EUROPEAN MECHANICS SOCIETY

Newsletter 36

November 2009

President's Address

This newsletter contains essential information regarding the elections to the EUROMECH Council for 2010. The Advisory Board has prepared a list of eight candidates to fill five vacant seats on the EUROMECH Council. All these seats are for a six-year term starting on 1 January 2010. Short biographical statements by the candidates are included in this newsletter.

Bernhard Schrefler and Wolfgang Schroeder have been re-appointed as Secretary-General and Treasurer respectively until the end of 2010 and they have expressed their willingness to continue serving EUROMECH in following years. The Advisory Board has therefore decided to have them appear as candidates unopposed in the first two slots on the election ballot. Six candidates have been selected for the remaining three slots on the election ballot, having regard for subject and geographical balance on the Council. It is always gratifying to see that such a distinguished group of scientists are prepared to devote some of their time to serve our community.

The EUROMECH voting procedure has gone electronic! In order to vote, please log on our website www.euromech.org and access the member area in the lower left-hand corner of the Home page by entering the username and password which have been e-mailed to you by our scientific officer Dr. Sara Guttilla. Short biographical statements by the candidates are available for consultation in electronic form. You will then be able to express your vote in a straightforward manner. The voting deadline is January 15, 2010.

For those of you not accessible by e-mail, please urgently send your e-mail address to S.Guttilla@cism.it . If any problem arises, please feel free to let her know.

Now is the time also to submit nominations for the EUROMECH Fluid Mechanics prize and for EUROMECH Fellows. Detailed instructions for the preparation of nomination packages are available herein and on the website. The awards will be officially conferred in September 2010, on the occasion of the 8th European Fluid Mechanics Conference in Munich. I invite you to participate in this important process in the life of our society.

Patrick Huerre

President, EUROMECH

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EUROMECH Council Elections

Voting instructions

At the end of 2009, five seats on the EUROMECH Council will become vacant. In accordance with the statutes, the Advisory Board has drawn up a list of eight candidates. All seats correspond to a six-year term of office. The Advisory Board has decided to have Bernhard Schrefler and Wolfgang Schroeder appear as candidates unopposed in the first two slots, since they will continue to serve as Secretary-General and Treasurer respectively. (F) stands for research interests in Fluid Mechanics, and (S) in Solid Mechanics.

The deadline for the vote is January 15, 2010.

Bernhard.A. Schrefler

Dr. Bernhard A. Schrefler has been Professor of Structural Mechanics at the University of Padua since 1980 and is Secretary General of the International Centre for Mechanical Sciences (CISM) in Udine. He obtained his Ph.D. and D.Sc. at the University of Wales. He has received honorary doctorates from: the St. Petersburg State Technical University; the University of Technology in Lodz; the University of Wales, Swansea; the Leibniz University of Hanover; and the Russian Academy of Sciences. He is also an honorary professor at the University of Technology of Dalian. He is the recipient of the 2009 Maurice A. Biot Medal of ASCE. He has published over 400 papers on structural engineering, soil mechanics, environmental mechanics and technology for nuclear fusion, and has written or edited 23 books.

Bernhard Schrefler serves on the editorial board of 21 International Journals, is Regional Editor of Mechanics Research Communications and Corresponding Editor of Computer Modelling in Engineering & Sciences. He is Secretary General of EUROMECH. He also serves on the Executive Council of IACM (International Association for Computational Mechanics) and on the Executive Council of the Congress Committee of IUTAM (International Union of Theoretical and Applied Mechanics).

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Wolfgang Schröder is Director of the Institute of Aerodynamics and holds the Chair of Fluid Dynamics at RWTH Aachen University. He received his doctorate in 1987 from RWTH Aachen University. After postdoctoral work at the California Institute of Technology from 1987 through 1989 he was in charge of the Aerothermodynamics Department, Space Infrastructure at the German Aerospace AG until 1995. He was then at the University of Applied Sciences in Braunschweig, before returning to Aachen in 1998.

His main research interests are in the fields of aeroacoustics, turbulence, and vortex dynamics in subsonic, transonic, and supersonic flows as well as biological and medical flows. He emphasizes a coupled numerical-experimental approach to double-check the research results and to develop innovative theoretical models.

Wolfgang Schröder is a member of: Nordrhein-Westfälische Akademie der Wissenschaften; the Board of the Deutsche Komitee für Mechanik; the IUTAM General Assembly; and the Editorial Board of the *International Journal of Aeroacoustics*. He has been Treasurer of EUROMECH since 2005.

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Pedro P. Camanho

Dr. Pedro Camanho received his PhD in Composite Materials from the Department of Aeronautics, Imperial College of Science, Technology and Medicine, University of London, in 1999. In 1999, he joined the Institute of Mechanical Engineering and Industrial Management (Porto, Portugal) as Director of the Structural Integrity Unit and the Department of Mechanical Engineering of the University of Porto as Assistant Professor. Since 2008 he has been Associate Professor in the Department of Mechanical Engineering at the University of Porto.

The main research interests of Pedro Camanho are the structural integrity of advanced composite materials, continuum damage and fracture mechanics, size effects on composites, fatigue and new concepts for advanced composite materials for aerospace applications such as hybrid and variable stiffness composites. Pedro Camanho is Guest Editor of Composites-Part A (Elsevier) and is Editor of the book "Mechanical Response of Composites", European Community on Computational Methods in Applied Sciences (ECCOMAS) Series, Springer, 2008. He has been invited to give several plenary lectures, including one at the forthcoming 7th EUROMECH Solid Mechanics Conference in 2009.

Pedro Camanho has been a Visiting Scientist at NASA-Langley Research Center since 2000, was a Visiting Scientist at the US Air Force Research Laboratory and has coordinated several research projects funded by the European Space Agency, NASA and the US Air Force. He received the 2006 NASA H.J.E. Reid Award for Outstanding Scientific Paper and also the 2005 Young Researcher in Applied and Computational Mechanics Award from the Portuguese Association of Theoretical, Applied and Computational Mechanics.

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Javier Cuadrado is Professor of Mechanical Engineering at the University of La Coruña and Head of the Laboratory of Mechanical Engineering at the same university. He obtained his PhD from the University of Navarra in 1993 and, one year later, joined the University of La Coruña. His field of research is the computational kinematics and dynamics of multibody systems with rigid and flexible links and he has about 100 publications in this area. He has collaborated in projects funded by the European Space Agency and the US Army Research Office, and has participated in NATO sponsored Advanced Study Institutes. He was a member of the team that developed COMPAMM (COMPuter Analysis of Machines and Mechanisms), which has been sold worldwide by Mechanical Dynamics Inc. Presently, he is concerned with projects on training simulators, control of vehicles, and the biomechanics of human motion.

Javier Cuadrado is member of the editorial boards of Multibody System Dynamics, the Journal of Multi-body Dynamics, and Mechanics-Based Design of Structures and Machines. He co-chaired the ECCOMAS Thematic Conference Multibody Dynamics 2005, held in Madrid, Spain, and chaired EUROMECH Colloquium 476 "Real-time Simulation and Virtual Reality Applications of Multibody Dynamics", held in Ferrol, Spain, in 2006. He is co-organizing a mini-symposium on multibody dynamics within the 7th EUROMECH Solid Mechanics Conference, ESMC2009. He has also chaired the Technical Committee on Multibody Dynamics of IFToMM (International Federation for the Promotion of Mechanism and Machine Science) since 2005.

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Bruno Eckhardt

Bruno Eckhardt holds a chair in theoretical physics at the Philipps-University of Marburg. He received his PhD from the University of Bremen in 1986 and has held visiting positions at the Weizmann Institute, University of California at San Diego, the Institute of Theoretical Physics at Santa Barbara and the University of Maryland, College Park. He has held an adjunct appointment at TU Delft since 2009.

Bruno Eckhardt's interests range from low to high Reynolds number flows, covering chaotic mixing and synchronization of cilia as well as turbulence transition in pipe flow, the formation of localized turbulent patches, and the scaling and statistical properties of fully developed turbulence. He enjoys the application of ideas from dynamical systems and statistical mechanics to flows and is fascinated by the wide variety of fluid phenomena that still await an explanation. He is author or co-author of 3 books and about 180 papers.

Bruno Eckhardt is a Fellow of EUROMECH, of the American Physical Society and of the Institute of Physics, London. In 2002, he was awarded the Leibniz Prize by the German Research Foundation. He is associate editor for Physical Review E and is responsible for its Fluid Mechanics section. He is editor of Physik Journal and serves on the editorial boards of Nonlinearity and the Journal of Nonlinear Science. Within EUROMECH, he is active in the EETC Turbulence conference committee and is organizer of the 12th EUROMECH European Turbulence Conference.

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His primary research interests are in the areas of geophysical fluid dynamics (rotating and stratified flows), vortex dynamics, and viscous mixing. He is also interested in quasi-two-dimensional turbulence, as encountered in rotating and/or stratified fluids and in shallow-layer flows.

GertJan van Heijst is a member of the Royal Netherlands Academy of Arts and Sciences. He is also Co-Editor-in-Chief of the European Journal of Mechanics /B-Fluids, and has been serving on the editorial boards of Physics of Fluids and Geophysical and Astrophysical Fluid Dynamics. He was chairman of the organizing committee of the 4th EUROMECH Fluid Mechanics Conference in 2000 in Eindhoven, and has been a member (1998 – 2008) of the EUROMECH Turbulence and Fluid Mechanics Conference committees, acting as chairman for the latter.

He was elected Fellow of EUROMECH in 2008.

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Ole Sigmund has been a professor in the Department of Mechanical Engineering, Technical University of Denmark (DTU) since 2001. He obtained his PhD degree in 1994 and Dr. techn. (Danish habilitation) degree in 2001, both from DTU. He has worked as research assistant at the University of Essen, Germany and as a postdoctoral researcher at Princeton University, USA. Ole Sigmund has been a member of the Danish Academy of Technical Sciences since 2003 and the Royal Academy of Science and Letters (Denmark) since 2008. He is the Secretary of the Danish Center for Applied Mathematics and Mechanics (DCAMM, affiliated with EUROMECH) since 2004 and serves on the editorial or advisory boards for 6 international journals within mechanics and numerical methods.

Ole Sigmund's research interests include theoretical extensions and applications of topology optimization methods to the design of extremal materials, smart materials, compliant mechanisms, MicroElectroMechanical Systems, crashworthiness, fluid systems and wave-propagation problems in acoustics, elasticity, nano-optics, metamaterials and antennas.

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Viggo Tvergaard's primary research interests are instabilities of structures and solids, the mechanics of materials, fracture mechanics, damage mechanics, and micromechanics.

Viggo Tvergaard has been Editor-in-Chief of the European Journal of Mechanics A/Solids since 1995. He is a foreign member of Royal Netherlands Academy of Arts and Sciences, a foreign associate of the US National Academy of Engineering, and an honorary member of the European Structural Integrity Society (ESIS). He is a member of the Congress Committee of IUTAM, and is chair of the Solid Mechanics Symposium Panel of IUTAM.

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EUROMECH Solid Mechanics Fellow 2006 Paper

"The fracture mechanics of lattice materials"

Norman A Fleck [1],

N A Fleck was named Fellow of EUROMECH at the 6th EUROMECH SOLID Mechanics Conference held in Budapest, August 2006

Abstract

The fracture mechanics of elastic-brittle lattice materials are reviewed. Failure initiates when the local tensile stress at any location in the elastic lattice attains a local tensile fracture strength. Predictions are given for the fracture toughness in terms of the relative density, cell size, imperfection and architecture of the lattice. The concept of compressive fracture toughness is also discussed.

1. Introduction

Recently, a wide range of lattice materials has been developed with periodic 2D and 3D microstructures, see Fig. 1. These lattices are increasingly used in applications where severe mechanical loads lead to material damage: for example, catalytic converters for automobiles, and orthopaedic implants for bone repair. The macroscopic, effective stiffness (and strength) of lattice materials is more sensitive to the nodal connectivity n than to the degree of randomness of microstructure [1, 2]. A transition value of nodal connectivity n_t=4 can be identified for prismatic 2D microstructures and n_t=6 for prismatic 3D microstructures. For lattices satisfying $n>n_t$ the effective properties commonly result from the axial stretching stiffness and strength of the constituent cell walls, and the macroscopic stiffness and strength scale linearly with the relative density $\bar{\rho}$. In contrast, for $n<n_t$ the macroscopic effective properties are commonly dictated by the bending stiffness and strength of the cell walls, and consequently the stiffness and strength scales with some power of $\bar{\rho}$ exceeding unity. Thus, a high nodal connectivity gives a high specific stiffness and strength. These features are associated with the existence or absence of macroscopic strain-producing mechanisms in the parent pin-jointed truss with rigid bars: for the case $n>n_t$ no collapse mechanisms may exist, while for $n<n_t$ inextensional collapse mechanisms can exist and give rise to

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macroscopic strain. (These arguments have been made precise in [3] using the language of linear algebra.)

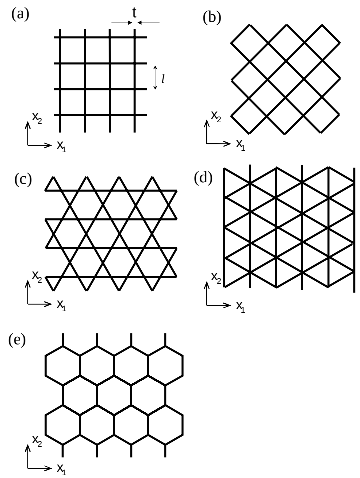


Fig. 1: Examples of 2D lattice. (a) 0/90° square; (b) ± 45° diamond; (c) Kagome; (d) triangular; (e) hexagonal.

Consider the example of the hexagonal honeycomb. This prismatic lattice has n=3 and the macroscopic response is bending-dominated, with an effective in-plane modulus that scales with $\bar{\rho}^3$, and strength that scales as $\bar{\rho}^2$. In contrast, the fully triangulated lattice has n=6 and the macroscopic response is stretching-dominated; both stiffness and strength scale linearly with $\bar{\rho}$. These two lattices are isotropic in their in-plane elastic response, yet have markedly different effective stiffnesses (and strengths) due to this difference in nodal connectivity. Their effective properties are only slightly influenced by randomly perturbing the location of the nodes: the underlying property of being bending-dominated or stretching-dominated does not change with level of imperfection.

Open-celled foams have random 3D microstructures with a value of nodal connectivity of n=3-4; these values are below the transition value of n_t=6 and consequently the mechanical response of foams are bending-dominated.

Microstructures do exist with the transition value of nodal connectivity. The isotropic Kagome lattice and the orthotropic square lattice both possess $n=n_t$=3. Likewise, the 3D cubic lattice has $n=n_t$=6. In the absence of imperfections, the Kagome lattice is stretching-dominated. The square and cubic lattices are stretching-dominated along some loading directions but are bending-dominated along other directions. These transition lattices are imperfection-sensitive: for example, the random perturbation of nodal position induces local bending of the cell walls of the Kagome lattice, and the stiffness and strength drop significantly [1].

2. The damage tolerance of lattice materials

Cracks can exist in a lattice material and cause a significant decrease in fracture strength. Frequently, the lattice is loaded in a sandwich panel configuration with stiff and strong face-sheets. The damage tolerance of these structures can be quantified by two strength parameters for the lattice material: the unnotched strength and the fracture toughness. At short crack lengths, the unnotched strength governs the response, whereas at large crack lengths, a K-field exists near the crack tip and the fracture toughness dictates the response.

Consider, as a representative example, a centre-cracked sandwich panel with an elastic-brittle diamond-celled lattice core, Figure 2. The sandwich panel has rigid face-sheets and a diamond-celled lattice core of cell size l, cell thickness t, and core angle 45°. The panel is of height $2H$ and width $2W$, and the core contains a central crack of length $2a$. Simple analytical models can be used to determine the strength of the cracked sandwich panel in tension, compression or shear as a function of crack length [4, 5, 6]. In order to determine the strength of the cracked-lattice, values must be known for the unnotched strength of the sandwich layer (in the absence of a centre-crack) and for the fracture toughness of the lattice.

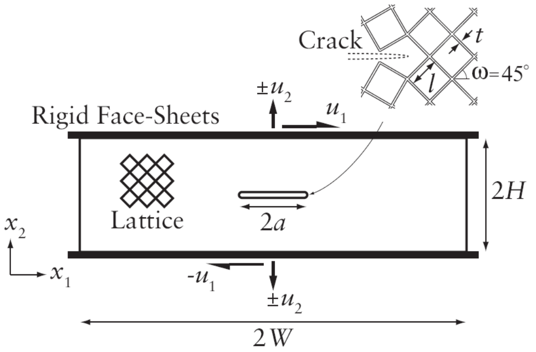


Fig. 2: Sandwich panel comprising a cracked diamond-celled lattice core.

3. Fracture toughness of the lattice

The dependence of the fracture toughness upon relative density can be obtained for any lattice via the finite element method. The procedure is as follows. A square mesh is constructed from the discrete lattice using elastic beam elements, with the co-ordinate system (x_1, x_2) at the centre of the mesh. A traction-free crack is assumed on the line $(x_1 < 0, x_2 = 0)$. On the outer boundary of the mesh, the applied displacements $\boldsymbol{u}$ are derived from the K-field in an equivalent orthotropic continuum. This configuration, referred to as boundary layer analysis, simulates the near-tip conditions associated with a K-field.

We consider here the case of a mode I crack in an elastic lattice. The fracture toughness for local tensile failure K_{IC} is calculated by equating the maximum tensile stress at any material point in the lattice to the tensile strength σ_{TS} of the solid. Numerical simulations [1] confirm that K_{IC} has a power-law dependence upon relative density $\bar{\rho}$ according to

$$K_{IC} = D\bar{\rho}^{d} \quad (1)$$

with values for (D, d) given in Table 1.

Lattice	***D***	***d***
0/90°	0.278	1
± 45°diamond	0.216	1
Kagome	0.205	1/2
Triangular	0.607	1
Hexagonal	0.902	2

Table 1. The fracture toughness of some 2D lattices

We note that K_{IC} scales linearly with $\bar{\rho}$ for stretching-dominated lattices such as the triangular lattice, while K_{IC} scales as $\bar{\rho}^2$ for the bending-dominated hexagonal lattice. Thus, the hexagonal lattice is intrinsically more brittle than the triangular lattice for the same value of relative density. It is remarkable that K_{IC} for the Kagome lattice scales with $\bar{\rho}^{1/2}$. This implies a very high value of fracture toughness, and this feature can be traced to a reduction of stress concentration at the crack tip by the presence of elastic zones of shear lag emanating from the crack tip. But now a word of caution. The random perturbation of nodal position in a Kagome lattice eliminates the zones of elastic shear lag, and the fracture toughness is severely degraded to a level comparable with that of the hexagonal lattice.

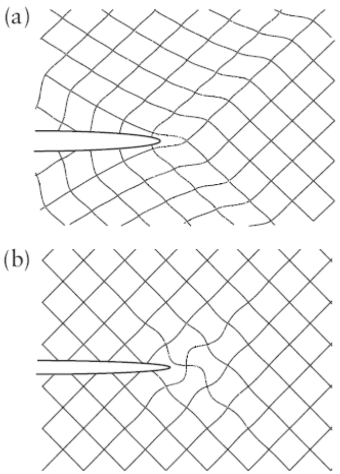
The concept of a *compressive fracture toughness* also exists for a lattice containing a pre-existing crack on the order of several cell sizes. It is recognised that the crack faces approach each other under compressive loading, and so a finite compressive stress intensity factor cannot be generated for the case of a mathematical line crack of zero initial opening. Here, we envisage that initial defects exist in the form of sharp notches, with tip acuity defined by the lattice cell size. Consequently, the crack will remain open under applied compressive loading, and a stress intensity will be generated. If crack face contact does occur the crack face tractions will be small due to the low 'rubble strength' of the failed lattice.

Brittle fracture under remote compressive loading can occur by the generation of local tensile stress near the crack tip by macroscopic compressive loading. For the example of a $\pm$ 45° diamond lattice the associated fracture toughness is $K_{IC}^{T} = 0.37\bar{\rho}\sigma_{TS}\sqrt{l}$, see [5] for full details. Two other failure mechanisms can intervene:

(i) local compressive crushing occurs at a stress intensity of $K_{IC}^{C} = 0.216\bar{\rho}\sigma_{CS}\sqrt{l}$ when the compressive stress at any point in the lattice attains the compressive strength of the cell wall material, σ_{TS}.

(ii) local elastic buckling at the crack tip. The typical bifurcation mode for the $\pm$ 45° diamond lattice is shown in Fig. 3, and this occurs at a buckling stress intensity of $K_{IC}^{B} = \frac{1}{4}\bar{\rho}^{2}E_{S}\sqrt{l}$, where E_S is the Young's modulus of the cell wall material.

The competition between failure mechanisms for the diamond lattice is summarised in Fig. 4: the dominant failure mechanism is dependent upon both material and relative density, $\bar{\rho} = 2t/l$.



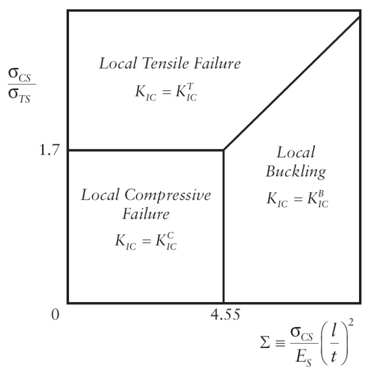


Fig. 3: Deformed mesh near the crack tip in a $\pm$ 45° diamond lattice. (a) Fundamental equilibrium path; (b) first buckling mode.

Fig. 4 Fracture mechanism map for compressive fracture toughness of the diamond lattice.

4. Concluding Remarks

The successful uptake of lattice materials requires a knowledge of defect sensitivity both due to manufacturing and service flaws. Whilst steps have been taken recently in order to assess the fracture response of elastic-brittle lattices, much less is known about the defect sensitivity of elastic-plastic lattices. It is anticipated that a J-field exists at the crack tip for such lattices and that the macroscopic toughness will be sensitive to the cell wall ductility at the crack tip. Likewise, the creep resistance will scale with the creep ductility. These are topics of future investigation.

5. References

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EUROMECH Solid Mechanics Fellow 2009 Paper

"Optimal Locomotion of Multibody Systems in Resistive Media"

Felix L. Chernousko [2]

Felix L. Chernousko was named Fellow of EUROMECH at the 7th European Solid Mechanics Conference held in Lisbon, August 2009

1. Introduction

During recent decades, various types of mobile robots have been developed that are based on different concepts of mechanical motion. These robots are usually equipped with special outward propelling devices like wheels, legs, tracks, etc. On the other hand, it is well-known that multibody systems without any outward devices can move inside a resistive medium, if its parts perform special relative motions with respect to each other. This locomotion principle typical to snakes, fish, and insects [1, 2] is also used in robotics [3-5].

In this paper, we restrict ourselves to two non-conventional types of mobile systems that are developed and analyzed in the Institute for Problems in Mechanics of the Russian Academy of Sciences, namely, to snake-like robots and vibro-robots.

Snake-like multilink mechanisms are equipped with actuators installed at their joints. Their locomotion is a result of periodic twisting of the linkage at its joints. By contrast to snake-like robots equipped with passive wheels [3] (these robots are nonholonomic systems), our systems have no wheels and interact with the horizontal plane by means of friction forces only [6-9].

Vibro-robots contain movable internal masses, and their locomotion is based on periodic oscillations or rotations of internal masses relative to the main body in the presence of external resistance forces acting upon the body such as dry friction, linear or quadratic resistance [10-13].

Kinematics and dynamics of these two types of mobile robots have been analyzed. Optimal geometrical and mechanical parameters as well as optimal controls of periodic motions have been determined that correspond to the maximal average locomotion speed.

Results of experiments with prototypes of robots [11, 14] confirm the theoretical predictions. The locomotion principles considered are applicable to

2 Institute for Problems in Mechanics of the Russian Academy of Sciences, pr. Vernadskogo 101-1, Moscow 119526, Russia

mobile robots capable of moving in a complicated and hazardous environment, along various surfaces and inside tubes.

2. Snake-like systems

Motions of snakes and other crawling animals have always been of great interest for researchers. By contrast to walking and running creatures who alternate their supporting legs, snakes mostly keep permanent contact between their bodies and the ground. Although the friction force acting upon each moving segment of the body is directed against the velocity of the segment, the resultant of the friction forces, i.e. the thrust, should be directed along the velocity of the centre of mass. To explain the mechanism of the snake-like locomotion various models have been proposed in which the motion is considered in the presence of obstacles or passive wheels [1, 3].

We have considered plane multilink systems without wheels that can move along a horizontal plane in the presence of Coulomb's dry friction between the linkage and the plane [6-9].

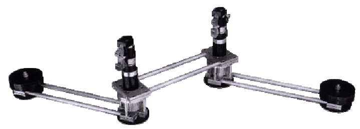

Fig. 1: Three-link robot.

A simple three-link mechanism shown in Fig. 1 consists of three links, two actuators installed at the joints, and two end masses. Denote by $2a$ the length of the central link, by l the lengths of the end links, by m_1 the masses of the joints, and by m_0 the masses of the end links. The masses of links are considered much smaller than m_1 and m_0, so that the total mass of the mechanism is $m = 2(m_0 + m_1)$.

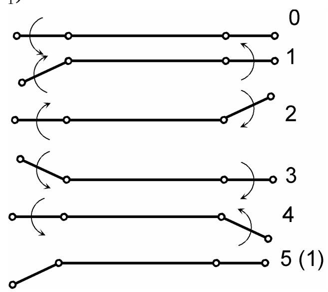

Fig. 2: Longitudinal motion.

The forward (longitudinal) motion of the linkage can be organized as shown in Fig. 2. The motion consists of alternating slow and fast phases. Each of them begins and ends at the state of rest of the linkage. In slow phases, one or both end links rotate in the same direction by a certain angle γ, while the central link does not move. In fast phases, both end links rotate by the same angle γ in the opposite directions. In Fig. 2, the configurations before slow (fast) phases are indicated by even (odd) numbers. Note that configurations 1 and 5 coincide; hence, the cycle of four motions can be repeated any number of times. After that, the linkage can return to configuration 0 by a slow phase. As a result, the linkage moves progressively with the average speed

$$v = \Delta x/(2T),\ \ \Delta x = 8m_0 m^{-1} l \sin^2(\gamma/2),$$

where T is the duration of the slow phase.

To ensure the periodic motion described above, the angular velocity and acceleration of the end links in slow phases must be small enough, and the condition

$$m_0 k_0 (a+l) < m_1 k_1 a$$

should hold. Here, k_0 and k_1 are the coefficients of friction for masses m_0 and m_1.

For fast motions, the angular velocity and acceleration of the end links must be sufficiently high, and the magnitude M of control torques produced by the actuators must satisfy the condition

$$M\ ?\ m^* g k^* l^*, \quad m* = \max(m_0, m_1),$$
$$k^* = \max(k_0, k_1), \quad l^* = \max(a, l).$$

Here, g is the gravity acceleration.

Similarly, lateral and rotational motions of the linkage can be implemented. Hence, the three-member linkage can reach any prescribed position and configuration in the plane.

The two-member linkage equipped with only one actuator can also move in a similar way by alternating slow and fast phases. However, for the two-link system the periodic motion becomes more complicated, and its speed is slower than for the three-link mechanism.

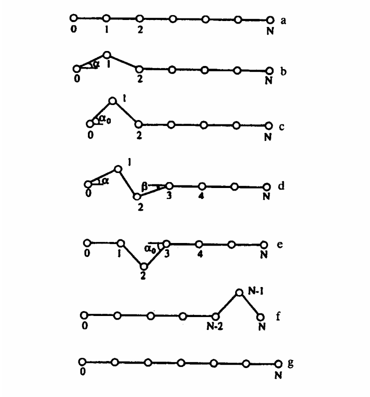

Fig. 3: Wavelike motion with three moving links.

Multilink mechanisms having more than four identical links can perform wavelike motions shown in Fig. 3. In these motions, not more than three or four links are involved in motion at each instant of time. Here, all motions are slow, and the required control torque M produced by actuators is bounded by the condition $M \le 2mgka$, where k is the coefficient of friction and a is the length of the link.

The average speed of snake-like mechanisms depends on geometrical and mechanical parameters as well as on the parameters of periodic motions. All these parameters are subjected to several constraints. Optimization of the average speed for the three-link and two-link mechanisms has been reduced to certain problems of nonlinear programming and solved numerically [9].

Consider again the longitudinal motion of the three-link mechanism and suppose that the coefficients of friction are bounded by the inequalities

$$k^- \le k_0 \le k^+, \quad k^- \le k_1 \le k^+,$$

the mass m_1 and the length $2a$ are fixed, while the parameters m_0, l, and T are to be chosen so as to maximize the speed v. It is shown that the optimal values of k_0 and k_1 are $k_0 = k^-$, $k_1 = k^+$. Denote

$$\chi = k^-/k^+, \quad v_0 = (gak^+)^{1/2},$$
$$\lambda = l/a, \quad V_1 = v/v_0.$$

The maximal dimensionless velocity V_1 and the optimal ratio λ as functions of the angle γ and χ are shown in Figs. 4 and 5.

An experimental model of the three-link mechanism has been made (Fig. 1). The experiments carried out with this model have shown that the modes of locomotion described above can be implemented, and our theoretical conclusions have been confirmed [14].

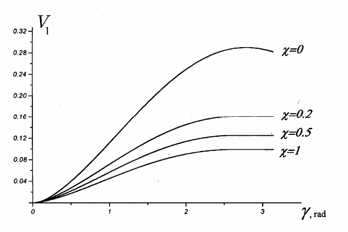

Fig. 4: Maximal speed.

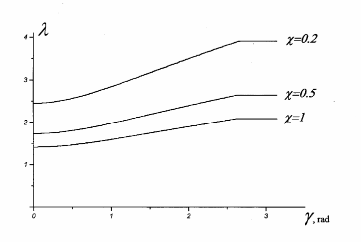

Fig. 5: Optimal λ.

3. Vibro-Robots

Under certain conditions, a body can move in a resistive medium, if an internal mass performs special periodic motions inside the body. This phenomenon is utilized in various devices and robotic systems [4, 5], especially, in micro-robots. Optimal motions of mechanical systems containing internal moving masses have been studied [10-13].

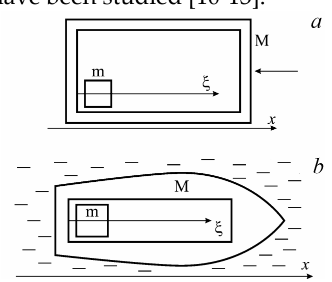

Fig. 6: Two-mass system.

Consider a two-mass system consisting of a rigid body of mass M and an internal mass m that can move inside the body (Fig. 6). Denote by x and v the absolute coordinate and velocity of body M, and by ξ, u, and w the displacement, velocity, and acceleration of mass m relative to body M, respectively. Suppose the motion of mass m relative to body M can be imposed. Body M moves in a resistive medium and is subjected to the resistance force F.

The equations of motion are reduced to the equations

$$\dot{x} = v, \quad \dot{v} = -\mu w - r(v),$$

where $r = -F/(M+m)$ and $\mu = m/(M+m)$. Different resistance laws are considered, namely, anisotropic Coulomb's dry friction, where

$$r(v) = \begin{cases} k_+ g & \text{for} \quad v > 0 \\ -k_- g & \text{for} \quad v < 0, \end{cases} \qquad (1)$$

linear and quadratic resistance laws, where

$$r(v) = c_\pm v \quad \text{for} \quad v \gtrless 0,$$
$$r(v) = \kappa_\pm |v| v \quad \text{for} \quad v \gtrless 0, \qquad (2)$$

respectively.

We look for the relative periodic motion of the internal mass m that satisfies the imposed constraint $0 \le \xi(t) \le L$ and such that the corresponding periodic motion of mass M has the maximal possible average velocity $V = [x(T) - x(0)]/T$. Here, T is the period of motion.

This problem has been solved [10-12] for various resistance laws (1), (2) and under different assumptions about the relative motion of mass m.

For the dry friction, the cases of piecewise constant relative velocity $u(t)$ and acceleration $w(t)$ have been considered. For example, in the case of the acceleration control, the optimal profile of the velocity $v(t)$ of body M is shown in Fig. 7. There are intervals of rest and no reverse motion that is present in the case of the velocity control. Complete results and proofs are given in [10, 12].

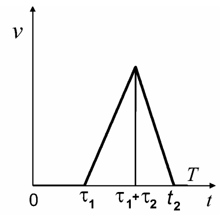

Fig. 7: Velocity $v(t)$ of body M.

Periodic motions of internal masses inside the main body can be implemented by means of different devices and actuators: inverted pendulums, wheels, electromagnetic drives, etc., see [11]. Vibro-robots that can move inside tubes of different diameter ($5 \div 30$ mm) have been created in the Institute for Problems in Mechanics [11] (Fig. 8).

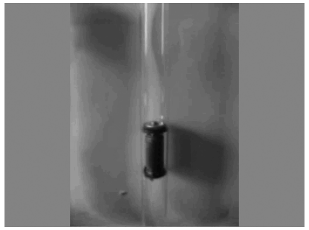

Fig. 8: Robot in a tube.

Note that there can be more than one internal mass that can perform two-dimensional motions in a vertical plane. Due to vertical motions, the normal pressure of body M on a horizontal surface changes; hence, the dry friction force will change too. In this way, it is possible to increase the average speed of mass M. This idea is implemented in models equipped with wheels that carry an eccentric mass and rotate about a horizontal axis [11].

In the case of an isotropic linear resistance ($c_+ = c_-$ in (2)), the progressive motion of body M is impossible: the system will oscillate about a certain mean position.

For an anisotropic linear resistance, the optimal motion of mass m with a bounded relative velocity $|u(t)| \le U$ is defined by

$$u = U \quad \text{for} \quad t \in (0, T/2);$$
$$u = -U \quad \text{for} \quad t \in (T/2, T),$$

where $T = 2L/U$. The corresponding maximal average speed of body M is given by

$$V = \frac{\mu U^2 (1-e_1)(1-e_2)}{L(1-e_1 e_2)} (c_+^{-1} - c_-^{-1}),$$
$$e_1 = \exp(-c_- L/U), \quad e_2 = \exp(-c_+ L/U)$$

and is positive, if $c_+ < c_-$.

In the case of the quadratic resistance, unlike the linear case, the average speed is positive also for the isotropic law ($\kappa_+ = \kappa_- = \kappa$ in (6)). The maximal average speed of body M for $\mu\kappa L < 1$ is given by

$$V = -\frac{U(1-\mu\kappa L)\log(1-\mu^2\kappa^2 L^2)}{2\kappa L} > 0.$$

4. Conclusions

Certain principles of locomotion for mobile mechanisms described above can be used for mobile robots that can move along surfaces, inside tubes, in various media, and, especially, for micro-robots. Optimization of geometrical and mechanical parameters of these systems as well as optimal control of their periodic motions can lead to a considerable gain in the average velocity of locomotion. Experimental models and prototypes of mobile robots have been created and tested.

5. Acknowledgements

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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.

NOMINATION FORM FOR FELLOW

NAME OF NOMINEE:………..………………………………………………………….…

OFFICE ADDRESS:……………………..…………………………………………….....

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EMAIL ADDRESS:…………..……………………………………………………………..

FIELD OF RESEARCH: ……………………………………………………………………..

Fluids: ☐ Solids: ☐

NAME OF SPONSOR 1: ..………..……………………………………………………….

OFFICE ADDRESS:……………………..……………………………………………..…

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EMAIL ADDRESS:……………………………………………………………………………

SIGNATURE & DATE: ……………………………………………………………………

NAME OF SPONSOR 2: ..………..……………………………………………………….

OFFICE ADDRESS:………..………….…………………………………….……...….

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EMAIL ADDRESS:……………………………………………………………………………….

SIGNATURE & DATE: ……………………………………………………………………….

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;
- Eponsor'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

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

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

Chairman's address
Professor A. Kluwick
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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
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Fax : +49 711 685-66400
Email: schiehlen@itm.uni-stuttgart.de

EUROMECH Conferences in 2010 - 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.

2010

EFMC8
8th European Fluid Mechanics Conference
DATE: 13 – 16 September 2010
LOCATION: Munich, Germany
CONTACT: Prof. Nikolaus A. Adams
E-MAIL: nikolaus.adams@tum.de

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 Colloquia in 2010

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 2009, and preliminary information for some Colloquia in 2010, are given below.

EUROMECH Colloquia in 2010

505. Multiscale effects in fatigue metals
Chairperson : Dr. Andrei Constantinescu
CNRS Ecole Polytechnique
Laboratoire de Mécanique des Solides
91128 Palaiseau cedex, France
Phone:+33 1 69 33 57 56
Fax: +33 1 69 33 57 06
E-mail: andrei.constantinescu@lms.polytechnique.fr
Co-Chairperson: Dr. Pedro Donatella Portella
Date and location: 5-9 July 2010, Palaiseau, France
Website:http://www.lms.polytechnique.fr/users/constantinescu/Euromech/index.html

511. Biomechanics of Human Motion. New Frontiers of Multibody Techniques for Clinical Applications
Chairperson : Prof. Jorge A.C. Ambrosio
IDMEC- Instituto Superior Tecnico
Av. Rovisco Pais 1
1049-001 Lisbon, Portugal
Phone: +351 2184 17680
Fax: +351 2184 17915
E-mail: Jorge@dem.ist.utl.pt
Co-Chairpersons: Prof. Frans van der Helm, Prof. Andrés Kecskemethy
Date and location: March 2010, Açores, Portugal

513. Dynamics of non-spherical particles in fluid turbulence
Chairperson: Prof. Helge I. Andersson
Department of Energy and Process Engineering

Norwegian University of Science and Technology
7491 Trondheim, Norway
Phone: +47 73 59 35 56
Fax: +47 73 59 34 91
Email: helge.i.andersson@ntnu.no
Co-Chairperson: Prof. Alfredo Soldati
Date and location: 29 September-1 October 2010, Trondheim, Norway

515. Advanced applications and perspectives of mutibody system dynamics
Chairperson: Prof. Dr. Evtim Zahariev
Institute of Mechanics
Bulgarian Academy of Sciences
Acad. G. Bonchev St., bl. 4
1113 Sofia, Bulgaria
Phone: +359-2-9547147
E-mail: evtimvz@bas.bg
Co-chairperson: Prof. Marco Ceccarelli
Date and location:* 13-16 *July 2010, Blagoevgrad, Bulgaria

517. Interfaces and inhomogeneous turbulence
Chairperson: Prof. Ian Eames
University College London
Torrington Place
London, WC1E 7JE, UK
Phone: +44 20 7679 3550
Fax: +44 20 7388 0180
E-mail: i_eames@meng.ucl.ac.uk
Co-chairpersons: Prof. Jerry Westerweel, Prof Carlos B. da Silva
Date and location: June 2010, UCL, London, UK.

518 Biomechanics of the Eye
Chairperson: Dr. Jennifer Siggers
Department of Bioengineering
Imperial College London
London SW7 2AZ, UK
Phone: +44 (0)20 7594 3663
Fax: +44 (0)20 7594 9817
E-mail: j.siggers@imperial.ac.uk
Co-chairperson: Dr. Rodolfo Repetto
Date and location: 26-28 July 2010, Imperial College, London, UK.

519. Mixing and dispersion in flows dominated by rotation and buoyancy
Chairperson: Prof. Herman Clercx

Fluid Dynamics Laboratory, CC 2.15
Department of Applied Physics
Eindhoven University of Technology
PO Box 513
NL-5600 MB Eindhoven, The Netherlands
Phone: + 31 40 247 2680 or + 31 40 247 3110
Fax: + 31 40 246 4151
E-mail: h.j.h.clercx@tue.nl
Co-chairperson: Dr. Beat Lüthi
Date and location: 20-23 June 2010, Conference Centre Rolduc, Limburg, NL.

520. High Rayleigh number convection
Chairperson: Prof. Francesca Chilla
Ecole Normale Supérieure de Lyon
Laboratoire de Physique
46 allée d'Italie
69007 Lyon, France
Email: francesca.chilla@ens-lyon.fr
Date and location: 25-29 January 2010, Les Houches, France

EUROMECH Colloquia Reports

3rd European Student Fluid Dynamics Conference

13-16 July 2009, The University of Nottingham

Chairperson: Igor hernyavsky
Co-Chairpersons: Oliver Bain, Leah Band, Zofia Jones

The 2009 EPFDC meeting included 31 talks and 9 posters by postgraduate students, covering many aspects of theoretical and experimental fluid dynamics, with 40 delegates from 8 countries. The extended time of the meeting allowed four distinguished academics from across Europe to share their expertise with young researchers, through four plenary lectures:

- Environmental and Industrial Flows (Prof. Andrew Fowler, Oxford);
- Biological Fluid Dynamics (Prof. Timothy Pedley, Cambridge);
- Interface Phenomena and Thin Films (Prof. David Quéré, ESPCI, Paris);
- Flow Instabilities (Prof. Jacques Magnaudet, IMFT, Toulouse).

Other topics included Non-Newtonian Flows, Computational Fluid Dynamics and Experimental Techniques. The Conference Programme and the Book of Abstracts can be found at:
www.epfdc.org.uk/EPFDC09-abstracts.pdf.

The quality of the presented talks and posters was high, making it difficult for the invited speakers to select winners of the the student prizes. The Best Talk award was given to Andre Nicolle (University College London) for "Flow Through and Around Groups of Bodies" and the Best Poster award was given to Georgy Kitavtsev (Humboldt University of Berlin) for "Derivation, Analysis and Numerics of Reduced ODE Models Describing Coarsening Dynamics".

The meeting continued the EPFDC traditions of bringing together researchers with experimental and theoretical backgrounds and of unifying different topics in fluid dynamics; this helps to maintain a broader view of the subject and facilitates the exchange of ideas. An informal question and answer session with the plenary speakers gave fresh insights into careers in academia and industry for future researchers. Feedback indicated that social events during the Colloquium had given more networking opportunities for delegates than at previous EPFDC meetings. Several delegates have already expressed interest in hosting next year's conference.

The organisers are grateful to EUROMECH, LMS, IMA and Springer for the financial support that made the event possible and to the School of Mathematical Sciences at the University of Nottingham for offering essential infrastructure and help.

EUROMECH Colloquium 500

"Non-smooth Problems in Vehicle System Dynamics – Analysis and Solutions"

17-20 June 2008, Lyngby, Denmark.

Chairperson: Prof. Per Grove Thomsen
Co - Chairperson: Prof. Hans True, Prof. Werner Schiehlen

Theoretical problems in Vehicle System Dynamics are most often formulated as the dynamics of mechanical multibody systems that are nonlinear, non-smooth, with kinematic constraints and with a high number of degrees of freedom. Subsystems consisting of continuum mechanical systems or control systems may occur.

The solution of dynamical problems is based on the mathematical theory of nonlinear and non-smooth systems, and numerical handling of large systems of this kind. The Colloquium brought together scientists working in nonlinear dynamics, non-smooth dynamics and numerical analysis with scientists and engineers working in vehicle system dynamics. This helped to acquaint the latter with the most recent advances in theoretical dynamics and numerical methods, and to motivate the former to increase their efforts to meet the demands from vehicle system dynamics.

All but five of the presentations have been published in full by Springer in 'Non-smooth Problems in Vehicle System Dynamics, Proceedings of the EUROMECH 500 Colloquium'. Two additional abstracts have been included, but three presentations were not made available in written form. The boundaries between topics are blurred by the cross-disciplinary nature of the Colloquium, but the proceedings have been subdivided into three parts. These are:

- Problems in Vehicle Dynamics:
- Dynamics of Non-smooth Problems;
- Numerical Analysis of Non-smooth Problems.

EUROMECH Colloquium 503

“Nonlinear Normal Modes, Dimension Reduction and Localization in Vibrating Systems”

27 September -2 October 2009, Rome, Italy

Chairperson: Professor G. Rega
Co-chairperson: Professor Alexander F. Vakakis

EUROMECH Colloquium 503 followed two previous international events dealing with the topic of Nonlinear Normal Modes (NNMs). These were: EUROMECH Colloquium 457 on Nonlinear Normal Modes of Vibrating Systems, Fréjus, France, 2004; and the 2nd International Conference on Nonlinear Normal Modes and Localization in Vibrating Systems, Samos, Greece, 2006.

The concept and technique of NNMs, first addressed by Rosenberg in the 1960s, have been developed during the last twenty years by using modern advances in both dynamical systems and nonlinear vibration theories. Current interest is now focused on continuous and discontinuous mechanical systems, strongly nonlinear regimes and discretised structures. Also, the scientific community has identified an increasing range of NNM applications.

Dimension reduction was included explicitly in EUROMECH 503 to emphasize the role played by NNM-based reduced order models in analysis of high-dimensional vibrating systems in the real world. Localization, which is one major topic in wave propagation and targeted energy transfer that might be addressed via NNMs, was introduced at Samos 2006 to mark some existing links between topics in mechanics and other disciplines. There is a particular interest in analysing the possible occurrence in mechanics of such dynamic phenomena as the discrete breathers highlighted in applied mathematics and physics, where they are paradigmatic solutions in periodic lattices.

Cross-fertilization allows exploitation of results that are used to describe analogous phenomena in engineered materials and devices, with benefits in terms of efficient and robust energy focusing/transfer, and material/system design. EUROMECH 503 helped to clarify various theoretical and practical aspects, while at the same time highlighting the need for further advancement.

A scientific committee, with representatives in Europe and North America, was established to guide the Colloquium. The technical program included 3

keynote lectures and 44 oral presentations devoted to the main topics of the Colloquium and to some related topics in nonlinear, regular and non-regular vibrations. A 176-page booklet of abstracts was published.

The Keynote Lectures were:

- Resonances in chains of oscillators (Ferdinand Verhulst, Utrecht);
- Energy exchange phenomena (Leonid Manevitch, Moscow);
- NNM-based system identification and reduced order modelling (Alexander Vakakis, Urbana-Champaign).

The 13 sessions were devoted to:

- Model Reduction I, II;
- Nonlinear Normal Modes I, II, III;
- Vibrational Mechanics I, II, III;
- Nonlinear Energy Sink I, II;
- Dynamics of Reduced Order Models;
- Wave Propagation;
- Fluid-Structure Systems.

The Colloquium ended with a round table discussion chaired by F. Vestroni, where suggestions for future direction of the NNM series of events were discussed.

EOROMECH 503 was organized by the Department of Structural and Geotechnical Engineering at Sapienza University of Rome, where a local organizing committee was established. The Colloquium was held in the Villa Vecchia Hotel at Frascati, following the tradition of holding NNM events in small villages. Participants came from about 20 countries, including: Brazil, 4 participants; Canada, 1; Israel, 2; Japan, 1; USA, 4. Financial support from the Faculty of Engineering and the Department of Structural and Geotechnical Engineering at Sapienza University of Rome is gratefully acknowledged.

EUROMECH Colloquium 507

"Immersed Boundary Methods, Current Status and Future Research Directions"

15-17 June 2009, Amsterdam, The Netherlands

Chairperson: Professor M. Pourquie
Co-chairperson: Dr. S. Turek

So-called immersed boundary methods (IBMs) have become increasingly popular in computational fluid dynamics. In these methods, the boundaries of obstacles in a fluid are represented on a non-conforming grid, for instance curved obstacles are represented on a Cartesian grid. The reasons for the popularity of these methods are ease of programming and cost-effectiveness. These issues are of primary importance for applications which involve costly simulations, such as LES and DNS. Moreover, these methods still retain much of their elegance if there are moving boundaries, as in biological flows, or when many particles are added.

Following a review article by Mittal and Iaccarino in Ann. Rev. Fluid Mech in 2005 and some conference special sessions (for instance, ECCOMAS 2006, 2008) it was thought useful to hold a colloquium focused specifically on IBM methods. Thus, EUROMECH 507 was held to address subjects of current interest in a combined Colloquium and Workshop. These included: theory, error analysis, applications, implementation issues and best practice. The goal was to bring together people who are established experts, possible users and other interested parties to assess the current status and guide future research direction.

Three well know authorities in the field gave invited lectures: G. Iaccarino, Stanford, USA; R. Verzicco, Universita' degli Studi di Roma "Tor Vergata"; and A. Prosperetti, Twente, Netherlands and Maryland, USA. Participants had widely varying backgrounds, as intended, including not only those who have contributed to recent developments in areas such as error analysis, but also users from science and industry. All aspects of IBM mentioned above occurred in several lectures and the number of fields in which IBM is applied is ever growing. Particular attention was paid to the attainable order of accuracy, especially for Navier-Stokes solvers using a pressure correction technique, stability and energy conservation. The proceedings are available on the website:
www.ahd.tudelft.nl/academy/proceedings_acadcol_ibm_june2009.pdf

The IBM workshop was supported by five organisations: EUROMECH; the Royal Dutch Academy of Arts and Sciences (KNAW) who sponsored the workshop financially and logistically; ERCOFTAC; ECCOMAS; and the J.M. Burgers Centre for Fluid Dynamics. Interest in the workshop was exceptionally high, showing wide interest in the subject, but numbers had to be restricted to allow effective interaction and discussion. The workshop was a success and it was decided to have a follow-up IBM workshop in 2011, probably in Italy or the USA.

EUROMECH Colloquium 508

"Wind Turbine Wakes"

20-22 October 2009, Madrid, Spain

Chairperson: Professor A. Crespo
Co-chairperson: Professor G. Larsen

Wind turbine wakes are of increasing importance; wind energy is being exploited all over the world and particularly in Europe, and it is important to achieve optimal efficiency. There is a growing number of wind-farms, with large machines and high installed power. Flow interference effects in wind farms may lower power production and increase the fatigue loads that reduce turbine life. The study of wind turbine wakes can therefore help to improve wind farm performance and therefore more efficient production of cheaper and cleaner energy. These issues are the main motivation for all the research and technical work presented at EUROMECH Colloquiumn 508. There was a previous meeting of participants in the European TOPFARM project on 19 October with 18 participants; most of them participated subsequently in EUROMECH 508. 50 presentations were expected at the Colloquium and included in the book of abstracts; all but three were given. EUROMECH 508 attracted 69 participants. Many were representatives of European wind energy companies who wanted to learn about the latest developments.

Ten sessions covered:

Wake models.

Existing models were analysed and compared, and possible improvements discussed, for single and multiple wakes. The effect of heterogeneous wind fields was considered. Existing benchmarks were discussed, and new ones suggested to take into account features such as complex terrain or advanced control schemes. The incorporation of meandering effects in existing wake models was considered. Fast linear models that allow superposition and the use of look-up tables were presented.

Turbulence closure models.

Classical models were considered, and alternative procedures and strategies were proposed. Comparisons were made with results obtained using a full Reynolds Stress Model and Large Eddy Simulation (LES) Models. Energy preservation was examined. Application and validation of commercial codes to simulate wakes was considered.

Analysis of turbine aerodynamics and the near wake.

The actuator line method has been used to study wake interaction between two wind turbines, and to study meandering characteristics. The actuator disk force field and its choice in relation to the appropriate wake flow characteristics were discussed. An actuator disc momentum theory for low values of the tip speed ratio was presented, and a model proposed. A review of actuator disc and actuator surface methods was presented.

The influence of topography and atmospheric characteristics on wakes, and the modification of the atmospheric boundary layer by very large arrays of wind farms.

The effect of the different scales of the flow was examined. A review of numerical simulation of the logarithmic layer was presented. Existing laws to simulate the effect of large arrays of wind turbines by an equivalent roughness were considered. The effect of atmospheric stability on wakes was examined.

Experimental work and interpretation of measurements (two sessions).

Results from the Model Rotor Experiment under Controlled Conditions (MEXICO) were presented, including comparisons with predictions. The complex aerodynamic field behind a vertical axis turbine was analyzed, both experimentally and numerically. Wake meandering was studied experimentally for a single full-scale machine and in a wind tunnel. Wake measurements of a multi-MW turbine were performed in the near and far wake field. A helicopter-mounted probe has been used to depict the interaction of ambient flow with turbulent wake structures. Data from several wind farms located in complicated terrain were used to investigate turbulence characteristics in wakes.

Wake meandering (two sessions).

The latest developments in the dynamic wake meandering (DWM) model were presented. It can be used to facilitate wind farm topology and control optimization and has been applied to estimate load reductions of wind turbines in wakes, using flaps or pitch control. The meandering wakes of two wind turbines were simulated with LES using a commercial code. A new procedure to estimate velocity deficit and a stochastic simulation of wake meandering in a wind farm were also presented.

Offshore wind farms and large wind farms.

LES has been used to study the flow field of very large wind farms. A typical challenge is to predict the interference of one wind farm on the power output of the next wind farm. Large wind farms are expected to be highly non-homogeneous.

Strategies for control, fatigue and loads, and optimization.

In the framework of project AEOLUS, preliminary maps of wind fields and mechanical loads were presented, together with preliminary results from predictive models. Strategies used in the TOPFARM topology optimization project were presented. The Wind Sector Management approach has been extended to include both shutdown and de-rating of wind turbines located in wakes. The potential for load reduction, initial cost reduction and production increase through optimization of the farm layout was described.

EUROMECH Colloquium 509

“Vehicle Aerodynamics”

24-25 March 2009, Berlin, Germany

Chairperson: Professor M. Schober
Co-chairperson: Professor L. Löfdahl

With the increasing service speed of modern high-speed railway traffic, aerodynamic aspects are becoming more and more important. Aerodynamic research topics comprise both pure performance improvements, such as the continuous lowering of aerodynamic drag for energy efficiency, as well as safety relevant topics, such as cross-wind stability. The latter topic was most recently brought to attention when a Swiss narrow-gauge train overturned during the severe storm Kyrill in January 2007. The shape of the train head usually has the largest influence on cross wind stability.

Slipstream effects of passing trains cause aerodynamic loads on objects and passengers waiting on platforms. The strength of the slipstream is determined by both the boundary layer development along the length of the train and the wake developing behind the tail of the train. Since high-speed trains can be considered technically smooth, attention is focused on the wake region. The wake of the train again is also an important factor for the total drag of a train.

Due to the fact that trains are bi-directional, optimisation of the leading car of a train with respect to drag and cross wind performance, while simultaneously minimising the wake of the train for drag and slipstream performance, is a great challenge. Modern optimisation tools are used to solve this multi-parameter multi-constraint design optimisation in conjunction with both CFD and wind tunnel investigations.

Since many of the aerodynamic effects in the railway sector occur also with road vehicles, the aim of EUROMECH 509 was to cross-fertilise the application of shape optimisation principles between rail and road vehicles and at the same time to connect industrial product development and academic research

There were altogether 51 participants and 31 presentations at EUROMECH 509, including two keynote lectures by Chris Baker and by Lennart Löfdahl & Heinrich Hucho. The participants came from 10 countries (Czech, 1 participant; France, 7; Germany, 25; Great Britain, 2; Israel, 1; Italy, 3; Netherlands, 1; Portugal, 1; Sweden, 7; Spain, 2).

Particular topics addressed in the Colloquium were:

Drag, Energy consumption and emissions

Due to the increase in energy cost, drag reduction has become more and more important. Pressure induced drag was identified to be of common importance for both rail and road vehicles. The optimisation of head and tail shape for road vehicles as well as for bi-directional vehicles (trains) was of special interest. Interference drag between adjacent components was also addressed.

Slipstream Effects

Slipstream effects are a safety issue for high-speed train operation. For example, prams can be sucked onto the track by train-induced draught flows when trains pass platforms at high speeds. For road vehicles, the ride stability of overtaking cars is influenced by the wake of the leading trucks and buses. The minimisation of wake effects for both rail and road vehicles is of common interest.

Cross-Wind Safety, Ride stability under strong winds

Both are safety issues for rail and road vehicles. The aerodynamic forces must be minimised (roll moment for trains and also yaw moment for road vehicles) by optimising the vehicle shape. Strategies for vehicle shape optimisation (head, tail and roof shape) in order to minimise aerodynamic moments, including the possibilities of both passive and active flow control, were discussed intensively.

Optimisation strategies

The optimisation processes for automotive and rail applications, including the parameterisation and the analysis (CFD), as well as the optimisation strategies, tools and methods, have been compared.

Most of the speakers contributed their results to the proceedings, which can be downloaded from the Colloquium website:
www.fd.tu-berlin.de/euromech509
and from the TU-documentserver:
opus.kobv.de/tuberlin/frontdoor.php?source_opus=2249&la=de

Feedback confirmed that the size of EUROMECH 509 was sufficient to allow inclusion of a large variety of topics, while still encouraging detailed discussion during the sessions and the coffee breaks. The short duration of only two condensed days permitted participants from industry to attend the complete Colloquium. The nearly equal number of industrial and university participants enhanced knowledge transfer in both directions and initiated joint research. The organisers are grateful to the University of Berlin and EUROMECH for their support. It was agreed that the Colloquium should be repeated in 2011, in Sweden.

EUROMECH Colloquium 510

“Mechanics of generalized continua: a hundred years after the Cosserats”

13-16 May 2009, Paris, France

Chairperson: Professor G. A. Maugin
Co-chairperson: Professor A. V. Metrikine

EUROMECH Colloquium 510 attracted 54 registered participants, delivering a total of 43 oral presentations. Participants came from nine European countries and five non-European countries, so that the colloquium was truly international. Most represented were: France, 11 participants; Russia, 11; Germany, 7; USA, 5; Great Britain, 4. The relatively large participation from Russia may be explained by the efficiency of the two chairpersons and also by the origin of the initial idea for EUROMECH 510 in Russia.

The explicit aims of the Colloquium were to celebrate the centennial of publication of “Théorie des corps déformables” by the Cosserat brothers and to examine the subsequent evolution of generalized continuum mechanics, to which work by the Cosserats contributed to such an important extent. The Cosserats book belongs to the collection of classics that are more often cited than read. The reason for this is twofold. First the vocabulary and mathematical symbols have evolved greatly since the early 1900s and second, the Cosserats book is intrinsically difficult to read. Besides introducing precisely the notion of Cosserat media, representing a special class of generalized continua, the Cosserats book had a wider ambition. It sought to present a reflection on the general framework of continuum mechanics, with the notion of permeating its structure in a subtle way (cf. the notion of “action euclidienne”).

Several contributions given at the beginning of the Colloquium, in particular those by Maugin, Epstein and Markenscoff, dealt with this general situation. The first of these placed the contribution by the Cosserats in a long evolution started in the 19th century and led to various generalizations in the 20th century by relaxing more and more working hypotheses of the standard modelling of continua (by Euler, Lagrange and Cauchy). This led to the gradual introduction of models of micropolar, micromorphic, gradient-like (weakly nonlocal) and truly nonlocal types. Epstein interpreted the Cosserats’ work in more modern language. Markenscoff emphasized that, apart from their book, the Cosserats contributed to two-dimensional elasticity with the useful notion of the Cosserat spectrum.

The following principal sections can be identified with their corresponding contributors:

<u>Cosserat media (rigidly rotating microstructure)</u>
- Models: Palmov, Muschik, Pietraszkiewicz, Lhuillier
- Applications to structures: Altenbach, Boutin, Tucker
- Mathematical aspects: Neff
- Measurement of coefficients: Pasternak, Stulov
- Coupling with electromagnetism: Sargsyan, Sharma.

<u>Micromorphic media (deformable microstructure)</u>
- Models: Jänicke, Lee

<u>From the discrete to the continuum description (Cosserat and other continua, often in relation to dynamical properties)</u>
- Aero, Erofeyev, Metrikine, Porubov, Potapov

<u>Gradient theory (weakly nonlocal theories)</u>
- Aifantis, Askes, Caillerie, Froiio, Lurié, Sab

<u>Complex structured media (often with application to dislocations)</u>
- Bammann, Berezovski, Dyskin, Lazar, Maximov, Pastrone, Peerlings, Podio-Guidugli, Steeb

<u>Numerical problems</u>
- Rubin, Georgiadis, Sansour

<u>Original approaches (kinematics, geometry, fractals)</u>
- Murdoch, Rakomanana, Ostoja-Starzewski

The whole spectrum of contemporary generalized continuum mechanics was covered, from models to applications to structures, dynamical properties, problems with measurement of new material coefficients, numerical questions posed by the microstructure, and new possible developments (nanomaterials, fractal structures, new geometrical ideas). Remarkably absent were models and approaches using the concept of strong nonlocality (constitutive equations that are functionals over space) despite the many contacts established by the Scientific Committee of the Colloquium. There is certain to be further evolution in this area.

An interesting comparison can be made with the contents of the landmark IUTAM Symposium held in 1967 in Stuttgart-Freudenstadt under the chairmanship of the late E. Kröner. Most of the models presented at that meeting by luminaries such as Noll, Eringen, Rivlin, Green, Sedov, Mindlin, Nowacki, Stojanovic, and others, were essentially of the Cosserat type and, still in their infancy, had much questioned usefulness. Most of the contributions were either American or German. At EUROMECH 510, an enlargement of the classes of models, with a marked interest in gradient-type theories, was apparent. Also, because the political situation has changed drastically in the last forty years, the importance of the Russian school can now be appreciated fully. The latter was in fact very much ignored in the 1960s and 1970s while some Russian teams were ahead of their Western colleagues in acknowledging their debt to the Cosserats and other scientists such as Leroux, Le Corre and Laval in France. E. Aero and V. Palmov, both from St-Petersburg, who published on the subject matter in the early 1960s, were present at EUROMECH 510. Professor A. C. Eringen (who was at Freundenstadt in 1967) was unable to attend, but sent a welcome address. This is printed in the booklet of abstracts and will be used as a preface to the book which will be produced by Springer in 2010. This will include carefully structured and edited contributions to EUROMECH 510. This book will be distributed free of charge to the active participants.

E-CAero Project

"Harmonizing the dissemination of scientific knowledge in disciplines relevant to Aeronautics and Air Transport in Europe: Kick-off meeting of the E-CAERO Support Action."

In the green paper 'The European Research Area: New perspectives' the European Commission recognizes that a fragmentation of the European Research Area (ERA) still exists that prevents Europe from fulfilling its research and innovation potential. In particular, effective knowledge sharing should be achieved at European level.

In the field of Aeronautics and Air Transport, there are many initiatives at European level undertaking the dissemination of scientific knowledge in the different relevant disciplines. Different associations are active with different formats of events such as, for example, large conferences, moderate size thematic conferences, symposia, workshops, short courses. In addition to presentations in events, the knowledge is further disseminated in the form of journal publications, proceedings, etc. More and more publications are now electronic which creates great potential for easy dissemination and the use of electronic search facilities.

However, we feel that there is a lack of coordination at European level. There would be a benefit in coordinating the planning of the events and in combining events when this has added value in terms of organisation, impact and visibility. Having a common dissemination platform where all events would be advertised and potentially including a search facility based on keywords for proceedings, papers or any other document would also be very useful. This could also contribute to increasing the visibility of good publications that do not receive the attention they deserve because of fragmentation and lack of a global view on the sector.

Based on this position, the Aeronautics unit of DG RTD opened a Topic for a Specific Support Action in the second call for proposals in the field of Aeronautics and Air Transport. A consortium of associations that are active at European level decided to answer the challenge. These are ECCOMAS, the coordinator, CEAS, ERCOFTAC, EUCASS, EUROMECH and EUROTURBO. These associations have different histories, different focus and scope of activities, organize events of different types and size. They are active in different phases of research ranging from fundamental to applied research. This is often reflected in the origins of their members which spans from researchers from universities, research centres and industry.

The common denominator is that they all are active in disciplines relevant to Aeronautics and often Space. We see therefore considerable potential for impact on the dissemination of scientific knowledge resulting from the coordination of these key players. The kick-off meeting took place in Barcelona on 28-29 September 2009. The project will run for 3 years with a budget of approximately 700 kEuro.

The approach taken in the project is to respect the history, origin and practices of the associations and definitely not to create a unique entity which would embrace all the activities. The project is built around four different work packages.

First, a state of the art of the situation will be drafted. It will go beyond this group of associations and cover different aspects such as journal publications, the different dissemination channel and formats used, in particular the electronic ones. From this state of the art, the weaknesses to be addressed most urgently will be identified and solutions proposed.

The second work package consists in learning by doing. The different associations will identify a number of events where there is potential for fruitful collaboration. Different formats of events will be organized in collaboration on a bi-lateral or multilateral basis.

The third work package consists of the development of common resources. The process of registration for conferences or workshops, collecting the contributions, reviewing them and disseminating the proceedings is often very similar for the different events and associations. Therefore, a common electronic platform will be developed that can be used by the partners. When possible, the proceedings will be made available and searchable on the common electronic platform. A minimum common standard should be agreed to allow this. Other type of information will be available on this platform such as a centralized calendar of events with links to the relevant web sites, links to the different scientific prizes offered by the associations, etc.

The fourth work package consists of an evaluation of the results of the project and formulating recommendations in terms of further harmonization, of a common policy with a view to increasing the visibility of selected journals and a plan to continue working together once the support action has finished.

The success of the collaboration between the associations will be measured by several elements. If the information available on the platform (centralized calendar of events, searchable proceedings, etc.) is relevant and useful to the stakeholders (researchers), it will naturally become a reference web site. If the electronic resources developed in the project are versatile enough and answering the needs of the stakeholders, it will be made available for event organizers who want to use an already developed product rather than developing specific resources themselves. If the collaboration between the associations is successful, a more coherent and rational calendar of events will result with dissemination material that can be accessed easily with a level of quality that will ensure a proper impact. But the clearest indicator of success would be the fact that this group of associations continue to collaborate without EC support after the end of the project and even extend its scope of disciplines and membership.

R. Dénos
Project Officer
Unit H3 Aeronautics

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 co-operation 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.

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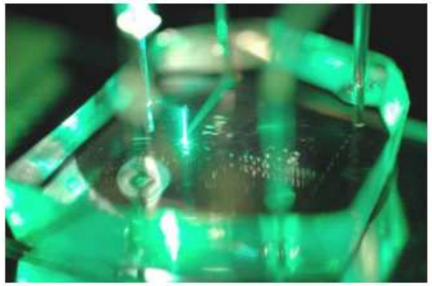

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