NEWSLETTER46
Winter 2015
EUROPEAN MECHANICS SOCIETY

President's Address

This year has started with an important event for our Society: the election of new Council members. Three vacancies had to be filled: one 'Fluids' slot and two 'Solids' slots. The following scientists were elected: Prof. Roberto Verzicco (Roma), Prof. Marc Geers (Eindhoven), and Prof. Anna Pandolfi (Milano). Besides, Prof. Pierre Suquet (Marseille) was elected for a new term and myself (Eindhoven) was re-elected for another term, so that we can continue in our roles as Secretary-General and President of EUROMECH, respectively. We welcome the newly elected members, and we are confident that they will play a constructive role in the Council of our mechanics society.
A word of thanks is appropriate to their 'opposing' candidates: we are grateful that they were willing to serve as candidate for a possible Council membership. No doubt, all of them were excellent, highly qualified candidates. They have served and will certainly continue to serve EUROMECH.

A word of thanks also to the Council members whose term ended at the end of 2015: Prof. Pedro Camanho (Porto), Prof. Bernhard Schrefler (Padua), Prof. Wolfgang Schroeder (Aachen), and Prof. Viggo Tvergaard (Copenhagen). Their active role in the Council is greatly appreciated. Bernhard Schrefler has been Secretary-General for a number of years, and Wolfgang Schroeder has taken care of EUROMECH's financial matters as Treasurer for a long period. We are very thankful for their contributions to the European mechanics community.

Last year, the EUROMECH Solid Mechanics Prize and Fellowships were awarded at the 9th ESMC in Madrid. In 2016, it is the turn of the EUROMECH Prize and Fellowships in Fluid Mechanics. There is still time to nominate excellent colleagues for these awards: the deadline has been extended until 5 February 2016. We encourage you to nominate excellent scientists in fluid mechanics for these awards. Details of the nomination procedure can be found on the renewed EUROMECH website.
The Fluid mechanics Prize and Fellowships will be awarded at the 11th European Fluid Mechanics Conference, to be held 13 – 16 September 2016 in Sevilla.

I also would like to draw your attention to the 8th European Postgraduate Fluid Dynamics Conference, which will be held 6-8 July 2016 in Warsaw. These meetings are conferences for postgraduates, organised by postgraduates: they are meant to bring junior scientists together, in order to learn about each other's work, and therewith to extend their overview of the field of fluid dynamics and to build a network. EUROMECH sponsors these conferences by providing some financial support. I would encourage all senior members of our society to stimulate their PhD students and postdocs to participate in this junior-scientists conference.
It would be nice if in the future we would have a similar conference in Solid Mechanics.
Who is willing to take the initiative?

The time for submitting a proposal to organize a EUROMECH Colloquium is also approaching. The deadline is 20 March 2016. Information about the application procedure may be found on the website.

In this Newsletter you will find the information as usual, including reports on EUROMECH Colloquia organised in the past few years. As you may see on the agenda, a number of Colloquia and Conferences are scheduled for 2016. I hope this will add to the flourishing of the European mechanics community. In case you plan to organise a meeting of this format, we encourage you again to apply for EUROMECH support by submitting a proposal.

GertJan van Heijst
President, EUROMECH

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EFMC9-EUROMECH Young Scientist Prize Paper

"Intermittent Boundary Layers in Taylor-Couette Flow"

Hannes Brauckmann won the EUROMECH Young Scientist Prize, awarded at the 9th EUROMECH FLUID Mechanics Conference held in Rome, September 2012

Hannes J. Brauckmann[1] and Bruno Eckhardt[1]

Abstract

In Taylor-Couette flow with counter-rotating cylinders that have sufficiently large angular velocities, the turbulence near the outer cylinder shows intermittent oscillations in the form of turbulent bursts. We present this phenomenon in direct numerical simulations for radius ratios $\eta = 0.5$ and 0.71 and identify a critical value in the rotation ratio µ for its onset. We propose a physical explanation for this critical value that also rationalises the observed agreement with the rotation ratio of the torque maximum. While this model conforms well with observations for these radius ratios, it most likely has to be refined or replaced for $\eta \to 1$.

1. Introduction

The flow between two concentric independently rotating cylinders (Taylor-Couette flow) becomes turbulent either after a sequence of instabilities or via a sub-critical transition scenario [1]. In the first case, streamwise vortices, denoted as Taylor vortices, typically develop that fill the entire cylinder gap and persist up to the turbulent regime. In the latter case, the turbulence is not always space-filling but can form turbulent spots and spirals for counter-rotating cylinders. In this regime, Coughlin and Marcus [2] described a flow state that is additionally inhomogeneous in the radial direction and shows turbulent bursts. These intermittent turbulent bursts were also observed in experiments at much higher Reynolds numbers of $\sim 10^6$ [3]. In Ref. [3], the onset of the bursting has been additionally associated with the maximum that occurs in the torque for counter-rotating cylinders [4–6]. Here, we summarise the results of our study of turbulent bursts and their connection to the torque maximum [6,7]. In the following, we present our numerical simulations, introduce the bursting phenomenon, identify the onset of turbulent bursts and determine the torque maxima. Next, we derive a physical model to predict the onset and compare it to our numerical results.

2. Numerical Simulations

To investigate the intermittent turbulent bursts, we performed direct numerical simulations (DNS) of Taylor-Couette flow using the spectral scheme described in [8]. We study two different cylinder configurations defined by the radius ratios $\eta = r_i/r_o = 0.5$ and 0.71, where r_i and r_o denote the radii of the inner and outer cylinders. To avoid the effects caused by rigid endwalls, the simulations are periodic in the axial direction with a height $L_z = 2(r_o - r_i)$, which is large enough to represent one pair of Taylor vortices. In addition, the azimuthal length of the domain is restricted to one third for $\eta = 0.5$ and one ninth for $\eta = 0.71$ of the full cylinder circumference with periodic repetition. We tested that these restrictions do not bias the computed torque for a stationary outer cylinder [6]. As the turbulent bursts were only observed for counter-rotating cylinders, we are interested in the occurrence of this phenomenon with varying mean rotation of the Taylor-Couette system defined by the rotation ratio $\mu = \omega_o/\omega_i$, where ω_i and ω_o denote the angular velocities of the inner and outer cylinder. We study the influence of μ for a constant differential rotation of the cylinders measured by the shear Reynolds number [9]

$$Re_S = \frac{U_0 d}{\nu} = \frac{2}{1+\eta}(Re_i - \eta Re_o) = 2.0 \times 10^4, \qquad (1)$$

with the traditional Reynolds numbers $Re_i = \omega_i r_i d/\nu$ and $Re_o = \omega_o r_o d/\nu$ and the kinematic viscosity ν. Here, the characteristic velocity U_0 and gap width $d = r_o - r_i$ are used to render all velocities and lengths dimensionless.

2.1 Turbulent Bursts

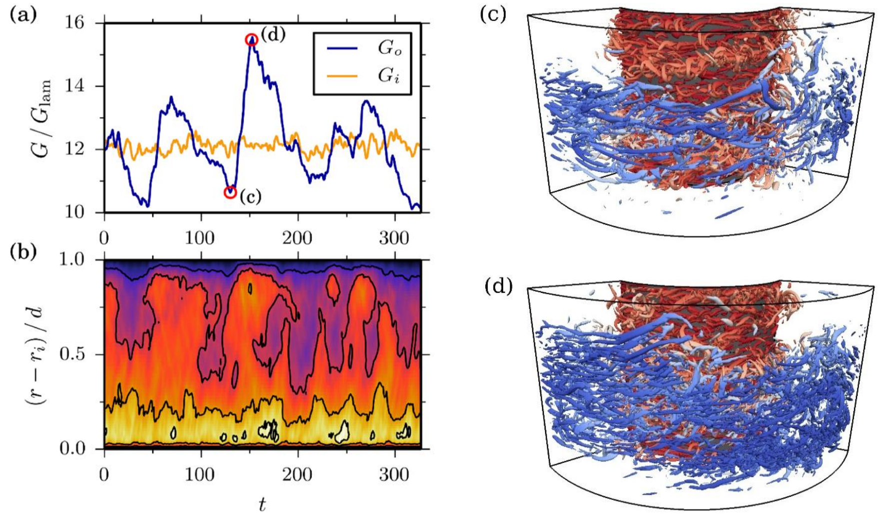

Fig. 1: Turbulent bursts for $\eta = 0.5, Re_S = 2 \times 10^4$ and $\mu = -0.5$. (a) Time-series of the torque calculated at the outer cylinder (G_o) and inner cylinder (G_i) and compensated by the laminar value G_{lam}. (b) Spatio-temporal plot of the cross-flow energy $E_{cf}(r,t)$ averaged over concentric cylindrical surfaces with white (black) showing maximum (minimum) energy. The turbulent vortices for the low- and high-torque state (marked by circles in (a)) are visualised in (c) and (d), respectively.

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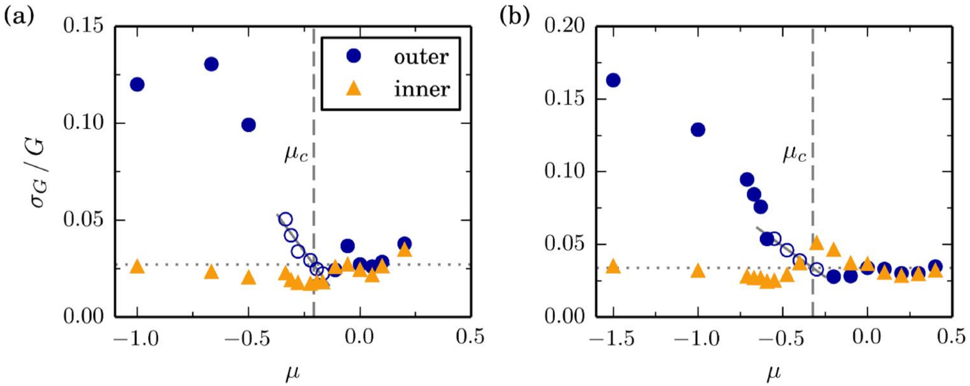

Fig. 2: Standard deviation σ_G (divided by the mean G) of temporal torque fluctuations calculated at the outer and inner cylinder for a constant shear $Re_S = 2 \times 10^4$ and varying rotation ratio μ. The outer fluctuations exceed the fluctuation base level (dotted line). A linear fit to the open circles determines the intersection point μ_c (dashed line) that defines the onset of the bursting behavior for $\eta = 0.5$ in (a) and $\eta = 0.71$ in (b).

We characterise the turbulent flow by the torques G_i and G_o that are exerted on the inner and outer cylinder, respectively, and that have to agree when averaged over long times. Our simulations revealed that the inner and outer torques also agree in their temporal fluctuations, but only for co-rotating ($\mu \geq 0$) and slightly counter-rotating cylinders [6]. In contrast for strong counter-rotation, the outer torque fluctuations strongly increase in amplitude as exemplified for $\eta = 0.5$ and $\mu = -0.5$ in Fig. 1(a). The outer torque G_o shows relatively slow and larger variations over time that differ qualitatively from the inner torque fluctuations. These variations correspond to a modulation in the turbulent intensity that is measured by the instantaneous cross-flow energy at the radial distance r,

$$E_{cf}(r,t) = \langle u_r^2 + u_z^2 \rangle_{\varphi,z}\ , \tag{2}$$

based on the radial and axial velocities u_r and u_z. The spatio-temporal plot of E_{cf} in Fig. 1(b) reveals a permanently strong turbulence near the inner cylinder and temporal variations in the turbulent intensity near the outer cylinder. Furthermore, the strongly turbulent phases in the outer layer are synchronised with the maxima in the outer torque and correspond to turbulent bursts, as exemplified by snapshots of the flow for a low- and high-torque state in Fig. 1(c) and (d), respectively. While the inner cylinder is completely covered with small turbulent vortices in both cases, the number of vortices and area covered by them increase near the outer cylinder during the bursting phase in (d). This radial partitioning of the flow into a permanently active inner region and an outer region, that shows turbulent bursts, was previously observed at $Re_S \sim 2.3 \times 10^3$ by Coughlin and Marcus [2] and extends to Reynolds numbers $Re_S \sim 10^6$ as angular velocity measurements show [3].

Since turbulent bursts only occur for a sufficiently fast counter-rotation of the outer cylinder, i.e. for $\mu < \mu_c < 0$, we aim here to identify the critical rotation ratio $\mu_c(\eta)$ for the onset of this bursting behaviour. For this purpose, we use the observation that turbulent bursts are connected with increased torque fluctuations and characterise the fluctuation amplitude by the standard deviation σ_G relative to the mean G. Fig. 2 reveals that while σ_G/G varies only little with μ at the inner cylinder, σ_G/G at the

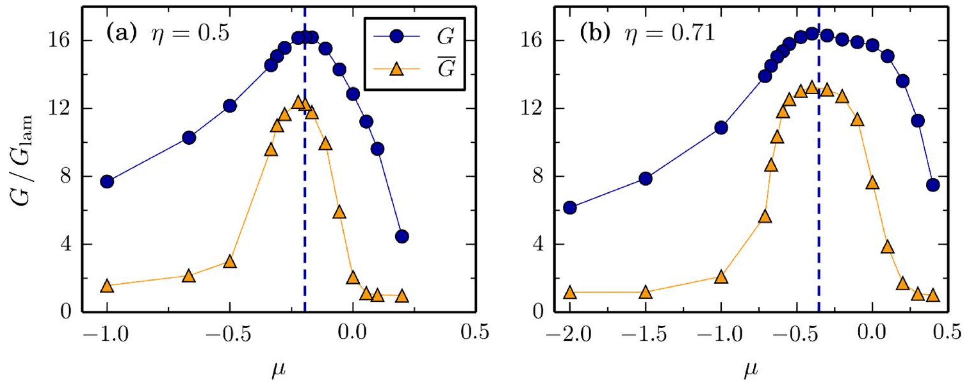

Fig. 3: Variation of the torque G with the rotation ratio μ for $Re_S = 2 \times 10^4$. The dashed line marks the position μ_{max} of the torque maximum for counter-rotating cylinders. In addition, the torque contribution $\bar{G}$ of the mean-vortex flow is shown.

outer cylinder exceeds its base level for $\mu = 0$ when μ decreases, which serves as the requirement to identify the critical values for the onset,

$$\mu_c(0.5) = -0.208 \pm 0.014, \qquad \mu_c(0.71) = -0.325 \pm 0.050. \tag{3}$$

The onset $\mu_c(\eta)$ clearly depends on the radius ratio and the value for $\eta = 0.71$ conforms with $\mu_c(0.716) \approx -0.368$ determined for the onset of intermittent bursts in the experiment [3].

2.2 Torque Maxima

Two recent Taylor-Couette experiments [3–5] for $\eta \approx 0.72$ and $Re_S \sim 10^6$ revealed another phenomenon: the torque as a function of the rotation ratio exhibits a maximum at $\mu_{max} = -0.33$, i.e. for counter-rotating cylinders. Our simulations at $Re_S = 2 \times 10^4$ also show such a torque maximum for $\eta = 0.5$ and 0.71, see circles in Fig. 3. Using a quadratic fit to the data, we determine the maximum locations,

$$\mu_{max}(0.5) = -0.195 \pm 0.019, \qquad \mu_{max}(0.71) = -0.354 \pm 0.061, \tag{4}$$

which agree (within the usual uncertainties) with the experimental observations $\mu_{max}(0.5) = -0.20$ [10] and $\mu_{max}(0.72) = -0.33$ [3,4] at much higher shear Reynolds numbers. Furthermore, these torque-maximizing rotation ratios nearly coincide with the bursting onsets μ_c from Eq. (3), as previously found in the experiment for $\eta = 0.716$ [3].

3. Onset of Radial Inhomogeneity

To explain the dependence of the bursting onset μ_c on the radius ratio η and its connection to the location μ_{max} of the torque maximum, we propose a physical model that is based on the radial partitioning of the flow into an actively driven inner region and a stabilised outer region. Coughlin and Marcus [2] already noted that the bursting is linked to the presence of a neutral surface at the

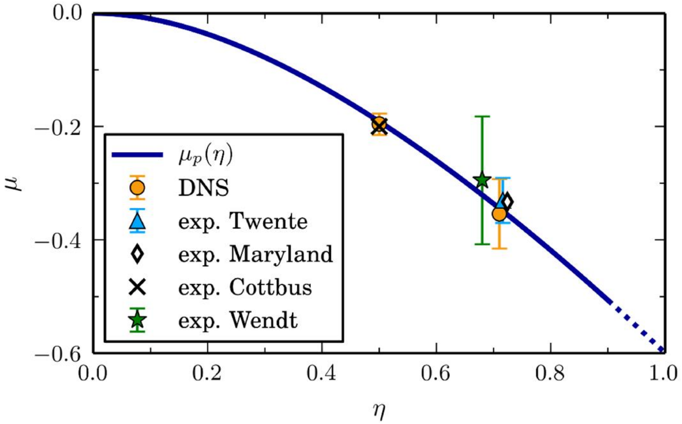

Fig. 4: Position μ_{max} of the torque maximum as a function of the radius ratio η. The circles mark the numerical results from Fig. 3 and the other symbols show results from experiments in Twente [3], Maryland [4], Cottbus [10], and by Wendt [13]. These are compared to the prediction $\mu_p(\eta)$ from Eq. (7).

radius r_n, where the laminar velocity profile passes through $u_\varphi(r_n) = 0$ for counter-rotating cylinders. Inviscid stability calculations give the radius of the neutral surface as

$$r_n(\mu) = r_i \sqrt{\frac{1-\mu}{\eta^2 - \mu}}\,; \tag{5}$$

which separates the unstable inner region ($r_i < r < r_n$) from the stable outer region ($r_n < r < r_o$). However, the stabilised outer region cannot remain laminar but is susceptible to turbulent bursts, see also [2,3]. Therefore, the key idea is that the bursting occurs when the unstable inner region detaches from the outer cylinder. However, experiments and viscous calculations show that flow structures from the unstable inner region extend beyond r_n [11]. Accordingly, we estimate this increase in the width of the inner region by the factor $a(\eta) \in [1.4, 1.6]$ that was deduced by Esser and Grossmann from their stability calculation [12]. Thus, the effective extension of turbulent flow structures from the inner region is

$$r_t(\mu) = r_i + a(\eta)(r_n - r_i) \qquad \text{with} \qquad a(\eta) = (1-\eta)\left[\sqrt{\frac{(1+\eta)^3}{2(1+3\eta)}} - \eta\right]^{-1}. \tag{6}$$

Consequently, the condition $r_t(\mu_p) \equiv r_o$ determines the rotation ratio μ_p where the unstable inner region detaches from the outer cylinder. This gives

$$\mu_p(\eta) = -\eta^2 \frac{(a-1)^2\eta + a^2 - 1}{(2a-1)\eta + 1}. \tag{7}$$

Since the stable outer region occurs for $\mu < \mu_p$, Eq. (7) serves as a prediction for the onset of the bursting, i.e. for $\mu_c(\eta)$. Evaluating Eq. (7) for the radius ratios studied here gives the predictions

$\mu_p(0.5) = -0.191$ and $\mu_p(0.71) = -0.344$ which are close to the empirically found bursting onsets from Eq. (3).

To connect $\mu_p(\eta)$ also to the observed torque maxima we analyse the torque contribution $\bar{G}$ of the temporally and streamwise averaged Taylor vortices, as defined in [7]. Fig. 3 shows that the mean-vortex torque $\bar{G}$ (triangles) increases with the onset of counter-rotation ($\mu < 0$) and drops again when the bursting sets in ($\mu < \mu_c$), which interferes with the Taylor vortices. Consequently, also the total torque G decreases after the bursting onset, as previously noted by van Gils *et al.* [3], and since $\mu_c \sim \mu_p$, we can use $\mu_p(\eta)$ also to predict the location of the torque maximum. The comparison in Fig. 4 demonstrates that the predictive line $\mu_p(\eta)$ agrees well with the torque maximum locations μ_{max} determined in our numerical simulations (4) and with various experimental observations, including the torque measurements by Wendt [13] that were reanalyzed in [7].

4. Conclusions

In summary, the presented results suggest that the torque increases with the onset of counter-rotation since the mean Taylor vortices gain in strength. For stronger counter-rotation, the torque drops again when the vortices detach from the outer cylinder wall and thereby create space for a stabilised outer region, which shows intermittent turbulent bursts. This picture resulted in the prediction $\mu_p(\eta)$ for both the fluctuation onset μ_c and the location of the torque maximum μ_{max}.

Since the predictive model relies on the partitioning of the flow into an unstable inner and intermittent outer region, it has to be refined or replaced in the limit $\eta \to 1$ where this partitioning disappears. This is supported by the deviation of the torque maximum location from $\mu_p(\eta)$ observed in recent experiments for $\eta = 0.909$ [14].

5. Acknowledgements

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6. References

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ETC14-EUROMECH Young Scientist Prize Paper

"Influence of the stratification on the convection flow in a tilted channel"

E.Rusaouen won the EUROMECH Young Scientist Prize, awarded at the 14th EUROPEAN TURBULENCE Conference held in Lyon, September 2013

Eléonore RUSAOUËN2, Julien SALORT, Xavier RIEDINGER, Bernard CASTAING, Francesca CHILLA

Abstract

A thermal channel connecting two chambers, a hot one at the bottom and a cold one at the top is inclined in order to study the influence of the stratification on a turbulent convective bulk flow. Particle Image Velocimetry measurements evidence a change of the longitudinal velocity profile with the increasing inclination. It is interpreted and modeled as an effect of the competition between stratification and turbulence. The comparison of the modeled and experimental velocity profiles suggests the validity of this interpretation.

1. Introduction

Turbulent thermal convection is an ubiquitous phenomenon in natural and industrial flows. Most of the time, there are composed of boundary layers and a bulk flow. Both contribute to the thermal behavior of the flow. The disentanglement of the contribution of the bulk to the one of the boundary layers is achieved using a thermal channel which connects two chambers as schematized in figure 1. As explained in Gibert *et al* [Gib1], when submitted to an imposed heat flux, the response of the system is a longitudinal temperature gradient β constant along the $\vec{z}$ direction defined in figure 1. In this particular case, Gibert *et al* [Gib2] have shown that the thermal behavior in the central part of the channel is characteristic of a flow free of boundary layers influence. The Nusselt number (the dimensionless heat flux) is then related to the Rayleigh number (dimensionless difference of temperature) as follow :

$$Nu \propto Ra^{1/2} \quad (1.1)$$

In this relation $Nu = Q_z / C_p \kappa \beta$, where Q_z is the longitudinal heat flux, C_p the specific heat and κ the thermal diffusivity of the fluid, and $Ra = g\cos(\psi)\alpha\beta d^4 / \kappa\nu$, where ν is the kinematic viscosity, and g the gravity acceleration. The last parameter of (1.1) is the angle ψ defined as the inclination of the axe $\vec{z}$ with respect to the gravity. Inclining the entire apparatus allows to study the influence of a controlled stratification on such a flow. Such a study had been performed by Riedinger *et al* [Rie] on the thermal behavior of the cell, by measuring the longitudinal temperature gradient. It had showed that at sufficiently high injected power and low inclination the flow is turbulent. In the present paper, we will present a Particule Image Velocimetry study of this turbulent flow, and develop physical arguments to understand the PIV observations.

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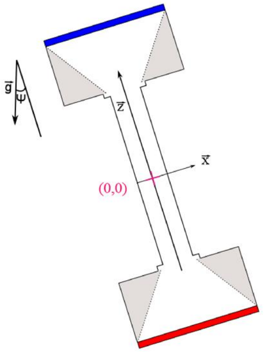

Fig.1 : Sketch of the thermal channel in an inclined position.

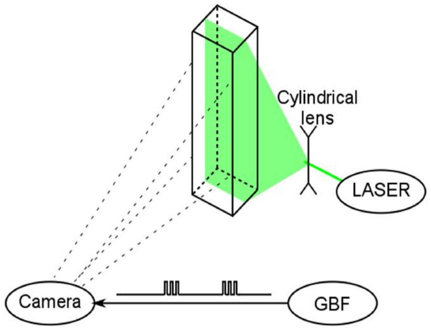

Fig.2 : Sketch of the PIV setup

2. Experiment

2.1. Experimental Apparatus

As previously said, the experimental apparatus is schematized on figure 1. A square channel connects two conical chambers, a cold one at the top and a hot one at the bottom. The chambers are designed to ensure that the small circles of the conical is inscribed inside the square base of the channel. We define its caracteristic lengths, H is the longitudinal length along the $\vec{z}$ direction, and d is the transverse length along the $\vec{x}$ direction. The aspect ratio is then $\Gamma = H/d$. A recent study, presented in *Rusaouen* [Rus], on the influence of the aspect ratio on the behavior of the channel shows that if $\Gamma \geq 4$ the channel is sufficiently long to prevent interactions between its central part and the boundary conditions near the plates. In the present paper, the aspect ratio will be 4, corresponding to $H = 20cm$ and $d = 5cm$. The channel walls are made of PMMA which allows visualisation.

2.2. Particule Image Velocimetry

The experimental measurements consist in Particule Image Velocimetry, schematized in figure 2. A green laser, optical power 1.2W, provided by Melles Griot, allows to produce a laser sheet placed in the middle plane of the channel. The fluid, deionised water, is seeded with hollowed glass particules of typical diameter which lies in the range between $1\mu m$ and $10\mu m$.

The typical velocity in this experiment varies between $1cm/s$ and $2cm/s$. In order to access the both high and low frequency dynamics of the flows, we choose a discontinous recording which consists in packets of three images (two velocity fields) separated by $40ms$. Each packet is separated from the following by $10s$. A three hours recording is then constituted of 2160 velocity fields.

3. Experimental results

The time averaged field of the longitudinal component, $\langle V_z \rangle_t$, remains nearly unchanged along the $\vec{z}$ direction. It is, then, possible to average along the $\vec{z}$-direction and compute mean velocity profiles defined as $U_{x,z} = \langle V_{x,z} \rangle_{t,z}$. Figure 3.a presents these velocity profiles for both longitudinal (continuous lines) and transverse (dotted lines) components.

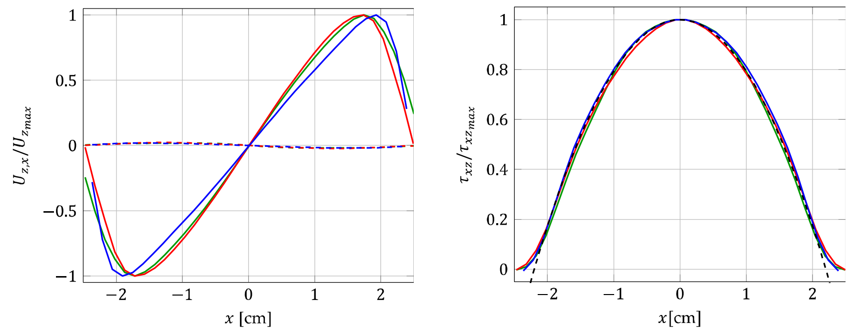

Fig.3.a and Fig.3.b : a :Velocity profiles normalised to the maximum of the longitudinal component for an applied power of 77W. Red curves correspond to an inclination angle ψ of $5°$, the green ones are for $\psi = 10°$, and the blue ones for $\psi = 20°$. Full lines are for the longitudinal components, and dotted lines for the transverse one. b : Reynolds stress tensor, same colors.

Those curves are normalised by the maximum of the longitudinal components. We can note that the transverse component is significantly lower than the longitudinal one for each inclination angles. The second information comes from the longitudinal component. The red profile is close to a sinus whereas the blue one is more linear. As the inclination increases the longitudinal velocity profile deforms and becomes more linear. This is interpreted as an effect of the increasing stratification. We can define the slope at the center of the channel as:

$$\partial_x U_z = C_v U_t \quad (3.1)$$

In this expression, C_v is a coefficient and U_t is a velocity which caracterizes the heat flux in the system. Following Riedinger *et al* [Rie], it is defined as:

$$U_t = \left(\frac{Q_z \cos(\psi) \alpha g d}{C_p} \right)^{1/3} \quad (3.2)$$

In the same time, the Reynolds stress tensor, defined as the products of the velocity fluctuations $\tau_{xz} = \langle v_x' v_z' \rangle = \langle (V_x - \langle V_x \rangle_{t,z})(V_z - \langle V_z \rangle_{t,z}) \rangle_{t,z}$, remains nearly unchanged and close to a parabolic curve. Figure 4.b presents this quantity normalized by its maximum in order to highlight the form of the curves. The black dotted curve is a parabola of equation :

$$C_\sigma U_t^2\left(1-\frac{4x^2}{d_{eff}^2}\right) \quad (3.3)$$

where $d_{eff}=4.4cm$ is the efficient section of the channel where the stress becomes negligible, and C_σ is a coefficient caracteristic of this stress.

As emphasized previously, the longitudinal velocity profile deforms as the inclination angle increases. This is interpreted as an effect of the increasing stratification.

4.Effect of stratification

4.1. Physical equations and closure in terms of turbulent viscosity

To understand this deformation, we shall consider the physical equation of the flow, the Boussinesq equations. Considering the z-invariance, the stationnarity and the symmetry of the gravity of the system, the equations can be reduced to the following forms :

$$\partial_x\sigma = g_z\alpha\Theta(x)$$

$$\beta U_z = \partial_x Q_x$$

The first equation relates the stress tensor, reduced to $\sigma=\langle v_x^{'}v_z^{'}\rangle$ by neglecting the viscous effects in the central part of the channel section, to the temperature profile, $\Theta(x)$. The second one relates the longitudinal gradient, $\beta=\partial_z\Theta(x)$, to the tranverse heat flux, Q_x. The system is then constituted of two equations and involves four variables. Two more expressions are needed to close the system. To do so, a turbulent viscosity and a turbulent diffusivity are introduced as following :

$$\sigma = -\nu_{turb}\partial_x U_z$$

$$Q_x = -\kappa_{turb}\partial_x\Theta$$

Those two phenomenological quantities are related to each other by a turbulent Prandtl number, $\mathrm{Pr}_{turb}=\frac{\nu_{turb}}{\kappa_{turb}}$. Considering the expressions (3.1) and (3.3), Pr_{turb} can be expressed in terms of experimental quantities and remains close to 0.7. The problem is now to express only one quantity: ν_{turb}. To do so, we introduce a mixing length l_m which is related to the turbulent viscosity as follow:

$$\nu_{turb} = \omega_0 l_m$$

The mixing length is direclty related to the efficient section of the channel. The influence of the stratification is included in the pulsation ω_0. Following the work of Eidson [Eid], this pulsation is expressed as :

$$\omega_0 = \left(\left(\partial_x U_z\right)^2 - N^2\right)^{1/2}$$

where N is a Brünt-Väisälä frequency, caracteristic of the stratification in the flow. In our case, this expression is equivalent to :

$$\omega_0 = \left(\left(\partial_x U_z\right)^2 - \Upsilon\left(\alpha g_z\beta - g_x\alpha\partial_x\Theta\right)\right)^{1/2}$$

The term $\partial_x U_z$ is a classical model of turbulent viscosity. The two other terms coming from the development of the Brünt-Väisälä frequency, have different roles. The $\alpha g_z\beta$ term is destabilising the flow and then enhances the turbulence, whereas $g_x\alpha\partial_x\Theta$ is a stabilising term which reduces the turbulence of the flow. The deformation of the profile is induced by the competition between turbulence and stratification which is balanced by the coefficient Υ. It is an arbitrary coefficient. All the calculation details can be found in Salort *et al* [Sal].

4.2. Comparison between model and experiments

The system of equations is then closed by a turbulent viscosity which includes the influence of stratification on the flow. The deformation of the profiles comes from the competition between turbulence and stratification which is balanced by an arbitrary coefficient.

In order to validate this modelisation, a comparison with experimental results is needed. Velocity profiles are generated through the model and compared to the corresponding experimental velocity profiles (corresponding to the same injected power and inclination), figure 4. The two sets of profiles are close to each other, symbols versus solid lines. The model is then able to reproduce the deformation of the velocity profiles induced by the competition between turbulence and stratification in the flow.

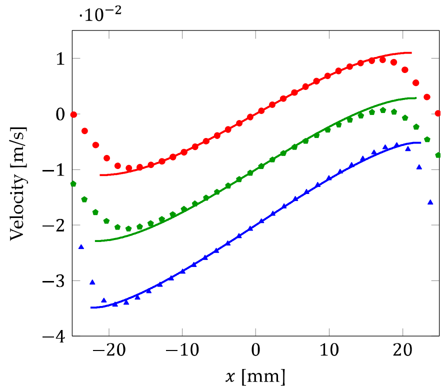

Fig.4 : Comparison between experimental velocity profiles, symbols, and modelised velocity profiles, lines. The applied power is 77W and inclination is 5°, black, 10°, red, and 20° blue.

5. Conclusion

The flow in an inclined thermal channel is turbulent at sufficiently high applied power and low inclination. In this case, PIV measurements reveal a deformation of the longitudinal velocity profile with the increasing inclination. This deformation is interpreted as a competition between turbulence and stratification. A modeling of this phenomenon in terms of a turbulent viscosity reproduces well this deformation. The competition is then contained into three different terms, a classical turbulent viscosity model to which is added a destabilising term which tends to increase the turbulence in the flow and a stabilising term which tends to decrease it.

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EUROMECH Young Scientist Prize Paper

Glowing droplets in turbulent flows

Humberto Bocanegra Evans*

April 17, 2014

Humberto Bocanegra Evans won the EUROMECH Young Scientist Prize, awarded at the 14th EUROMECH European Turbulence Conference held in Lyon, France, September 1–4, 2013.

We present a novel experimental technique suitable for the study of particle-laden flows. The technique consists of creating phosphorescent droplets which can be tagged by a laser pulse. The tagged droplets emit light for a few milliseconds, which enables the visualization of these droplets for a few small-eddy turnover times. We explore two possible scenarios where this technique can be used to shed light on the dynamics of particle-laden flows.

I. INTRODUCTION

In fluid dynamics, the notion of particle tagging is not a new one. Almost a century ago, both Taylor [1] and Richardson [2] made use of this once hypothetical concept to develop our understanding of absolute and relative turbulent dispersion, respectively. In recent years, technological developments in lasers, imaging systems, and numerical methods have allowed scientists to take great strides towards the understanding of the Lagrangian statistics of turbulence by applying the concept of tagged particles [3]. Non-intrusive, optical techniques, such as particle tracking velocimetry, are able to follow flow tracers—which can, in practice, be seen as tagged fluid parcels—and get information about their velocity and acceleration in a Lagrangian sense. Because of this, they have become a major tool in turbulence research. On the numerical side, scientists have been able to implement simulations which follow millions of particles for relatively long periods of time—on the order of the large-eddy turnover time—giving us insight into both their dynamical and statistical behavior. The applicability of these methods to particle-laden flows, however, is negatively impacted by high particle concentrations, therefore the exploration of new techniques to further understand such flows, and complement the currently available information, is necessary. It has been shown by Krüger and Grünefeld [4] that phosphorescent tagging presents an alternative when the flow at hand has a high particle density. Here, we will explain a novel experiment in which we *literally* tag phosphorescent particles. In a nutshell, the method consists of generating droplets out of a phosphorescent solution and tagging these droplets by illuminating them with a UV laser, after which only the tagged droplets then emit light for a few milliseconds, allowing their visualization and tracking.

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The understanding of particle-laden flows has been a focus of extensive research in recent years (see e.g. [3] and [5]), this due to the prevalence of such flows in both industrial and natural flows. Particle-laden flows can be found in clouds, pollution dispersion, natural gas pipelines, and fuel injection in internal combustion engines, among many others. In many cases, particle statistics are accurately described by the Lagrangian statistics of fluid tracers. However, there comes a point in which the size and mass of the particle cannot be neglected, and the effects of inertia become apparent. The inertia of the particles can be quantified by the particle reaction time, which depends on the size of the particle and the density ratio between the fluid and the particle. It is defined as $\tau_p = d_p^2\rho_p/(18\mu)$, where d_p and ρ_p represent the diameter and density of the particle, respectively, and μ is the dynamic viscosity of the carrier fluid. The effect of inertia on the particle dynamics depends on the Stokes number, which is defined as the ratio between the particle reaction time and a characteristic timescale of the flow. Since we are interested in the short-time effects of inertia, we use the small-eddy turnover time, also known as the Kolmogorov timescale τ_η, so we have $\mathrm{St} = \tau_p/\tau_\eta$. Here we focus on particles which have a higher density than the carrier flow, i.e. water droplets in air. The effects of inertia can be readily seen on the simplified equation of motion of a fluid particle.

$$\frac{\mathrm{d}v_p}{\mathrm{d}t} = \frac{1}{\tau_p}\left(u - v_p\right), \tag{1}$$

where u is the velocity of the fluid and v_p is the velocity of the particle. This equation is applicable to point-particles, that is, particles that are small and have a much higher density than the carrier flow. It neglects the added mass term, the Basset history force, the buoyancy and Faxén correction, terms which are much smaller than the Stokes drag, and therefore have little impact on the motion of the particle. One can see, from Eq. (1) that the velocity of the particle lags that of the fluid, which may have a considerable effect on the velocity and acceleration statistics of the particle, and create particle concentration inhomogeneities.

The statistical side of preferential concentration is well documented, where an array of quantities can be obtained from a screenshot of the particle field. These include the correlation function $g(\boldsymbol{r})$, which measures the probability of finding a particle a distance $\boldsymbol{r}$ away from a reference particle; the fractal dimension, which probes the structure of the spatial distribution of particles in space by looking at its dimensionality; and the Voronoï tesselation, which measures the deviation from total randomness of the spatial distribution of droplets. While our proposed technique allows us to calculate these statistical quantities, the novelty of our method resides on its capability to obtain dynamical information about the behavior of droplets in turbulent flow, that is, we can observe the time evolution of the particle field.

Throughout this study we will explain the details of the phosphorescent tagging technique. We will first describe the properties of the phosphorescent solution, in Section II, and illustrate the experimental setup in Section III. Thereafter, we will explore the tagging of a thin, pencil-like volume and a sheet within a cloud of phosphorescent droplets, and discuss the quantities that can be extracted from the data in Section IV.

II. PHOSPHORESCENT SOLUTION

The phosphorescent solution plays a crucial role in the experiment, since it determines the amount of time the particles will be visible. Many different lanthanides have phosphorescent properties, however, we must choose one with optimum properties for our application. These include excitation and emission wavelengths, ease of synthesization. no toxicity and, of course, a lifetime applicable to the phenomenon at hand, that is, longer than the Kolmogorov timescale. We choose Europium (Eu^{3+}), which has accessible excitation and emission wavelengths of 355 nm and 613 nm, respectively. The excitation wavelength is readily available by frequency-tripling a 1064 nm source and the emission wavelength can be detected by our camera. As will be seen below, the lifetime is well within the required value.

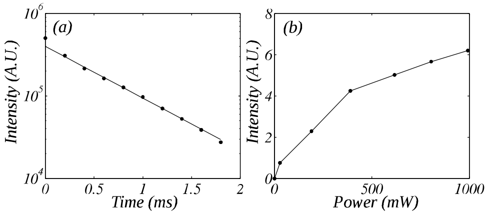

FIG. 1. (a) Phosphorescence intensity as a function of time for case with power of 616 mW, resulting in $\tau_{ph} = 691\,\mu$s.(b) Phosphorescent signal intensity as a function of laser power for the phosphorescent solution. Error bars for both cases are on the order of the symbol size.

Due to its relatively long emission time, phosphorescence produces a very low amount of light. To increase it, a chelation process is used, where ligands create a cage, which acts as 'antennae' around an Europium nucleus. The ligands help in the absorption of excitation photons, resulting in a brighter and longer emission by the core. For the present study, the ligands used are thenoyltrifluoroacetone (TTA) and trioctylphosphine oxide (TOPO). The resulting solution has an exponential decay with a decay constant $\tau_{ph} \approx 650\,\mu$s (see Fig. 1(a)), which allows for a droplet visibility of approximately 2 ms. This translates to roughly four small-eddy turnover times.

With the aim of increasing the quality of the recorded images, we inspect the result of the emission strength with laser power increase. As can be seen in Fig. 1(b), the phosphorescent signal saturates as the laser power is increased. This may result in multiple scattering, which has the negative effect of widening the tagged volume. Therefore, the laser power must be adjusted on a case by case basis in order to optimize the resulting data.

III. EXPERIMENTAL SETUP

In order to test the proposed experimental method we resort to an idealized setting: homogeneous, isotropic turbulence with zero mean velocity. To accomplish such characteristics, a turbulence chamber similar to that proposed by Hwang & Eaton [6] was fabricated. The flow in such chambers is generated by synthetic jets mounted on the corners of a cubical box. The jets are driven by colored noise with random amplitudes and impinge on each other at the center of the chamber. This results in a small region at the center of the box where the mean velocity is very low in comparison with the turbulent fluctuations. A 3D model of our chamber is shown in Fig. 2(a). The speakers have a diameter of 365 mm, and the jet orifice has a diameter of 40 mm. The box has an interior side length of 400 mm. We use PIV to measure the velocity and the turbulence statistics of the velocity field at the central part of the chamber. The magnitude of the velocity fluctuations and the large-scale isotropy of the flow are presented in Fig. 2(b,c). Due to the inherent filtering of PIV processing algorithms, we resort to a method proposed by Sheng *et al.* [7] capable of approximating the sub-grid stresses and estimating the energy dissipation rate ε. The turbulence statistics are shown in Table I.

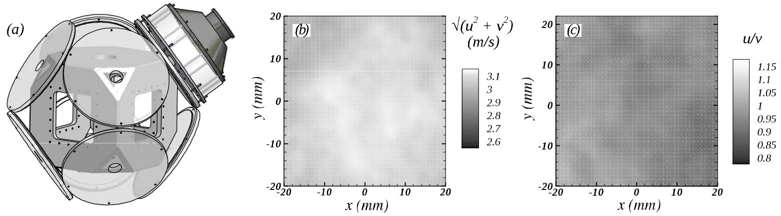

FIG. 2. (a) 3D model of the turbulence chamber with only one of the speakers shown for clarity. (b) Contour plot of the magnitude of the velocity fluctuations. The magnitude of the mean flow is approximately one-tenth of the velocity fluctuations. (c) Contour plot of the large-scale isotropy. It can be seen that over the entire velocity field, the ratio u/v remains within 15%.

$\langle u_{rms} \rangle$ (m/s)	ε (m^2/s^3)	Re_λ	η (μm)	τ_η (μs)	d_p (μm)	St
2.2	61	548	86	497	15.4	1.67

TABLE I. Turbulence statistics of the flow with droplet diameter and corresponding Stokes number.

IV. DROPLET TAGGING

Our aim in this section is to present two out of many possible applications for the use of phosphorescent droplets. These are, the tagging of a thin pencil-like volume and the tagging of a thin slab. The question is, what information can we get from these experiments? Before we answer this question, let us look at the procedure for both tagging experiments.

The setup for the phosphorescent tagging technique consists of the aforementioned chamber, with the addition of a frequency-tripled, pulsed Nd:YAG laser, a spinning disk droplet generator capable of producing a narrow size distribution of droplets and an intensified high-speed camera. The droplets are considerably smaller than the Kolmogorov length scale, therefore can be treated with the point-particle approximation. Furthermore, the concentration of droplets is low enough that their effect on the flow can be neglected. This is usually referred to as one-way coupling.

The experiments are carried out by generating phosphorescent droplets inside the box until the relative humidity is greater than 90%, to avoid evaporation effects. Once the humidity is high enough, the turbulence chamber is turned on, and both the aerosol generator and the turbulence chamber run simultaneously while the tagging experiment takes place. Tagging events are realized by illuminating the cloud volumes with a fast laser pulse ($\sim$ 5 ns). This creates a well-defined tagged volume. For the pencil-like volume tagging we

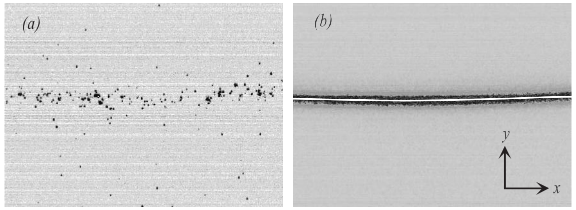

FIG. 3. (a) Single shot of the tagged volume. The sparseness of the droplets can be appreciated. (b) Resulting intensity map after phase-averaging showing the backbone (solid white). It can be observed that, due to optical aberrations, the line appears bowed. This is corrected by straightening the backbone and shifting the intensity profile accordingly.

use a 1000 mm spherical lens, which allows us to have a relatively uniform beam diameter throughout the region of interest. The diameter of the cylinder is approximately 1 mm, which is equivalent to 12η. The sheet experiment only requires the addition of a cylindrical lens that allows the creation of a light sheet, which has the same width as the cylindrical volume, but covers the camera's entire region of view. For every tagging event, we image the evolution of the phosphorescent cloud during approximately 2 ms at a rate of 5 kHz, which is roughly equivalent to $0.4\tau_\eta$ inter-frame time. For each experiment we record 3,000 independent tagging realizations.

The cylindrical cloud experiments can be processed in two different ways. By phase-averaging the recorded sequences, that is, superimposing the n^{th} frame of each sequence and getting its mean width, we can, in principle, calculate the absolute or point source dispersion of a cloud. If we, instead, process each sequence independently, we can obtain the relative dispersion of the particle cloud, that is, the growth of the distance between cloud pairs. Fig. 3 shows images for a single tagging event and for a phase-average over 3,000 realizations.

The sheet experiment gives us the ability to study preferential concentration from both statistical and dynamical perspectives. From single shots, we can calculate the correlation and fractal dimension, and see their evolution as a function of time. Fig. 4 shows the two-dimensional correlation function $g(\boldsymbol{r})$ and a time sequence of the radial correlation function. It can be observed that the tails increase and the middle part of the correlation dips, which is a signature of the voids and clusters generated by preferential concentration.

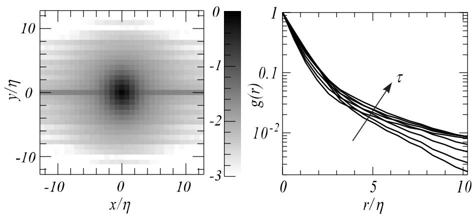

FIG. 4. (a) Correlation function $g(\boldsymbol{r})$ of the intensity distribution of glowing droplets at a delay of $\tau/\tau_\eta = 0.4$ since tagging them in a laser sheet. The gray scale is logarithmic. (b) Azimuthal average $g(r)$ of $g(\boldsymbol{r})$ at increasing delay times, $\tau/\tau_\eta = 0.4 - 3.2$.

As stated earlier, we are interested in the dynamics of preferential concentration. To quantify the timescales of clustering, we must find a quantity that captures the short-time dynamics of this phenomenon. Balkovsky *et al.* [8] proposed using the local moments of the particle concentration n and comparing them to the average concentration throughout the field. $\langle n^\alpha \rangle / \langle n \rangle^\alpha$. From theoretical predictions, this quantity is expected to grow exponentially if clustering is indeed present in the particle concentration field. This quantity can be calculated using our phosphorescent tagging technique, however, a few modifications are required before this can be done, since the instantaneous velocity field is required.

V. CONCLUSION

We have presented a novel method to study particle-laden flows which uses phosphorescent droplets that can be tagged and followed for a relatively long time. The droplets are made out of a solution doped with Europium and glow for a few small-eddy turnover times after the tagging event. We have demonstrated two possible applications of the technique, that is, tagging of thin cylindrical clouds and sheets. The information that these experiments provide may help decipher the short-time dynamics of particle-laden flows.

Throughout this study we have established the applicability of the phosphorescent tagging technique. The method has the capability of revealing new aspects of the physics of multiphase flows that other experimental techniques may not capture. We believe this is a promising technique that can find applications in many other settings and help scientists and engineers better understand particle-laden flows.

Acknowledgements This work was performed under the supervision of N. Dam and W. van de Water. The phosphorescent solution was developed in collaboration with Thanja Lamberts. This work is part of the research program of the 'Stichting voor Fundamenteel Onderzoek der Materie (FOM)', which is financially supported by the 'Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO)'. The author would also like to acknowledge support from COST Action MP0806 Particles in Turbulence.

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EFMC10-EUROMECH Young Scientist Prize Paper

"Hydrodynamics of stealthy propulsion by plankton"

Navish Wadhwa won the EUROMECH Young Scientist Prize, awarded at the 10th EUROMECH Fluid Mechanics Conference held in Copenhagen, September 2014

Navish Wadhwa[*3], Thomas Kiørboe[4], Anders Andersen[1]*

Abstract

Small planktonic organisms face significant challenges in open waters, having to constantly scan large amounts of water for food and mates, and avoid predators at the same time. Mechanical cues are exceedingly important in the absence of vision at small scales, thus there is an incentive to minimize any flow disturbances. In this paper, we summarise our examination of swimming associated flows using a combination of experiments and theory. Measurements of the flows for a wide range of plankton reveal that the spatial decay of the flow velocity is dictated by the swimming mode, a dependence explained by simple physical models. Breast stroke swimming, a common propulsion mode in plankton, results in "quiet" swimming, in which flow velocity decays as one over distance cubed. We used a simple three point force model to simulate this swimming gait, the results from which agree well with experiments.

1. Introduction

Plankton are an important group of aquatic organisms, most of which have sizes smaller than a few millimetres. Phytoplankton, the photosynthesis performing component of the plankton community, are responsible for a large fraction of the primary production that makes life possible on the planet. Zooplankton, the non-photosynthetic plankton, acquire energy by feeding on smaller plankton, in turn making it available for the higher organisms such as fish. Thus, phytoplankton and zooplankton form two of the most important components in any models of mass and energy fluxes in the global biogeochemical cycles [1].

Many plankton need to swim in order to find nutrients and mates. But swimming comes at a cost – any form of propulsion generates flow disturbances which can be picked up by mechanosensitive predators. Thus, while swimming improves fitness by aiding in reproduction and food acquisition, it puts survival itself at risk, potentially outweighing the gains. It is thus imperative for all swimming organisms to maximize the ratio between gains and risks by reducing the flow disturbance produced during swimming.

Planktonic propulsion can be divided into two main categories, consisting of four propulsion modes (Figure 1). In the first category, plankton feed and swim at the same time. An example of this category is the so-called cruising mode, in which the organism moves forward at a constant speed. The organism constantly scans the water for prey and captures them upon coming into contact, thus feeding while it swims. In other cases, the organism stays stationary due to being denser than water, the force of pull from the current equalling its excess weight. This mode is termed hovering. Even though there is no net propulsion in hovering, we include it in our analysis due to the flow disturbance it creates.

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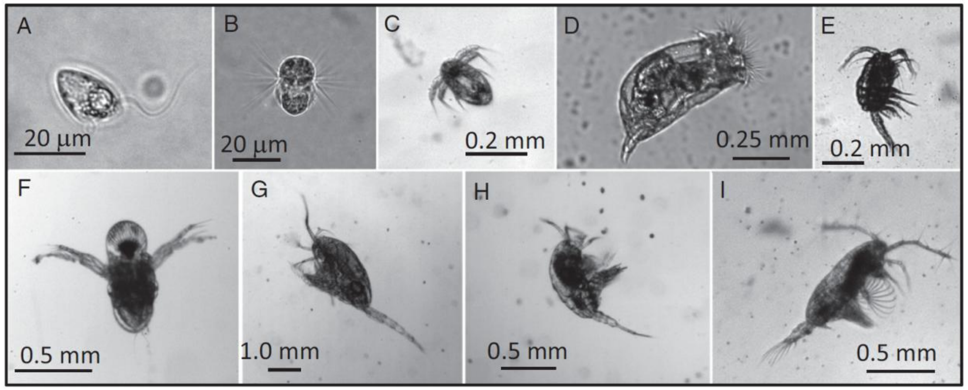

Fig. 1: Examples of planktonic organisms which swim with different modes. The dinoflagellate *Oxyrrhis marina*, cruiser (A), the ciliate *Mesodinium rubrum*, breast stroke swimmer (B), *Acartia tonsa* nauplius (juvenile), breast stroke swimmer (C), the rotifer *Brachionus plicatilis*, cruiser (D), the copepod *Oithona davisae*, jumper (E), the cladoceran *Podon intermedius*, breast stroke swimmer (F), the copepod *Metridia longa*, cruiser (G), the copepod *Temora longicornis*, hoverer (H), and the copepod *A. tonsa*, jumper (I). Adapted from Ref. [2].

The other category consists of modes used for swimming alone. It consists primarily of two propulsion modes – breast stroke swimming and jumping. In breast stroke swimming, bilaterally organized swimming appendages or equatorial cilia move backwards simultaneously to push the organism forward, similar to human breast stroke swimming. In jumping, a number of appendages move backwards impulsively, creating high forward accelerations. Both breast stroke swimming and jumping are used only for propulsion, as the organisms does not feed while in the motion with these modes.

Given the relevance of flow disturbances for planktonic interactions, how does the generated flow depend on the swimming mode? Can the relationship between the swimming mode and flow disturbance be understood using simple physical principles?

2. Flow disturbance due to various plankton

The dependence of the flow disturbance on the swimming mode has recently been studied experimentally [2]. Using particle image velocimetry, Kiørboe et al. (2014) measured the velocity fields created by a variety of free swimming plankton (Figure 1). From the velocity fields, they measured the size of the region around the organism where the flow velocity exceeded a certain threshold. By varying the threshold velocity and measuring the corresponding size of the region of influence, spatial decay of the swimming generated flow could be characterized and approximated in terms of power laws. A swimming mode was characterized as quiet or not, depending on how fast the spatial decay of velocity was.

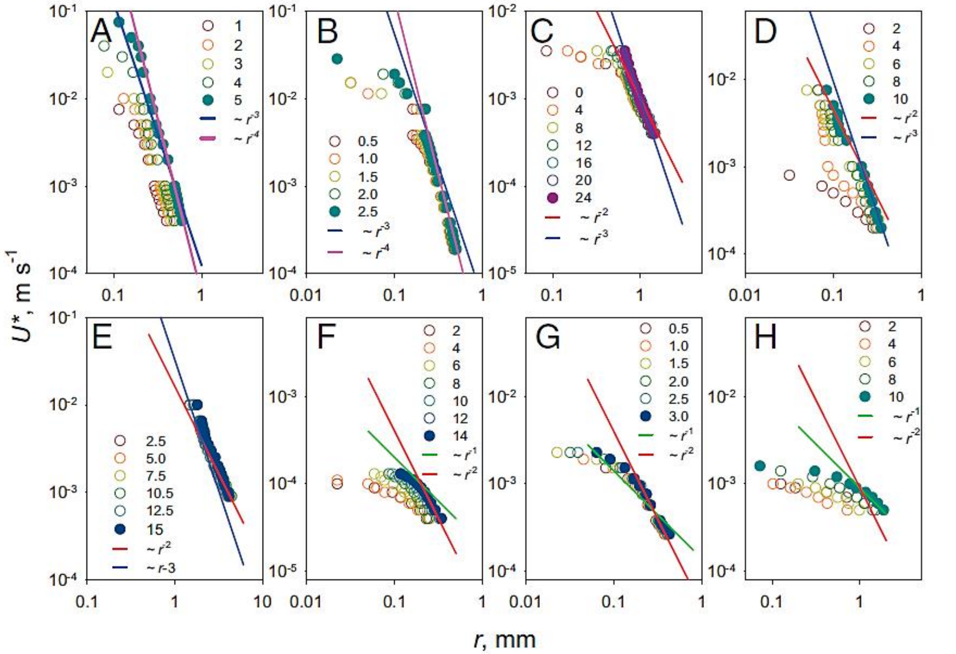

Fig. 2: Measured spatial attenuation of flow velocities. *A. tonsa* copepodite jump (A), *O. davisae* jump (B), *P. intermedius* breast stroke (C), *A. tonsa* nauplius breast stroke (D), *M. longa* cruising (E), *O. marina* cruising (F), *T. longicornis* nauplius feeding(G), and *T. longicornis* hovering (H). The solid circles show the velocity at the peak of the power stroke and the open circles the velocity during the time leading up to the peak at times given in milliseconds. The solid lines show power laws with slopes between −1 and −4 and were adjusted to line up with the far field flow attenuation at the peak of the power stroke. Adapted from Ref. [2].

2.1 Decay of flow velocity

Figure 2 shows the decay of velocity (U^*) with distance (r) for the various planktonic species, measured at different instances during the swimming stroke of the organism. Only the flow velocity measured at the peak of the stroke when the influenced area is the largest, is used for analysis (filled circles in Figure 2). When distinguished by the exponent of the power law describing the velocity decay, the different species fall into four groups. For hovering organisms, the velocity decays as r^{-1}, for cruisers, it decays as r^{-2}, for breast stroke swimmers, r^{-3}, and for jumping plankton, velocity decays with distance as r^{-4}. Thus the spatial decay of velocity away from the organism was strongly affected by the swimming mode. Moreover, the modes used for swimming alone (breast stroke swimming and jumping) have a faster spatial decay of velocity, than the modes which are used for swimming and feeding at the same time (hovering and cruising).

2.2 Rationalization of the observed differences in the spatial decay of flow velocity

The observed dependence of the spatial decay of velocity on the propulsion mode can be explained with the help of simple point force models. The case of a hovering organism can be approximated by a single point force acting on the fluid ([3], Figure 3A). This idealized force configuration has been studied thoroughly, a well-known analytical solution known as the Stokeslet describes the flow created by such a configuration [4]. The Stokeslet indeed gives a flow-field in which the velocity decays with the inverse of distance, similar to the measurement for hovering organisms [3,4].

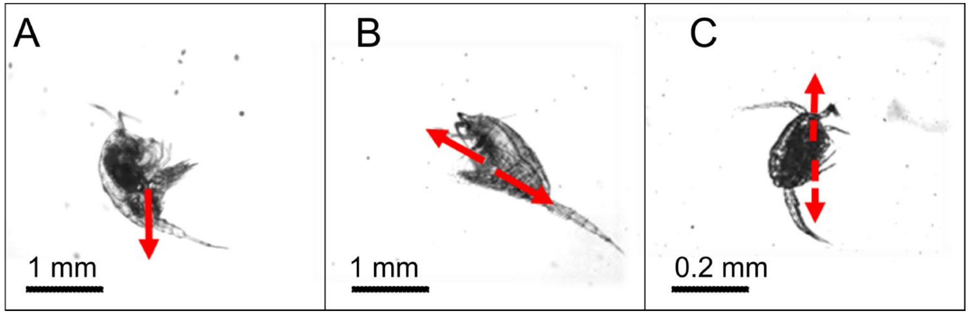

Fig. 3: Schematic representation of the propulsive forces and the drag forces for a hovering *T. longicornis* (A), a cruising *M. longa* (B), and a jumping *O. davisae* (C) as point forces. Only the red forces act on water. The dashed vectors in (C) represent the impulsiveness of the point forces.

For the cruising organisms, the flow behavior can be described by another singularity model known as the stresslet, in which the velocity decays as r^{-2} [3, 5]. A stresslet is composed of two equal and opposite point forces acting at points separated by a very small distance, a configuration which approximates the thrust and drag forces applied on the water by a cruising organism (Figure 3B). If the forces act for only a very short amount of time, as is the case for jumping organisms (Figure 3C), then the solution is given by an impulsive stresslet, for which the velocity decays as r^{-4} [6].

3. Breast stroke swimming

Breast stroke swimming is a common mode of swimming among plankton, and there has been much work towards understanding the associated hydrodynamics. Most of the previous work has focused on the biflagellate green algae *Chlamydomonas reinhardtii*, particularly focusing on questions related to synchronization of flagella [8]. While there have been measurements of the velocity field created by *C. reinhardtii* [9,10], the spatial decay of velocity has only been measured for the time averaged flow in Ref. [9]. Also, flow fields created by other planktonic breast stroke swimmers have received little attention in the literature. In the rest of this article, we focus on the breast stroke swimming mode and describe a simple model that explains the observed decay of velocity for such swimmers. The following discussion on breast stroke swimming also highlights the more general question of how far field flow disturbances can be modified by changes in the spatial organization of the propulsive forces. The following is based on our recently published work [7].

3.1 Three point force model

The simple model we used to represent breast stroke swimming organisms consists of three point forces acting on the water, all acting in the *xz* plane (Figure 4). Two forces of magnitude F each, representing the thrust produced by the appendages, acting at (a, b) and ($-a$, b), point in the negative z direction. A single force of magnitude $2F$, representing the drag force from the body acting at (0, $-b$), points in the positive z direction. There is thus no net force acting on the water, a condition required for low Reynolds number propulsion by neutrally buoyant organisms. In our analysis, we keep the force magnitude constant and only vary the aspect ratio α of the configuration, given by $\alpha = a/b$.

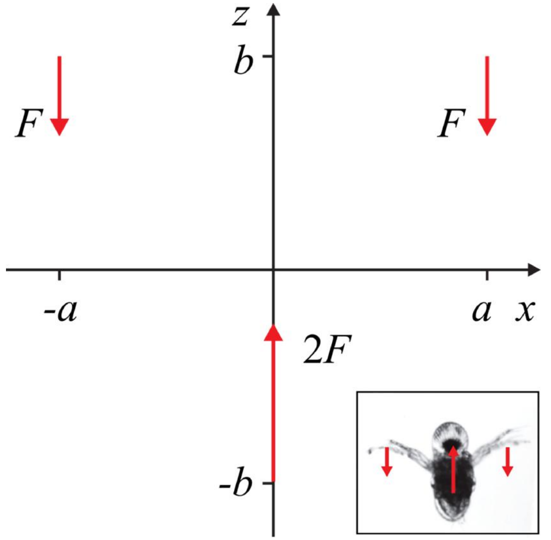

Fig. 4: The three point force model. The forces act in *xz* plane and the sum of forces is zero. The inset shows a schematic representation of the three point forces produced by a swimming *Podon intermedius*.

The flow field due to a single point force $\boldsymbol{f}$ acting at a point $\boldsymbol{x}'$ is given by the Stokeslet, for which the velocity $\boldsymbol{v}$ at a point $\boldsymbol{x}$ can be written in index notation as

$$v_i(x) = \frac{1}{8\,\pi\,\mu}\left[\frac{f_i}{|\boldsymbol{x}-\boldsymbol{x}'|} + \frac{f_j(x_j - x_j')(x_i - x_i')}{|\boldsymbol{x}-\boldsymbol{x}'|^3}\right],$$

where μ is the dynamic viscosity of water. Since the Stokes equations are linear, flow due to a number of Stokeslets distributed in space, like the configuration shown in Figure 3, can be added together to find the net flow resulting from the action of all of the forces. We analyzed the net flow due to the three point force model, and studied the effect of the aspect ratio α on the flow structures and the spatial decay of velocity.

It is worth noting here that the far field flow behaviour for arbitrary force configurations can be conveniently studied by applying a multipole expansion on them, as described in Ref. [7]. In the following plots, we also show for reference the far field velocity predicted by the multipole expansion. For the complete expressions of those curves, the reader is referred to Ref. [7].

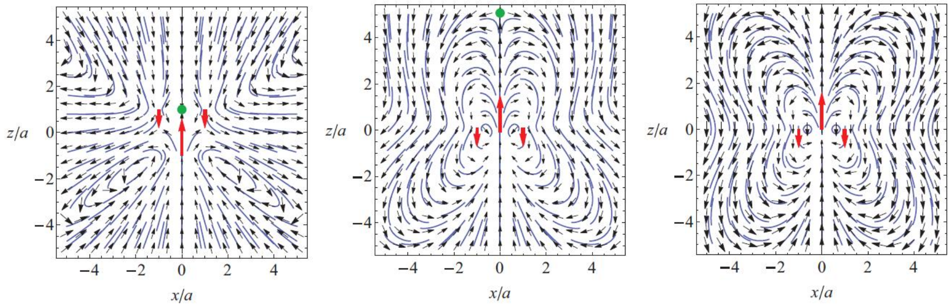

Fig. 5: Velocity fields in the three point force model for α = 1 (left), α = 0.1(middle), and α = 0 (right). The red arrows represent the point forces and the green dots the stagnation points on the z axis. The flow fields are shown as black vectors and blue streamline segments. Adapted from Ref. [7].

3.2 Results

Figure 5 shows the flow fields due to the three point force model for three different values of α: 1, 0.1, and 0. It is evident that the flow structure changes quite significantly with changing values of α. When α = 1, the flow structure resembles the flow fields for a puller stresslet, with downwards flow on the positive z axis and upwards on the negative z axis. The distinguishing feature is the two counter-rotating whirls on each side of the z axis, and a stagnation point on the positive z axis. As α is reduced, the stagnation point moves further up along the z axis and eventually when $\alpha = 0$, the stagnation point moves away to $+\infty$. In this situation, the flow mainly consists of two counter-rotating flow structures, qualitatively similar to what has been experimentally observed for breast stroke swimming plankton [2].

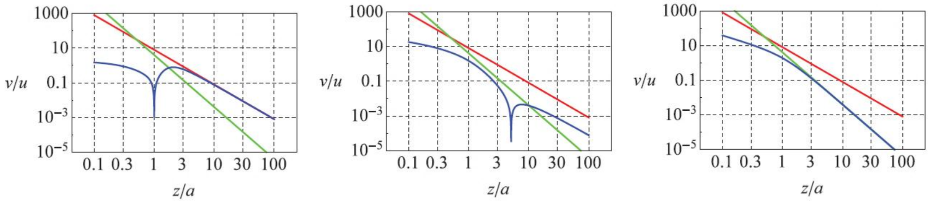

Fig. 6: Magnitude of the velocity in the three point force model (blue) on the positive *z* axis with α = 1 (left), α = 0.1 (middle), and α = 0 (right). Also shown are the far field approximations for α = 1 (red) and α = 0 (green), based on the multipole expansion. Adapted from Ref. [7].

The velocity magnitude in the three point force model for the different values of α is shown in Figure 6. Only the velocity on the z axis is shown here, but the far field behaviour is qualitatively the same in all directions. The expressions for the far field velocity predicted from the multipole expansion are also shown for reference in red and green for $\alpha = 1$ and $\alpha = 0$, respectively. We find that just like the flow structure, the spatial decay of velocity is strongly affected by the value of α. For $\alpha = 1$, the far field flow velocity decays as one over distance squared (red curve), while for $\alpha = 0$, the far field decay is faster as the velocity decays as one over distance cubed (green curve). In general, the flow field of a three point force model is composed primarily of dipole and quadrupole components, which decay as r^{-2} and r^{-3} respectively. Thus, for large α, the flow is dominated by a dipole while for $\alpha = 0$, the dipole is eliminated and the flow is dominated by a quadrupole. For small values of α, e.g. 0.1, while the far field flow decays as a dipole (r^{-2}), closer to the organism the flow field is dominated by the quadrupole component with r^{-3} decay. Moreover, not just the spatial decay is stronger, the magnitude of the flow velocity is also smaller for $\alpha = 0$ as compared to the case with $\alpha = 1$. Thus, our study shows that with small α, a three point force model captures both the flow structure and velocity decay observed for breast stroke swimmers.

4. Conclusions and Outlook

Swimming in many groups of plankton over a large range in size has recently been studied. These studies have revealed a high diversity in the hydrodynamics, more than has been reported previously for other small organisms such as bacteria and green algae. In particular, there are different degrees of spatial decay in velocity for different groups of plankton, which are strongly related to the swimming mode. The spatial decay of velocity is undeniably important for plankton due to its role in modulating predator-prey interaction in the open ocean.

Swimming modes such as breast stroke swimming and jumping have been found to be hydrodynamically quieter than the other modes such as hovering and cruising. Motivated by this observation and hypothesizing that the spatial decay could be affected by the spatial organization of the propulsion forces, we have explored a simple model to capture the hydrodynamics of breast stroke swimming. Using point forces to represent thrust and drag forces, we found that the flow structure and its spatial decay could indeed be manipulated by changing the organization of the forces, in this case by changing the aspect ratio α. When the points of action for forces became collinear on the x axis, the dipole component of the flow vanished and the flow decayed as one over distance cubed, thus becoming “quieter”. This matches well with the spatial decay of velocity measured for small breast stroke swimmers [2].

Moreover, a further analysis of the three point force model using the multipole expansion showed that it works quite well even relatively close to the organisms [7]. This underscores the strength of point force models and multipole expansion for studying propulsion in small organisms. The quiet swimming effects of spatial organization of the propulsive forces might also explain the diversity in propulsive apparatus of organisms that is found in nature.

The biggest limitation of such models is their inability in incorporating the effects of inertia. It is especially relevant for some of the swimmers studied here as the Reynolds number for them is of the order of 10. The impulsive stresslet model discussed before incorporates the inertial acceleration term, but all other models discussed here are devoid of inertial effects, and are applicable only in a quasi-steady sense. We recognize that in some quiet swimmers, fast spatial decay of velocity might be due to inertial effects. These considerations might be needed for the breast stroke swimmers at Reynolds numbers between 1 and 100.

4. Acknowledgements

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ESMC9-EUROMECH Young Scientist Prize Paper

"Multiscale simulations of fracture propagation in hierarchical composites"

Lucas Brely won the EUROMECH Young Scientist Prize, awarded at the 9th ESMC in Madrid, 6-10 July 2015.

Lucas Brely [1], Federico Bosia [1], Nicola M. Pugno [2, 3, 4]

5

Abstract

It is known that an appealing strategy in developing novel artificial materials is to reproduce optimized structures found in nature, leading to smart and multifunctional solutions in mechanical engineering [1]. To do this, one needs to understand how the complex structure of biomaterials at various size scales influences their overall mechanical properties, and to apply optimization criteria to artificial ones. The arrangement of nano- to macro- components is generally organized in a hierarchical structure in the materials found in Nature. Some well-known examples are spider silk, gecko toes, sea shells, bone, etc. These novel structural criteria introduce new possibilities in the field of composite material design, in particular since the introduction of nano-reinforcements such as nano-tubes, or graphene, open up the possibility of creating truly multiscale composite materials. These novel materials should be able to achieve tailor-made, simultaneously optimized mechanical properties, such as stiffness, strength, toughness, etc. To design such complex artificial materials, a robust simulation approach needs to be developed to aid in preparing experimental solutions.

Here, we develop a multiscale numerical model to simulate the mechanisms involved in damage progression and energy dissipation at different size scales in such hierarchical composites, considering all relevant parameters. These depend on the heterogeneity of the material (defects and reinforcements), hierarchical structure, interface properties between matrix and reinforcements, etc.. All of these aspects are incorporated into a numerical model, based on a Lattice Spring Model (LSM) [2], with quasi-static loading conditions.

1. Introduction

Mechanical properties displayed by biomaterials differ and stand outside traditional engineering materials in that they shows some optimized competing properties such as strength and toughness or stiffness and density [3, 4]. The mechanisms involved in those properties are usually linked to the biomaterials internal structures, which may include complex heterogeneous architectures, with a hierarchical arrangement of microstructural and base components [5, 6].

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In order to obtain artificially created materials with similar properties, the challenge is therefore to capture the optimization criteria related to the internal structure and to replicate them [7, 8]. Fibre based composites already combine lightweight and directional strengthening properties to optimize the material response to specific applications, but are still not able to obtain simultaneously the stiffness/density or strength/toughness combinations seen in biocomposites. With the recent introduction of nano reinforcements such as carbon nanotubes, nano ribbons or graphene [9, 10], new possibilities for artificial multiscale hierarchical composites have emerged and the present work could provide valuable support for the design and optimization of these advanced materials, drawing inspiration from, and going beyond, biological materials with exceptional mechanical properties.

Therefore, we developed a numerical model to study the impact of the composite structures on global mechanical properties. Classic finite element models encounter difficulties in modelling crack growth, which is in the present study related to the determination of the composite toughness, and requires complex remeshing procedures. The LSM approach allows accurate descriptions of crack growth problems.

2. Numerical model

To simulate fracture propagation in heterogeneous media, the domain is discretized in a set of nodes that are connected with axial springs. The Lattice Models approach is based on a discontinuous formulation which avoids singularity related issues. An example of the regular grid used to discretize a material portion is showed in Figure 1. The spring properties (Elastic modulus and volume) are obtained through a homogenization procedure based on the equivalence of stored strain energy between the spring network and the continuum. The stored strain energy for the spring network is obtained as the sum of the spring's strain energy contributions in one node:

$$\begin{aligned} U_{continuum} &= \frac{1}{2}\int_V (\sigma_{xx}\varepsilon_{xx} + \sigma_{yy}\varepsilon_{yy} + \sigma_{zz}\varepsilon_{zz} + \tau_{yz}\gamma_{yz} + \tau_{xz}\gamma_{xz} + \tau_{xy}\gamma_{xy})dV \\ &= \sum_s U_s \end{aligned} \quad (1)$$

The regular lattice obtained can be local or non-local (one node is linked with its first neighbours or in a wider range). It has been shown that for fracture propagation simulations, a non-local network avoids path dependency problems [11].

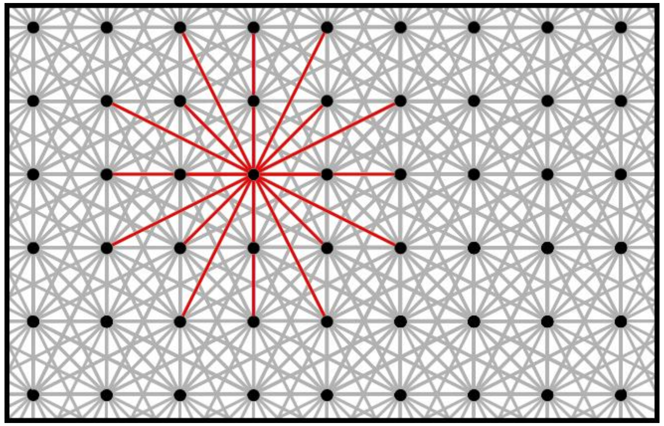

Fig. 1: Example of a 2D spring network with non-local bonding.

An iterative scheme is used to deal with the large rigid motion and large deformation arising from fracture growth during simulations. The total Lagrangian formulation is employed at each simulation step in order to achieve equilibrium between internal and external forces.

Fracture is introduced by removing springs that exceed a maximum strain at each loading step.

Figure 2 shows an example of the strain distributions in 2D samples around singularities, a centred crack in the first case and a rigid line inclusion in the second case.

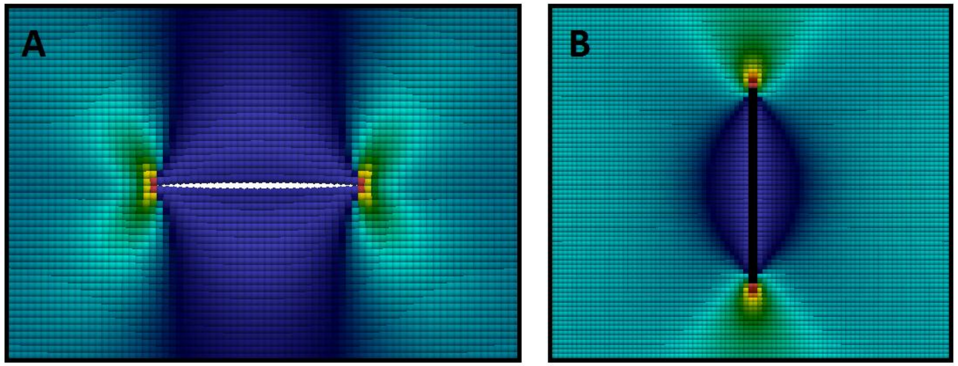

Fig. 2: Strain fields around a cracked sample (A) and a line stiffener (B).

To simulate multiple scale levels, i.e. the hierarchical organisation of the composite, we apply a bottom up strategy. From the nano or micro scale, we derive mechanical properties and global material response to various loading cases and use them as input for the upper scale level (Figure 3). If random structures are added at the bottom hierarchy level, the mechanical properties are defined in the upper level by a Weibull probability law, by the calculation of scale and shape parameters from the distribution obtained.

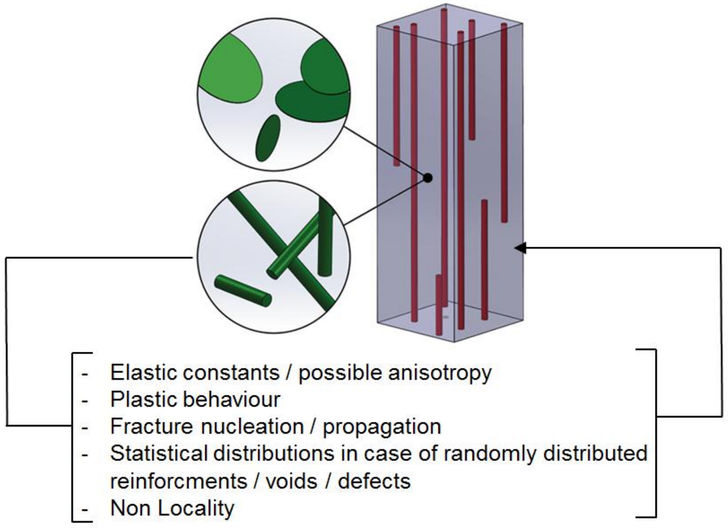

Fig. 3: Schematic representation of the bottom up strategy employed for the description of hierarchical composites.

3. Simulations

Deriving the material properties from the lower scale to the upper ones, the first step is to define the mechanical properties as a function of the reinforcement's shape, size and orientation (Figure 4) at the lowest scale (nanotubes or graphene embedded in the matrix). It is well known [12] that the presence of stiff inclusion gives on one hand a stiffening of the material, but on the other hand a stress concentration inside the material, which lead to a decreased toughness. Matrix properties also plays an important role here, such as the non-locality or the non-linear behaviour which is useful to spread the load around the most stressed domains and delay the crack nucleation.

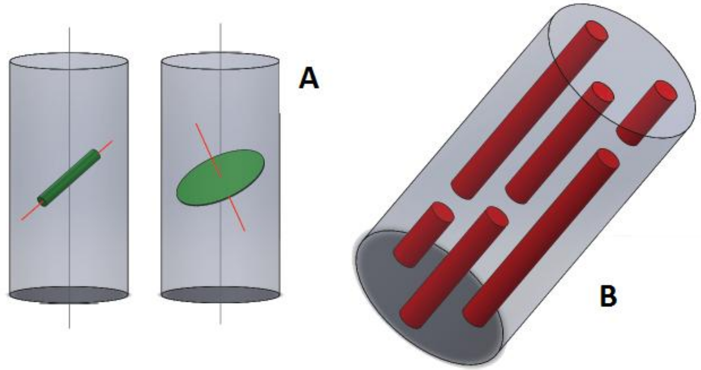

Fig. 4: Orientation of the reinforcements inside the matrix (A), overlapping in the composite structure (B).

Then, at a single scale level, we derive an optimization criterion as a function of the pattern of the inclusions. Some organized structures with preferential orientation or/and overlapping of the reinforcements are likely to give results that differ from a fully random configuration. As a simple example, orientated line inclusion (such as nanotubes) will increase the stiffness of the composite in the direction of the lines, whereas the stiffness in the other directions remains almost unchanged. The challenge is then to create a structure at the upper scale level where the load transfers between the reinforcements through the matrix take advantage of the lower scale optimization.

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EUROMECH Fellows: Nomination Procedure

The European Mechanics Society (EUROMECH) Council introduced the category of **EUROMECH Fellow**, starting in 2006. 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.

The nomination form for Fellow can be downloaded on the websitehttp://www.euromech.org/fellows.

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 package (nomination form and supporting letters) must be submitted **before 31 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 Fellowship 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 Fellowship award ceremony will take place during the EFMC or ESMC as appropriate.

EUROMECH- European Mechanics Society: Fellow Procedure

EUROPEAN MECHANICS SOCIETY

Required documents and how to submit nominations:

Suggested citation to appear on the Fellowship Certificate (30 words max);
Supporting paragraph enlarging on the citation, indicating the originality and significance of the contributions cited (limit 250 words);
Nominee's most significant 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, employer, duties, dates);
Each sponsor (there are two sponsors) should sign the nomination form, attach a letter of recommendation and provide the following information:

1. sponsor's name;
2. professional address;
3. email address;
4. sponsor's signature/date.

Required documents and how to submit nominations:

Nomination packages need to be sent as electronic files, before 31 January of the respective EFMC and ESMC, to the Chair of the Fellowship Committee with a copy to the President (G.J.F.v.Heijst@tue.nl) and to the Secretary General (suquet@lma.cnrs-mrs.fr) of EUROMECH.

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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:

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

Nomination packages need to be sent as electronic files before **31 January in the year of the respective EFMC and ESMC** to the Chair of the Prize Committee with a copy to the President (G.J.F.v.Heijst@tue.nl) and to the Secretary General (suquet@lma.cnrs-mrs.fr) of EUROMECH.

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 European Fluid 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
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Solid Mechanics Prize

The nomination deadline for the Solid Mechanics prize is **31 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)
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EUROMECH Conferences in 2016

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.

2016

EMMC15
15th European Mechanics of Materials Conference
DATE: 7-9 September 2016
LOCATION: Brussels, Belgium
CONTACT: Prof. L. Delannay
E-MAIL: laurent.delannay@uclouvain.be
Website: http://sites.uclouvain.be/emmc15/

EFMC11
11th European Fluid Mechanics Conference
DATE: 13-16 September 2016
LOCATION: Sevilla, Spain
CONTACT: Prof J. Gordillo
E-MAIL: jgordill@us.es
Website: http://www.efmc11.org/

EUROMECH Conferences Reports

ETC14 - 14th European Turbulence Conference

ETC14 included 8 invited papers, covering four important areas in the field of fluid turbulence. These were:

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 (identification of noise sources).
Turbulent transport of particles
A. Johansson (fibres in a turbulent channel flow).

The invited 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 and Lattice Boltzmann simulations.

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:

1 Particles in Turbulence.
2 Lagrangian Turbulence.

was demonstrated by the number of presentations. These topics had featured prominently during ETC13 in Warsaw. Other well-represented topics were:

3 Instability and Transition.
4 Turbulence in Boundary Layers.
This encompasses many fundamental aspects also with major applicative challenges, such as drag reduction.
5 Turbulent convection.
This covers fundamental aspects of instabilities, but also important geophysical questions. The seemingly simple problem of Rayleigh-Benard convection continues to challenge the community, and fundamental issues about heat transport are still highly debated.
6 Magnetohydrodynamics This included presentations over a wide range of sub-topics, from planetary dynamics, turbulence in plasmas, and liquid metal technologies.

Six sessions were dedicated to advances in methodologies: two each for experimental advances, numerical studies and theoretical aspects. Four sessions were dedicated to Geophysical and Astrophysical questions, where turbulence plays a crucial role. Other presentations with geo-astrophysical motivations were also programmed into more specific sessions with emphasis on: Rotation, Stratification, MHD and 2-dimensional effects. The three sessions dedicated to Cryogenic Turbulence are a sign of the recent growth of interest in the turbulence community, which has now developed the tools needed to investigate extreme regimes of classical turbulence at very high Reynolds numbers, as well as other aspects related to the quantum properties of superfluid 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. The two sessions dedicated to Taylor-Couette flows showed renewed interest in this area, with the stress on momentum transport in a very turbulent system. Two sessions were dedicated to specific industrial problems and prototype studies. Several other sessions, such as those entitled Control, Mixing, Compressible Turbulence and Reactive Flows, also covered industrial applications. This is an important aspect of ETC conferences which stimulates the connection between academic and industrial worlds.

EMMC14 – 14th European Mechanics of Materials Conference

The 14th European Mechanics of Materials Conference (EMMC14) took place at Chalmers University of Technology (Campus Johanneberg) in Gothenburg, Sweden on August 27-29 2014. The venue is within walking distance of the Gothenburg city center. The conference was organized by the division of Material and Computational Mechanics at Chalmers University of Technology under the chairmanship of Prof. Kenneth Runesson.

The aim was to bring together researchers working in various fields of material mechanics and with different backgrounds (engineering and applied mathematics as well as physics, chemistry, etc.). Contributions were welcomed on any material of mechanics issue covering the macroscale down to the atomic-quantum level. Altogether 20 sessions were organized by specially appointed Session Organisers on the following topics (topical sessions):

1 Ductile damage and fracture. Organiser: Jonas Faleskog, Royal Inst of Tech. Stockholm
2 Experimental nano- and micromechanics. Organiser: Ruth Schweiger, Karlsruhe Inst. of Tech.
3 Functional materials and coupled mechanics (hygro-electro-thermo-mechanical). Organiser: Andreas Menzel, Univ. of Dortmund
4 Advanced full-field deformation measurements and parameter identification. Organiser: Magnus Ekh, Chalmers Univ.
5 Higher-order continua. Organiser: Samuel Forest, MINES Paris Tech.
6 Time-dependent mechanics of metals: visco-elasticity, visco-plasticity, creep. Organiser: Laurent Stainier, Ecole Centrale de Nantes
7 Time-dependent polymer mechanics. Organiser: Rafael Estevez, Grenoble INP-SIMaP
8 Stochastics & material mechanics. Organiser: Francois Willlot, MINES Paris Tech.
9 Multi-scale techniques and scale bridging. Organiser: Varvara Kouznetsova, The Tech. Univ. of Eindhoven
10 Surfaces and interfaces. Organiser: Joris Remmers, The Tech. Univ. of Eindhoven
11 Phase field approaches in mechanics of materials. Organiser: Ingo Steinbach, Univ. of Bochum
12 Contact and friction mechanics. Organiser: Laura De Lorenzis, Techn. Univ. Braunschweig
13 Complex microstructures and microstructure evolution. Organiser: Håkan Hallberg, Univ. of Lund
14 Fatigue, reliability and lifetime predictions. Organiser: Lennart Josefson, Chalmers Univ.
15 Phase transformations and moving interfaces. Organiser: Kerstin Weinberg, Univ. of Siegen
16 Plasticity across the scales. Organiser: William Curtin, EFPL Lausanne
17 Failure in quasi-brittle materials: Organiser: Jerzy Pamin, Crakow Tech. Univ.
18 Particle mechanics (granular flows) Organiser: Vanessa Magnanimo, Univ. of Twente
19 Quantum and atomistic modeling. Organiser: Paul Erhart, Chalmers Univ.
20 Biomaterials. Organiser: Liz Tanner, Univ. of Glasgow

The chosen scheme, with session organisers inviting contributions in addition to an open call for abstracts, worked well in terms of attracting high-quality contributions. A plenary lecture by a younger, highly respected scientist was scheduled for the morning session on each one of the three days of the conference. The plenary lecturers were: Prof. Erica Lilleodden, Helmholtz-Zentrum Geesthacht, Germany; Prof. Eric Maire, Univ of Lyon, France; Prof. Vikram Desphande, Univ. of Cambridge, U.K.

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 2016, and preliminary information for some Colloquia in 2017, are given below.

EUROMECH Colloquia in 2016

553. Bearing Technologies in Rotor Dynamics
Chairperson: Dr. F. Donhal
Department of Mechanical Engineering
Petersenstrasse 30
D-64287 Germany
E-mail: donhal@sdy.tu-darmstadt.de
Co-chairperson: Prof. P. Pennacchi
Dates and location: 5-8 September 2016, Italy
Website: http://553.euromech.org/

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-Chairpersons: Prof. Stepan Lomov
Dates and location: 1-5 September 2015, France

571 Jet Noise Modeling and Control
Chairperson: Lutz Lesshafft
Laboratoire d'Hydrodynamique (LadHyX)
Ecole Polytechnique
91128 Palaiseau cedex, France
E-mail: lesshafft@ladhyx.polytechnique.fr
Dates and location: 28-30 June 2016, France
Website: http://571.euromech.org/

572 Constitutive Modelling of Rocks and Soils
Chairperson: Günter Hofstetter
Institute for Basic Sciences in Engineering Science
Faculty of Engineering Science, University of Innsbruck
Technikerstraße 13
A-6020 Innsbruck, Austria
E-mail: Guenter.Hofstetter@uibk.ac.at
Co-Chairpersons: Prof. Alessandro Gajo, Prof. Dimitrios Kolymbas
Dates and location: 22-24 February 2016, Austria
Website: http://572.euromech.org/

576 Wind Farms in Complex Terrains
Chairperson: Prof. Dan Henningson
Royal Institute of Technology (KTH Mechanics)
Osquars Backe 18
100-44 Stockholm, Sweden
E-mail: henning@mech.kth.se
Co-Chairpersons: Prof. Jens Sorensen, Prof. Henrik Alfredsson
Dates and location: 8-10 June 2016, Sweden
Website: http://576.euromech.org/

580 Strongly Nonlinear Dynamics and Acoustics of Granular Metamaterials
Chairperson:Prof. Guillaume James
Laboratoire Jean Kuntzmann and INRIA Grenoble Rhône-Alpes
Tour IRMA, BP 5338041
Grenoble Cedex 9, France
E-mail: guillaume.james@inria.fr
Co-Chairpersons: Prof. Alexander F. Vakakis, Prof. Chiara Daraio
Dates and location: 11-13 July 2016, France
Website: http://580.euromech.org/

581 Dynamics of concentrated vortices
Chairperson: Prof. Sergey Alekseenko
Kutateladze Institute of Thermophysics, SB RAS
1 Lavrentyev Ave
Novosibirsk, 630090, Russia
E-mail: aleks@itp.nsc.ru
Co-Chairpersons: Prof. Jens N. Sørensen, Prof. Valery Okulov
Dates and location: 30 May-1 June 2016, Russia
Website: http://581.euromech.org/

582 Short fibre reinfoced cementitious composites and ceramics
Chairperson: Dr. Heiko Herrmann
Centre for Nonlinear Studies, Laboratory of Nonlinear Dynamics
Tallinn University of Technology
Akadeemia Tee 21
EE 12618 Tallinn, Estonia
E-mail: hh@cens.ioc.ee
Co-Chairpersons: Prof. Jürgen Schnell
Dates and location: 20-23 June 2016, Estonia
Website: http://582.euromech.org/

583 Scientific and technological challenges in offshore vertical axis wind turbines
Chairperson: Prof. Carlos Simão Ferreira
Delft University Wind Energy Research Institute
TU Delft
Kluyverweg 1
2629 HS Delft, The Netherlands
E-mail: c.j.simaoferreira@tudelft.nl
Co-Chairpersons: Dr. Uwe Schmidt Paulsen
Dates and location: April 2016, The Netherlands
Website: http://583.euromech.org/

584 Multi-uncertainty and multi-scale methods and related applications
Chairperson: Prof. Andrade Pires
Department of Mechanical Engineering of Porto University
Rua Dr. Roberto Frias,
s/n 4200-465 Porto, Portugal
E-mail: fpires@fe.up.pt
Co-Chairpersons: Dr. Chenfeng Li
Dates and location: 13-16 September 2016, Portugal
Website: http://584.euromech.org/

587 Modelling and simulation of additive manufacturing processes
Chairperson: Prof. Robertt Valente
GRIDS Research Group, Centre for Mechanical Technology and Automation
Department of Mechanical Engineering
University of Aveiro, Portugal
E-mail: robertt@ua.pt
Co-Chairpersons: Prof. Ferdinando Auricchio, Prof. Paulo Jorge Bártolo, Prof. Hinnerk Hagenah
Dates and location: 9-11 May 2016, Portugal
Website: http://587.euromech.org/

EUROPEAN MECHANICS SOCIETY

EUROMECH Colloquia in 2017

578. Rolling Contact Mechanics for Multibody System Dynamics
Chairperson: Prof. Jorge A.C. Ambrósio
IDMEC, Instituto Superior Técnico, Universidade de Lisboa
Av. Rovisco Pais 1
1049-001 Lisbon, Portugal
E-mail: jorge@dem.ist.utl.pt
Co-Chairpersons: Prof. Werner Schiehlen
Dates and location: 10-13 April 2017, Angra do Heroismo, Portugal

579 Generalized and microstructured continua with inextensible fibers: new ideas in modeling and applications
Chairperson: Prof. Francesco Dell'Isola
Department of Structural and Geotechnical Engineering
Università degli Studi La Sapienza di Roma
via Eudossiana 18
00184, Rome, Italy
E-mail: francesco.dellisola.memocs@gmail.com
Co-Chairpersons: Prof. David Steigmann
Dates and location: 3-8 April 2017, Italy

585 Advanced experimental methods in tissue biomechanics
Chairperson: Prof. Markus Böl
Technische Universität Braunschweig
Institute of Solid Mechanics
Schleinitzstr. 20
38106 Braunschweig, Germany
E-mail: m.boel@tu-bs.de
Co-Chairpersons: Prof. Alexander E. Ehret
Dates and location: February 2017, Germany

586 Turbulent superstructures in closed and open flows
Chairperson: Prof. Joerg Schumacher
Department of Mechanical Engineering,
P.O.Box 100565, TU Ilmenau,
D-98684 Ilmenau, Germany
E-mail: joerg.schumacher@tu-ilmenau.de
Co-Chairpersons: Prof. Bruno Eckhardt, Prof. George Haller
Dates and location: 12-15 July 2017, Germany

EUROMECH Colloquia Reports

EUROMECH Colloquium 554
“Dynamics of Capsules, Vesicles and Cells in Flow”
15 – 18 July, 2014, Compiègne, France
Chairperson: Dr. Anne-Virginie Salsac
Co-Chairperson: Dr. Mark Blythe

The DynaCaps 2014 Symposium on the “Dynamics of Capsules, Vesicles and Cells in Flow”, designated EUROMECH Colloquium 554, was held at the University of Technology of Compiègne (UTC) in Compiègne (France) on July 15-18, 2014. It received the support of the European Mechanics Society, International Union of Theoretical and Applied Mechanics, Association Française de Mécanique and the Région Picardie.

Scope of the Colloquium
Encapsulated soft particles are commonly encountered in nature (seeds, cells, phospholipid vesicles) and in different industrial applications (biotechnology, pharmacology, cosmetics, food industry). The role of encapsulation is to protect a substance with a solid envelope. It avoids its dispersion in the ambient environment or its degradation in contact with it. The membrane may be a lipid bilayer (vesicles), a reticulated membrane with elastic properties (artificial capsules) or a lipid bilayer connected to a cytoskeleton (cells).
Various aspects of the mechanics of capsules/vesicles/cells were covered during the meeting:

Characterization of their mechanical properties, which is difficult owing to their small size and fragility;
Role of the fabrication process on the physical and mechanical properties of artificial capsules or vesicles (shape, size, degree of reticulation, membrane mechanical properties). Controlling the membrane properties is essential to optimize the design and production of specific particles for each application;
Deformation of the capsules/vesicles/cells when suspended in an external flowing fluid The Symposium has brought bring together theoreticians and experimentalists who work on the mechanics, physics and biology of capsules/vesicles/cells.

EUROMECH Colloquium 554 provided the opportunity to confront the various approaches used to study the flow and deformation of such deformable particles. Relatively few experimental studies of these phenomena exist, but recent progress in microtechnology has opened new perspectives. The motion and deformation of these particles is a complex fluid-structure interaction problem. The present numerical models all include simplifying assumptions, the relevance of which has yet to be established. The Colloquium provided an opportunity for discussion of current results and the needs of future research.

Best Poster Award
The committee was composed of the invited speakers. The Best Poster prize was awarded to Matsanuga Daiki, Tohoku University (Japan).

Best Presentation Award
All the graduate students served as members of the Best Presentation Award committee. The prize was awarded to Merkel Tobias, Karlsruhe Institute of Technology (Germany).

EUROMECH Colloquium 556
"Theoretical, Numerical and Experimental Analyses in Wood Mechanics"
27 – 29 May, 2015, Dresden, Germany
Chairperson: Prof. Michael Kaliske
Co-Chairperson: Prof. Josef Eberhardsteiner

Background

Wood is one of the oldest materials used by mankind. Timber and wooden products continue to be widely used in architecture and industry. Wood finds a huge variety of applications ranging from large-span glued laminated timber beams and load-carrying components in Civil Engineering, through musical instruments to pressure, heat and moisture modified material for new, innovative products. Apart from the mechanical and aesthetic quality of the material, its eco-friendly features are highly significant and are likely to grow in the future.

In order to provide the desired, optimised components and to develop new applications, deep mechanical knowledge, theoretical modelling, experimental investigations and numerical simulation approaches are required. Features to be identified inlude anisotropic elasticity, ductile plasticity, brittle fracture and time-, moisture- and temperature-dependency. Moreover, wood shows properties that depend on length scales so that it might be described as a composite structure instead of a homogeneous material. The features depend on a large number of influence factors like growth conditions and yield a significant amount of scattering with respect to its properties. Much research is required in order to understand and describe wood properly from the mechanical point of view. Currently, lively and advanced research activities are under way in order to develop a comprehensive knowledge. EUROMECH Colloquium 556 aimed to bring wood-mechanical scientists together for the presentation of their research and to provide a platform for fruitful discussions.

There were altogether about 50 participants and 39 presentations, among them three keynote lectures, by:

- Erik Serrano (Lund University, Sweden);
- Ingo Burgert (ETH Zurich, Switzerland);
- Hans Joachim Blaß (KIT Karlsruhe, Germany).

There were many opportunities during the Colloquium for discussion and informal dialogue between participants. A large number of different issues can be categorised into experimental and theoretical/numerical analysis.

- **Experimental Analysis** In different sessions, knowledge was shared concerning the specific material properties of exotic wood species and timber which are important for an appropriate analysis of them. The participants gained insight into topics such as the behaviour of moulded wooden beech tubes and the influence of climate on an antique violin during a concert. Further, the mechanical behaviour of joints, such as dowel connections, was considered. Measurement techniques for damage detection in wood and wooden structures were discussed in other sessions. Techniques for the optical measurement of strains in living trees under bending, and the monitoring of deformations in the famous Mona Lisa painting were described.

- **Theoretical and Numerical Analysis** The theoretical and numerical analysis of wood and wooden or timber structures is highly dependent on the results of experimental analysis. For all developed and applied theories and material models, verification by experiment is essential. In recent research projects, discussed at the Colloquium, wood failure mechanisms have been studied intensively. Therefore, one session dealt with the simulation of fracture. Different theories and models, such as XFEM, were introduced. Simulation of timber structures continues to be a major challenge. Due to the high variability of all properties of this natural material and inhomogeneities such as knots, there is large uncertainty in the behaviour of timber.

The inclusion of knot orientation and element in FE element formulations, as well as representation of uncertain parameters by randomness or fuzziness, were presented. Another aspect was the modelling of wooden products, such as wood shear walls, furniture or cross-laminated timber. Hygro-mechanical coupling was pointed out as a predominant influence on the performance of wood. Theoretical models and investigations for the origin of swelling and shrinkage gave an insight into the microstructure of wood, while different models for simulating moisture transport and its effect on the mechanical behaviour of wooden structures were discussed. The practical relevance of numerical analyses on the macro-scale was underlined by case studies concerning panel paintings and a violin. Recent advances in understanding the physical properties of wood, the mechanical behaviour of wood based products, and in simulating related problems, were discussed at EUROMECH Colloquium 556. The Colloquium has helped to stimulate collaboration that will lead to better understanding of this fascinating material and its products.

Finally, the organisers wish to thank EUROMECH for making this fruitful scientific colloquium possible, and for financial and organisational support.

EUROMECH Colloquium 559
"Multi-scale computational methods for bridging scales in materials and structures"
23 – 25 February, 2015, Eindhoven, The Netherlands
Chairperson: Dr. Varvara Kouznetsova
Co-Chairpersons: Prof. Dr. Julien Yvonnet, Prof. Christian Miehe

Background
In recent years, considerable progress has been made in bridging the mechanics of materials to the structural engineering level supported by advances in multi-scale modelling. Different classes of computational scale bridging methods have been developed to this purpose, spanning different disciplines, e.g. engineering, computational mechanics, mathematics, physics, chemistry etc. Although these methods have usually been equipped for a specific research problem, from a methodological point of view, similarities and distinctive features can be identified. Examples include:

- Methods that either rely on the separation of scales principle, or directly embed the fine scale model in the course scale one, leading to either nested or concurrent solution procedures;
- Two-way coupling (fine-coarse and vice versa) or one-way (fine scale informed coarse scale model);
- The use of fine scale models for either extracting new emerging phenomena at the coarse scale, or quantification of the a-priori known coarse scale behaviour.

EUROMECH Colloquium 559 served as a forum for bringing together scientists from different disciplines working on scale bridging problems (both spatial as well as temporal) in materials and structures. The Colloquium aimed to identify common and distinct features of different techniques as well as their limitations and upcoming challenges, in order to stimulate interdisciplinary cross-fertilisation.

The colloquium attracted about 60 participants from various European countries, as well as The USA, Japan and Argentina. The scientific program included 33 invited oral presentations and 15 contributed posters. The presentations and posters covered a broad range of multi-scale subjects.

Colloquium Topics
The following topics were addressed throughout Colloquium 559.

- **Multi-scale modelling of damage and fracture** Damage and fracture are by their nature multi-scale processes initiating at the very fine microscopic scale and propagating through scales up to the macroscopic cracking and failure. This is a particularly challenging topic, since fundamental hypotheses such as scale separation are violated in the case of damage and fracture. This requires the development of dedicated multi-scale schemes, several of which were presented and discussed during the Colloquium.
- **Model order reduction techniques in space and time** Many scale bridging techniques, especially those suitable for non-linear problems, lead to high computational costs. This hampers their application to the practical problems relevant for engineering practice. Dedicated multi-scale reduced-order modelling techniques are needed. Several such approaches were presented.
- **Uncertainty and stochasticity** The issues of randomness, uncertainty and stochasticity in geometrical and material properties are inherent to microstructures. In scale bridging, it is therefore important to consider the propagation of microstructural stochasticity towards the macroscopic material and structural performance. Multi-scale approaches dealing with these issues were discussed.
- **Coupled-field, multi-scale problems** The use of advanced materials requires solution of multi-scale, multi-field problems. Typically the mechanical stress field is coupled to other fields, such as diffusion of certain elements, phase transformation, electrical and magnetic fields and fluid-saturated porous media. This requires the careful reconsideration of single-field multi-scale approaches and the development of new techniques.
- **Surface and interface phenomena** Consideration of multi-scale phenomena at the surfaces and interfaces brings in new challenges, These were illustrated by multi-scale modelling of friction, delamination of polymer-metal interfaces and coarse-grained atomistics with free surfaces.
- **Expanding application areas** Application areas requiring multi-scale and scale bridging methods for materials and structures is growing. It spans classical engineering materials, such as metals, polymers and composites, through natural materials that include geological and granular materials, to materials that enable new emerging technologies.

The Colloquium programme included a visit to the Multi-scale Laboratory of the Mechanics of Materials Group at Eindhoven University of Technology, where new experimental techniques for multi-scale material characterisation were demonstrated. We thank our sponsors: 3TU Research Centre "Fluid and Solid Mechanics', Eindhoven Multiscale Institute and Université Paris-Est Marne-la-Vallée. Finally, we thank EUROMECH for making this meeting possible, and for financial and organisational support.

EUROMECH Colloquium 560
"Mechanics of Biological Membranes"
8 – 12 February, 2015, Ascona, Switzerland
Chairperson: Prof. Edoardo Mazza
Co-Chairperson: Prof. Jean-François. Ganghoffer

Background
The term "biological membrane" refers to biological structures on various length scales from cell membranes to thin soft tissues such as the capsules of the abdominal organs, the foetal membrane, the eardrum, heart valve leaflets, layers of the arterial wall or skin, to mention only a few examples. In-vivo, many of these structures also function as membranes in a mechanical sense, allowing dedicated formulations of mechanical problems. Biological membranes have inspired the search for and development of synthetic materials and engineered tissues with comparable characteristics. Fundamental research in biology and medical questions associated with these fields increasingly motivate investigations aimed at characterising, understanding and modelling the mechanical behaviour of biological membranes and their bio-inspired counterparts. These investigations, their implications, and future directions formed the scope of EUROMECH Colloquium 560.

Colloquium 560 brought together international leading experts and young scientists from all areas of research related to the mechanics of biological membranes, from both fundamental research and applied science. It was open for contributions that address fundamental questions, experimental techniques, mechanical models and numerical simulations.

Scope of Colloquium 560
The aims of Colloquium 560 were to:

- Develop a common language;
- Foster the interaction between the disciplines;
- Identify common problems and strategies of solution;
- Establish a strong link between research and technical or biomedical applications as well as clinical practice.

The scientific programme included 29 oral presentations, six of which were keynote lectures given by international experts which highlighted distinct aspects of the mechanics of biological membranes. These concerned:

- Rupture of the foetal membrane;
- Simulation of the tympanic membrane;
- Characterisation of microcapsules;
- Tissue engineering of cardiovascular membranes;
- Clinically applicable skin grafts;
- Heart valve implants for the developing world.

All contributions were followed by active discussion between participants.

Conclusions
The meeting was attended by researchers from different disciplines, including various fields of engineering, biology, physics, mathematics and medicine. The meeting showed that, in spite of the different areas of expertise, it is possible to develop a common understanding of current problems, which might be one of the milestones towards their solution. At the same time, it underlined the importance of establishing and using an interdisciplinary "language" understandable for all researchers in the fields of interest.

The relatively small size of the meeting in combination with the convenient conference venue at Monte Verità hosting all participants provided an ideal basis to train such a language and foster the scientific exchange between the disciplines not only during the lectures but also during coffee breaks, lunch and dinner.

Many of the scientific results discussed during the Colloquium will be disseminated to the scientific community in a dedicated, peer reviewed special issue of the Journal of the Mechanical Behavior of Biomedical Materials. The feedback from participants was very positive throughout. We are very grateful to EUROMECH, the Congressi Stefano Franscini and the Swiss National Science Foundation for their support, making Colloquium 560 possible.

EUROPEAN MECHANICS SOCIETY

EUROMECH Colloquium 562
“Stability and control of nonlinear vibrating systems”
25 – 29 May, 2015, Sperlonga, Italy
Chairperson: Prof. Angelo Luongo
Co-Chairperson: Prof. Sara Casciati

Scope of Colloquium 562
Studies of the dynamics of nonlinear systems show that, when the nonlinearities are explicitly considered in the calculations, they allow a correct understanding of the behaviour that can be exploited to improve the performance. Both controlled and uncontrolled systems were considered and the stability issues were addressed. Modelling of the mechanical system was recognised as a key ingredient, and problems were formulated at either the macro or micro scale.

A plethora of nonlinear phenomena observed in macrostructures are waiting to be observed and exploited for mass sensing at the microscale. Pull-in, sudden collapse of electrostatic MEMS, or any other unsafe bifurcation, sub-critical pitchfork or cyclic fold bifurcation, can be used as mass detection mechanisms in binary chemical and biological sensors. At the macroscale, the large amplitude dynamics of rotating pendula, delayed van der Pol oscillators, and bistable oscillators might be exploited in energy harvesting applications. Moreover, the nonlinear dynamics and the modal stability of cables, beams, moving strings, discrete systems with a large number of degrees of freedom and towers, under both conservative and nonconservative actions, are being studied intensively with a view to discovering and understanding their rich bifurcation scenarios. To this end, also the study of classical paradoxical systems is alo being addressed.

Specific topics
Examples of specific topics discussed at Colloquium 562 are listed below.

- **Modelling issues in stability and bifurcation of dynamical systems** The modelling of complex mechanical structures and the external actions are key to the analysis of the stability and post-critical behaviour of dynamical systems. Reduced models were shown to be valuable since, in a variety of applications they are able to capture the essential dynamical phenomena.
- **Unexpected phenomena in nonlinear dynamical systems** Unexpected phenomena can sometimes manifest themselves in nonlinear systems. Examples discussed at the Colloquium were: tensile instability in beam-like structures; interactions between nonlinear normal modes and linear frequencies; static and dynamic stability of a thin rod under axial compression. Some celebrated paradoxes related to follower actions in one-dimensional systems, were also addressed.
- **Vibration control in operational conditions** In controlled systems, the task of vibration mitigation can be pursued using passive, active or semi-active strategies. Including nonlinearities in the design of the controllers is often a difficult process, which is however fundamental to ensure a correct performance. Relevant research efforts are dedicated to the development of simplified modelling techniques.
- **Motion tracking control** The development of tension control strategies that allow a tethered satellite to be steered from one position to another in minimal time and allowing for tether oscillations was discussed.
- **Limit cycle control** When the control objective is stabilisation of a system by suppressing or reducing its limit cycle oscillations, the coupling of the main system with a nonlinear energy sink can be considered as an effective passive control strategy. The particular case in which the main system is an oscillator with hardening elasto-plastic behaviour was discussed.
- **Generalised continua** Generalized continua were discussed in a dedicated session. They provide as a powerful tool for the description of newly conceived materials and complex structures, such as the biological systems. Metamaterials are among the most promising and rapidly developing research areas, and the link between theoretical aspects and new possibilities in computer-aided manufacturing is of great interest.

EUROMECH Colloquium 567
"Turbulent mixing in stratified flows"
22 – 25 March, 2015, Cambridge, UK
Chairperson: Prof. Paul Linden
Co-Chairperson: Prof. Jean-Marc Chomaz

EUROMECH Colloquium 567 consisted of 3 invited lectures, 49 oral presentations and 12 posters over 3 days.

Colloquium themes
The main themes of the Colloquium are listed below.

- **Instability and transition** The discussion was concerned with stability and transition in stratified shear flows. Results were presented of transient growth and minimal seeds using the direct-adjoint-looping method, coupled with direct numerical simulations. The role of stratification as characterised by the Richardson number was clearly identified by the way in which streamwise streaks prevalent in unstratified flows were significantly altered by stratification. The form of the stratification was also shown to be an important factor, with interfaces having high density gradients producing significant spatial variability in momentum, energy and mass fluxes. This, in turn, raises questions about the relevant length scales in stratified flows, the way in which overturns are characterised, and the importance of viscous forces as measured by the buoyancy Reynolds number.
- **Buoyancy-driven mixing and plumes** Buoyancy-driven flows correlate buoyant fluid with vertical motion and so provide an effective means of vertical disper-sion and mixing. This was studied in unsteady plumes generated by time-varying buoyancy fluxes, and in confined regions with an imposed unstable buoyancy flux. Both experiments and DNS results were interpreted in terms of dispersion closure models, where the dispersion coefficients depended on the buoyancy flux. These models work well even when the flow is multi-phase, such as in a particle-laden flow.
- **Field observations** Oceanographic measurements made in a range of locations showed the importance of finite amplitude waves and other structures in causing mixing. Tidally forced events caused large shears and turbulence, as did other structures such as internal bores. At the associated high Reynolds numbers, the form of shear instabilities observed by acoustic backscatter were quite different from classical KH billows typically seen in laboratory experiments and DNS and there was a suggestion that sustained forcing plays an important role in some cases.
- **Effects of rotation** Potential vorticity gradients can provide restoring forces that inhibit mixing in a manner similar to stable density gradients. These effects were nicely demonstrated in experiments on rotating plane Couette flow and in stratified Taylor-Couette flow. Intriguing finite amplitude structures were observed in these flows through the interaction with the horizontal shear and a restoring force. Equally, these flows also exhibit new instabilities such as stratorotational instability. Pancake vortices in rotating flows also exhibit a range of instabilities depending on their aspect ratio and relative vorticity.
- **Internal waves** Internal waves are ubiquitous in stratified fluids and they interact with topography and generate turbulence and mixing. This was discussed in the context of breaking solitary waves on a slope, waves impinging on a slope at the critical angle, and through parametric subharmonic instability, whereby the energy in the primary wave is redistributed to a pair of waves with resonant wavenumbers and frequencies. These triadic interactions were also found to be very sensitive to background flow. Experiments and numerical studies showed that contributions to mixing can be significant in the right circumstances, and the predictions are supported by field measurements.
- **Diapycnal mixing** A distinguishing feature of stratified turbulence is the resulting mixing across density surfaces. Papers at Colloquium 567 discussed field observations in the ocean and atmosphere, driven by convection or other mechanical driving mechanisms such as separation from buildings. The effects of strong stratification on these processes were discussed through analysis of high-resolution DNS and LES and experiments on gravity currents. The efficiency of these various flows remains a major question, considered in a number of papers. These showed that details of both the large and small-scale features of the flows were important, since the efficiency depends on irreversible modification of the density field which is a molecular process. Consequently, the approximation often used in practice of a constant value for the mixing efficiency should only be used under severe caution.

EUROMECH Colloquium 570
"Multi-scale analysis of the impact of microstructure on plasticity and fracture in interface-dominated materials"
20 – 23 October, 2015, Houffalize, Belgium
Chairperson: Prof. Laurent Duchêne
Co-Chairperson: Prof. Aude Simar

EUROMECH Colloquium 570 was held far from cities, at a location that encouraged participantion in the meeting room. The presentations and activities were indeed well-supported throughout. There were 60 participants, most of whom participated in the entire 3 days of the Colloquium. More than half were young PhD students. 36 presentations where given orally, including 6 keynote lectures, and 10 posters. Invited speakers increased the quality of Colloquium 570. The conference hotel environment favoured further discussion during lunch and dinner, which sometimes continued late into the night. Other discussions were initiated during a visit to the Ashouffe brewery, which favoured new friendships within the community.

Two communities that do not talk together often enough were represented in the presentations: experimentalists and modelling specialists. They were invited to exchange views on the common theme of mechanics of interfaces. The divide between the two communities could be seen clearly during the question/answer sessions, but both communities took advantage of these exchanges and various collaborations have been initiated.

Colloquium themes

- **Elementary plasticity mechanisms** Frédéric Mompiou of the Centre d'Elaboration de Matériaux et d'Etudes Structurales of Toulouse (France) discussed his original method for observation of plasticity by in-situ TEM. William Curtin of the Ecole Polytechnique Fédérale de Lausanne (Switzerland) discussed his molecular dynamics model results. He explained both the limitations of the method and the extra value that can be derived from experimental data.
- **Crystal plasticity** Christian Niordson of the Technical University Denmark presented his results on strain gradient plasticity and also discussed the advantages and limitations of the method.
- **Interface fracture** Dominique Leguillon of the Université Pierre et Marie Curie of Paris (France) presented a theoretical study of the interaction of cracks with interfaces. This emeritus professor allowed the young researchers to take advantage of his extensive experience in the field. That was also true during the discussion around posters.
- **Plastic localization, ductility and interface fracture** Cem Tasan of the Max-Planck Institut (Germany) discussed the new method he has developed to analyse in-situ the fracture of metallic materials. This experimental method is impressive and it initiated a strong debate about the scales at which the mechanisms should be observed.
- **New systems (primarily metallic)** Harry Bhadeshia discussed the theme of percolation in steels. Senior researchers as well as junior researchers were unanimous in saying that the presentation was very interesting and didactical. All were glad to get the chance to hear this renowned scientist talk and discuss their poster on the final day.

The presentations were followed by an animated debate that was usually initiated by the more senior researchers but with younger scientists playing an active role in the developing discussion. The invited speakers participated actively in the debates and gave useful comments to the young researchers during the poster presentation session.

Poster presentations
The 10 poster presentations were a great success. All presenters gave two minute summaries of their poster presentations, before a more personalised discussion in front of the posters. The young researchers were well-satisfied with the discussions around their posters, which remained on display for the 3 days of the colloquium.

Closing session
Further animated discussion took place during the closing session. The young researchers took an active part in that discussion. It highlighted the contributions of Colloquium 570 and revealed interest in developing new experimental methods and an increase in 3D tomography imaging to investigate interface questions in material science. It also highlighted the interest in advanced numerical methods for investigation of the problem of transfer of plasticity at the interfaces.

EUROMECH Colloquium 574
"Recent trends in modelling of moving loads on elastic structures"
15 – 17 April, 2015, Anadolu University, Turkey
Chairperson: Dr. Baris Erbas
Co-Chairperson: Prof. Julius Kaplunov

Background
Analysis of moving loads on elastic structures, including bridges, tunnels, half-spaces and rings, is an important area of modern interdisciplinary research. The significance of modelling of high-speed train operations, near-surface dynamics of underground structures such as tunnels, vibration responses of bridges subject to moving loads, as well as harvesting of energy through the use of moving masses, particularly in the mining industry, motivates theoretical and experimental analysis of the related problems. Recent advances in the development of analytical, numerical procedures and experimental techniques enable treatment of 3D real world problems instead of 2D studies prevailing some time ago. The main aim of EUROMECH Colloquium 574 was to bring together researchers from diverse areas to exchange and share the latest achievements in the fields of their own expertise. The main topics of the Colloquium are indicated below.

Colloquium Topics

- **Experimental investigation of train-induced environmental vibration** Moving loads on the surface of the earth or in underground tunnels induce soil vibrations, which can strongly affect the environment. Sensitive machines can also be disturbed by these vibrations. Therefore, both experimental investigation of the vibrations due to high-speed trains, including the movement along underground tunnels, and accurate modelling of the surrounding media are of interest. Experimental data on high-speed train operations for existing networks were compared with the results of computer modelling [Bratov, Çelebi, Göktepe].
- **Computer modelling (numerical simulations) of realistic railway configurations** The effect of moving load speeds on ground vibrations was analysed numerically. The surface loads arising from high-speed trains and the interior loads moving along underground tunnels were considered. The advancement of computational technology nowadays gives a chance to approach sophisticated 3D problems modelling realistic setups. The results of numerical analysis of some of these problems were presented at the Colloquium [Bratov, Cao, Hackenberg].
- **Analytical Methods** Near resonant behaviour of elastic structures, including half-spaces and plates resting on a foundation, was a prominent theme. Although numerical methods are widely employed, analytical approaches are still important in deriving physical insights into the nature of novel moving load problems. For example, an asymptotic approach has been developed for simplifying analysis of the near-surface dynamic response [Ege, Erbaş, Kaplunov, Prikazchikov, Sahin]. The results demonstrated that such an approach is robust for tackling the difficult 3D problems associated with the case of a layered half-space. Another procedure allows derivation of the associated Green's functions in accessible form and facilitates analysis for circular and cylindrical geometries [Alexeyeva, Zakiryanova]. Kiselev described a possible anomality of the wave field induced by a source having rather general time dependence. Some nonlinear effects associated with surface wave propagation were described by Rushchitsky. Certain aspects of the relation between moving load problems and surface waves, including the peculiarities of exciting surface waves and the drift of wave speed, were mentioned.
- **Harvesting of energy** A very interesting and novel direction was introduced by Rylnikova. In her talk, she presented the possibility of harvesting energy from the moving masses, encountered particularly in the mining industry. There are important potential applications to renewable energy sources.
- **High-tech areas including micro-mechanical engineering** The modern applications of moving load problems are not restricted to the traditional fields like railway transport but also arise in high-tech domains including micromechanical engineering. Fundamental talks by Borodich and Petrov studied important problems that arise in fracture mechanics and tribology.

Concluding Remarks
The concluding open session was chaired by Prof. Kaplunov, one of the organisers of Colloquium 574. The interdisciplinary nature of the subject theme of the conference was emphasised. Recently developed advanced methodologies and possibilities for collaborative research were discussed. Colloquium 574 included valuable contributions from Munich Technical University, Delft University of Technology, Timoshenko Institute of Ukraine, Steklov Institute of St. Petersburg and Beijing University. The social programme included a banquet and a social tour of Eskişehir. These social events stimulated fruitful discussions and a friendly atmosphere among the participants, leading to very positive feedback. We would like to thank EUROMECH for supporting the Colloquium from early planning to a successful conclusion.

EUROMECH Colloquium 575
"Contact mechanics and coupled problems in surface phenomena"
30 March – 2 April, 2015, Lucca, Italy
Chairperson: Prof. Marco Paggi
Co-Chairperson: Prof. David Hills

Organisation
EUROMECH Colloquium 575 was organised under the patronage of various public authorities and associations: Città di Lucca, Provincia di Lucca, Regione Toscana, Assindustria Lucca, Lucense SCpA. The Scientific Committee, composed of worldwide experts in contact mechanics, is listed at http://575.euromech.org/committees.
Their work in promoting the Colloquium is gratefully acknowledged.

The scientific programme of Colloquium 575 featured 43 talks of 30 minutes each. This format was chosen primarily to promote discussion and interaction among participants, in line with the aims of EUROMECH Colloquia. A booklet containing the 43 abstracts of the talks was distributed to the participants in paper version and can be downloaded from http://575.euromech.org/program/scientific-program.

Background
Following previous Colloquia on Contact Mechanics and related areas: "New Trends in Contact Mechanics" (Cargese, 2012), "Nonsmooth Contact and Impact Laws in Mechanics" (Grenoble, 2011), "Contact Mechanics of Coated Bodies" (Moscow, 2002), EUROMECH Colloquium 575 demonstrated the emergence of new topics of research and open problems within topics that are summarised below.

Colloquium Topics
1. Frictional contacts and coupling between normal and tangential loading problems;
2. Multi-scale modelling of tribological problems;
3. Coupling between elastic and thermal fields in contact problems;
4. Coupling between elastic and electric fields in contact problems;
5. Solid-fluid interaction and related coupled problems;
6. Contact and wear;
7. Contact and fracture of heterogeneous materials or involving materials with voids;
8. Contact mechanics applied to biological systems, functional surfaces and thin films.

Concluding Remarks and the Prospect for Future Colloquia
EUROMECH Colloquium 575 showed a balance between analytical methods, numerical techniques, and experimental investigations. Mathematicians, physicist and engineers shared their points of views on methods and applications of contact mechanics. Active discussion between participants took place during the whole Colloquium, promoted by the choice of slots of 30 minutes for each talk and the pleasant atmosphere inside the IMT Campus of San Francesco. In spite of the long-standing tradition of the Contact Mechanics discipline, many theoretical and computational aspects remain only partially solved today. Moreover, novel areas of application of Contact Mechanics, such as in bioengineering and in composite materials, open new frontiers for research requiring further experimental confirmation.

The organisers of EUROMECH Colloquium 575 believe there is room for further exploratory colloquia on contact mechanics. These might be on a bi-annual basis, either on specific topics like contact mechanics between rough surfaces, or on topics breaking the walls between specific disciplines to foster the discussion of contact mechanics problems within a multidisciplinary perspective. This aim is not in conflict with established thematic conferences in the field and would help to enlarge the contact mechanics community.

EUROMECH Colloquium 577
"Micromechanics of metal ceramic composites"
30 March – 2 April, 2015, Lucca, Italy
Chairperson: Prof. Marco Paggi
Co-Chairperson: Prof. David Hills

Background
Metal ceramic composites are applied in different fields, including: nuclear energy, ae-rospace, prime mover development and energy conversion. The mechanical behaviour of composites is evaluated on both microscopic and macroscopic scales to take into account inhomogeneities, including cracks, and interactions between inhomogeneities.
Participation
EUROMECH Colloquium 577 concentrated on new ideas and innovations in modelling of different types of metal ceramic composites as well as on fracture of composites. The Colloquium was held at the University of Stuttgart and included a guided visit to the Mercedes Benz Museum. The main organiser was the Institute for Materials Testing, Materials Science and Strength of Materials (IMWF). 46 scientists from European and non-European countries participated in the Colloquium: 17 from the host country Germany; 8 from Russia; 21 from other countries, including Canada, Japan and USA. This worldwide representation demonstrated the international relevance of the Colloquium.

Colloquium Topics
The various contributions showed a good combination of theoretical, analytical and numerical modelling on different length scales, and experimental work. There were many opportunities for participants to exchange ideas. The Colloquium focussed on the following aspects of metal ceramic composites including functionally graded materials:

- Modelling of thermal and elastic properties from a practical point of view and of the applicability to specific problems, such as failure analysis;
- Micromechanisms of deformation and microstructural fracture aspects;
- Atomistic studies on deformation and fracture;
- Mathematical and computational modelling of cracks;
- Layered metal-ceramic composite materials, multilayer graded structures and graded interfaces.

State of the art lectures were presented by internationally known experts. The plenary lectures were delivered by Helmut J. Böhm (TU Wien, Austria), Javier LLorca (TU Madrid, Spain) Wolfgang H. Müller (TU Berlin, Germany), and keynote lectures by Georges Cailletaud (MINES Paristech, France), Pedro Ponte Castañeda (University of Pennsylvania, USA), Sergei Mikhailov (Brunel University, UK), Sergey Panin (SB RAS, Tomsk, Russia), Viggo Tvergaard (TU Denmark), and Patrizia Trovalusci (Sapienza University of Rome, Italy). There were 42 presentations in total. Talks were organized in the following sections:

- Processing, experiments;
- Micromechanics of deformation and fracture;
- Functionally graded materials;
- Fracture and failure;
- Bio/nanomaterials.

Various constitutive models were presented for particle-reinforced composites. A statistical approach for micro-scale modelling of metal ceramic composites was also presented for several specific types of composite microstructure.

There was a particular focus on composites where void growth in the metals is affected by the presence of a ceramic phase. Metal-ceramic layered composites were considered for nano-laminates. The contribution was focused in the analysis of the deformation and failure mechanisms of a model Al/SiC metal-ceramic nanolaminate by means of a combination of nanomechanical experiments and simulations. Metal-ceramic nanolaminates were found to show a dramatic increase in strength as compared to standard metal-ceramic nanocomposites. Several presentations were devoted to functionally graded materials (FGMs), a special type of composite.
Modelling was carried out on nano, meso and macro length scales. Advanced techniques for modelling of composites, such as X-FEM, coupling molecular dynamics and FE, cohesive finite element methods, as well as hierarchical FE models have been used. A wide range of metal ceramic composites was investigated, including bio-inspired materials.

Concluding Remarks
The response from participants with respect to the organisation of Colloquium 577 was very positive. The scientific programme was quite intensive, but there was also time for discussions during coffee breaks and meals. Financial support was provided by EUROMECH, SimTech, SFB-716 and DFG. The participants took advantage of opportunities to discuss problems, establish new trends and consider possibilities for future scientific cooperation. Selected papers will be published in a special issue of "Computational Materials Science".

Objectives of EUROMECH, the European Mechanics Society

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

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

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

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

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

European Journal of Mechanics - A/Solids

ISSN: 0997-7538

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

European Journal of Mechanics - B/Fluids

ISSN: 0997-7546

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

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