EUROPEAN MECHANICS SOCIETY

Newsletter 34

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President's Address

EUROMECH has recently joined forces with five leading societies (ECCOMAS, ERCOFTAC, CEAS, EUCASS and EUROTURBO) actively engaged in Aeronautics research, to promote closer cooperation through jointly sponsored events. These include conferences and workshops, research schools and the organization of mini-symposia by one society in a major conference of another society. Benefits will include mutually reduced registration fees for event participants from the six societies. It is a great pleasure to announce that the European Commission has agreed to support this effort within a Coordination and Support Action project entitled "**E**uropean **C**ollaborative Dissemination of **Aero**nautical research and applications", or E-CAero for short. This award will foster not only a much stronger collaboration between the partner societies but also an increased visibility for all.

In order to encourage a larger section of our research community to become involved in EUROMECH, a new policy has been established regarding participation in the events of the society: from now on, all non-members wishing to attend a colloquium or a conference will be expected to become members upon registration. We hope that this will give an opportunity for all delegates to experience for one year the full benefits of membership and that it will entice them to renew their membership in subsequent years!

Patrick Huerre

President, EUROMECH

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Some remarks on identification strategies for constitutive behavior

O. Allix ⋆

Olivier Allix was named fellow of EUROMECH at the sixth European Solid Mechanics Conference held in Budapest, August 2006

Abstract

Most often, identification is viewed as an ill-posed data fitting problem. The optimum set of parameters is deduced from a direct comparison between numerical experiments and actual tests, and the ill-posed nature of the problem leads to the use of a regularization technique. When the data are highly scattered, one uses filtering techniques, among which the most widely known is that proposed by Kalman and its numerous variations. Here, our objective is to discuss the potential of a somewhat different approach inspired by verification and validation concepts and techniques.

1 Introduction

Most often, identification is viewed as an ill-posed data fitting problem. The optimum set of parameters is deduced from the minimization of a least-squares functional which compares data obtained through numerical experiments and actual test results. Here, we would like to consider identification as a model quality assessment problem. Even though at first glance the differences between the two points of view may appear subtle, they can

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be important. Our approach opens a connection with the field of verification and validation. By verification, we mean an answer to the question: is the result of a calculation close enough to reality? A considerable amount of work has been devoted to the assessment of the quality of a numerical calculation compared to a theoretical model: could this experience be of some use for identification purposes? By validation, we mean an answer to the question: is a model close enough to reality? This issue of the assessment of model quality has received less attention. One should note that verification is often considered to be related to validation; verification can be viewed as a subset of model validation using an intermediate, perfectly defined reference: the conceptual model [7]. Thus, the problem of verification is rather well-posed and presents less of a challenge. Verification and identification are usually considered to be unrelated, contrary to identification and validation, due mainly to the updating process, which is usually carried out as part of a validation procedure. The first issue in verification and validation is that of the definition of an error measure between an approximate model and a reference. This raises two questions: What is the reference? What constitutes a good measure of the distance between two entities, one of which is unknown? We will start with a brief discussion of these two questions in the context of verification and validation, then, we will illustrate their relevance to identification through some basic examples.

2 Choice of the reference and of the error measure in verification and validation

a) Verification

First, we consider verification, which is clearer because the reference is given. Let us assume that the calculation of the mechanical model was performed using the classical finite element displacement method. With regard to the error measure, there are two approaches (with many variations). The first approach, proposed by Babuska in 1988 [3], is based on the non-verification of the equilibrium relation, which is the only equation of the theoretical model which is not verified. This works well in elasticity, but leads to difficulties in nonlinear problems, in which the constitutive relation is verified (at best) only at discrete times. Nevertheless, this approach has inspired some innovative identification methods [4]. The second approach to the error measure in verification, which I find well-suited for the purpose of the identification of constitutive laws, is that of the Constitutive

Relation Error (CRE), first proposed in [5]. This consists in comparing two (stress) fields: one defined through the constitutive relation and associated with a kinematically admissible displacement, and the other being a statically admissible stress field. Energy measures of the distance between two such fields can then be defined. In the case of standard materials these measures are associated with the free energy and the dissipation potential of the material.

b) Validation and updating

This topic has received much attention since 1980 and some engineering tools have become available. The area which seems to have progressed the most is that of the updating of dynamic structural models (mass, stiffness and damping) in the low-frequency range [10]. Compared to the verification problem, the question of the reference is far less clear. In some cases, the reference is assumed to be defined by the experimental measurements. In the CRE approach, the reference contains the "reliable" part of the model, such as the equilibrium equations. Moreover, if scattering of the measurements is assumed (as is often the case), the experimental data themselves are not considered to be part of the reference. This led to the concept of the Modified Constitutive Relation Error (MCRE), which has been used for the validation and updating of dynamic structural models using vibration tests [6], [8].

3 The example used in our discussion

The motivation behind the example that we are about to consider can be found in the use of tests with corrupted measurements, by which we mean uncertain measurements for which the usual approach to taking measurement uncertainties into account is not sufficient. Usually, as described by G. Maier in [9], uncertainties are taken into account simply by using the inverse of their covariance matrix to define the discrepancy function (in order to give more "weight" to more accurate data), then exploiting the data and their statistical inaccuracies sequentially, starting from an "expert estimation", to obtain estimates of the parameters and of their variances and covariances. In the case of corrupted data, the level of uncertainty can be very high, so that no statistical information can be derived from the measurements. Such tests are not rare (especially in the case of dynamic failure), and considerable amounts of money and effort are spent on tests which, due to data corruption, can be used neither for identification, nor for validation.

In order to illustrate the interest and the use of an identification strategy based on model error estimation, let us consider a simple example intended to represent a split Hopkinson bar test with corrupted measurement at both ends. The bar is assumed to be elastic, which will enable us to study the treatment of this problem with different error methods without excessive development effort. We will briefly discuss the case of a damageable rod up to failure. No technical details on the treatment of the problem will be given: these can be found in [1] for the elastic case and in [11] for cases involving damage and fracture. The direct problem which we calculated and which represents the experiment consists in loading a one-dimensional elastic specimen of length L over a period of time $[0, T]$. The rod is clamped at one end and subjected to a half-sine traction at the other end over a period of time of about 1.5 wavelengths. The quantities being measured, similar to those which could be obtained from an SHPB test, are the displacements and traction at both ends of the rod. For the sake of clarity, we focus on the simple objective of identifying the Young's modulus of the rod. Therefore, the direct problem is described by the following equations and data, where u is the scalar displacement and σ the scalar stress:

- equilibrium: $\rho\, \ddot{u}(x,t) - \sigma_{,x}(x,t) = 0$
- constitutive relation: $\sigma = E\, u_{,x}$
- initial conditions: $u(x,0) = u_0$ and $\dot{u}(x,0) = \dot{u}_0$
- measured displacements: $\tilde{u}_d(t)$ at both $x = 0$ and $x = L$
- measured traction: $\tilde{f}_d(t)$ at both $x = 0$ and $x = L$. Let us note that in this case $\tilde{f}_d$ is chosen to be a traction per unit area.

Let us observe that if all these equations were verified this would lead to an ill-posed direct problem. In fact, it is the redundancy of the boundary conditions (BC) which makes the identification possible. From a first calculation, the BC were recovered in terms of displacements $f_d^{ex}(t)$ and tractions $u_d^{ex}(t)$ at both ends, as shown in Figure 1. These quantities can be considered to be the unperturbed measurements. In order to test the robustness of the method, perturbations in terms of both displacements and traction were added to the BC.

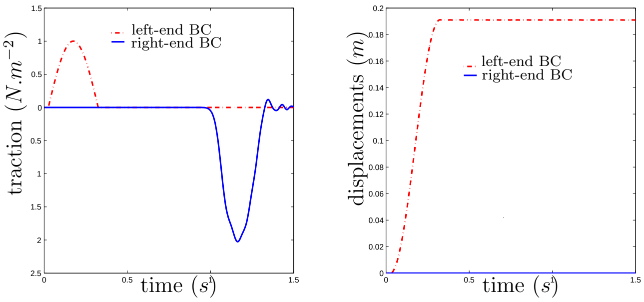
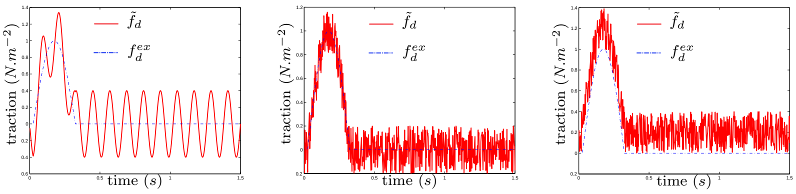


Figure 1. Boundary conditions $u_d^{ex}(t)$ and $f_d^{ex}(t)$ for the reference calculation

Several types of perturbations were used. Figure 2 illustrates one of the traction boundary conditions:



(a) Sine perturbation - 40 %

(b) Uniform white noise perturbation - 20 %

(c) Uniform white noise perturbation, nonzero mean (0.2) - 20 %

Figure 2. Traction boundary conditions at one end for various types of perturbations

4 Discussion of the CRE approaches in the case of identification

4.1 The approach with two auxiliary problems

The first method, which is easier to implement in the case of redundant information at the boundary, consists in using the experimental data to define two auxiliary problems (one with prescribed displacements, and the other with prescribed traction), then use the energy difference between the two solutions as the error indicator [12]. In statics, this type of approach was developed particularly in [2]. In our case, it works well for relatively low levels of perturbation, but leads to erroneous results in more severe cases, as can be seen in Figure 3.

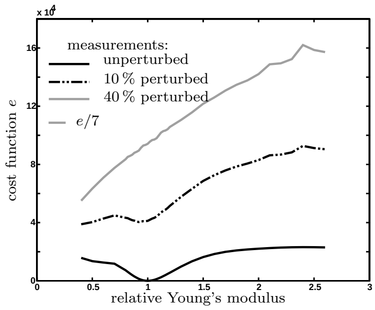


Figure 3. The cost function for various perturbation levels

4.2 Modified Constitutive error approach

There are, in fact, two questionable points in this method: (i) there are many ways to divide the experimental data into two sets, each leading to a different estimation, and (ii) the uncertain measurements are strictly prescribed in the calculation. Therefore, one would prefer a method which is exempt from these two drawbacks. This take us back to the question of how the reference is defined. The data associated with corrupted measurements should not be considered part of the reference. Therefore, we propose to divide the information into the following two groups, as shown in Table 4.2 in the case of 1D elasticity: In the following development, we will call "constraints" the conditions which must hold in order for the reliable equations to be verified.

Reliable		Unreliable	
Equilibrium:	$\rho\,\ddot{u} - \sigma_{,x} = 0$	Constitutive relation:	$\sigma = E\,u_{,x}$
Conditions:	$u(x,0) = u_0$, $\dot{u}(x,0) = \dot{u}_0$	Boundary conditions:	$\tilde{u}_d$ and $\tilde{f}_d$

Table 1. The reliable and unreliable relations in the case of 1D elasticity

Then, the basic problem we have to solve becomes:

> ***Find*** *the fields* $u(x,t)$, $\sigma(x,t)$, $u_d(t)$, $f_d(t)$, *with* $(x,t) \in [0,L] \times [0,T]$, *which minimize:*
> $$J(\sigma,u,u_d,f_d) = \frac{1}{2}\int_0^T \left\{ \int_0^L E^{-1}\left(\sigma - E.u_{,x}\right)^2 dx + A \left|\left(u_d - \tilde{u}_d\right)^2\right|_0^L + B \left|\left(f_d - \tilde{f}_d\right)^2\right|_0^L \right\} dt \quad (1)$$
> *under the constraints*

where, for all f, $\left|f(x)\right|_0^L = f(0) + f(L)$. Here, A and B are two parameters chosen such that the two terms have the same weight. The best fit corresponds to the solution of:

$$\min_E \; g(E) = J(\sigma(E), u(E), u_d(E), f_d(E), E)$$
$$\text{where } (\sigma(E), u(E), u_d(E), f_d(E)) \text{ is the solution of the basic problem} \quad (2)$$

As shown in Figure 4, the results are quite satisfactory and insensitive to the perturbation level. Let us observe that the framework was deterministic, since each identification was carried out from one set of measurements.

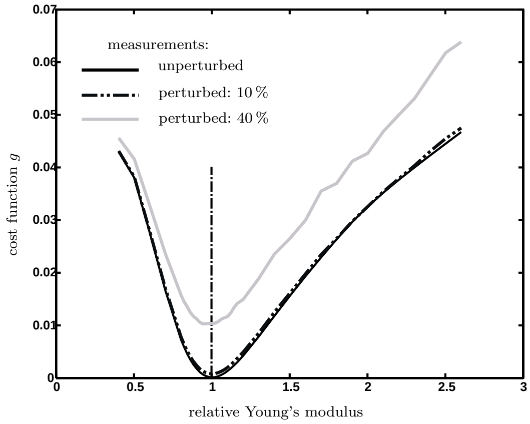


Figure 4. The cost function $g(E)$ for various perturbation levels

In order to determine the relative effects of the two features we introduced compared to the first method, let us consider a CRE method with no term to account for the error in the measurements, but which takes all the experimental information into account with no *a priori* splitting of the redundant boundary conditions. The basic formulation associated with this new problem is:

> ***Find*** *the fields* u, σ *which minimize:*
> $$J_2(\sigma, u) = \int_0^T \frac{1}{2} \int_0^L (\sigma - E.u_{,x}) .E^{-1}. (\sigma - E.u_{,x}) \, dx \, dt$$
> *under the constraints:*
> $$u \in \mathcal{U}_{Ad}(\tilde{u}_d), \quad \sigma \in \mathcal{D}_{Ad}(\tilde{f}_d, u) \tag{3}$$

The calculation fits the measurements strictly and the optimum Young's modulus minimizes the previous functional. As can be seen in Figure 5, the results are much better than with the method using two auxiliary fields. This example shows that taking into account all the experimental data in a single calculation is a key point, and also that in the case of measurement corruption the introduction of a distance between the calculation and the measurements (*i.e.* the use of a MCRE approach) is mandatory.

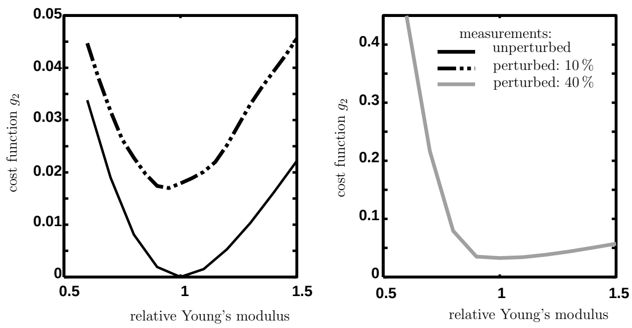
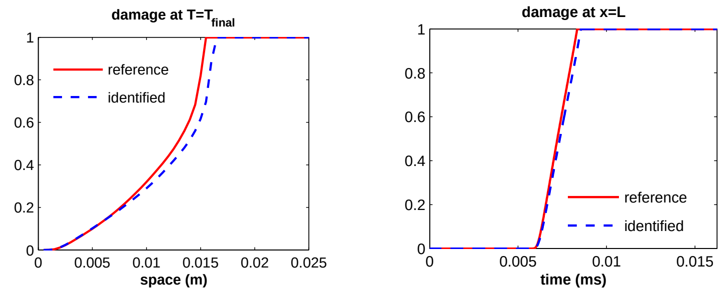


Figure 5. The cost function G_2 as a function of the Young's modulus

Let us note that the same type of result can be obtained in the more complex case of the identification of a damage model in dynamics up to failure [11]. In Figure 6, one can see that the damage field along the bar's length can be reconstructed quite well, even in the presence of very high corruption.



(a) Final reconstruction of the damage distribution

(b) Example of reconstruction of the damage evolution

Figure 6. Comparison between the reference and reconstructed damage distributions for 40 % perturbation

5 Conclusion

The point of departure of this study was our conviction that it is interesting to formulate an identification problem using a modified model error approach. Even though the technical treatment, at least in dynamics [1], [11], requires the development of new tools similar to those used in optimal control theory, this point of view opens new opportunities, especially regarding the filtering and treatment of corrupted measurements. Moreover, we think that this also opens new possibilities in terms of goal-oriented identification, much in the same way as the new developments taking place in verification.

References

[1] O. Allix, P. Feissel, and H.M. Nguyen. Identification strategy in the presence of corrupted measurements. *Engineering Computations*, 22(5/6):487–504, 2005.

[2] S. Andrieux and T.N. Baranger. An energy error-based method for the resolution of the cauchy problem in 3d linear elasticity. *Comp. Meth. in Applied Mech. and Engrg.*, 197:902–920, 2008.

[3] I. Babuska and T. Strouboulis. *The Finite Element Method and its Reliability*. Oxford University Press, 2001.

[4] Claire D., Hild F., and Roux S. A finite element formulation to identify damage fields : the equilibrium gap method. *Int. J. for Num. Meth. in Engrg.*, 61(2):189–208, 2004.

[5] P. Ladevèze. *Comparaison des modèles de milieux continus*. Thèse de doctorat dètat, Universitè Paris VI, 1975.

[6] P. Ladevèze. Recalage de modélisations des structures complexes. Technical Report 33.11.01.4, Aérospatiale, Les Mureaux, 1983.

[7] P. Ladevèze. Model validation, or how can one describe the lack of knowledge? *IACM expressions*, 19:32–35, 2006.

[8] P. Ladevèze and A. Chouaki. Application of a posteriori error estimation for structural model updating. *Inverse Problems*, 15:49–58, 1999.

[9] G. Maier, M.Bocciarelli, and R. Fedele. Parameter identification by inverse analysis in structural mechanics. *IACM expressions*, 19:21–26, 2006.

[10] J.E. Mottershead and M.l. Friswell. Model updating in structural dynamics: a survey. *Journal of Sound and Vibration*, 167 (2):347–375, 1993.

[11] H.M. Nguyen, O. Allix, and P. Feissel. A robust identication strategy for rate-dependent models in dynamics. *Inverse problems*, submitted.

[12] L. Rota. An inverse approach for identification of dynamic constitutive equations. In Bui and Tanaka, editors, *ISIP 94 : Second international symposium on Inverse problems in engineering Mechanics. Paris, 2-4 Nov 1994*, pages 157–164. Balkema, 1994.

EUROMECH Fellows: Nomination Procedure

The EUROMECH Council was pleased to announce the introduction of the category of **EUROMECH Fellow**, starting in 2005. The status of Fellow is awarded to members who have contributed significantly to the advancement of mechanics and related fields. This may be through their original research and publications, or their innovative contributions in the application of mechanics and technological developments, or through distinguished contribution to the discipline in other ways.

Election to the status of Fellow of EUROMECH will take place in the year of the appropriate EUROMECH Conference, EFMC or ESMC respectively. The number of fellows is limited in total (fluids and solids together) to no more than one-half of one percent of the then current membership of the Society.

Nomination conditions:

- The nomination is made by **two sponsors** who must be members of the Society;
- Successful nominees must be members of the Society;
- Each nomination packet must contain a completed Nomination Form, signed by the two sponsors, and no more than four supporting letters (including the two from the sponsors).

Nomination Process:

- The nomination packet (nomination form and supporting letters) must be submitted **before 15 January** in the year of election to Fellow (the year of the respective EFMC or ESMC);
- Nominations will be reviewed before the end of February by the EUROMECH Fellow Committee;
- Final approval will be given by the EUROMECH Council during its meeting in the year of election to Fellow;
- Notification of newly elected Fellows will be made in May following the Council meeting;
- The Fellow award ceremony will take place during the EFMC or ESMC as appropriate.

Required documents and how to submit nominations:
Nomination packets need to be sent before the deadline of **15 January** in the year of the respective EFMC or ESMC to the President of the Society. Information can be obtained from the EUROMECH web page **www.euromech.org** and the Newsletter. Nomination Forms can also be obtained from the web page or can be requested from the Secretary-General.

NOMINATION FORM FOR FELLOW

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

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

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

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

Fluids: ☐ Solids: ☐

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

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

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

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

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

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

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

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

SUPPORTING DATA

- Suggested Citation to appear on the Fellowship Certificate (30 words maximum);
- Supporting Paragraph enlarging on the Citation, indicating the Originality and Significance of the Contributions cited (limit 250 words);
- Nominee's most Significant Principal Publications (list at most 8);
- NOMINEE'S OTHER CONTRIBUTIONS (invited talks, patents, professional service, teaching etc. List at most 10);
- NOMINEE'S ACADEMIC BACKGROUND (University Degrees, year awarded, major field);
- NOMINEE'S EMPLOYMENT BACKGROUND (position held, employed by, duties, dates).

SPONSORS' DATA

Each sponsor (there are two sponsors) should sign the nomination form, attach a letter of recommendation and provide the following information:

- Sponsor's name;
- Professional address;
- Email address;
- Sponsor's signature/date.

ADDITIONAL INFORMATION

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

TRANSMISSION

Send the whole nomination packet to:

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EUROMECH Prizes: Nomination Procedure

Fluid Mechanics Prize
Solid Mechanics prize

Regulations and Call for Nominations

The *Fluid Mechanics Prize* and the *Solid Mechanics Prize* of EUROMECH, the European Mechanics Society, shall be awarded on the occasions of Fluid and Solid conferences for outstanding and fundamental research accomplishments in Mechanics.

Each prize consists of 5000 Euros. The recipient is invited to give a Prize Lecture at one of the European Fluid or Solid Mechanics Conferences.

Nomination Guidelines:

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

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

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

Prize committees

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

Fluid Mechanics Prize

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

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

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Solid Mechanics Prize

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

- W. Schiehlen (Chair)
- H. Myhre Jensen
- N.F. Morozov
- M. Raous
- B. A. Schrefler

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EUROMECH Conferences in 2009

The general purpose of EUROMECH conferences is to provide opportunities for scientists and engineers from all over Europe to meet and to discuss current research. Europe is a very compact region, well provided with conference facilities, and this makes it feasible to hold inexpensive meetings.

The fact that the EUROMECH Conferences are organized by Europeans primarily for the benefit of Europeans should be kept in mind. Qualified scientists from any country are of course welcome as participants, but the need to improve communications within Europe is relevant to the scientific programme and to the choice of leading speakers.

A EUROMECH Conference on a broad subject, such as the ESMC or the EFMC, is not a gathering of specialists all having the same research interests. Much of the communication that 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.

2009

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

ESMC7
7th European Solid Mechanics Conference
DATES: 7 – 11 September 2009
LOCATION: Lisbon, Portugal
CONTACT: Prof. Jorge Ambrosio
E-MAIL: jorge@dem.ist.utl.pt

EUROMECH Colloquia in 2009 and 2010

EUROMECH Colloquia are informal meetings on specialized research topics. Participation is restricted to a small number of research workers actively engaged in the field of each Colloquium. The organization of each Colloquium, including the selection of participants for invitation, is entrusted to a Chairman. Proceedings are not normally published. Those who are interested in taking part in a Colloquium should write to the appropriate Chairman. Number, Title, Chairperson or Co-chairperson, Dates and Location for each Colloquium in 2008, and preliminary information for some Colloquia in 2009, are given below.

EUROMECH Colloquia in 2009

497. Recent Developments and New Directions in Thin-Film Flow
Chairperson: Prof. Stephen K. Wilson
Department of Mathematics
University of Strathclyde,
Livingstone Tower
26 Richmond Street
Glasgow, G1 1XH, UK
Phone: +44(0)141 548 3820; Fax: +44(0)141 548 3345
E-Mail: s.k.wilson@strath.ac.uk
Co-Chairperson: Prof. G. M. Homsy, Dr. Brian R. Duffy,
Date and location: Summer 2009, Edinburgh, UK

503. Non-linear Normal Modes, Dimension Reduction and Localization in Vibrating Systems
Chairperson: Prof. Giuseppe Rega
Dipartimento di Ingegneria Strutturale e Geotecnica
Università di Roma La Sapienza
Via A. Gramsci 53
00197 Roma, Italy
Ph: +39-06-49919195, Fax: +39-06-49919192 or +39-06-3221449
E-mail: Giuseppe.Rega@uniroma1.it
Co-chairperson: Prof. Alexander Vakakis
Date and location: 27 September – 2 October 2009, Rome, Ital

504. Large Eddy Simulation for Aerodynamics and Aeroacoustics
Chairperson: Prof. Dr.-Ing. Michael Manhart
Fachgebiet Hydromechanik
Arcisstraße 21
80333 München, Germany

Ph: +49 (0) 89 289 22583
Fax: +49 (0) 89 289 28332
E-mail: m.manhart@bv.tum.de
Co-chairperson: Prof. Christophe Brun
Date and location: 23 - 25 March 2009, Technische Universität München, Germany
Website: http://www.hy.bv.tum.de/Euromech504/

506. CPNLS-09 Solitons in their roaring forties: coherence and persistence in non-linear waves
Chairperson: Prof. Jean Guy Caputo,
Laboratoire de Mathematiques,
INSA de Rouen, BP 8, 76131
Mont-Saint-Aignan cedex, France
Ph: +33 2 35 52 83 44
Fax: + 33 2 35 52 83 32
E-mail: caputo@insa-rouen.fr
Co-Chairperson: Prof. Mads Peter Soerensen
Date and location: 6 - 10 January 2009, Observatory of Nice, France

507. Immersed boundary methods: current status and future research directions, co-sponsored by ERCOFTAC
Chairperson: Dr. M. Pourquie
Laboratory for Aero- and Hydrodynamics
Dept. of Mechanical Engineering
Mekelweg 2
2628 CD Delft, The Netherlands
Ph: +31-15-2782997
Fax: +31-15-2782947
E-Mail: m.j.b.m.pourquie@tudelft.nl
Co-Chairperson: Prof. S. Turek
Date and location: 15 - 17 June 2009, Amsterdam, The Netherlands
Website: http://www.ahd.tudelft.nl/academy/

508. Wind turbine wakes
Chairperson: Prof. Antonio Crespo
Departamento de Ingenieria Energetica y Fluidomecanica
E.T.S.I. Industriale
Universidad Politecnica de Madrid
Jose Gutierrez Abascal,
228006 Madrid, Spain
Ph: +34 91 336 3152
Fax: +34 91 336 3006

E-Mail: crespo@etsii.upm.es
Co-Chairperson: Prof. Gunner Chr. Larsen
Date and location: 20 – 22 October 2009, Universidad Politécnica de Madrid, Spain

509. Vehicle aerodynamics
Chairperson: Dr. Martin Schober
MLN/TSSA Bombardier Transportation
Am Rathenaupark 16761
Hennigsdorf, Germany
Ph: +49 3302 89 3405
Fax: +49 3302 89 3669
E-mail: Martin.Schober@de.transport.bombardier.com
Co-Chairpersons: Prof. Lennart Löfdahl, Dr. Christian Navid Nayeri
Date and location: 24 - 25 March 2009, Tu Berlin, Germany

510. Mechanics of generalized continua: a hundred years after the Cosserats
Chairperson: Prof . Gérard A. Maugin
Institut Jean Le Rond d'Alembert
Université Pierre et Marie Curie
Case 162, Tour 55, 4 Place Jussieu
75252 Paris Cedex 05, France
Ph:+33.1.44.27.53.12
Fax:+33.1.44.27.52.59
E-mail: gam@ccr.jussieu.fr
Co.Chairpersons: Prof. A.V. Metrikine, Prof. V.I. Erofeyev
Date and location: 13 - 16 May 2009, UPMC-Paris, France

EUROMECH Colloquia in 2010

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

511. Biomechanics of Human Motion. New Frontiers of Multibody Techniques for Clinical Applications

Chairperson : Prof. Jorge A.C. Ambrosio
IDMEC- Instituto Superior Tecnico
Av. Rovisco Pais 1
1049-001 Lisbon, Portugal
Ph: +351 2184 17680
Fax: +351 2184 17915
E-mail: Jorge@dem.ist.utl.pt
Co-Chairpersons: Prof. Frans van der Helm, Prof. Andrés Kecskemethy

Date and location: March 2010, Ponta Delgada, Açores, Portugal

EUROMECH Colloquia Reports

EUROMECH Colloquium 489

"Modeling of Multiphase Materials"

19-21 September 2007, Chalmers University, Göteborg, Sweden.

Chairperson: Prof. Ragnar Larsson, Chalmers University, Sweden
Co - Chairperson: Prof. Stefan Diebels, Saarland University, Germany

The area of multiphase materials modeling is an established and growing field in the mechanical scientific community. There has been rapid development in recent years concerning the conceptual theoretical core of multiphase materials modeling, computational methodologies and experimental procedures.

The aim of EUROMECH Colloquium 489 "Modeling of Multiphase Materials" was to present active research in this important field and to allow discussion about problems of current interest to the community and to foster future cooperation. Issues discussed included:

- Modeling of interaction between compressible and incompressible fluids and solids;
- Phenomena of consolidation, compaction, erosion, growth, wetting and drying,

with applications in:

- Biomechanics;
- Structural foams;
- Composites;
- Soils;
- Road Mechanics.

The colloquium was supported by 35 participants from 9 European countries.

EUROMECH Colloquium 498

"Non-linear Dynamics of Composite and Smart Structures"

21-24 May 2008, Kazimierz Dolny, Poland.

Chairperson: Prof. Jerzy Warminski, Lublin University of Technology, Poland
Co-Chairperson: Prof. Matthew P. Cartmell, University of Glasgow, UK

The aim of Colloquium 498 was to provide a forum for scientists and engineers working in the field of non-linear dynamics, with a particular emphasis on composite structures, and/or structures with controllable and adaptive properties. A wide range of theoretical and applications-based problems in nonlinear dynamics were included within the scope of the colloquium. The conference also accommodated a meeting of the partners of the EU FP6 *Transfer of Knowledge* action entitled "*New Modern Composite Materials Applied in Aerospace, Civil and Mechanical Engineering: Theoretical Modeling and Experimental Verification*", coordinated by Lublin University of Technology.

About 60 people from 12 countries attended the conference; 47 oral presentations were delivered, including 7 invited keynote lectures and 3 presentations from industrial partners. Also, in addition to the regular presentations, 9 posters were presented by PhD students and young researchers from Lublin University of Technology.

Several important scientific sub-topics were discussed during Colloquium 498, including:

- Dynamics of rods, beams, plates, shells, cables;
- Modeling and control of composite and smart structures;
- Non-linear normal modes, bifurcations, stability and chaos of non-linear systems;
- Numerical and analytical methods;
- Interdisciplinary problems e.g. dynamics of the human middle ear system.

The dominant theme at the colloquium concerned composite structures and structures with Shape Memory Alloy elements. Also, granular materials, materials with Magnetic Shape Memory and composite structures with embedded PZT elements have all been investigated thoroughly in various theoretical and practical applications. An interesting presentation concerning smart structures applied in aviation was given by the PZL Swidnik SA helicopter factory.

Keynote lectures were presented by:

- **Rene de Borst (Netherlands)** - Computational Dynamics of Crack Propagation in Heterogeneous Structures;
- **Matthew P. Cartmell (UK)** - Smart Material Applications in Rotating Machines and Structural Dynamics;
- **Wieslaw Ostachowicz (Poland) -** Lamb-Wave Based Detection of Delamination and Matrix Cracking in Composite Laminates;
- **Giuseppe Rega (Italy)** - Theoretical and Experimental Non-linear Dynamics of Sagged Elastic Cables;
- **Katica Stefanovic Hedrih (Serbia)** - Dynamically Determined and Undetermined Hereditary Discrete Systems;
- **Marian Wiercigroch (UK)** - Engineering Dynamics of Strongly Non-linear Mechanical Systems;
- **Hiroshi Yabuno (Japan)** – Non-linear Control of Mechanical Systems Based on Generation and Modification of Slow Dynamics.

The colloquium meetings and accommodation were located in the same place, so that the participants could be in direct contact at any time. In addition to the formal presentations, EUROMECH Colloquium 498 provided an opportunity for useful informal discussions. The fourth day of the meeting was devoted to a tourist trip to Lublin's Old Town, the Kozlowka Palace, and Naleczow - the famous health resort.

After the colloquium, the authors of some of the most interesting presentations were invited to prepare full papers, which will be published in well-known academic journals related to the conference topic. On the basis of many comments expressed directly at the colloquium, and subsequently sent by e-mail, we believe that the meeting was really successful and that many participants learned of new scientific ideas and established new international contacts.

We would like to express special thanks to the reviewers and to the members of the Scientific Committee for their work in the preparation of the colloquium proceedings. The organisation of this colloquium was made possible due to the financial support provided by EUROMECH, the Rector of the Technical University of Lublin, the Dean of the Mechanical Engineering Faculty, and the Conference Industrial Sponsors: EC Test Systems – Grupa Energocontrol, The PZL ´Swidnik SA helicopter factory, the PKO SA Bank and Bogdanka and EkoKlinkier SA company.

EUROMECH Colloquium 501

"Mixing of Coastal, Estuarine and Riverine Shallow Flows"

8-11 June 2008, Ancona, Italy.

Chairperson: Prof. Maurizio Bocchini, Università Politecnica delle Marche, Ancona, Italy
Co - Chairperson: Prof. GertJan van Heijst, Eindhoven, NL

EUROMECH Colloquium 501 was divided into 10 sessions devoted to the following main topics:

- **Fundamentals of mixing**
  A number of contributions were devoted to the dynamics of vortices in shallow waters, including experimental, theoretical and numerical studies. Attention was also paid to fundamental aspects of the evolution of stratified flows, with a particular focus on the interaction between turbulence and stratification. Numerical simulation of mixing was addressed in a few contributions.

- **Coastal mixing**
  Presentations were given on the evolution of shallow water vortices in complex near-shore bathymetries, with specific emphasis on the related mixing features. Mixing properties of internal waves were also discussed.

- **Estuarine mixing**
  Some of the participants highlighted the role of density-driven flows and the related mixing properties, with papers devoted to vortex dynamics and flushing properties of tidal inlets and lagoons.

- **Riverine mixing**
  In a number of contributions, mixing in shallow riverine flows was evaluated on the basis of properties of shallow water vortices. Discussion included the evolution of buoyant river plumes and forcing by topographical features such as groynes and cross-sections.

EUROMECH Colloquium 501 provided an important forum for discussion of themes related to transport and mixing phenomena in geophysical flows. This is also in line with the growing public awareness (see for example the recent EU 'call for proposals' FP7-ENV-2007-1 on environmental issues) of topics like coastal protection and mitigation of pollution in riverine and estuarine waters.

Talented junior researchers and more established senior researchers of international reputation were involved in discussion, ranging from theoretical fluid dynamics to practical applications and management issues. There were approximately 40 participants from 20 different countries.

EUROMECH Colloquium 502

"Reinforced Elastomers: Fracture Mechanics, Statistical Physics and Numerical Simulations"

8-10 September 2008, Dresden, Germany

Chairperson: Prof. Gert Heinrich, Leibniz-Institut für Polymerforschung, Dresden, Germany
Co-Chairpersons: Prof. Dr. Michael Kaliske, Institute for Structural Analysis, TU Dresden, Germany; Prof. Dr. M. Erwan Verron, Institut de Recherche en Genie Civil et Mechanique, Ecole Centrale de Nantes, France

Both natural and synthetic elastomers are widely used in the automotive industry, medical applications and household products, among other applications. In the industrial context, elastomers are generally reinforced with particle such as carbon black and silica. Thus, the unique properties of elastomeric parts, such as tyres, tubes, dampers, gloves and seals, depend on both the intrinsic properties of the rubber matrix and the characteristics of the reinforcing additives. Furthermore, elastomeric materials are subjected to different loadings from which material failure can result. This failure is caused by initiation and propagation of cracks that can result in catastrophic events involving loss of life and capital, such as when a tyre bursts or a rubber O-ring seal fails.

Physical understanding of rubber reinforcement and modeling of their mechanical response is still a challenge in fundamental research. The improvement of design tools for rubber parts, such as finite element software, necessitates new investigations focused on the influence of reinforcement particles on the properties of these materials. Moreover, the characterisation of fracture mechanical and durability features is of important to the reliability and the quality of products; it is therefore a key aspect of investigation and a central design aspect.

The goal of EUROMECH Colloquium 502 was to focus on recent advances in understanding of physical, mechanical and durability properties of reinforced elastomers, as well as on simulating related problems. Both theoretical and experimental approaches were presented, allowing an exchange of ideas. There were 74 participants from 14 countries, among them young scientists, researchers from rubber industry and established authorities such as Prof. A. G. Thomas from Queen Mary College, University of London, one of the pioneers of the fracture mechanics of rubber compounds.

Recurring issues in the 29 presentations and associated discussion were:

- **Interfaces and interphases**
  The interaction between the polymer and filler particles is relevant to the mechanical behaviour of composite materials. However, its incorporation in FE-based approaches, e.g. in the form of cohesive elements for delamination problems or as graduation of interface stiffness, is done mainly in a phenomenological manner. Experimental investigations, such as NMR, neutron scattering and mechanical measurements, give more detailed insights into the coupling between polymer and filler that can lead to more physically based descriptions.

- **Fracture and fatigue behaviour**
  Experimental characterisation of fracture initiation and crack growth behaviour in elastomeric compounds under quasi-static, impact, sinusoidal and pulsating loading is important for correct material selection in practical applications. Different concepts such as J-integral, essential work of fracture and tearing energy are used for characterisation. From the theoretical point of view, approaches based on Eshelbian mechanics are used for characterisation of fracture and as fatigue predictors. The phase field approach to fracture has been shown to be promising for description of the interaction between macroscopic fields in the vicinity of the crack tip and the microscopic fracture process whose influence on the crack path is not negligible.

- **Deformation and crack growth mechanisms**
  The elucidation of deformation and crack growth processes is essential for understanding how structural modifications of the material influence the mechanical behaviour. On-line measurements of the strain field and structural characterisation using scattering techniques, as well as in-situ observation of fracture processes and cavity formation and the post-mortem analysis of fracture surfaces, give further insight into the important mechanisms.

- **Molecular dynamics of stretched polymer chains**
  When pre-cracked rubber samples are loaded, the polymeric chains in

the vicinity of the crack tip are strongly stretched. Theoretical studies of the mechanical relaxation properties of strongly stretched chains using analytical and numerical methods and their implications for chain rupture lead to a detailed understanding of the fracture process in elastomeric materials.

- **Constitutive models and finite element analysis**
  The design of rubber components is often accompanied by appropriate finite element calculations. The development of material models is therefore an important task. The modeling of filler-induced softening, viscoelastic and viscoplastic finite strain behaviour, as well as the modeling of inherent anisotropy, were presented and can be used for large-scale calculation of structural components.

Despite substantial progress in research concerning the behaviour of elastomeric materials, many aspects that have been exposed in experimental and theoretical investigations are not fully understood. Hence, EUROMECH Colloquium 502 offered an important platform for communication and discussion of new trends and approaches. We thank the Deutsche Forschungsgemeinschaft (German Research Foundation, DFG) and EUROMECH for financial and organisational support.

Objectives of EUROMECH, the European Mechanics Society

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

Activities within the field of mechanics range from fundamental research on the behaviour of fluids and solids to applied research in engineering. The approaches used comprise theoretical, analytical, computational and experimental methods. The Society shall be guided by the tradition of free international scientific co-operation developed in EUROMECH Colloquia.

In particular, the Society will pursue this objective through:

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

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

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

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; optimisation, 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 that they serve to clarify some identifiable problems in fluid mechanics, and provided that the significance of results is explained. Similarly, experimental papers must add physical insight in to the understanding of fluid mechanics. Published every two months, *EJM B/Fluids* contains:

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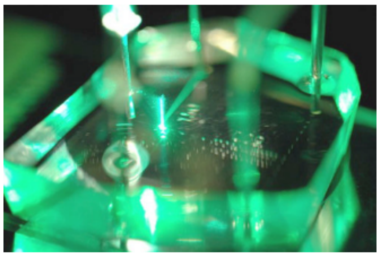

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