NEWSLETTER 44
Spring 2014
EUROPEAN MECHANICS SOCIETY

President's Address

As you may know, quite a few EUROMECH activities are scheduled for 2014. Some of the larger European conferences will take place in the course of this year: the 8th European Nonlinear Oscillations (Nonlinear Dynamics) Conference in Vienna (6-11 July 2014), the 14th European Mechanics of Materials Conference in Göteborg (27-29 August 2014), and the 10th European Fluid Mechanics Conference in Copenhagen (14-18 September 2014). At the latter conference, the biannual EUROMECH Fluid Mechanics Prize will be awarded, and the winner will deliver the plenary Prize Lecture. At this meeting, three Fluid Mechanics Fellowships will also be awarded. This is always a very pleasant occasion. Next year, at the 9th European Solid Mechanics Conference in Spain (6-10 July 2015), it is the turn of the EUROMECH Solid Mechanics Prize and Fellowships.

In addition to the larger conferences, we have also a number of smaller meetings taking place in 2014: the Colloquia. For various organizational reasons, quite a few of the Colloquia that were originally planned for 2014 have been shifted to 2015, so that the number of Colloquia in 2014 is less than usual.
A number of proposals for Colloquia in 2015 and 2016 has been submitted, and the outcome of the selection process (to be carried out by the Council) will be published on the website shortly.

I also wish to draw your attention to the 7th European Postgraduate Fluid Dynamics Conference, this year taking place in Ilmenau, Germany (14-17 July 2014). This conference is organized for and by PhD students and postdocs. It is aimed at providing a network for junior researchers in fluid mechanics as well as offering them a wider overview of the field. Previous postgraduate conferences have been very successful and were highly appreciated by the participants. Until now, meetings of this type have only been organized in the fluid dynamics field, but it would be nice to see similar meetings in solid mechanics. Are there any volunteers for organizing a European Postgraduate Solid Mechanics Conference?

As I wrote in the previous Newsletter (no. 43), the term of Professor Bernhard Schrefler as Secretary-General ended in 2013. He has now been succeeded by Professor Pierre Suquet (Marseille), who is an expert in theoretical solid mechanics, in particular the mechanics of nonlinear composites. We are happy that he is willing to take up the job of Secretary-General of our Society.

You have surely noticed that the homepage of our website (www.euromech.org) shows an animation of figures and photographs, illustrating research that is being carried out in the groups of some of our members. We would welcome any new contributions. So, if you have some interesting and/or esthetically attractive illustrations (obtained from either experiments or numerical simulations): please send them to Dr. Sara Guttilla (sara.guttilla@euromech.org). We hope that we will be overwhelmed by all your illustrations, figures, and photographs!

GertJan van Heijst
President, EUROMECH

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EUROMECH Young Scientist Prize Paper

"On the formation of vortex rings under the influence of Coriolis forces"

Mark Brend won the EUROMECH Young Scientist Prize, awarded at the 8th EUROMECH FLUID Mechanics Conference held in Bad Reichenhall, September 2010

M. A. Brend[1], A. J. Skeen[2], P. J. Thomas[3]

Abstract

This work summarises the impact of Coriolis forces on the formation of a vortex ring. The initial formation of the ring and subsequent transient migration to a steady structure is described, focussing on the processes by which the transition occurs. A side-by-side comparison of vortices generated with and without the impact of Coriolis forces is made using 3 component planar velocity field data in a reference plane moving with the vortex ring. Subsequent to generation, an axially aligned vortex wake is formed, which is shown to induce a secondary vortex shedding phenomenon.

1. Introduction

Vortex rings are of fundamental importance, presenting perhaps the simplest example of a coherent vortex, in addition to being capable of undergoing a non-linear instability to turbulence. Vortex rings in non-rotating environs have been studied extensively, with several review articles published [1-3]. The behaviour of vortex rings in rotating systems has however received comparatively less study. In these cases, Coriolis forces act upon the vortex, resulting in changes to its structure.

Verzicco et al.[4] demonstrated that generating the vortex coaxially with the rotation vector resulted in fundamental changes to the flow structure. Significant axially aligned vorticity was observed within the wake, and a transient phenomenon, resulting in the shedding of a vortex ring of opposite sign to that of the generated vortex, was seen to occur. For cases of high rotation rate (relative to inertial input), it was observed that no vortex ring formed and instead inertial waves were created. This result is in agreement with an earlier analysis using a vortex ring as a perturbation to a rotating system [5]. Further data have indicated that generation of a vortex ring within a rotating system results in earlier decay of the ring. The length travelled before decay was found to be connected to the Rossby number (a non-dimensional rotation rate) by a power law relationship [6].

This work considers the vortex ring as it evolves within a rotating system and is therefore subject to the effects of Coriolis forces. The fluid structure is considered from generation to the point where secondary structures are shed. This provides improved understanding of the interaction between Coriolis forces and the vortex during its formation.

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2. Experimental configuration

2.1 Experimental facility

The measurements were performed at the specialist large rotating water tank facility at the University of Warwick (Fig. 1). This comprises a large vertical water tank mounted on top of a computer controlled rotating turntable. The tank is an octagonal structure of 1m section and 2.5m high; sufficiently large to prevent wall-effects influencing the vortices generated.

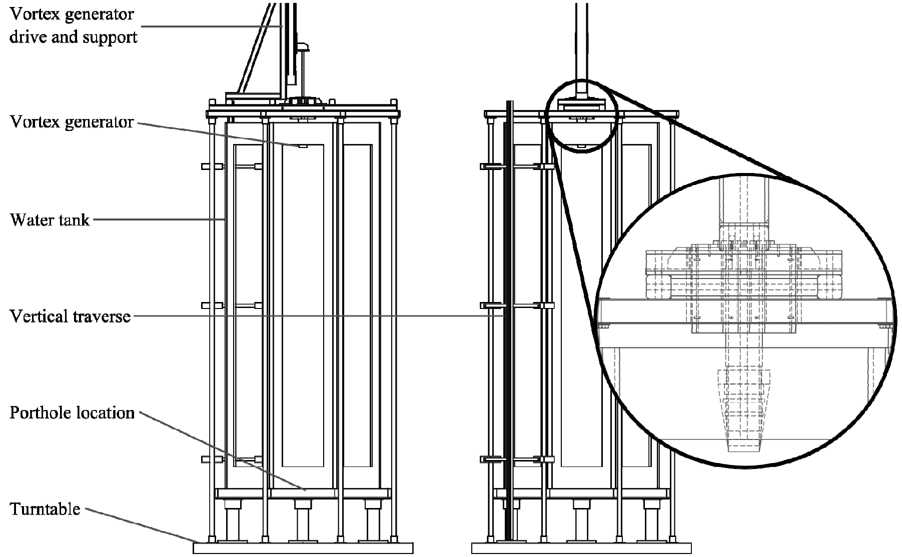


Fig. 1: Engineering drawings illustrating the large rotating turntable facility at the University of Warwick with detail view of the vortex generator geometry.

For the vortex ring experiments described here, measurements are made after the tank has been spinning for sufficient time for the water to achieve solid body rotation. The sides of the tank are fitted with large glass windows and the base a porthole, providing good optical access. A standard piston-cylinder type vortex generator (50mm diameter, 15^{o} included angle) is sited at the top of the tank such that it rotates with the tank and is completely immersed within the water. The direction of vortex generation is anti-parallel to the rotation vector.

2.2 Measurement system

The three-component velocity field was measured using a stereoscopic particle imaging velocimetry (PIV) system developed in-house. The measurement was made in a *moving* reference frame, centred upon the vortex ring. By moving the region of interest thus, high spatial resolution velocity measurements across large distances of travel (up to 2.2m) were possible. To enable these measurements, the laser was positioned between the turntable and water tank and the light sheet projected vertically upwards, along the turntable's axis, towards the vortex generator. The cameras were driven vertically down the side of the tank using a computer controlled traverse. The speed of camera travel was matched to that of the vortex ring by iteratively optimizing the traverse profile. The configuration of the measurement system is shown in Fig. 2.

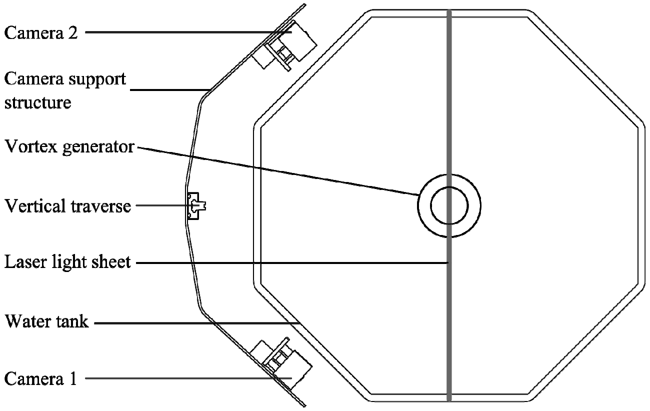


Fig. 2: Engineering drawing showing the location of the PIV system components relative to the water tank. View is from the turntable towards the vortex generator.

2.3 Data acquisition and processing

For each condition measured, 400 vortex generations were performed. For each generation, a time resolved PIV measurement was made, such that the evolution of the vortex could be discerned. Between each vortex generation 10-15 minutes was allowed for any motion induced by the previous vortex to dissipate. This allowed ample time for image pre-processing and various housekeeping tasks, such as window cleaning, removal of bubbles from the vortex generator and intermittent mixing to remove any formed density gradients. By using Etalon Research's rtControl software to automate the entire measurement process, a total run time of 3-4 days per test condition was achieved.

Vector correlation was performed using LaVision DaVis software, resulting in Cartesian velocity fields as illustrated by Fig. 3. The resulting velocity vector fields indicated vibration of the PIV cameras. The camera motion between exposures led to a time varying bias across the entirety of the displacement field measured from each camera. The change in viewing angle between individual exposure-pairs resulting from this motion added a further time varying registration error impacting the stereoscopic reconstruction process. The velocity fields further indicated that the translational velocity and trajectory of the vortex ring varied from run to run. Detailed corrections were applied to mitigate all of these sources of error and significant improvements to the measured velocity fields were achieved. Full details of this process and the measurements made are presented in [7].

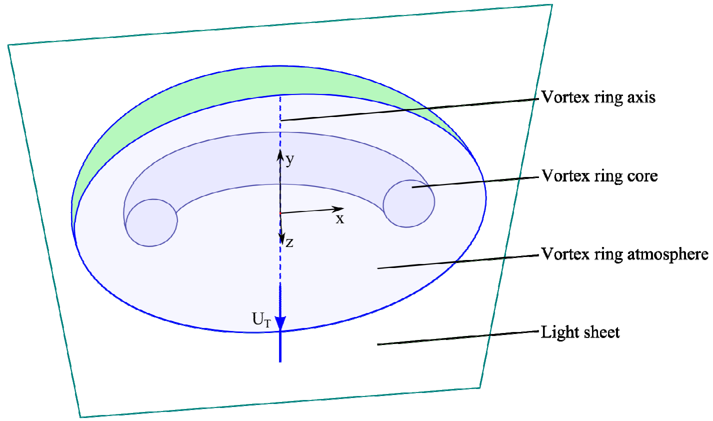


Fig. 3: Illustration of the PIV measurement plane within a typical vortex ring and the relative orientation of the measurement coordinate system.

Non-dimensionalisation of the data follows [4], with the starting jet from which the vortex forms providing the basis. The inner radius of the vortex generator R_O provides a characteristic length scale and the maximum fluid velocity during the jet formation U_O, is used as a characteristic velocity. This naturally leads to the definition of a time scale $T_O = R_O / U_O$, a Reynolds number $\mathrm{Re}_O = R_O U_O / \nu$ and a Rossby number Ro_O, commonly employed in rotating flows to characterize the relative inertial and rotational timescales: $Ro_O = U_O / 2R_O\Omega$. Here Ω refers to the rotation rate of the system into which the vortex is generated: low Ro_O corresponding to high rotation rates and the non-rotating case being given by $Ro_O = \infty$.

3. Results and discussion

To provide clear definition of the effects of Coriolis forces on the vortex ring flow field, the same experiment was performed with and without rotation. To demonstrate the process by which the vortex is influenced, a moderate Rossby number (Ro_o=6.4) condition has been selected for comparison with a non-rotating ($Ro_o=\infty$) case. The selection of the rotating case is such that the vortex actually forms, propagates away from the generator and emphasizes the Coriolis induced effects. The phenomena observed for the Ro=6.4 case are representative of all conditions where the vortex ring actually forms and are consistent with prior observation [4].

The vorticity component normal to the measurement plane (ω_z) was computed from the mean velocity field and is plotted in Fig. 4. During vortex generation, the Coriolis forces appear to have little effect on the vortex formation, and little difference is seen between Fig. 4(a) and 4(b). The vortex sheet formed from the boundary layer separation at the generator lip clearly rolls up to form the vortex ring core.

After pinch-off, the vorticity distribution within the ring and the wake continues to exhibit little difference between the non-rotating and rotating cases (Figs. 4(c) and 4(d) respectively). Some vorticity resulting from the generation is not entrained and remains as a wake that is connected to the vortex core.

As the vortex ring propagates downstream, differences between the rotating and non-rotating cases become apparent. The vorticity distribution within the non-rotating ring changes little after $T/T_o \geq 5.11$ (Figs 4(e), 4(g), 4(i) and 4(k)) with some vorticity diffusion and shedding from the cores into the wake, consistent with prior observations [8,9]. As the core of the non-rotating ring loses some vorticity to its wake, the shed vorticity is necessarily of the same sign as that of the core from which it originated. For the rotating case, the opposite is observed: vorticity forms within the vortex atmosphere, located inboard of the core, *but of opposite sign to it* (Fig. 4(f)). As the ring propagates further downstream, this opposite signed vorticity is advected, wrapped around the vortex core (Fig. 4 (h)) and shed downstream (Fig. 4(j) and 4(l)). This is the secondary structure observed in prior work [4].

To understand the origins of these differences, the discussion must turn to the impact of the addition of background rotation. The rotation interacts with fluid motion as a consequence of conservation of angular momentum. Where the measured reference frame rotates with the system, the background rotation exerts the Coriolis force, appearing in the Navier-Stokes equations as an acceleration $\vec{A}_c = 2\vec{\Omega} \times \vec{u}$ [10].

The coaxial alignment of the vortex generator with the rotation vector renders the interpretation of this forcing trivial. Motion inwards towards the rotation vector results in *cyclonic* acceleration (in the direction of rotation) and motion outwards from the rotation vector results in an *anti-cyclonic* acceleration. In the measurement plane presented, the cyclonic acceleration will (for sufficient rotation timescales) induce a positive u_z for $x<0$ and a negative u_z for $x>0$. Conversely the anti-cyclonic motion will induce a negative u_z for $x<0$ and a positive u_z for $x>0$. As succinctly shown in [4], the velocity field associated with a vortex core gives rise to an anti-cyclonic axial swirl upstream and cyclonic axial swirl downstream of the vortex ring core.

It is pertinent therefore to consider the measurement plane normal velocity field (u_z), which is plotted in Fig. 5. The non-rotating measurement is provided for comparison (Figs. 5(a), 5(c), 5(e), 5(g), 5(i) and 5(k)) and indicates little real fluid motion: the artefacts observed relate primarily to residual errors associated with the measurement and the limitations of the corrections described in section 2.3. The discussion will therefore focus instead on the rotating measurement.

During generation (Fig. 5(b)), the boundary layer within the generator separates at the lip and moves radially outboard, rolling up to form the vortex ring core, this was observed in Figs. 4(a) and 4(b). This outboard motion manifests itself in an anti-cyclonic flow, given the measurement coordinate system, this is positive to the right of centre and negative to the left of centre in Fig. 5(b).

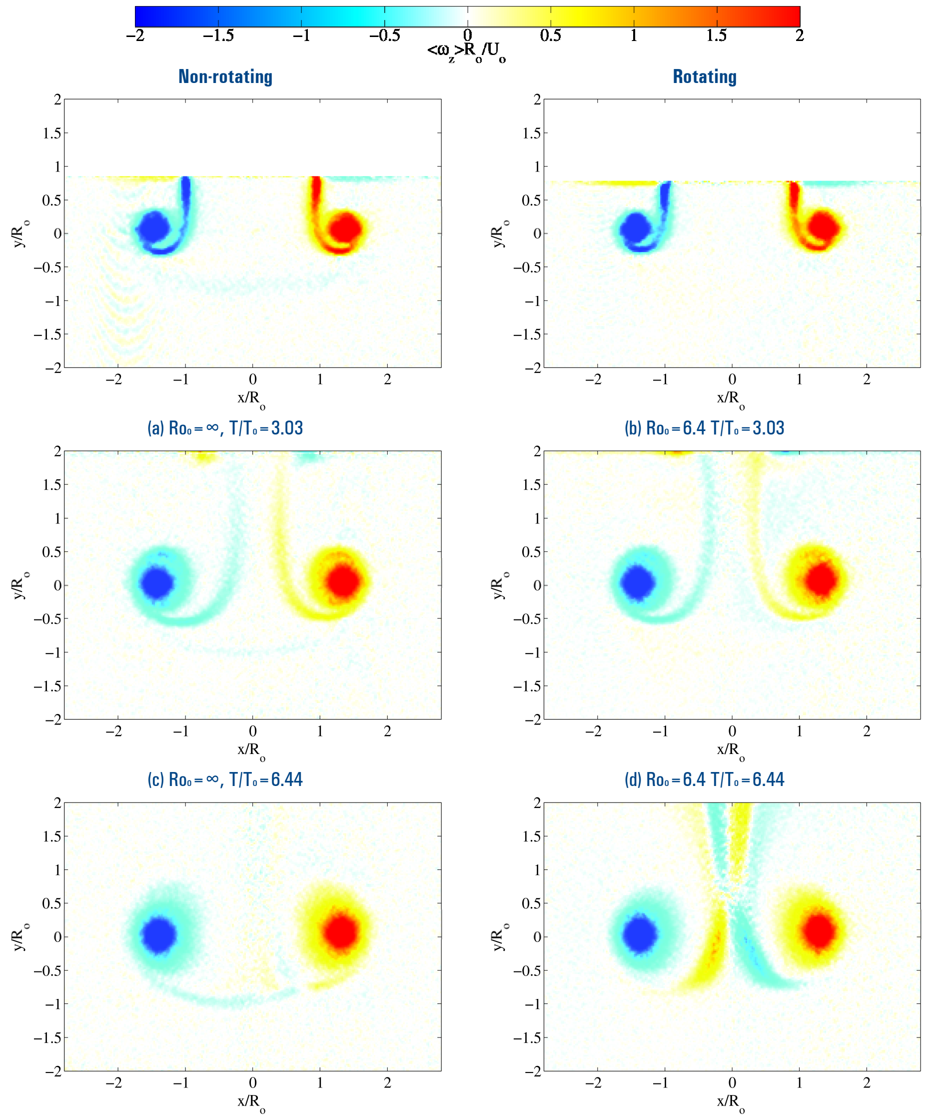
As the vortex ring moves away from the generator, the impact of the radial motion directed inwards downstream of the vortex core is observed, with a confined region of cyclonically swirling fluid forming an axial wake vortex located on the centreline, Fig. 5(d). This is characterized by strong positive u_z to the left of the centreline and strong negative u_z to the right. The vortex filaments from which the wake is comprised are at this point attached to both the ring and the generator piston. As the ring moves downstream, the vortex filaments are therefore stretched, as required by Kelvin's circulation theorem. This stretching results in increasing intensity of the measured swirl component, u_z (Fig. 5(f)). At some point, the strain exceeds that which the filaments within wake vortex can tolerate and they break, destroying the link between the ring and generator. At this point, the wake vortex is free to relax, retracting towards the vortex ring. In doing so, it increases in diameter and decreases in swirl. Fig. 5(h) shows the field shortly after this has occurred and demonstrates that the velocity within the axial wake vortex has already decreased significantly. It is this process of retraction towards the vortex ring which releases the opposite signed secondary vortex from its formation point within the atmosphere and allows it to be shed, as seen in Figs. 4(h), 4(j) and 4(l).

Subsequent to the violent shedding process, the u_z field inside and surrounding the vortex ring stabilizes in the form shown in Fig. 5(l). Upstream and outboard of the vortex core, the flow is anti-cyclonic, due to the outward motion of the vortex. Downstream, this pattern is naturally reversed, with cyclonic flow largely confined to the vortex ring wake.

4. Concluding remarks

Previous work had identified striking differences to the structure of a vortex ring when generated within a rotating system; namely a swirling wake and a secondary vortex shedding event. New results have been obtained using time resolved PIV measurements in a reference frame that moves with the vortex ring. These measurements have enabled the relationship between these two events to be studied and further understood.

The cyclonic wake swirl is found to remain attached to the vortex generator subsequent to formation. As the vortex propagates away from the generator this wake is stretched, resulting in increased vortex intensity. At some point the stretching exceeds that which is tolerable by the vortex filaments, resulting in their breakage. This is seen to initiate the shedding of an opposite signed secondary vortex around the primary core. This transient event, resulting in the separation of the vortex ring from its generating geometry, allows the formation of a stable structure, which undergoes no further transient until decay.



(a) $Ro_0 = \infty$, $T/T_0 = 3.03$

(b) $Ro_0 = 6.4$ $T/T_0 = 3.03$

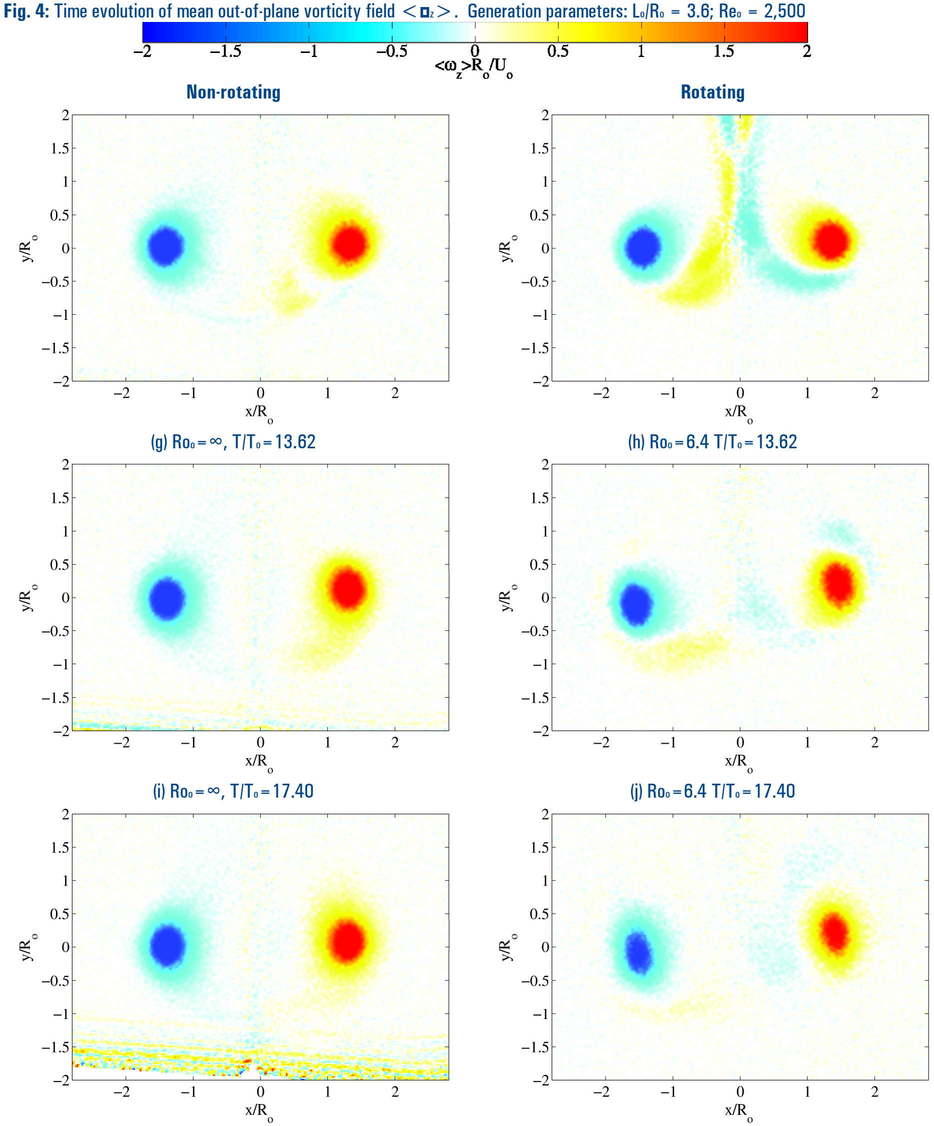
(c) $Ro_0 = \infty$, $T/T_0 = 6.44$

(d) $Ro_0 = 6.4$ $T/T_0 = 6.44$

(e) $Ro_0 = \infty$, $T/T_0 = 10.22$

(f) $Ro_0 = 6.4$ $T/T_0 = 10.22$

Fig. 4: Time evolution of mean out-of-plane vorticity field $\langle \omega_z \rangle$. Generation parameters: L_0/R_0 = 3.6; Re_0 = 2,500



(g) $Ro_0 = \infty$, $T/T_0 = 13.62$

(h) $Ro_0 = 6.4$ $T/T_0 = 13.62$

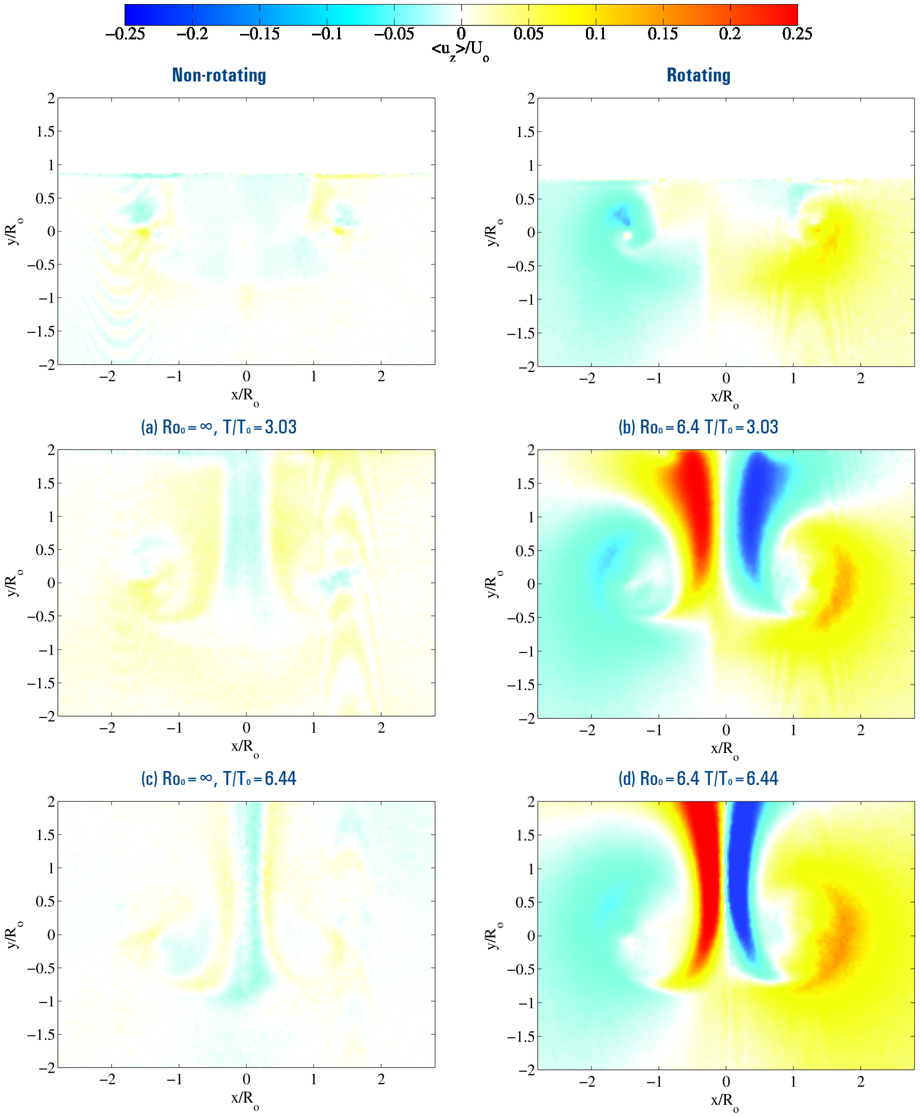
(i) $Ro_0 = \infty$, $T/T_0 = 17.40$

(j) $Ro_0 = 6.4$ $T/T_0 = 17.40$

(k) $Ro_0 = \infty$, $T/T_0 = 20.81$

(l) $Ro_0 = 6.4$ $T/T_0 = 20.81$

Fig. 4 cont'd: Time evolution of mean out-of-plane vorticity field $\langle \omega_z \rangle$. Generation parameters: L_0/R_0 = 3.6; Re_0 = 2,500

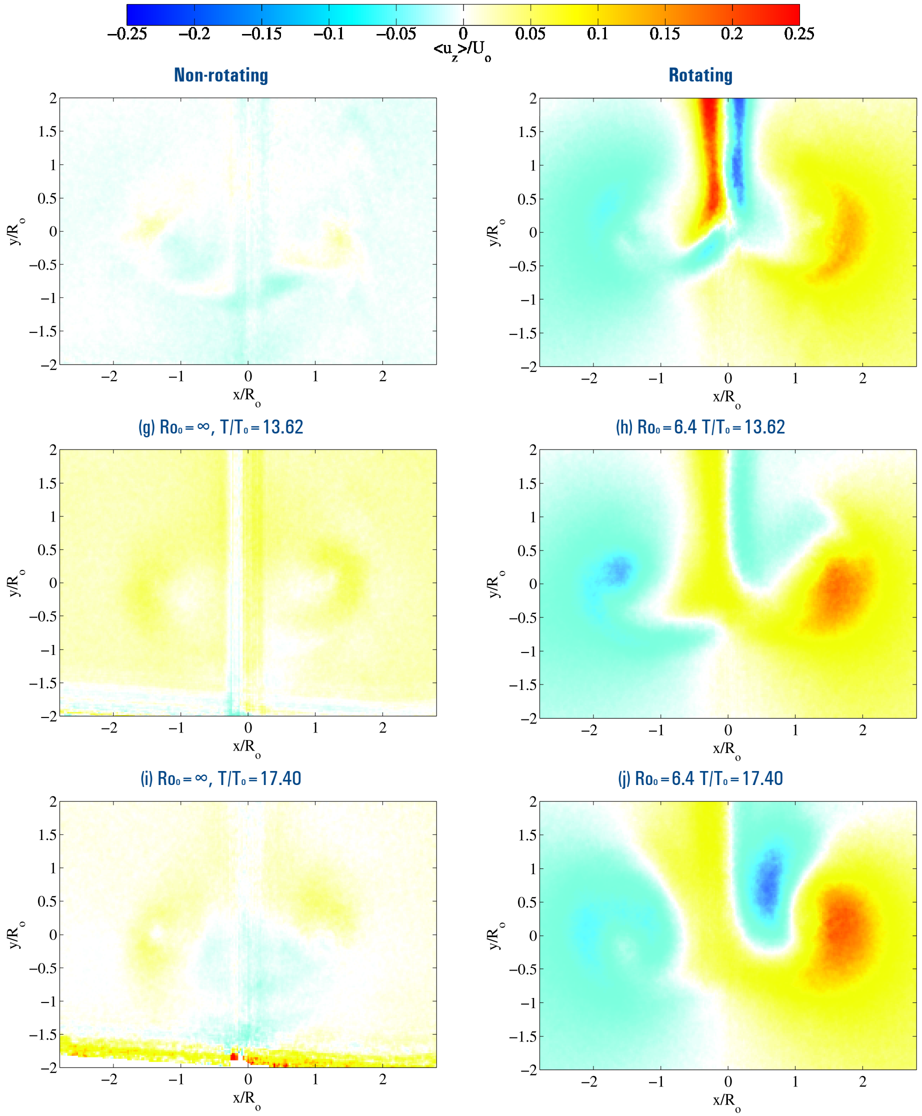


(a) $Ro_o = \infty$, $T/T_o = 3.03$ (b) $Ro_o = 6.4$ $T/T_o = 3.03$

(c) $Ro_o = \infty$, $T/T_o = 6.44$ (d) $Ro_o = 6.4$ $T/T_o = 6.44$

(e) $Ro_o = \infty$, $T/T_o = 10.22$ (f) $Ro_o = 6.4$ $T/T_o = 10.22$

Fig. 5: Time evolution of mean out-of-plane velocity field $\langle u_z \rangle$. Generation parameters: $L_o/R_o = 3.6$; $Re_o = 2{,}500$



(g) $Ro_o = \infty$, $T/T_o = 13.62$ (h) $Ro_o = 6.4$ $T/T_o = 13.62$

(i) $Ro_o = \infty$, $T/T_o = 17.40$ (j) $Ro_o = 6.4$ $T/T_o = 17.40$

(k) $Ro_o = \infty$, $T/T_o = 20.81$ (l) $Ro_o = 6.4$ $T/T_o = 20.81$

Fig. 5 cont'd: Time evolution of mean out-of-plane velocity field $\langle u_z \rangle$. Generation parameters: $L_o/R_o = 3.6$; $Re_o = 2{,}500$

5. References

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EUROMECH Solid Mechanics Fellow 2012 Paper

"A Brief History of Fracture Mechanics"

Jean-Baptiste LEBLOND was named Fellow of EUROMECH at the 8th EUROMECH Solid Mechanics Conference held in Graz, July 2012

Jean-Baptiste Leblond[1]

Abstract

The aim of fracture mechanics is to predict and prevent the initiation and propagation of cracks in solid materials. It consists of two separate and independent topics: brittle fracture mechanics and ductile fracture mechanics. The origin of the distinction lies in the different physical mechanisms promoting fracture. In this paper, we briefly expound the foundations of each discipline and describe some issues arising in their context.

1. Introduction

Fracture mechanics is a rather recent scientific discipline. After Griffith's seminal contribution [1] of 1920, the topic was somewhat neglected until 1950. Important work by Williams [2], Irwin [3], Rice and Tracey [4], Gurson [5] then marked the true beginning of the discipline. Its aim is to predict and prevent the initiation and propagation of cracks in solid media. It is widely used in the transport and energy industries.

Fracture mechanics may be divided into two sub-disciplines, brittle fracture mechanics and ductile frature mechanics, the methods and reasonings of which have little in common. The origin of the difference lies in the physical mechanisms responsible for fracture, which are very different in brittle and ductile materials. At the macroscopic scale, the main consequence of these different mechanisms is that plasticity is of minor importance in brittle materials (one speaks about "confined plasticity" in the sense that it occurs only in the immediate vicinity of the crack front), but very important in ductile ones (one speaks about "extended plasticity" in the sense that it occurs in the whole cracked structure). Typical examples of brittle materials are glasses and metals at low temperatures (generally lower than room temperature). Typical examples of ductile materials are metals at moderate or high temperatures, and more generally all solid materials close to the fusion point.

2. Mechanics of brittle fracture

From a microscopic point of view, brittle fracture is generally characterized (at least in crystalline materials) by transgranular cracking, that is cracking occurring inside the grains, along well-defined atomic planes which gradually move away from each other. However the standard theory of brittle fracture mechanics completely ignores this mechanism and provides a purely heuristic and macroscopic description of the fracture process within the classical framework of linearized elasticity.

One first, fundamental result, due to Williams [2], pertains to the asymptotic behavior of the stresses near the crack front, in pure elasticity and in the quasistatic case. Williams showed that whatever the geometry and the loading, these stresses are always asymptotically inversely proportional to the square root of the distance to the crack front. The geometry and the loading appear in Williams' expressions only through three multiplicative constants called *the stress intensity factors of modes I, II and III*, and classically denoted K_I, K_{II}, K_{III}. When $K_{II} = K_{III} = 0$, the crack is said to be in a state of pure mode I; the deformation of the crack faces generates an *opening of the crack*. When $K_I = K_{III} = 0$, the crack is in a situation of pure mode II; the crack is *sheared in a plane orthogonal to its front*. When $K_I = K_{II} = 0$, the crack is in a situation of pure mode III; the crack is *sheared in a plane orthogonal to its direction of propagation*.

Using this result, Irwin [3] proposed a heuristic description of the fracture process in pure mode I and in the 2D case, that is in situations in which the strains and stresses are invariant in translatory motions parallel to the crack front. His proposal consisted in assuming the existence of a new material constant called *the fracture toughness* and denoted K_{Ic}, such that propagation of the crack be impossible for $K_I < K_{Ic}$ but possible for $K_I = K_{Ic}$. The whole physics of the fracture process is then "summarized" in the single phenomenological constant K_{Ic}. This proposal immediately opens the way to practical applications. The role of the experimenter is to measure the fracture toughness. Once this is done for the material considered, the mechanical analyst calculates (analytically or, more frequently, numerically using the finite element method) the mode I stress intensity factor, as a function of the geometry of the structure and the loading applied onto it. He then compares the values of K_I and K_{Ic} so as to identify the possibility of propagation of a crack. It must be noted that this approach presupposes the existence of a crack; this is one basic difficulty of the standard theory, which is able to predict crack propagation but *not* crack initiation.

Another weakness of Irwin's approach is that it ascribes a fundamental role to the stress intensity factor K_I, which in reality does not exist since plasticity prohibits the divergence of the stresses near the crack front predicted by linear elasticity. Griffith's earlier approach [1] was free of this shortcoming. Griffith performed a thermodynamic analysis of quasistatic crack propagation (again for 2D and pure mode I situations). He evidenced the importance of a quantity called the *energy-release-rate*, classically denoted G and equal to the opposite of the derivative of the total energy of the structure with respect to the crack length, under conditions of constant loading. He showed that the crack propagation criterion could be written in the form $G = G_c$ where G_c is a new material constant. He interpreted this constant as representing the reversible energy of separation of the crack faces per unit advance of the crack. It was shown much later that this interpretation was wrong and that G_c was in fact to be interpreted as the work dissipated through

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plasticity in the small plastic zone surrounding the crack tip, per unit advance of the crack; but this did not change the basic expression of "Griffith's criterion" $G = G_c$, G_c being always considered as an adjustable parameter anyway.

Another fundamental contribution of Irwin [3] was to establish the equivalence of his approach and that of Griffith [1], that is, the equivalence of the propagation criteria $K_I = K_{Ic}$ and $G = G_c$. In order to do so, he established a famous relation henceforward called *Irwin's formula* and connecting K_I and G. A consequence of Irwin's formula is the equivalence of Irwin's and Griffith's criteria, the "critical" quantities K_{Ic} and G_c being connected by a similar relation. This equivalence provides a fresh and probably better justification of Irwin's criterion, since it shows that the reference made by this criterion to the in fact non-existent stress intensity factor K_I may be replaced by a reference to the energy-release-rate G, the physical significance of which is indisputable.

When the crack is loaded in a situation of "mixed mode" I+II, the problem may remain 2D but becomes more complex, because the crack no longer propagates along its original direction but abruptly kinks away from this direction. Thus the prediction of propagation must now include, in addition to the value of the loading promoting propagation of the crack, that of its kink angle. This issue raised numerous discussions in the 70s and 80s, but a general consensus has now been reached according to which at least in isotropic materials, this kink angle is given by Goldstein and Salganik's *principle of local symmetr*y [6], which stipulates that this angle is determined by the condition that the stress intensity factor of mode II be zero immediately after the initial kink.

When the crack is loaded in mixed mode I+III or I+II+III conditions, the situation becomes even more complex. The problem, even if initially 2D, cannot remain so when the crack starts propagating, because the presence of mode III promotes an abrupt or gradual rotation of the crack front about the direction of propagation, which destroys the invariance of the problem in translatory motions parallel to the crack front. This rotation may occur through general rotation of the entire front or, more frequently, through formation of small fracture facets rotating independently of each other. The theoretical description of such phenomena still represents an important challenge for future researches, although considerable progress has recently been made on the topic [7,8].

More generally, the mechanics of brittle fracture is still, or perhaps even more than ever, a very active scientific field; numerous issues of considerable theoretical and/or practical interest remain to be solved.

3. Mechanics of ductile fracture

The successes of the theory of brittle fracture mechanics have naturally induced mechanical analysts to try and transpose the methods and reasonings of this theory to ductile fracture. The approach resulting from this transposition is called the *global approach of ductile fracture*, in the sense that just like the theory of brittle fracture mechanics, it completely ignores the physical details of the fracture process. It is still widely used in the industry. However, the severe limitations of this approach have gradually been realized over the years. It will suffice here to mention that these limitations are basically linked to its purely macroscopic character. It so happens that when the material behavior is no longer essentially elastic, it is no longer possible to schematize a crack as a mere surface of discontinuity of the displacement and stresses, and consider the fracture dissipation as concentrated on the line (the crack front) limiting this surface; indeed such an approach leads to paradoxes. It becomes necessary to adopt a more refined view of the crack region and accurately analyze the fracture mechanisms in the vicinity of the crack front. The more modern version of the theory of ductile fracture mechanics, currently known as the *local approach of ductile fracture*, thus relies on micromechanical approaches and homogenization theory, in contrast to the purely macroscopic theory of brittle fracture mechanics.

The physical mechanisms of ductile fracture have been known for a long time and consist of three successive steps:

1. In a first step, microvoids are generated through decohesion of the interface between the metallic matrix and chemically distinct inclusions, and/or brittle fracture of such inclusions.

2. In a second step, these microvoids grow through plastic flow of the surrounding matrix.

3. In a third and final step, the voids coalesce, thus leading to formation or development of a macroscopic crack.

Because of its complexity, the first step has seldom been the subject of theoretical investigations, and is generally modeled in a heuristic manner. In contrast, the second and third steps are amenable to theoretical analyses. The aim of such analyses is to provide a macroscopic description of the behavior of plastic porous materials, and more precisely to accurately describe the *gradual softening of such materials arising from the increase of their porosity*.

The central problem of the local approach of ductile fracture is thus to describe the *constitutive behavior* of ductile materials, in contrast to the theory of brittle fracture which considers this behavior to be purely elastic and essentially studies *structural problems*. Of course, once the constitutive behavior of ductile materials has been defined, practical structural problems must be solved; but this is almost systematically done numerically, by the finite element method, and there is no equivalent of the extensive analytical solutions of cracked structures typical of the theory of brittle fracture.

One seminal contribution to the local approach of ductile fracture is due to Rice and Tracey [4]. In this work, the authors analyzed the growth of an isolated void embedded in an infinite plastic matrix subjected to some arbitrary remote stress state. Their major result was to evidence the decisive importance of the *triaxiality*, that is the ratio of the overall mean stress over the overall von Mises equivalent stress, upon the void growth rate. The main shortcoming of the work was that it did not really provide a general description of the macroscopic behavior of a plastic porous material, since the consideration of a single void in an infinite matrix automatically implied that the porosity was necessarily zero.

This limitation was eliminated in the fundamental work of Gurson [5], which proposed an approximate limit-analysis of a hollow sphere (typical "elementary cell" in a porous medium) made of some rigid-ideal-plastic material and subjected to conditions of homogeneous boundary strain rate. The advantage of considering such a sphere was that any value of the porosity could be envisaged. Gurson derived an approximate, but accurate expression of the overall yield criterion of the hollow sphere. He also showed that the normality rule for the plastic strain rate was preserved in the homogenization process, with the consequence that the expression of the overall plastic strain rate directly resulted from that of the overall criterion with no additional hypothesis. Since plastic incompressibility of the metallic matrix also implied a direct connection of the porosity rate to the trace of the overall plastic strain rate, the conclusion was that *defining the overall criterion was sufficient to fully define the macroscopic constitutive behavior*.

Gurson's model, in a slightly extended form known as the GTN (Gurson-Tvergaard-Needleman) model [9,10], has been extensively used to study practical problems of ductile fracture, with considerable success. One fine example of a successful application is the numerical simulation of the so-called phenomenon of "cup-cone fracture" of a round tensile bar. In such a specimen, loaded in tension, the following successive phenomena are observed: (i) necking of the central part of the specimen; (ii) initiation of a flat crack on the central axis of rotational symmetry; (iii) flat propagation of this crack toward the free surface; (iv) final deviation at 45° of the crack from its original plane, when it gets close to this surface. The GTN model, used in a finite element simulation of the problem, allows precise reproduction of each of these steps [10]. Such a reproduction would represent an impossible challenge for the global approach.

There are however numerous limitations to both the Gurson and GTN models. Such limitations have stimulated considerable research, especially in the last 20 years, the aim being to eliminate some of the restrictive hypotheses made by Gurson so as to extend his approach and model. Maybe the most important extension was the incorporation of void shape effects. Gurson implicitly made the hypothesis of spherical voids since the elementary cell he considered was a hollow sphere. Very recently, ellipsoidal cells containing ellipsoidal voids were considered by Madou and Leblond [11,12], who thus defined an extended Gurson-like model accounting for such voids. This model is of interest for problems of ductile fracture under low triaxialities, for which voids are expected not to remain spherical but evolve toward more complex shapes, which may be considered as ellipsoidal in a first approximation.

Many other topics of considerable interest, which cannot all be cited here, are also currently being investigated. Thus the discipline, though more recent than brittle fracture mechanics, is just as, or perhaps even more active.

4. References

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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.

EUROPEAN MECHANICS SOCIETY

EUROMECH - European Mechanics Society

NOMINATION FORM FOR FELLOW

NAME OF NOMINEE: ....

OFFICE ADDRESS: ....

....

EMAIL ADDRESS: ....

FIELD OF RESEARCH: ....

Fluids: ☐ Solids: ☐

NAME OF SPONSOR 1: ....

OFFICE ADDRESS: ....

....

....

EMAIL ADDRESS: ....

SIGNATURE & DATE: ....

NAME OF SPONSOR 2: ....

OFFICE ADDRESS: ....

....

....

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;
- Sponsor's signature/date.

ADDITIONAL INFORMATION

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

TRANSMISSION

Send the whole nomination packet to:

Send the whole nomination packet to:
Professor GertJan van Heijst
Fluid Dynamics Laboratory, Department of Physics
Eindhoven University of Technology
PO Box 513, 5600 MB Eindhoven, The Netherlands
E-mail: G.J.F.v.Heijst@tue.nl

EUROPEAN MECHANICS SOCIETY

EUROMECH Prizes: Nomination Procedure

Fluid Mechanics Prize
Solid Mechanics Prize

Regulations and Call for Nominations

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

Nomination Guidelines

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

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

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

Prize committees

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

Fluid Mechanics Prize

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

- E.J. Hopfinger (chair)
- L. Biferale
- P. Huerre
- N. Peake
- G.J.F. van Heijst

Chairman's address
Professor E. Hopfinger
LEGI / Institut de Mécanique de Grenoble
Université de Grenoble
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38041 Grenoble-Cédex, France
France
E-mail: emil.hopfinger@legi.cnrs.fr

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:

- D.H. van Campen (chair)
- O. Allix
- P. Camanho
- V. Tvergaard
- P. Wriggers

Chairman's address
Prof. Dick van Campen (Chair, Solids)
Dept. Mechanical Engineering
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E-mail: d.h.v.campen@tue.nl

EUROMECH Conferences

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.

EUROMECH Conferences in 2014

ENOC8
8th European Nonlinear Oscillations Conference
DATE: 6-11 July 2014
LOCATION: Wien, Austria
CONTACT: Prof. H. Ecker
E-MAIL: horst.ecker@tuwien.ac.at
Website: http://enoc2014.conf.tuwien.ac.at/

EMMC14
14th European Mechanics of Materials Conference
DATE: 27-29 August 2014
LOCATION: Gothenburg, Sweden
CONTACT: Prof. K. Runesson
E-MAIL: Kenneth.Runesson@chalmers.se
Website: http://www.chalmers.se/emmc14

EFMC10
10th European Fluid Mechanics Conference
DATE: 14-18 September 2014
LOCATION: Copenhagen, Denmark
CONTACT: Prof. J. N. Sorensen
E-MAIL: jns@mek.dtu.dk
Website: http://www.efmc10.org/

EUROMECH Conferences Reports

14th European Turbulence Conference (ETC14-2013)

ETC14 included 8 invited papers, covering a wide variety of subjects in the field of fluid turbulence. These were distributed between four main areas:

- Fundamental questions: F. Daviaud (instability of turbulence), H. Xu (Lagrangian turbulence), R. Kerswell (turbulence and dynamical systems);
- Turbulence in natural systems: S. Malinowski (turbulence in clouds), A. Brandenburg (turbulent MHD dynamos);
- Applications to control: B. McKeon (wall turbulence), R. Camussi (identication of noise sources);
- Turbulent transport of particles: A. Johansson (fibers in a turbulent channel).

These presentations were successful not only in reviewing a number of interesting phenomena, but also in presenting many recent developments in the field, in particular in describing state of the art methodologies (theoretical, numerical and experimental) used by the contemporary turbulence research community. These include Lagrangian description of turbulence, analogies with dynamical systems, analogies with statistical physics, Lattice Boltzmann simulations, etc.

To accommodate the large number of high quality abstracts submitted by participants from many countries, in Europe and elsewhere, five parallel sessions had to be organized. They covered a broad range of aspects of turbulent flows, from fundamental to more applied, including subjects of industrial relevance.

The importance of the sessions devoted to Lagrangian turbulence ("Particles in Turbulence" and "Lagrangian turbulence") is clearly demonstrated by the number of presentations. These subjects were also among the most debated topics during the previous ETC conference (ETC13 in Warsaw). Other well-represented topics were:

- Instability and Transition;
- Turbulence in Boundary Layers, which encompasses many fundamental aspects with major application challenges such as drag reduction;
- Turbulent convection, which covers fundamental aspects of instabilities, and also important geophysical questions.
- The seemingly simple problem of Rayleigh-Benard convection, which continues

to challenge the community;

- Fundamental issues about heat transport, which continue to be debated actively;
- Magnetohydrodynamics, with presentations over a wide range of sub-topics, from planetary dynamics, turbulence in plasmas, and liquid metal technologies.

The large number of sessions covered a wide range of fundamental studies and practical applications, as shown in the following list:

- Six sessions were dedicated to advances in methodologies: two each for experimental advances, numerics and theoretical aspects;
- Four sessions were specifically dedicated to Geophysical and Astrophysical questions, where turbulence plays a crucial role;
- Other presentations with geo-astrophysical motivations were also programmed in more specific sessions with emphasis on Rotation, Stratification, MHD and 2-Dimensional effects;
- Three sessions dedicated to Cryogenic Turbulence are a sign of the recent growth of this part of the turbulence community. It has succeeded in developing the pro per tools to investigate extreme regimes of classical turbulence, in the limit of very high Reynolds numbers, as well as other aspects, related to the quantum properties of super fluid Helium;
- Three sessions were dedicated to Pipe Flows, which in spite of the simplicity of the configuration remains a canonical system to address fundamental questions related to the transition to turbulence. The progress in this field rests, however, on a small group of extremely active research groups.
- Two sessions dedicated to Taylor-Couette flows showed a renewed interest in the community, with the stress on momentum transport in a very turbulent system;
- Two sessions were dedicated specifically to engineering aspects. These sessions were focussed on studies concerned with specific industrial situations, prototype studies, etc;
- Several other sessions included presentations that were concerned with practical applications, such as Control, Mixing and Compressible Turbulence. This is an important aspect of ETC conferences which stimulate the connection between academic and industrial worlds.

EUROMECH Colloquia

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

EUROMECH Colloquia in 2014

554. Dynamics of capsules, vesicles and cells in flow
Chairperson: Dr. Anne-Virginie Salsac
Biomechanics and Bioengineering
Laboratory
Université de Technologie de Compiègne
BP 30529
60205 Compiègne cedex, France
Email: a.salsac@utc.fr
Co-chairperson: Dr. Mark Blythe
Dates and location: 15-18 July 2014, Université de Technologie de Compiègne, France
http://www.utc.fr/dynacaps2014/

557. Fluid Mechanics of Collective Behaviour across Scales
Chairperson:Prof. Petros Koumoutsakos
ETH Zurich
Clausiusstrasse 33 CLT,
F12 CH-8092, Zurich, Switzerland
Email: petros@ethz.ch
Co-chairpersons: Prof. J.L. van Leeuwen, Dr. Guy Theraulaz
Dates and location: 22-26 September 2014, Zurich, Switzerland

561. Dimensionality in Turbulence
Chairperson: Prof. Alban Pothérat
Applied Mathematics Research Centre
Coventry University
Priory Street, Coventry CV1 5FB, UK
Email: alban.potherat@coventry.ac.uk
Co-chairpersons: Prof. GertJan van Heijst, Dr. Nicolas Plihon
Dates and location: 19-21 May 2014, Coventry, UKy
http://euromech.complexity-coventry.org/overview.xhtml

563. Generalized Continua and their application to the design of composites and metamaterials
Chairperson: Prof. Francesco dell'Isola
Università di Roma La Sapienza
Dipartimento di Ingegneria Strutturale e Geotecnica
Via Eudossiana 18
00184 Rome, Italy
Email: francesco.dellisola@uniroma1.it
Co-Chairpersons: Prof. Samuel Forest
Dates and location: 17-21 March 2014, Cisterna di Latina (Rome), Italy
http://www.memocsevents.eu/euromech563/?page_id=20

565. Subcritical transition to turbulence
Chairperson: Dr. Yohann Duguet
LIMSI-CNRS,
Université Paris-Sud,
F-91403 Orsay, France
Email: duguet@limsi.fr
Co-Chairperson: Dr. José Eduardo Wesfreid
Dates and location: : 6-9 May 2014, Cragese, Corsica
http://www.euromech545.de/

EUROPEAN MECHANICS SOCIETY

EUROMECH Colloquia in 2015

553. Bearing Technologies in Rotor Dynamics
Chairperson: Dr. F. Donhal
Department of Mechanical Engineering
Petersenstrasse 30
D-64287 Germany
Email: donhal@sdy.tu-darmstadt.de
Co-Chairperson: Prof. P. Pennacchi
Dates and location: 2015 (Postponed from 2014), Baden, Switzerland

556. Theoretical, Numerical and Experimental Analyses in Wood Mechanics
Chairperson: Prof. Michael Kaliske
Institute for Structural Analysis
Technische Universität Dresden
Germany
Email: michael.kaliske@tu-dresden.de
Co-chairperson: Prof. Josef Eberhardsteiner
Dates and location: 2015 (Postponed from 2014), Germany

558. Ocular Biomechanics and Correlation with Microstructure
Chairperson: Prof. Ahmed Elsheikh
School of Engineering
University of Liverpool
Brownlow Hill
Liverpool L69 3GH, UK
Email: elsheikh@liv.ac.uk
Co-chairpersons: Dr Philippe Buchler
Dates and location: 2015 (Postponed from 2014), UK

559. Multi-scale computational methods for bridging scales in materials and structures
Chairperson: Dr. Varvara Kouznetsova
Eindhoven University of Technology
Department of Mechanical Engineering
Den Dolech 2,
5612 AZ Eindhoven, The Netherlands
Email: V.G.Kouznetsova@tue.nl
Co-Chairperson: Prof. Dr. Julien Yvonnet, Prof.Dr.-Ing. Christian Miehe
Dates and location: 23-25 February 2015, Eindhoven, The Netherlands

560. Mechanics of Biological Membranes
Chairperson: Prof. E. Mazza
ETH Zurich
LEO C16, ETH Zentrum
8092 Zurich
Switzerland
Email: emazza@ethz.ch
Co-chairperson: Prof. J.-F. Ganghoffer
Dates and location: 8-12 February 2015, Ascona, Switzerlan

562. Stability and control of nonlinear vibrating systems
Chairperson: Prof. Angelo Luongo
Department of Civil, Architectural and Environmental Engineering
University of L'Aquila, Via Giovanni Gronchi 18
L'Aquila 67100, Italy
Email: angelo.luongo@univaq.it
Co-chairperson: Dr. Sara Casciati
Dates and location: July 2015, L'Aquila, Italy

564. Ionic liquids in nanoconfinement
Chairperson: Dr. James Seddon
Faculty of Science and Technology
University of Twente
Office Carré 4.413
P.O. Box 217
7500 AE Enschede, The Netherlands
Email: j.r.t.seddon@utwente.nl
Co-Chairpersons: Prof. Alexei Kornyshev
Dates and location: 2015 (Postponed from 2014), The Netherlands

EUROMECH Colloquia Reports

EUROMECH Colloquium 533
"Biomechanics of the Eye"
22-24 July 2013, Genoa, Italy
Chairperson: Prof. Rodolfo Repetto
Co-Chairperson: Prof. Jennifer Siggers

Mechanics play an extremely important role in the functioning of the eye, in both health and disease. The themes of EUROMECH Colloquium 533 included various applications of mechanics to physiology or pathological conditions affecting the eye. For example, the following subjects were covered:

- The physiology of the cornea, lens, sclera, aqueous humour, vitreous humour, lamina cribrosa, optic nerve, tear film, retinal blood circulation;
- The effect of pathological conditions such as keratoconus, glaucoma and retinal detachment.

There were 35 official participants, from 11 different countries, plus several participants from the University of Genoa, who attended some of the talks. Participants had different backgrounds, including ophthalmology, engineering, physics and mathematics, so the environment had the highly multidisciplinary character that is essential when dealing with a topic such as the one of this Colloquium. There were four one-hour presentations by the following distinguished invited speakers:

- Peter Pinsky, Department of Mechanical Engineering, Stanford University, USA.
- Claude F. Burgoyne, Optic Nerve Head Research Laboratory, Devers Eye Institute, USA.
- Phil Luthert, Institute of Ophthalmology, University College London, UK.
- Richard J. Braun, Department of Mathematical Sciences, University of Delaware, USA.

Financial support for the invited speakers to attend Colloquium 533 was provided.
In addition there were 25 contributed talks. Some of the main themes discussed are described in the following list.

- **Mechanics of the cornea** Peter Pinsky gave a very interesting invited lecture on structural multiscale models of the cornea. The biomechanics of the cornea was also the subject of seven contributed talks.
- **Glaucoma** This pathological eye condition is the second largest cause of blindness worldwide (it is the largest in Western countries). Mechanics plays a very important role in the pathogenesis and progression of the disease.
  We had a very comprehensive overview on the subject from an invited speaker (Claude Burgoyne) and several related contributed talks.
- **Tear film dynamics** Richard Braun gave a very comprehensive talk concerning the mechanics of tear films after blinking.
- **Vitreous humour and retinal detachment** The rheological properties of the vitreous humour and its dynamics induced by eye rotations have mechanical implications for the generation of retinal detachment and for drug delivery by injection into the vitreous chamber. These issues were discussed in nine contributed talks, during which numerical, analytical and experimental results were presented.
- **Blood flow in the eye** This is a very important issue to understand several pathological conditions of the eye. During the colloquium Philip Luther presented, in his invited lecture, many problems related to blood flow in the eye. Moreover, we had two very interesting contributed talks on this topic.

In the view of the organising committee the meeting was very successful. One of the key reasons for this was the fact that participants had a variety of different backgrounds. After each talk there was extensive discussion that invariably extended during the breaks. The majority of the participants, including young researchers, contributed actively to such discussions in an informal atmosphere. During Colloquium 533, several possible future collaborative projects were discussed. As a result, we anticipate that new collaborations might arise out of the meeting. The talks were overall of a very high quality. Many of the participants commented to the organisers that the meeting was very useful and interesting.

The organising committee wishes to thank EUROMECH for making Colloquium 533 possible.

EUROMECH Colloquium 543
"Quantification of uncertainties in modelling and predictive simulation of fluids"
10-11 October, 2013, Munich, Germany
Chairperson: Prof. Dr. Nikolaus Adams
Co-Chairperson: Prof. Dr. Wolfgang Schröder

Uncertainty Quantification (UQ) is a relatively new approach to investigate and evaluate the unknown fidelity in numerical and experimental investigations in fluid mechanics. The mathematical approach helps to identify the sensitivities and the possible systematic error propagation in complex fluid dynamic systems. UQ can help to reduce the number of simulations/experiments that are needed to quantify the sensitivity of the result to different error sources, such as unknown inflow conditions and other parameters, and on the overall error of the investigated system. Optimisation strategies can benefit from knowledge of the level of uncertainty in the final result.

EOROMECH Colloquium 543 brought together researchers from various countries to exchange ideas and concepts on UQ in fluid mechanics. 14 presentations were selected from those submitted. The colloquium drew 22 participants from 6 different countries in Europe, plus Israel and the USA. It took place at TU München in the Institute of Aerodynamics and Fluid Mechanics. The two-day event saw intense discussion of the topics presented and led to fruitful ideas for further work. Prof. Moser from UT at Austin, Texas, gave the invited lecture on the topic of UQ as a means to build confidence in predictive simulations, using the example of atmospheric re-entry vehicles. The presentations can be grouped into four main topics, as shown below.

- **Turbulence** Three presentations dealt with UQ in a turbulent environment with RANS. The first authors estimated the errors in RANS simulations due to the turbulence closure model. The method of UQ was applied to the unknown model parameters and their influence on wall-bounded flows with different pressure gradients. The second presentation dealt with uncertainty in low-dimensional models of the Navier-Stokes equations. To reduce the uncertainties in treatment of turbulent flows at high Reynolds numbers it is necessary to study the coupling between large/resolved and small/unresolved scales. The third authors showed a practical application where porous material at the trailing edge led to a reduction in emitted noise of up to 6 dB.
- **Experiments** Three presentations demonstated the use of UQ in the processing of experimental data and the effects on the experimental setup. The first showed how the formulation of accurate inflow data in numerical simulations depends on experimental knowledge which is unavailable to the required detail. UQ can help to identify the regions which are responsible for the largest error propagation in the inflow data. The next presentation concerned the accuracy of heat transfer measurements in natural convection. The error propagation for the calculation of the Nusselt number and its related data interpretation from the measurements was discussed. The next talk described the use of UQ in particle image velocimetry (PIV).
- **Supersonics/flows with shocks** Shocks are extremely sensitive to initial conditions. The first talk showed the uncertainty of a shock/bubble interaction in comparison with published experimental results and identified the most likely cause. The second dealt with Polynomial Chaos methods applied to a scramjet intake with uncertain inflow Mach number and uncertain angle-of-attack. UQ led to a better understanding of the sensitivities in the problem with various different flow regimes. The third talk concerned simulations during the design stage of the scramjet combustion chamber flow, where UQ can lead to a significant decrease in parameter permutations.
  The final presentation in this session concerned the quantification of initial-data uncertainty for a shock-accelerated gas cylinder.
- **Miscellaneous** The first talk described the combination of an inverse approach and UQ in refinement of initial interface conditions in a shock-tube setup. The problem was looked at inversely, developing the initial conditions from the nonlinear evolution of the interface hit by the shock. In a second contribution, the interaction between the wakes of two cylinders in proximity was presented. In a presentation on the formulation of the polynomial chaos expansions, the role of incomplete statistical input information was detailed. The error quantification of passive scalar transport in the context of LES was also presented.

Colloquium 543 gave insight into various applications of uncertainty quantification in fluid mechanics. Improved understanding of error propagation in experiments and the quantification of the direct impact of initial errors on the final result in non-linear environments was clearly shown. The colloquium showed how UQ can deliver a deeper insight into the uncertainties and their propagation in complex environments. This leads to an increase in confidence in the experimental measurements and the numerical predictions. The discussions showed increasing awareness of the potential of UQ among the participants. The organizers and the participants express their gratitude to EUROMECH for support of the colloquium.

EUROPEAN MECHANICS SOCIETY

EUROMECH Colloquium 544
"Dense flows of soft objects: Bringing together the cases of bubbles, droplets and cells"
13-15 May, 2013, Grenoble, France
Chairperson: Prof. Gwennou Coupier
Co-Chairperson: Prof. Philippe Marmottant and Ralf Seemann

The main goal of EUROMECH Colloquium 544 was to allow people from two communities (namely bubbles and drops on one side and cells, vesicles and capsules on the other side) to meet. They could then share their recent achievements and the new problems they were facing in the study of deformable objects under confinement and/or in interaction with each other. It was hoped to develop a clearer idea on what all these deformable objects have in common and how their flow could be described at microscopic and macroscopic scales, especially in complex networks such as blood capillary networks and microfluidic chips.

The received abstracts showed that the aim of Colloquium 544 was well understood by the different communities. It was possible to identify successive presentations dealing with the same problem with different objects, and studies of the same object but under different confinements or with different density of neighbours. There was also a good balance between theoretical/numerical works and experimental studies, that represented 48% of the presentations. Another goal evoked in the announcement of the colloquium was to address the development of active manipulation of soft objects within microfluidic devices, for lab-on-chip applications.

In total, there were 5 invited presentations of 50 minutes each, 19 oral presentations of 20 minutes each and 16 posters, selected from the received abstracts. However, each participants having a poster was invited to advertise it during a 3-minute presentation. The poster session itself lasted 1 hour 30 minutes and was placed in the middle of the first day, so as to encourage inspection. The plan worked well.

Two prizes were awarded during the colloquium:

- A poster prize, with a jury composed of the invited speakers, was awarded to Michael Levant, from Weizmann Institute in Israel, for his poster "Amplification of thermal noise by vesicle dynamics".
- A best oral presentation prize was also awarded by a jury composed solely of PhD students, not giving an oral presentation. They took their job very seriously, with a tough final debate. The prize was eventually awarded to Anne-Virginie Salsac, from UTC Compiègne, France, for her talk "Flow of a microcapsule suspension in a square microchannel: characterisation of the capsule mechanical properties".

Two companies (Fluigent and Elveflow) were present during the 3 days and had a booth in the coffee break room. Both sell equipments dedicated to microfluidics such as pressure driven pumps.

Much positive feedback was received during the colloquium, relating particularly to the opportunity to hear presentations from one community that were relevant to the other. It is probably too early to estimate the consequences of this meeting in terms of new ideas and collaborations. During the colloquium, some scientific achievements were highlighted.

- Reliable 3D simulations with many deformable particles are now run in several research groups. Going beyond zoology and addressing the question of accuracy possible with this powerful tool remains a critical task;
- There is still a need for accurate characterization of single particle properties, from their mechanical properties to their behaviour under flow. Predicting the velocity of a confined object remains a complicated task;
- Several experiments with many interacting particles in microfluidics devices were presented. Numerical tools are favoured by several groups.

The community now needs to better understand long-range diffusion and transport phenomena, as well as non-local rheology. Phonon transport within suspensions also remains an unsolved problem. An important observation was made by several participants: it appeared to them that Colloquium 544 focused mainly on fundamental issues regarding confined flows, an aspect that tends to disappear in most microfluidic dedicated conferences, such as the third European Conference on Microfluidics, which was held in Heidelberg in December 2012. This encourages the organisation of a subsequent EUROMECH colloquium, probably in another country so as to increase the contributions coming from other countries than France.

EUROMECH Colloquium 545
"Frontiers in Finite-Deformation Electromechanics"
22-24 May 2013, TU Dortmund, Germany
Chairperson: Prof. Andreas Menzel
Co-Chairperson: Prof. Ellen Kuhl, Prof. Dr. Serdar Göktepe

The experimental investigation, modelling and simulation of smart materials attracts a continuously growing research community from mechanics, biomechanics, material science and applied mathematics. The goal of EUROMECH Colloquium 545 was to actively bring researchers in these fields together and to focus on the modelling and simulation of electro-mechanically coupled materials as well as of magneto-electromechanical continua, both at large deformations.

Approximately 40 European and non-European scientists attended the Colloquium at which 25 presentations were given. Each presentation had a length of 30 minutes; no distinction was made between keynote talks and other presentations so far as time was concerned. This format, as well as the substantial amount of time offered to the participants between the talks, made an active and lively scientific discussion possible. The location at which the volloquium took place offered a premium platform, due to the availability of different rooms equipped with individual seating and discussion groups. The following topics were prominent during the scientific exchange at Colloquium 545:

- Numerous scientific contributions focused on the numerical solution of electro-mechanical, magneto-mechanical and electro-magneto-mechanical problems for continua undergoing large deformations, for which the Finite Element Method has been established as an appropriate simulation framework. Apart from those contributions on variational approaches, different approaches and representations of Maxwell stresses were discussed as well.
- The multiscale modelling of electromechanical and magneto-mechanical materials turned out to be one of the key aspects of the colloquium. On the one hand, FE-Square-Methods were presented, as well as analytical investigations on electrical-mechanically coupled composites with a focus on the instability phenomena of these anisotropic composite materials.
- Apart from electromagnetic active polymers, further classes of composite materials were dealt with, as for example within the field of modelling lithium ion batteries. All the talks given with regard to this active field of research made use of innovative and current-edge numerical methods such as phase field approaches in order to describe these materials.

Another key aspect of Colloquium 545 was the modelling of active biological tissue such as muscle tissue and, in particular, the heart. A major bonus of this colloquium was that the community working in the field of modelling electroactive polymers was brought together with the community dedicated to electromechanical active biological tissue. The "history-dependent" electromechanical stimulus in biological tissue, however, is presented differently especially when the heart is activated as it is in the case of classic electroactive polymers. Its implementation in connection with active stresses in biological tissue was discussed during several presentations and extrapolated to the special physiology of the heart. In addition to the physical modelling, the simulation of large representative boundary problems was of key importance, which coincides with the concepts of parallel and high-performance computing.

Experimental research was also presented during the colloquium, especially the research on magneto-active polymers. These contributions were of particular interest because this specific field of modelling and simulation still lacks appropriate and accurate data from experimental research on electro-active and magneto-active materials.

The lively discussions during and after Colloquium 545 showed that there are still many open issues which will keep the community actively involved in the future. Subsequent to the Colloquium, a special issue in the European Journal of Mechanics / A-Solids was initiated, in which selected contributions were collated in the form of peer-reviewed articles. The feedback from the participants in Colloquium 545 was very positive, and there was general interest in a another colloquium that would further stimulate development of ideas concerning Finite-Deformation Electromechanics.

We would like to thank EUROMECH for support which contributed greatly to the success of Colloquium 545.

EUROMECH Colloquium 548
"Direct and variational methods for nonsmooth problems in mechanics"
24-26 June 2013, Amboise, Indre-et-Loire, France
Chairperson: Prof. Géry de Saxcé
Co-Chairperson: Prof. Gianpietro Del Piero

In solid mechanics and in the mechanics of structures, engineers and scientists are faced by a large class of nonsmooth phenomena such as unilateral contact, friction, adhesion, collisions, plasticity, viscoplasticity and fracture. A common feature of these problems is that they are unilateral, in the sense that their formulation and modelling requires systematic use of inequalities. For several decades, significant theoretical advance have been achieved in different ways.
One of the objectives of EUROMECH Colloquium 548 was to bring together two European communities: the "Limit states of materials and structures - Direct Methods" group, whose researchers share their latest results every two years (Aachen 2007, Lille 2009, Athens 2011) and the "Unilateral Problems in Structural Analysis" group which has quite similar research interests, but is more focused on the formulation of the problems and on the quest for the most appropriate solution techniques (Siracusa 2007, Palmanova 2010).

There were thirty-eight participants in Colloquium 548 from seven countries: Italy, France, Greece, Czech Republic, Germany, Switzerland, Lithuania. There were thirty-one communications of 25 minutes each. The final programme enabled fruitful exchanges on many topics:

- Contact mechanics with friction and adhesion for continuum or discrete systems;
- Ductile and brittle fracture mechanics with new developments based on limit analysis or variational approaches;
- Shakedown analysis of structures such as beams and frames;
- Numerical treatment of Shape Memory Alloys (SMA);
- Thin film behavior and damage;
- New developments based on bipotentials.

The contrasts between different visions or approaches to similar problems were exposed during the colloquium The extended coffee breaks also promoted these exchanges. Finally, a visit of the "Clos Lucé" in Amboise, the last home of Leonardo Da Vinci, showed that engineers' objectives remain almost the same throughout history: the commitment to lightweight, reliable and efficient structures.

Colloquium 548 will give rise to special issues of:

- Annals of Solid and Structural Mechanics, edited by Michel Frémond and Franco Maceri and published by Springer;
- Advances in Mathematical Sciences and Applications, edited by Noboyuki Kenmochi and published by Gakkötosho.

EUROMECH Colloquium 549
"Immersed Boundary Methods: Current Status and Future Research Directions"
17-19 June 2013, Leiden (The Netherlands)
Chairperson: Prof W. P. Breugem
Co-Chairperson: Prof. R. Verzicco

Over the past 10 years, so-called Immersed Boundary Methods (IBMs) have seen rapid development. A characteristic of IBMs is that the flow geometry is 'immersed' in a simple computational, often Cartesian, grid. The boundary conditions are fulfilled to a good approximation by imposing additional forces on the flow field in the immediate vicinity of boundaries (direct-forcing and continuous-forcing IBMs) or by building exceptional cell forms near boundaries (cut-cell methods). The flexibility and cost-effectiveness of these methods have made them very popular. After the very successful EUROMECH Colloquium 507 with the same title held in Amsterdam in 2009, it was thought desirable to hold a follow-up colloquium, so that progress in this rapidly developing field could be evaluated. Thus, Colloquium 549 was organised in Leyden, The Netherlands, on June 17-19 2013. It addressed subjects of current interest such as theory, error analysis, applications, implementation issues and best practice.

EUROMECH Colloquium 549 was supported by three organisations: Euromech, Ercoftac and the J.M. Burgerscentrum (the Dutch research school for fluid mechanics). Three very well-known researchers in the field accepted invitations to the keynote lectures, namely:

- R. Mittal (Johns Hopkins University, Maryland, USA);
- T. Kempe (Technical University of Dresden, Germany);
- J.J. Derksen (University of Aberdeen, UK).

The participants had widely varying backgrounds, as intended. They included developers in areas such as error analysis and users from science and industry. The number of fields in which IBMs are used continues to grow. Special attention was paid to the order of spatial accuracy that can be attained and stability. A short summary, including a comparison with the former colloquium, is given below.

- In Colloquium 507 many early applications had been described, using Peskin's original IBM, the direct-forcing method of Verzicco et al., the LS-STAG (cut-cell) method in 2D and the method of Prosperetti (Physalis). There were many examples of Fluid-Structure Interaction (FSI), usually with rigid moving parts, and simulations with finite-sized particles. Items deserving particular attention were: the finite penetration velocity at immersed boundaries, conservation properties, flow near boundaries and the grid-locking phenomenon.
- In Colloquium 549, applications were more complicated. Examples include a beating heart with FSI and platelets, and Peskin's method with Marangoni effects. Many FSI applications included deforming obstacles. Finite-sized particle applications included modelling of features such as the very thin fluid layer between two particles prior to impact.
- The problem of non-zero penetration velocity at the wall is still an issue for direct forcing methods. One work-around is the so-called direct discretisation method, which adapts the discretisation scheme locally.
- The grid-locking problem is not yet entirely solved for the direct-forcing method and LS-STAG. It can be alleviated for the direct-forcing method by an extrapolation procedure. For LS-STAG it can be alleviated by smoothing, but at the expense of conservation properties.
- Higher-order applications are becoming available, combining spectral and spectral element codes with IBM. However, the order of accuracy near the boundary is still lower than desired.
- Analysis of the IBM by studying the properties of the resulting discrete system of equations is progressing, but unfortunately there was only one talk on this subject.
- A novel method is BDIM (Boundary Data Immersion Method), in which the continuous equations are smoothed and blended near the boundary. Grid locking is absent, higher-order treatment should be possible, and the issue of conservation is under study.
- Much work has been done on compressible flow around deformable obstacles, adapting the Riemann solver to impose the boundary conditions. Work is in progress to extend LS-STAG to higher order and 3D. Wall-law type modelling for high Reynolds number flows is also receiving attention.

Summarizing, work has been done on conservation, grid locking, greater accuracy of the methods near the boundary and wall treatment for high Reynolds number flow. Work is still in progress, and new results are to be expected in a follow-up colloquium. The program and proceedings of Colloquium 549 are available at: http://www.pe.tudelft.nl/~wim/euromech549. The colloquium was a great success, and it was decided to have a follow-up colloquium on IBMs in 2016. R. Mittal and R. Verzicco agreed to organize it in the USA this time. Finally, the organisers wish to thank EOROMECH, Ercoftac and the JM Burgerscentrum for making Colloquium 549 possible.

EUROMECH Colloquium 550
"Multiphysics of solid polymers: experiments and modelling"
1-5 July 2013, Poitiers, France
Chairperson: Dr. Sylvie Castagnet
Co-Chairperson: Prof. Alexander Lyon

The mechanical properties of polymers can be affected by interactions with their surrounding environment or exposure to external fields. Such interactions may also lead to damage evolution or provoke degradation. Strong coupling, multiple time scales and pronounced gradients make the experimental characterization, constitutive representation and numerical simulation of these phenomena big challenges. Experimental challenges are to determine the relative effects of variables on the coupled macroscopic behavior and also to track the key parameters governing couplings at the microstructure scale. The selection of accurate state or internal variables, the relevant expression of coupled evolution laws and reliable identification protocols are challenges for continuum mechanics. Consistent space-discretization, versatile time-discretization and identification of appropriate algorithms are challenges for optimized numerical simulations of the coupled mechanical response.

EUROMECH Colloquium 550 was intended to be interdisciplinary and was open to scientists with a common interest in multiphysics of solid polymers and more specifically in coupling between mechanics and diffusion, chemical reaction or electro-magnetic fields. It aimed to cross-link physical and mechanical approaches by bringing together experts in molecular simulation, coupled experiments, analytical approaches and numerical methods. The focus was on unreinforced polymers. Special attention was paid to fully-coupled approaches.

37 researchers from Germany, The Netherlands, Italy, The United Kingdom, Austria, Japan, The United States and France participated in the colloquium, including 7 PhD students. There were 28 presentations, with allowances of 45 minutes for the invited speakers and 30 minutes for submitted contributions. There were also 12 poster presentations during a special session on the first day which could then be inspected throughout the Colloquium.

Four sessions were scheduled following a progressive scheme.

- Thermo-mechanics was addressed first as an intrinsic coupling in polymers. Glass transition and physical ageing were discussed as key phenomena involving this type of coupling.
- The second session was dedicated to mass transport and plasticizing or damage effects induced by gas or liquid transport.
- The issue became even more complex in the third session, since the transported species take part into chemical reactions such as cross-linking, oxidation, thermolysis or hydrolysis.
- In the fourth session, electro-magneto-mechanical couplings were discussed, in trying to emphasize the analogies/differences between the first three topics.

One of the main conclusions was that the polymer is always a heterogeneous system. It is clear at the macroscopic scale, due to structural effects or to gradients associated with couplings, but heterogeneity is also found at smaller scales. It arises in the lamellar structure of semi-crystalline polymers or in filled rubbers, but it can also arise from penetrants in a pure amorphous polymer.

A major challenge is to distinguish between different mechanisms. Several experiments with this aim were presented, such as Fourier-Transform Infra-Red spectroscopy (FTIR) in the case of water diffusion and Nuclear Magnetic Resonance (NMR) in semi-crystalline polymers. Depending on the type of coupling, the lowest accessible scale can be different. It can change from that of magneto-fillers to the molecular scale in the case of mass diffusion.

The most widely used methods to track the microstructure evolution and deformation/damage micro-mechanisms often display averaged information. Tomography appears to be an interesting technique for evaluation of damage gradients and progress should be made by increasing the resolution of devices. Molecular dynamics can be a way to improve understanding of mechanisms at fine scales. Several other types of modelling, including 3D finite strain theories and work on the development of special surface elements were also presented. Indentation experiments were presented as an interesting route.

Fruitful discussions arose from this Colloquium, both from sessions and informal discussions during the week. The Colloquium was judged very interesting by all participants. They welcomed the proposal to organize a follow-up colloquium in Munich in spring 2015. Euromech Colloquium 550 was hosted by Institut Pprime and ISAE-Ensma. We thank EUROMECH for making it possible and Région Poitou-Charentes, Grand Poitiers, University of Poitiers and ISAE-ENSMA for their financial support.

EUROPEAN MECHANICS SOCIETY

EUROMECH Colloquium 551
"Mechanics of Fibre-reinforced Materials: Theory and Applications"
2-5 September 2013, University of Nottingham, UK
Chairperson: Professor Ray Ogden
Co-Chairperson: Dr Kostas P. Soldatos and Professor Jose Merodio

EUROMECH Colloquium 551 focused on developments in the mechanics of fibre-reinforced materials, including theoretical, analytical and experimental developments and their applications. The main concern was with the linear and nonlinear elastic, viscoelastic and plastic behaviour of fibre-reinforced solids but also included fluid-like behaviour and constitutive modelling. The type of materials considered ranged from soft solids such as biological tissues and fibre-reinforced polymers to harder materials such as carbon-fibre or glass-fibre reinforced materials. There was particular interest in the effect of fibre reinforcement on material integrity and stability from both the static and dynamic perspectives.

The continuum theory of fibre-reinforced materials has largely been shaped by the contributions of members of the former Department of Theoretical Mechanics at the University of Nottingham and has its origins in the pioneering work of J. E. Adkins and R.S. Rivlin, published in 1955. Adkins became the Head of the Department of Theoretical Mechanics and the subject flourished in Nottingham under the leadership of A. J. M. Spencer, who was the successor of Adkins. The University of Nottingham was therefore a very appropriate venue for the Colloquium 551 on the Mechanics of Fibre-Reinforced Materials: Theory and Applications.

There were 38 participants from 14 countries and 32 presentations, including one plenary lecture by Professor Patrick Selvadurai (who gained his PhD with Spencer at Nottingham in 1971) from McGill University on the implications for fracture mechanics of flaw bridging in fibre-reinforced elastic materials.
Application of the theory of fibre-reinforced materials to the mechanics of soft biological tissues was very well represented with eight talks, reflecting the enormous potential that the theory has to contribute to our understanding of the biomechanical behaviour of various parts of the human anatomy. Progress in the dealing with the theory and computation of cells, ligaments, arteries and the left ventricle was reported.

Several talks discussed the properties of fibre-reinforced composites, including both linearly and nonlinearly elastic multiphase composites, their macroscopic response and stability, the formation of kink bands and computational analysis of failure. In the context of the finite elastic deformations of fibre-reinforced materials the instabilities of tubes undergoing inflation, swelling or azimuthal shear were examined in a number of papers with particular reference to non-smooth solutions. Based on the theory of incremental deformations superimposed on a large deformation, the effect of strong fibres in a soft matrix on the incidence of surface wrinkling of a half-space was exposed.

Four talks dealt with the dynamics of strongly fibre-reinforced elastic plates, the propagation of weakly nonlinear waves elastic and the influence of initial stress on the properties of nonlinearly elastic materials and its effect on the characteristics of both plane and surface waves.

Computational methods are required for the solution of specific boundary-value problems, particularly for situations where the geometry is not very simple, and computational methods featured in several talks. It was demonstrated in one talk that for anisotropic materials particular care is needed when using finite element packages that rely on the volumetric/deviatoric separation of the energy function since physically sensible results are not always achieved.

Much progress has been made in the nonlinear elasticity theory of fibre-reinforced materials in recent years, but it is clear that much more needs to be done. On the theoretical side, from the construction of constitutive laws informed by experimental data, particularly where residual stress is important, to the solution of realistic boundary-value problems, especially those where instabilities arise such as those associated with the onset of non-smooth deformations. Application of the theory is then need to address a variety of problems for particular material structures, in engineering where 'soft' material such as rubber is reinforced with strong flexible fibres or in the biomechanics of soft biological tissues where collagen provides the reinforcement amongst a diversity of softer 'matrix' materials. More data are needed for these types of materials so that we can more effectively derive realistic materials models, validate them and have confidence in them, and trust that the computed results are meaningful. That also requires reliable implementations of anisotropic models in finite element software. In conclusion, there is scope for considerable and diverse research in the nonlinear mechanics of fibre-reinforced materials.

EUROMECH Colloquium 551 was very successful. The organization was excellent and, apart from the scientific programme, which generated valuable discussions and led to new collaborations, a very friendly group of colleagues made for a collegial atmosphere, which was helped by the splendid social arrangements provided by our host in Nottingham, Kostas Soldatos.

EUROMECH Colloquium 552
"Modelling Atmospheric and Oceanic Flows: insights from laboratory experiments and numerical simulations"
26-28 September 2013, Berlin, Germany
Chairperson: Dr Thomas von Larcher
Co-Chairperson: Dr Paul Willians

EUROMECH Colloquium 552 brought together approaches and recent results from laboratory experiments and corresponding numerical simulations, performed to improve our understanding of atmospheric and oceanic fluid motion. As sufficient computer resources and numerical codes become available, the interplay of numerical simulations and experimental research is attracting increasing interest in the scientific community. Therefore, the main focus of Colloquium 552 was on the comparison of results of laboratory experiments with adequate numerical simulations, with the particular aim of accurately simulating laboratory flows using numerical models, and on combined laboratory and numerical investigations of a system. On the experimental side, new designs of experiments on the laboratory scale, developments in instrumentation and data acquisition techniques, and the computer-based analysis of experimental results have been addressed.

On the numerical side, developments in simulation techniques, from model

- formulation to the assimilation of experimental data into the model configuration, initialisation or forcing were addressed. The presentation of results from corresponding experiments and numerical models brought the two sides together with a discussion of methodologies for reliable laboratory-model comparisons. Contributions under the following topic headings were presented:

- Rotating flows;
- Balanced and unbalanced flows;
- Atmospheric flows (Earth and other planets);
- Oceanic flows, Jets, waves and vortices, Turbulent flows;
- Advances in numerical methods;
- Validation of numerical methods using laboratory experiments;
- Technical and methodological advances in laboratory experiments.

The programme was devised with the idea of stimulating discussions between all participants throughout the colloquium. A permanent poster exhibition was provided instead of a particular display time, with a specific "Authors in Attendance Time" on the first day of the colloquium.
Five keynote speakers set the scene at the beginning of each day as well as in the afternoon with a state-of-the-art review on selected topics. These were:

- Jan-Bert Flør, LEGI, Grenoble, France;
- Uwe Harlander, BTU Cottbus-Senftenberg, Germany;
- Leo R.M. Maas, Utrecht University, The Netherlands;
- Peter L. Read, University of Oxford, UK;
- Laurette S. Tuckerman , PMMH-ESPCI, Paris, France.

There were 45 participants in total, including 12 junior scientists. There were 33 inspiring oral presentations and 11 poster contributions, plus the 5 keynote lectures. The Colloquium showed the substantial progress in combining laboratory experiments and numerical simulations for research on atmospheric and oceanic flows that has been achieved over the last couple of years. It also highlighted the benefits from recent advances in methodology. Some issues discussed in depth were:

- Spontaneuos emission of inertia-gravity waves;
- The role of local mechanisms of wave emission;
- The role of nonlinearities;
- The route to chaos specifically in the thermally driven, rotating annulus;
- Extension of path-following techniques;
- The development and the benefits of decomposition methods;
- The development of numerical techniques.

Many issues remained open and another meeting in two or three years would seem appropriate. The organizers thank EUROMECH very much for making Colloquium 551 possible and gratefully acknowledge funding from the German Science Foundation (DFG, LA2286/2-1).

Objectives of EUROMECH, the European Mechanics Society

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

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

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

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

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

EUROPEAN MECHANICS SOCIETY

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