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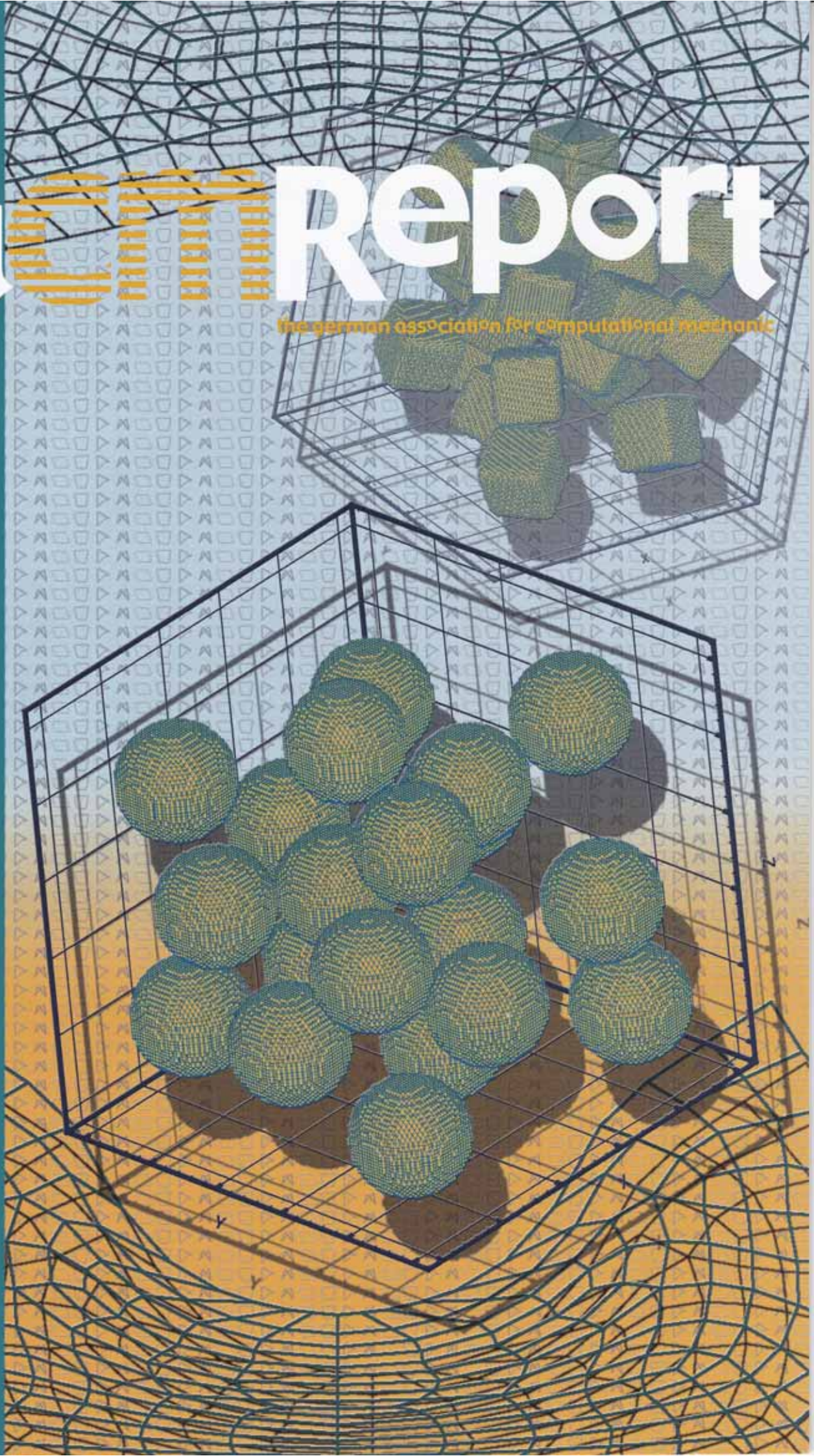
gamm Report

the german association for computational mechanic



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gacmReport

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GACM
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editorial

The German Association of Computational Mechanics (GACM) was established in 1990 as a national branch of its international head organization IACM.The objective of GACM is to stimulate and promote education, research and practice in computational mechanics, and to provide forums and meetings for the dissemination of knowledge about computational mechanics in Germany. It addresses researchers, practitioners, graduate students and companies from all engineering disciplines as well as from applied sciences with an interest in computational mechanics.

With this issue of GACM Report we like to start an extended newsletter as a new service for GACM members, supplementing the IACM Expressions as an international newsletter and the GACM Homepage www.gacm.de. Besides a part containing news and information related to the association and to computational mechanics in general, GACM Report will mainly consist of a guest editorial part addressing technical and scientific matters. Here in particular young members are encouraged to publish short up-to-date feature articles and state of the art overviews of general interest. The Report is thereby oriented to both academia and industry. It is intended to publish the Report twice a year.
In the present issue the reader will find contributions on computational material science, nonlinear dynamics and computational methods for rubber materials.

March 2002

Ekkehard Ramm
Chairman of GACM
University of Stuttgart

Peter Wriggers
Vicechairman of GACM
University of Hannover

Ekkehard Ramm

Peter Wriggers

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gacm News

Nominate the president of GACM

At the meeting of the executive council of IACM it was approved to nominate the president of GACM, Prof. E. Ramm, as Corresponding Member in the IACM Executive Council.
Furthermore Professor E. Stein and Professor W. Wunderlich were nominated Honorary Members of the Executive Council of IACM during the same meeting.
The next full assembly of the GACM members will be held at the WCCM V in Vienna. Members will receive an extra invitation with the exact date, time and location.

Professor Stein will organize an exhibition of the work of the great philosopher and mathematician G. F. Leibniz at WCCM V in Vienna. Details can be found on the WEB under http://wccm.tuwien.ac.at.

The GACM web-site http://www.gacm.de is installed. It will be in the future the main source for informations regarding GACM. The following services are planned: actual news regarding GACM and IACM, job offers, software, reports and links to relevant web-sites. The GACM-site can only be successful if also GACM-members contribute to this site by sending information regarding the above mentioned topics. For details, please contact Dr. W. A. Wall under gacm@statik.uni-stuttgart.de.

R. L. Taylor

Honorary doctoral degree for Prof. R. L. Taylor at the University of Hannover

Prof. Taylor was awarded the honorary doctoral degree "Dr.-Ing. ehrenhalber" for his outstanding scientific achievements, his teaching record and his contribution to the development in the field of Computational Mechanics in Germany by hosting many young scholars at the Department of Civil Engineering at UC Berkeley.
Robert Taylor known to all friends and colleagues as Bob was born in Riverside, California, on July 14, 1934. He studied Civil Engineering at the department of Civil Engineering at UC Berkeley and obtained the Ph.D. degree in 1963 at age 29. His first academic appointment was in the 1962-63 session when he became, before finishing the PhD, "Acting Assistant Professor" at UC Berkeley. Prof. Taylor became "Associate Professor" in 1968 and was appointed "Full Professor" in 1972. Prof. Taylor started already in the early stages of his career to work in finite element methods and soon realized the wide field of applicability of the new method. With his insight and intuition he was able to contribute to many areas of Computational Mechanics. Developments which will have a long lasting impact in the community of finite element people are related to seepage, finite elements for plates and shells, algorithms for plasticity and contact. Many of his achievements are now used in major commercial finite codes. Due to that Prof. Taylor is well known on the world scene and his distinction as a researcher is well established. Many colleagues of the German Computational Mechanics community had over the years the benefit discussing scientific matters with Bob Taylor who intuitively and invariably dissected and understood the real issues of their scientific work.

Honorary doctoral degree for Prof. R. L. Taylor at the University of Hannover

Latest news regarding the world congress WCCM V in Vienna

1260 abstracts for contributed papers and papers for minisymposia were sent from participants of 62 countries for the WCCM V in Vienna (chairmen H. A. Mang and F. G. Rammerstorfer from the TU Wien). Due to this there will be approximately 24 parallel sessions including poster sessions and 19 minisymposia.
With this amount of papers it is not possible to supply a printed version of the conference proceedings. These will be published on the WEB (http:// wccm.tuwien.ac.at). Out of all submitted abstracts 118 contributions are from German researchers which represent the second largest group. Only the participants from the United States will represent a larger group with 127 contributions. It is also interesting to note that the number of participants coming from industry is increasing.

Conferences and World congress of IACM

In the Dearborn meeting, August 2001, it was decided to held the IACM world congress at every two years interval jointly with a regional congress. With this change it is hoped that the IACM world congress will have a bigger regional impact worldwide. This new procedure will be implemented beginning with the next world congress in 2004 in Asia. In 2006 the world congress will be held in the USA.

Executive Council Meeting in Sydney, November 2001

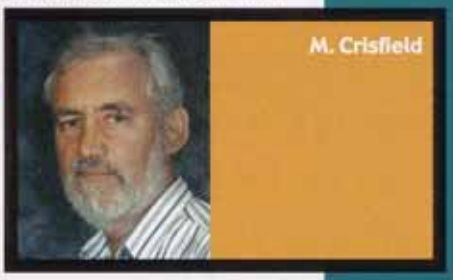
At the Executive Council Meeting three proposals from the Asian Pacific Association on Computational Mechanics (APCAM) were presented to host the next world congress. The proposals came from the associations in China, Korea and Japan. The Executive Committee of APCAM decided to select the city of Beijing, China, as the candidate to hold the next WCCM together with the regional Asian Pacific Congress on Computational Mechanics (APCOM 04).
At this meeting Prof. Owen, University of Swansea, was elected as Corresponding Member of the Executive Council of IACM.

APCOM 04 and WCCM VI

The world congress WCCM VI will be held in Beijing (Peking), China, 2004. The host organization is the China Association for Computational Mechanics with its president Prof. M. Yuan, Deptartment of Mechanics and Engineering Science at Peking University.
Congress topics will be
Micro and Nano Mechanics
Contact Mechanics
Meshless methods
Smart materials, control
Composites
Coupled problems
Chaotic systems
Multiphase flows
Environmental flow problems
Virtual reality, graphics

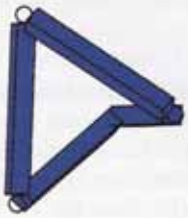
Birthdays

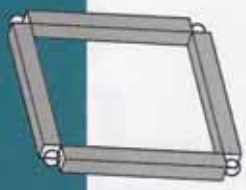
There will be a special conference on behalf of leading researchers who celebrate their 60th birthday this year in Ibiza. These are H. Mang, R. Ohayon, D. R. J. Owen, K. C. Park, J. Periaux and B. Schrefler.


M. Crisfield

Prof. M. Crisfield (1942 – 2002)

It is with great sadness that we report the passing of Mike Crisfield on19 February 2002 in Britain. His great interest in research topics and his scientific intuition which was coupled with a broad knowledge in many fields has been a challenge for everyone. He was working hard, but always with having great fun in discussing different topics either with students or colleagues. Mike gave stimulating presentations of original research contributions, which in his case were finite element formulations on nonlinear beams, shells, solids and associated algorithmic treatments. Besides this he liked to play the piano in the bars after all the sessions in conferences were over. Everybody in the research community over the world who got to know him was fascinated by his personality and admired his scientific work. His impact on research was great and will last. The community will keep him in mind as one of the leading researchers in his field. He will be missed by all knowing him.





MECHANICAL INTEGRATORS FOR FLEXIBLE MULTIBODY DYNAMICS

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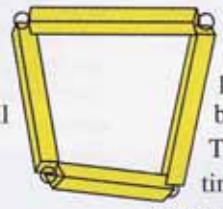
In this article, the author comments on his perspective concerning the computational treatment of flexible multibody dynamics. Within the framework of computational mechanics, flexible multibody dynamics bring together different branches of mechanics which often have been treated separately in the past. In particular, continuum mechanics, structural mechanics and the principles of classical mechanics have to be combined.

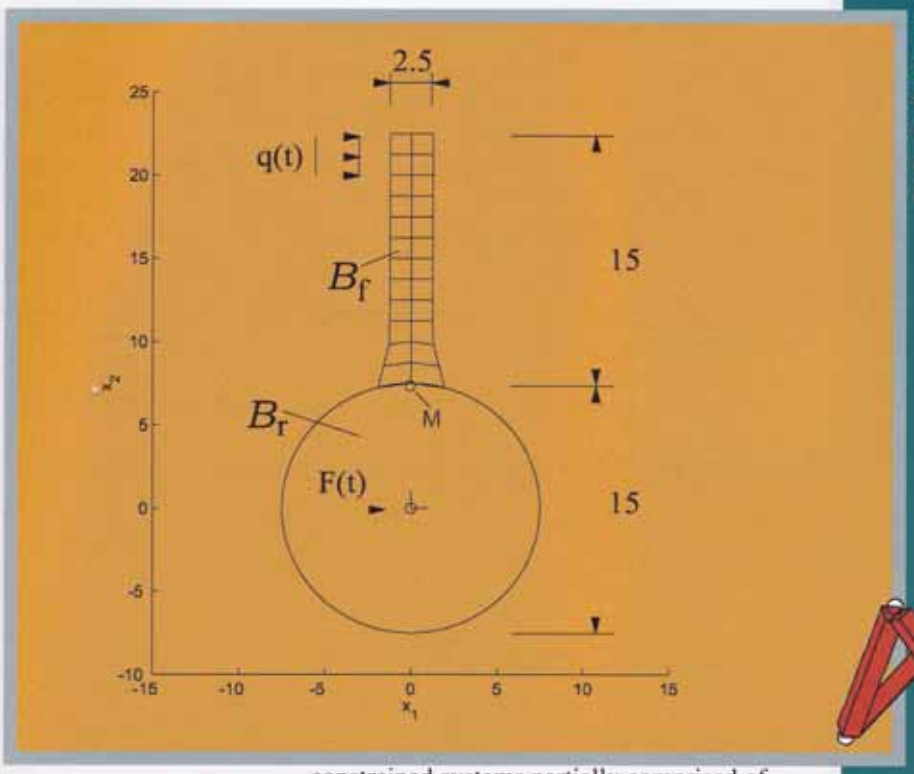
Main issues in computational flexible multibody dynamics are (i) the space discretization of flexible structures such as beams and shells as well as continuum bodies, (ii) the incorporation of (mostly holonomic) constraints for the modelling of various types of joints interconnecting flexible parts as well as rigid parts and (iii) the discretization in time.



It is nowadays customary to apply the finite element method for the computer simulation of flexible bodies undergoing large displacements in space, possibly accompanied by finite strains. Contemporary finite element formulations, including structural elements, are usually developed from nonlinear continuum mechanics. This approach is at variance with previously proposed "corotational" or "floating frame" formulations which have been mostly discarded by the finite element community.

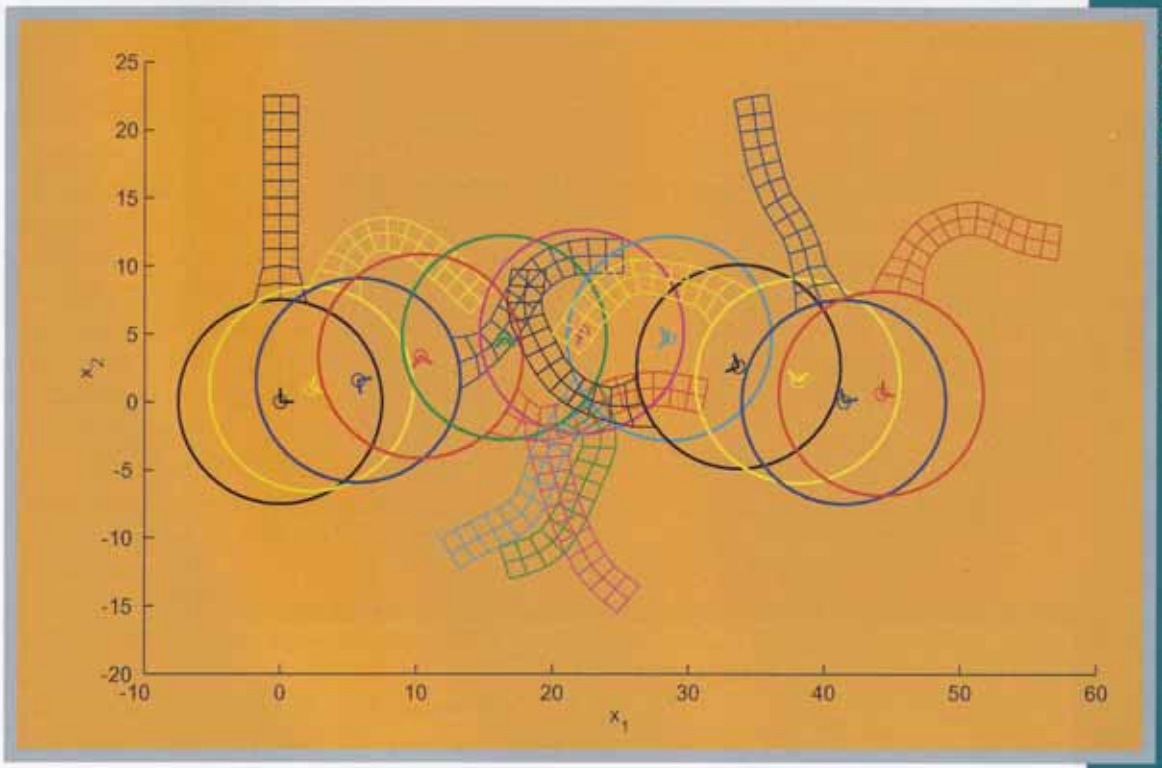
The space discretization leads to semi-discrete systems which can be classified as finite-dimensional dynamical systems. In the case of (hyper-)elastic bodies, these systems fit well into the Hamiltonian framework of classical mechanics. The semi-discrete problems can be classified as "stiff" or "highly oscillatory" dynamical systems. Due to this fact, the time discretization of such systems is quite demanding, especially in comparison with rigid body dynamics. Traditionally, implicit numerical integration methods, specifically the Newmark family of one-step methods, are used.

These methods have originally been developed for the integration of linear problems. In the linear regime, the specific features (stability and dissipation properties) of such integrators are well-known. However, when applied to nonlinear problems, new numerical instability phenomena have been observed. To remedy the problem, mechanical integrators have been developed during the last decade. The term mechanical integrator refers to time-stepping schemes which inherit key conservation properties from the underlying continuous system.
In particular, energy-momentum schemes which obey the conservation laws of energy and angular momentum independent of the time-step size seem to be most appropriate for



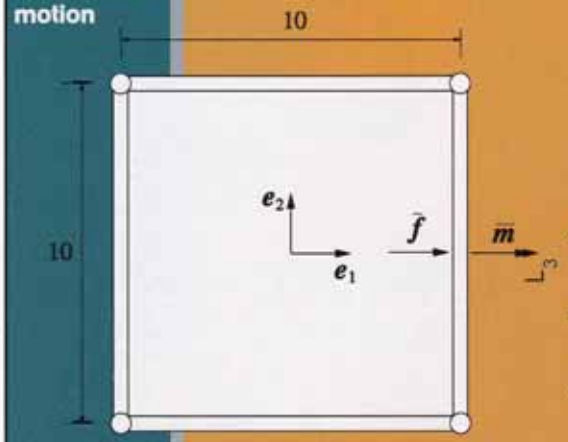
1. Fig. Initial configuration of the coupled rigid and flexible bodies

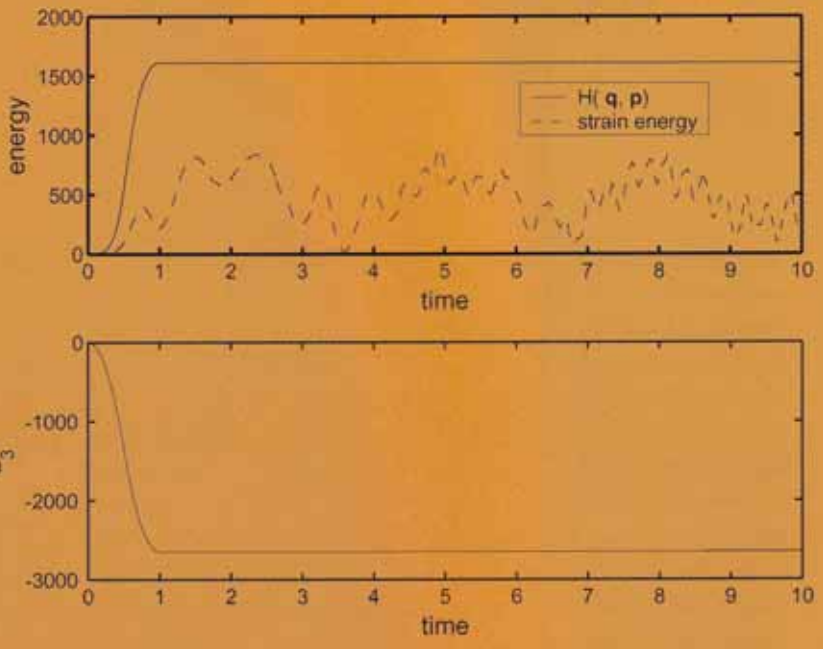
the stiff mechanical systems under consideration. Indeed, since the pioneering work of Simo and Tarnow the value of energy-momentum schemes has been well established for the analysis of nonlinear structural mechanics and elastodynamics. Algorithmic energy conservation is sought to ensure numerical stability. In addition to that, algorithmic conservation of angular momentum is important for the accuracy of simulations. The above considerations naturally extend to constrained systems partially comprised of flexible components. Due to the fact that the forces of constraint are workless, energy conserving schemes turn out to be especially desirable in the case of mechanical systems with constraints.



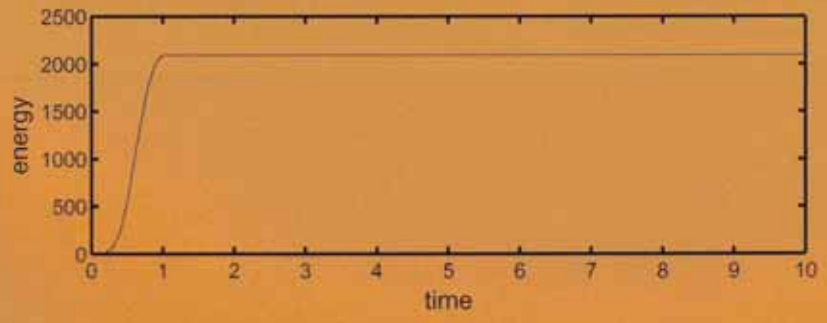
2. Fig. Motion of the coupled rigid and flexible bodies

3. Fig. Algorithmic conservation properties corresponding to the coupled motion

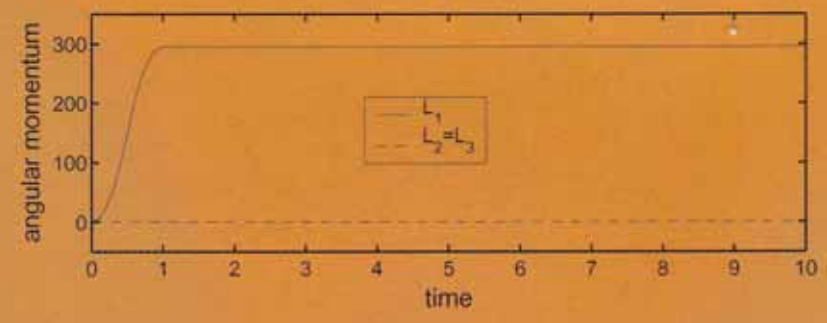




4. Fig. Initial configuration of the closed loop multibody system



6. Fig. Closed loop multibody system: Algorithmic conservation properties



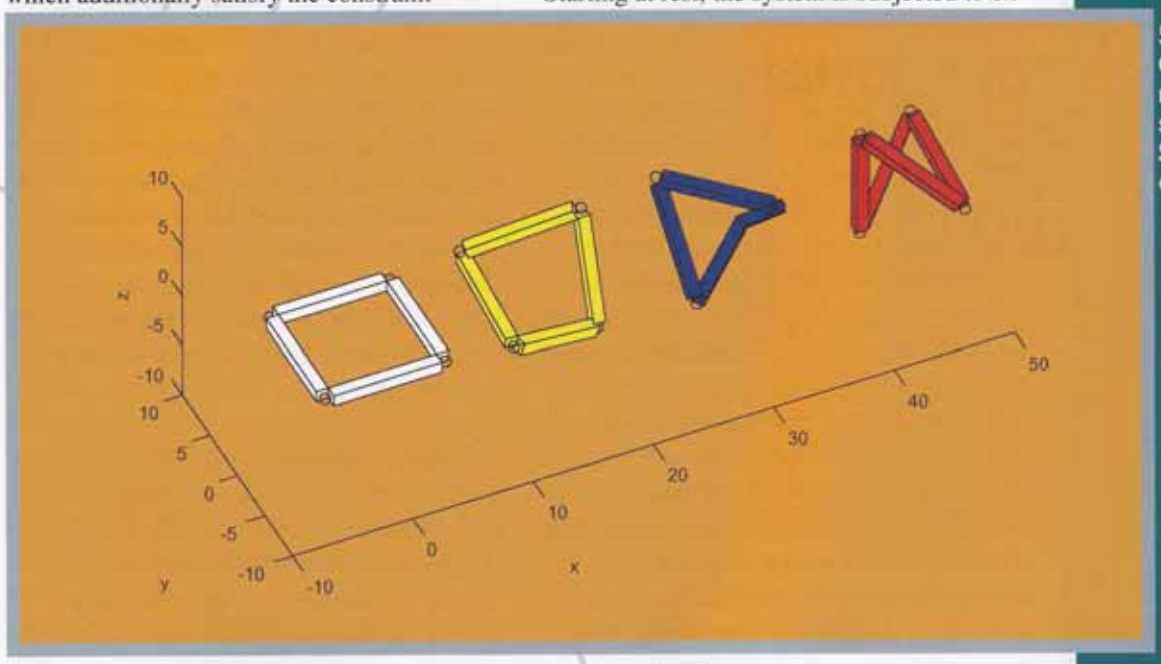
For that reason, the development of mechanical integrators for flexible multibody dynamics has increasingly attracted research in recent years. Employing highly-developed finite element discretizations for the flexible bodies, the Lagrange multiplier method can be conveniently applied to take the constraint conditions into account. This approach leads to index three differential algebraic equations (DAEs). It is possible to design mechanical integrators for the DAEs at hand. In particular, energy-momentum schemes can be devised, which additionally satisfy the constraint conditions.

The following two examples illustrate the application of mechanical integrators to constrained mechanical systems. The first example deals with the coupled motion of rigid and flexible bodies. In the example shown in Fig.1, the rigid body.

B_r consists of a circular disc which is attached to a flexible beam-type body B_f. Three nodes at the base of the finite element mesh are also part of the rigid body. Six holonomic constraint equations arise due to these coupling nodes which can be easily incorporated into the present DAE description. In Fig. 1, q(t) and F(t) denote external (dead) loads acting on the body

In particular, the loading functions assume the form of hat functions in time. The external loading vanishes at t = 1 such that the total energy H (**q**, **p**) and angular momentum $L = L_i e_i$ have to be preserved for t > 1. These fundamental conservation laws are inherited by the applied energy-momentum scheme for any time-step size, see Fig. 3. A sequence of calculated deformed configurations is depicted in Fig. 2.

The second example deals with a closed loop multibody system consisting of 4 rods and 4 spherical joints. The initial configuration of the multibody system is depicted in Fig. 4. Starting at rest, the system is subjected to external loading in form of a force $\bar{f}$ and torque $\bar{m}$ both acting on the right body in Fig. 4. As before, for t > 1, the system is force-free so that the algorithmic conservation properties can be examined. In fact, energy and angular momentum are conserved for any time-step size, see Fig. 6. A sequence of deformed configurations is shown in Fig. 5.



5. Fig. Closed loop multibody system: Sequence of configurations

The reader interested in more details about the present approach is referred to P. Betsch and P. Steinmann, Conservation properties of a time finite element method. Part III: Mechanical systems with holonomic constraints, Int. J. Numer. Methods Eng., 53:2271-2304, 2002.

Figure 1a

Figure 2: Compression of a rubber block (a) result of a locking-free element formulation

COMPUTATIONAL MODELLING OF RUBBER MATERIALS

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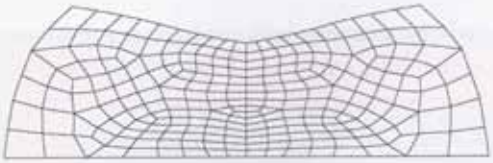
Polymers find many uses in industrial applications. Examples are utensils made of glass or plastic, bearings, shock absorbers, seals or tires to name only a few (see also Fig. 1). The designation "rubber" stands for the group of *rubber-like* polymers which are characterized by their ability to undergo extreme deformation. Current industrial research seeks to improve the manufacturing and testing methods as well as to optimize the chemical composition of the material for special purposes. Until recently, technological progress was usually achieved on the basis of experimental work. Nowadays, numerical simulations are becoming more and more important since they are cheaper and offer the opportunity to look inside the material.

Rubber has always been a fascinating material and attracted the scientific interest as early as at the beginning of the nineteenth century. At this time, Gough discovered that a rubber sample when loaded contracts during heating and lengthens during cooling (Gough-Joule effect). This discovery created great excitement in the scientific community since it was inconsistent with the known thermoelastic behaviour of metals. Today, the thermomechanical behaviour of rubber is explained by the so-called kinetic theory of elasticity. This concept is based on the observation that the special material behaviour of rubber is characteristic for many other polymers as well if one considers a sufficiently large range of temperatures and loading rates. Such polymers consist of chain-like macromolecules, and their chemical composition determines whether they reach the rubbery state at "high" or "low" temperatures. The notion "rubber" is used for an amorphous polymer which exhibits the typical behaviour at about room temperature and at a relatively low loading velocity. Since the material behaviour is dominated mainly by the entropy in the system, the macroscopic stress is proportional to the temperature (which explains the Gough-Joule effect).

It is further important to note that due to the entangled structure of the polymer network in the undeformed configuration, very large deformations (up to 700 % strain) of a test sample are possible until the chains in the loading direction are almost stretched straight.

On the basis of experimental observations, the first mathematical descriptions of the *macro*-mechanical stress-strain behaviour were developed in the forties by e. g. Treloar ("Neo-Hooke" model), Mooney and Rivlin. An important extension of these early models was in the seventies achieved by Ogden on the basis of the Valanis-Landel hypothesis. Looking at the highly non-linear structure of Ogden-type models, it is not astonishing that analytical calculations of rubber construction elements were mostly restricted to simple geometries and purely elastic behaviour under iso-thermal conditions. In view of practical applications, however, these investigations were not realistic enough. So, advanced numerical simulations, in particular finite



(b) result of a standard formulation)

element computations, could not be carried out before the rapid development of the computer technology took place in the eighties. With respect to the modelling of rubber, the following three aspects should be considered in more detail.

Firstly, the material behaviour has to be described as realistically as possible. Experimental investigations reveal that rubber materials exhibit besides their highly non-linear elasticity a great variety of *inelastic* effects. The most important among these are the Mullins' effect (damage) and the viscous behaviour of rubber which is in addition strongly influenced by temperature changes. Many continuum mechanical models have been derived which show satisfactory agreement with experimental results. However, these experiments are mostly restricted to isothermal conditions as well as certain homogeneous deformation states and a rather narrow range of loading rates. Thus, a "general purpose" model for rubber is not available at the present time, and it is rather doubtful that this goal will be ever reached by means of the classical continuum mechanical approach.

In contrast, the state of the art concerning the numerical implementation of complex material models has reached a very high level. The development started mainly at the beginning of the nineties, when the Ogden model became standard in finite element codes of membranes and continua. The key point was to formulate the material law as well as its linearization with respect to principal axes, something already suggested by Chadwick and Ogden in the seventies. As soon as the implementation of arbitrarily non-linear isotropic hyperelastic stress-strain relations had been understood, finite element formulations of inelastic rubber models developed rapidly. The present state of research can be described as follows. It is common knowledge in continuum mechanics that within the concept of internal variables, the evolution of the inelastic deformation is described by means of a differential equation of first order. In the framework of the finite element method, the inelastic deformation is determined by integrating the differential equation via appropiate algorithms known from the mathematical literature. The integration procedure usually takes place at the Gauss point level. As soon as the inelastic deformation is known, one proceeds as in the purely elastic case. In this way, quite general models can be implemented, as long as they are based on the concept of internal variables. Current research is more and more directed towards computational efficiency of the implementation, for example the issue of time step adaptivity.

The preceding remarks refer exclusively to the *material part* of the finite element formulation. But it is well-known that the numerical modelling of rubber-like polymers places high demands on finite element technology. This is due to the fact that rubber materials are almost incompressible. This property leads in the case of low order displacement formulations to the undesirable effect of locking. One of the first ideas against this problem were the so-called selective reduced integration methods which are in linear elasticity equivalent to mixed finite element formulations based on the displacement and the pressure as independent variables. The difference between the

Figure 1b

Figure 1: Bellow, spring seat, gasket (rubber construction elements)

Figure 1c

results of a locking-free and the standard ele-ment formulation is shown in Fig. 2. But the use of such mixed methods is not satisfactory, if bending deformations are involved. More efficient is in this regard the enhanced strain method which, however, has meanwhile been recognized to exhibit non-physical instability phenomena. Due to these difficulties, again, "**u**-*p*" formulations and modern derivates of it are in frequent use. Another promising idea are non-linear versions of the reduced integra-tion concept originally initiated by Belytschko and coworkers. Recent publications have shown that formulations of this kind are very suitable for rubber computations and extremely efficient from the computational point of view. But in summary, it remains to state the disappointing fact that none of these strategies works for *all* kinds of problems. Recent papers of researchers from the mathematical side introduce higher order formulations into the discussion, frequently in combination with adaptive algorithms. But since these ap-proaches have still not been subjected to the highly demanding element tests typical for rubber computations, it cannot be yet decided whether this development leads to a fruitful new branch in element technology for rubber-like materials.

Finally, one has to consider the fact that finite element computations of rubber-like polymer structures require the numerical treatment of geometrical as well as physical non-linearities. After the assembly procedure, a system of strongly non-linear equations is obtained, the solution of which is neither necessarily unique nor stable. Not even the existence of a solution can be guaranteed in general. This means to leave the secure ground of many mathematical theorems to enter the mysterious realm of engineering intuition.

Systems of non-linear equations have to be solved iteratively. The most common proce-dure is to solve the consistently linearized equations *directly* (Newton's method). The use of indirect (iterative) solvers for these equations is not recommended, since the large ratio between the bulk modulus and the shear moduli leads to ill-conditioned equations. So, if one strives for an *implicit* solution of the solution, numerical investigations of rubber-like polymer structures are still very time-consuming (see also Figs. 3 and 4). In certain cases, explicit solution methods are more advisable. However, due to the necessity to consider the upper bound for a non-critical time step, such a procedure is only rewarding for relatively high numbers of unknowns as they occur in highly complex industrial applications.

In conclusion, the computational modelling of rubber has reached a point where the simulat-ion of arbitrary rubber-like polymer structures is it *in principal* possible. The major stumb-ling block is not the FE implementation of material models, but rather the formulation of material models which can describe an increasingly wider range of experimental results. But the costs of experimental data begin to exceed even the financial capacity of industrial companies. This dilemma could be avoided by so-called "computer" experiments, where the deformation of a test sample is numerically simulated on the micromecha-nical level. As briefly discussed at the begin-ning of this article, the micromechanical behaviour of rubber is well understood. Unfortunately, the computer power presently available is still insufficient to carry out computations of this kind in a practical manner. Therefore, continuum mechanical modelling cannot be neglected. But a better access to data would improve the under-standing of the material behaviour signifi-cantly and hence lead to a more accurate material modelling.

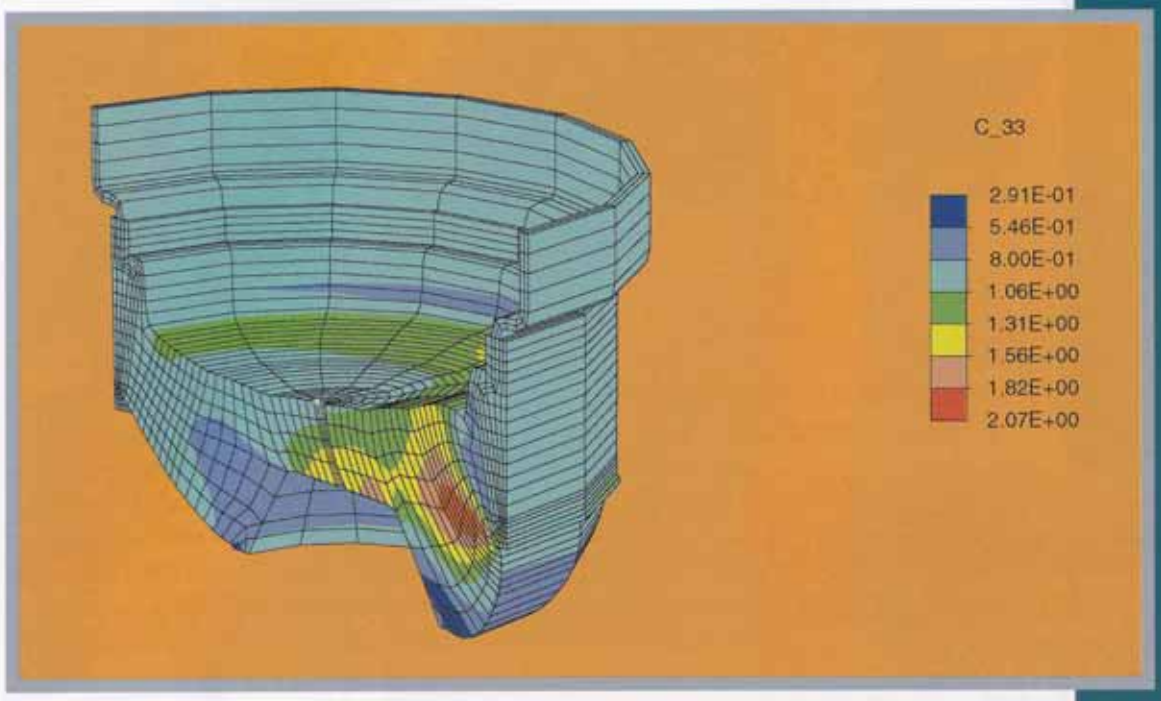


Figure 3: Shearing of a viscoelastic rubber bearing: deformation in vertical direction (relaxed state)

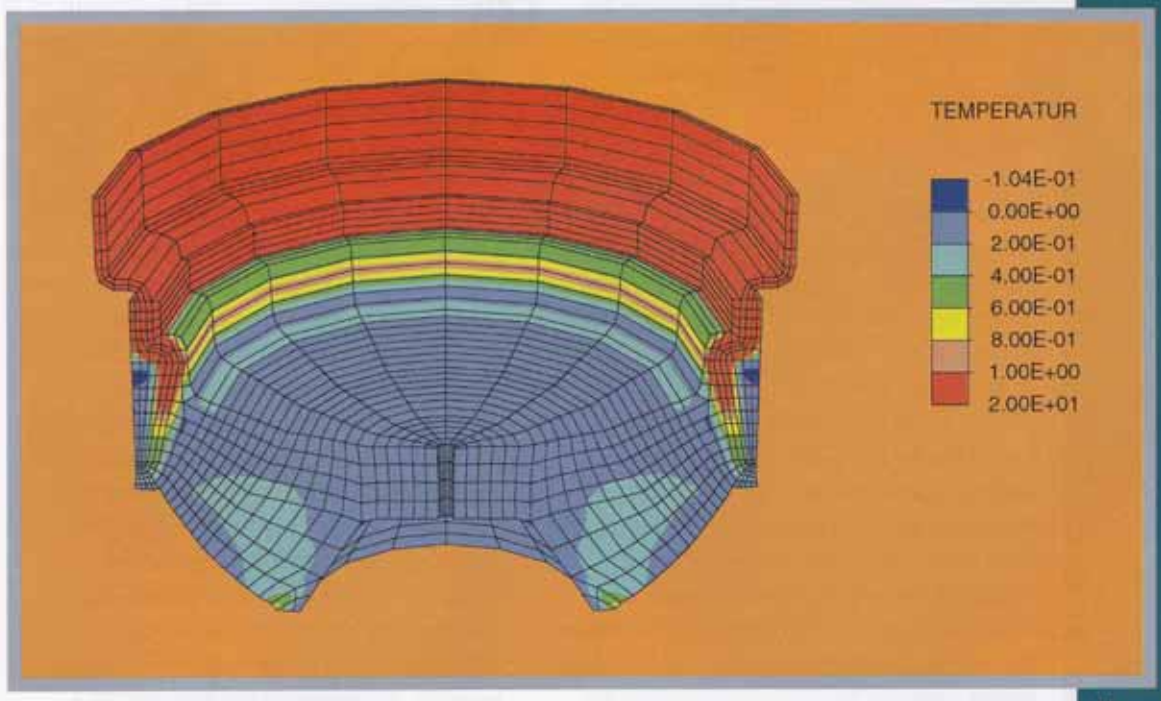


Figure 4: Compression and heat conduction in a thermo-viscoelastic rubber bearing: temperature distribution

COMPUTATIONAL MICRO-MACRO MATERIAL TESTING

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Introduction

A key to the success of many modern structural components is the tailored behavior of the material. A relatively inexpensive way to obtain macroscopically desired responses is to enhance a base matrix properties by the addition of microscopic matter, *i.e. to manipulate the microstructure.* Accordingly, in many modern engineering designs, materials with highly complex microstructures are now in use. The macroscopic characteristics of modified base materials are the aggregate re-sponse of an assemblage of different "pure" components, for example several particles or fibers suspended in a binding matrix material (Figure 1). In the construction of such materials, the basic philosophy is to select material combinations to produce aggregate responses possessing desirable properties from each component. For example, in structural engineering applications, the classical choice is a harder particulate phase that serves as a stiffening agent for the base matrix material. Such inhomogeneities are encountered in metal matrix composites, concrete, etc.

If one were to attempt to perform a direct numerical simulation, for example of the mechanical response of a macroscopic engineering structure composed of a micro-heterogeneous material, incorporating all of the microscale details, an extremely fine spatial discretization mesh would be needed to capture the effects of the relatively fine scale heterogeneities. The resulting system of equations would contain literally billions of numerical unknowns. Such problems are beyond the capacity of computing machines for the forseeable future. Furthermore, the exact subsurface geometry is virtually impossible to ascertain exactly. In addition, even if one could solve such a system, the amount of information to process would be of such complexity that it would be difficult to extract any useful information on the desired macroscopic behavior. It is important to realize that solutions to partial differential equations, of even linear material models, at infinitesimal strains, of small bodies containing a few heterogeneities are still open problems and complete solutions are virtually impossible. Because of these facts, the use of *regularized* or *homogenized* material properties (resulting in smooth coefficients in the partial differential equations) are commonplace in virtually all branches of physical sciences. The usual approach is to construct a constitutive "relation between averages", relating volume averaged field variables. There after, the regularized properties can be used in a macroscopic analysis. The volume averaging takes place over a statistically representative sample of material, referred to in the literature as a representative volume element (RVE). The internal fields to be volumetrically averaged must be computed by solving a series boundary value problems with test loadings.

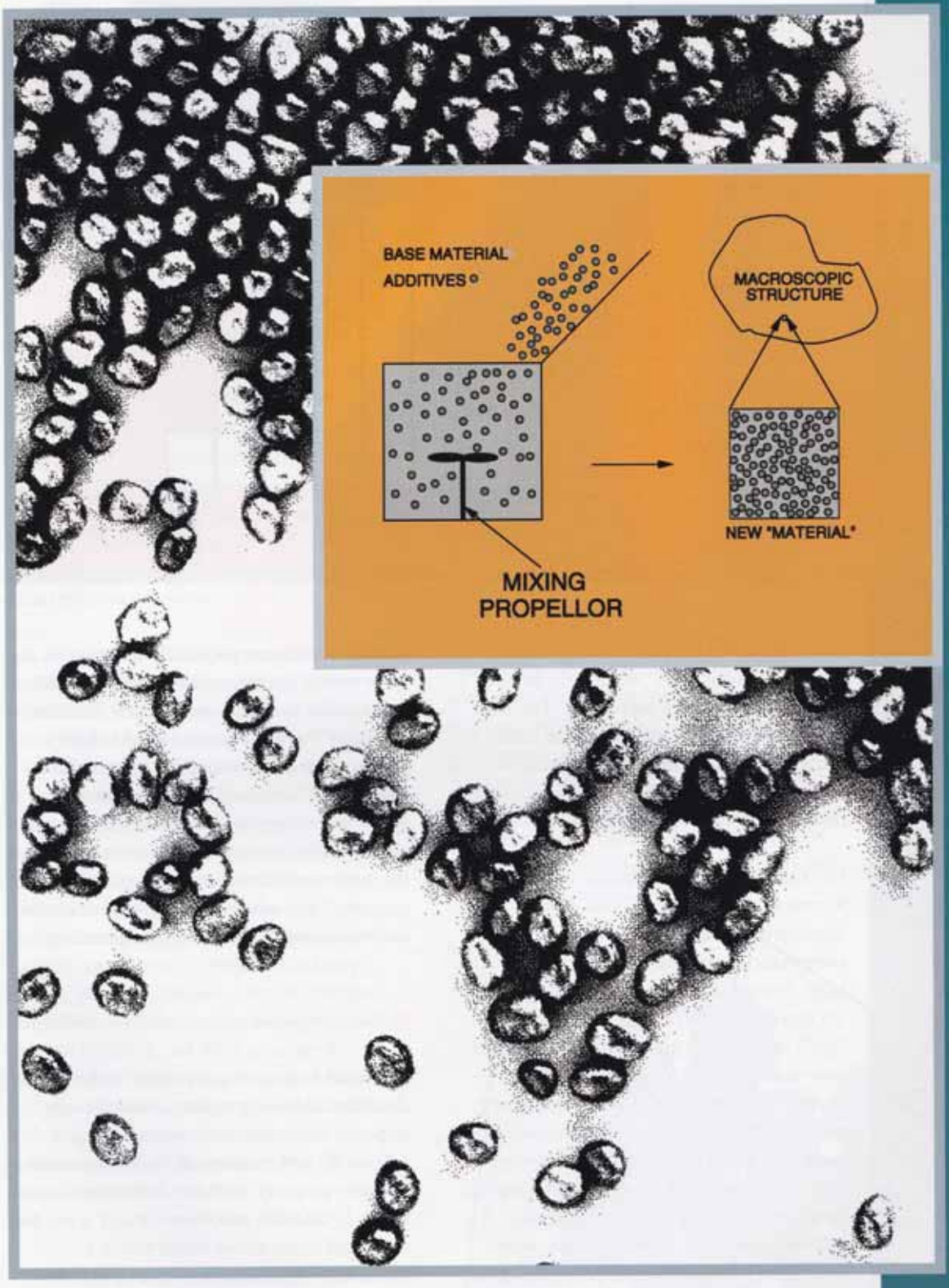
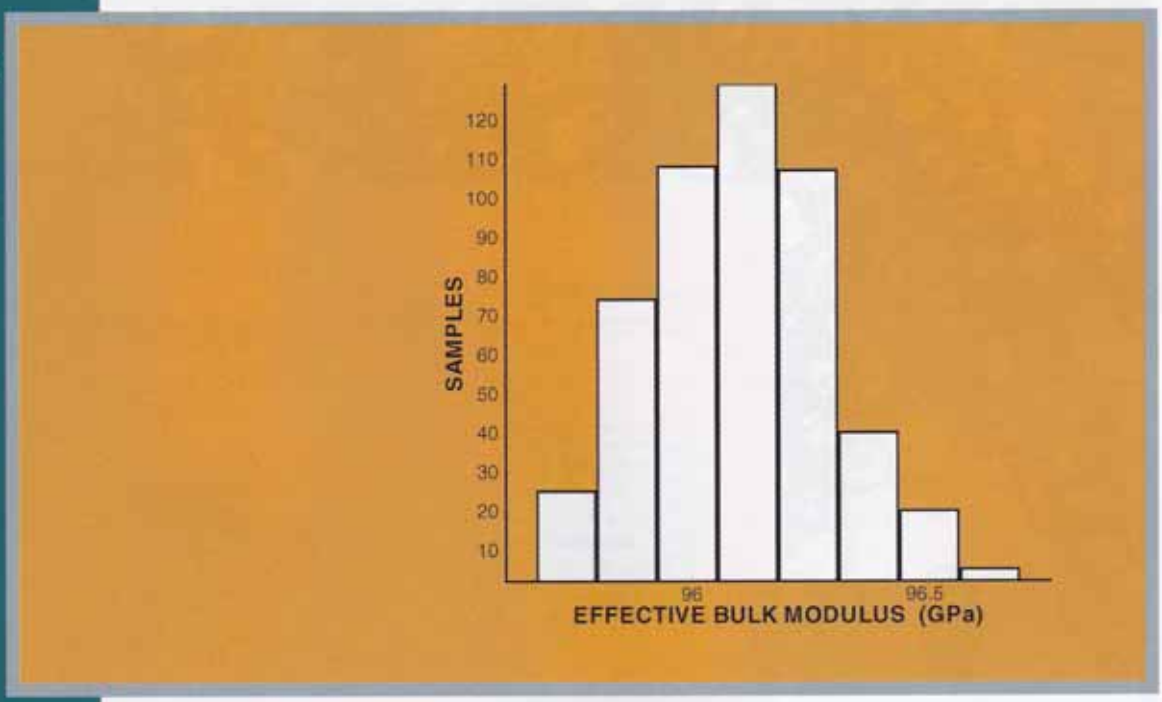


Figure 1 :

Big : Typical loose particulate additives.

Small : Doping a base material with particulate additives.

Figure 2 a: The effective bulk modulus distribution for 512 samples

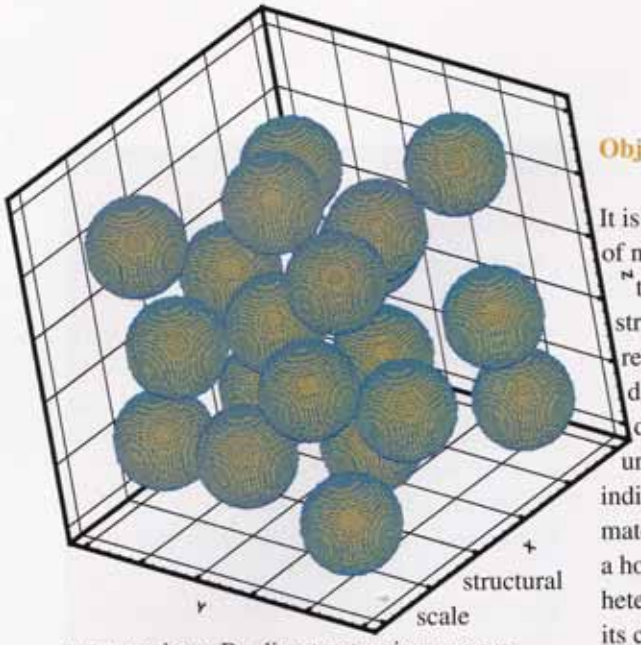


Such regularization processes are referred to as "homogenization", "mean field theories", "theories of effective properties", etc. For overviews, we refer the interested reader to Jikov et. al. [1] for mathematical reviews or to Nemat-Nasser and Hori [2] for mechanically inclined accounts of the subject.

For a sample to be statistically representative it must usually contain a great deal of heterogeneities and therefore the computations over the RVE are still extremely large, but are of reduced computational effort in comparison with a direct attack on the "real" problem. Historically, most classical analytical methods for estimating the macroscopic response of such engineering materials have a strongly phenomenological basis, and are in reality non-predictive of material responses that are unknown a-priori. This is true even in the linearly elastic, infinitesimal strain, range. In plain words, such models require extensive experimental data to "tune" parameters that have little or no physical significance. Criticisms, such as the one stated, have led to computational approaches which require relatively simple descriptions on the microscale, containing parameters that are physically meaningful. In other words, the phenomenological aspects of the material modeling are reduced, with the burden of the work being shifted to high performance computational methods. *Stated clearly, the "mission" of computational micro-macro mechanics is to determine relationships between the microstructure and the macroscopic response or "structural property" of a material, using models on the microscale that are as simple as possible.*

Basic concepts in macro-micro modeling

The usual engineering approach is to characterize the aggregate or macroscopic response via a relation between averages $\langle \sigma \rangle_\Omega = \mathbb{E}^* : \langle \epsilon \rangle_\Omega$ where $\mathbb{E}^*$ is known as the effective property, with the definition $\langle \bullet \rangle_\Omega = \int_\Omega \bullet \, d\Omega / |\Omega|$, and where σ and ϵ are the stress and strain tensor fields within a statistically representative volume element (RVE) of volume $|\Omega|$. The microscale mechanical properties of the heterogeneous material are characterized by a spatially varying elasticity tensor $\mathbb{E}$. The effective property is the tensorial parameter used in



structural scale

computations. By direct extension, we are interested in $\langle \sigma \rangle_{\Omega}$ versus $\langle \epsilon \rangle_{\Omega}$ in the materially nonlinear/geometrically linear range, or the appropriate conjugate pairing in the geometrically nonlinear range, such as $\langle S \rangle_{\Omega_0}$ versus $\langle C \rangle_{\Omega_0}$ etc ..., where $\underline{S}$ is the second Piola Kirchhoff stress and $\underline{C}$ is the right Cauchy-Green strain and where Ω_0 is the initial reference volume.

It is emphasized that effective quantities such as $\mathbb{E}$ *are not material properties, but relations between averages.* More appropriate terms might be "apparent properties". It is clear that for the relation between averages to be useful, it must be computed over a sample containing a statistically representative amount of material. Classical methods make ad-hoc assumptions and estimates on the interaction between microscale constituents. Furthermore, many classical methods of analysis treat the microstructure as being a regular, periodic, infinite array of identical cells. Such assumptions are not justifiable for any real material, and their accuracy is questionable. Furthermore, many of these analysis are performed two-dimensionally, which, in contrast to many structural problems, is relatively meaningless in micro-macro mechanics.

Objectives of computational methods

It is now commonly accepted that some type of numerical simulation is necessary in order to determine more accurate micro/macro structural responses. For statistically representative samples of randomly dispersed microstructural material, three-dimensional numerical simulations are unavoidable for reliable results. As we have indicated, the analysis of even *linearly-elastic* materials, at infinitesimal strains, composed of a homogeneous matrix filled with microscale heterogeneities, is still an open problem and its complete solution is virtually impossible for even a small microheterogeneous domain. The dramatic increase in computational power available for mathematical modeling and simulation raises the possibility that modern numerical methods can play a significant role in the analysis of heterogeneous structures.

Ideally, in an attempt to reduce laboratory expense, one would like to make predictions of a new material's behavior by numerical simulations. The primary goal being to accelerate the trial and error laboratory development and analysis of new high performance materials. Computational micromechanical models offer advantages over phenomenological approaches by employing relatively simple descriptions on the microscale which contain parameters that are physically meaningful.

Several research areas exist

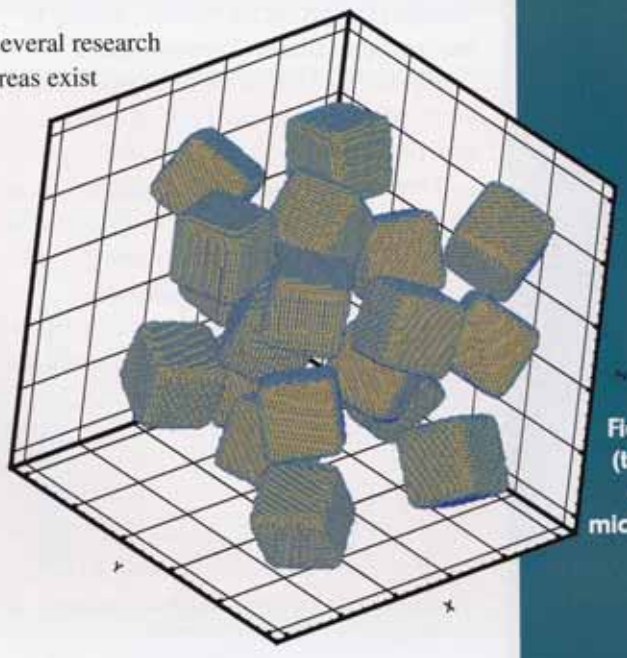


Figure 3 a: An (topological) alternative microstructure

Figure 2 b: A random microstructure consisting of 20 non-intersecting boron spheres, occupying approximately 22 % of the volume in an aluminum matrix.

like the relationship between sample size and effective response. As an example we consider a composite material combination is that of an Aluminum matrix (77.9, 24.9 GPa) embedded with (stiffening) Boron particles (230, 172 GPa). This is a widely used composite due to its light weight. We chose Al/Bo as a material combination which exhibits significant enough mismatch in the mechanical properties to be representative of a wide range of cases. All tests were run on a single IBM RISC 6000 workstation. Comparable hardware is available in most academic and industrial work places, therefore such simulations are easily reproducible elsewhere for other parameter selections. We simulated 512 different samples, each time with a different random distribution of 20 nonintersecting particles occupying 22 %. Consistent with the previous test's mesh densities per particle, we used a 24 x 24 x 24 mesh see Figure 2b (9 x 9 x 9 trilinear hexahedra or 2344 dof per particle, 46875 dof per test sample), which provided mesh-insensitive results. Multiaxial, uniform strain loading was applied. The results, in form of a histogram are shown in Figure 2a. The use of statitisical techniques to further analyze such samples can be found in Zohdi and Wriggers [3].

Further research areas are: (1) propagation of damage through microstructure leading to macroscopic failure, (2) micro-macro multifield modeling of aging of materials, (3) micro-macro plastic behavior of light weight materials and (4) inverse micro-macro design problems. The results of such simulations are shown for the microstructure of Figure 3a in Figures 3b. The macroscopic responses are determined by simply volumetrically averaging the direct microscopic simulations. For more information we refer the interested reader to Zohdi and Wriggers [3].

Closing remarks

It is frequently asked of a theoretical or computational analyst, "Have the theoretical and computational results been compared to experiments?" Computational and theoretical micro-macro mechanics open the reverse question: "Have the experimental results been compared to computations and theory?" At the risk of closing on a controversial note, it is not unfair to think that computational methods have perhaps become more accurate than experiments. Minimally, no one can argue that computations cannot now play a strong complementary role to laboratory experiments. Furthermore, the continual rise in computational power will only push research more towards reliance on numerical simulations employing non-phenomenological micro-macro models, which are less expensive than laboratory tests. *For successful modern research, computations, modeling and experiments are symbiotic and interactive.*

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2. Nemat-Nasser, S. and Hori, M. (1999). *Micromechanics: overall properties of heterogeneous solids.* 2nd. ed.Elsevier, Amsterdam.

3. Zohdi, T. I. and Wriggers, P. (2001). Computational micro-macro material testing. *Archives of Computational Methods in Engineering.* Vol 8, 2, 131-228.

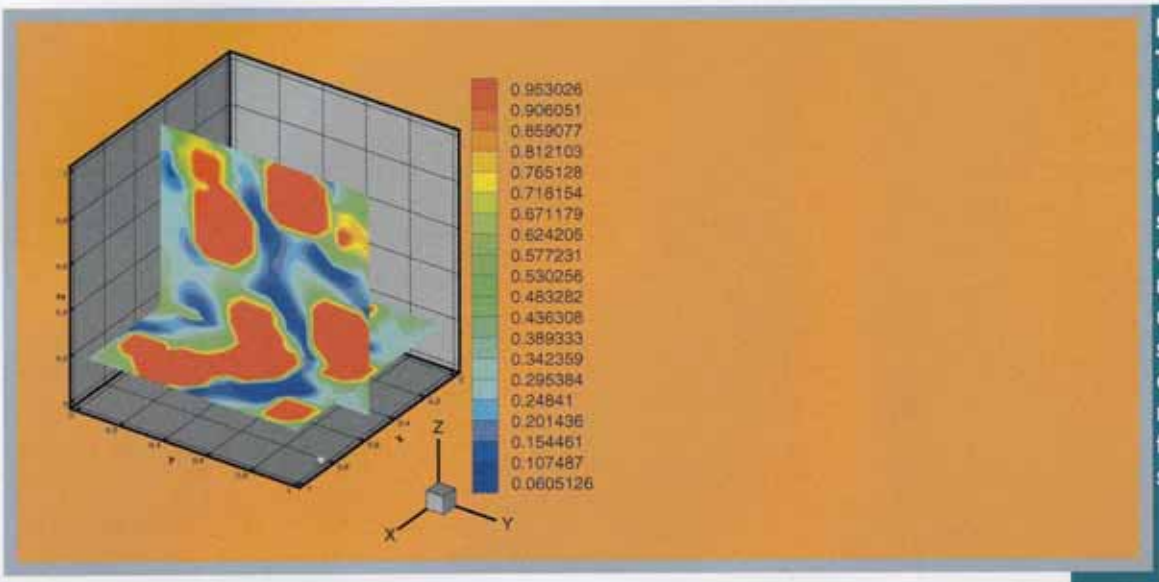
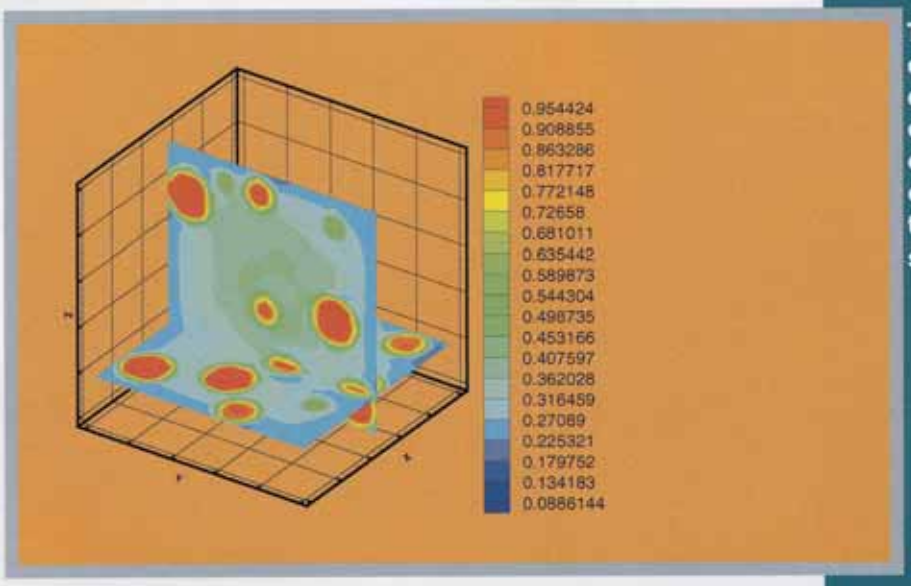
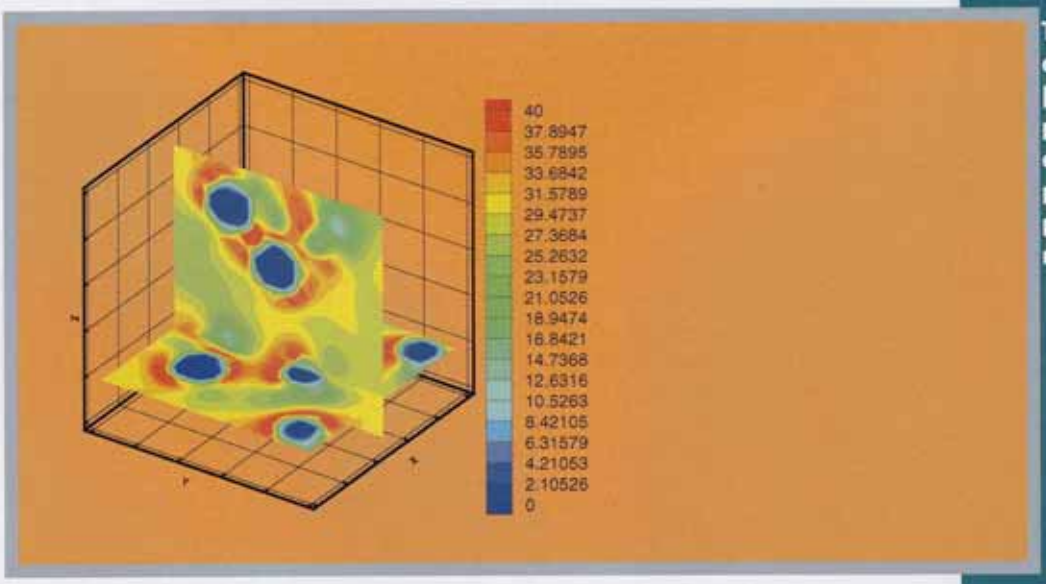


Figure 3b: The damage distribution in the micro-structure due to mechanical stress. A value a = 1 represents an undegraded state, while a =0 represents a fully degraded state.



The damage distribution due to aggressive chemical absorption in the micro-structure.



The distribution of $\|\sigma'\|$ in a porous elastic-perfectly plastic material.

conferenceReport

THE FIRST ASIAN-PACIFIC CONGRESS ON COMPUTATIONAL MECHANICS TOOK PLACE IN SYDNEY, AUSTRALIA.

November 20-23, 2001
P. Wriggers

The congress was organized by Prof. S. Valliappan. Within the four days of the conference technical session on different topics in the area of computational techniques, like structural mechanics, contact mechanics, coupled problems, dynamic analysis, fracture mechanics optimization and plasticity were attended by over 250 participants. Plenary lectures were given by Prof. H. Mang from Vienna on the numerical simulation of NATM tunneling and Prof. G. Yagawa from Japan on parallel computing of a local mesh finite element method. One of the major topics was related to geotechnical engineering. Within this topic papers were presented in 6 different sessions including applications of particle methods and constitutive theory.

The congress participants were mainly from Asia however the second largest group came from Europe. In total, I can conclude, that the congress was very successful, well organized and had nice and interesting social events in which also the stimulating research discussions did continue. Only the weather did not act as it should since it was raining most of the time besides the fact that it was summertime in Australia.

Australian and European scientists: Australia (J. Bonet, Sydney & Swansea), Germany (P. Wriggers) and France (E. Oñate) (from left to right)

The opera of Sydney

The Harbour of Sydney

conference

date	name	venue	email	www
02-05. 06. 2002	EM 2002 The 15th Engineering Mechanics Division Conference of the American Society of Civil Engenineers	New York, USA	em2002@civil.columbia.edu	civil.columbia.edu/em2002
17-19. 06. 2002	24th World Conference on Boundary Element Methods	Sintra, Portugal	peosouta@wessex.ac.uk	wessex.ac.uk/conferences
18-20. 06. 2002	FWMF Friction and Wear in Metal Forming	Valenciennes, Francee	euromech435@univ.valenciennes.fr	univ-valenciennes.fr/euromech435
07-12. 07 2002	WCCM V Fifth World Congress on Computational Mechanics	Vienna, Austria	registration@wccm.tuwien.at	//wccm.tuwien.ac.at/
14-16. 07. 2002	IABMAS '02 First International Conference on Bridge Maintenance, Safety and Management	Barcelona,Spain	iabmas02@cimne.upc.es	cimne.upc.es/iabmas
15-17. 07. 2002	Euromech Colloquium 438 Constitutive Equations for Polymer Microcomposites	Vienna, Austria	euromech@iki.boku.ac.at	//iki.boku.ac.at/euromech/
18-19. 07. 2002	Workshop Inelasticity and Viscoelasticity of Rubber	Vienna, Austria	euromech@iki.boku.ac.at	//iki.boku.ac.at/euromech/
21-26. 07. 2002	b'02 IFAC-15th World Congress	Barcelona, Spain	secretariatnoc@b02.ifc2002.org	ifac2002.org
02-05. 09. 2002	Eurodyn 2002	Munich, Germany	eurodyn2002@bv.tum.de	eurodyn2002.de
16-18. 09. 2002	Third International Euro Conference on Trefftz Methods	Exeter, United Kingdom	e.a.w.Maunder@ex.ac.uk	
9-12. 10. 2002	SSTA The 7th Conference Shell Structures Theory and Applications	Gdansk-Jurata,	ssta2002@pg.gda.pl	pg.gda.pl/ssta2002
21-25. 10. 2002	NUMISHEET 2002	Jeju Island, Korea,	webmaster@numisheet2002.org	numisheet2002.org
31.3 - 03.4. 2003	FEF 03 13th International Conference on Finite Elements in Flow Problems	Nagayo, Japan	fef03@cmlab.meijo-u.ac.jp	cmlabtp.meijo-u.ac.jp/fef03/index.html
7.04-10.04.2003.	Complas 2003 VII International Conference on Computational Plasticity	Barcelona, Spain	complas@cimne.upc.es	cimne.upc.es/congress/complas
30.6 - 03.7.2003	Structural Membranes 2003	Barcelona, Spain	membranes03@cimne.upc.es	congress.cimne.upc.es/membranes03
24-28. 07. 2004	ECCOMS 2004 International Concress on Computational Methods in Applied Science and Engineering	Jyväskylä, Finnland	pirjoleena.putkanen@paviljonki-ikl.com	mit.jyu.fi/ECCOMAS2004

awards

THE ERWIN STEIN AWARD

Announcement of the Erwin Stein Competition for the best Student Paper in Computational Mechanics

It is our pleasure to announce the competition for the Erwin Stein Award for best paper in the area of computational solid mechanics. This is sponsored by the University of Hannover.

History

The Erwin Stein Award Competiton has been initiated to honor Professor Stein, an international leader in computational solid mechanics, and former Director of the Institute for Structural Mechanics and Computational Mechanics (IBNM) in Hannover. Professor Stein's professional career has not only included building and leading the IBNM, for nearly 30 years, to become a recognized center for research in computational mechanics in Europe, but also strong industrial contacts by being an official Inspection Engineer for the State of Lower Saxony. He is a member of all important international organizations pertaining to computational mechanics, and is founding member of both the IACM (International Association for Computational Mechanics) and the GACM (German Association for Computational Mechanics), as well as serving on the editorial board of numerous major scientific journals in the area. His research interests have spanned virtually all fields of computational solid mechanics, including structural analyses, adaptive methods and error estimation, high-performance computing, impact and contact mechanics, phase transformations, composite materials and material theory. In light of Professor Stein's great breadth of research, the competition committee welcomes papers in all areas of computational solid mechanics.

The winner receives 1000 Euros and an award to be presented by the sponsor. The winner is to give a presentation of her/his paper at a special workshop of the ICCES which includes the award ceremony

Application Prodedure

The competition is broken into two parts. Part one involves submission of extended abstracts, no longer then three pages. The format, in Latex, can be found at the ICCES website:

http://www.icces.de.

Part two consists of requests for a selected number of full length papers which are chosen for final judgement. The winner is selected by an international panel. Papers and abstracts are to be submitted in English.

Topics

Papers must pertain to one or more of the following areas in computational solid mechanics:

- **structural mechanics**
- **impact and contact mechanics**
- **adaptive methods arad error estimation**
- **high-performance computing, solution techniques**
- **parallel processing and large-scale computation**
- **mathematical theory of finite elements**
- **material theory**
- **phase transformations and composite materials**

Restrictions

The restictions for the competitor are:

- under 35 Years old, therefore anyone born before January 1, 1968 is ineligible
- graduated from an European educational institution

Timetable

- Deadline of extended abstracts: November 30, 2002
- Notification for final papers: February 1, 2003

All submission and inquiries should be send to:

International Center for Computational Engineering Science

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Appelstrasse 9A, 30167 Hannover, Germany
Tel.: +49 511 / 762 22 20
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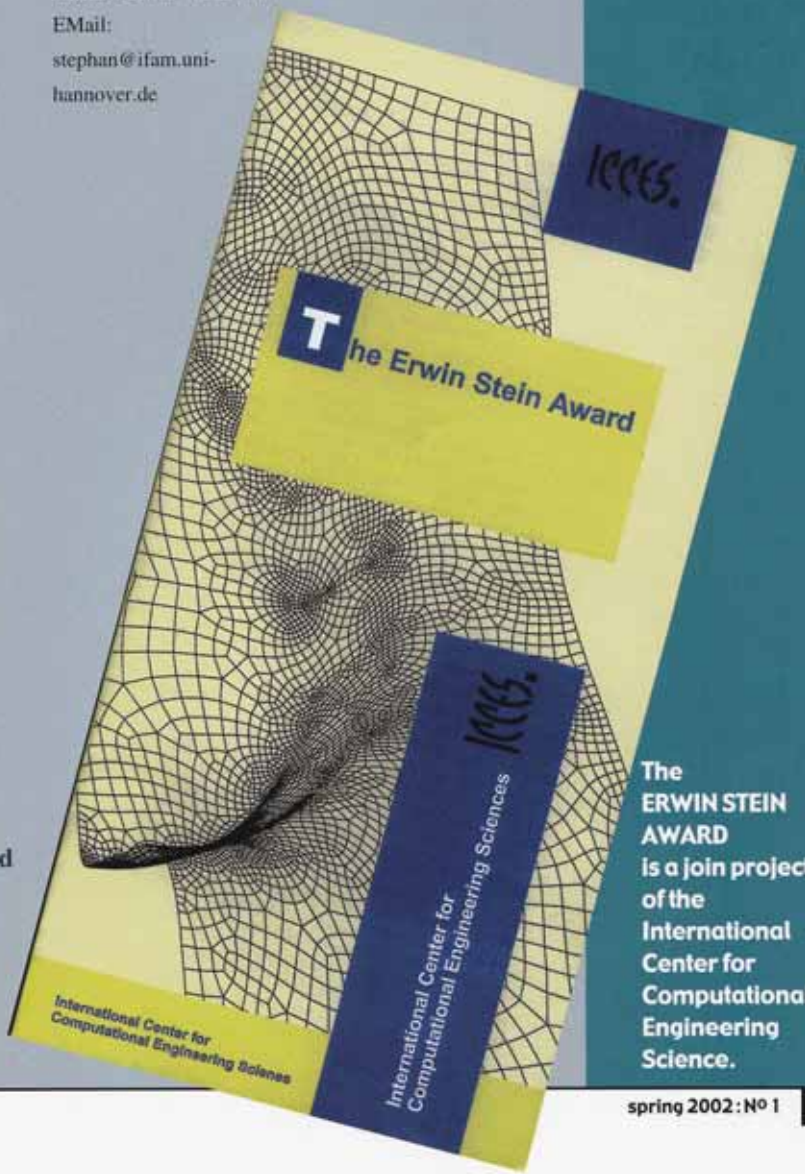

The ERWIN STEIN AWARD is a join project of the International Center for Computational Engineering Science.

what?

The German Association for Computational Mechanics (GACM) is a non-government association. The objective of GACM is to stimulate and promote education, research and practice in computational mechanics, and to provide forums and meetings for the dissemination of knowledge about computational mechanics in Germany.

who?

Researcher, practitioner, graduate students and companies from all engineering disciplines as well as from applied sciences with an interest in computational mechanics and computational methods in applied sciences.

costs?

The annual member fee (that also covers your membership fee in IACM) is currently
EURO 25,-

benefits?

A GACM membership not only gives you up-to-date informations and an active network of contacts that are necessary for engineers and scientists involved in commercial and academic activities in computational mechanics.

You also

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