plane Couette flow both in the rotating and non-rotating cases.

Thermocapillary convection in materials processing.

Researcher(s): Henrik Alfredsson, Gustav Amberg

Graduate student(s): Renaud Lavalley, Christian Winkler

Sponsor(s): TFR, Rörlig resurs, KTH, Nippon Steel

If surface tension depends on temperature, a fluid motion will be induced along a free surface with a temperature gradient. This is an important phenomenon in many materials processes, characterized by large temperature gradients, small volumes of liquid metal, and the presence of free surfaces. This convection is often 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. An experimental study of the transition from stationary to oscillatory motion in buoyant thermocapillary convection has been made. The instability was observed by flow visualizations and PIV measurements, and quantitative agreement was found with numerical calculations. The emphasis is on identifying instability mechanisms and to design efficient active control strategies to suppress oscillations. Welding of the light metals Aluminum and Titanium today presents a number of practical difficulties. The flow in the melt during welding of Al and Ti alloys will be studied by numerical simulation, using tools and models developed in accompanying projects. This will be closely coupled to an experimental study of Al and Ti welding carried out by Torbjörn Carlberg, Sundsvall. The melt flow in stainless steel welding has also been simulated and compared to experiments performed at Nippon Steel, Futtsu,Japan. Another process where thermocapillary convection is crucial is float zone crystal growth. The stability of the flow in such processes are simulated numerically and comparisons are made with actual float zone experiments in space and on earth (Torbjörn Carlberg, Sundsvall). During the work described above, symbolic code generation tools (www.mech.kth.se/ gustava/femLego) have been used to a large extent. Cooperation with Torbjörn Carlberg, Sundsvall, Mårten Levenstam, CTH and Nippon Steel.

Publication(s): (3)

Modelling of magnetohydrodynamic (MHD) turbulence.

Researcher(s): Fritz Bark, Said Zahrai

Graduate student(s): Ola Widlund

Sponsor(s): Faxén Laboratoriet

Electrostatic magnetic fields are used in continuous casting of steel to brake and control the mean flow of liquid metal in the mould. The magnetic field also causes magnetic Joule dissipation of turbulence, thus affecting turbulent transport of heat and mass. Numerical simulations of this and other turbulent magnetohydrodynamic (MHD) flows suffer from the inability of conventional turbulence models to deal with the large anisotropies of length scales in MHD turbulence. The objective of the project is to develop an extended Reynolds-stress closure suitable for modelling of MHD turbulence in engineering applications. The extended closure includes structural information, which is shown to be vital for a correct description of MHD turbulence.

Computing the two-phase flow in gas-evolving, electrochemical cells.

Researcher(s): Anders Dahlkild

Graduate student(s): Ruben Wedin

Sponsor(s): Faxén Laboratoriet

This work aims at develop computational tools for flow in electrochemical reactors with gas-evolving electrodes. Focus is on the effect of the gas bubbles on the process, which are used to force a circulating convective flow of the electrolyte in the reactor. Two-phase flow models are applied compute bubble concentrations and flow velocities in different parts of the reactor. First, a global model is formulated for the whole reactor, where available two-phase flow models of the commercial software CFX is used. An important question to answer is e.g. to predict the flow distribution of electrolyte through the various channels of the electrode packet depending on reactor design. Secondly, a more detailed model of the flow between an electrode pair is developed. A source of bubbles appear on the surface of a gas-evolving electrode. Since the hydrogen bubbles studied are very small, the transport of bubbles away from the electrode in laminar flow conditions is obtained from available models of hydrodynamic diffusion of small Reynolds number-particles.

Publication(s): (40)

Computing the flow of a stratified headbox.

Researcher(s): Anders Dahlkild

Graduate student(s): Mehran Parsheh

Sponsor(s): Faxén Laboratoriet

Using the commercial fluid dynamics software CFX, we have modeled the mixing of the different layers of a three-layer stratified headbox jet. We have studied the transport of a passive scalar component dyed into the middle fluid layer to the other layers. It has been found that vane length has considerable and vane tip shape has little effect on mixing. Vanes shorter than the headbox cause less mixing and vanes longer than the headbox cause more mixing. Parallel slice lips worsens the mixing. Furthermore, the nozzle angle was changed and the optimum angle was found to be between 8-11 degrees.

Hypersonic afterbody flow fields.

Researcher(s): Anders Dahlkild

Graduate student(s): Tor-Arne Grönland

Sponsor(s): ESA

This work is part of a research project performed external to KTH by the team FFA and DASA. The aim of the study is to make a thorough and basic investigation of the importance of different physical and geometrical effects which influence the efficiency and versatility of a hypersonic afterbody design. The complete propulsion system is an integrated part of the airframe of a hypersonic airbreathing vehicle. The vehicle body will act as expansion surface, yielding an unsymmetric expansion of the engine exhaust gases to the surrounding pressure. In the design of such an afterbody there are a number of critical issues of which one needs a thorough knowledge.

Numerical Simulation of Flows of Fluids Containing Small Particles.

Researcher(s): Laszlo Fuchs

Graduate student(s): Per Olsson

Sponsor(s): SSF

In multiphase flow, the models used to describe the resence of particles in a fluid usually ignore the force interaction among particles and a fluid flow governed by the Navier-Stokes' equations. In order to gain some insight into the physical phenomena in a "micro" flow environment, we study the interaction among fixed and moving solid spheres and the surrounding fluid. Due to the presence of attracting and repelling forces that depend on the geometrical configurations, one can expect an intensive and complex motion of the particles when they are allowed to move freely. Due to this effect simple rheological (isotropic) models are inadequate.

Boundary layer transition - Theory and DNS

Researcher(s): Dan Henningson

Graduate student(s): Stellan Berlin, Luca Brandt

Sponsor(s): TFR, FFA

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.

Publication(s): (44), (45)

Active Control of Boundary-Layer Transition

Researcher(s): Dan Henningson, Martin Berggren, Ori Levin

Graduate student(s): Markus Högberg, Mattias Chevalier

Sponsor(s): TFR, FFA, NGSSC

Study and design of active control strategies for transition in boundary layer flows is done within this project. The control strategies will are designed using the optimal-control approach to control of the Navier-Stokes equations and the adjoint-equation technique for associated gradient computations. The strategies will be designed to control or delay bypass transition as well as other flow instabilities. This represents a significant new step compared to previous work almost exclusively devoted to anti-phase modal suppression of two-dimensional TS-waves or wave packets. In particular the aim is to control the growth of streaky structures associated with most bypass transition scenarios. The application is flows with free-stream turbulence, where an optimally designed feed-forward control will be implemented experimentally to delay transition.

Publication(s): (42), (43)

Modern stability prediction methods.

Researcher(s): Dan Henningson, Martin Berggren, Andreas Möller

Graduate student(s): Paul Andersson

Sponsor(s): KTH, FFA

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 efficient 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 EURO-TRANS 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.

A new direction is to incorporate these transition prediction in an automatic manner into engineering CFD codes. This is partly done within the EU project HiAer at FOI/FFA.

Optimal design of vehicles with low drag.

Researcher(s): Dan Henningson, Martin Berggren

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.

Publication(s): (46), (67)

Measurement, modelling and simulation of turbulence.

Researcher(s): Arne Johansson

Graduate student(s): Stefan Wallin, Franck Grégoire, Björn Lindgren, Johan Gullman-Strand

Sponsor(s): TFR, KTH, FFA

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. 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 large effort has also been devoted to formulations of Large Eddy Simulations in homogeneous turbulence and in channel flow geometry. For the latter case also a direct numerical simulation study for various rates of system rotation has recently been finished. The construction of a new wind-tunnel has recently been finished. Together with the MTL tunnel it is a primary experimental tool in this project. A main underlying theme has been the improvement of understanding of the many aspects involved in the development of single point closures of turbulence. Among recent major achievements of the group in the modelling area we may mention:
* the first direct experimental determination of slow and rapid pressure strain-rate
*new versatile, interactive tools for testing and calibration of turbulence models with ongoing work for general 2D-geometries.
* new explicit algebraic models for the Reynolds stress tensor and the passive scalar flux vector
* new simulations of rotating channel flow and channel flow with heat transfer
* a new forcing method to obtain stationary homogeneous turbulence in simulations The 2D model tester is based on finite element methods with extensive use of highly automated code generation.

Publication(s): (6), (9)

Numerical simulation of turbulent pipe flow.

Researcher(s): Arne Johansson

Graduate student(s): Jukka Komminaho

Sponsor(s): KTH

A new code for the direct numerical simulation of turbulent pipe flow is being developed. It is based on spectral methods in all directions with Fourier series in the azimuthal and axial directions and Chebyshev polynomials in the radial direction. This technique has so far not been successfully applied to this problem although attempts in this direction have been pursued by some research groups. The complexity of the algebra involved is quite severe. Verification of the algorithm has been done by comparing analytical and numerical growth rates of eigenmodes. The results from this verification have shown excellent agreement. The code is written in two different versions, one for pipe flow and one for an annular cylindrical geometry. With the latter we have obtained solutions for instabilities and flow patterns in Taylor-Couette flow with an imposed axial flow.

Jukka Komminaho‘s doctoral thesis was presented in December 2000.

Publication(s): (62)

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

Researcher(s): Arne Johansson

Graduate student(s): Björn Lindgren, Jens Österlund

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

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 are carried out in the MTL wind tunnel at KTH, on a 7 mlong 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 is used with X-probes with box sides down to 0.10 mm. A traversing equipment especially suited for measurements in the near-wall region has been constructed and new measurements using single and double probe arrangements have recently been carried out. Measurements of fluctuating wall shear stress with a number of different types of probes have been carried out. Among the techniques are the 'hot-wire on the wall‘ technique and a new MEMS type of sensor developed at UCLA-Caltech. This silicon based sensor was recently tested in the MTL tunnel and was found to have a performance superior to that of traditional hot-films. 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. A new wind-tunnel was inaugurated in October 1998 and its calibration was finished in June 1999. The design and calibration results are included in the Licentiate thesis of B. Lindgren (June 1999). A special feature of this tunnel is that expanding corners are used to eliminate a substantial part of the need for diffusers. In fact, all the area expansion in the plane of the circuit is given by the corners (in total a factor of three). The contraction ratio of nine is achieved by the use of plane diffusers with a total expansion of a factor of three in the direction normal to the plane of the wind-tunnel circuit. The tunnel will be used for a variety of applications with a test section construction that enables easy variation of the design.

Publication(s): (7), (19)

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 Angele

Sponsor(s): TFR

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.

Publication(s): (37)

Supersonic Flow Separation

Researcher(s): Barbro Muhammad-Klingmann, Jan Östlund (fd. Matsson)

Sponsor(s): TFR

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.

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

Researcher(s): Anders Dahlkild

Graduate student(s): Claes Holmqvist

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 controll of flock distribution and fibre orientaion. The latter factors determine the quality of the paper.

Active control of flow separation in an asymmetric plane diffuser

Researcher(s): Arne Johansson

Graduate student(s): Olle Törnblom, Björn Lindgren

Sponsor(s): TFR

The flow in a plane asymmetric diffuser is studied experimentally. For this purpose, an open wind-tunnel with a blowing radial fan has been designed. The inlet conditions are set to be a fully developed turbulent channel flow with a friction Reynolds number of about 2000. The aspect ratio of the flow is 50 at the inlet of the one-sided diffuser the opening is made variable in the experimental setup and the initial studies have used a value of 8.5 degrees, and a ratio of outlet area to inlet area of 4.7. The diffuser design is similar to that of previously made experiments (Buice:1995, Obi:1993a) and theoretical studies (Kaltenbach:1999). By choosing this diffuser shape we can avoid practical problems such as poor two-dimensionality of the flow in the measurement section. The basic flow in this configuration is also of significant interest for turbulence modelling purposes. LDV measurements have been started to map the flow field. Possibilities for active control by blowing and suction through a slit have been prepared with the aim of studying methods of separtion control.

6.3 Education didactics

Distance Education and Flexible Learning

Researcher(s): Richard Hsieh, Göran Karlsson

Sponsor(s): The Distance Consortium

Development of a national distance course for distance teachers. Period of development was Jan. 10 - Sept. 15, 1998 followed by the 5 credit point courses given 1998/1999 and 1999/2000. Cooperating universities: KTH, University of Lund, University of Uppsala, University of Umeå, University of Växjö.

Distance Teacher Education and PBL

Researcher(s): Göran Karlsson

Sponsor(s): Fees from participants organisations

This 5 point credit course was originally developed through private investments outside KTH and from 1998 integrated into KTH continuing education scheme; it is given once or twice every academic year in cooperation with University of Karlstad and Centronics AB, Uppsala.

CECEN - Continuing Education Centres Network in the Oltenia Region.

Researcher(s): Göran Karlsson

Sponsor(s): EU: TEMPUS JEP 12083-97

The objective of the project CECEN is the setting up of a continuing education and retraining centres network 'CECEN' in the Oltenia region in southeast Romania with a multi-disciplinary approach in the areas of high technology (Telecommunications, Computer Science, Software Engineering, Robotics, energy production, mining, public administration, quality control, tourism.) The main outcome of the proposed project envisages setting up of Oltenia University Enterprise Liaisons Centres Network (OLC) aimed for continuing education and retraining for university graduates in the Oltenia region. The regional approach of such an complex endeavour is basically the gradual solution of implementing the restructuring reform of higher education having as an endpoint the future interconnection. These centres are located in all Oltenian universities, Craiova, Petrosani and Targu-Jiu and the major activity planned in are short and medium-term retraining/ updating courses including complementary education in a multi-disciplinary approach. Among other forms of courses, there are planned short intensive courses held by professors from EU partner universities and organisations and short intensive courses for data communications node administrators. These centres (OLC) are to be interconnected via a regional academic computer network as a part of ROEDUNET (Romanian Academic Network).With the contribution of EU university partners a credit recognition transfer scheme for the complementary education, compatible to ECTS, is proposed. Activities 1999: 1. Göran Karlsson participated in project meeting i Munich, Germany, June 15-18, 1999. 2. Göran Karlsson participated in project meeting in Petrosani, Romania, December 8-12, 1999. 3. One guest scientist, Prof. Mircea Grosu, from Craiova visiting the Mechatronics Group at Dept. of Machine Design (Prof. Jan Wikander) Febr.8 - March 6, 1999. 4. Two guest scientists, Assoc. prof. Constantin Pattrascu and Prof. Ilie Diaconu, from Craiova visited Production Engineering at the Dept, of Materials Processing (Prof. Mihai Nicolescu) Nov. 11 - Dec. 15, 1999. 5. Prof. Gheorge-Viorel Stoian and Mr. Dorin Popescu from Craiova visiting Production Engineering at the Dept, of Materials Processing (Prof. Mihai Nicolescu) May 1 -June 30, 2000. 6. Mrs. Sirkku Männikkö from KTH/Stockholm University Dept. of Computer and Systems Sciences gave seminars at Univ. of Craiova June 20-23, 2000. 7. Göran Karlsson and Mihai Nicolescu gave seminars at University of Craiova Dec. 14-18, 2000 and visited Institute of Solid Mechanics of the Romanian Academy in Bucharest Dec. 13, 2000.

7 Research activities

7.1 Doctoral theses defended 2000

Koji Fukagata

Thesis title: Large Eddy Simulation of Particulate Turbulent Channel Flows

Date: February 11 , 2000
Faculty opponent: PhD Olivier Simonin, LNH/EDF, France
Evaluation Commitee: Professor in Fluid Physics Henrik Alfredsson, KTH, MekanikTrädgårdh, Prof. A.E. Almstedt, CTH
Main Advisor: Professor Fritz Bark

Stefan Wallin

Thesis title: Engineering turbulence modelling for CFD with a focus on explicit algebraic Reynolds stress models

Date: February 25 , 2000
Faculty opponent: Dr Thomas Gatski, NASA Langley Research Center
Evaluation Commitee: Professor Håkan Gustavsson, LuTH, Dr. Nathalie Duquesne, Aeronautics, KTH, Graduate student Magnus Olsson, KTH, Mekanik
Main Advisor: Professor Arne Johansson

Carl Häggmark

Thesis title: Investigations of disturbances developing in a laminar separation bubble

Date: March 31 , 2000
Faculty opponent: Prof Per-Åge Krogstad, NTNU, Trondheim, Norge
Evaluation Commitee: Prof. Rolf Karlsson, Vattenfall Utveckling AB, Prof. Ulf Ringertz, KTH, Prof. Bengt Sundén, LTH.
Main Advisor: Professor Henrik Alfredsson

Christian Winkler

Thesis title: Thermocapillary convection in fusion welding and floatzones and the role of surfactants

Date: May 19 , 2000
Faculty opponent: Prof Taransankar DebRoy, The Pennsylvania State University
Evaluation Commitee: Professor Lars-Erik Lindgren, LTU, Guest Professor Laszlo Fuchs, KTH, Mekanik, Dr Staffan Hertzman, Institutet för metallforskning
Main Advisor: Professor Gustav Amberg

Francois Gurniki

Thesis title: Turbulent Convective Mass Transfer in Electrochemical Systems

Date: December 5 , 2000
Faculty opponent: Professor Hiroshi Kawamura, Science University of Tokyo, Japan
Evaluation Commitee: Univ. lektor Jesper Oppelstrup, KTH, Professor Lars Davidsson, CTH, PhD, Doctor Eduardo Fontes, Comsol AB, Tegnergatan 23, Stockholm

Jukka Komminaho

Thesis title: Direct numerical simulation of turbulent flow in plane and cylindrical geometries

Date: December 8 , 2000
Faculty opponent: Helge Andersson
Evaluation Commitee: Univ. lektor Jesper Oppelstrup, KTH, Professor Lennart Löfdahl, CTH, Prof Per Lötstedt, TDB, Uppsala
Main Advisor: Professor Arne Johansson

Ola Widlund

Thesis title: Modeling of magnetohydrodynamic turbulence

Date: December 15 , 2000
Faculty opponent: Prof. Kemo Hanjalic, TU Delft, The Netherlands
Evaluation Commitee: Prof. Bo Lehnert, Alfvénlaboratoriet, KTH, Dr. Magnus Hallbäck, Siemens-Elema AB, Stockholm, PhD Erik Aurell, KTH

7.2 Licentiate theses presented 2000

Ivan Pavlov

Thesis title: Diffraction of sound from a point source against screens with periodical edge profiles

Date: January 1 , 2000
Main Advisor: Ass. ('Biträdande') Professor Bengt Enflo

Tadahisa Terao

Thesis title: Direct numerical simulation of active control of turbulent channel flow

Date: March 22 , 2000
External examiner: Guest Professor Laszlo Fuchs, KTH, Mekanik
Main Advisor: Professor Arne Johansson

Bo Johansson

Thesis title: Experimental study of shock wave focusing in a confined reflector

Date: April 28 , 2000
External examiner: Professor Nils-Erik Molin, Luleå Tekniska Universitet
Main Advisor: Senior Lecturer Nicholas Apazidis

Franck Grégoire

Thesis title: Automated code generation for turbulence models

Date: June 15 , 2000
External examiner: Dr. Nathalie Duquesne, Aeronautics, KTH
Main Advisor: Professor Gustav Amberg

Petri Piiroinen

Thesis title: Passive Walking: Transition from 2D to 3D

Date: August 22 , 2000
External examiner: Professor Viktor Berbyuk, Mekanik, Chalmers
Main Advisor: Guest researcher Harry Dankowicz

Kristian Angele

Thesis title: PIV measurements in a separating turbulent APG boundary layer

Date: December 20 , 2000
External examiner: Professor Michel Stansilas, École Centrale de Lille
Main Advisor: Research Associate Barbro Muhammad-Klingmann

7.3 Publications 2000

7.3.1 Published (and accepted) papers in archival journals and books

[1] Dankowicz, H., Nordmark, A., 2000, On the Origin and Bifurcations of Stick-slip Oscillations , *Physica D*, **136**, 280-302

[2] Dankowicz, H., Adolfsson, J., Nordmark, A., 2000, Repetitive Gait of Passive Bipedal Mechanisms in a Three-Dimensional Environment, *J. Biomech. Eng*

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[4] Cohen, I., 2000, AMIS-Applied Mathematics Internet Server , *European Journal of engineering education*, **25**, 157-164

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[9] Alvelius, K., Johansson, A.V., 2000, LES computations and comparison with Kolmogorov theory for two-point pressure-velocity correlations and structure functions for globally anisotropic turbulence, *J. Fluid Mech.*, **403**, 23-36

[10] Wikström, P.M, Wallin, S., Johansson, A.V., 2000, Derivation and investigation of a new explicit algebraic model for the passive scalar flux, *Phys. Fluids*, **12**, 688-702

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[14] Häggmark, C. P., Bakchinov, A.A, Alfredsson, P.H., 2000, Measurements with a flow direction boundary-layer probe in a two-dimensional laminar separation bubble. , *Exp. in Fluids*, **28**, 236-242

[15] MATSUBARA, M., 2000, Disturbance growth in boundary layers subjected to free stream turbulence., *J. Fluid Mech.*

[16] SÖDERHOLM, L.H., 2000, A Higher Order Acoustic Equation for the Slightly Viscous Case, *Acta Acustica*

[17] ENFLO, B.O., RUDENKO, O., 2000, Nonlinear N-wave propagation through a one-dimensional phase screen, *Acta Acustica*, **86**, 229-238

[18] ZAHRAI, S., BARK, F.H., WIDLUND, O., 2000, Structure information in rapid distortion analysis and one-point modeling of axisymmetric magnetohydrodynamic turbulence , *Phys. Fluids*, **12**, 2609-2620

[19] ÖSTERLUND, J. M., JOHANSSON, A.V., NAGIB, H.M., 2000, Comment on 'A note on the intermediate region in turbulent boundary layers´ [Phys. Fluids 12, 2159] , *Phys. Fluids*, **12**, 2360-2363

[20] ESSÉN, H., 2000, On the equilateral triangle solution to the three-body problem , *European journal of physics*, **21**, 11

[21] ESSÉN, H., 2000, Folk, filosofer och fysik , *Folkvett (Organ för föreningen Vetenskap och folkbildning)*, **no 3-4**, 31-43

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[23] GULLMAN-STRAND, J., CARROLL, B.F., 2000, Pressure-Sensitive Paint Measurements in Planar Transonic Nozzle Flow , *AIAA Journal*, **38**, 1758-1760

[24] LOGINOVA, I., AMBERG, G., AGREN, , 2000, Phase-field simulations of non-isothermal binary alloy solidification , *Acta Materialia*

[25] WINKLER, C., AMBERG, G., CARLBERG, T., 2000, Radial segregation due to weak convection in a floating zone , *J. Crystal growth*, **210**, 573-586

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[28] LINDBORG, E., CHO, Y.N., 2000, Determining the Cascade of Passive Scalar Variance in the Lower Stratosphere , *Phys. Lett.*, **85**, 5663-5666

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[31] Abrahamsson, H, Eriksson, J., Karlsson, R.I., Löfdahl, L., George, K., Wosnik, M, 2000, A similarity theory for the turbulent plane wall jet without external stream , *J. Fluid Mech.*, **425**, 367-411

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7.3.2 Published (and accepted) papers in conference proceedings

[35] Bark, F.H., Zahrai, S., Gurniki, F, 2000, Validation of the Fringe region Technique in LES of Turbulent Mass Transfer at High Schmidt Number, *3rd Int. Symp. on Turbulence, Heat and Mass Transfer, 2-6 April 2000*

[36] Widlund, O., Tallbäck, G., 2000, Modeling of anisotropic turbulent transport in simulations of liquid metal flows in magnetic fields , *Proc. 3rd Int. Symp. on Electromagn. Proc. of Materials, EPM2000, April 3-6, 2000, Nagoya, Japan (ISIJ)*

[37] Angele, K., Muhammad-Klingmann, G.B., 2000, PIV measurements in high Reynolds number boundary layers , *Advances in Turbulence VIII. (2000) Proc. 8th European Turbulence Conference, Barcelona, Spain*

[38] Holm, R., Gustavsson, J., Björck, A., Muhammad-Klingmann, G.B., 2000, A PIV study of speärated flow around a 2-D airfoil , *Proc. 9th International Symposium on Flow Visualization, Edinburgh, 2000 (Eds G M Carlomagno & I Grant)*

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[41] Widlund, O., 2000, Modeling anisotropic MHD turbulence in simulations of liquid metal flows , *Proc. 4th PAMIR Conference, Presqu´ile de Giens, France, 18-22 Sept., 2000*

[42] Högberg, J, Henningson, D.S, Berggren, M., 2000, Optimal Control of Bypass Transition , *Advances in Turbulence VIII. (2000) Proc. 8th European Turbulence Conference, Barcelona, Spain*, 205-208

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[49] Gullman-Strand, J., Carroll, B.F., 2000, PSP Measurements in Planar Transonic Flow , *9th International Symposium on Flow Visualization*

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[55] Matsubara, M., Bakchinov, A.A, Fransson, H. M., Alfredsson, P.H., 2000, Growth and breakdown of streaky structures in boundary layer transition induced by free stream turbulence , *Laminar-Turbulent Transition, Proc. IUTAM Symp., Sedona, Sept. 13-17, 1999, eds Fasel, H.F. & Saric, W.S., Springer*, 371-376

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7.3.3 Technical reports

[57] Wallin, S., 2000, Engineering turbulence modelling for CFD with a focus on explicit algebraic Reynolds stress models, *Doctoral thesis*, KTH/MEK/TR–00/1–SE

[58] Häggmark, C. P., 2000, Investigations of disturbances developing in a laminar separation bubble flow., *Doctoral thesis*, KTH/MEK/TR–00/3–SE

[59] Johansson, B, 2000, Experimental study of shock wave focusing in a confined reflector , *Licentiate thesis*, KTH/MEK/TR–00/4–SE

[60] Piiroinen, P., 2000, Passive Walking: Transition from 2D to 3D , *Licentiate thesis*, KTH/MEK/TR–00/8–SE

[61] Widlund, O., 2000, Modeling of magnetohydrodynamic turbulence , *Doctoral thesis*, KTH/MEK/TR–00/11–SE

[62] Komminaho, J., 2000, Direct numerical simulation of turbulent flow in plane and cylindrical geometries, *Doctoral thesis*, KTH/MEK/TR–00/14–SE

[63] Delabre, F., Trempe, F., 2000, Developing a DNS code for annular geometries, *MSc thesis (Examensarbete)*, KTH/MEK/TR–00/09–SE

[64] Terao, T, 2000, Direct numerical simulation of active control of turbulent channel flow , *Licentiate thesis*, KTH/MEK/TR–00/02–SE

[65] Angele, K., 2000, PIV measurements in a separating turbulent APG boundary layer , *Licentiate thesis*, KTH/MEK/TR–00/15–SE

[66] Alvelius, K., Skote, M., 2000, The performance of a spectral simulation code for turbulence on parallel computers with distributed memory , *Technical report*, KTH/MEK/TR–KTH/MEK/TR–00/17–SE–SE

[67] Pralits, J. O., Hanifi, A., Henningson, D.S, 2000, Adjoint-based Suction Optimization for 3D Boundary Layer Flows. FFA TN 2000-58 , *Technical report*

[68] Winkler, C., 2000, Thermocapillary convection in fusion welding and floatzones and the role of surfactants , *Doctoral thesis*, KTH/MEK/TR–00/05–SE

[69] Grégoire, F., 2000, Automated code generation for turbulence models , *Licentiate thesis*, KTH/MEK/TR–00/07–SE

7.4 Seminars

February 3 Nicola Fornariari, KTH, Mekanik
Experimantal investigation of a relaminarized boundary layer.

February 4 Jafar Mahmoudi, FaxénLaboratoriet
Modeling of solidification processing and continuous strip casting for copper based alloys.

February 11 Koji Fukagata, KTH, Mekanik, Faxen Laboratory
Large Eddy Simulation of Particulate Turbulent Channel Flows

February 11 Olivier Simonin, LNH/EDF, France
Numerical study of the influence of particle-particle collisions on the dispersed phase transport properties using Large Eddy Simulation of gas-solid turbulent flows

February 11 Koji Fukagata, KTH, Mekanik, Faxen Laboratory
Large Eddy Simulation of Particulate Turbulent Channel Flows.

February 17 Jan Pralits, KTH, Mekanik
Sensitivity analysis of compressible flows.

February 24 Nulifer Ipek, KTH, Mekanik, Faxén Laboratory
Electrolytic pickling of stainless steel.

February 25 Stefan Wallin, KTH,
Engineering turbulence modeling for CFD with a focus on explicit algebraic Reynolds stress models.

March 2 Carl Häggmark, KTH, Mekanik
Investigations of a laminar separation bubble.

March 9 Luca Brandt, KTH, Mekanik
Secondary instability of streaks in boundary layers.

March 10 Ivan Pavlov, KTH, Mekanik
Diffraction of sound from a point source against screens with periodical edge profiles.

March 16 Tadahisa Terao, KTH, Mekanik

Direct numerical simulation of active control of turbulent channel flow.

March 17 Sergey Gurbatov, Radiophysics Department, University of Nizhny Novgorod, Russia
The multidimensional Burgers equation and its applications: nonlinear acoustics, interface growth, gravitational instability

March 17 Timmy Sigfrids, KTH, Mekanik
Shape and rotation of meteors.

March 22 Tadahisa Terao, KTH, Mekanik
Direct numerical simulation of active control of turbulent channel flow.

March 23 Martin Skote, KTH, Mekanik
Simulation of streak breakup

March 24 Oleg Rudenko, Moscow
Nonlinear Acoustic Problems Connected With Movable Boundaries.

March 31 Per-Åge Krogstad,
Localized injection in a turbulent boundary layer

March 31 Carl Häggmark, KTH, Mekanik
Investigations of disturbances developing in a laminar separation bubble flow

April 10 Johan Hamberg, FOA, avd 61
The Method of Controlled Lagrangians

April 13 Nils Tillmark, KTH, Mekanik
Experiments on rotating plane Coette flow.

April 14 Stefan Bergström, KTH
Dust particles in space

April 14 Erik Gustafsson, KTH
Design of a parallel kinematic machine on the MEMS-level.

April 28 Bo Johansson, KTH, Mekanik
Experimental study of shock wave focusing in a confined chamber

May 3 Bengt Enflo, KTH, Mekanik
Nonlinear standing waves in closed tubes

May 11 Peter Voke, University of Surrey
Progress on LES of Turbomachinery and Aerofoil Flows

May 17 Karl Borg, KTH, Mekanik
Thermophoresis of axially symmetric bodies

May 18 Taransankar DebRoy, The Pennsylvania State University
Computor Modeling of Fusion Welding

May 19 Naoki Hirose, Computational Science Div, NAL
CFD Research and Recent Results at NAL using the Numerical Wind Tunnel

June 6 Donatella Ponziani, KTH, Mekanik
A weakly nonlinear analysis for transition mechanisms in Poiseuille flow

June 8 Mehran Parsheh, KTH, Mekanik, Faxén Laboratory
Turbulent wakes of flat plates subjected to a favourable pressure gradient.

June 9 Ori Levin, KTH, Mekanik
Optimization of a Flexible Low Reynolds Number Airfoil

June 15 Franck Grégoire, KTH, Mekanik
Automated Code Generation for Turbulence Models

June 15 Fredrik Lundell, KTH, Mekanik
Streak breakdown and transition control in wall-bounded flows

June 22 Francois Delabre & Fabien Tempre, Ecole polytechnique, Paris
Development of a new spectral DNS code for circular Taylor-Couette and/or annular pipe flow.

August 22 Petri Piiroinen, Mekanik, KTH
Passive Walking: Transition from 2D to 3D

September 4 Yoshio Sone, Dept Aeronautics and Astronautics, Kyoto University
Kinetic theory and fluid dynamics

September 19 Zbigniew Peradzynski, Warsaw
On fluid models of plasma thrusters

October 19 Markus Högberg, KTH, Mekanik
Linear control of transition and turbulence

October 26 Irina Loginova, KTH, Mekanik
Phase-filed simulations of non-isothermal binary alloy solidification

November 2 Penelope Parkin, Imperial College, London
A PIV study of the wake of a horizontal axis wind turbine

November 9 William George, Chalmers
Effect of upstream conditions on turbulent boundary layers

November 16 Johan Nilsson, Meteorologiska Inst. SU
An idealized model of superstable thermohaline ocean circulation

November 21 Alexander Bobylev, Karlstad University
Discretization of "continuous" kinetic equations and related problems in number theory

November 23 Fredrik Lundell, KTH, Mekanik
Secondary instability breakdown

November 30 Jukka Komminaho, KTH
Spectral DNS in cylindrical geometries

December 1 Francois Gurniki, Faxenlaboratoriet-KTH
Turbulent Convective Mass Transfer in Electrochemical Systems

December 7 Björn Lindgren, KTH, Mekanik
Structures in turbulent boundary layers

December 8 Jukka Komminaho, KTH
Direct numerical simulation of turbulent flow in plane and cylindrical geometries

December 14 Junichiro Shiomi, KTH, Mekanik
Active control of oscillatory thermocapillary convection

December 15 Ola Widlund, KTH, Mekanik, Faxén Laboratory
Modeling of magnetohydrodynamic turbulence

December 20 Michel Stansilas, École Centrale de Lille
PIV

8 FaxénLaboratoriet

A short description of FaxénLaboratoriet is given below for 2000. The text in this section is an extract (with some modifications) of a separate activity report for FaxénLaboratoriet written by Anders Dahlkild. The Department of Mechanics is the host institute for FaxénLaboratoriet (web address: http://www2.mech.kth.se/faxenlab).

8.1 Introduction

FaxénLaboratoriet, below referred to as FLA, is a NUTEK 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, NUTEK, and the following industrial partners:

ABB Automation Systems AB
ABB Corporate Research
ABB Switchgear AB
AGA AB
Albany Nordiskafilt AB
Alfa Laval Separation AB
Avesta Sheffield AB
Eka Chemicals AB
Ipsen International GmbH
Outokumpu Copper Partner AB
Permascand AB
SCA Research AB
SKF ERC
Stora Enso Research
Valmet Corporation
Vattenfall Utveckling AB
Volvo Personvagnar Komponenter AB

The following contribute financially as non-signatory partners:
University of Tokyo
Institut National Polytéchnique de Grenoble
University of Pennsylvania
MISTRA (Stiftelsen för Miljöstrategisk Forskning)

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

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: Magnus Davidsson (Eka Chemicals AB), Torsten Holm (AGA AB), Rolf Karlsson (Vattenfall Utveckling AB (Chairman)), Arne Johansson (Dept. of Mechanics, KTH), Björn Widell (ABB Industrial Systems), Anders Wigsten (Stora Enso Research), Lars Hanarp (Albany Nordiskafilt AB).

The operative leadership at FLA consists of the following persons:
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

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

Participating bodies from industry: ABB Corporate Research, Avesta Sheffield AB, EKA Chemicals AB, Permascand AB, Vattenfall Utveckling AB.

Other parties: Institut Polytéchnique de Grenoble, University of Pennsylvania.

General description:

Electrolysis takes place in baths of electrolyte in so-called electrolysers, in which a number of electrodes are immersed, either connected in series or in parallel. Due to the reactions at the electrodes the concentration field varies in space, with the result that the electrolytes weight (per unit volume) will be locally either less or more than the average weight in the bath. Consequently the electrolyte is set in motion by the force of gravity. This motion is nearly always turbulent. Furthermore, in e.g. the production of sodium chlorate, hydrogen gas is generated at the cathode and in the zinc electro-winning process, oxygen gas is evolved also at the anode. Due to drag force between the bubbles and the electrolyte, the upward motion of the bubbles of gas causes turbulent circulation of the electrolyte in the reactor.

Many problems which are closely related to the fluid mechanical phenomena mentioned above, are highly relevant for optimisation of the design of electrolysers. For instance, the exchange of mass at the electrodes should be maximized, which requires a rapid supply of undepleted electrolyte. However, high velocities result in short residence times in the electrolysers, which leads to a lot of electrolyte passing through the electrolyser without being fully used. The development of gas bubbles at the electrodes is often exploited to drive the electrolyte through the electrolyser, but at the same time a large volume fraction of bubbles increases the electrical resistance of the electrolyte, which increases the Ohmic loss of energy. Today, the consumption of energy is perhaps the most critical problem in the electrochemical process industry.

Projects:

Contracted projects:

I:1 Turbulent free convection in large cells
- Researcher: François Gurniki
- Advisor: Said Zahrai

I:2 Gas-evolving electrodes
- Researchers: Ruben Wedin, Philip Byrne
- Advisors: Anders Dahlkild, Fritz Bark, Göran Lindberg, Ed Fontes

I:3 Pickling of steel
- Researcher: Nulifer Ipek
- Advisors: Noam Lior, Michael Vynnycky

I:4 Forced convection
- Researcher: Jan Eriksson
- Advisor: Rolf Karlsson

Externally financed projects:

I:5 Modelling of annular flow in nuclear fuel reactors/ ABB CRC
- Researcher: Ulrike Windecker
- Advisor: Said Zahrai

I:6 Hydrodynamics of solid polymer fuel cells/ MISTRA
- Researcher: Erik Birgersson
- Advisors: Göran Lindberg, Michael Vynnycky

Cooperation schemes with companies:

- Avesta Sheffield AB, Eka Chemicals AB and Vattenfall Utveckling AB are represented in FLA's Guidance Group for Electrochemical Processes.
- Philip Byrne's experimental setup of gas-evolving electrodes is completed by Permascand AB, and the first experiments will be carried out at the Eka Chemicals plant in Sundsvall or at KTH. LDV equipment for measurements is supplied by Vattenfall Utveckling AB.
- Jan Eriksson, doctoral student at FaxénLaboratoriet, has been 50 per cent employed by Vattenfall Utveckling AB.
- Test rig for high Rayleigh number free convection experiment was built at Vattenfall Utveckling AB.
- Said Zahrai, ABB Corporate Research, is tutoring two of the research students active in this programme.
- Rolf Karlsson, Vattenfall Utveckling AB is tutoring one research student.
- A model test rig for flow field vizualization of electrolytic pickling was built by Avesta Sheffield AB.

International cooperation

- The Two-Phase Flow Team of LEGI, Grenoble, hosted Ruben Wedin for six months from January 2000 for experiments in their bubble flow loop.

Guest researchers
Prof. Noam Lior : 21-31 January, 6-24 June, 22 September-2 October.

8.3.2 Materials Processing

Participating bodies from industry: ABB Corporate Research, ABB Automation Systems AB, ABB Switchgear AB, AGA AB, Ipsen International GmbH, Outokumpu Copper Partner AB, SKF ERC, Volvo Personvagnar Komponenter AB.
Other parties: University of Pennsylvania, University of Tokyo

General description:
In the continuous casting of metal,s the molten material or melt is supplied continuously through

a cooling annulus, the mould. Solidification first takes place at the rim of the melt, forming a shell in contact with the mould. The solidification continues outside the mould, gradually building up a thicker shell until the whole cross section is solid metal. The quality of the steel and structure of the metal surface depends to a great extent on the flow of the melt in the mould. Due to the turbulent motion caused by the violent filling process, slag material at the upper surface of the melt is easily mixed into the melt, contaminating the final product with small inclusions. One way of reducing this contamination is to use a so-called electromagnetic brake, by which a magnetic field is used to calm down the turbulent motion. The surface structure of the final product is dependent on the flow in the neighbourhood of the contact line at the mould between molten and solidified material. The poorly understood interplay between the solidification process, surface tension, gravity and forces induced by the flow is now being investigated.

In the mechanical engineering industry heat treatment is a central process in the manufacture of high-performance components such as bearings, gears and sledge-hammers. These products obtain their mechanical properties as a result of the phase changes which take place during cooling (quenching or hardening) after heat treatment. The activities of the Centre concerning hardening of steel will be carried out in collaboration with the Swedish Institute for Metals Research at which theoretical and experimental research is being carried out under the supervision of the Technical Council of the Swedish Mechanical Engineering Industry. Also the Brinell Centre for Metallurgical Research will participate in these efforts. In FaxénLaboratoriet, realistic computational methods will be developed for the heat transfer between component and cooling gas. These methods will complement the existing simulation models for the transport of heat, the phase changes and the mechanical response, i.e. rest stresses and deformation, within the component. The resulting computational model will constitute both a unique and a powerful tool for controlling hardening processes.

Projects:

Contracted projects:

II:1 Modelling of MHD-turbulence
- Researcher: Ola Widlund
- Advisor: Said Zahrai

II:2 Stability of contact lines
- Researcher: Jessica Elfsberg
- Advisor: Hasse Fredriksson

II:3 Continuous casting of copper alloys
- Researchers: Jafar Mahmoudi, Jenny Kron
- Advisors: Hasse Fredriksson, Michael Vynnycky

II:4 Quenching of steel
- Researchers: Jerome Ferrari, Mats Lind
- Advisor: Noam Lior

II:5 Simulation of turbulent flow with particles

- Researcher: Koji Fukagata
- Advisor: Said Zahrai

II:6 Material changes when braking large currents
- Researcher: Torbjörn Nielsen
- Advisor: Said Zahrai

II:7 Modelling of turbulence at small Rossby numbers
- Researcher: Gustaf Mårtensson
- Advisor: Arne Johansson

II:8 Numerical modelling of liquid metal flow with a free surface
- Researcher: Mats Larsson
- Advisor: Torbjörn Hellsten, Jin Li

Externally financed projects:
II:9 Cable extrusion/ ABB CRC
- Researcher: Johan Palm
- Advisor: Said Zahrai

Cooperation schemes with companies:

- ABB Automation Systems AB, AGA AB and SKF ERC are represented in the guidance group.
- Koji Fukagata, QUEST, University of Tokyo and FLA, worked for his PhD within FaxénLaboratoriet while employed in Tokyo.
- Said Zahrai of ABB Corporate Research is working 20 per cent of his time at FaxénLaboratoriet, tutoring Ola Widlund by spending one day a week at KTH.
- In the course of his AGA AB project Mats Lind is in constant touch with the Project group for low-pollution hardening at the Swedish Institute of Production Engineering Research. Besides AGA AB this group includes Ovako Steel AB, UGAB, Volvo PV AB Transmission, Sandvik Rock Tools AB, SKF Sweden AB and Scania AB.
- Torbjörn Nielsen has his office at ABB CRC and makes use of their computer system.
- Mats Larsson spends much of his office time at ABB ASY where Jin Li acts as his assisting supervisor.
- The student active in project II:7 spends part of his time at Alfa Laval Separation AB and performs his experimental work there.

8.3.3 Paper Technology

Participating bodies from industry: Albany Nordiskafilt AB, SCA Research AB, Stora Enso Research AB, Valmet Corporation.

General description:
In a paper-making machine a suspension of cellulose fibres is turned into a wet mat of fibre by squirting out most of the water. In traditional forming, most of the water is squirted out of the suspension on a moving horizontal filtering net, a so called 'wire'. The suspension is transferred to the wire by the means of a thin but broad jet from a 'head box'. The water is then sucked out of the suspension through the wire. However, there are a number of drawbacks in this method. Hydrodynamic instabilities in the interface between the suspension and the air above it will limit the speed at which the process can take place. Furthermore, one-sided de-watering makes the structure of the surface of the paper different on its two sides, which is most inconvenient in he case of for instance printing paper.

These disadvantages can be eliminated to a great extent in modern twin-wire machines. In these the jet from the head box is directed into the space between two almost parallel wires, which are kept close together and at high tension. The pair of wires is then passed over one or more rollers or blades which makes the separation between the stream lines increase due to the centrifu-gal force. This leads to an increase in the pressure, which drives the water out of the suspension. This method works reasonably well in actual operation, but the understanding of its basic mechanics is far from complete. A better understanding will almost certainly lead to considerable improvements in the method. Basically the quality of the final product, measured by homogeneity and the isotropy of the fibres, is determined by the flow in the head box and the flow on and between the wires.

Projects:
Contracted Projects:

III:1 Forming between twin wires
- Researchers: Claes Holmqvist, Krister Åkesson
- Advisors: Anders Dahlkild, Bo Norman

III:2 Initial roll forming
- Researchers: Richard Holm, Roger Bergström
- Advisors: Henrik Alfredsson, Bo Norman

III:3 Flow in stratified head boxes
- Researcher: Mehran Parsheh
- Advisor: Anders Dahlkild

Cooperation schemes with companies:

- Stora Enso Research, SCA Research AB and Valmet Corporation have representatives in the guidance group.

8.4 Financial status

The turnover during 2000 reached 15 MSEK. The total cash (in MSEK) contributions for 2000 from the three major parties amounted to:

KTH	3.8
Industry	2.1
NUTEK	5.3
Total	11.2

In addition to this, there are also in-kind contributions, totalling roughly 4.6 MSEK (according to budget), from industry and KTH.

8.5 Miscellaneous

Attendance at courses and conferences outside KTH:

During 2000, representatives from FaxénLaboratoriet have attended:

- 3-6 April: 3rd International Symposium on Turbulence, Heat and Mass Transfer (Nagoya, Japan)
- 3-6 April: 3rd International Symposium on Electromagnetic Processing of Materials, EPM2000 (Nagoya, Japan)
- 7-9 June: ASM Heat Treat Congress, Europe (Gothenburg, Sweden)
- July 10-13: 10th International Symposium for Applications of Laser Techniques to Fluid Mechanics (Lisbon, Portugal)
- 18-22 September: 4th International PAMIR Conference (Presqu'île de Giens, France)
- 23-28 October: 7th International Frumkin Symposium: Basic Electrochemistry for Science and Technology (Moscow, Russia)

The year 2000 at FaxénLaboratoriet: a sample of events

February 4: Ph.D. defence, Jafar Mahmoudi
February 11: Ph.D. defence, Koji Fukagata
May 3: FLA Board Meeting at KTH September 26: FLA Board Meeting in Jyväskylä, Finland
September 26-27: FLA Annual Meeting in Jyväskylä, Finland
September 28-29: International evaluation by NUTEK
December 1: Ph.D. defence, François Gurniki
December 15: Ph.D. defence, Ola Widlund