NEWSLETTER 39

May 2011

EUROPEAN MECHANICS SOCIETY

President's Address

Members of the society will have no doubt noticed that the EUROMECH Newsletter now appears in a much more attractive format: The lay-out is crisper and articles by Prize winners and Fellows may include colour pictures and graphs. We very much hope that EUROMECH awardees will take advantage of these new features to continue submitting articles which appeal to a wide audience within the society. Dr. Sara Guttilla, our Management advisor, supervised and coordinated this change. On behalf of all of us, let me thank her for this initiative.

Hans Fernholz, who has been deeply involved in the founding stages and in the development of EUROMECH, has kindly written an account of its history entitled "The European Mechanics Society: From its Founding in 1964 to 2000" with Appendices by L. van Wijngaarden and M. Okrouhlik. This is a very vivid recollection of the birth of EUROMECH and its transformation in 1993 into EUROMECH-European Mechanics Society. The booklet may be freely downloaded. A selection of photographs kindly gathered by Mila Okrouhlik is displayed in the "History" section of the website. Many thanks to Hans Fernholz, Leen van Wijngaarden and Mila Okrouhlik for making us aware of what has been accomplished since 1964.

As mentioned in earlier issues, EUROMECH is actively involved in the E-CAero consortium of six Aerospace-related societies which is supported by a grant from the European Commission. Several events have been scheduled in the coming months to foster closer collaborations between these societies. A joint mini-symposium on "Advanced Numerical Methods for Turbulent Flows"(organizers: P. Huerre, Ph. Reijasse, J.P. Taran) has been scheduled within EUCASS- 4th European Conference for Aerospace Studies, 4-8 July 2011, in St. Petersburg. A joint mini-symposium on "Modeling of aeronautics materials" with ECCOMAS and EUCASS (organizers: P. Diez, F. Feyel and A. Roos) will take place within EMMC12-12th European Mechanics of Materials Conference-ICMM2, 31 August-2 September 2011, in Paris. Other joint events are still in the planning stages.

In the past few years, EUROMECH has been sponsoring and supporting European Postgraduate Fluid Dynamics Conferences (EPFDC). This yearly series is organized by doctoral students for doctoral students, in an informal setting, with minimal interference from senior researchers and faculty.
The latest edition of the event (EPFDC5) will be held in Göttingen from 9th to 12th August, 2011.
For more information, please consult:

http://www.uni-marburg.de/fb13/epfdc5?language_sync=1

Doctoral students are strongly encouraged to participate.

In the same spirit, the Council has decided to promote and support a corresponding European Postgraduate Solid Mechanics Conference series (EPSMC), also organized by doctoral students for doctoral students. We invite interested PhD students to consider organizing such an event in 2012.
Proposals to be sent to Bernhard Schrefler, should include the objectives of the conference, its organization, dates, location, local organizing committee, invited lectures by senior researchers, preliminary schedule, social event, budget, accommodation, etc. The selected proposal will be financially supported by EUROMECH, up to a maximum of 5000 €. We invite prospective organizers to contact their fluid mechanics colleagues in charge of EPFDC5, Kerstin Avila (kavila@ds.mpg.de) and Matthew Salewski (salewskm@staff.uni-marburg.de) for more detailed information regarding the recommended format.

Patrick Huerre
President, EUROMECH

EUROPEAN MECHANICS SOCIETY

Contents

Addresses for EUROMECH Officers

President: Professor Patrick Huerre
Laboratoire d'Hydrodynamique, Ecole Polytechnique
F - 91128 Palaiseau cedex, France
E-mail: huerre@ladhyx.polytechnique.fr
Tel.: +33(0)1 6933 5252
Fax: +33(0)1 6933 5292

Vice President: Professor Hans-H. Fernholz
Hermann-Föttinger-Institut, Technische Universität Berlin
Müller-Breslau Strasse 8
D-10623 Berlin, Germany
E-mail: fernholz@pi.tu-berlin.de
Tel.: +49 30 314 23359
Fax: +49 30 314 21101

Secretary-General: Professor Bernhard Schrefler
Dipartimento di Costruzioni e Trasporti
Università di Padova, Via Marzolo 9
I-35131 Padova, Italy
E-mail: bas@dic.unipd.it
Tel.: +39(0)49 827 5611
Fax: +39(0)49 827 5604

Treasurer: Professor Wolfgang Schröder
Chair of Fluid Mechanics and Institute of Aerodynamics
RWTH Aachen, Wüllnerstr. 5a
D-52062 Aachen, Germany
E-mail: office@aia.rwth-aachen.de
Tel.: +49(0)241 809 5410
Fax: +49(0)241 809 2257

Newsletter editors: Dr Roger Kinns (E-mail: rogerkinns@aol.com)
Professor Bernhard Schrefler (E-mail: bas@dic.unipd.it)

Newsletter Assistant: Dr Sara Guttilla (E-mail: s.guttilla@cism.it)

Web page: http://www.euromech.org

EUROMECH Council Members

PATRICK HUERRE, Laboratoire d'Hydrodynamique, Ecole Polytechnique, 91128 Palaiseau cedex, France ■ E-mail: huerre@ladhyx.polytechnique.fr

HANS H. FERNHOLZ, Herman - Föttinger - Institut für Strömungsmechanik, Technische Universität Berlin, Müller-Breslau Strasse 8, 10623 Berlin, Germany ■ E-mail: fernholz@pi.tu-berlin.de

BERNHARD A. SCHREFLER, Dipartimento di Costruzioni e Trasporti, Università di Padova, Via Marzolo 9, I-35131 Padova, Italy ■ E-mail: bas@dic.unipd.it

WOLFGANG SCHRÖDER, Chair of Fluid Mechanics and Institute of Aerodynamics RWTH Aachen, Wüllnerstr. 5a, 52062 Aachen, Germany ■ E-mail: office@aia.rwth-aachen.de

PEDRO CAMANHO, IDMEC, Instituto Superior Técnico, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal ■ E-mail: pcamanho@fe.up.pt

OLIVER E. JENSEN, School of Mathematical Sciences, University of Nottingham, NG72RD, United Kingdom ■ E-mail: oliver.jensen@nottingham.ac.uk

HENRYK PETRYK, Institute of Fundamental Technological Research, Polish Academy of Sciences, Swietokrzyska 21, 00-049 Warsaw, Poland ■ E-mail: hpetryk@ippt.gov.pl

MICHEL RAOUS, Laboratory of Mechanics and Acoustics - CNRS, 31 Chemin Joseph Aiguier, 13402 Marseille Cedex 20, France ■ E-mail: raous@lma.cnrs-mrs.fr

VIGGO TVERGAARD, DTU Mechanical Engineering Department, Nils Koppels Allé, Building 404, room 134, 2800 Kgs. Lyngby, Denmark ■ E-mail: viggo@mek.dtu.dk

GERT JAN F. VAN HEIJST, Eindhoven University of Technology, Phys. Dept., Fluid Dynamics Lab., P.O. Box 513, NL-5600 MB Eindhoven, The Netherlands ■ E-mail: g.j.f.v.heijst@tue.nl

EUROPEAN MECHANICS SOCIETY

Chairpersons of Conference Committees

JACQUES.MAGNAUDET (Fluid Mechanics), Institut de Mécanique des Fluides de Toulouse ■ E-mail: jacques.magnaudet@imft.fr

MARC GEERS (Mechanics of Materials), Eindhoven University of Technology, Mechanical Engineering, Materials Technology, PO Box 513 ,WH 4.135, 5600 MB, Eindhoven, The Netherlands ■ E-mail: m.g.d.geers@tue.nl

DICK H. VAN CAMPEN (Non-linear Oscillations), Eindhoven University of Technology, Mechanical Engineering Department, Den Dolech 2, P.O. Box 513, 5600 MB Eindhoven, The Netherlands ■ E-mail: d.h.v.campen@tue.nl

RAY W. OGDEN (Solid Mechanics), Department of Mathematics, University of Glasgow, University Gardens, Glasgow G12 8QW, Scotland, UK ■ E-mail: rwo@maths.gla.ac.uk

DETLEF LOHSE (Turbulence), University of Twente, Department of Applied Physics, P.O. Box 217, 7500 AE Enschede, The Netherlands ■ E-mail: d.lohse@utwente.nl

EUROMECH Solid Mechanics Fellow 2009 Paper

"The perturbative approach to material instabilities"

Davide Bigoni was named Fellow of EUROMECH at the 7th EUROMECH SOLID Mechanics Conference held in Lisbon, September 2009

Davide Bigoni[1]

Abstract

Material instabilities, modelling the formation of shear bands and other localized strains, can be detected and tested using a perturbative approach. The perturbing agent, in the form of a concentrated force, crack, rigid line inclusion or a pre-existing shear band, is analyzed within a prestressed homogeneous medium. In this way, the incremental stress/strain fields emerging near the perturbation disclose features of the instability that otherwise may be difficult to investigate.

Introduction

A material instability is usually identified with a localized loss of homogeneity of strain. This may occur in a solid sample subject to a loading path compatible with continued uniform strain, which is constrained on the whole boundary to prescribed displacements (or to smooth contact with a rigid wall, Ryzhak, 1993), Fig. 1.

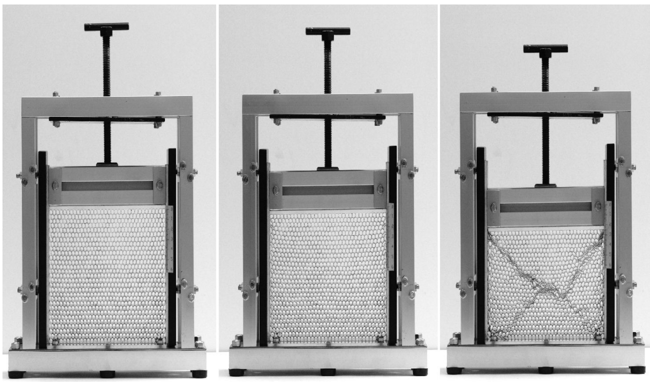

Fig. 1: Uniaxial deformation of a regular packaging of identical and parallel thin-walled cylinders (drinking straws), constrained within a rigid-wall box. The unloaded configuration is shown on the left and a configuration where deformation is still homogeneous is shown at the centre. While the strong confinement precludes diffuse bifurcations, strain localization can develop and is visible on the right [experiment inspired from Poirier et al. (1992) and performed at the University of Trento].

[1] *Dipartimento di Ingegneria Meccanica e Strutturale, Università di Trento. Via Mesiano 77, I-38050 Italy. Email: bigoni@ing.unitn.it; Web page: http://www.ing.unitn.it/~bigoni*

Since the stiff boundary constraint prevents development of 'global' (such as Euler-like buckling) or surface (such as necking) bifurcations, the loss of homogeneity occurring in the sample may be interpreted as a deformation mechanism 'alternative' to the homogeneous one, or, in other words, as a 'localized' bifurcation. Roughly speaking, this bifurcation results from a strongly nonlinear (nominal) stress vs. (conventional) strain curve of the type sketched in Fig. 2 (referred to the experiment on drinking straw packaging reported in Fig. 3). This exhibits an initial linear response, followed by a nonlinear range showing a peak and subsequent strain softening.

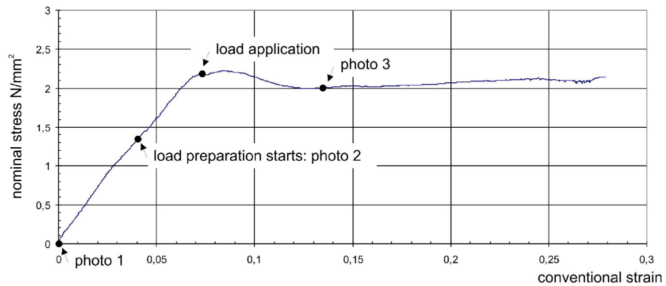

Fig. 2: Vertical nominal stress versus 'global' uniaxial conventional strain curve for a packaging of regularly disposed drinking straws. Note that, due to the lateral constraint, the state of stress in the test is not uniaxial. The photographs are shown in Fig. 3, where the application by hand of a vertical concentrated load is visible.

The softening may, as in Fig. 2, terminate at a certain strain level to give rise to a more or less pronounced strain hardening regime.

The strain localization visible in Fig. 1 is a manifestation of a material, in this case drinking straw packaging, traversing an unstable state. This begins at a certain high strain level and culminates with localization and a subsequent accumulation of deformation bands. In other cases, intense strain and damage can occur within a single deformation band (Gajo *et al*, 2004).

Since the 'standard' approach to material instability is limited to the determination of the *onset* of strain localization, identified with the loss of ellipticity of the incremental governing equations (Rice, 1977), the unstable state previously traversed by the material is usually left unexplored. However, this state can efficaciously be investigated through the analysis of the material response to a *perturbation* applied at a certain level of deformation. For instance, we can perturb the sample in the experiment shown in Fig. 1, by applying a concentrated force when the deformation is still uniform, but the peak of the curve is approached (Fig. 3). As a result, the deformation induced by the perturbing force becomes highly focused and localized, which would have not been the case if the perturbation had been provided much before the peak of the stress/strain response.

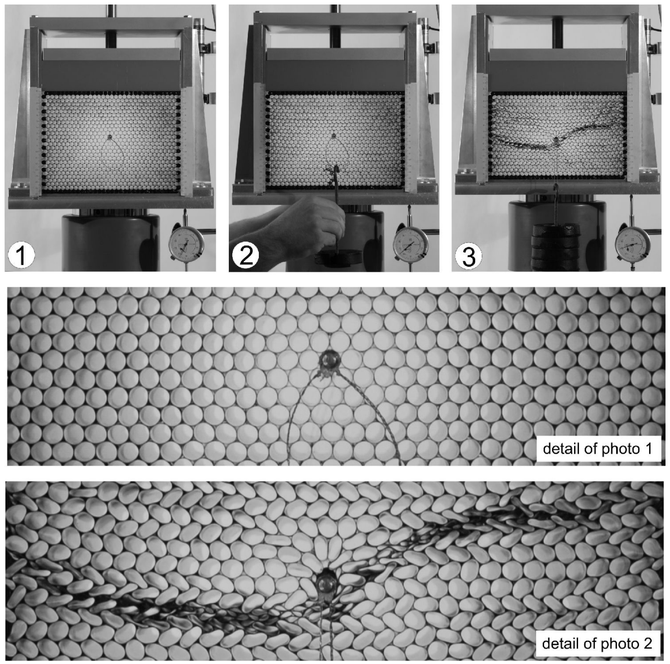

Fig. 3: Application of a concentrated load (50 N) during uniaxial deformation of a packaging of regularly disposed drinking straws. Photograph 1 in the upper row was taken before the test start, while a vertical load was applied at the instant when Photograph 2 was taken. The shear bands emanating from the applied load are visible in Photograph 3. The lower photographs show details from Photographs 1 (unloaded configuration) and 3 (strain localization already developed). The device used to apply the concentrated load is clearly visible.

This experimental procedure has been rationalized by Bigoni and Capuani (2002), who have defined a perturbation in terms of a concentrated force acting in an infinite prestressed continuum. In addition to the concentrated force, different perturbing agents have been envisaged: namely a fracture, a rigid-thin inclusion, and a pre-existing shear band. The perturbative approach has been shown to be capable of describing phenomena that involve dynamics of shear bands (Bigoni and Capuani, 2005), strain pattern emergence for materials in flutter conditions (Piccolroaz *et al*, 2006), and interactions between shear bands and inclusions (Bigoni and Dal Corso, 2008; Bigoni *et al*, 2008; Dal Corso and Bigoni, 2009; Dal Corso *et al*, 2008).

The perturbative approach

To explain in a simple way the perturbative approach to material instability, we follow Bigoni and Noselli (2010a, b) and refer to an orthotropic elastic material, rather than to a prestressed medium, which is defined in plane strain by the constitutive equations

$$\sigma_{11} = \frac{E_1}{1-\nu_{12}\nu_{21}}\left(\varepsilon_{11} + \nu_{21}\varepsilon_{22}\right),\ \sigma_{22} = \frac{E_2}{1-\nu_{12}\nu_{21}}\left(\varepsilon_{22} + \nu_{12}\varepsilon_{11}\right),\ \sigma_{12} = 2\,\mu_{12}\,\varepsilon_{12}, \tag{1}$$

relating the stress σ_{ij} to the strain ε_{ij} through the elastic moduli E_i, the shear modulus μ_{12} and contraction coefficients ν_{ij}. For extreme values of orthotropy, the boundary of ellipticity can be approached and this condition can be tested employing an appropriate perturbation. We can consider, in particular, an elastic half space, with orthotropy axes parallel and orthogonal to the free surface and perturb this configuration by imposing a concentrated load orthogonal to the surface. The solution for this problem has been given by Lekhnitskii (1981) in a polar coordinate system r and ϑ centered at the applied concentrated force F as

$$\sigma_r(r,\vartheta) = -\frac{F}{\pi}\cdot\frac{\cos\vartheta}{r}\cdot\sqrt{\frac{E_2}{E_1}}\cdot\frac{u_1+u_2}{\Lambda(\vartheta)}, \tag{2}$$

where, assuming for simplicity $\nu_{ij} = 0$,

$$\Lambda(\vartheta) = \frac{E_2}{E_1}\sin^4\vartheta + \frac{E_2}{\mu_{12}}\sin^2\vartheta\cos^2\vartheta + \cos^4\vartheta, \tag{3}$$

and u_1 and u_2 are two roots of the equation

$$\frac{E_2}{E_1}u^4 - \frac{E_2}{\mu_{12}}u^2 + 1 = 0. \tag{4}$$

By definition, $\Lambda(\vartheta)$ is positive for all ϑ in the elliptic range, but vanishes for some ϑ when the boundary of ellipticity is touched. This condition makes already evident that there is a blow up of the solution when the elliptic boundary is approached, but the interesting aspect is the behaviour of the solution *before* the threshold is attained. We report in Fig. 4 the response to a concentrated force of an isotropic (left, the so-called ‘Flamant solution’) and a highly orthotropic (right, for a ratio E_2/E_1 between vertical and horizontal elastic moduli equal to 300) half space. The solution pertaining to the highly orthotropic material represents the response near a material instability and is:

i) highly localized;
ii) strongly directional (in this case oriented parallel to the direction of the applied force).

These effects have been noticed also by Everstine and Pipkin (1971), who provided an asymptotic approximation to Eqn. (2) valid for an extreme orthotropy similar to that considered here. They also noticed the 'stress channeling effect' shown in Fig. 4 on the right, for fibre-reinforced materials, so that they envisaged a route to material instability in essence similar to the perturbative approach proposed independently by Bigoni and Capuani (2002).

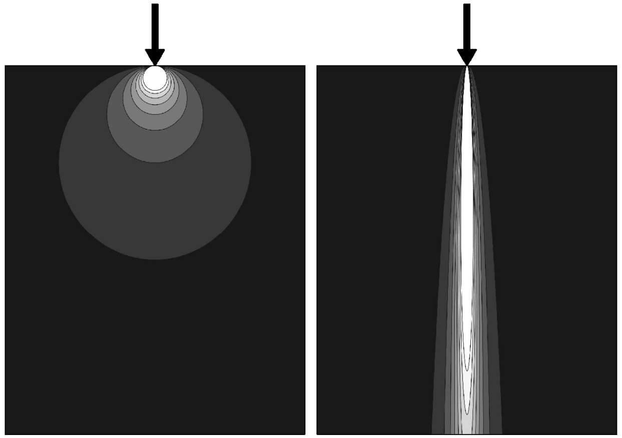

Fig. 4: Maps of in-plane principal stress difference for two elastic materials, one isotropic (left) and another highly orthotropic (right), subject to a concentrated load, denoted by the black arrow. Compare with the photoelastic experiments shown in Fig. 5.

The nearly vertical stress percolation shown in Fig. 4 on the right can be observed in highly orthotropic material, such as masonry (Bigoni and Noselli, 2010a, b). In particular, a transmission photoelastic investigation is presented in Fig. 5 for scale models of a rectangular platelet on the left, and of a dry masonry on the right. The photographs in Fig. 5 should be compared with the stress contours in Fig. 4. The Flamant solution results are confirmed for a platelet of intact material, simulating a semi infinite elastic half space. More important for our purposes, the model of dry masonry reported on the right shows a highly localized stress percolation, in agreement with the Lekhnitskii solution (2) for high orthotropy contrast. The localized stress distribution obtained for high orthotropy contrast degenerates at the boundary of ellipticity into a set of vertical lines, transmitting the load without diffusion, as pointed out by Heyman (1965).

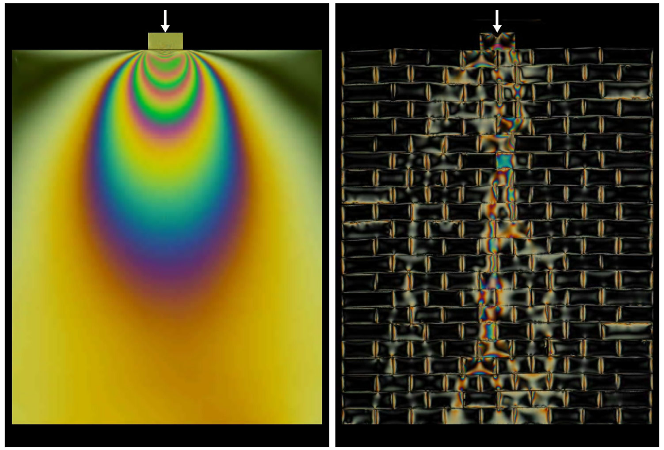

Fig. 5: Maps of isochromatic photoelastic fringes, detected with a circular transmission polariscope using white light, of a resin platelet (left) and of a model of dry masonry (right), both subject to a vertical load denoted with a white arrow. While in the left hand map the load is diffused within the material according to the Flamant solution, there is a strong vertically localized stress percolation in the right hand map, which is in agreement with the Lekhnitskii solution (2) at high orthotropy contrast, see Fig. 4.

It is important to conclude from Fig. 4 on the right that as a response to a perturbation, strain localization emerges still inside the elliptic range.

Conclusions

The conventional approach to material instability is confined to the analysis of failure of ellipticity for a uniformly deformed solid. This yields the threshold of the instability, in terms of a control parameter, such as the level of prestress, or the hardening and the shear band inclinations (Rice, 1977). Assuming that this conventional analysis can be performed easily and that results are available, the perturbative approach to material instability has been tailored to analyze the unstable state that is traversed by the material *before* ellipticity loss. In this way, features of this unstable state, otherwise remaining undetected, can be investigated. In particular, the following effects can be detected: (i) dynamical effects near the border of ellipticity (Bigoni and Capuani, 2005), or near the so-called 'flutter instability' (Piccolroaz *et al*, 2006); (ii) interactions of a shear band with a thin rigid inclusion, or with a crack, or with a pre-existing shear band. Fig. 8 shows some sample results than can be compared with each other.

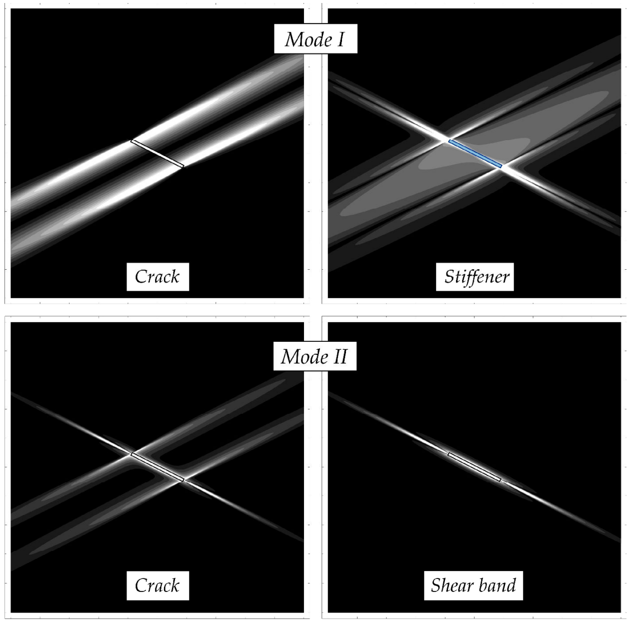

Fig. 8: Interactions between shear bands in a ductile metallic material (J_2-deformation theory) near the elliptic border for: (i) a crack (upper and lower photographs on the left, see Bigoni and Dal Corso, 2008); (ii) a thin rigid inclusion (upper photograph on the right, see Bigoni *et al*, 2008, Dal Corso and Bigoni, 2009, Dal Corso *et al*, 2008); and (iii) a pre-existing shear band (lower photograph on the right, see Bigoni and Dal Corso, 2008).

In all these problems, where defects incrementally perturb a prestressed solid, the resulting complex stress states (involving singularities and high stress concentrations) can be detailed through analytical solutions. They can be employed to study incremental energy release rate and the associated tendency to defect growth or reduction (Bigoni and Dal Corso, 2008; Dal Corso and Bigoni, 2009, 2010).

References

[1] Bigoni, D. and Capuani, D. 'Green's function for incremental nonlinear elasticity: shear bands and boundary integral formulation', *J. Mech. Phys. Solids*, **50**, 2002, 471-500.

[2] Bigoni, D. and Capuani, D. 'Time-harmonic Green's function and boundary integral formulation for incremental nonlinear elasticity: dynamics of wave patterns and shear bands', *J. Mech. Physics Solids*, **53**, 2005, 1163-1187.

[3] Bigoni, D. and Dal Corso, F. 'The unrestrainable growth of a shear band in a prestressed material', *Proc. Royal Soc. A*, **464**, 2008, 2365-2390.

[4] Bigoni, D. and Noselli, G. 'Localized stress percolation through dry masonry walls. Part I - Experiments', *European J. Mech. A/Solids*, **29**, 2010, 291-298.

[5] Bigoni, D. and Noselli, G. 'Localized stress percolation through dry masonry walls. Part II - Modelling', *European J. Mech. A/Solids*, **29**, 2010, 299-307.

[6] Dal Corso, F. and Bigoni, D. 'Growth of slip surfaces and line inclusions along shear bands in a softening material', *Int. J. Fracture*, **166**, 2010, 225-237.

[7] Dal Corso, F. and Bigoni, D.'The interactions between shear bands and rigid lamellar inclusions in a ductile metal matrix', *Proc. Royal Soc. A*, **465**, 2009, 143-163.

[8] Dal Corso, F., Bigoni, D. and Gei, M. 'The stress concentration near a rigid line inclusion in a prestressed, elastic material. Part I Full-field solution and asymptotics', *J. Mech. Physics Solids*, **56**, 2008, 815–838.

[9] Dal Corso, F., Bigoni, D. and Gei, M. 'The stress concentration near a rigid line inclusion in a prestressed, elastic material. Part II Implications on shear band nucleation, growth and energy release rate', *J. Mech. Physics Solids*, **56**, 2008, 839–857.

[10] Everstine, G.C. and Pipkin, A.C. 'Stress channelling in transversely isotropic elastic composites', ZAMP, **22**, 1971, 825-834.

[11] Gajo, A., Bigoni, D. and Muir Wood, D. 'Multiple shear band development and related instabilities in granular materials', *J. Mech. Phys. Solids*, **52**, 2004, 2683-2724.

[12] Heyman, J. 'The stone skeleton', *Int. J. Solids Struct.*, **2**, 1966, 249-279.

[13] Lekhnitskii, S.G. 'Theory of Elasticity of an Anisotropic Body', 1981, Mir Publisher, Moscow.

[14] Piccolroaz, A., Bigoni, D. and Willis, J.R. 'A dynamical interpretation of flutter instability in a continuous medium', *J. Mech. Phys. Solids*, **54**, 2006, 2391-2417.

[15] Poirier, C., Ammi, M., Bideau, D. and Troadec, J.P. 'Experimental study of the geometrical effects in the localization of deformation', *Phys. Rev. Letters*, **68**, 1992, 216-219.

[16] Rice, J. R. 'The localization of plastic deformation' In Koiter, W.T., ed., Theoretical and Applied Mechanics. Amsterdam, North-Holland, 1977, 207-220.

[17] Ryzhak, E. I. 'On stable deformation of "unstable" materials in a rigid triaxial testing machine', J. Mech. Phys. Solids, 41, 1993, 1345-1356.

EUROMECH Fluid Mechanics Prize 2008

"Unusual Properties of Convection and Dynamos in Rotating Spherical Shells"

Friedrich Busse won the EUROMECH Fluid Mechanics Prize awarded at the 7th European Fluid Mechanics Conference, in Manchester.

F. H. Busse[1]

Convection in rotating spherical fluid shells is a basic dynamical process in the description of heat transports in planets and in stars. Since the respective fluids are often electrically conducting, the occurrence of convection is frequently associated with the generation of magnetic fields (dynamo process). The interaction between velocity and magnetic fields gives rise to rich dynamical structures such as relaxation oscillations, bistable turbulent dynamos and hysteresis phenomena.

PACS numbers: 47.32.Ef, 47.55.pb, 92.60.hk, 95.30.Lz, 96.12.Hg

Introduction

Interest in the problem of convection in rotating spheres has been stimulated by its astrophysical applications and by the search for the origin of geomagnetism in the Earth's liquid outer core. The exploration of the solar system and the discovery of the magnetic fields of other planets has amplified this interest and in recent decades a large number of papers dealing with convection in fluid shells and its dynamo action have appeared. Instead of reviewing all of this work we just wish to draw attention to a number of surprising features that have appeared in the course of this work and which are of more general interest in the field of fluid dynamics. In order to make this article more readily accessible to a general readership the use of mathematical equations and formulas is minimized. For more complete introductions to the subject we refer to the book [1] and the review article [10].

Thermal Rossby waves

A basic theorem of the dynamics of rotating fluids is the Proudman-Taylor theorem which states that steady small amplitude motions of a barotropic rotating fluid do not vary in the direction of the axis of rotation when viscous effects can be neglected. "Small amplitude" means in this connection that the vorticity of the motion is negligible in comparison to the rotation rate of the system. The Proudman-Taylor condition is a consequence of the complete balance between the Coriolis force and the pressure gradient. This balance is also called geostrophic balance since it holds in good approximation for the large scale motions in the Earth's atmosphere.

[1] *Institute of Physics, University of Bayreuth, D-95440 Bayreuth, Germany,* busse@uni-bayreuth.de

Two-dimensional fluid motions do not often correspond to physical reality. In particular, in a spherical shell two-dimensional motions with a radial component are prevented by the boundary conditions. Fluid flows are thus forced to become time dependent. In the simplest cases the motions assume the form of nearly two-dimensional propagating Rossby waves. The physical mechanism of Rossby waves can be understood on the basis of the conservation of angular momentum. Fig. 1 shows an annular fluid layer with decreasing depth for increasing distance from the axis. When a column of fluid (aligned with the axis of rotation) moves into a shallower place it becomes compressed and - because of the conservation of mass - its moment of inertia increases. To conserve angular momentum its rotation relative to an inertial frame of reference must decrease. Relative to the rotating system it thus acquires anticyclonic vorticity. The opposite process happens when the column moves to a deeper place where it gets stretched in the direction of the axis of rotation and acquires cyclonic vorticity.

In the lower sketch of Fig. 1 we look at the equatorial plane of the annular layer. A sinusoidal displacement of the initially static fluid columns leads to a flow structure in the form of cyclonic and anticyclonic vortices which tend to move the columns to new positions as indicated by the dashed line in the lower plot of the figure, i.e. the initial sinusoidal displacement propagates as a wave in the prograde direction. A retrograde propagation relative to the sense of rotation will be obtained when the depth of the annular layer increases with distance from the axis.

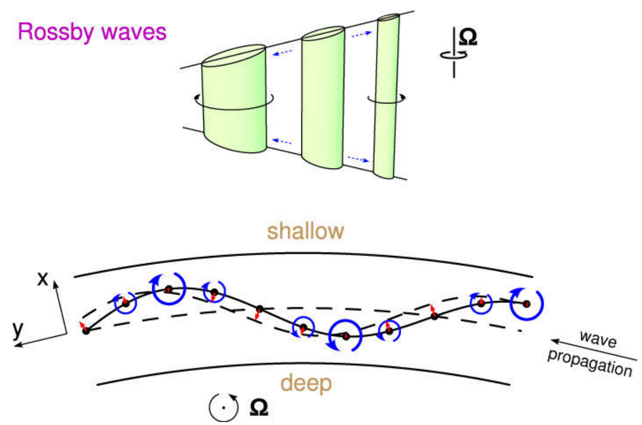

Fig. 1: Two sketches illustrating the dynamics of Rossby waves in an annular fluid layer with decreasing depth for increasing distance from the axis

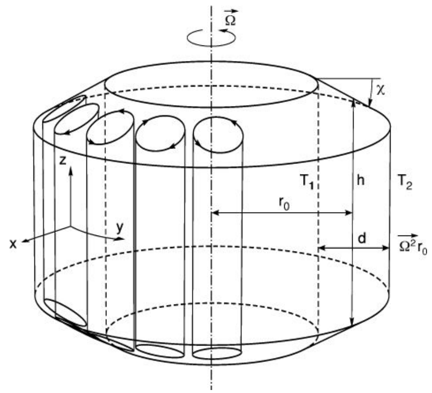

Fig. 2: Geometrical configuration of the rotating annulus in which convection is driven by centrifugal buoyancy

Like water waves, Rossby waves decay when there is no force sustaining them against viscous dissipation. The possibility for sustainment exists in a thermally unstably stratified system where thermal Rossby waves may be generated. Growing disturbances are obtained in an annular configuration as sketched in Fig. 2 when a temperature difference, T_2 - T_1, and a gravity force are applied in the x-direction. In the experimental realization of the problem [2] the centrifugal force $\Omega^2 r_0$ plays the role of gravity and the temperature gradient must point outward in order to create the unstable density stratification. For geophysical applications the opposite directions of gravity and temperature gradient are more appropriate, but the mathematical problem remains the same in both cases.

The annulus configuration of Fig. 2 may be regarded as an annular section of a rotating spherical shell. Indeed, the theory developed for the rotating annulus can be applied in good approximation to the case of convection in a self-gravitating rotating fluid sphere heated from within [3]. As a standard model a spherical fluid shell of thickness d rotating with a constant angular velocity Ω is often assumed for which a static state exists when the temperature depends only on the distance rd from the centre. Here we shall assume the particular temperature distribution $T_S = T_0 - \beta d^2 r^2 /2$ which corresponds to a homogeneously heated sphere. The gravity field is assumed to have the form $\vec{g} = -d\gamma\vec{r}$. Using the length d, the time d^2/ν and the temperature $\nu^2/\gamma\alpha d^4$ dimensionless equations can be formulated in which

Fig. 3: Convection columns in a rotating spherical fluid shell for $\tau = 10^4$, $R = 3.8\times10^5$, $P = 1$. Dark and light surfaces correspond to a constant positive and negative value of the radial velocity.

the Rayleigh number R, the Coriolis number τ and the Prandtl number P,

$$R = \frac{\alpha\gamma\beta d^6}{\nu\kappa}, \quad \tau = \frac{2\Omega d^2}{\nu}, \quad P = \frac{\nu}{\kappa}, \tag{1}$$

appear as dimensionless parameters. Here ν denotes the kinematic viscosity of the fluid, κ its thermal diffusivity and α is its coefficient of thermal expansion. Since the Boussinesq approximation is assumed, the velocity field $\vec{u}$ is solenoidal and the general representation in terms of poloidal and toroidal components can be used,

$$\vec{u} = \nabla\times(\nabla v\times\vec{r}) + \nabla w\times\vec{r}, \tag{2}$$

such that the radial velocity depends on v alone and is given by $u_r = L_2 v/r \equiv \partial^2 rv/\partial r^2 - r\nabla^2 v$. A typical picture of a thermal Rossby wave in a rotating spherical fluid shell is shown in Fig. 3. The ratio of the radius of the inner spherical boundary to the radius of the outer spherical surface is taken to be 0.4 for all the results presented in this paper. Because of the symmetry of the progradely propagating velocity field with respect to the equatorial plane it is sufficient to plot streamlines in this plane, given by $r\partial v/\partial r = const.$, in order to characterize the convection flow as has been done in Figs. 4, 5 and 7. Even in the case of turbulent convection the part of the velocity field that is antisymmetric with respect to the equatorial plane is rather small.

As the Rayleigh number R increases beyond its critical value R_c, the onset of convection in the form of thermal Rossby waves is followed by a sequence of bifurcations similar to those found in other convection problems. First, typical oscillations in amplitude are observed as shown in Fig. 4, then another bifurcation may add low wavenumber modulations in the azimuthal direction as shown in Fig. 5. Finally, a chaotic state of convection is obtained.

Chaotic convection in rotating spherical shells

The sequence of transitions is also evident in the time dependence of average quantities such as the contributions to the kinetic energy density. These are defined by

$$\overline{E}_p = \frac{1}{2}\left\langle \left| \nabla \times (\nabla \overline{v} \times \vec{r}) \right|^2 \right\rangle, \; \overline{E}_t = \frac{1}{2}\left\langle \left| \nabla \overline{w} \times \vec{r} \right|^2 \right\rangle \tag{3a}$$

$$\breve{E}_p = \frac{1}{2}\left\langle \left| \nabla \times (\nabla \breve{v} \times \vec{r}) \right|^2 \right\rangle, \; \breve{E}_t = \frac{1}{2}\left\langle \left| \nabla \breve{w} \times \vec{r} \right|^2 \right\rangle \tag{3b}$$

where the angular brackets indicate the average over the fluid shell. $\overline{v}$ is the azimuthally averaged component of v and $\breve{v} = v - \overline{v}$. At low supercritical Rayleigh numbers these energy densities approach constant values corresponding to steadily drifting thermal Rossby waves as shown in Fig. 6.

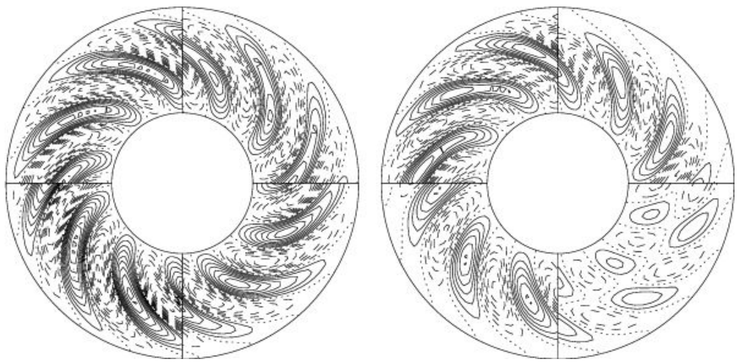

Fig. 4: Time periodic vacillations of convection at R = 2.8×10^5 (left side) and R = 3×10^5 (right side) for $\tau = 10^4$, P = 1.The streamlines, $r\partial v / \partial\varphi = const.$ are shown in one quarter of the equatorial plane. Positive (negative) values are indicated by solid (dashed) lines. The four quarters are equidistant in time with $\Delta t = 0.015$ ($\Delta t = 0.024$) in the left (right) case in the clockwise sense such that approximately a full period is covered by the circles.

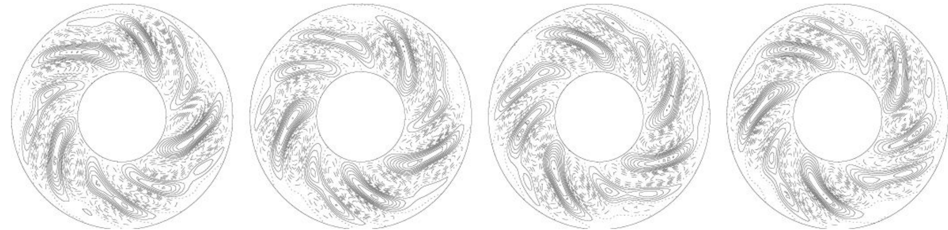

Fig. 5: Modulated shape vacillations of convection for R = 2.9×10^5, $\tau = 10^4$, P = 1. The plots show streamlines, $r\frac{\partial v}{\partial \phi} = const.$, in the equatorial plane and are equidistant in time with $\Delta t = 0.04$ so that approximately a full period is covered.

The onset of vacillations manifests itself in the sinusoidal oscillations of the kinetic energies. $\overline{E}_t$ describes the energy density of the differential rotation which increases most strongly with increasing *R* as can be noticed in Fig. 6. This increase is caused by the strong azimuthal Reynolds stress exerted by the convection eddies resulting from their inclination with respect to radial direction as is apparent in Figs 3 through 5. The shear of the differential rotation, however, tends to inhibit convection in that it shears off the convection eddies. This is a consequence of the nearly two-dimensional nature of the dynamics in a rotating system: In a non-rotating system the convection rolls would simply align themselves with the direction of the shear and the heat transport would thus remain unchanged. In the rotating sphere a precarious balance is realized in the form localized convection. As shown in Fig 7 convection occurs only in a restricted azimuthal section of the spherical shell where the convection amplitude is strong enough to overcome the inhibiting influence of the shear. The axisymmetric differential rotation continues to be driven by the localized convection. For the geostrophic zonal flow it does not matter whether it is driven locally or in an axisymmetric fashion. The advection by the differential rotation of the thermal boundary layers which expand in the non-convecting region of the shell actually strengthens the localized convection in that its available buoyancy is replenished.

Instead of a localization in space the localization of convection in time offers another possibility for the precarious balance, as demonstrated in Figs. 8 and 9. Here convection exists only for a short period while the differential rotation is sufficiently weak. As the amplitude of convection grows the differential rotation grows even more strongly as the Reynolds stress increases with the square of the amplitude. Soon the shearing action becomes strong enough to cut off convection. Now a viscous diffusion time must pass before the differential rotation has decayed sufficiently for convection to start growing again. It is remarkable to see how the chaotic system exhibits the nearly periodic relaxation oscillations shown in Fig. 8.

Fig. 9 shows a sequence of plots for four instances in time around a convection peak. At first there is hardly any convection, - the green lines just indicate zero. At the next instance the differential rotation as shown by the upper row has decayed sufficiently for the convection columns to grow, reaching nearly their maximum amplitude in the third plot.

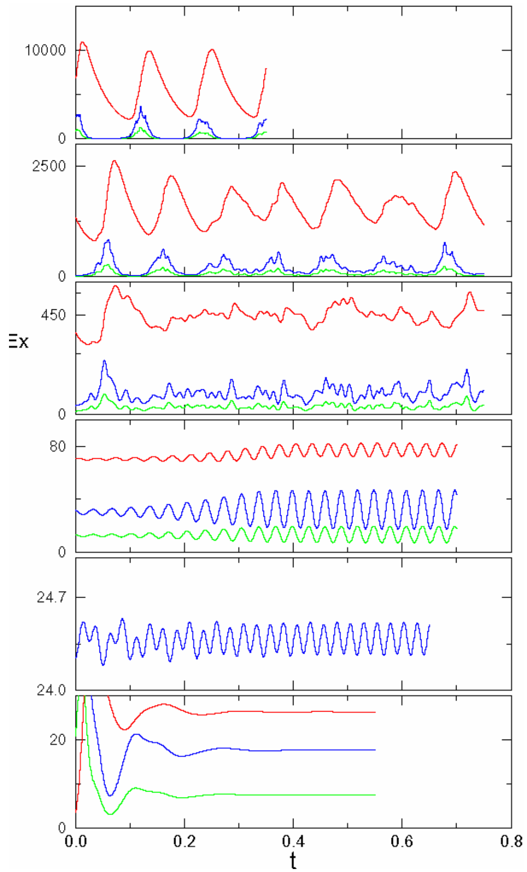

Fig. 6: Time series of energy densities of convection for P = 0.5, $\tau = 1.5 \times 10^4$ and R = 3×10^5, 3.2×10^5, 3.45×10^5, 5×10^5, 7×10^5, 10^6, (from bottom to top). Red, blue and green lines indicate $\bar{E}_t$, $\breve{E}_t$ and $\breve{E}_p$, respectively. The critical Rayleigh number for onset is Rc = 215142.

The differential rotation has grown at the same time and begins to exert its inhibiting effect. Thus, convection is reduced at the fourth instance of the sequence, while the differential rotation reaches its maximum. It should be mentioned that localized convection and relaxation oscillations occur at moderate Prandtl numbers of the order unity or less. At higher values of *P* the Reynolds stresses are no longer powerful enough to generate a strong differential rotation. Instead

variations of the temperature field with latitude cause a differential rotation in the form of a thermal wind. At very low values of *P* convection assumes the form of inertial oscillations [5, 6, 7, 9] which do not exert significant Reynolds stresses [8].

The convective heat transport in the case of localized convection as well as in the case of the relaxation oscillations is much reduced relative to a case without strong differential rotation. Here the magnetic field operates in an important way. By putting brakes on the differential rotation through its Lorentz force, the magnetic field permits a much higher heat transport than would be possible in an electrically-insulating fluid. This is the basic reason that rapidly rotating stars and planets with convecting cores exhibit magnetic fields. A demonstration of this effect is seen

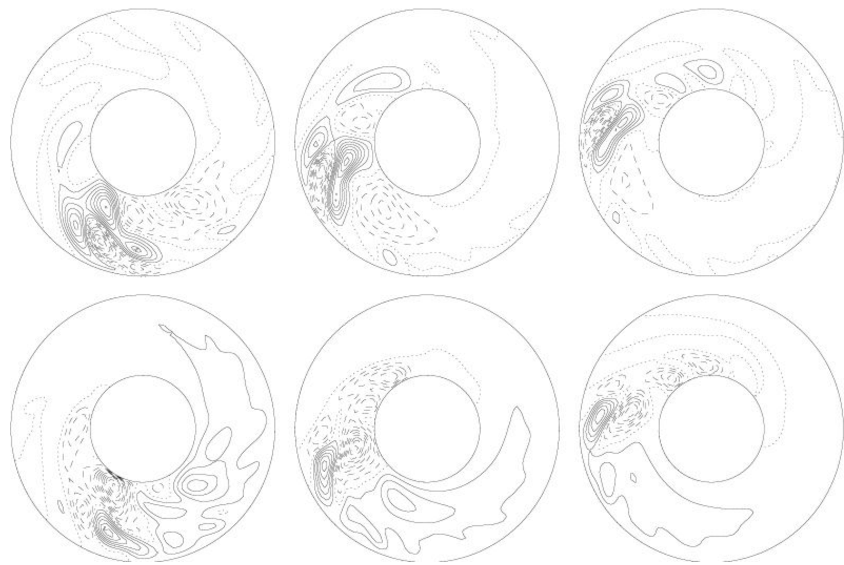

Fig. 7: Localized convection for R = 7×10^5, $\tau = 1.5 \times 10^4$, P = 0.5 The streamlines, $r\partial v / \partial\varphi = const.$ (upper row) and the isotherms, Θ = constant (lower row), are shown in the equatorial plane for equidistant times (from left to right) with $\Delta t = 0.03$.

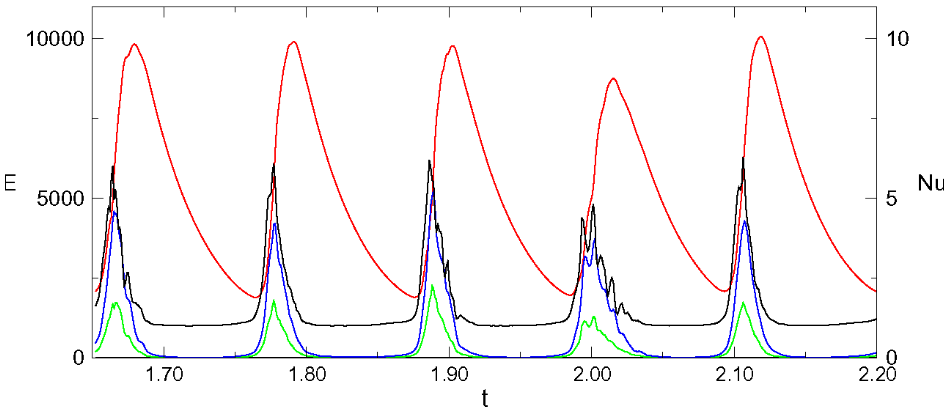

Fig. 8: Relaxation oscillations of chaotic convection in the case $\tau = 10^4$, $R = 6.5 \cdot 10^5$, $P = 0.5$. The energy densities $\overline{E}_t$ (red line), $\breve{E}_t$ (blue line), $\breve{E}_p$ (green line) and the Nusselt number (black, right ordinate) are shown as functions of time.

in Fig. 10 where by chance the convection driven dynamo was just marginal such that it could not recover after a downward fluctuation of the magnetic field. Hence the relaxation oscillations with their much reduced average heat flux take over from the dynamo state.

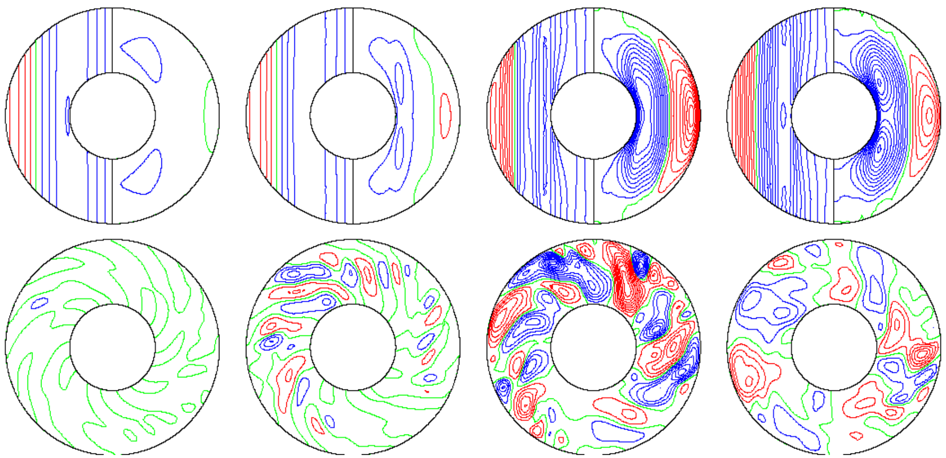

Fig. 9: Sequence of plots starting at $t = 2.31143$ and equidistant in time ($\Delta t = 0.01$) for the same case as in Fig. 8. Lines of constant $\overline{u}_\varphi$ and mean temperature perturbation, $\overline{\Theta}$ = const. in the meridional plane, are shown in the left and right halves, respectively, of the upper row. The lower row shows corresponding streamlines, $r\partial v / \partial \varphi = const.$, in the equatorial plane.

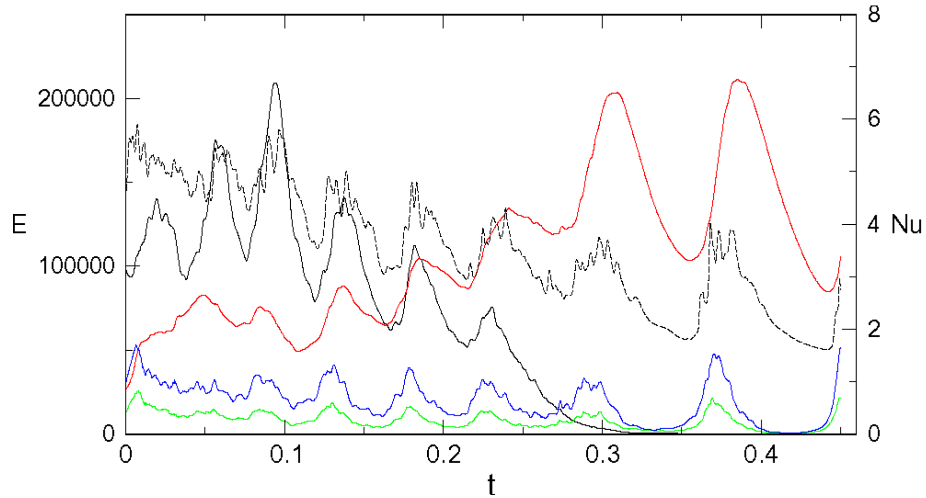

Fig. 10: Transition from a dynamo state to a state of chaotic relaxation oscillations for $\tau = 3\times10^4$, $R = 29\times10^5$, $P = 1$, $Pm = 0.4$. The energy densities $\overline{E}_t$ (red line), $\breve{E}_t$ (blue line), $\breve{E}_p$ (green line), the total magnetic energy density multiplied by a factor 8 (solid black line) and the Nusselt number Nu (dashed line, right ordinate) are shown as functions of time.

Two distinct turbulent dynamos at identical parameter values

Convection driven dynamos in rotating spherical fluid shells are often subcritical as already indicated in Fig. 10. At slightly higher Rayleigh number, convection with a strong magnetic field persists, while the dynamo will decay when the magnetic field is artificially reduced to, say, a quarter of its averaged energy. There thus exists the possibility of a convection driven dynamo state and of a non-magnetic convection state at identical values of the external parameters R, τ, P, P_m.

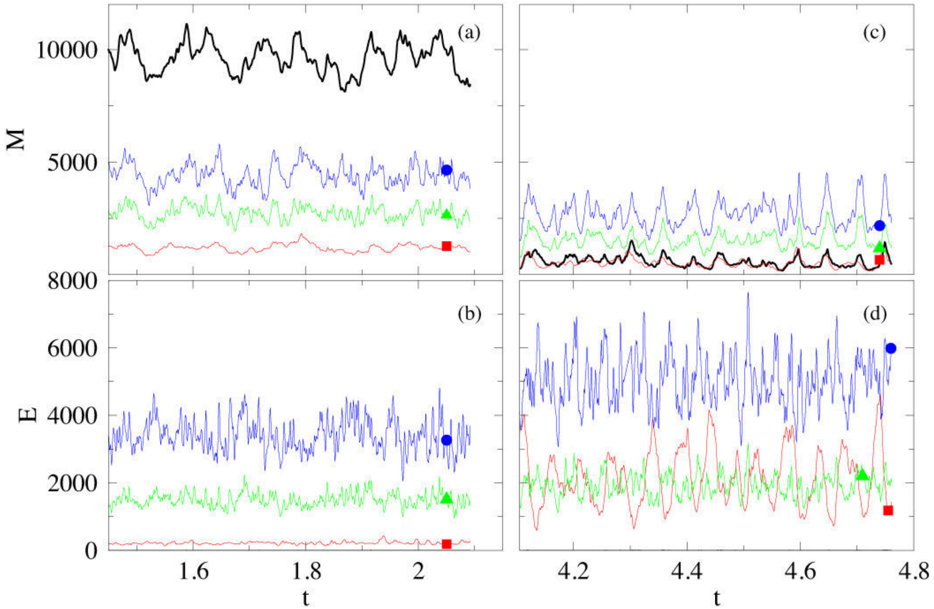

Fig. 11: Time series of two different chaotic attractors are shown - a MD (left column (a,b)) and a FD dynamo (right column (c,d)) both in the case $R = 3.5 \times 10^6$, $\tau = 3 \times 10^4$, $P = 0.75$ and $Pm = 0.75$. The top two panels (a,c) show magnetic energy densities. and the bottom two panels (b,d) show kinetic energy densities in the presence of the magnetic field. The components $\bar{M}_p$ are shown by thick solid lines, while $\bar{X}_t$, $\breve{X}_p$, and $\breve{X}_t$ are indicated by squares, triangles and circles, respectively. X stands for either M or E.

Here the latter parameter denotes the magnetic Prandtl number which is defined as the ratio between kinematic viscosity and magnetic diffusivity, $P_m = \nu/\lambda$. The magnetic diffusivity itself is defined as the inverse of the electrical conductivity times the magnetic permeability, $\lambda = \sigma^{-1}\mu^{-1}$. The bistable coexistence of a non-magnetic convection state and a dynamo state is typical for a subcritical bifurcation as it is also found in the case of shear flow instability.

More surprising is the fact that two different turbulent dynamo states can exist at identical values of the external parameters as has been shown in [11] and is demonstrated by the two examples shown in Fig. 11. Here the representation of the magnetic flux density $\vec{B}$ in terms of poloidal and toroidal components, $\vec{B} = \nabla \times (\nabla h \times \vec{r}) + \nabla g \times \vec{r}$, (4) has been used and magnetic energy densities have been defined in analogy to expressions (3),

$$\bar{M}_p = \frac{1}{2}\left\langle \left| \nabla \times (\nabla \bar{h} \times \vec{r}) \right|^2 \right\rangle, \quad \bar{M}_t = \frac{1}{2}\left\langle \left| \nabla \bar{g}_t \times \vec{r} \right|^2 \right\rangle \qquad (5a)$$

$$\breve{M}_p = \frac{1}{2}\left\langle \left| \nabla \times (\nabla \breve{h}_p \times \vec{r}) \right|^2 \right\rangle, \quad \breve{M}_t = \frac{1}{2}\left\langle \left| \nabla \breve{g}_t \times \vec{r} \right|^2 \right\rangle \qquad (5b)$$

The two turbulent dynamo states differ strongly in their magnetic energies as well as in their kinetic energies as is apparent from Fig. 11. While a strong mean poloidal magnetic field as shown in the left half of Fig. 11 acts as an efficient brake on the differential rotation as measured by $\bar{E}_t$, it also inhibits convection. The alternative dynamo on the right side of the figure is characterized by a relatively weak mean magnetic field and dominant fluctuating components. Here the kinetic energy densities of convection are larger, but the differential rotation is still much weaker than in the non-magnetic case.

The bistability in the form of two different types of dynamos is not a singular phenomenon, but exists over an extended region of the parameter space, as demonstrated in Fig. 12. A basic reason for the competitiveness of both dynamos is that they exhibit nearly the same convective heat transport as measured by the Nusselt number Nu_i which denotes the ratio of the

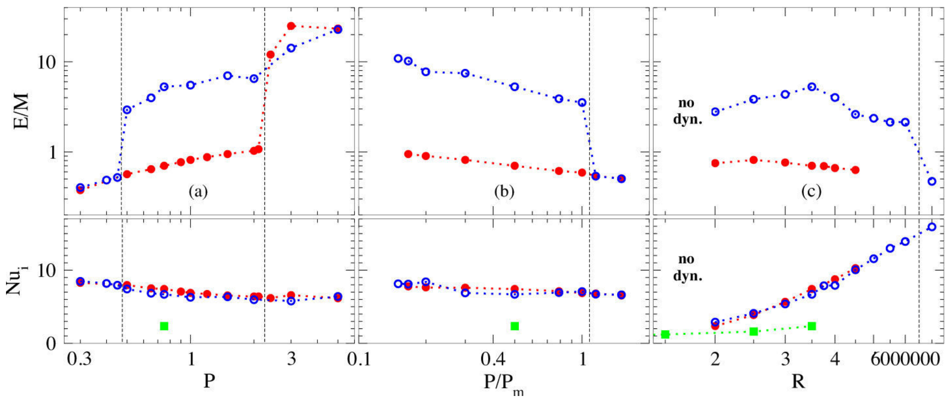

Fig. 12: The upper row shows the hysteresis effect in the ratio of magnetic to kinetic energy, E/M, at $\tau = 3 \times 10^4$ (a) as a function of the Prandtl number in the case of $R = 3.5 \times 10^6$, $P/Pm = 0.5$; (b) as a function of the ratio P/Pm in the case of $R = 3.5 \times 10^6$, $P = 0.75$ and (c) as a function of the Rayleigh number in the case $P = 0.75$, $Pm = 1.5$. Full and empty circles indicate FD and MD dynamos, respectively. The critical value of R for the onset of thermal convection for the cases shown in (c) is $Rc = 659145$. A transition from FD to MD dynamos as P/Pm decreases in (b) is expected, but is not indicated owing to lack of data. The lower row shows the value Nui of the Nusselt number at $r = ri$ for the same dynamo cases. Values for non-magnetic convection are indicated by a filled square for comparison.

mean temperature gradients at the inner boundary of the shell in the presence and in the absence of convection. The lower half of Fig. 12 not only demonstrates the surprising coincidence of the heat transports of the two dynamo types, but also shows that these heat transports exceed by far that found in the absence of a magnetic field.

Concluding remarks

The existence of two distinct turbulent states is a rare phenomenon, although examples exist in non-magnetic hydrodynamics, see for instance [12, 13]. In magnetohydrodynamics the magnetic field offers new degrees of freedom which allow the co-existence of more than one turbulent state. Initial conditions thus determine which of the competing states is actually realized.

The possibility of bistability could be of interest for the interpretation of planetary and stellar magnetism. Magnetic hysteresis effects associated with stellar oscillations could eventually be explained in this way. Colleagues involved in numerical simulations of convection driven dynamos should be reminded that their solutions may depend quite strongly on the initial conditions used.

Acknowledgments

The help of Dr. R. Simitev in creating the figures and useful comments of Prof. W. Pesch are gratefully acknowledged.

References

[1] E. Dormy, A.M. Soward, eds., Mathematical Aspects of Natural Dynamos, CRC Press, Taylor & Francis Group, 2007

[2] F. H. Busse, C. R. Carrigan, Laboratory simulation of thermal convection in rotating planets and stars, SCIENCE, 191, 81-83 (1976)

[3] F. H. Busse, Thermal instabilities in rapidly rotating systems J. Fluid Mech., 44, 441-460 (1970)

[4] F. H. Busse, Asymptotic theory of convection in a rotating, cylindrical annulus. J. Fluid Mech., 173, 545-556 (1986)

[5] K. Zhang, On coupling between the Poincaré equation and the heat equation. J. Fluid Mech., 268, 211-229 (1994)

[6] K.-K. Zhang, and F. H. Busse, On the onset of convection in a rotating spherical shells. Geophys. Astrophys. Fluid Dyn., 39, 119-147 (1987)

[7] M. Ardes, F. H. Busse and J. Wicht, Thermal convection in rotating spherical shells. Phys. Earth Planet. Inter., 99, 55-67 (1997)

[8] H. P. Greenspan, On the nonlinear interaction of inertial modes. J. Fluid Mech., 36, 257-264 (1969)

[9] R. D. Simitev and F. H. Busse, Patterns of convection in rotating spherical shells, New J. Phys., 5, 97.1-97.20 (2003)

[10] F. H. Busse, Convective flows in rapidly rotating spheres and their dynamo action, Phys. Fluids, 14, 1301-1314 (2002)

[11] R. D. Simitev and F. H. Busse, Bistability and hysteresis of dipolar dynamos generated by turbulent convection in rotating spherical shells, Euro Phys. Lett., 85 (2009) 19001

[12] F. Ravelet, L. Marìe, A. Chiffaudel and F. Daviaud, Multistability and Memory Effect in a Highly Turbulent Flow: Experimental Evidence for a Global bifurcation, Phys. Rev. Lett. 93, 164501 (2004).

[13] N. Mujica and D. P. Lathrop, Bistability and hystreresis in a highly turbulent swirling flow, Physica A49, 162-166 (2005)

EUROPEAN MECHANICS SOCIETY

EUROMECH Fellows: Nomination Procedure

The EUROMECH Council was pleased to announce the introduction of the category of **EUROMECH Fellow**, starting in 2005. The status of Fellow is awarded to members who have contributed significantly to the advancement of mechanics and related fields. This may be through their original research and publications, or their innovative contributions in the application of mechanics and technological developments, or through distinguished contribution to the discipline in other ways.

Election to the status of Fellow of EUROMECH will take place in the year of the appropriate EUROMECH Conference, EFMC or ESMC respectively. The number of fellows is limited in total (fluids and solids together) to no more than one-half of one percent of the then current membership of the Society.

Nomination conditions:

- The nomination is made by **two sponsors** who must be members of the Society;
- Successful nominees must be members of the Society;
- Each nomination packet must contain a completed Nomination Form, signed by the two sponsors, and no more than four supporting letters (including the two from the sponsors).

Nomination Process:

- The nomination packet (nomination form and supporting letters) must be submitted **before 15 January** in the year of election to Fellow (the year of the respective EFMC or ESMC);
- Nominations will be reviewed before the end of February by the EUROMECH Fellow Committee;
- Final approval will be given by the EUROMECH Council during its meeting in the year of election to Fellow;
- Notification of newly elected Fellows will be made in May following the Council meeting;
- The Fellow award ceremony will take place during the EFMC or ESMC as appropriate.

Required documents and how to submit nominations:

Nomination packets need to be sent before the deadline of 15 January in the year of the respective EFMC or ESMC to the President of the Society. Information can be obtained from the EUROMECH web page www.euromech.org and the Newsletter. Nomination Forms can also be obtained from the web page or can be requested from the Secretary-General.

EUROMECH - European Mechanics Society

NOMINATION FORM FOR FELLOW

NAME OF NOMINEE: ....

OFFICE ADDRESS: ....

....

EMAIL ADDRESS: ....

FIELD OF RESEARCH: ....

Fluids: ☐ Solids: ☐

NAME OF SPONSOR 1: ....

OFFICE ADDRESS: ....

....

....

EMAIL ADDRESS: ....

SIGNATURE & DATE: ....

NAME OF SPONSOR 1: ....

OFFICE ADDRESS: ....

....

....

EMAIL ADDRESS: ....

SIGNATURE & DATE: ....

EUROMECH- European Mechanics Society: Fellow Application

EUROPEAN MECHANICS SOCIETY

SUPPORTING DATA

- Suggested Citation to appear on the Fellowship Certificate (30 words maximum);
- Supporting Paragraph enlarging on the Citation, indicating the Originality and Significance of the Contributions cited (limit 250 words);
- Nominee’s most Significant Principal Publications (list at most 8);
- NOMINEE’S OTHER CONTRIBUTIONS (invited talks, patents, professional service, teaching etc. List at most 10);
- NOMINEE’S ACADEMIC BACKGROUND (University Degrees, year awarded, major field);
- NOMINEE’S EMPLOYMENT BACKGROUND (position held, employed by, duties, dates).

SPONSORS’ DATA

Each sponsor (there are two sponsors) should sign the nomination form, attach a letter of recommendation and provide the following information:

- Sponsor’s name;
- Professional address;
- Email address;
- Sponsor’s signature/date.

ADDITIONAL INFORMATION

Supporting letters (no more than four including the two of the sponsors).

TRANSMISSION

Send the whole nomination packet to:

Professor Patrick Huerre
President EUROMECH
Laboratoire d’Hydrodynamique, École Polytechnique
91128 Palaiseau Cedex, France
E-mail: huerre@ladhyx.polytechnique.fr

EUROPEAN MECHANICS SOCIETY

EUROMECH Prizes: Nomination Procedure

Fluid Mechanics Prize
Solid Mechanics Prize

Regulations and Call for Nominations

The Fluid Mechanics Prize and the Solid Mechanics Prize of EUROMECH, the European Mechanics Society, shall be awarded on the occasions of Fluid and Solid conferences for outstanding and fundamental research accomplishments in Mechanics.
Each prize consists of 5000 Euros. The recipient is invited to give a Prize Lecture at one of the European Fluid or Solid Mechanics Conferences.

Nomination Guidelines

A nomination may be submitted by any member of the Mechanics community. Eligible candidates should have undertaken a significant proportion of their scientific career in Europe. Self-nominations cannot be accepted.
The nomination documents should include the following items:

- A presentation letter summarizing the contributions and achievements of the nominee in support of his/her nomination for the Prize;
- A curriculum vitae of the nominee;
- A list of the nominee's publications;
- At least two letters of recommendation.

Five copies of the complete nomination package should be sent to the Chair of the appropriate Prize Committee, as announced in the EUROMECH Newsletter and on the Society's Web site www.euromech.org Nominations will remain active for two selection campaigns.

Prize committees

For each prize, a Prize Committee, with a Chair and four additional members shall be appointed by the EUROMECH Council for a period of three years. The Chair and the four additional members may be re-appointed once. The committee shall select a recipient from the nominations. The final decision is made by the EUROMECH Council.

Fluid Mechanics Prize

The nomination deadline for the Solid Mechanics prize is **15 January in the year of the Solid Mechanics Conference**. The members of the *Solid Mechanics Prize and Fellowship Committee* are:

- A. Kluwick (Chair)
- O. E. Jensen
- D. Lohse
- P. Monkewitz
- W. Schröder

Chairman's address
Professor A. Kluwick
Institut für Strömungsmechanik und Wärmeübertragung
Technische Universität Wien
Resselgasse 3,
A -1040 Wien, Austria
Tel. : +43 1 58801 32220
Fax : +43 1 58801 32299
Email: akluwick@mail.tuwien.ac.at

Solid Mechanics Prize

The nomination deadline for the Solid Mechanics prize is **15 January in the year of the Solid Mechanics Conference**. The members of the *Solid Mechanics Prize and Fellowship Committee* are:

- W. Schiehlen (Chair)
- H. Myhre Jensen
- N.F. Morozov
- M. Raous
- B. A. Schrefler

Chairman's address
Professor W. Schiehlen
Institut für Technische und Numerische Mechanik
Universität Stuttgart
Pfaffenwaldring 9
D-70550 Stuttgart, Germany
Tel. : +49 711 685-66391
Fax : +49 711 685-66400
Email: schiehlen@itm.uni-stuttgart.de

EUROMECH Conferences in 2011

The general purpose of EUROMECH conferences is to provide opportunities for scientists and engineers from all over Europe to meet and to discuss current research.
Europe is a very compact region, well provided with conference facilities, and this makes it feasible to hold inexpensive meetings.
The fact that the EUROMECH Conferences are organized by Europeans primarily for the benefit of Europeans should be kept in mind. Qualified scientists from any country are of course welcome as participants, but the need to improve communications within Europe is relevant to the scientific programme and to the choice of leading speakers.
A EUROMECH Conference on a broad subject, such as the ESMC or the EFMC, is not a gathering of specialists all having the same research interests. Much of the communication which takes place is necessarily more in the nature of imparting information than exchange of the latest ideas. A participant should leave a Conference knowing more and understanding more than on arrival, and much of that gain may not be directly related to the scientist's current research. It is very important therefore that the speakers at a Conference should have the ability to explain ideas in a clear and interesting manner, and should select and prepare their material with this expository purpose in mind.

2011

ENOC7
7th European Nonlinear Oscillations Conference
DATE: 24 - 29 July 2011
LOCATION: Rome, Italy
CONTACT: Prof. Giuseppe Rega
E-MAIL: giuseppe.rega@uniroma1.it

ETC13
13th European Turbulence Conference
DATE: 5 - 8 September 2011
LOCATION: Warsaw, Poland
CONTACT: Prof. Konrad Bajer
E-MAIL: kbajer@fuw.edu.pl

EUROMECH Conferences Reports

"12th EUROMECH European Turbulence Conference (ETC12)"

Chairperson: Prof. Bruno Eckhardt

The 12th EUROMECH European Turbulence Conference was held on 7-10 September 2009 at the Philipps-Universität Marburg, Germany. The conference was attended by 299 researchers from around the world, including 92 either working towards their PhD or finishing after 2007. The main purpose of the Conference was to bring together researchers with a common interest in turbulent flows in all their aspects, from fundamental properties to applications in engineering and atmospheric and geophysical contexts.

Eight plenary lectures of 40 minutes each provided simulating introductions and summarized recent developments in topics ranging from environmental flows to convection and magnetic dynamo experiments. More than 240 oral contributions arranged in 4 parallel sessions covered the entire range of topics in turbulence including the theoretical, computational and experimental aspects of the discipline. Each of the oral presentations was allowed 15 minutes, including 2 minutes for discussion. There were also more than 60 poster papers.

The conference committee awarded two prices for outstanding contributions by young participants: The winners were Marc Avila, Barcelona/Göttingen for his paper "Forced localized turbulence in pipe flows", and Mickael Bougoin, Grenoble, for "Lagrangian statistics of inertial particles in turbulent flows".

Two coffee breaks and joint lunches on each day, together with a wine and cheese reception and the conference dinner, provided many opportunities for further discussion, interaction and networking. All technical events were located in the central lecture halls of the university. The conference dinner was held at a nearby hotel.

The proceedings of the conference were published as volume 1321 in the Springer Proceedings in Physics series, Advances in Physics XII, B. Eckhardt (ed), 973 pages, ISBN 978-3-642-03084-0. The proceedings were also published online and handed out to the participants on a memory stick.

"8th EUROMECH Fluid Mechanics Conference (EFMC8)"

Chairperson: Prof. Nikolaus Adams, Lehrstuhl für Aerodynamik und Fluidmechanik, Technische Universität München, Germany.

The 8th EUROMECH Fluid Mechanics Conference took place on 13-16 September, 2010 in Bad Reichenhall, Germany. The conference was attended by 510 researchers from around the world, including 173 under the age of 35. The main purpose of the conference was to bring together researchers with a common interest in fluid mechanics.

Seven plenary lectures were presented by internationally-recognized researchers. 380 oral presentations in 11 sessions covered the entire range of topics in fluid mechanics including the theoretical, computational and experimental areas of the discipline. Each of the oral presentations (12 minutes) in these sessions was followed by time for questions and further discussion.

In addition, 5 minisymposia were hosted. These were entitled: Fluid-structure interaction; Geophysical processes; Reactive flows, Particle methods in fluid dynamics; and EUCASS-EUROMECH mini-symposium on Flow Control. In these minisymposia, a number of invited papers were presented by experienced researchers, with the aim of providing training to early-stage researchers in these particular areas of fluid mechanics research.

J. Hinch was awarded the EUROMECH Fluids Prize and gave the EUROMECH Fluids Lecture entitled "A perspective of Batchelor's research in Micro-hydrodynamics".

The two coffee breaks and the lunch that took place on each day provided many opportunities for further discussion, interaction and networking. This was the first large-scale meeting to take place in the Royal Spa House Bad Reichenhall, a town renowned for its art and culture as well as its thermal springs. Much positive feedback was received by the organisers regarding the facilities, the organisation of the event and the quality of the papers presented.
The conference banquet was held at the Konzertrotunde of the Royal Spa House.

The website http://efmc8.aer.mw.tum.de/ remains live, at which abstracts of all presentations, together with the presentations of the plenary lecturers can be found.

EUROMECH Colloquia in 2011-2012

EUROMECH Colloquia are informal meetings on specialized research topics. Participation is restricted to a small number of research workers actively engaged in the field of each Colloquium. The organization of each Colloquium, including the selection of participants for invitation, is entrusted to a Chairman. Proceedings are not normally published. Those who are interested in taking part in a Colloquium should write to the appropriate Chairman. Number, Title, Chairperson or Co-chairperson, Dates and Location for each Colloquium in 2010, and preliminary information for some Colloquia in 2011 and 2012, are given below.

EUROMECH Colloquia in 2011

516. Nonsmooth contact and impact laws in mechanics
Chairperson: Prof. Bernard Brogliato
INRIA Grenoble Rhone-Alpes
Inovallée
655 avenue de l'Europe
Montbonnot, 38 334 Saint Ismier Cedex France
Email: bernard.brogliato@inrialpes.fr
Co-chairpersons: Prof. Christoph Glocker, Prof. Caishan Liu
Dates and location: 6 - 8 July 2011, Grenoble, France

521. Biomedical Flows at Low Reynolds Numbers
Chairperson: Prof. Leonhard Kleiser
Institute of Fluid Dynamics
ETH Zurich
Switzerland
Email: kleiser@ifd.mavt.ethz.ch
Co-chairpersons: Prof. Thomas Rösgen Prof. Timothy Pedley
Dates and location: 29 - 31 August 2011, ETH Zurich, Switzerland
Website: http://www.ifd.mavt.ethz.ch/research/EC521

522. Recent Trends in Optimization for computational Solid Mechanics
Chairperson: Prof. Paul Steinmann
University Erlangen/Nuremberg
Erlangen, Germany

Email: paul.steinmann@ltm.uni-erlangen.de
Co-chairpersons: Prof. Kai-Uwe Bletzinger, Prof. Gunther Leugering
Dates and location: 10 - 13 October 2011, Erlangen/Nuremberg, Germany
Website: http://www.ifd.mavt.ethz.ch/research/EC521

523. Ecohydraulics: linkages between hydraulics and ecological processes in rivers
Chairperson: Prof. Wim S.J. Uijttewaal
Environmental Fluid Mechanics section
Faculty of Civil Engineering and Geosciences
Postbox 5048, 2600 GA Delft, The Netherlands
Email : w.s.j.uijttewaal@tudelft.nl
Co-chairpersons: Dr. Johannes Steiger
Dates and location: 15 - 17 June 2011, GEOLAB University Blaise Pascal Clermont-Ferrand, France

525. Instabilities and transition in three-dimensional flows with rotation
Chairperson: Prof. Benoît Pier and Prof. Fabien Godeferd
Laboratoire de mécanique des fluides et d'acoustique
CNRS-Université de Lyon
École centrale de Lyon
36 avenue Guy-de-Collongue
F-69134 Lyon, France
Email: benoit.pier@ec-lyon.fr
Email: fabien.godeferd@ec-lyon.fr
Co-chairpersons: Prof. Nigel Peake
Dates and location: 21 - 23 June 2011, École centrale de Lyon, France

526. Patterns in soft magnetic matter
Chairperson: Dr. habil. Adrian Lange
Chair Magnetofluiddynamik
Institute of Fluid Mechanics
TU Dresden
D-01062 Dresden, Germany
Email: adrian.lange@tu-dresden.de
Co-chairpersons: Dr. Sofia Kantorovich
Dates and location: 21 - 23 March 2011, Dresden, Germany

527. Shell-like Structures – Nonclassical Theories and Applications
Chairperson: Prof. Dr.-Ing. Holm Altenbach
Lehrstuhl Technische Mechanik
Zentrum für Ingenieurwissenschaften
Martin-Luther-Universität Halle-Wittenberg
Kurt-Mothes-Str. 1
06120 Halle (Saale), Germany
Email: holm.altenbach@iw.uni-halle.de
Co-chairpersons: Prof. Victor A. Eremeyev
Dates and location: 22 - 26 August 2011

529. Cardiovascular Fluid Mechanics
Chairperson: Prof. Giorgio Querzoli
Dipartimento di Ingegneria del Territorio,
Università di Cagliari
Via Marengo 3
09123 Cagliari, Italy
Email: querzoli@unica.it
Co-chairpersons: Prof. Gianni Pedrizzetti
Dates and location: 27 - 29 June 2011, Cagliari, Italy
Website: http://cvfm.unica.it/

530. Structural Control and Energy Harvesting
Chairperson: Dr. Simon Neild
Department of Mechanical Engineering
University of Bristol
Queen's Building
University Walk
Bristol, BS8 1TR, UK
Email : Simon.Neild@bristol.ac.uk
Co-chairpersons: Prof. Dan Inman
Dates and location: 25 - 27 July 2011, University of Bristol, UK

531. Vortices and waves: identifications and mutual influences
Chairperson: Prof. Yuli D. Chashechkin
Institute for Problems in Mechanics of the Russian Academy of Sciences
101/1 prospect Vernadskogo
Moscow, 119526, Russia
Email: chakin@ipmnet.ru
Co-chairpersons: Prof. Xavier Carton
Dates and location: 21 - 24 June 2011, Moscow, Russia

EUROPEAN MECHANICS SOCIETY

EUROMECH Colloquia in 2012

514. New trends in Contact Mechanics
Chairperson: Dr. Michel Raous
Directeur de Recherche CNRS
Laboratoire de Mécanique et d'Acoustique
31, Chemin Joseph Aiguier
13402 Marseille Cedex 20, France
Email : raous@lma.cnrs-mrs.fr
Co-chairpersons: Prof. Peter Wriggers
Dates and location: May 2012, Marseille, France

524. Multibody system modelling, control and simulation for engineering design
Chairperson: Prof. Ben Jonker
University of Twente, Faculty CTW
Mechanical Automation
P.O. Box 217 – Building Horst
7500 AE Enschede, The Netherlands
Email : J.B.Jonker@utwente.nl
Co-chairpersons: Prof. Werner Schiehlen
Dates and location: 28 February - 2 March 2012, Ensched, The Netherlands

528. Wind Energy and the impact of turbulence on the conversion process
Chairperson: Dr. Joachim Peinke
Institute of Physics & ForWind
University of Oldenburg
D 26111 Oldenburg, Germany
Email: peinke@uni-oldenburg.de
Co-chairpersons: -
Dates and location: April 2012, Oldenburg, Germany

[532]. Time-periodic structures:current trends in theory and application
Chairperson: Dr. Fadi Dohnal
Institute for Structural Dynamics
Department of Mechanical Engineering
Technische Universität Darmstadt
Petersenstr. 30, 64287 Darmstadt, Germany
Email: dohnal@sdy.tu-darmstadt.de
Co-Chairperson: Prof. Dr. J. J. Thomsen
Dates and location: August 2012, TU Darmstadt, Germany

533. Biomechanics of the Eye
Chairperson: Dr Rodolfo Repetto
Department of Civil Environmental and Architectural Engineering,
University of Genoa
Via Montallegro 1, 16145, Genoa, Italy
Email: rodolfo.repetto@unige.it
Co-Chairpersons: Jennifer Siggers, Alessandro Stocchino, Michael Girard
Dates and location: July 2012, University of Genoa, Italy

534. Advanced experimental approaches and inverse problems in tissue biomechanics
Chairperson: Prof. Stéphane Avril
Ecole Nationale Supérieure des Mines
158 cours Fauriel, 42023 SAINT-ETIENNE cedex 2
Email: avril@emse.fr
Co-Chairperson: Prof. Sam Evans
Dates and location: September 2012, Saint-Etienne, France

535. Similarity and Symmetry Methods in Solid Mechanics
Chairperson: Prof. Jean-François Ganghoffer
LEMTA - ENSEM
2, Avenue de la Forêt de Haye, BP 160
54504 Vandoeuvre Cedex France
Email: jean-francois.Ganghoffer@ensem.inpl-nancy.fr
Co-Chairperson: Dr. Ivailo Mladenov
Dates and location: 6 - 9 June 2012, Varna, Bulgaria

536. Nanobubbles and micropancakes
Chairperson: Dr. James Seddon
University of Twente
Faculty of Science and Technology
Physics of Fluids, P.O. Box 217
7500 AE Enschede, The Netherlands
Email: j.r.t.seddon@utwente.nl
Co-Chairpersons: Dr. Detlef Lohse , Dr. Elisabeth Charlaix
Dates and location: 13 - 17 February 2012, Les Houches, France

537. Multi-scale Computational Homogenization of heterogeneous structures and materials
Chairperson: Prof. Julien Yvonnet
Université Paris-Est, Laboratoire Modélisation et Simulation Multi Echelle (UMR CNRS 8208)

5 Bd Descartes, 77454 Marne-la-Vallée cedex 2, France
email: julien.yvonnet@univ-paris-est.fr
Co-Chairpersons: Dr. Marc Geers, Dr. Frederic Feyel
Dates and location: February 2012, Université Paris-Est, France

538. Physics of Sports
Chairperson: Prof. Christophe Clanet
Laboratoire d'Hydrodynamique (LadHyX)
Ecole Polytechnique
91128 Palaiseau cedex, France
Email: christophe.clanet@ladhyx.polytechnique.fr
Co-Chairperson: Prof. Metin Tolan
Dates and location: March 2012, Ecole Polytechnique, Paris, France

539. Mechanics of Unsaturated Porous Media:Effective stress principle from micromechanics to thermodynamics
Chairperson: S. Majid Hassanizadeh
Department of Earth Sciences
Faculty of Geosciences
Utrecht University
P.O. Box 80021
3508 TA Utrecht, The Netherlands
Email : hassanizadeh@geo.uu.nl
Co-Chairperson: Ehasan Nikooee
Dates and location: September 2012, Utrecht University, The Netherlands

540. Advanced Modelling of Wave Propagation in Solids
Chairperson: Dr. Radek Kolman and Prof. Miloslav Okrouhlík
Institute of Thermomechanics AS CR, v. v. i.
Academy of Sciences of the Czech Republic
Dolejškova 1402/5
182 00 Prague 8, Czech Republic
Email: kolman@it.cas.cz
Co-Chairperson: Arkadi Berezovski
Dates and location: September 2012, Prague, Czech Republic

EUROMECH Colloquia Reports

EUROMECH Colloquium 518
"Biomechanics of the Eye"
26 - 28 July 2010, Imperial College London, UK
Chairperson: Jennifer Sigerson

Biomechanics plays an important role in the functioning of the eye, in both health and disease. The importance of this research area is evident from the large number of researchers worldwide, and from the existence of sessions on ocular biomechanics that have run for several years at major international conferences. However, to our knowledge, there has so far been no such meeting in Europe.

The themes of this colloquium included any application of mechanical principles to physiology or conditions affecting the eyes. Examples are: the physiology of components such as the sclera, lens, cornea, aqueous humour, vitreous humour, lamina cribrosa, optic nerve and tear film; the effect of conditions such as glaucoma and retinal detachment; and the dynamics of eye movements.

There were 34 official participants, plus seven locals who came to some of the talks, taking advantage of Colloquium 518. We had 24 presentations and a total of 13.5 hours of talks, including five invited lectures by Professors C. Ross Ethier (Imperial), Anthony Bron (Oxford), Anna Pandolfi (Milan), Alistair Fitt (Southampton) and Victor Barocas (Minnesota).

The sessions were entitled:

- Biomechanics of glaucoma I (1 invited and 4 contributed talks). Chair: D. R. Overby;
- Eye disease (1 invited talk). Chair: R. M. Pedrigi;
- Injury of the eye (1 contributed talk). Chair: A. Stocchino;
- Biomechanics of glaucoma II (2 contributed talks). Chair: M. J. A. Girard;
- Biomechanics of the cornea and lens (1 invited and 4 contributed talks). Chair: A. Tatone;
- Mathematical modelling (1 invited and 2 contributed talks). Chair: C. L. Hall;
- Eye movements (2 contributed talks). Chair: V. H. Barocas;
- Biomechanics of the iris (1 invited talk). Chair: A. Pandolfi;
- Dynamics of the vitreous humour (4 contributed talks). Chair: A. D. Fitt.

Four of the principal themes are described below.

- **Glaucoma.** This condition is the second largest cause of blindness worldwide. It is known to be related to high intraocular pressure. Although the pressure rise is thought to be caused by an increased resistance in the outflow path of the aqueous humour, the site of the increase in resistance is not completely understood, nor why a high intraocular pressure increases the risk of developing glaucoma.
Mechanics plays a central role in both the above points. We had a very comprehensive overview on the subject from an invited speaker (C. R. Ethier). The above issues were discussed further in six contributed talks.

- **Mechanics of the cornea.** A. J. Bron gave a stimulating invited lecture on various aspects of diseases of the anterior segment of the eye, focusing on the cornea.
A. Pandolfi's invited lecture concentrated on the effects of cornea deformations following laser corrective surgery. Corneal biomechanics was also considered in three contributed talks.

- **Flow in the aqueous humour.** We had excellent talks on this topic from two invited speakers (V. H. Barocas and A. D. Fitt). Barocas considered the mechanics of the iris, which is a muscle interacting with the surrounding aqueous humour.
Fitt proposed a mathematical model for the fluid mechanics relating to the cure for detachment of Descemet's membrane.

- **Vitreous humour.** Motion of the vitreous humour due to eye rotations has mechanical implications for the generation of retinal detachment and for drug delivery by injection into the vitreous chamber. These issues were discussed in five contributed talks, during which numerical, analytical and experimental results were presented.

One of the key reasons for the success of Colloquium 518 was that participants had a variety of different backgrounds, essential when dealing with a multidisciplinary topic. Engineers with expertise in solid and fluid mechanics, mathematicians, biologists and ophthalmologists were among the participants. The size of the Colloquium allowed participants to interact with one another extensively. The meeting also brought together European researchers who would normally attend different meetings and, in many cases, did not know each other. High quality talks stimulated questions which often led to follow-up discussions. During the Colloquium several possible future projects were discussed, and it is anticipated that new collaborations will arise out of the meeting. Professor Fitt, Pro Vice Chancellor of the University of Southampton commented, "it was truly the very best and most interesting [conference] that I have been to for years!"

EUROMECH Colloquium 526
"Patterns in Soft Magnetic Matter"

21 - 23 March 2011, Technische Universität Dresden, Germany
Chairperson: Dr. Adrian Lange

Euromech Colloquium 526 was devoted to the most recent development and research into pattern formation in soft magnetic matter in Europe. This covers areas such as surface instabilities and patterns of magnetic fluids, instabilities of elastic magnetic matter, including magnetic gels, and flow instabilities of magnetorheological fluids. It was the goal of the colloquium to discuss highlights and recent developments in this research field during the previous two or three years.

There were nearly 40 participants from 10 different European countries, who gave 27 oral presentations, among them three invited plenary talks from Prof.
Jean-Francois Berret (Paris), Prof. Miklos Zrinyi (Budapest), and Dr. Philip J. Camp (Edinburgh). The combination of the number of participants and the duration of two and a half days provided enough time for informal discussions in small as well as in larger groups. Presentations were scheduled so that discussions could continue as desired after an oral presentation.

Among the most frequent issues addressed in the talks and in the discussions, two are described below.

- Description of the Rosensweig instability. The Rosensweig instability describes the phenomenon that a flat horizontal layer of magnetic fluid becomes unstable creating a hexagonal arrangement of peaks if the applied magnetic induction, oriented vertically to the initially flat surface, surpasses a certain threshold.
One approach is to solve the underlying equations numerically by direct simulation. That approach was represented by Prof. Boudouvis (Greece) and Dr. Olga Lavrova (Byelorussia). Results from another approach using a model equation of the Swift-Hohenberg type were given by Dr. David Lloyd (UK). An intensive discussion developed between them about the advantages and drawbacks of the respective approaches. Experimental results, presented by Dr. Reinhard Richter and Thomas Friedrich (both from Germany), further stimulated the debate.

- Swelling of a magnetic gel under the influence of a uniform magnetic field.
The key questions of whether this phenomenon occurs, and if yes in which way, were raised during the opening day of Colloquium 526 by Rudolf Weeber (Germany). His results from computer models predicted a directed shrinking of the gel in an

external magnetic field. That such a shrinking can be observed experimentally, as one of several possible macroscopic reactions, was shown by Prof. Zrinyi (Hungary) in his review of the interaction of magnetic gels with magnetic fields. In his talk about the microscopic structures of ferrogels, Dr. Philip Camp noted that this type of macroscopic deformation is not observed if only affine translations of particles are allowed in quasi-continuous computer simulations. However, these simulations could reproduce the elastic properties of an anisotropic magnetic gel, also presented by Prof. Miklos Zrinyi on the previous day. The issue of ferrogel swelling was under active discussions during the entire colloquium, which helped to unify experimental studies and numerical models of these systems, and deepen the understanding of magneto-elastic coupling.

Objectives of EUROMECH, the European Mechanics Society

The Society is an international, non-governmental, non-profit, scientific organisation, founded in 1993. The objective of the Society is to engage in all activities intended to promote in Europe the development of mechanics as a branch of science and engineering. Mechanics deals with motion, flow and deformation of matter, be it fluid or solid, under the action of applied forces, and with any associated phenomena. The Society is governed by a Council composed of elected and co-opted members.

Activities within the field of mechanics range from fundamental research on the behaviour of fluids and solids to applied research in engineering. The approaches used comprise theoretical, analytical, computational and experimental methods.
The Society shall be guided by the tradition of free international scientific cooperation developed in EUROMECH Colloquia.
In particular, the Society will pursue this objective through:

- The organisation of European meetings on subjects within the entire field of mechanics;
- The establishment of links between persons and organisations including industry engaged in scientific work in mechanics and in related sciences;
- The gathering and dissemination of information on all matters related to mechanics;
- The development of standards for education in mechanics and in related sciences throughout Europe.

These activities, which transcend national boundaries, are to complement national activities.

The Society welcomes to membership all those who are interested in the advancement and diffusion of mechanics. It also bestows honorary membership, prizes and awards to recognise scientists who have made exceptionally important and distinguished contributions. Members may take advantage of benefits such as reduced registration fees to our meetings, reduced subscription to the European Journal of Mechanics, information on meetings, job vacancies and other matters in mechanics. Less tangibly but perhaps even more importantly, membership provides an opportunity for professional identification; it also helps to shape the future of our science in Europe and to make mechanics attractive to young people.

European Journal of Mechanics - A/Solids

ISSN: 0997-7538

The *European Journal of Mechanics A/Solids* continues to publish articles in English in all areas of Solid Mechanics from the physical and mathematical basis to materials engineering, technological applications and methods of modern computational mechanics, both pure and applied research.

The following topics are covered: Mechanics of materials; thermodynamics; elasticity; plasticity; creep damage; fracture; composites and multiphase materials; micromechanics; structural mechanics; stability vibrations; wave propagation; robotics; contact; friction and wear; optimization, identification; the mechanics of rigid bodies; biomechanics.

European Journal of Mechanics - B/Fluids

ISSN: 0997-7546

The *European Journal of Mechanics B/Fluids* publishes papers in all fields of fluid mechanics. Although investigations in well established areas are within the scope of the journal, recent developments and innovative ideas are particularly welcome. Theoretical, computational and experimental papers are equally welcome. Mathematical methods, be they deterministic or stochastic, analytical or numerical, will be accepted provided they serve to clarify some identifiable problems in fluid mechanics, and provided the significance of results is explained. Similarly, experimental papers must add physical insight in to the understanding of fluid mechanics. Published every two months, EJM B/Fluids contains:

- Original papers from countries world-wide
- Book reviews
- A calendar of scientific meetings