Department of Mechanics

KTH, SE-100 44 Stockholm, Sweden

Activity Report 2001

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 for extracting this information from the data-base. The report reflects the activities of the ninth budget year of the (new) department of mechanics in education, research and other areas.

Stockholm, February 2002

Arne Johansson, department chairman
Gustav Amberg, department vice chairman

1 Introduction

This is the ninth annual activity report of the new mechanics department and covers the year 2001. The mechanics department (web address: http://www.mech.kth.se) has about 80 employees and a yearly turnaround of about 60 MSEK. It is also host department for the Faxén Laboratory, a NUTEK competence centre for the fluid dynamics of industrial processes.

During the first half of 2001 five of the six professors represented various research areas within fluid mechanics. July 2001 the department was happy to welcome professor Anders Eriksson (professor in 'byggnadsstatik') and his group in computational mechanics. This gives a substantial long-term strengthening of the theoretical and computational mechanics area within the department, and opens up several possibilities for new initiatives and collaborations.

The head of department ('prefekt') is professor Arne Johansson and vice *ditto* ('proprefekt') is professor Gustav Amberg, as of July 1, 2001, succeeding professor Martin Lesser who has served almost six years on the post. The study rector ('studierektor') is Hanno Essén.

The department board (as of July 2001) consists of: Nicholas Apazidis, Fritz Bark, Dan Henningson, Arne Johansson (chairman), Lars Thor, Ingunn Wester, Peter Gudmundsson (prof. Dept of solid mechanics, external board member), Johan Gullman-Strand (grad. stud. repr.) and an undergraduate student representative.

The teaching activities comprise courses in basic mechanics at almost all parts of KTH, and a large number of higher level and graduate courses on many different aspects of mechanics of solids as well as of fluids. The addition of Anders Eriksson's group in computational mechanics has also meant a substantial increase in the teaching activities in the civil engineering program at KTH. The collaboration with NADA in the teaching of computational fluid dynamics has been further developed with a common course in that area.

The planning for a new basic mechanics course for the micro-electronics program at KTH-Kista has been started, and the course will be given the first time during 2002. We are proud to acknowledge that Nicholas Apazidis was appointed 'Teacher of the Year 2001' at KTH. Nicholas enjoys a well known popularity as a teacher in many programs at KTH, and continuously develops new teaching material and introduces new elements in the teaching. In the continuation course in mechanics at F he introduced a new possibility during 2001 to obtain a higher grade by carrying out a computer-algebra ('Sophia') based project. This new possibility attracted more than 60 students.

The research activities can essentially be classified into major areas of "Fluid mechanics", "Theoretical and applied mechanics" and "Computational mechanics", although no strict boundaries exist between them. In December 2001 there were altogether 50 graduate students active at the department (13 of which are associated with the Faxén Laboratory) and 14 external graduate students in industry and research institutes. Six doctoral degrees and eight licentiate degrees were awarded during 2001.

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 are divided into the program areas of Electrochemistry, Material process technology and Paper technology (for details see section 8).

The Mechanics department has the coordinator role for the Nordic ERCOFTAC Pilot Centre. This coordinatorship was held by Dan Henningson up to June 2001, and is now held by G Amberg. A number of partners from the different Nordic countries are members of the centre.

During 2001 the Mechanics department was host for the Second international conference on Turbulence and Shear Flow Phenomena. The symposium attracted 340 participants from 30 different countries and was held at KTH during the period June 27-29, 2001.

Dan Henningson organized, together with prof Håkan Gustavsson, LTU, an ERCOFTAC workshop on Flow Control in Abisko in April 2001 with about 25 participants.

Personel related matters 2001 and miscellaneous

Arne Nordmark was appointed as senior lecturer ('univ.lektor')

Anders J Thor retired (in June) after almost half a century at the Mechanics department.

Erik Lindborg was awarded the Docent degree.

The department board met on Feb. 14, June 18 and Dec. 14, 2001.

A number of Department faculty meetings and 'samverkansgruppsmöten' were also held.

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

2 Personnel

Professors

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

'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. Retired in 2000, but continues on a part-time basis.
- Laszlo Fuchs. Ph.D. in Gasdynamics KTH 1977, Docent KTH 1980. Adj. prof. Applied CFD (50 %), KTH 1989–1994 IBM Sweden (50 %) 1989-1992. Prof. Fluid Mechanics LTH 1994–. Guest Prof. (20%) at the Mechanics Dept, KTH 1994– Research in CFD methods and models, with application to compressible flows and combustion in engines and furnaces.

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.
- Arne Nordmark. PhD in mechanics 1992. At KTH since 1984. Docent 1999. Senior lecturer 2001. Research in the dynamics of mechanical systems with discontinuous or impulsive forces.
- Christer Nyberg, PhD in mechanics 1979 KTH. Research in acoustics.
- Lars Söderholm, PhD and Docent 1970 in theoretical physics, Univ. of Stockholm. Two years at Nordita. At KTH since 1980. Research on relativity and continuum mechanics: Klein-Alfvén cosmology, relativistic temperature, material frame indifference, constitutive relations and kinetic theory.
- Anders J Thor. TeknL in mechanics, KTH 1964. At KTH since 1956. Work on standards for quantities and units. Retired 2001.
- 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.)

- Jean-Marc Battini (also 50% doctoral student)
- 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, Docent at KTH 2001, Research in turbulence.

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

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

Professors emeritii

Bengt-Joel Andersson
Sune Berndt
Stig Hjalmars

Graduate students (in Swedish: doktorander)

Jesper Adolfsson
Anders Ahlström
Kristian Angele
Jean-Marc Battini (also 50% acting lecturer)
Erik Birgersson (FLA)
Karl Borg
Luca Brandt
Arnim Brüger
Carl-Ola Danielsson (FLA)
Gitte Ekdahl
Luca Facciolo
Jerome Ferrari (FLA)
Alexandar Filipovski
Jens Fransson
Kazaya Goto
Olof Grundestam
Johan Gullman-Strand
Francois Gurniki (FLA)
Astrid Herbst
Richard Holm (FLA)
Claes Holmqvist (FLA)
Jérome Hoepffner
Thomas Hällqvist
Marcus Högberg
Nulifer Ipek (FLA)
Jukka Komminaho
Ori Levin
Mats Lind (FLA)
Björn Lindgren
Irina Loginova
Fredrik Lundell
Davide Medici
Do-Quang Minh
Gustaf Mårtensson (FLA)
Per Olsson
Mehran Parsheh (FLA)
Ivan Pavlov
Petri Piiroinen

Jan Pralits
Henrik Sandqvist
Junichiro Shiomi
Timmy Sigfrids
Martin Skote
Gunnar Tibert
Olle Törnblom
Ruben Wetind (FLA)
Ola Widlund (FLA)
Thomas Wright

External graduate students (not employed by department of mechanics)

Leonard Borgström, Alfa Laval, Tumba
Mattias Chevalier, FOI/FFA
Jan Eriksson, Vattenfall Utveckling AB, Älvkarleby
Jan-Erik Gustafsson, STFI
Jonas Gunnarsson, Bombardier
Marco Hyensjö, Metso Paper (FLA)
Hans Moberg, Alfa Laval, Tumba
Andreas Möller, FOI/FFA
Torbjörn Nielsen (FLA) ABB Corp. Res.
Johan Persson (FLA) Vattenfall Utveckling AB
Lars Tysell, FOI/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. Six 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

The department has a laboratory with several experimental facilities for research and student demonstration purposes. Among the main research facilities the following are of interest for the present project:

- MTL subsonic windtunnel, 7 m long (1.2 m $\times$ 0.8 m) test section, max. speed 69 m/s
- new subsonic wind-tunnel (1998), 0.5 m $\times$ 0.75 m test section, max. speed 48 m/s
- plane Couette flow apparatus with and without system rotation
- a new asymmetric diffuser facility for studies of turbulent separation and control
- plane Poiseuille flow apparatus (2m$\times$0.8m) for transition and control studies, etc.

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

A smaller windtunnel based on the same concept as the MTL-tunnel was taken into operation during 1999 both for research and education purposes.

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

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

Flow visualization techniques, based on smoke visualization have been developed for boundary layer transition work, and pictures from these flow visualizations has been well received and are nowadays appearing as introductory material in many lectures at conferences. The laboratory also has some equipment for flow visualisation in compressible flows, such as a Schlieren system with possibility for short duration double flash exposure, and a high speed camera (up to 500 frames per second). Development has also been made regarding temperature sensitive paint for determining surface temperature distributions in connection with heat transfer measurements. Recently work has started in order to evaluate the use of pressure sensitive paint.

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

3.2 Computers

The department has a computer system consisting of more than 40 workstations, 70 PC:s/Mac:s and a Compaq AlphaServer ES40 to serve as a new numbercruncher. It has four EV6 500MHz processors and a total of 3 GB shared memory.

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

4 Economy

A brief overview of the different categories of incoming resources to the department is given below for 2001. The FLA sum does not inlude in-kind contributions.

INCOME (in Mkr)

	Dept. total
Education (GRU)	**12**
Research (FOFU)	**17**
External	**18**
FLA (external)	**11**
Σ	**58**

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

There was a strong increase in the external funding during 2001. This, together with a high production of licentiate and doctoral degrees, resulted in a strong economical situation for the department, and for the FoFu side in particular.

5 Teaching activities

5.1 Undergraduate courses

Basic courses (grundkurser)

School	Year	Course no.	Credit	Name
K, E	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
T (E, B)	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

Structural mechanics (Byggnadsstatik)

School	Year	Course no.	Credit	Name
V	3	1C1103	5	Structural Mechanics III
V	2	1C1109	5	Structural Mechanics I
V	2	1C1115	5	Structural Mechanics II
V	4	1C1116	5	Structural Dynamics
V	4	1C1117	5	Finite Element Methods
V	4	1C5020	5	Finite Element Methods, Advanced Course
V	4	1C5024	5	Stability of Structures
V	4	1C5032	5	Structural Dynamics, Advanced Course
M, T, V	4	1C5049	5	FEM Modelling
V	4	1C5051	5	Advanced Structure Dynamics, Modelling and Measurements

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, Continuation 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 computational mechanics

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): (8), (36), (44), (55)

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): (25), (24), (9)

Theoretical investigations of underwater sound

Researcher(s): Bengt Enflo

Graduate student(s): Henrik Sandqvist

Sponsor(s): TFR

The project is to study theoretically the propagation of underwater sound under conditions similar to those occurring in realistic applications. That means that refraction and the stratification of the medium are taken into account. Nonlinear effects are taken into account: low frequency narrow beams are assumed to be produced by nonlinear interaction of fundamental monochromatic waves (so called parametric radiators). Attempts are made to find, numerically and analytically, solutions of generalizations of Burgers' equation, which describe sound beams in dispersive and inhomogeneous media.

Diffraction of sound by noise barriers

Researcher(s): Bengt Enflo

Graduate student(s): Ivan Pavlov, Henrik Sandqvist

Sponsor(s): BFR, KFB

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

Dynamic simulation of wind power plants (VindSim)

Researcher(s): Anders Eriksson

Graduate student(s): Anders Ahlström

Sponsor(s): STEM

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

Biomechanical simulations of the Skeleto-muscular system

Researcher(s): Anders Eriksson, Kazuya Goto

Sponsor(s): KTH

This trans-disciplinary project aims at an improved understanding of the skeleto-muscular system in the human body. It takes as its background clinical and experimental knowledge on the behaviour of muscles and muscle cells, and connects this to the computational modelling of mechanical systems. The background knowledge is used to develop relevant and computationally efficient numerical models for skeleton muscles in the human body. These numerical models are created for the use in a general mechanical simulation context, focussing on the description of dynamic loading and movement situations. Aspects of the motor control systems will also be considered in the project, in particular with reference to the force distribution in synergistic muscles. A special interest will be directed towards the fatigue aspects of muscles, and their effects on the force-movement relations in the muscle model. The project will lead to an improved knowledge on the behaviour of the skeleto-muscular system, when subjected to impact or sustained high loading conditions. Due to its trans-disciplinary approach, it will lead to new development in the mechanical understanding of human locomotion and work, but also to new ideas for the physiological experimentation on muscle behaviour. The aim is also, in addition to developing the framework of a general simulation algorithm, to give at least some result of clinical interest on the damage or injury of a human joint.

Buckling and collapse behaviour of optimised thin-walled structures (cont.)

Researcher(s): Anders Eriksson

Graduate student(s): Aleksandar Filipovski

Sponsor(s): VR

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

Active and Passive Damping with Applications in Manufacturing.

Researcher(s): Göran Karlsson

Sponsor(s): Swedish Institute Project 2657/2001.

This project is a three year project in cooperation between Dept. of Mechanics, Dept of Industrial Production, KTH,Stockholm (Mihai Nicolescu) and Institute of Solid Mechanics of the Romanian Academy, Bucharest. The project started in September 2001 and it objectives are:

1. Development of passive and active vibration control based on damping technologies to substantially improve the dynamic behavior of manufacturing systems.
2. Theoretical studies and practical applications of damping materials, such as viscoelastic and piezoelectrics, for increasing dynamic stability of manufacturing systems.
3. Modelling and analysis methodologies and tools for viscoelastic and piezoelectric materials.

4. Establish a reference base on the subject.
5. Organize common workshop, conferences or meetings.
6. To facilitate the access of young researchers from Romania to KTH/facilities that are essential for high quality research.
7. To improve the scientific and technological level and to contribute to attainment of a general level of scientific excellence (PhD courses, workshops and meetings).
8. To give the opportunity to young Romanian scientists to work at their doctoral theses at KTH.

Publication(s): (6)

Optimization of Middle Ear Replacement Device

Researcher(s): Martin Lesser

Graduate student(s): Tom Wright

Sponsor(s): KTH

The object is to find possible simple replacement mechanisms that will replicate as far as possible the functions of the middle ear bone linkage. This involves both determining an appropriate model of the middle ear and a study of simplified models which show the same dynamic behaviour.

Dynamics of Moderately and Highly Rarefied Gases

Researcher(s): Lars Söderholm

Graduate student(s): Karl Borg

Sponsor(s): KTH

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.

Publication(s): (38), (35)

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 wave propagation in fluids

Researcher(s): Lars Söderholm

Sponsor(s): KTH

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.

Semiclassical Mechanics

Researcher(s): Karl-Erik Thylwe, H. Korsch

Sponsor(s): NFR

In order to understand details of atoms and molecules interacting with external fields, it is essential to understand the underlying classical theory of timedependent Hamiltonian systems. Theoretical research in this area is of basic importance for interpreting and predicting a growing body of experimental data obtained by the most sophisticated experiments. The semiclassical research topics include:

- New time-dependent normal forms for resonant dynamics. The usual semiclassical theory of tunnelling through chaotic separatrix regions, resulting in the splitting of degenerate quasi energies, gives merely a rough estimate of the spectrum and would benefit from a more detailed level of approximation.
- A unified complex angular momentum theory for scattering models used in analysing spectra of quantized biliard systems. This would clarify the identification of classical and non-classical (ghost) contributions.
- The development of new semiclassical approximations for field switching in single and more-dimensional states. These provide an understanding of nonadiabatic effects beyond the perturbation theory and provide transparent link between transition probabilities and switching profiles in quantum optics models.

6.2 Fluid mechanics

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

Researchers: Henrik Alfredsson, Nils Tillmark, Johan Westin Masahara Matsubara, Alessandro Talamelli

Graduate students: Fredrik Lundell, Jens Fransson, Timmy Sigfrids, Luca Facciolo, Davide Medici

Sponsor(s): VR, STEM, KTH

The common theme among different projects within this area is to develop knowledge about various flow phenomena in transitional and turbulent boundary layer flows, and also find mechanisms to control such flows. All projects are basically experimental and are carried out in various facilities at KTH. Measurement techniques comprise hot-wire anemometry, Laser Doppler Velocimetry, Particle Image Velocimetry, flow visualization etc.

One project deals with how suction through a porous surface influences a boundary layer, both with regard to transition, turbulence and separation. Most of the work has so far been carried out in the MTL-wind tunnel and presented in the licentiate thesis of Fransson in September 2001. This work dealt with the (laminar) asymptotic suction boundary layer. The development of TS-waves shows good agreement with theory, however the main emphasis of the work was on how free stream induced disturbances develop inside the boundary layer. It was shown that for the present Reynolds number even the highest free stream turbulence level (>4%) did not give transition. Further experiments aim at increasing the Reynolds number to see the effect on transition, but also to study the influence on suction on turbulent spots and fully developed turbulence. The effect of suction on the flow around a circular porous cylinder will also be studied.

In another experiment localized control (blowing and suction) is attempted in order to control free-stream turbulence induced transition (Lundell). A rake of wall-mounted hot-wires is used to detect flow structures and control will be applied through local (in time and space) suction/blowing at the wall downstream of the sensors. Results from theoretical and numerical flow control indicate that the skin friction in turbulent flows can be considerably decreased, or laminar/turbulent transition delayed, with a small amount of input energy, if the energy is used in an optimal way. It is however far from straightforward to apply the methods developed in numerical flow control to a physical experiment. In the current experiment, system identification is used in order to study how the information from the sensors is to be used to determine an appropriate actuator response. The two main questions to be answered are i) how to model the reaction of the flow on the control action and ii) what property to control in order to achieve the overall design objectives, such as reduced skin friction or transition delay.

Impigning rotating jets, where the heat transfer at the impignment zone is of special interest, is studied in a new project (Facciola). A new facility has been built which can give a well controlled rotating jet flow. This facility will later be integrated into a wind tunnel in order to study how a cross flow influnces the jet and heat transfer characterstics.

A new reserach area with the laboratory is shock-boundary layer interaction (Sigfrids). Here we study transonic flow over a bumb. This project is within a cooperation with the Department of Energy technology at KTH and Chalmers. The experimental work is done at KTH where various measurement techniques are used to determine the flow field and shock behaviour. So far a technique to calibrate hot-wires in compressible flow has been developed and the initial flow conditions in the wind tunnel has been determined, including the turbulent boundary layer approaching the bumb. Surface flow visulaization in the shock region has also been made.

A project dealing with wind power has a slightly more practical objective (Medici). Wind power is becoming a common alternative for electric power generation and to economise the utilisation of wind power, several units are usually collected in parks. In order not to interfere with each other, design criteria has to be developed for the interspacing of the turbines. For some wind directions downstream turbines will nevertheless be disturbed by upstream turbines and thereby produce less output than with an undisturbed inflow. However, there might be a possibility to optimise the output by actively controlling the yaw angle of the upstream turbine and thereby deflecting the wake. The present study can be considered as a fundamental study of the behaviour of wakes behind deflecting bodies, but it also has a clear application since the results can be used to actively control and maximise power output from wind turbine farms.

Publication(s): (29)

Thermocapillary convection in materials processing.

Researcher(s): Henrik Alfredsson, Gustav Amberg

Graduate student(s): Renaud Lavalley, Christian Winkler

Sponsor(s): VR, 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): (2)

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

Researcher(s): Anders Dahlkild

Graduate student(s): Ruben Wetind

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): (20), (7), (21), (54)

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.

Publication(s): (46)

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): Luca Brandt

Sponsor(s): FOI, VR

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

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

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

Publication(s): (5), (1), (17)

Active Control of Boundary-Layer Transition

Researcher(s): Dan Henningson, Martin Berggren

Graduate student(s): Markus Högberg, Mattias Chevalier, Ori Levin, Jérome Hoepffner

Sponsor(s): NGSSC, STEM, FOI, VR

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

Publication(s): (39), (18), (53)

Modern stability prediction methods.

Researcher(s): Dan Henningson, Ardeshir Hanifi, Martin Berggren

Graduate student(s): Andreas Möller

Sponsor(s): KTH, FOI

The project concerns a new transition prediction tool which is being developed in cooperation with DLR in Gottingen. The code uses the parabolized stability equations (PSE) and is so far based on the linearized equations. The method uses a wave ansatz with a slowly varying amplitude function and wave number, similar to the WKB method. In addition an auxiliary condition is introduced which ensures uniqueness of the solution so that the traditional WKB expansion can be avoided. This method has proven to be 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 EUROTRANS and ALTTA programs.

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

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.

Direct numerical simulation of turbulent separation and separation control

Researcher(s): Dan Henningson, Martin Skote

Graduate student(s): Astrid Herbst

Sponsor(s): PSCI, FOI, STEM

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

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

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

Publication(s): (45)

Optimal design of vehicles with low drag.

Researcher(s): Dan Henningson, Ardeshir Hanifi

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): (4), (50)

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

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

Graduate student(s): Arnim Brüger

Sponsor(s): VR, IVS, NGSSC

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

The final goal is to simulate turbulence phenomena on a wing profile geometry. This is an important step towards realistic applications of a DNS method. Another important issue is to simulate turbulent flow separation in an asymmetric diffuser, a case where ongoing experiments is performed at the department of Mechanics.

In a further step the DNS code will form a basis for inclusion of large eddy simulation (LES) models. The research will build on the compact higher-order finite difference methods developed in an ongoing cooperation project between the department of Mechanics, KTH and TDB, Uppsala University.

Measurement, modelling and simulation of turbulence.

Researcher(s): Arne Johansson

Graduate student(s): Stefan Wallin, Björn Lindgren, Johan Gullman-Strand, Olle Törnblom

Sponsor(s): VR, 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.

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. Some contiued efforts have been pursued also during 2001.

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

Researcher(s): Arne Johansson

Graduate student(s): Björn Lindgren

Sponsor(s): VR

For turbulent boundary layers typical Reynolds numbers are in most applications very high, whereas most laboratory experiments have been carried out at low to moderate Re. In the present project boundary layer measurements 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.

New results concerning the overlap region of turbulent boundary formed an important part of the doctoral theses of J. Österlund, presented in Dec. 1999. The results contradicted some new proposals of a power-law for the mean velocity in the overlap region, and instead cofirmed a classical log-law, although with new values of the constants involved. It was also concluded that the universal overlap region starts further out from the wall than previously assumed. The results from these experiments have been made available in a data base on the web. Collaboration with Jens Österlund has continued and has recently ben focused on the testing of new ideas derived through the use of Lie group symmetry methods. In particular a new exponential velocity defect law has been tested and confirmed with the present data base.

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): VR

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

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

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

Supersonic Flow Separation

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

Sponsor(s): VR

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

1. validated turbulence models to be applied in CFD codes for computation of supersonic flow fields with separation
2. 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.

Luminiscence in compressed gases and sonoluminescence

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

Sponsor(s): VR

The project involves both theoretical and experimental investigations to determine the causes and nature of luminescence in gases. A main purpose is to characterize what occurs in extreme bubble collapse in a liquid, especially that driven by high frequency acoustic radiation. It is also of interest to examine extreme mechanisms that can drive the emission of radiation to higher frequencies and amplitudes. The main approach is to use shock focusing in various forms to achieve this end.

Active control of flow separation in an asymmetric plane diffuser

Researcher(s): Arne Johansson

Graduate student(s): Olle Törnblom, Björn Lindgren

Sponsor(s): VR

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.

Control of oscillatory thermocapillary convection

Researcher(s): Gustav Amberg, Henrik Alfredsson

Graduate student(s): Junichiro Shiomi

Sponsor(s): VR

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

In the new phase of the project that is proposed here, the possibility to stabilize thermocapillary convection will be explored further. The design of sensors and heaters must be improved to obtain complete suppression of modes with a higher spatial wavelength. The control schemes must be developed to be effective in highly nonlinear regimes.

Diffuse interface methods for computations in materials science

Researcher(s): Gustav Amberg

Graduate student(s): Irina Loginova

Sponsor(s): VR

The structure of materials is changed by phase transformations during synthesis and processing. Many phase transformations involve diffusion and/or heat transfer and the rate of such a phase transformation may often be evaluated quite precisely by solving a diffusion problem. The growth or dissolution of a secondary particle in a parent phase is a classical problem. When there are several diffusing species the problem becomes quite complicated. The phase diagram becomes multidimensional and thus the operating compositions at the moving phase interface cannot be read directly from the phase diagram. At present such multicomponent systems have only been solved by assuming very simple geometries, e.g. spheres, plates, etc. A drawback is that the shape of a growing particle is not predicted by the calculation.

Diffuse interface methods have been used increasingly to study the dynamics of phase boundaries over the last ten years. In this approach a new field variable, the order parameter, is used to track the phase boundary. A value of 0 or 1 designates the two phases, and transition regions are identified with the phase boundary. Over the last ten years a number of phase field simulations of thermal solidification have appeared in the litterature. However, until now no simulations for truly multicomponent transformations in two or three dimensions have been reported. It is proposed to develop diffuse interface methods that can treat multicomponent phase change. The numerical methods that have been used so far must be improved significantly in order to do such simulations efficienty.

Numerical simulation of weld pools

Researcher(s): Gustav Amberg

Graduate student(s): Minh Do-Quang

Sponsor(s): PSCI

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

High level modelling for high-lift aerodynamics

Researchers: Arne Johansson, Stefan Wallin

Graduate student(s): Olof Grundestam

Sponsor(s): EU

This project is part of a research program (HiAer) funded by EU, with partners also in Finland, Germany, England, Italy and France. It is aimed at one of the big challenges for future generations of European transportation aircraft, namely the development of new and unconventional high-lift devices leading to substantial improvements in both cruise efficiency and landing and take-off performance. The goal of HiAer is to contribute to lowering the industrial cost and risk in design of new high lift systems by improving the flow modelling state-of-the-art CFD tools, and (in the part that concerns this project) to develop new turbulence models and with the aid of these demonstrate accurate prediction of 3D high lift flows. The turbulence modelling work is focussed around explicit algebraic Reynolds stress modelling (EARSM), which is a rational approximation of a full differential Reynolds stress model (DRSM) at a two-equation level. The development work will be directed into four different strongly interacting routes:

- Effect of strong streamline curvature will be considered by rational extensions of terms from the DRSM.
- The choice of basic 'length-scale determining' equation in EARSM will be studied and optimised by the use of rational constraints. The near-wall treatment is closely connected to this work. Adaptive 'wall-function' kind of boundary conditions, for optimal grid-point distribution in 3D cases where resolution is critical, will also be considered.
- The choice of basic quasi-linear pressure-strain rate model will be optimised and a reduced functional basis in 3D mean flow will be searched for.
- Finally, a strongly non-linear, realisable DRSM will be tested and possibilities to include such ideas at the EARSM level will be investigated.

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

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

Graduate student(s): Carl-Ola Danielsson

Sponsor(s): Faxén Laboratoriet

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

Two-phase modelling of dilute fibre suspensions.

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

"3D Nozzle": Compressible Flow with Shock, Transition, Turbulence and Unsteadiness

Researcher(s): Henrik Alfredsson, Nils Tillmark

Graduate student(s): Timmy Sigfrids

The object of the project is to enhance the fundamental physical understanding of compressible flow with shock, transition, turbulence and unsteadiness. The application of the basic research is aimed towards prediction models, which can be used towards solving industry-relevant problems of various types. The project involves several elements in a 3D viscous compressible flow environment:

- Overall flow measurements in a nozzle at sub- and transonic speeds.
- Detailed boundary layer measurements.
- Applying modern measurement techniques (hot-wire, LDV, PIV) to compressible viscous flow.
- Development of a new measuring technique towards time-dependent pressures.
- Implementation, development and test of advanced transition/turbulence models into a general purpose Navier-Stokes solver from an overall perspective.

The highly complex flow conditions found in most energy-conversion components will be significantly simplified for the purpose of the research study, while retaining most of the fundamental and essential flow features present in such components. Experiments will be performed on a nozzle test facility, in which two- and three-dimensional bumps are inserted. These models will represent several complex flow phenomena appearing in energy-converting components. The test section allows also for a time-dependent variation of the flow. The modular design of the test facility will provide testing possibilities of new sensor technology in compressible flow. Modern techniques as pressure sensitive paint and shear stress sensitive liquid crystals will also be tried out to be able to map the pressure distribution at the model surface. Numerical predictions will be performed on the model object using Reynolds-averaged Navier-Stokes codes. The comparison between experimental and numerical results will serve as an aid for the development of basic models related to boundary layer transition and separation in a complex compressible flow environment. The research project will include four graduate students, each with a distinct responsibility and research task. Collaboration between fundamental and applied research groups, as well as between research groups at different universities in Sweden, will greatly improve the progress of the research and be a fruitful experience for all graduate students involved in the project. The experimental parts will take place at KTH. The significant industrial perspective of the underlying physical phenomena will further enhance the students' experience. Four interdisciplinary TeknL. theses are expected to result from the project.

Nonlinear interactions between internal gravity waves

Researcher(s): Erik Lindborg

Sponsor(s): VR

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

6.3 Education didactics

CECEN - Continuing Education Centres Network in the Oltenia Region.

Researcher(s): Göran Karlsson

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

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 2001:

1. Veine Samuelsson (KTH-Syd College of Engineering in Haninge) and Rodica Gherman (Finance House KPA in Stockholm) visited Craivoa Febr. 22-25, 2001 where the participated in round table discussions about continuing education. They also visited the Eloctroputere plant and protocol office and University of Targu Jiu.
2. During the period Febr. 2 - March 15, 2001 Eugen Dumitrascu, Nicolae Enescu, Liviu Vasiluta and Florin Grofu from University of Craiova visited KTH as guest scientists within ther project. Nicolae Enescu had Department of Computer and Systems Sciences at the Kista Campus (Sirkku Männikkö) as his host, Eugen Dumitrascu had KTH Network Centre - KTH-NOC (Adrian Popescu) as his host, while Liviu Vasiluta and Florin Grofu had Department of Industrial Production (Mihai Nicolescu) as their host.
3. Göran Karlsson and Roza Dumbraveanu participated in he 'CECEN' final meeting at Ecole des Mines de Nancy March 7-11,2001. The project finished at the end of March.

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. In total 11 courses have been given.

7 Research activities

7.1 Doctoral theses defended 2001

Mehran Parsheh

Thesis title: Flow in contractions with application to headboxes
Date: January 26, 2001
Faculty opponent: Professor Ian Castro, University of Southampton, UK
Evaluation Commitee: Prof. Lars Davidsson, Prof. Richard Gebart, Doc. Jari P. Hämäläinen
Main Advisor: Senior Lecturer Anders Dahlkild

Martin Skote

Thesis title: Studies of turbulent boundary layer flow through direct numerical simulation
Date: February 23, 2001
Faculty opponent: Professor Javier Jimenez, U. Politecnica, Madrid
Evaluation Commitee: Dr Said Zahrai, ABB Corp. Res., Univ. lektor Jesper Oppelstrup, KTH, Professor Lennart Löfdahl, CTH
Main Advisor: Professor Dan Henningson

Pedro Olivas

Thesis title: On the fluid mechanics of electrochemical coating and spray painting
Date: March 26, 2001
Faculty opponent: Prof. S. Martemianov, Université de Poitiers, France.
Evaluation Commitee: Professor Fritz Bark, KTH, Mekanik, PhD, Doctor Eduardo Fontes, Comsol AB, PhD Daniel Söderberg, KTH, Mekanik, Professor Antoine Alemany, INPG, Grenoble
Main Advisor: Professor Fritz Bark

Jesper Adolfsson

Thesis title: Passive control of mechanical systems, bipedal walking and autobalancing
Date: May 11, 2001
Faculty opponent: Prof. Friedrich Pfeiffer, Institute for Applied Mechanics, Technical University of Munich
Evaluation Commitee: Doc. Virgil Stokes, Control department, Uppsala Univ., Prof. Annika

Stensson, dept of Vehicle Technology, KTH, Professor Anders Eriksson, Dept of Construction Technology, KTH.
Main Advisor: Professor Martin Lesser
Assistant Advisor: Doc. Arne Nordmark

Ruben Wetind

Thesis title: Two-Phase Flows in Gas-Evolving Electrochemical Applications
Date: August 13, 2001
Faculty opponent: Professor Martin Sommerfeld, Martin-Luther-Universität Halle-Wittenberg, Germany
Evaluation Commitee: Dr C. Trädgårdh, Dr F. Alavyoon, Professor Anders Rasmusson, Chalmers
Main Advisor: Senior Lecturer Anders Dahlkild

Markus Högberg

Thesis title: Optimal Control of Boundary Layer Transition
Date: November 9, 2001
Faculty opponent: Dr P. Luchini, Dept of Engineering Mechanics, University of Salerno
Evaluation Commitee: Professor Håkan Gustavsson, LuTH, Prof. Bo Wahlberg, S3, KTH, Dr. Per Weinerfelt, SAAB Aerospace, Future Products, Linköping
Main Advisor: Professor Dan Henningson

7.2 Licentiate theses presented 2001

Gitte Ekdahl

Thesis title: A Simple Model of the Mechanics of Trombone Playing
Date: March 15 , 2001
External examiner: Prof. Annika Stensson, Fordonsdynamik, KTH
Main Advisor: Professor Martin Lesser

Karl Borg

Thesis title: Transport of bodies small compared to the mean free path in non-uniform gases
Date: May 3 , 2001

External examiner: Doc. Alexei Heintz, Dept of Mathematics, Chalmers.
Main Advisor: Doc. Lars Söderholm

Henrik Sandqvist

Thesis title: Theoretical studies of shock waves in dispersive and dissipative media
Date: May 7 , 2001
External examiner: Oleg Rudenko, Moscow
Main Advisor: Adjunct Professor Bengt Enflo

Torbjörn Nielsen

Thesis title: Electric arc-contact interaction in high current gasblast circuit breakers
Date: May 23 , 2001
External examiner: Doc. Ingvar Axnäs, Alfvénlaboratoriet, KTH
Main Advisor: Professor Fritz Bark
Assistant advisor: Doc. Said Zahrai

Jan Pralits

Thesis title: Towards optimal design of vehicles with low drag: Applications to sensitivity analysis and optimal control
Date: June 6 , 2001
External examiner: Professor Peter Schmid, Department of Applied Mathematics, University of Washington
Main Advisor: Professor Dan Henningson

Luca Brandt

Thesis title: Study of generation, growth and breakdown of streamwise streaks in a Blasius boundary layer
Date: June 6 , 2001
External examiner: Professor Peter Schmid, Department of Applied Mathematics, University of Washington
Main Advisor: Professor Dan Henningson

Jens Fransson

Thesis title: Investigations of the asymptotic suction boundary layer
Date: September 27 , 2001
External examiner: Professor Håkan Gustavsson, LuTH
Main Advisor: Professor Henrik Alfredsson

Thomas Wright

Thesis title: The non-linear dynamics of mechanical frogs and similar toys
Date: December 6 , 2001
External examiner: Professor Sören Andersson, Dept of Machine Design, KTH
Main Advisor: Professor Martin Lesser

7.3 Publications 2001

7.3.1 Published books

Referenser

[1] SCHMID, P.J., HENNINGSON, D.S, 2001, Stability and transition in shear flows, Book, *Springer*

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

Referenser

[2] LEVENSTAM, M., AMBERG, G., WINKLER, C., 2001, Instabilitites of thermocapillary convection in a half-zone at intermediate Prandtl numbers , *Phys. Fluids*, **13**, 807-816

[3] FUKAGATA, K., ZAHRAI, S., KONDO, S., BARK, F.H., 2001, Anomalous velocity fluctuations in particulate turbulent channel flow, *Int. J. Multiphase Flow*, **27**, 701-719

[4] PRALITS, J. O., AIRIAU, C., HANIFI, A., HENNINGSON, D.S, 2001, Sensitivity Analysis Using Adjoint Parabolized Stability Equations for Compressible Flows, *Flow, Turbulence and Combustion, Kluwer*, **65 3/4**, 321-346

[5] ANDERSSON, P., BRANDT, L., BOTTARO, A., HENNINGSON, D.S, 2001, On the breakdown of boundary layer streaks, *J. Fluid Mech.*, **428**, 29-60

[6] SÖDERHOLM, L.H., 2001, A Higher Order Acoustic Equation for the Slightly Viscous Case, *Acta Acustica*, **87**, 29-33

[7] DAHLKILD, A.A., 2001, Modelling the two-phase flow and current distribution along a vertical gas-evolving electrode., *J. Fluid Mech.*, **428**, 249-272

[8] PIIROINEN, P., DANKOWICZ, H., NORDMARK, A., 2001, On a Normal-Form Analysis for a Class of Passive Bipedal Walkers, *Int J. of bifurcation and Chaos*, **11(9)**, 2411-2425

[9] GURBATOV, S.N., ENFLO, B.O., PASMANIK, G.V., 2001, The decay of Plane Wave Pulses With Complex Structure in a Nonlinear Dissipative Medium, *Acta Acustica*, **87**, 16-28

[10] LOGINOVA, I., AMBERG, G., AGREN, , 2001, Phase-field simulations of non-isothermal binary alloy solidification, *Acta Materialia*, **49**, 573-581

[11] BEHNIA, M., PRALITS, J. O., NAKAYAMA, W, 2001, Numerical Simulation of Jet Impingement/Channel Flow Cooling of an Array of Heated Strips by a Flourinert Liquid, *International Journal of Transport Phenomena*, **3/4**, 437-448

[12] DANKOWICZ, H., PIIROINEN, P., NORDMARK, A., 2001, Low-velocity Impacts of Quasiperiodic Oscillations , *Chaos, Solitons & Fractals*

[13] Mahmoudi, J., Vynnycky, M., 2001, Modelling of fluid flow, heat transfer and solidification in the strip casting of copper base alloy (II). Heat transfer, *Scandinavian Journal of Metallurgy*, **30**, 30-40

[14] Mahmoudi, J., Vynnycky, M., 2001, Modelling of fluid flow, heat transfer and solidification in the strip casting of copper base alloy (I). Water model, *Scandinavian Journal of Metallurgy*, **30**, 21-29

[15] Mahmoudi, J., Vynnycky, M., Fredriksson, H, 2001, Modelling of fluid flow, heat transfer and solidification in the strip casting of copper base alloy (III). Solidification - a theoretical study, *Scandinavian Journal of Metallurgy*

[16] Levin, O., Shyy, W., 2001, Optimization of a Low Reynolds Number Airfoil with Flexible Membrane, *Computer Modeling in Engineering & Sciences*, **2**, 523-536

[17] Häggmark, C. P., Hildings, C., Henningson, D.S, 2001, A numerical and experimental study of a transitional separation bubble, *Aerospace Science and Technology*

[18] Högberg, M., Chevalier, M., Berggren, M., Henningson, D.S,,2001, Optimal control of wall bounded flows, *FOI-R-0182-SE*

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[22] Thylwe, K.-E., Korsch, H.-J, 2001, Harmonic oscillator subject to parametric pulses: An amplitude (Milne) oscillator approach, *J. Phys. A: Math. Gen*, **34**, 3497-3510.

[23] Audenis, G., Dahlkild, A.A., 2001, Impingement of an inviscid plane liquid jet on a porous wall: a fixed domain method, *Nordic Pulp and paper research Journal*, **16**, 274-283

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[26] Nordmark, A., 2001, Existence of Periodic Orbits in Grazing Bifurcations of Impacting Mechanical Oscillators, *Nonlinearity*, **14**, 1517-1542

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[28] Lavalley, R., Amberg, G., Alfredsson, P.H., 2001, Experimental and numerical investigation of nonlinear thermocapillary oscillations, *European Journal of Mechanics B/Fluids*, **20**, 771-797

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[30] Eriksson, A., Pacoste, C, 2001, Element formulation and numerical techniques for stability problems in shells, *Comp Meth Appl Mech Eng*

[31] Tibert, G., Pellegrino, S, 2001, Review of Form-finding Methods for Tensegrity Structures, *Int J Space Struct*

[32] Cho, Y.N., Lindborg, E., 2001, Horizontal velocity structure functions in the upper troposphere and lower stratosphere 1. Observations , *J. Geophys. Res.*, **106**, 10,223-10,232

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7.3.3 Published (and accepted) papers in conference proceedings

Referenser

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[37] Vynnycky, M., Ferrari, J., Lior, N., 2001, Some basic analytical and numerical solutions to inverse problems in gas quenching, *Proc. 35th National Heat Transfer Conference, Anaheim, CA*

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[39] Högberg, M., Bewley, T. R., Berggren, M, Henningson, D.S, 2001, Optimal control of transition initiated by oblique waves in channel flow., *Turbulence and Shear Flow Phenomena - 2*, **I**, 157-161

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7.3.4 Technical reports

Referenser

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[46] Parsheh, M., 2001, Flow in contractions with application to headboxes, *Doctoral thesis*, KTH/MEK/TR—-SE

[47] Ekdahl, G., 2001, A Simple Model of the Mechanics of Trombone Playing, *Licentiate thesis*, KTH/MEK/TR–01/03–SE

[48] Olivas, P., 2001, On the fluid mechanics of electrochemical coating and spray painting, *Doctoral thesis*, KTH/MEK/TR–01/02–SE

[49] Sandqvist, H., 2001, Theoretical studies of shock waves in dispersive and dissipative media, *Licentiate thesis*, KTH/MEK/TR–01/04–SE

[50] Pralits, J. O., 2001, Towards optimal design of vehicles with low drag: Applications to sensitivity analysis and optimal control, *Licentiate thesis*, KTH/MEK/TR–01/07–SE

[51] Brandt, L., 2001, Study of generation, growth and breakdown of streamwise streaks in a Blasius boundary layer, *Licentiate thesis*, KTH/MEK/TR–01/10–SE

[52] Fransson, H. M., 2001, Investigations of the asymptotic suction boundary layer, *Licentiate thesis*, KTH/MEK/TR–01/11–SE

[53] Högberg, M., 2001, Optimal Control of Boundary Layer Transition, *Doctoral thesis*, KTH/MEK/TR–01/13–SE

[54] Wedin, R., 2001, Two-Phase Flows in Gas-Evolving Electrochemical Applications, *Doctoral thesis*, KTH/MEK/TR–01/12–SE

[55] Adolfsson, J., 2001, Passive Control of Mechanical Systems: Bipedal Walking and Autobalancing, *Doctoral thesis*, KTH/MEK/TR–01/06–SE

7.4 Seminars

January 26 Mehran Parsheh, KTH, Mekanik, Faxén Laboratory
Flow in contractions with application to Headboxes.

January 30 Sergey Gurbatov, Radiophysics Department, University of Nizhny Novgorod, Russia
The decay of multiscale signals - a deterministic model of Burgers turbulence

February 22 Javier Jimenez, U. Politecnica, Madrid
The low-dimensional dynamics of a turbulent wall in the absence of the turbulent boundary layer

February 23 Martin Skote, KTH, Mekanik
Studies of turbulent boundary layer flow through direct numerical simulation

March 15 Gitte Ekdahl, KTH, Mekanik
A Simple Model of the Mechanics of Trombone Playing

March 20 Lars Falk, FOI (Swedish Defence Research Agency)
Newton´s superb theorem - why does Earth attract like a point?

March 26 Pedro Olivas, KTH, Mekanik
On the fluid mechanics of electrochemical coating and spray painting

March 27 Anders Martin-Löf, Institute of Actuarial Mathematics and Mathematical Statistics, Stockholm University
On the physical theory of Brownian motion

April 6 Erik Lindborg, KTH, Mekanik
The kinetic energy spectrum of mesoscale motions in the stratosphere

April 24 Arne Nordmark, KTH, Mekanik
Discontinuities in sliding systems

May 3 Karl Borg, KTH, Mekanik
Transport of Bodies Small Compared to the Mean Free Path in Non-uniform Gases

May 7 Henrik Sandqvist, KTH, Mekanik

Theoretical studies of shock waves in dispersive and dissipative media

May 10 Friedrich Pfeiffer, Institute for Applied Mechanics, Technical University of Munich
Unilateral Contact Problems in Mechanics

May 11 Jesper Adolfsson, KTH, Mekanik
Passive Control of Mechanical Systems: Bipedal Walking and Autobalancing

May 23 Torbjörn Nielsen, KTH, Mekanik, Faxén Laboratory
Electric Arc-Contact Interaction in High Current Gasblast Circuit Breakers

June 1 P L Sachdev, Dept Mathematics, Indian Institute of Science, Bangalore
On the Asymptotic Solution of Some Nonlinear PDEs

June 6 Jan Pralits, KTH, Mekanik
Towards optimal design of vehicles with low drag: Applications to sensitivity analysis and optimal control.

June 6 Luca Brandt, KTH, Mekanik
Study of generation, growth and breakdown of streamwise streaks in a Blasius boundary layer

June 7 Peter Schmid, Department of Applied Mathematics, University of Washington
Some results on the stability of swept Himenz flow

September 6 Yoshio Sone, Dept Aeronautics and Astronautics, Kyoto University
Bifurcation Studies of Cylindrical Couette Flow with Evaporation and Condensation on the Boundaries

September 27 Jens Fransson, KTH, Mekanik
Investigations of the asymptotic suction boundary layer

October 4 Geert Brethouwer, KTH, Mekanik
Micro structure and Lagrangian statistics of the scalar field with a mean gradient in isotropic turbulence

October 9 I.A. Molotkov, Inst. of Terrestrial Magnetism, Ionosphere, and Radio Wave Propagation, Russian Academy of Sciences, Moscow

Asymptotic analysis of some nonlinear models for localized waves

October 12 Martin Sommerfeld, Martin-Luther-Universität Halle-Wittenberg, Germany
Analysis and modelling of turbulence in bubble columns.

October 12 Ruben Wedin, KTH, Mekanik, Faxén Laboratory
Two-phase flows in gas-evolving electrochemical applications

October 18 Gustaf Mårtensson, FaxénLaboratoriet, KTH
Evaluation of turbulence models for rapidly rotating flows using automated code generation automated code generation

October 25 Ori Levin, KTH, Mekanik
Transient vs exponential growth in boundary layer flow

November 1 Arnim Brüger, KTH, Mekanik
Development of a higher-order finite difference code for DNS in complex geometriesfor DNS in complex geometries

November 6 Jan-Olov Strömberg, Dept. Mathematics, KTH
Wavelet methods with applications in processing of signals in dimension one and two (images)

November 8 Paolo Luchini, Universita di Salerno
Control of nonlinear boundary layer perturbations through mean suction

November 9 Markus Högberg, KTH, Mekanik
Optimal Control of Boundary Layer Transition

November 13 Jack Lidmar, Fysikum, University of Stockholm
A buckling transition on a sphere and the shapes of viruses

November 15 Johan Gullman-Strand, KTH, Mekanik
Numerical study of asymmetric diffuser flow

November 22 Timmy Sigfrids, KTH, Mekanik
Hot-wire measurements of the compressible subsonic turbulent boundary layer

November 29 Lars Davidson, Chalmers
Hybrid LES-RANS: A combination of a one-equation SGS model and RANS eddy-viscosity model

December 6 Olle Törnblom, KTH, Mekanik
Experiments in a plane asymmetric diffuser

December 18 Stefan Ivanell, KTH
Computational hydrodynamic simulation of torpedo X

8 FaxénLaboratoriet

A short description of FaxénLaboratoriet (web address: http://www2.mech.kth.se/ faxenlab) is given below for 2001. The text in this section is an extract (with some modifications) of the operational plan for FaxénLaboratoriet for the period 2001-3. The Department of Mechanics is the host institute for FaxénLaboratoriet.

8.1 Introduction

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

ABB Automation Systems AB
ABB Corporate Research
ABB HVC AB
ABB Switchgear AB
Albany Nordiskafilt AB
Alfa Laval Tumba AB
Borealis AB
Eka Chemicals AB
Ipsen International GmbH
Linde Gas AG
Metso Paper, Inc
MetsäSerla
Outokumpu Copper Partner AB
SAPA
SCA Packaging Research AB
Stora Enso Research
Vattenfall Utveckling 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
- Dept. of Solid Mechanics

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

8.2 Management and organisation of the Centre

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

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

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

Electrochemical Processes
Materials Processing
Paper Technology

8.3 Research performed at FaxénLaboratoriet

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

8.3.1 Electrochemical Processes

Industrial partners: ABB Corporate Research, EKA Chemicals AB, Vattenfall Utveckling AB.

Other parties: Institut Polytéchnique de Grenoble, University of Pennsylvania.
Graduate students: Erik Birgersson, Philip Byrne, Carl-Ola Danielsson, Nulifer Ipek, Ruben Wedin, Ulrike Windecker.
Supervisors: Fritz Bark, Anders Dahlkild, Göran Lindbergh, Noam Lior, Michael Vynnycky, Anna Welin, Said Zahrai.

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:

I:1 Mass transport in turbulent bubbly cells
I:2 Gas-evolving electrodes
I:3 Pickling of steel
I:4 Modelling of annular flow in nuclear fuel reactors
I:5 Development of an electrodialysis cell
I:6 Hydrodynamics of solid polymer fuel cells

8.3.2 Materials Processing

Industrial partners: ABB Corporate Research, ABB Automation Systems AB, ABB HVC AB, ABB Switchgear AB, Alfa Laval Tumba AB, Borealis AB, Ipsen International GmbH, Linde Gas AG,

Outokumpu Copper Partner AB, SAPA.
Other parties: University of Pennsylvania, University of Tokyo
Graduate students: Jerome Ferrari, Jenny Kron, Mats Lind, Gustaf Mårtensson, Torbjörn Nielsen, Lorent Olasz, Johan Palm.
Supervisors: Fritz Bark, Hasse Fredriksson, Peter Gudmundsson, Torbjörn Hellsten, Jin Li, Hans Moberg, Arne Johansson, Noam Lior, Galina Shugai, Michael Vynnycky, Said Zahrai.

General description:

In the continuous casting of metals, 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 dampen 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:

II:1 Modelling of thermal stresses in the continuous casting of copper and aluminium alloys
II:2 Quenching of steel
II:3 Material changes in circuit breakers
II:4 Modelling of turbulence at small Rossby numbers
II:5 Numerical modelling of liquid metal flow with a free surface
II:6 Cable extrusion
II:7 Modelling of the XLPE-Cable manufacturing process

8.3.3 Paper Technology

Industrial partners: Albany Nordiskafilt AB, Metso Paper, Inc, MetsäSerla, SCA Packaging Research AB, Stora Enso Research AB.

Graduate students: Roger Bergström, Richard Holm, Claes Holmqvist, Marko Hyensjö, Mehran Parsheh, Krister Åkesson.
Supervisors: Henrik Alfredsson, Anders Dahlkild, Bo Norman.

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 streamlines increase due to the centrifugal 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:
III:1 Forming between twin wires
III:2 Initial roll forming
III:3 Flow in stratified head boxes

8.4 Financial status

The total cash (in MSEK) contributions for 2001 from the three major parties amounted to:

KTH	4.6
Industry	3.6
VINNOVA	6.0
Total	14.2

In addition to this, there are also in-kind contributions, totalling roughly 6.2 MSEK (according to budget), from industry and KTH.

8.5 Miscellaneous

The year 2001 at FaxénLaboratoriet: a sample of events

January 23: FLA Board Meeting at KTH
January 26: Ph.D. defence, Mehran Parsheh
April 19: FLA Board Meeting at KTH
May 23: Lic. Eng. defence, Torbjörn Nielsen
June 8: Ph.D. defence, Philip Byrne
September 24-25: FLA Annual Meeting at KTH
September 25: FLA Board Meeting at KTH
October 12: Ph.D. defence, Ruben Wedin
December 12: FLA Board Meeting at KTH