NEWSLETTER 45
Fall 2014
EUROPEAN MECHANICS SOCIETY

President's Address

2014 is a special year for our society: although EUROMECH – the European Mechanics Society - was officially established in 1993, it all started in 1964 when Professors George Batchelor and Dietrich Küchemann founded the European Mechanics Committee. That is now 50 years ago. Both founders recognised the need to build and stimulate a network between European researchers in both fluid and solid mechanics. Their vision was to establish a European umbrella organisation, which should provide a meeting platform for scientists in both Eastern and Western Europe, which were in those days quite separated politically. Such a platform would promote a better exchange of ideas and new developments, and encourage collaboration.

George Batchelor was in favour of having rather small-scale, informal meetings. He initiated the European Mechanics Colloquia, informal gatherings with a maximum of 50 participants, usually taking place over 2 – 5 days, without published proceedings. Of course, participants from outside Europe were more than welcome. The first European Mechanics Colloquium took place in Berlin in 1965. The topic was: 'The Coanda effect'.

The European Mechanics Committee initially consisted of 4 members. Later, its size increased in order to include representatives from different countries in both Eastern and Western Europe. George Batchelor served as chairman of the Committee for 23 years until 1987. His successor was David Crighton. In 1993, the Committee was expanded to become the European Mechanics Society, EUROMECH.

Since 1964 the Committee and later the Society have been chaired by Professors George Batchelor (1964 – 1987), David Crighton (1987 – 1997), Hans Fernholz (1997 – 2003) and Patrick Huerre (2003 – 2012). I succeeded Patrick Huerre in 2013. The Society is governed by a Council, consisting of 10 members from the fluid and solid mechanics communities, with a fair geographical spread.

Now, 50 years after the foundation of the European Mechanics Committee, EUROMECH has become a well-established international society. It provides an important platform for the fluid mechanics and solid mechanics communities in Europe, and it has important links with various international sister organisations like IUTAM, the International Union for Theoretical and Applied Mechanics. As an umbrella organisation, EUROMECH is responsible for the organisation of a number of larger conferences in fluid and solid mechanics. The Colloquia are also very successful: approximately 10 such small-scale meetings take place each year on different timely topics in mechanics, at various locations all over Europe. This year (2014) the Colloquium counter has passed 560.

For a detailed account of the history of our society, I refer to a document entitled "The European Mechanics Society – From its founding in 1964 to 2000" written by former president Hans Fernholz, which can be found on the website.

At the 10th European Fluid Mechanics Conference in Copenhagen, 14 – 18 September 2014, the EUROMECH Fluid Mechanics Prize was awarded to Professor Andrea Prosperetti (Johns Hopkins University, Baltimore, USA and Twente University, The Netherlands), with the following citation: "In recognition of his profound, seminal contributions to fluid dynamics and acoustics in general and to bubble dynamics and rain noise in particular, including the development of novel numerical techniques, and for his world leadership in these fields and his brilliance in their applications to engineering". Three EUROMECH Fluid Mechanics Fellowships were also awarded, namely to Professors Eberhard Bodenschatz (Göttingen, Germany), Jens Eggers (Bristol, UK), and Javier Jiménez (Madrid, Spain).

Next year, it is the turn for the solid mechanics awards: the EUROMECH Solid Mechanics Prize and three Solid Mechanics Fellowships will be awarded at the 9th European Solid Mechanics Conference in Madrid, 6 – 10 July 2015. A call for nominations was sent recently to all members. You are invited to nominate deserving candidates for their outstanding achievements in Solid Mechanics. The award criteria and the nomination procedure are outlined in the appropriate field of our website.

This summer the 7th European Postgraduate Fluid Dynamics Conference, took place in Ilmenau, Germany on 14-17 July 2014. This meeting, organised for and by PhD students and postdocs, was attended by 50 participants from 12 different countries. This type of conference is aimed at providing a network for junior researchers in fluid mechanics as well as offering them a wider overview of the field. Until now, meetings of this type have only been organised in the fluid dynamics field, but it would be nice to see similar meetings in solid mechanics. If you have suggestions for organising such a Postgraduate Conference, either in Solid or in Fluid Mechanics, please contact Sara Guttilla (sara.guttilla@euromech.org) or our secretary-general, Prof. Pierre Suquet (suquet@lma.cnrs-mrs.fr).

GertJan van Heijst
President, EUROMECH

GJF van Heijst

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EUROMECH Young Scientist Prize Paper

"Cavitation in rubber: The role of elasticity"

Oscar Lopez Pamies won the EUROMECH Young Scientist Prize, awarded at the 7th EUROMECH SOLID Mechanics Conference held in Lisbon, September 2009

Oscar Lopez-Pamies[1]

1. Introduction

Under certain conditions, large enclosed cavities may suddenly "appear" in the interior of rubber. This phenomenon has come to be popularly known as cavitation. It corresponds, at heart, to nothing more than to the growth of defects inherent in rubber. Such defects can be of various natures (e.g., weak regions of the polymer network, actual holes, particles of dust) and of various geometries ranging from submicron to supramicron in length scale [1]. Roughly speaking, when rubber is subjected to critically large mechanical (or possibly other type of) forces, these underlying defects may suddenly grow elastically up to the point at which the surrounding polymeric chains reach their maximum elongation. Beyond that point, the defects may continue to grow inelastically by a fracture process, i.e., by the irreversible creation of new surfaces.

As a first theoretical attempt to explain and describe cavitation in rubber, Gent and Lindley [2] proposed to consider the initiation of cavitation as an *elastic instability*. In essence, they examined the elastostatics problem of a single vacuous spherical cavity of infinitesimal size (or defect) embedded at the centre of a Gaussian (i.e., Neo-Hookean) rubber ball that is subjected to uniform hydrostatic pressure on its outer boundary. Under the *faulty assumption* that rubber remains an elastic solid for arbitrarily large deformations — in other words, under the assumption that the defect can only grow elastically — they found that as the applied pressure approaches the critical value

$$P = \frac{5}{2}\mu, \tag{1}$$

where μ denotes the initial shear modulus of the rubber at zero strain, the size of the cavity suddenly becomes finite. Based on this result, Gent and Lindley [2] postulated that cavitation ensues at any point in the interior of rubber at which the hydrostatic component of the stress reaches the critical value (1). In a later effort, Ball [3] formalised and extended the result (1) to arbitrary incompressible isotropic nonlinear elastic solids (not just Neo-Hookean). This more general result reads as

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$$P = \int_1^{\infty} \frac{1}{z^3 - 1} \frac{\mathrm{d}\phi}{\mathrm{d}z} \left(z^{-2}, z, z\right) \mathrm{d}z, \tag{2}$$

where $\phi = \phi(\lambda_1, \lambda_2, \lambda_3)$ stands for the stored-energy function of the solid in terms of the principal stretches λ_1, λ_2, λ_3. The unbounded upper limit of integration in (2) reveals that the onset of cavitation depends on the behaviour of the rubber at *infinitely large* deformations. While mathematically profound, this, of course, is physically incongruous since rubber behaves approximately as an elastic solid up to a critical set of large but *finite* deformations, beyond which, much like any other solid, it ruptures. Based on this observation, one might expect that the result (1), or more generally (2), is not applicable to real rubber. Yet, the result (1) has been shown by Gent and co-workers (see [1] and references therein) to agree reasonably well with a number of experimental observations. This agreement suggests that the elastic properties of rubber may play a significant — possibly even dominant — role on the onset of cavitation.

Motivated by the plausible prominence that the elastic properties of rubber may have on cavitation, Lopez-Pamies et al. [4] have recently developed a theory that permits to examine, now in full generality, the occurrence of cavitation as an elastic instability. In particular, generalizing the classical results referred to above, this new theory allows rigorous consideration of the onset of cavitation (*i*) under arbitrary loading conditions (not just hydrostatic loading), (*ii*) for general nonlinear elastic solids (not just incompressible and isotropic), and (*iii*) distributions of defects with general shapes (not just a single spherical defect). *The purpose of this paper is to test this theory using results from a classical poker-chip experiment due to Gent and Lindley [2] in order to gain insight into the relevance of the elastic properties of rubber on the phenomenon of cavitation*.

For convenience and clarity, we recall in Section 2 the elastic cavitation theory of Lopez-Pamies et al. [4] for the practically relevant case when the underlying defects at which cavitation can initiate are vacuous and their spatial distribution is random and isotropic. The specialization of this result to the basic case when the rubber is Gaussian is spelled out in Subsection 2.1. Section 3 compares this latter theoretical result with the poker-chip experiment of Gent and Lindley [2].

2. The elastic cavitation theory of Lopez-Pamies et al. [4]

Stimulated by experimental evidence [1] and the partial success of the classical theoretical results (1)-(2), Lopez-Pamies et al. [4] considered the phenomenon of cavitation in rubber as the sudden *elastic growth* of its underlying defects in response to critically large applied external loads. The defects at which cavitation can initiate were modelled as nonlinear elastic cavities of zero volume, but of arbitrary shape otherwise, that are randomly distributed throughout the rubber. This point of view led to formulating the problem of cavitation as the homogenisation problem of nonlinear elastic solids containing zero-volume cavities [6], which in turn led to the construction of a general — yet computationally tractable — rigorous criterion for the onset of cavitation.

2.1. The case of a random isotropic distribution of vacuous defects

The purpose of this paper is to test this new theory in an experiment where, due to the processing of the specimen, the spatial distribution of defects is expected to be *random* and *isotropic*. We shall further assume that the defects are *vacuous*. Granted these geometric and constitutive features for the defects, the onset-of-cavitation criterion of Lopez-Pamies et al. [4] can be stated as follows:

Inside a rubber whose nonlinear elastic response is characterized by the stored-energy function $W(\mathbf{F})$, cavitation occurs at material points where the Cauchy stress $\mathbf{T}$ satisfies the condition

$$\mathbf{T}=\frac{1}{\det\mathbf{F}}\mathbf{S}_\bigstar(\mathbf{F})\,\mathbf{F}^T \quad \textit{with} \quad \mathbf{F}\in\partial\mathcal{Z}\left[f_\bigstar(\mathbf{F})\right], \tag{3}$$

where $\partial\mathcal{Z}[f_\bigstar(\mathbf{F})]$ denotes the boundary of the zero set of $f_\bigstar(\mathbf{F})$,

$$f_\bigstar(\mathbf{F})\doteq\lim_{f_0\to0+}f(\mathbf{F},f_0) \qquad \textit{and} \qquad \mathbf{S}_\bigstar(\mathbf{F})\doteq\lim_{f_0\to0+}\frac{\partial E}{\partial\mathbf{F}}(\mathbf{F},f_0). \tag{4}$$

Here, the scalar functions $E(\mathbf{F},f_0)$ and $f(\mathbf{F},f_0)$ are defined by the initial-value problems

$$f_0\frac{\partial E}{\partial f_0}-E-\frac{1}{4\pi}\int_{|\boldsymbol{\xi}|=1}\max_{\boldsymbol{\omega}}\left[\boldsymbol{\omega}\cdot\frac{\partial E}{\partial\mathbf{F}}\boldsymbol{\xi}-W\left(\mathbf{F}+\boldsymbol{\omega}\otimes\boldsymbol{\xi}\right)\right]\mathrm{d}\boldsymbol{\xi}=0 \qquad \textit{with} \qquad E(\mathbf{F},1)=0 \tag{5}$$

and

$$f_0\frac{\partial f}{\partial f_0}-f-\frac{f}{4\pi}\int_{|\boldsymbol{\xi}|=1}\boldsymbol{\omega}\cdot\mathbf{F}^{-T}\boldsymbol{\xi}\,\mathrm{d}\boldsymbol{\xi}-\frac{1}{4\pi}\int_{|\boldsymbol{\xi}|=1}\boldsymbol{\omega}\cdot\frac{\partial f}{\partial\mathbf{F}}\boldsymbol{\xi}\,\mathrm{d}\boldsymbol{\xi}=0 \qquad \textit{with} \qquad f(\mathbf{F},1)=1, \tag{6}$$

where $\boldsymbol{\omega}$ in (6) denotes the maximizing vector $\boldsymbol{\omega}$ in (5).

The function E defined by the first-order nonlinear pde (5) corresponds to the total elastic energy (per unit undeformed volume) characterizing the homogenized constitutive response of a nonlinear elastic solid with stored-energy function W containing a certain isotropic distribution of disconnected vacuous cavities of initial volume fraction f_0. The function f defined by the first-order linear pde (6), on the other hand, characterizes the evolution of the volume fraction of the cavities along finite-deformation loading paths. The asymptotic behaviour (4) of these functions — in the limit as $f_0\to0+$ when the underlying cavities become *point defects* — are the quantities that serve to identify the critical stresses (3) at which cavitation ensues.

2.1.1. Onset of cavitation in Gaussian rubber

In the comparison with the experimental results that follows, we shall assume that the nonlinear elastic response of rubber is Gaussian (or Neo-Hookean) and thus characterised by the stored-energy function

$$W(\mathbf{F})=\begin{cases}\frac{\mu}{2}[\mathbf{F}\cdot\mathbf{F}-3] & \text{if } \det\mathbf{F}=1\\ +\infty & \text{otherwise}\end{cases}, \tag{7}$$

where, again, μ stands for the initial shear modulus of the specific rubber under investigation. For this type of behaviour, the limiting functions (4) can be shown to be given by

$$f_\bigstar(\mathbf{F})=1-\frac{1}{\det\mathbf{F}} \qquad \text{and} \qquad \mathbf{S}_\bigstar(\mathbf{F})=\mu\mathbf{F}+\frac{\mu(1+2\det\mathbf{F})}{2(\det\mathbf{F})^{1/3}}\Phi(\mathbf{F})\,\mathbf{F}^{-T}+\frac{3\mu(\det\mathbf{F}-1)}{2(\det\mathbf{F})^{1/3}}\frac{\partial\Phi}{\partial\mathbf{F}}(\mathbf{F}), \tag{8}$$

where the function Φ is defined implicitly by a first-order nonlinear pde in two variables (see Section 3.1 and Appendix C in [7]). For all practical purposes, as discussed in Section 6 of [7], the function Φ may be approximated simply as being equal to its maximum value, $\Phi=1$. By making use of this approximation, it is not difficult to deduce that the cavitation criterion (3)-(6) reduces in this case to:

$$8t_1t_2t_3-12\mu(t_1t_2+t_2t_3+t_3t_1)+18\mu^2(t_1+t_2+t_3)-35\mu^3=0 \quad \textit{with} \quad t_i>\frac{3}{2}\mu. \tag{9}$$

The interested reader is referred to [7] for the derivation and thorough discussion of the criterion (9). Here, it is relevant to record that for states of purely dilatational stress when $t_1=t_2=t_3=P$, the general criterion (6) reduces — rather remarkably, as explained in Section 5 of [4] — to the approximate "hydrostatic" criterion proposed by Gent and Lindley [2]:

$$\frac{1}{3}(t_1+t_2+t_3)-\frac{5}{2}\mu=0. \tag{10}$$

For more complex states of stress with non-vanishing shear ($t_2-t_1=0$ and/or $t_3-t_1=0$), the general criterion (9) — as opposed to the hydrostatic criterion (10) — indicates that cavitation occurs at mean stress values $P=(t_1+t_2+t_3)/3>5/2\mu$. In other words, shear stresses stabilize the rubber in the sense that their presence postpones the onset of cavitation.

3. Comparison of the theory with the poker-chip experiments of Gent and Lindley [2]

In a seminal contribution, Gent and Lindley [2] reported a beautiful set of experiments where cavitation was induced within thin disks of rubber bonded to metal plates subjected to uniaxial tensile forces. Specifically, the test-pieces were made up of thin disks of (filled and unfilled) natural rubber bonded to circular metallic plates by means of cement during the vulcanisation process. The rubber disks were $R=1$ cm in initial radius and from $H=0.056$ cm to $H=0.980$ cm in initial thickness (hence their name "poker-chip" experiments). The load was applied quasistatically under displacement control by means of a Hounsfield tensometer, which provided measurements of the load f induced by a given applied displacement $h-H$. Gent and Lindley [2] reported these raw measurements in terms of the "macroscopic" stress measure $\sigma = \mathrm{f}\,/\pi R^2$ and the "macroscopic" strain measure $\varepsilon = h/H-1$. Figure 1 depicts a schematic of the geometry and deformation of the specimens with the various quantities of interest indicated.

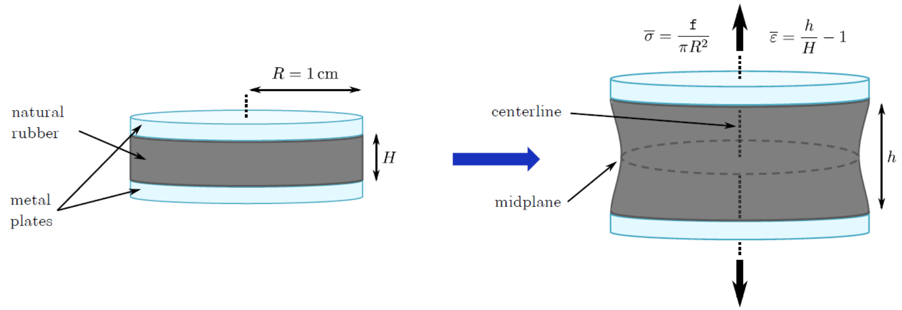

Fig. 1 Schematic of the poker-chip experimental setup of Gent and Lindley [2]. The initial radius of the rubber disks was fixed at R = 1 cm, while their initial thicknesses were varied from H = 0.056 cm to H = 0.980 cm in order to induce stress fields with a wide range of triaxialities (from large for the thinnest disk to relatively small for the thickest one) inside the rubber.

In the sequel, we report finite-element (FE) simulations of the experiment of Gent and Lindley [2] for the thinnest rubber disk with $H = 0.056$ cm. We begin in Subsection 3.1 by showing when and where the cavitation criterion (9) is satisfied within the disk, as a function of the applied macroscopic strain ε. In Subsection 3.2, we explicitly introduce defects — in the form of vacuous spherical cavities of $\varDelta = 1\ \mu\mathrm{m}$ radius —into the FE model at the locations disclosed by the criterion, in order to investigate the ensuing growth and interaction of the "nucleated" cavities upon further loading. We dedicate Subsection 3.3 to comparing the simulations with the experiment.

3.1. Pointwise monitoring of the cavitation criterion

Figure 2 shows the deformed configurations of the rubber disk with thickness $H = 0.056$ cm at five values of the applied macroscopic strain, $\varepsilon = 0,\ 0.2816,\ 0.2820,\ 0.2998$, and 1.40%. Material points at which the cavitation criterion (9) is satisfied are depicted in red.

As indicated by arrows in Fig. 2(b), the first points to reach the cavitation criterion are those at the rubber/plates interfaces along the centreline of the disk. This is because — in contrast to popular belief in the literature — the hydrostatic stress in poker-chip experiments is always largest at the rubber/plates interfaces along the centreline of the test-piece, and *not* at the centre of the rubber disk. As the applied strain ε increases, the region where the criterion is satisfied grows radially along the rubber/plates interfaces and also propagates to the centre of the rubber disk reaching it at the value $\varepsilon = 0.2820\%$; this is shown by Fig. 2(c). As the applied strain ε increases even further, the region where the criterion is satisfied continues to grow radially from the centreline of the disk towards its lateral free boundary. Figures 2(d) and (e) illustrate two snapshots of this propagation.

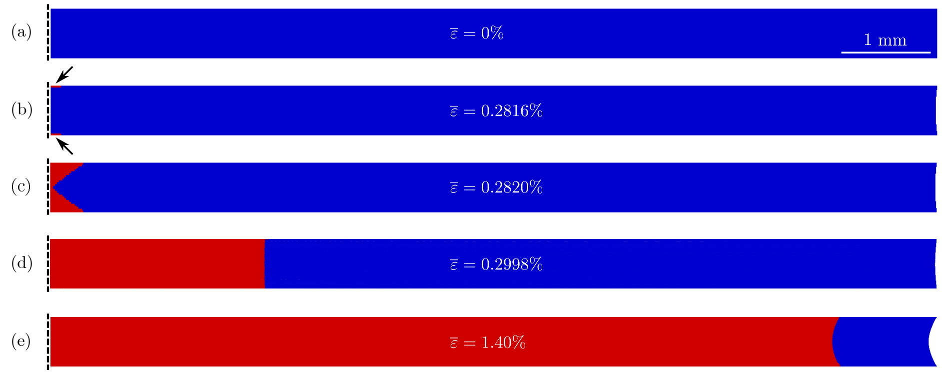

Fig. 2 Axisymmetric FE simulation of the poker-chip experiment with rubber disk thickness H = 0.056 cm. Parts (a) through (e) show the deformed configurations of half (for better visualization) of the rubber disk at five values of the applied macroscopic strain $\overline{\varepsilon}$. The material points at which the cavitation criterion (9) is progressively satisfied are depicted in red.

3.2. Full-field simulations accounting for the growth of the defects

The preceding analysis has served to reveal the critical macroscopic loads and associated spatial locations at which defects in rubber may start to grow to finite sizes during poker-chip experiments (with thin rubber disks). In this subsection, we investigate the extent to which they grow and how they interact with one another. To this end, we introduce defects explicitly in the FE models at the locations disclosed by the criterion (9) and monitor their growth. Here, defects are modelled as vacuous spherical cavities of initial radius $\varDelta = 1\ \mu\mathrm{m}$. In this regard, it is important to remark that we have performed a variety of simulations wherein the defects are micron and submicron in size and spherical and non-spherical in shape. Interestingly, the results of such simulations indicate that provided the defects are no larger than roughly $1\ \mu\mathrm{m}$ in length scale, their specific shape and size do not significantly influence when and how they grow (at least during the poker-chip simulations of interest here), hence our choice to model them as spherical cavities of initial radius $\varDelta = 1\ \mu\text{m}$.

For sufficiently thin test-pieces such as the one considered here, the attainability of the cavitation criterion (9) eventually propagates across the larger part of the rubber disk. In the sequel, we thus consider the explicit presence of defects throughout the rubber. Because of the extremely small size of the defects ($1\ \mu\text{m}$ in radius), the discretisation of the rubber disk explicitly containing defects is required to be in the form of a structured mesh. In practice, this requirement forces the spatial distribution of defects in the simulations to exhibit some level of periodicity thus preventing the consideration of a truly random distribution. For definiteness, based on results from a variety of distributions [5], we consider here that the defects are located within three planes: a plane adjacent ($1\ \mu\text{m}$ away) to the top rubber/plate interface, a plane adjacent ($1\ \mu\text{m}$ away) to the bottom rubber/plate interface, and the midplane of the rubber disk. Within each of these planes, 5 defects at radial distances $0,\ 0.25,\ 0.50,\ 0.75,$ and $0.95\ \text{cm}$ from their centre are placed at angular intervals of $\pi/8$ radians. This amounts to a total of 65 defects per plane, and thus a total of 195 defects in the entire rubber disk.

Figures 3(a) through (d) depict a 2D radial perspective of half of the disk at various values of the applied macroscopic strain, $\varepsilon = 0,\ 0.43,\ 1.00,$ and 2.30%. This string of snapshots show that the first defect to grow is the one located in the centre of the disk and that, upon further loading, adjacent midplane defects successively grow in a radial cascading sequence; as the exception, the defects closest to the lateral free boundary of the disk do not grow. This seemingly intricate behaviour can be readily understood from an energetic standpoint. Indeed, even though the cavitation criterion (9) is first satisfied at the rubber/plates interfaces slightly before than at the centre of the disk (see Fig. 2), it is energetically more favourable for the defect at the centre to accommodate all of the initial growth. As the macroscopic strain ε increases and satisfaction of the criterion (9) propagates radially outwards (see Fig. 2), it becomes energetically more favourable for the defects in the midplane of the disk adjacent to its centre — and *not* those near the rubber/plates interfaces — to then accommodate most of the growth at the expense of the defect at the centre. This radial cascading trend continues across the disk for increasing strains all the way up to reaching a narrow region containing the lateral boundary of the disk. There, the state of stress does not satisfy the criterion (9) and hence the underlying defects do not grow.

To aid the quantitative understanding of the above-described growth and interaction of defects and also their effect on the overall mechanical response of the poker-chip test-piece, Figs. 3(e) and (f) show plots of the volume variation v/V of the midplane defects and of the normalized macroscopic stress σ/μ as functions of ε. Figure 3(e) distinctly illustrates the radial cascading nature of the growth of the midplane defects with increasing loading. The primary observation from Fig. 3(f) is that the growth of midplane defects entails a severe softening of the overall mechanical response of the rubber disk; the response of the perfect rubber disk without defects is plotted in the same figure for direct comparison. Since the rubber is assumed to remain elastic for arbitrarily large deformations, this softening is purely *geometrical* in nature.

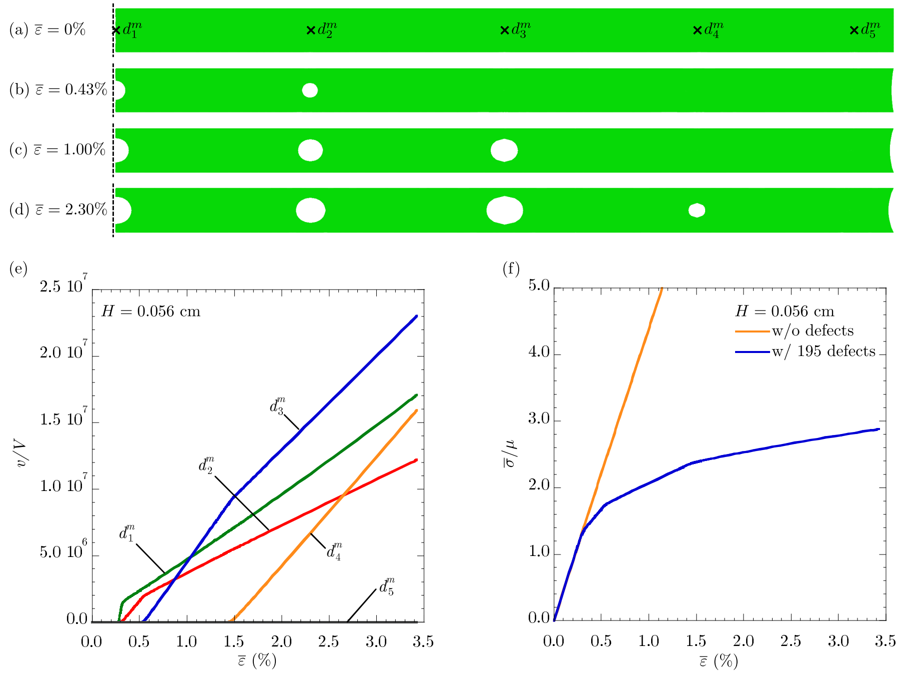

Fig. 3 3D FE simulation of the poker-chip experiment with rubber disk thickness H = 0.056 cm containing 195 defects throughout the entire disk. Parts (a) through (d) show a 2D radial perspective of half of the rubber disk at four values of the applied macroscopic strain ε. Parts (e) and (f) show plots of the volume variation of the midplane defects and the normalized macroscopic stress σ/μ as functions of ε.

3.3. Elastic cavitation theory vs. experiments

We are now in a position to apply the foregoing theoretical results to the experimental observations and measurements of Gent and Lindley [2]. Figure 4 reproduces a photograph of the midplane of a test-piece, made up of natural rubber with disk thickness $H = 0.061\ \text{cm}$, cut open after being subjected to a macroscopic stress of $\sigma = 2.74$ MPa; the shear modulus of the rubber is

$\mu = 0.59$ MPa (labelled as vulcanisate D in [2]). A key observation from this figure is that cavities appear in the midplane of the disk and *not* elsewhere. Another key observation is that cavities appear pervasively over the entire midplane, with the exception of a narrow region around the lateral free boundary. Remarkably, these two features are in agreement with the simulations, even though, again, the simulations assume that the rubber is Gaussian and that the defects can only grow elastically. This, of course, is not the case in the experiment. Indeed, the natural rubber utilized in the experiment is comprised of polymeric chains of finite length and thus its behaviour is not Gaussian beyond moderately large deformations (typically of the order of 300%). Moreover, as plainly shown by the post-mortem snapshot in Fig. 4, the defects do grow inelastically by the irreversible creation of new surface.

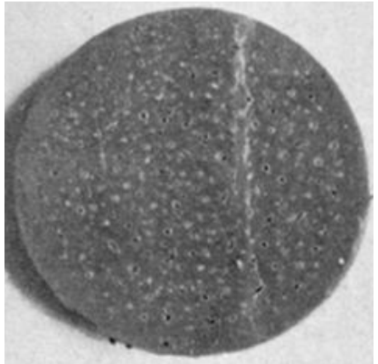

Fig. 4 Midplane of a poker-chip test-piece with disk thickness H = 0.061 cm, made up of natural rubber with initial shear modulus $\mu =$ 0.59 MPa, cut open after being subjected to a macroscopic stress of $\sigma = 2.74$ MPa [2].

While Gent and Lindley [2] did not monitor the growth of the defects *in-situ* (other than crudely in one of their specimens made up of transparent rubber, vulcanisate G), more recent poker-chip experiments have made use of X-ray computer tomography to access such information [8]. These experiments have shown that the cavities appear first in the centre of the disk and subsequently downstream in the direction of the lateral boundary. This radial cascading sequence is also in agreement with the simulations.

The comparisons presented in this paper (together with the more comprehensive results to be reported in [5]) have shown that theoretical results based on the premise that rubber is Gaussian and the further assumption that its inherent defects are vacuous and isotropically distributed are in good *qualitative* agreement with experiments in the sense of: (*i*) when and where cavitation first occurs as well as (*ii*) how cavities continue to grow and interact once they have been “nucleated”. This remarkable agreement suggests that the sudden growth of defects and their ensuing behaviour and interaction with other defects in real rubber is driven predominantly by the minimization of the elastic energy of the rubber. A direct practical implication of such a prominence of the elastic properties is that the *elastic* criterion (9) can be utilized effectively to gain quick insight into the possible occurrence of cavitation in real material systems comprising rubber.

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.

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.

EUROPEAN MECHANICS SOCIETY

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
BP 53X
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
Eindhoven University of Technology
PO Box 513
5600 MB Eindhoven
The Netherlands
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 2015

ESMC9
9th European Solid Mechanics Conference
DATE: 6-10 July 2015
LOCATION: Madrid, Spain
CONTACT: Prof. J. Llorca
E-MAIL: info@esmc2015.org
Website: http://www.esmc2015.org/

ETC15
14th European Mechanics of Materials Conference
DATE: 25-28 August 2015
LOCATION: Delft, The Netherlands
CONTACT: Prof B. J. Boersma
E-MAIL: b.j.boersma@tudelft.nl
Website: http://www.etc15.nl/

EUROPEAN MECHANICS SOCIETY

EUROMECH Conferences Reports

EMMC13 - 13th European Mechanics of Materials Conference

The 13th European Mechanics of Materials Conference (EMMC13) was jointly organised with the 3rd International Conference on Material Modelling (ICMM3), which took place in the Old Library Building at the University of Warsaw in Poland, 8 - 11 September 2013. The conference was organised by the Institute of Fundamental Technological Research of the Polish Academy of Sciences and the chairman was Professor Paweł Dłużewski. The conference venue was the historical building of the old library of WU, located close to other historic buildings near Warsaw city centre.

230 participants from 29 different countries attended the joint conference. The largest delegations came from: Germany (62), Poland (48), France (33), The Netherlands (13), Japan (10), Algeria (8), Italy (7), Russia (7), and The Czech Republic (7). The conference was focused on materials modelling and understanding the behaviour of materials. It was organised in cooperation with EUROMECH, EUCASS, ECCOMAS and the European Commission via the E-CAero project, with 22 sessions. A special session on the modelling of aeronautic materials was also organised in cooperation with EUROMECH, ECCOMAS and EUCASS. During a meeting of EMMC Scientific Board, it was decided that the next EMMC14 conference would take place on 27-29 August 2014 in Gothenburg, Sweden.

The joint EUROMECH-ECCOMAS-EUCASS session on aeronautic materials took place on 9 September 2013 as part of the ICMM3/EMMC13 conference. The session consisted of presentations by authors representing laboratories in France, Germany, Japan, Poland and Algeria. Subjects presented included theoretical modelling of aeronautic materials at different levels of observation, life-time predictions of mono- and polycrystalline superalloys under complex thermomechanical loading, and experimental verification of mechanical behaviour. The presentations covered classical crystalline materials as well as advanced aeronautic materials, such as: metal matrix composites, ceramic open-cell foam, layered material systems, nickel-based superalloys and AZ31 magnesium alloys. Many presentations included experimental results that confirmed theoretical models.

The effect of cooperation between research institutes and universities that had developed through EU-funded projects was clearly apparent. One example was "Modern material technologies in aerospace industry" by KomCerMet and MATRANS.

EUROMECH Colloquia

EUROMECH Colloquia are informal meetings on specialised 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 2015 are given below.

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: 27-29 May 2015, Dresden, Germany

558. Ocular Biomechanics and Correlation with Microstructure
Chairperson:Prof. Prof. Ahmed Elsheikh
School of Engineering
University of Liverpool
Brownlow Hill
Liverpool L69 3GH, UK
Email: elsheikh@liv.ac.uk
Co-chairperson: 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-Chairpersons: 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, Switzerland

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: 25-29 May 2015, Sperlonga, Italy

564. Ionic liquids in nanoconfinements
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-Chairperson: Prof. Alexei Kornyshev
Dates and location: 2015 (Postponed from 2014), The Netherlands

566. Anisotropic particles in turbulence
Chairperson: Professor Helge I. Andersson
Department of Energy and Process Engineering
Norwegian University of Science and Technology
7491 Trondheim, Norway
E-mail: helge.i.andersson@ntnu.no
Co-Chairperson: Prof. Alfredo Soldati
Dates and location: 10-12 June 2015, Trondheim, Norway

567. Turbulent mixing in stratified flows
Chairperson: Prof. Paul Linden
DAMTP
Centre for Mathematical Sciences
Wilberforce Road
Cambridge
CB3 0WA, UK
E-mail: pfl4@cam.ac.uk
Co-Chairperson: Prof. Jean-Marc Chomaz
Dates and location: 22-25 March 2015, Cambridge, UK

568. Coherent structures in fully developed turbulence
Chairperson: Prof. Javier Jiménez
School of Aeronautics
Universidad Politécnica
28040 Madrid, Spain
E-mail: jimenez@torroja.dmt.upm.es;
Co-Chairpersons: Prof. Bruno Eckhardt and Prof. Dan Henningson
Dates and location:19-22 May 2015, Madrid, Spain

569. Multiscale modeling of fibrous and textile materials
Chairperson: Dr. Damien Durville
Ecole Centrale Paris
Laboratoire MSSMat - UMR CNRS 8579
Grande Voie des Vignes
92290 Châtenay-Malabry, France
E-mail: damien.durville@ecp.fr
Co-Chairperson: Prof. Stepan Lomov
Dates and location: 1-5 September 2015, France

570. Multiscale analysis of the impact of microstructure on plasticity and fracture in interface-dominated materials
Chairperson: Dr. Laurent Duchêne
ARGENCO Department
MS2F Division
University of Liège
Chemin des Chevreuils, 1
4000 Liège, Belgium
Co-Chairpersons: Prof. Aude Simar, Prof. Rafael Estevez
Dates and location: October 2015, Belgium

573. Coupling and Nonlinear interactions in Rotating Machinery
Chairperson: Prof. Fabrice Thouverez
Ecole Centrale de Lyon
LTDS-UMR CNRS 5513
36, Avenue Guy de Collongue
69134 Ecully Cedex, France
E-mail: fabrice.thouverez@ec-lyon.fr
Co-Chairpersons: Prof. Paolo Pennachi, Prof. Regis Dufour
Dates and location: 24-26 August 2015, Lyon, France

574. Recent Trends in Modeling of Moving Loads on Elastic Structures
Chairperson: Dr. Baris Erbas
Anadolu University
Department of Mathematics
Yunus Emre Campus,
26470, Tepebasi
Eskisehir, Turkey
E-mail: erbas.baris@gmail.com
Co-Chairperson: Prof. Julius Kaplunov
Dates and location: 15-17 April 2015, Lyon, France

575. Contact Mechanics and Coupled Problems in Surface Phenomena
Chairperson: Prof. Marco Paggi
IMT Institute for Advanced Studies
Piazza San Francesco 19
55100 Lucca, Italy
Ph: +3905834326604
E-mail: marco.paggi@imtlucca.it
Co-Chairperson: Prof. David Hills
Dates and location: 30 March – 2 April 2015, Lucca, Italy

577. Micromechanics of Metal Ceramic Composites
Chairperson: Prof. Siegfried Schmauder
Institut für Materialprüfung
Werkstoffkunde und Festigkeitslehre (IMWF)
Universität Stuttgart
Pfaffenwaldring 32
70569 Stuttgart, Germany
E-mail: siegfried.schmauder@imwf.uni-stuttgart.de
Co-Chairpersons: Prof. Vera Petrova, Prof. Ryszard Pyrz, Prof. Holm Altenbach
Dates and location: 2-5 March 2015, Stuttgart, Germany

EUROMECH Colloquia Reports

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

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. As numerous sources of errors are to be accounted for, a large number of experiments or simulations would be necessary to identify the influence of a single error source on the quality of the result. UQ can help to reduce the number of simulations/experiments that are needed to understand the sensitivity of a result to different error sources, such as unknown inflow conditions andunknown parameters, as well as the overall error. Furthermore, optimization strategies can benefit from knowledge of the degree of uncertainty in the final result.

The colloquium brought together researchers from various countries to exchange ideas and concepts on 'Uncertainty Quantification' in fluid mechanics.
14 presentations drew 22 participants from 6 different countries in Europe, Israel and the USA. The colloquium took place at the TU München Institute of Aerodynamics and Fluid Mechanics. The two day event together with a social event on the evening of the first day brought forth fruitful ideas and saw intense discussion on the details of the presented subjects. 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 at Colloquium 543 were subdivided into four main topics : turbulence, experimental data uncertainty, supersonic flows with shocks and miscellaneous.

Turbulence:

- Errors in Reynolds-Averaged Navier-Stokes (RANS) simulations due to the turbulence closure model;
- Uncertainty in low-dimensional models of the Navier-Stokes equations;
- The influence of synthetic turbulence on trailing edge noise.

Experimental Data Uncertainty:

- Identification of the regions which are responsible for the largest error propagation in the inflow data;
- The accuracy of heat transfer measurements and implications for data interpretation in natural convection;
- Applications of UQ in particle image velocimetry (PIV).

Supersonics/flows with shocks:

- Identication of the most plausible cause for disparities in numerical and experimental work concerning shock/bubble interaction;
- Application of UQ to a scramjet intake with uncertain inflow Mach number and uncertain angle-of-attack;
- Applications of UQ to simulations during the early stages of scramjet combustion chamber flow;
- Quantification of initial-data uncertainty on a shock-accelerated gas cylinder.

Miscellaneous:

- The combination of an inverse approach and UQ to iteration of the initial conditions of an interface in a shock-tube setup;
- The interaction of the wakes of two cylinders in proximity. depending on the uncertainty of the cylinder shape and distance;
- The formulation of the polynomial chaos expansions with incomplete statistical input information;
- Error quantification of passive scalar transport in the context of large eddy simulation using implicit filtering.

Colloquium 543 gave insight into various applications of uncertainty quantification in different aspects of 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 demonstrated. The colloquium showed how UQ can deliver deeper insight into the uncertainties and their propagation in complex environments, leading to an increase in confidence in experimental measurements and numerical predictions. The discussions showed constructive awareness among the participating scientists and the desire for ongoing collaboration. The organizers and the participants express their gratitude to EUROMECH for allowing the meeting to take place under its auspices.

EUROPEAN MECHANICS SOCIETY

EUROMECH Colloquium 555
"Small scale numerical methods for multi-phase flows"
28-30 August 2013, Pessac France
Chairperson: Prof. Stéphane Vincent
Co-Chairpersons: Prof. Ruben Scardovelli, Dr. Martin Sommerfeld

The numerical simulation of multi-phase flows involving immiscible phases generally considers the interaction between an ambient fluid and another phase (solid particles, droplets, bubbles, films, sprays, jets). Either deformable grids, which are adapted to the interface, or fixed grids, with an independent representation of the interface, such as front-tracking, volume-of-fluid, level-set and phase-field, can be used to investigate these flows.

The goal of Colloquium 555 was to provide an overview of the latest numerical methods and application field for the direct numerical simulation of multi-phase flows that have been achieved using different mathematical models such as Navier-Stokes, Boltzmann, or Smooth-Particle Hydrodynamics. Different physical aspects of multi-phase flows were emphasised, in particular concerning the numerical representation of the capillary forces with constant and variable surface tension, phase change, wettability and contact lines. More complex phenomena involving magnetic fields, liquid atomization by plasma or multi-fluid representation of three phase flows with air, water and vapour were also presented for the first time. Another important contribution of the the colloquium concerned turbulence modelling in multi-phase flows, with special attention given to direct numerical simulation, large-eddy simulation and also the multi-scale modelling of multi-phase flows.

Another important issue was the sharing of experiences between code developers in the field of numerical methods for the simulation of multi-phase flows at small scales. Interesting new developments were presented for interface tracking, immersed boundary methods and representation of mass and momentum preserving discretization. Validation test cases that increase confidence in numerical results were a common research interest. Difficult problems that should be addressed in the near future included load balancing in adaptive mesh refinement techniques and mesh adaptation or coupling between various interface tracking methods.

Colloquium 555 was structured into three main topics: interfacial flows, particulate flows and complex interfacial problems coming from real applications. A wide range of multi-phase flow problems and potential applications was described, including jet atomization in engines, chemical exchangers, energy production, environmental flows, plasma material manufacturing and microfluidics. The colloquium brought together developers and users of different models, numerical approaches and codes to share their experience in the development and validation of algorithms and discuss the difficulties and limitations of the different methods. Three invited lectures were delivered in the fields of numerical representation of interfaces in multi-phase flows (S. Zaleski), particulate flows (M. Sommerfeld) and coupling between particles and turbulence (S. Balachandar). A selection of about ten contributions has been proposed for publication in a special issue of Computers and Fluids during 2014.

EUROMECH Colloquium 561
"Dense flows of soft objects: Bringing together the cases of bubbles, droplets and cells"
19-21 May, 2014, Coventry, UK
Chairperson: Prof. Alban Pothérat
Co-Chairpersons: Prof. GertJan van Heijst, Dr. Nicolas Plihon

One of the most remarkable features of turbulence is that it operates in a radically different way in two-dimensional (2D) flows than in three-dimensional (3D) flows. Whilst the former is characterised by an inverse energy cascade that sees larger, less dissipative structures emerge, the latter tends to very efficiently dissipate energy by transferring it to small scales where it is dissipated by viscous friction. The question of whether turbulence obeys two or three-dimensional dynamics therefore has drastic consequences for the natural and industrial processes where it is involved. This concerns numerous classes of realistic systems under the influence of rotation, stratification or magnetic fields as well as in purely 2D geometrical configurations.

The tendency to two-dimensionality in stratified flows and rotating flows is a prominent feature of planetary flows such as atmospheres and oceans. This feature has also been observed in electrically conducting flows under a strong magnetic field (MagnetoHydroDynamic flows), extending the relevance of the question of flow dimensionality to astrophysical and laboratory plasma flows (for instance, the understanding of particles and heat flux dynamics in the magnetic-field transverse directions has tremendous importance in the achievement of thermo-nuclear fusion), but also to liquid-metals engineering problems in the nuclear and metallurgical industries.

The common tendency to two-dimensionality hides a variety of physical mechanisms: the propagation of inertial waves along the rotation axis promotes two-dimensionality in rotating flows, while eddy currents induced play this role in MHD flows, by generating Alfven waves if magnetic advection is important (in plasmas for instance), or by diffusing momentum along the field if it is not (as often in liquid metals). In magnetized plasmas, drift waves play a leading role in momentum transport perpendicular in the directions perpendicular to the magnetic field. Their dynamics share many characteristics with inertial (Rossby) waves, both modelled by the Charney-Hasegawa-Mima equation. The geometry of the fluid domain too can favour either 2D or 3D dynamics, in particular if it is very thin along one direction, as in Hele-Shaw cells, or soap films. Nevertheless, the question of dimensionality of turbulence is conditioned by a number of features that are common to these systems: the boundaries are part of the very definition of the concept of two-dimensionality.

Colloquium 561 was very successful in gathering researchers from different communities.

In particular, dimensional transition were extensively discussed in the context of:

Colloquium 561 was very successful in gathering researchers from different communities. In particular, dimensional transition were extensively discussed in the context of:

- "Classical" hydrodynamic turbulence confined in plane layers bounded by physical walls or other boundary conditions;
- Rotating flows, in particular in geophysical context
- Stratified turbulence, also in geophysical context, relevant to geophysical flows. The occurrence of the "zig-zag" instability distinguishes this type of flow from others as it can lead to a rather unique "pancake" structure;
- Liquid metal MHD, where the tendency to two-dimenisonality follows form a diffusive process;
- Convective flows, where two-dimensional plumes can form also under the influence of any of the forces above.

A number of talks focused on the properties of 2D turbulence versus those of 3D turbulence. The colloquium clearly showed that the competition between these two types of dynamics takes place in a rather similar fashion in most of the physical systems that were mentioned. For example, striking features such as split energy spectra exhibit simultaneously a direct and an inverse cascade over different ranges of wavenumbers were a recurring feature of flows in states that are intermediate between purely 2D and 3D ones. The fact that similar features take place in systems driven by different underlying physical mechanisms suggests that the dimensional properties of these flows are very robust. Nevertheless, it seems difficult to draw one general picture covering all systems. For example, stratified flows exhibit mechanisms quite unlike rotating and MHD flows.

Colloquium 561 was also very successful in exposing complex examples where several of these basic phenomena are involved and compete to determine flow dimensionality:

- Rotating convection;
- Flows in a geophysical context, in particular those relevant to dynamo problems involving involve various combinations of rotation, MHD and convection;
- Astrophysical flows.

In conclusion, the meeting fully achieved its objective of initiating inter-disciplinary discussions around a unifying theme, and took place in excellent spirit. Feedback from the participants suggests that a second meeting in say 3-4 years would be likely to attract similar or even larger attendance.

EUROPEAN MECHANICS SOCIETY

EUROMECH Colloquium 563
"Generalised Continua and their application to the design of composites and metamaterials"
17-21 March, 2014, Cisterna, Italy
Chairperson: Prof. Francesco dell'Isola
Co-Chairperson: Prof. Samuel Forest

The main purpose of Colloquium 563 was to provide a forum for experts in generalized continua to exchange ideas and get informed about the latest trends of the research in generalised continua. Keeping in mind the application of macroscopic models to the development of newly and especially designed technological artefacts, many open problems need to be confronted. The most important of these involves the identification of macroscopic constitutive parameters in terms of microscopic properties of considered systems: the homogenisation procedures proposed up to now present serious theoretical drawbacks and need to be refined. The impact of the underlying microstructure on macro-crack formation and propagation is being investigated in porous metals for ductile fracture and in quasi-brittle materials. There is still no consensus for the determination of higher order elastic or nonlinear properties from the detailed geometry of the unit cell of composites. The relative efficiencies of competing techniques to address instability and fracture problems of heterogeneous materials may prove decisive.

The colloquium was a considerable success in terms of participation and the quality of featured presentation and discussions. There were about 70 participants, from 13 countries, among them five keynote lecturers, namely Gerard A. Maugin (Université Pierre et Marie Curie, Paris-6, France), Reinhold Kienzler (University of Bremen, Germany), Angelo Luongo (University of L'Aquila, Italy), Stelios Kyriakides (University of Texas at Austin, USA), Roger Fosdick (University of Minnesota, USA) and one junior keynote lecturer, Ali Javili (University of Erlangen-Nuremberg, Germany). The small town environment of Cisterna encouraged discussion during the colloquium week, even outside the official schedule, and most of all during lunch breaks and social events.

Key areas for discussion during Colloquium 563 included the following:

- General concepts for second and higher gradient media;
- Phenomenology of existing and designed composites and metamaterials;
- Homogenisation techniques and related numerical and mathematical problems;
- Beams and plates constituted by metamaterials;
- Strain and stress localisation phenomena;
- Dynamic behavior of metamaterials and composites;
- Acoustic properties of metamaterials and composites;
- Generalised continua in Biomechanics and mechanics of growing tissues;
- Damage and fracture in generalised continua.

Several topics are still very open, and the discussions provided impetus in what the organisers believe is the right direction for their solution and their complete understanding.
Numerous papers and preprints stemmed from the discussions and debates of this colloquium, providing evidence of how the meeting was successful in terms of scientific exchange and production. The community planned to regularise this event on a yearly basis.

EUROMECH Colloquium 565
"Subcritical transition to turbulence"
6-9 May 2014, Cargese, Corsica
Chairperson: Dr. Yohann Duguet
Co-Chairperson: Dr. José Eduardo Wesfreid

One of the earliest research topics in fluid dynamics, dating back to the 19th century, is still open: how does the flow of liquid or gas in a pipe, between two plates or above one plate, undergo transition to turbulence? How can one predict or characterise the resulting dramatic increase in drag, and perhaps even control it? Those flows share one property in common: linear stability theory does not help in predicting the route from laminar to turbulent flow. This problem lies at the crossroads between hydrodynamics, chaos theory and statistical physics; current research relies on cutting-edge experimental and numerical techniques.

An increasingly large and active international community interested in this topic has emerged since the last meeting in Bristol (United Kingdom) in 2004. The goal of Colloquium 565 was to bring together both experienced and younger experts in the field, in order to present and discuss the latest developments. 84 participants from more than 17 countries, representing at least 29 nationalities, were present over the full 4 days. There were 71 presentations of 20 minutes each, no distinction being made between keynote and younger speakers, as well as a poster session. Most leading scientists in the field were present, which made fruitful discussions possible throughout the colloquium. The event benefited greatly from the presence of a few important names from other related fields of nonlinear sciences. The facilities of IESC Cargèse, coupled with the fine location, pleasant atmosphere and dinners in town also helped in creating a friendly and cooperative feeling within this emerging community.

The schedule of the colloquium was structured around a number of topics, some of which (Non-Newtonian aspects of transition, Astrophysical Flows) were original within the discipline. Special attention was paid during development of the programme to bringing different scientific approaches together, rather than questioning their compatibility. New methodologies, such as flow visualisation techniques, simulation using parallel computing and new algorithms for data processing, were discussed throughout the talks. Major recurring topics and questions discussed over the whole week inluded:

- Spatio-temporal aspects of transition near its onset. Extensive experimental data obtained by B. Hof and coworkers in pipe flow have made it clear that the determination of the onset of transition requires statistical approaches. There is a wide interest in whether the onset of transition can be described as a critical phenomenon, whether it falls into the universality class of directed percolation and why this assumption makes sense by analogy with phase transition or ecology models. More experimental studies are needed and the question is not closed yet.
- Description of the transition process from a dynamical systems point of view. Theoretical ideas formulated by Waleffe, Mullin, Eckhardt, Kerswell, Cvitanovic and co-workers more than 15 years ago are now gaining quantitative support from well-resolved numerical data. Current efforts from many teams are aimed at extracting numerically and experimentally recurrent structures. Bifurcation diagrams and the notion of the edge manifold are receiving active attention. Promising emerging directions concern the reduction of symmetries and the ongoing extension of these ideas to localised turbulence regimes.
- Emergence of localization. Given the experimental and numerical evidence for localised turbulence near its onset, various new numerical techniques (bifurcation analysis, edge tracking, asymptotics, windowing…) are being developed in order to identify correspondingly localised solutions of the governing Navier-Stokes equations.
- Modelling of subcritical transition. Low-order modelling strategies were proposed to account for the spatio-temporal aspects of subcritical transition. Recent models by Barkley, Manneville and others, new ideas from synchronization theory and pattern formation will hopefully lead to new developments.
- Non-Newtonian transition. Two full sessions covered the recent developments in the case of non-Newtonian rheologies such as polymer flows, shear-thinning fluids, particle suspensions and extensions towards elastic turbulence. Unexpectedly, the concept of edge state is central in explaining drag reduction mechanisms.
- Astrophysical applications. There are several suggestions that turbulence in Keplerian discs can be explained by subcritical transition theories in close analogy with the purely hydrodynamical context (talk of F. Rincon). There were discussions about the relevance of academical geometries such as Taylor-Couette flows for this problem.
- Control of subcritical transition. Despite huge industrial interest, nonlinear control strategies for subcritical flows are only emerging. The team of B. Hof has demonstrated that forced full relaminarisation of pipe flow is experimentally possible using carefully designed obstacles, which opens up interesting possibilities for severe drag reduction.

Many questions remain open but there is optimism in the growing community. Thanks to the presence of many leading authorities, the novelty of many presented results, the pleasant environment and the social interaction, Colloquium 565 was considered a complete success. Several experienced participants called it "the best meeting ever on the subject". New links within the community were initiated during this week, which will facilitate further progress within this cross-disciplinary discipline.

EUROMECH Workshop

"Similarity and Symmetry Methods in Solid Mechanics"

7 – 12 June 2013, Varna, Bulgaria
Chairperson: Prof. Ivailo Mladenov
Co-Chairperson: Prof. Jean-François Ganghoffer

The aim of the workshop was to bring together researchers who apply similarity and symmetry analysis to engineering problems in analytical and solid mechanics, researchers interested in the fundamental aspects associated with symmetries and numerical analysts who develop and use such methods in numerical schemes.

Symmetries are useful for integrating the differential equations underlying the boundary value problems encountered in solid mechanics and those that result from the geometrical description of thin elastic solids. They constitute the main ingredient of Noether's theorem, which is strongly related to Lagrangian and Hamiltonian formulations in continuum mechanics. The field of Eshelbian Mechanics (in honour of the work of Eshelby), otherwise called Configurational Mechanics, relies on translational symmetries in the so-called material space, for the writing of field equations in terms of Eshelby stresses. Those symmetries, extended to rotations and dilatations, have been used to construct the well-known J, K, L, M integrals, which are widely used in fracture mechanics to characterise the singular stress field around the crack tip. Those path independent integrals result from conservation laws, which are the natural counterpart of symmetries.

In rheology, the response of materials under varying conditions of control parameters (such as temperature, strain rate) can sometimes be conveniently summarised into so-called master curves, resulting most of the time from an empirical construction. A typical example is the well-known time temperature equivalence principle, as originally proposed in the Williams, Landel and Ferry (WLF) model. One important field in which similar relations are used is high temperature creep of metallic alloys. The best known models in this context are by Larson-Miller and the Dorn; similar invariant models for rupture include the Monkman-Grant relation applicable to the 9Cr-1Mo alloy. The Lie symmetries can here be viewed as an interpolation method which allows continuous linking of experimental data, while relying on a well-chosen, limited set of experiments. In fracture mechanics, the master curve concept allows quantification of the variation of fracture toughness with temperature throughout the ductile-to-brittle transition region.

The Workshop covered the following topics:

- Symmetries and conservation laws in continuum mechanics; numerical schemes; variational integrators; symplectic schemes;
- Lagrangian and Hamiltonian formulations in solid mechanics; configurational mechanics; geometric mechanics;
- Similarity methods in rheology, fatigue and fracture mechanics (path-independent integrals); fractal mechanics;
- Geometry of thin elastic solids (membranes, biofilms, drops).

The Workshop consisted of introductory and advanced courses on the topic introduced by George Bluman (UBNC, Vancouver, Canada) and N. Ibragimov (State Aviation Technical University, Ufa, Russia), two world recognised specialists in the field of symmetry methods. They each delivered 6 one-hour lectures during the week of the Workshop. There were 36 participants and 32 oral presentations. The restricted size of the group of participants and the informal atmosphere allowed extensive interactions and discussions between the plenary lecturers and the participants.

The organisers feel that the Workshop was successful, with a good balance between general lectures, the courses and more specialised talks. As an outcome of the Workshop, a book will be published during 2014 by Springer in the series LNCAM (Lecture Notes in Computational and Applied Mechanics), entitled 'Similarity and symmetry methods: Applications in elasticity and mechanics of materials.' With contributions from internationally recognised authorities, the book will provide a complete overview of the field at a level accessible by non-specialists.

Objectives of EUROMECH, the European Mechanics Society

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

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

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

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

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

European Journal of Mechanics - A/Solids

ISSN: 0997-7538

The *European Journal of Mechanics A/Solids* continues to publish articles in English in all areas of Solid Mechanics from the physical and mathematical basis to materials engineering, technological applications and methods of modern computational mechanics, both pure and applied research.
The following topics are covered: Mechanics of materials; thermodynamics; elasticity; plasticity; creep damage; fracture; composites and multiphase materials; micromechanics; structural mechanics; stability vibrations; wave propagation; robotics; contact; friction and wear; optimization, identification; the mechanics of rigid bodies; biomechanics.

European Journal of Mechanics - B/Fluids

ISSN: 0997-7546

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

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