EUROPEAN MECHANICS SOCIETY

# Newsletter 33

## June 2008

## President's Address

The visibility of EUROMECH as the leading society for European scholars engaged in basic research in the Mechanical Sciences has been enhanced by establishing two types of awards: The *EUROMECH Fluid and Solid Mechanics* Prizes and *EUROMECH Fellowships*. We are very grateful to colleagues who took the initiative in preparing nomination files for Fluid Mechanics Prizes and Fellowships; the committee headed by Alfred Kluwick (Vienna University of Technology) received several highly deserving propositions. It is a great pleasure to announce that the *3rd EUROMECH Fluid Mechanics Prize* was awarded to Fritz Busse (University of Bayreuth) for his outstanding achievements in many areas ranging from thermal convection to rotating flows and to the geo-dynamo. Two Fellows have been elected for their seminal contributions to Fluid Mechanics: GertJan van Heijst (Eindhoven University of Technology) and Dan Henningson (Royal Institute of Technology, Stockholm). These awards will be conferred officially on the occasion of the 7th EUROMECH Fluid Mechanics Conference this coming September 2008 in Manchester.

EUROMECH is currently 1200 members strong. Although our events have become a major gathering point on the European scale, it is felt that many Fluid and Solid mechanicians still do not belong to our society. We are currently examining ways in which we could significantly increase our membership. May we encourage each one of you to actively promote EUROMECH and encourage colleagues to apply for membership. EUROMECH sponsored activities are all prominently displayed on our site www.euromech.org.

Many thanks for your assistance.

Patrick Huerre

President, EUROMECH

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## EUROMECH Council Members



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EUROMECH Solid Mechanics Fellow 2006 Paper

# "Challenges and Solutions in Finite Elasto-Plasto-Dynamics"

Paul Steinmann[1] , Rouven Mohr[2], Andreas Menzel[3]

*Paul Steinmann was named fellow of EUROMECH at the sixth European Solid Mechanics Conference held in Budapest, August 2006*

## I. INTRODUCTION

Computational modelling of materials and structures often demands the incorporation of inelastic and dynamic effects. However, the performance of classical time integration schemes for structural dynamics is severely restricted when dealing with highly non-linear systems. In a non-linear setting, advanced numerical techniques are required to satisfy the balance of linear and angular momentum, as well as the classical laws of thermodynamics.

Nowadays, energy and momentum conserving time integrators for dynamical systems, such as multibody or elasto-dynamic systems, are well-established in the computational dynamics community. In contrast to the commonly used time discretisation based on Finite Differences, one-step implicit integration algorithms relying on Finite Elements in space and time were developed, for instance, in Betsch and Steinmann [1, 2, 3]. Therein, conservation of energy and angular momentum have been shown to be closely related to quadrature formulas required for numerical integration in time. Furthermore, specific algorithmic energy conserving schemes for hyperelastic materials can be based on the introduction of an enhanced stress tensor for time shape functions of arbitrary order, compare Gross *et al.* [4]. However, most of the proposed approaches are restricted to conservative dynamical systems. Nevertheless, the consideration of plastic deformations in a dynamical framework, involving dissipative effects, is of cardinal importance for various applications in engineering.

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## II. SELECTION OF ANALYSIS TECHNIQUES

In this work, we follow the concepts which have been proposed for hyperelasticity in Ref. [3, 4] and pick-up the general framework of Galerkin methods in space and time, developing integrators for finite multiplicative elasto-plasto-dynamics with pre-defined conservation properties, compare Mohr *et al*. [5, 6, 7, 8]. By means of a representative numerical example, the excellent performance of the resulting schemes, which are based on linear Finite Elements in time, combined with different quadrature rules, will be demonstrated.

In the selected concept, not only the approximation in space but also the approximation in time relies on a Finite Element approach, compare also Ref. [1, 2]. In time-stepping schemes, special emphasis should always be placed on algorithmic conservation properties which strongly influence the numerical performance. In this context, it is often desirable to transfer as many of the conservation properties as possible from the continuous to the completely discrete system, especially regarding the underlying physics and the robustness of the related integration scheme. In fact, integrators with pre-defined conservation properties can be designed, adjusting the applied quadrature rule.

The application of a standard Gauss quadrature rule for the approximation of the time integral enables the conservation of both momentum maps (for vanishing external loads) if an adequate number of integration points in time is incorporated, compare Betsch and Steinmann [3]. Nevertheless, an additional conservation of the total energy for elastic deformations, for instance, cannot generally be achieved by means of a standard quadrature rule. Moreover, the incorporation of physical dissipation effects related to plastic deformations poses further challenges for the applied quadrature rule. To tackle potential problems concerning algorithmic conservation properties, non standard quadrature rules must be taken into account.

First, a non-standard quadrature rule is introduced to guarantee the thermo dynamical consistency of the integrator, in addition to the mechanical consistency which includes the conservation of both momentum maps. Thermodynamically consistent integrators for elasto-plasto-dynamics are characterised by the conservation of the total energy in the elastic case and by the (strictly) positive dissipation for plastic deformations, compare Mohr *et al.* [5]. Secondly, the application of an appropriate non-standard quadrature rule leads to energy-consistent Galerkin-based time-stepping schemes. Then, energy-consistency includes the conservation of the sum of the total energy and the dissipation for elastic as well as for plastic deformations. In the following discussion, the thermodynamically consistent and mechanically consistent cG method will be referred to as `TCMC-cG method' and the energy-consistent, mechanically consistent scheme as `ECMC-cG method' to abbreviate the notation. Detailed background information concerning the consistency of a Galerkin-based integration of finite elasto-plasto-dynamics and corresponding technical details, like for instance the local integration of the plastic evolution equations, are presented in Mohr *et al.* [6].

## III. COMPARISON OF NUMERICAL RESULTS

The performance of the Galerkin-based concepts is analysed by means of a representative numerical example (the free motion of a `Flying Frame'), evaluating the featured algorithmic conservation properties for the elastic as well as for the plastic case. To start the free flight, the frame is given an initial velocity and some external loads are applied. Thereby, the external load vector is prescribed by a piecewise linear function, as illustrated in Fig. 1 a). For the following computations, linear Finite Elements in time have been applied as a fundamental example. The constitutive law relies on a Helmholtz energy density of the Hencky-type and on a v. Mises-type yield function.

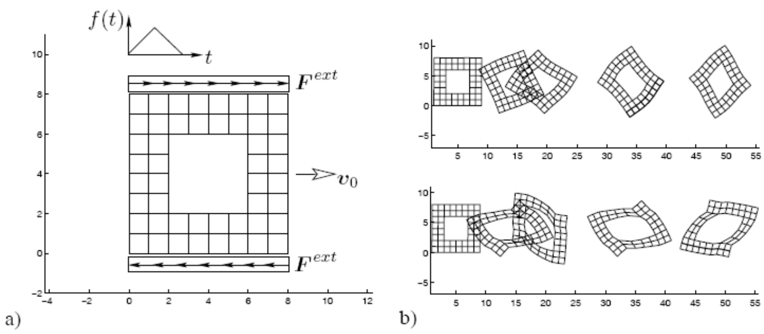


**Fig. 1:** a) initial mesh, b) sequence of the motion (elastic & plastic case)

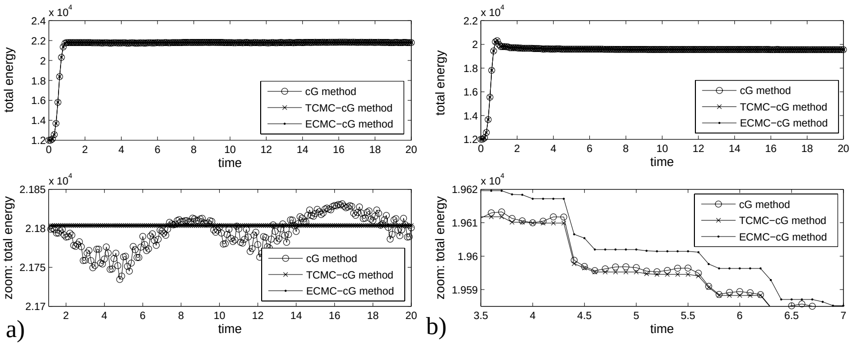


**Fig. 2:** total energy: a) purely elastic case, b) plastic case

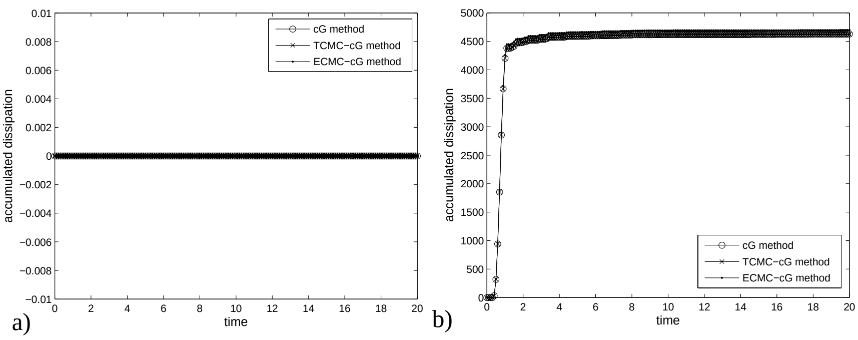


**Fig. 3:** accumulated dissipation: a) purely elastic case, b) plastic case

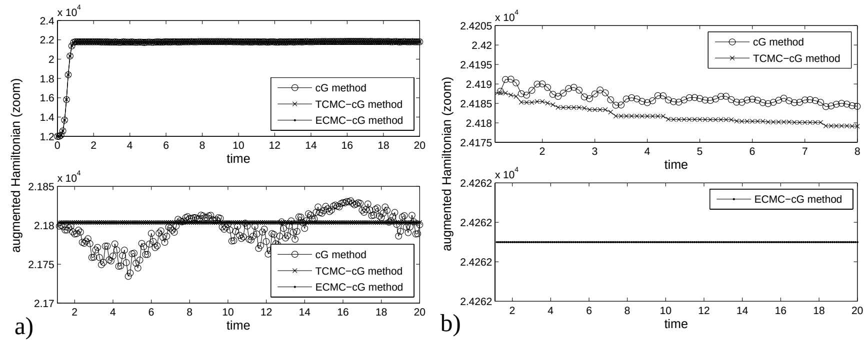


**Fig. 4:** augmented Hamiltonian: a) purely elastic case, b) plastic case

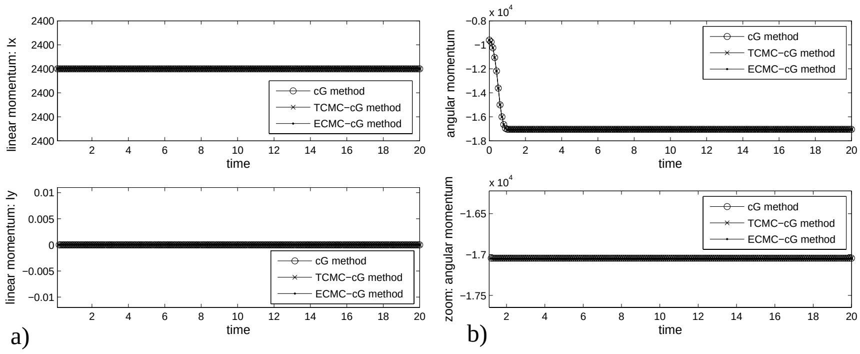


**Fig. 5:** a) linear momentum (elastic case), b) component of the angular momentum (plastic case)

The differences between the standard and non-standard quadrature rule for the approximation of the time-integrated internal load vector will be studied in detail, for the purely elastic as well as the plastic case. In this context, a standard cG(1) method is compared with the `TCMC-cG(1) method' respectively the `ECMC-cG(1) method'. Some snapshots of the motion are pictured in Fig. 1 b), whereby the plastic motion is displayed below the elastic case.

The global accumulated dissipation is, as expected, equal to zero for each of the considered Galerkin-based integrators if the deformations are purely elastic, and it is (strictly) positive if plastic deformations are involved due to the application of an adequate local update algorithm for the plastic variables, compare Fig. 3. Furthermore, it can be clearly seen in Fig. 5 that the mechanical consistency, related to a conservation of both momentum maps, can be guaranteed not only for time-stepping schemes which are based on non-standard quadrature rules, but also for the classical cG method which adopts a standard Gauss quadrature rule. Nevertheless, the influence of the applied quadrature rule becomes obvious when a plot of the total energy is considered, as displayed in Fig. 2. In the elastic case, the total energy calculated by means of the standard cG method is characterised by strong oscillations, whereas the `TCMC-cG method' as well as the `ECMC-cG method' guarantee both the conservation of the total energy. Moreover, the cG method features an unphysical increase of the total energy in the plastic case. Both schemes based on non-standard quadrature rules guarantee a monotonic decrease of the total energy caused by the (strictly) non-negative plastic dissipation. However, a physically correct decrease of the total energy, and an increase of the dissipation, are guaranteed exclusively by the `ECMC-cG method', as illustrated in Fig. 4.

It is important to emphasise that the above-mentioned consistency properties of the `ECMC-cG method' are guaranteed for small as well as for large time-step sizes, unaffected by changes of the step size during the calculation. Consequently, the proposed consistent Galerkin-based integration schemes enable an exceedingly robust integration of finite elasto-plasto-dynamics that is of particular importance for long-time simulations.

## IV. CONCLUSIONS

We have proposed time integration algorithms, based on Finite Elements in time, for non-linear dynamic problems including plastic deformations, whereby the kinematic description of the applied plasticity model includes a multiplicative decomposition of the deformation gradient into an elastic and a plastic part. Non-standard quadrature rules are required to feature thermo dynamical consistency as well as energy consistency in a physically correct integration. In this context, special emphasis has been placed on the assessment of the resulting schemes, especially in comparison to classical integrators which are well-established for linear-elastic dynamical systems. The superior performance of the proposed methods has been clearly demonstrated; in particular, the `ECMC-cG method' includes essential conservation properties of the continuum formulation for elastic as well as for plastic deformations. Galerkin-based time-stepping schemes combined with adequate quadrature rules are to be preferred for geometrically non-linear elasto-plasto-dynamics, providing an excellent numerical performance with pre-defined conservation properties.

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# Zigzagging/spiralling air bubbles: an archetype of wake-path couplings

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## I. INTRODUCTION

That millimetric air bubbles rising in a glass of water frequently follow a planar zigzag path or a helical path rather than a straight vertical trajectory is part of everybody's experience. Despite this shared evidence and the apparent simplicity of the corresponding physical arrangement, the rationale of the phenomenon has long been puzzling fluid dynamicists. In his Codex Leicester and Manuscript F, Leonardeo da Vinci made insightful comments on this problem and pointed out the mystery of this system which exhibits horizontal oscillations while the only external driving force acts in the vertical direction (see Fig. 1 and [1]). The problem motivated a great deal of experimental and theoretical activity during the second half of the last century, starting with Saffman's experiments and model ([2]). The general approach of these studies was to attribute path instability to an instability of the bubble shape when the deformation of the bubble (more precisely, the ratio of inertial effects to the restoring surface tension effects) exceeds some threshold. Based on these views, several theoretical attempts were carried out to build an explanation of the phenomenon using an irrotational approach ([3], [4]). Nevertheless, a detailed numerical stability analysis ([5]) demonstrated that this starting point was incorrect, as no path instability can be triggered by shape oscillations if the surrounding flow is irrotational. It is now striking to realize that, until the middle 90s, the subject evolved totally independently from its rigid body counterpart, namely the problem of free,

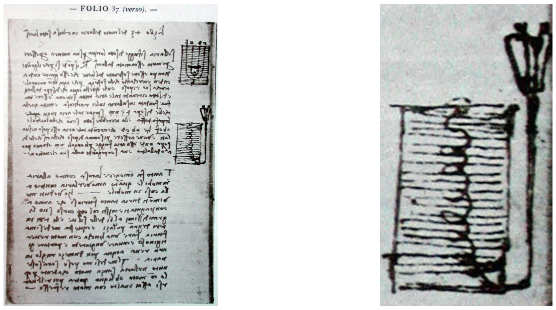



Figure 1: Leonardo da Vinci's thoughts on the problem (left) and detail of the drawing showing a spiralling bubble (right). From Manuscript F, folio 37r, French translation by C. Ravaisson-Mollien (1889). Courtesy Bibliothèque de l'Institut du Louvre.

buoyancy-driven, motions of rigid bodies such as seeds, dead leaves or paper cards. The main reason is that it was not widely accepted for a long time that clean spheroidal air bubbles which essentially impose a shear-free boundary condition on the surrounding liquid may develop a significant wake. Such wakes have been observed, (e.g. [6]), but there was a strong suspicion that water was contaminated by surfactants, so that the gas-liquid interface behaved essentially as a no-slip surface.

The situation changed drastically during the 90s, due to the combined application of several novel techniques. First, ultra-purification systems became available to produce hyper-clean water from which any trace of surfactant is virtually eliminated. Second, weakly intrusive visualization systems such as Particle Image Velocimetry started to allow detailed observations of wake structure. Last but not least, Direct Numerical Simulation became mature enough to tackle the problem of the free motion of a body of arbitrary shape in a viscous flow under well-controlled boundary conditions. The following sections present a summary of progress during the past decade concerning understanding of the above physical problem, with some emphasis on DNS "experiments" in which the author has been closely involved.

## II. THE MODEL PROBLEM

In the middle 90s, the state of the art of the problem made some of us postulate that the root of the mechanism lay in the wake of the bubble, irrespective of the fact that the fluid obeys a shear-free condition rather than a no-slip one at the body surface. A consequence of this assumption is that shape oscillations play only a secondary role in the phenomenon and can be ignored to first order, at least in a certain range of parameters within which bubbles rising at large Reynolds number basically adopt an oblate spheroidal shape (say for bubble diameters typically less than 4 mm in water). Therefore, the model problem that emerged was that of a bubble with a prescribed arbitrary oblate spheroidal shape moving in a Newtonian liquid obeying a shear-free condition at the gas-liquid interface. This model of course immediately leads to the question of vorticity generation at such a shear-free surface and the possibility for the corresponding wake to become unstable under certain conditions. Vorticity is nonzero at a curved shear-free impermeable boundary because the kinematic arrangement imposed by the corresponding boundary condition requires fluid particles to rotate in order to follow the surface. It has long been established that under such circumstances, the surface vorticity is just twice the tangential fluid velocity times the surface curvature in the local flow direction. This generates a weak viscous boundary layer along the bubble surface, the properties of which were studied in detail in the early 60s by Moore ([7]). What Moore could not address, owing to the breakdown of the boundary layer approximations near the rear stagnation point, was the stability of the axisymmetric wake that forms downstream of the bubble. Nevertheless, in contrast to the case of solid bodies, one can take advantage of the weakness of the vortical flow corrections within the boundary layer to get some insight into the problem by first estimating the surface vorticity and vorticity flux in the limit of very large Reynolds number ([8]). Defining the geometrical aspect ratio of the bubble as $\chi = b/a$ where $a$ and $b$ are the semi-minor and semi-major axes, respectively, and the Reynolds number as $Re = 2R_{eq}U/\nu$, where $U$ is the relative bubble velocity and $R_{eq} = (ab^2)^{1/3}$, it turns out that the maximum surface vorticity (normalized by $U/R_{eq}$), which is reached roughly on the bubble equator, evolves as $\chi^{8/3}$ for large $\chi$, while the corresponding vorticity flux that enters the liquid (normalized by $U^2/R_{eq}$) evolves as $Re^{-1/2}\chi^{7/2}$. Note that in the case of a solid body of given shape, the former quantity evolves as $Re^{1/2}$ for large enough

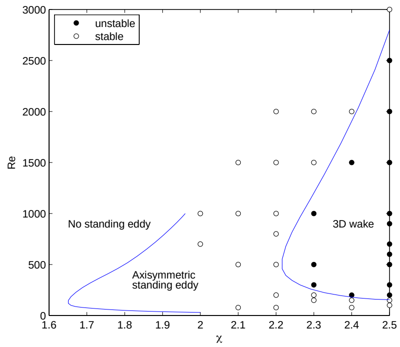



Figure 2: Phase diagram showing the range of $\chi$ and $Re$ within which the axisymmetric wake is: ∘ stable; • unstable.

$Re$, while the latter becomes $Re$-independent in this regime. Based on these estimates one can conjecture that, provided its oblateness is large enough, a spheroidal bubble may produce as much vorticity as a solid body such as a sphere for instance, and that the corresponding vorticity flux is also comparable for both bodies provided the Reynolds number is "not too large". These are the qualitative grounds on which wake instability behind oblate bubbles rising at moderate-to-large $Re$ can be expected to occur.

## III. THE FIXED BUBBLE CASE

This question was considered in detail through an extensive numerical investigation ([8]). For this purpose, the bubble was assumed to be artificially fixed in a uniform stream and $\chi$ and $Re$ were varied arbitrarily, which in a real system is equivalent to varying independently viscosity and surface tension. The wake of spherical and slightly oblate bubbles was found to be stable whatever $Re$. In contrast, beyond a critical aspect ratio $\chi_c \approx 2.21$, the axisymmetric wake was found to be unstable within a finite range of Reynolds number $[Re_1(\chi), Re_2(\chi)]$ which broadens as $\chi$ increases. The resulting stability diagram in the $(\chi, Re)$ phase space is shown in Fig. 2. For a given $\chi > \chi_c$, the wake is stable for low enough Reynolds number, $Re < Re_1(\chi)$, because viscous effects still limit the amount of vorticity generated on the surface. The wake also recovers its stability for $Re > Re_2(\chi)$, which may be interpreted as the fact that the surface vorticity flux is then small enough for the corresponding vorticity to be evacuated downstream by the axisymmetric wake. This upper branch of the neutral curve has no counterpart for a solid body, since the surface vorticity flux does not decrease when $Re \to \infty$ in this case. Within the finite interval $[Re_1(\chi), Re_2(\chi)]$, the wake experiences successive bifurcations, the first two of which were studied in detail. First, a steady supercritical bifurcation by which the wake loses its axial symmetry takes place for $Re = Re_1(\chi)$. The wake structure that sets up is made of two steady counter-rotating streamwise vortices resulting in a nonzero lift force (Fig. 3 left). Then, a secondary supercritical Hopf bifurcation occurs at a larger Reynolds number, making the flow unsteady with an alternation of positive and negative vorticity shed within each streamwise thread (Fig. 3 right). Note that the nature of these first two bifurcations and the associated wake structure are identical to those found with a solid sphere ([9]). More complex bifurcations occur at higher $Re$, until the $Re^{-1/2}$-decay of the surface vorticity flux starts limiting the strength of the instability. The bifurcation sequence then reverses and the wake eventually recovers its stability for $Re = Re_2(\chi)$. By recording the maximum of the normalized surface vorticity $\omega_m(\chi, Re) = \omega_{max}(\chi, Re)R_{eq}/U$ along both branches of the neutral curve, it turns out that this curve may also be defined as the locus of points such that $\omega_c(Re) = 12.5 + 4.3\ 10^{-3}Re$. Therefore the flow is stable (resp. unstable) if $\omega_m(\chi, Re)$ is less (resp. larger) than $\omega_c(Re)$. A remarkable point is that, if one attempts to apply the above criterion to a solid sphere, the solution of the equation $\omega_m(\chi, Re) = \omega_c(Re)$ is found to be $Re = 210$, which is the critical Reynolds number at which the sphere wake loses its axial symmetry ([9]). Therefore it appears that, despite the differences in the boundary condition on the two types of bodies, the critical conditions for which the wakes become unstable are identical, provided one re-interprets them in terms of surface vorticity.

## IV. THE FREELY-RISING BUBBLE

With these results at hand, the second step of the computational approach was to deal with the more realistic situation of a freely-moving, buoyancy-driven, bubble. For this purpose, the Navier-Stokes equations had to be solved together with the generalized Kirchhoff-Kelvin equations expressing the force and torque balances

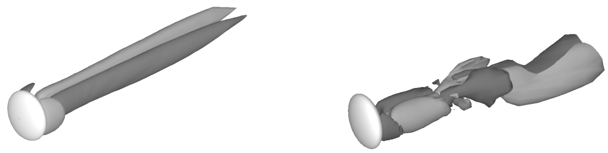


Figure 3: Two iso-contours of the streamwise vorticity behind a fixed oblate bubble with $\chi = 2.5$. Left: $Re = 180$; right: $Re = 300$; in this case, the first and second bifurcations take place at $Re \approx 150$ and $Re \approx 195$ respectively.

on a non-deformable body moving in a viscous fluid at rest at infinity ([10]). Starting from rest, all bubbles with $\chi < \chi_c$ were found to rise in straight line. In contrast, for larger $\chi$, the computations revealed that path evolutions entirely depend on the Archimedes number $Ar = (gR_{eq}^3)^{1/2}/\nu$ which may be thought of as a Reynolds number based on the gravitational velocity $(gR_{eq})^{1/2}$. Path instability occurs beyond a critical value $Ar_0(\chi)$ through a supercritical Hopf bifurcation ([11]). If we instead fix $Ar$ and vary $\chi$, a bifurcation of similar nature is observed for a critical aspect ratio $\chi_0(Ar)$. Beyond this point, the path first takes the form of a planar zigzag, the corresponding plane being selected by the initial disturbance introduced to trigger the instability. During this stage, the evolution of the wake structure is intimately coupled to the bubble kinematics (Fig. 4 left). Basically, the two streamwise vortices responsible for the lateral motion vanish at point (c) of Fig. 4, i.e. midway between the inflection point (b) of the path (where the bubble rotation vanishes) and the next extremity (d) of the zigzag. After having changed sign, they grow again until they reach their maximum strength midway between the extremity (d) and the next inflection point (e). Hence it appears that the sign of the streamwise vortices is entirely controlled by the bubble rotation which induces slight differences in the fluid velocity around the bubble ([12]). A remarkable feature is the strength of the transverse force induced by the streamwise vortices, whose maximum is of the order of the buoyancy force, making the associated lift effect capable of providing the mysterious horizontal forcing sought by Leonardo da Vinci.

One could expect the zigzag configuration to remain stable for ever. However, a third component of the bubble velocity perpendicular to the plane of the zigzag is found to grow very slowly, corresponding to a progressive loss of the planar symmetry of the streamwise vortices. This transverse component eventually becomes significant and the path turns into a circular helix with a vertical axis. In this final configuration, the two streamwise vortices are twisted and wrap around one another. Therefore, in contrast with the zigzag stage, the whole body+fluid system becomes stationary in a system of axes rotating with the bubble (Fig. 4 right). The above succession of stages was observed in all simulations that led to non-straight trajectories. An initial rotating disturbance was sometimes introduced to try to trigger directly the helical configuration but the zigzag always occurred first. An important feature of these non-straight paths is the drag crisis observed during each transition. As smaller and smaller structures are formed in the wake, the rate at which energy is dissipated increases. Since the drag force essentially balances the buoyancy force, it has to remain constant, so that the whole process results in a significant decrease of the rise velocity from the straight part of the path to the final helical path.

From the above results, it is clear that the zigzag and helical motions are driven by the pair of streamwise vortices that creates an intense transverse force capable of generating lateral displacements of the bubble. This is why these non-straight motions are directly linked to the wake instability mechanism described in the previous section. Also, the threshold $\chi_c = 2.21$ beyond which path instability may exist is identical to that revealed by Fig. 2 for the wake instability of a fixed bubble. Nevertheless, despite these obvious connections, the two systems exhibit many differences. For instance, no periodic vortex shedding is observed in the wake of a freely-moving bubble, even though the current Reynolds number is well beyond that at which the secondary Hopf bifurcation is detected for the same bubble held fixed (for instance, the Reynolds number is about 830 in Fig. 4 left). Also, the lift force and drag increase generated by the trailing vortices in the case of a fixed bubble are much smaller than those found in the freely-moving case. These features, together with the role of the bubble rotation mentioned above, indicate that the couplings between the wake and the geometrical degrees of freedom of the body are responsible for specific aspects of the system dynamics. A full understanding of these couplings, which is of central interest in the modelling of any freely-moving body, requires specific investigations based for instance on the prescription of some parameters of the body motion.

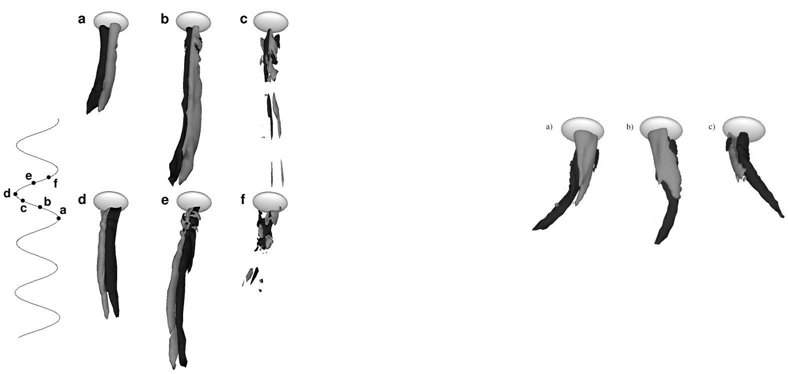
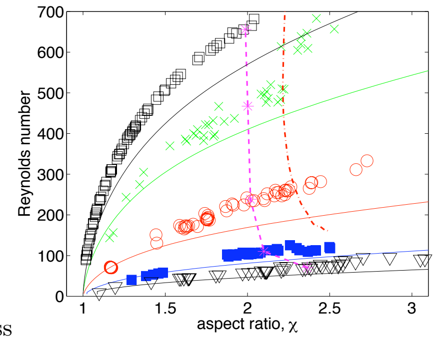


Figure 4: Wake structure during: the planar zigzag (left); half a period of the helix (right). ($\chi = 2.5, Ar = 138$; the bubble symmetry axis is arbitrarily shown as vertical).

## V. COMPARISON OF PREDICTIONS WITH EXPERIMENTAL RESULTS

Several confirmations of the above predictions came out almost simultaneously with the numerical results. In particular, the fact that the zigzag/helical motion is accompanied by a double-threaded wake structure was confirmed in [13] using a Schlieren visualization technique in hyper-clean water. Another central prediction of the computations is that the drift angle defined as the angle made by the instantaneous direction of the bubble velocity and that of the bubble minor axis is always very small, typically less than $2°$. The same conclusion was reached by Ellingsen and Risso ([14]) using Laser Doppler Velocimetry. This point is crucial because potential flow theory is only capable of predicting zigzag/helical paths with large angular drift angles (e.g. [4]), and this agreement between experiments and numerical predictions based on the Navier-Stokes equations is a clear proof that vortical effects play a key role in the phenomenon. Global features of the zigzag and helical paths, such as the amplitude of horizontal motions, maximum and mean pitch angles, were also compared with available experimental data. The agreement is typically within 20% , which, given the crude assumptions of the model, especially the fact that the bubble shape is preventing from changing all along the path, is very satisfactory. Finally, the fact that zigzag and helical paths appear in that order, while the reverse succession is never observed, is also supported by experiments.

Nevertheless, to confirm that the wake instability mechanism described in the case of a fixed bubble is the actual cause of path instability, it is necessary to determine precisely the threshold of the phenomenon. The first reliable information of this nature was provided by the experiments of Duineveld ([15]) performed in hyperclean water, where path instability was found to occur for bubbles with $\chi > 1.9$, approximately, an aspect ratio corresponding to a Reynolds number $Re \approx 650$. As $\chi$ and $Re$ cannot be varied independently in a real gas-liquid system, the above information is not sufficient to check convincingly the theory. For this reason, experiments were recently performed using silicone oils of various viscosities. The threshold of path instability was determined for each of them, as shown in Fig. 5 ([16]). What clearly appears in these results is that varying the liquid viscosity by a factor of ten makes the critical Reynolds number vary by roughly the same amount. In contrast, the critical aspect ratio is found to remain almost constant, increasing only for the most viscous fluid. When compared to the predictions of Fig. 2, the similarity is striking. The main difference between the two neutral curves is a shift by about 0.2 towards lower aspect ratios in the experiments. However real bubbles have a flatter front and a more rounded rear than the perfect spheroids considered in the numerical simulations. As vorticity generation is determined by the maximum curvature of the bubble surface, the geometry of the front half turns to be more relevant than the overall geometry in this respect. Using this observation, a corrected aspect ratio can be evaluated and is found to be about 10% larger than the experimental value of $\chi$, which makes the two curves almost collapse. Therefore, available experiments now strongly support the view that what determines the transition to path instability is the amount of vorticity produced at the surface, which in turn depends essentially on the aspect ratio if $Re$ is large enough.




ss

Figure 5: Bubble aspect ratio $\chi$ as as a function of $Re$. Results for oils with $\nu/\nu_{water}$=: 0.64 (×), 2.0 (○), 5.0 (■), 10.0 (▽); results in hyper-clean water (□) (from [15]).The dashed line is the experimentally determined neutral curve, while the dashed-dotted line is the corresponding part of the lower branch in Fig. 2.

## VI. CONCLUDING REMARKS

Over the last decade, the combination of novel experiments and numerical simulations has led to tremendous progress in our understanding of path instability of nearly spheroidal gas bubbles. There is now a strong set of converging results that proves the phenomenon to be due to the instability of the initially axisymmetric wake that develops behind the bubble. In this respect, path instability of rising bubbles does not differ much from that experienced by freely-moving solid bodies. Bubbles just represent a system of particular sensitivity to wake dynamics, as they are essentially massless and therefore respond in a spectacular way to wake-induced forces and torques. What makes bubbles differ from solid bodies is the boundary condition they impose on the surrounding flow, which in turn results in different evolutions of the surface vorticity and vorticity flux with the body shape and Reynolds number. However, this difference does not lead to distinct instability mechanisms and there are now indications that the conditions under which wake instability occurs with both sorts of axisymmetric bodies can be unified, provided one considers the strength of the surface vorticity rather than the Reynolds number and body aspect ratio. Despite these advances, several challenges remain. For instance the reason why the system selects zigzag and helical paths among all possible non-straight trajectories has still to be understood and the nature of the slow transition between these two configurations, i.e. the progressive loss of the planar symmetry of the streamwise vortices, needs to be clarified. Also the influence of shape oscillations, which take place for bubbles slightly larger than those considered here and appear to be strongly coupled to the vortex shedding process, deserves specific investigations. More generally, the quantitative modelling of freely-moving systems through low-dimensional sets of ordinary differential equations is an open and exciting field in which the triple approach of theory, detailed experiments and well-defined computations should lead to significant progress in the near future.

Over the years my personal understanding of the problem greatly benefited from endless discussions with many colleagues who at some point also became fascinated by zigzagging/spiralling bubbles. Among them, special thanks are due to Arie Biesheuvel, François Charru, David Fabre, Patricia Ern, Detlef Lohse, Guillaume Mougin, Andrea Prosperetti, Frédéric Risso, Howard A. Stone, Leen van Wijngaarden and Roberto Zenit.

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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: ☐

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

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

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

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

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

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

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

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

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## 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
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
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Tel. : +49 711 685-66391
Fax : +49 711 685-66400
Email: schiehlen@itm.uni-stuttgart.de

## EUROMECH Conferences in 2008, 2009

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.

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**2008**

**EMMC11**
**11th EUROMECH-MÉCAMAT Conference**
DATES: 10 – 14 March 2008
LOCATION: Turin, Italy
CONTACT: Prof. J.F. Ganghoffer, Prof. F. Pastrone
E-MAIL: jfgangho@hotmail.com, pastrone@dm.unito.it
WEBSITE: http://www.euromechmecamat2008.unito.it/

**ENOC6**
**6th EUROMECH Non-linear Oscillations Conference**
DATES: 30 June–4 July 2008
LOCATION: St. Petersburg, Russia
CONTACT: Prof. Alexander L. Fradkov ,
E-MAIL: fradkov@mail.ru

WEBSITE: http://conf.physcon.ru/enoc08/callforpap.html

**EFMC7**
**7th EUROMECH Fluid Mechanics Conference**
DATES: 14 – 18 September 2008
LOCATION: Manchester, UK
CONTACT: Prof. Peter Duck,
E-MAIL: duck@ma.man.ac.uk
WEBSITE: http://www.mims.manchester.ac.uk/EFMC/

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**2009**

**EETC12**
**12th EUROMECH European Turbulence Conference**
DATES: 7 – 10 September 2009
LOCATION: Marburg, Germany
CONTACT: Prof. Bruno Eckhardt
E-MAIL: bruno.eckhardt@Physik.Uni-Marburg.de

**ESMC7**
**7th European Solid Mechanics Conference**
DATES: August 2009
LOCATION: Lisbon, Portugal
CONTACT: Prof. Jorge Ambrosio
E-MAIL: jorge@dem.ist.utl.pt

# EUROMECH Colloquia in 2008 and 2009

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 2008, and preliminary information for some Colloquia in 2009, are given below.

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**EUROMECH Colloquia in 2008**

**495. Advances in Simulation of Multibody System Dynamics**
Chairperson: Prof. Dmitry Pogorelov
Department of Applied Mechanics
Bryansk State Technical University
b.50 let Oktyabrya, 7
241035 Bryansk, Russia
Phone: +7 4832 568637; Fax: +7 4832 568637
Email: pogorelov@tu-bryansk.ru
Co-Chairperson: Em. Prof. Dr.-Ing. Werner Schiehlen
***Date and location: 18-21 February 2008, Bryansk, Russia***
Website: http://umlab.ru/euromech/callforpapers.htm

**496. Control of Fluid Flow**
Chairperson: Prof. Peter Schmid
Laboratoire d'Hydrodynamique (LadHyX)
Ecole Polytechnique
F-91128 Palaiseau, France
Phone: +33 1 69 333780; Fax: +33 1 69 333030
e-mail:peter.schmid@ladhyx.polytechnique.fr
Co-Chairperson: Dan Henningson
***Date and location: 19-21 May 2008, Paris, France***

**497. Recent Developments and New Directions in Thin-Film Flow**
Chairperson: Prof. Stephen K. Wilson
Department of Mathematics
University of Strathclyde,
Livingstone Tower
26 Richmond Street
Glasgow, G1 1XH, UK

Phone: +44(0)141 548 3820; Fax: +44(0)141 548 3345
E-Mail: s.k.wilson@strath.ac.uk
Co-Chairperson: Dr. Brian R. Duffy,
***Date and location: Summer 2008, Edinburgh, UK***

**498. Non-linear Dynamics of Composites and Smart Structures**

Chairperson: Prof. J. Warminski
Lublin University of Technology
Department of Applied Mechanics
Nadbystrzycka 36
20-618, Lublin, Poland
Ph: +48 81 538 4197; Fax: +48 81 538 4205
E-mail: j.warminski@pollub.pl
Co-Chairperson: Prof. M. P. Cartmell
***Date and location: 21 – 24 May 2008, Kazimierz Dolny, Poland***
Website: http://www.ndcs.pollub.pl/

**499. Non-linear Mechanics of Multiphase Flow in Porous Media: Phase Transitions, Instability, Non Equilibrium, Modeling**

Chairperson: Mikhail Panfilov
LEMTA-ENSEM
2, av. de la Foret de la Haye
BP 160
F-54504 Vandoeuvre-les-Nancy Cedex, France
Ph: +33 3 83595697, Fax: +33 3 83595616
E-mail: mikhail.panfilov@ensem.inpl-nancy.fr
Co-Chairperson: Prof. Majid Hassanizadeh
***Date and location: 9 - 12 June 2008, Institut National Polytechnique de Lorraine, Nancy, France***
Website: http://lemta.ensem.inpl-nancy.fr/euromech.html

**500. Non-smooth Problems in Vehicle Systems Dynamics - Analysis and Solutions**

Chairperson: Prof. Per Grove Thomsen
Technical University of Denmark
Richard Petersens Plads 321
DK-2800 Kgs. Lyngby, Denmark
Ph: + 45 45253073, Fax : +45 45932373
E-mail: pgt@imm.dtu.dk
Co-Chairperson: Prof. Hans True
***Date and location: 17 - 20 June 2008, Danish Technical University, Lyngby, Denmark***

**501. Mixing of Coastal, Estaurine and Riverine Shallow Flows**
Chairperson: Prof. Maurizio Brocchini
Istituto di Idraulica e Infrastrutture Viarie,
Università Politecnica delle Marche,
60131 Ancona, Italy
Ph: +39 071 220 4522, Fax: +39 071 220 4528
E-mail: m.brocchini@univpm.it
Co-Chairperson: Prof. GertJan van Heijst
***Date and location: 8 - 11 June 2008, Istituto di Idraulica e Infrastrutture Viarie, Ancona, Italy***
Website: http://idra.univpm.it/colloquium/Participation_Fee.html

**502. Reinforced Elastomers: Fracture Mechanics Statistical Physics and Numerical Simulation**
Chairperson: Prof. G. Heinrich
Leibniz Institut für Polymerforschung Dresden e. V.
Postfach 120411
01005 Dresden, Germany
Ph: +49 0 351 4658 360, Fax: +49 0 351 4658 362
E-mail: gheinrich@ipfdd.de
Co-Chairperson: Prof. Erwan Verron
***Date and location: 8 – 10 September 2008, Leibniz Institut für Polymerforschung Dresden e.V., Germany***

**503. Non-linear Normal Modes, Dimension Reduction and Localization in Vibrating Systems**
Chairperson: Prof. Giuseppe Rega
Dipartimento di Ingegneria Strutturale e Geotecnica
Universita' di Roma La Sapienza
Via A. Gramsci 53
00197 Roma, Italy
Ph: +39-06-49919195, Fax: +39-06-49919192 or +39-06-3221449
E-mail: Giuseppe.Rega@uniroma1.it
Co-chairperson: Prof. Alexander Vakakis
***Date and location: June 2009,Rome, Italy***

**504. Large Eddy Simulation for Aerodynamics and Aeroacoustics**
Chairperson: Prof. Dr.-Ing. Michael Manhart
Fachgebiet Hydromechanik
Arcisstraße 21
80333 München, Germany
Ph: +49 (0) 89 289 22583
Fax: +49 (0) 89 289 28332
E-mail: m.manhart@bv.tum.de
Co-chairperson: Prof. Christophe Brun
***Date and location: 23-25 March 2009, Technische Universität München, Germany***

***11th EUROMECH-MECAMAT Conference***

***"Mechanics of microstructured solids: cellular materials, fibre reinforced solids and soft tissues"***

*10-14 March 2008, Torino, Italy*

*Chairpersons: Franco Pastrone and Jean-François Ganghoffer.*

The 11th EUROMECH-MECAMAT conference was held in the Museo Regionale delle Scienze. It brought together 50 scientists from 11 European countries, and was aimed at defining the current state of the art in the growing field of cellular and fibrous materials in Europe. Participants had interests in the constitutive models of micro-structured solids, non-linear wave propagation, setting up of models and identification of fibre reinforced solids and soft tissue behaviour in a biomechanical context.

The conference covered most of the mechanical and material aspects, grouped in the following four sessions:

- Fibre reinforced materials;
- Soft biological tissues;
- Generalized continua: models and materials ;
- Non-linear wave propagation.

The high quality talks showed a good balance between modelling and material aspects. An important part of the colloquium, with 12 presentations, was devoted to various aspects of the biomechanics of soft tissues. such as cell adhesion, constitutive models of soft tissues (brain; arteries), or models of blood flow.

The 30 minutes allocation for each of 37 oral presentations allowed thorough presentation of research, which in most cases triggered several questions from the audience. A session with 5 poster papers was also included, each paper being introduced by a short oral presentation. Prizes of 500 euros each for the best poster and the best oral presentation were awarded at the end of the meeting to Merle Randruut (Estonia) and Polina Dyatlova. A selection of articles from the conference will be published in a special issue of *Lecture Notes in Applied and Computational Mechanics*.Participants appreciated the informal and pleasant atmosphere of the meeting during coffee breaks, meals, the excursion and the official dinner.

# EUROMECH Colloquia Reports

**EUROMECH Colloquium 470**

***"Recent Development in Ferrofluid Research"***

*27 February-1 March 2006, Dresden, Germany*

*Chairperson: Prof. Dr. Stefan Odenbach, TU Dresden, Germany*
*Co - Chairperson: Prof. Dr. Elmars Blums, Latvian Academy of Science, Riga, Latvia*

EUROMECH Colloquium 470 was the first to concern ferrofluids in the context of research on magnetic fluids. These fluids, being suspensions of magnetic nanoparticles in appropriate carrier liquids, allow magnetic control of their properties and flows with magnetic fields of moderate strength. This gives rise to numerous possibilities in basic fluid mechanic research as well as concerning technical and medical applications. Due to the interdisciplinary nature of ferrofluid research the participants of the colloquium came from fields including chemistry, mechanical and electronic engineering, theoretical and experimental physics, fluid mechanics and medicine.

The research status in all areas of ferrofluid research was explored in 25 talks, of which 3 were plenary, and 27 poster presentations. Special attention was paid to new theoretical developments in the microscopic and macroscopic description of the fluids, taking account of inter-particle interaction and the resulting formation of wide-spanning structures of magnetic particles in the fluids. These structures have a significant influence on the flow of the fluids, which can be seen in experimental investigations of rheological properties. Current investigations, combined with microstructural measurements using scattering techniques, lead to a quite detailed picture of the microstructure of ferrofluids and its changes under the influence of magnetic fields and shear flows, which was intensively discussed during the meeting. A second important focus of the colloquium has been the development status of biomedical applications. In contrast to many former conferences, not only clinical applications like magnetic drug targeting or hyperthermia have been highlighted, but also the fundamental work needed for development their development. The synthesis of biocompatible ferrofluids, the resulting stability problems and the possibilities for in vivo diagnostics, all attracted strong interest.

The three plenary talks were chosen so that different areas of ferrofluid research, as well as prospects in new related fields could be addressed. Prof.

Helmut Bönnemann (MPI Mülheim) showed how airstable ferrofluids containing co-particles might be produced for applications requiring high saturation magnetization and extreme values of the initial susceptibility. Prof. Yurij Raikher (Institute of Continuous Media Mechanics, Perm) addressed the question of magnetic shielding using magnetic relaxation processes in ferrofluids and Prof. Roy Chantrell (University of York) gave an overview of magnetic storage techniques, the actual and future problems in this field and possible links to ferrofluid research in the development of storage devices with higher storage capacity. The colloquium was judged as a considerable success, providing time for intensive scientific discussions, while strengthening old and generating new contacts for collaboration. The participants suggested that a series of such meetings on a 2- 3 year cycle would be highly welcome and could help to stimulate further the research on colloidal magnetic suspensions.

**EUROMECH Colloquium 481**

***"Recent advances in the theory and application of surface and edge waves "***

*11-13 July 2007, Keele University, UK*

*Chairperson: Prof. Y. Fu, Keele University, UK*
*Co - Chairperson: Prof. Julius Kaplunov, Brunel University, UK.*

43 participants took part in EUROMECH Colloquium 481 at the Keele University conference centre. About half of the participants were from outside the UK.

It has been 20 years since EUROMECH Colloquium 226 was held on the same topic. The general feeling is that this gap has been too long, and Colloquium 481 was embraced with enthusiasm by researchers throughout the world. There has been recent intensive interest in the study of edge waves and edge resonance, which share many features with surface acoustic waves. It was decided from the outset that the colloquium should give equal prominence to the important research area of surface acoustic waves; indeed, most of the leading researchers in this field attended the colloquium.

Colloquium 481 provided an excellent platform for cross-fertilization between research on edge waves, edge resonance and surface acoustic waves. This is evidenced by the following list of 34 presentations, which also showed a good mixture of analytical, experimental and numerical studies:

1. *P. Chadwick:* Development of elastic surface wave theory up to 2000;
2. *P. Hess*: Non-linear surface acoustic waves: solitary and shock waves, fracture and NDE;
3. *R. Porter*: Edge waves along a semi-infinite thin elastic plate;
4. *K. Tanuma*: Perturbation of Rayleigh waves in prestressed anisotropic media;
5. *M. Destrade*: Waves at the edge of a cymbal;
6. *A.B. Movchan*: Waves around a crack propagating in a periodic inhomogeneous lattice;
7. *V. Pagneux*: Complex resonance behaviour of the edge resonance for a semi- infinite elastic waveguide;
8. *E. Ducasse*: An alternative approach to calculate the time-domain Green's tensor for anisotropic elastic media;
9. *P. Boulanger*: On "longitudinal" circularly polarized inhomogeneous plane waves;

10. *K. Mauritsson*: Approximate equations for a thin piezoelectric layer on an elastic plate;
11. *R.W. Ogden*: Magnetoelastic surface waves (cancelled at last minute);
12. *M. Destrade*: Surface instability of skin;
13. *J.B. Lawrie*: Edge waves on a semi-infinite crack in an elastic plate carrying an electric current;
14. *A.V. Porubov*: Cubic non-linearity and surface solitary wave propagation;
15. *P.E. Tovstik*: On the vibrations of pre-stressed anisotropic plates and shells lying on a pre-stressed anisotropic elastic foundation;
16. *A.V. Pichugin*: The link between surface and edge waves and trapped modes in one-dimensional waveguides;
17. *E.J. Brambley*: Stability of a thin-shell cylinder containing inviscid compressible fluid with mean flow;
18. *L.T. Wang*: Space of degeneracy in anisotropic elastic media;
19. *V. Zernov*: Three-dimensional edge waves in semi-infinite elastic layers
20. *A.P. Kiselev*: Surface waves with lateral structures;
21. *A. Maurel*: Scattering of Rayleigh waves by a buried dislocation;
22. *K.G. Ryne*: Existence of zero-curvature transonic states in anisotropic solids;
23. *R.V. Craster*: Long waves and negative group velocity modes in bent structures: asymptotics and numerics;
24. *S.D.M. Adams*: Topographically guided surface waves;
25. *Y.B. Fu*: Hamiltonian interpretation of the Stroh formalism;
26. *A. Zakharov*: Explicit hyperbolic-elliptic models for elastic and electro-elastic surface waves;
27. *G.A. Rogerson*: Edge waves in thin pre-stressed structures;
28. *A.N. Darinskii*: Specific features of electro-elastic mode conversion in the vicinity of the normal to the interface in piezoelectric structures;
29. *E.R. Ferreira*: Finite-amplitude love waves in special Blatz-Ko materials;
30. *D.A. Prikazchikov:* Explicit asymptotic model for the Stoneley interfacial wave in case of two elastic media;
31. *L. Sharipova*: Edge waves in a pre-stressed incompressible elastic plate;
32. *Ts. Ivanov*: Thermoviscoelastic surface waves of an assigned frequency;
33. *V.M. Babich*: On a ray theory of surface elastic waves;
34. *C.J. Chapman*: Energy paths in surface waves.

The Keele conference facilities provided an exceptionally comfortable environment for informal discussion, all meals being offered adjacent to the lecture theatre. The Colloquium was held on Monday, Tuesday and Wednesday, most participants having arrived on Sunday; there was also an excursion on Thursday. Professor David Abrahams, the UK EUROMECH representative, gave an excellent short speech publicizing EUROMECH at the banquet on Tuesday evening.

**EUROMECH Colloquium 482**
***"Efficient Methods for Robust Design and Optimisation"***

*10-12 September 2007, Queen Mary, University of London, UK*

*Chairperson: Dr. Fabian Duddeck, London, UK*
*Co – Chairpersons: K.-U. Bletzinger, Munich, C. Bucher, Vienna; H. Matthies, Braunschweig, M. Meyer, Berlin*

EUROMECH Colloquium 482 was concerned with new developments in design optimization. In recent years, optimisation has been well established in automotive, aerospace and building industries for very complex and multi-disciplinary problems. It is used, for example, in design of turbine blades, internal combustion engines, crashworthiness, vehicle dynamics and material modelling and selection.

Optimisation normally drives the design towards its limits, rendering it more sensitive to small changes in some design parameters due to factors such as manufacturing errors and natural variations in load conditions. To guarantee the quality of the optimisation results, it is necessary to perform either a robustness analysis including sensitivity studies at the end of the optimisation or to include robustness criteria within the optimisation procedure. Detailed qualitative and quantitative knowledge on uncertainties and on noise is then required. Often, special approaches to handle the data flow have to be integrated into the product development processes. Upper and lower bounds should be estimated. The necessary computation is highly demanding, with methods having to be implemented and tested in an industrial context. The following issues were addressed during Colloquium 482:

1. *Optimisation, reliability and robustness methods for turbines and airfoils*: Optimisation strategies and their applications for CFD in industrial context were presented by several participants, including a novel approach to robust optimisation of airfoils using Sigma-Point methods, a derivative-free approach for uncertainty propagation in airfoil design, and an approach using adjoint methods to link performance uncertainty to design parameters for turbines. Multi-objective and multi-disciplinary optimisation were investigated using techniques such as genetic algorithms (NSGA-II) or specially developed tools based on gradient optimisation.

2. *Efficient optimisation approaches for power-train design and metal forming*: The discussion focused on the meta-model approaches that might be used to tackle the important issue of reduction of computational effort

and to render optimisation feasible for the large numerical problems encountered in metal forming and combustion engine design. Approaches to automatic meta-model selection, that would facilitate the best predictions, were discussed. The inclusion of uncertainty and variability in optimisation schemes was addressed. The issue of meta-modelling is very important for optimisation of large-scale industrial problems and it is essential to integrate measures of the quality of surrogate models into the numerical approaches.

3. *Fuzzy stochastic simulations for consideration of uncertainties in large-scale numerical problems*: The usability of fuzzy technology was discussed in relation to problems in metal forming and crashworthiness. Aleatoric and epistemic uncertainties were included and their consequences for the design evaluated. Advantages and disadvantages of fuzzy modelling relative to stochastic approaches became evident.

4. *Robust design optimisation for crashworthiness and vehicle suspensions*: Several presentations focused on robust optimisation techniques for crashworthiness; scatter in numerical and physical results, originating for example from manufacturing and material variations, should be taken into account. A complete methodology is required, which incorporates robustness in the optimization process. Direct experience of scatter in physical testing was presented and should be further explored in the future. Optimisation should be accomplished by sensitivity and correlation analyses based on statistical measures.

5. *New developments in software for optimisation and robust design*: New approaches implemented in commercial software were presented focusing on response surface methods, robustness analysis, multidisciplinary optimisation techniques, and collaborative engineering.

6. *Topology optimisation*: New approaches for topology optimisation were presented in the context of friction stir welding and civil engineering. In addition to reliability and robustness, the topic of redundancy was addressed.

7. *Optimisation in heterogeneous environments:* In addition to the commercial software developments for optimization techniques in heterogeneous environments a special approach for civil engineering and architecture was discussed, where multi-disciplinary simulations were based on common data models.

It became clear during the colloquium that combining aspects of robustness into optimisation for large-scale industrial problems still needs further improvement and investigation. Development of data bases of relevant stochastic parameters for different applications, improved identification of the processes dominating design, and study of noise variables will be as necessary in the future as development of even more effective numerical approaches for integrated robust design optimisation. Surrogate modelling needs consolidation, while automatic procedures which help the engineer to decide which optimisation scheme is appropriate in normal design processes are also required. Colloquium 482 has confirmed that this is currently a very active and growing field with a growing number of important industrial applications.
The exchange between different fields of engineering stimulated new ideas for further research and development. A future meeting on the same topic was recommended at the end of the meeting.

**EUROMECH Colloquium 495**

***"Advances in simulation of multibody system dynamics "***

*18-21 February 2008, Bryansk, Russia*

*Chairperson: Prof. Dmitry Pogorelov,* Bryansk *State Technical University, Russia*
*Co–chairperson: Em. Prof. Dr.-Ing. Werner Schiehlen, University of Stuttgart, Germany*

The scope of EUROMECH Colloquium 495 covered new developments in multibody system (MBS) dynamics. These included: advanced methods of generation and solving equations of motion; new approaches in simulation of hybrid flexible/rigid MBS and electromechanical systems; recent applications to engineering systems (rail and road vehicles, wheel robots etc.); efficiency of multibody dynamics software. There were 42 participants from 10 countries and 31 presentations; 20 were by speakers from outside Russia, while 8 were by young scientists. Talks during the colloquium covered all topics listed above, and presented a good balance between fundamental and applied research.

The main topics are given in the following list, with the number of presentations in brackets:

- Numerical methods and equation generation formalisms (6);
- MBS software (2);
- Biomechanics (2);
- Rail and road vehicle dynamics (7);
- Models of force interactions (4);
- Control, optimization and robotics (4);
- Flexible MBS (5).

Some important theoretical results discussed during the colloquium were: simulation of MBS with redundant constraints; effective numerical iterative algorithm for solving linear equations during the simulation process, taking into account small perturbations of mass matrix for successive steps; results on mapping of conventional FEM beam and plate elements to the absolute nodal coordinate formulation elements; use of discrete elements in simulation of some mechanical models and processes, such as cutting.

Simulation of road and rail vehicle dynamics is one of the most frequent applications of MBS software. Real-time simulation of road vehicles was discussed in three presentations. Several talks in the field of rail vehicle dynamics presented recent results regarding the choice of a rational gauge value, methods of combined rail/wheel profile wear prediction, comparison of dynamics of different freight cars, and simulation of detailed electromechanical models of locomotives.

The Editors-in-Chief of the journal *Multibody System Dynamics,* proposed that selected papers presented in the EUROMECH 495 colloquium should be published in a special issue.

# 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.