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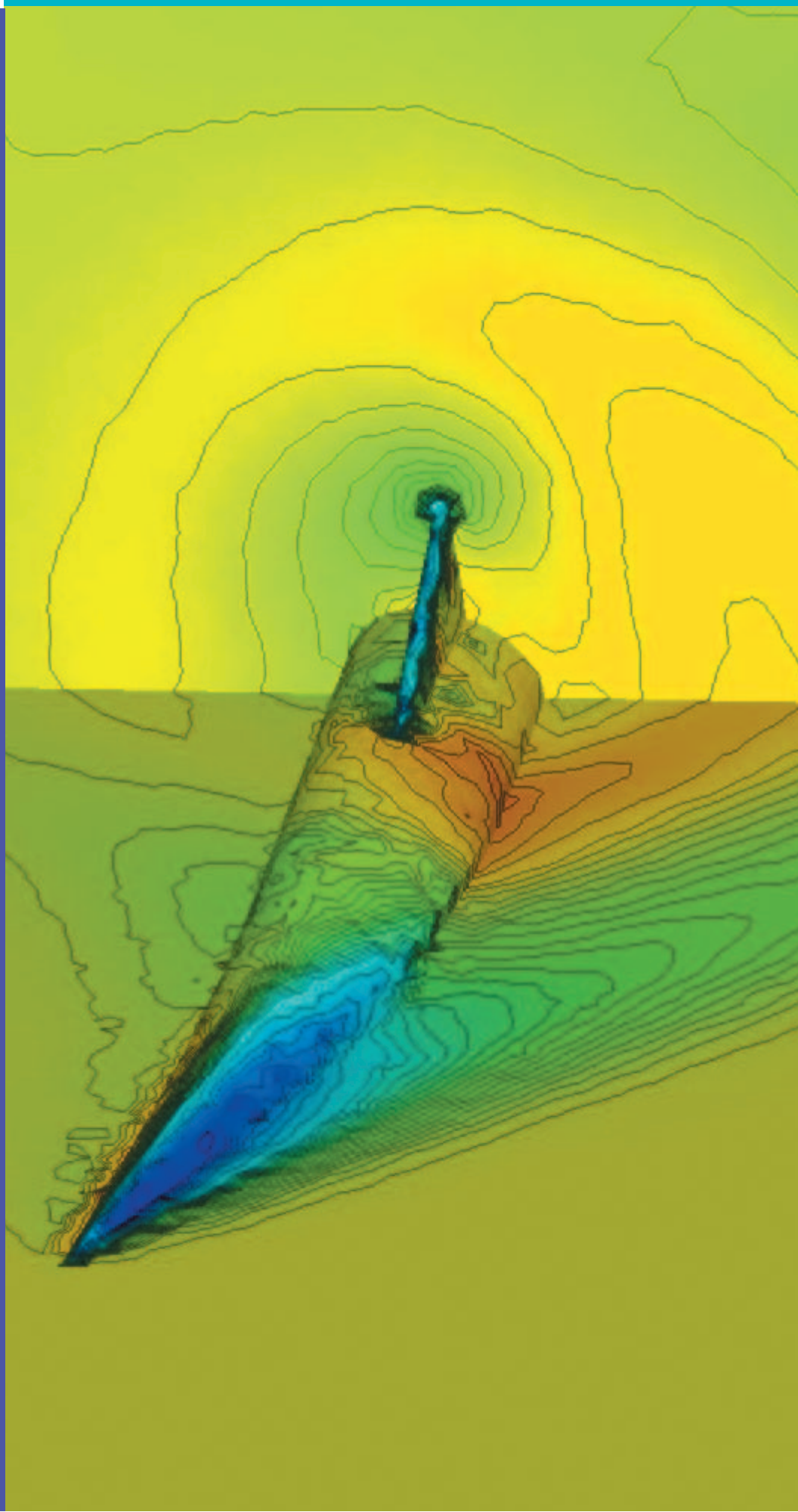

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contents

editorial

Many of those who work in the development of numerical methods and software in mechanics are not fully aware of the importance of data in the computational process. For years we have taken for granted that good data is to be graciously provided by third party persons or groups not necessarily associated to the computational world. This obviously has never been quite true, despite the distance kept from the computational arena by many who class themselves as “experimentalists”.

The fact is that nowadays the role of data is becoming more and more crucial in computational mechanics. In every day practice the word data is no longer associated only to input data for software codes. Data today means “information” and this refers both to the advice and knowledge needed for performing the analysis, as well as that for the post processing of the numerical results.

The integration of software, such as finite element-based codes, within more complex computational systems for optimal design of products and processes, requires a good interfacing of the codes with dynamic databases providing the necessary input data in a variety of ways.

Static and deterministic concepts in the past, such as the geometrical description of a body, the material properties, or the boundary conditions for the analysis, are to be seen today as dynamic information changing in time in a random way and intimacy related to the computational process itself. The increasing sophistication of CAD tools, earth observation systems, medical data acquisition technology and wireless sensing networks (WSN) are bringing in new concepts and methods for interfacing analysis software with the data necessary for the computation.

The same revolution is affecting the way numerical results will dialog with experimental data. This is not only a necessity for calibration or validation of new software. The emergence of networked info-mechanical systems (NIMS) whose behaviour is controlled by the output from sophisticated numerical codes using wireless devices, closes the loop where data (both numerical and experimental) is the key actor, both at the start and the end of the computational process.

I finish these lines with a change of subject.
The 6th World Congress on Computational Mechanics (WCCM VI) of the IACM held in Beijing last September was a huge success and all of us who took part in it enjoyed the technical programme and the hospitality of our hosts, to whom I would like to again express my gratitude on behalf of IACM.

In the pages of this magazine you will find that the coming months to come bring a promise of many interesting events for the computational mechanics community. Later, in July 2006, the VII World Congress of the IACM will take place in the city of Los Angeles.

This issue of Expressions being the first one of the New Year, let me express my best wishes for a happy, successful and peaceful 2005.

EUGENIO OÑATE
IACM President

The IACM 2004 Congress Medal Awardees

by
Thomas J.R. Hughes
Institute for Computational Engineering and Sciences (ICES)
The University of Texas at Austin
U.S.A.

IACM Expressions would like to acknowledge that the majority of articles in this issue were contributed by 2004 IACM Award Winners

IACM's highest award, the Congress Medal, also known as the Gauss-Newton Award, was bestowed on two outstanding computational mechanicians, ***Franco Brezzi*** and ***D.R.J. ("Roger") Owen***, at the Sixth World Congress of Computational Mechanics in Beijing, China, September 5th-10th, 2004. The awards ceremony was held during the congress banquet. Held outdoors, the banquet featured a lavish meal, entertainers, acrobats and a dazzling fireworks show. Franco is the first mathematician to receive the Congress Medal. Roger is the latest engineer to be similarly honoured. Although their scientific backgrounds are different, they share commitments to research excellence and extraordinary records of accomplishment.

Franco Brezzi received his mathematics degree from the University of Pavia in 1967. He became a full professor of mathematical analysis in the faculty of engineering in 1976 at the University of Turin. He returned to the University of Pavia in 1977 where he occupies a similar position and where he also serves as Director of the Institute of Applied Mathematics and Information Technologies (IMATI) of the Italian National Council of Research (CNR).

Franco has authored over 150 scientific papers and has been recognized by ISI Thompson as one of the most highly-cited researchers in mathematics. His scientific interests reside primarily in the field of numerical methods for partial differential equations and, in particular, finite element methods. He has applied his skills to various problems emanating from engineering disciplines such as structural mechanics, fluid mechanics, and electromagnetics. He serves in various capacities on the editorial boards of over 20 archival journals and book series, and is Editor-in-Chief of Mathematical Models and Methods in Applied Sciences. He is co-author of the classic monograph "Mixed and Hybrid Finite Element Methods." He has supervised many outstanding students, including Alfio Quarteroni, Claudio Canuto, Lucia Gastaldi, Alessandro Russo, Silvia Bertoluzza, Daniele Boffi, Annalisa Buffa, Carlo Lovadina, Ilaria Perugia, Giancarlo Sangalli, and Lourenço Beirão da Veiga.

Figure 1: *Tom Hughes announcing the Award Winners at the conference*

His research has focused on the following topics: existence, uniqueness, and regularity of solutions of boundary-value problems for partial differential equations; numerical solution of linear elliptic problems with irregular data; basic properties of finite element methods, in particular, "non-standard" finite element methods, such as mixed, hybrid, etc.; approximation of variational inequalities and free boundary-problems; behaviour and approximation properties of finite-dimensional discretizations of bifurcation problems; theoretical and numerical problems in semiconductor device simulations; finite element analysis of plates and shells; domain decomposition methods; stabilization techniques in finite element formulations; residual-free bubbles and subgrid-scale simulations; approximation of eigenvalue problems in mixed form; and discontinuous finite element methods.

He has made many fundamental contributions and one stands among the most celebrated and frequently-cited results in numerical analysis: the necessary and sufficient conditions for the stability of problems in mixed form, the fabled "inf-sup" or "BB condition." This legendary contribution, made at the outset of his career, would have guaranteed his membership in the exclusive pantheon of the all-time greats had he never made another contribution. But he followed it with many other important ones, including: a general theory of Galerkin approximations for mildly nonlinear problems, including branches of regular solutions, simple quadratic folds, and bifurcation points; the analysis of the so-called hybridization process, introduced by Fraeijs de

Veubeke, and the superconvergence of the multipliers; understanding and exploiting the use of bubble functions for the stabilization of Galerkin approximations of the Stokes equations and the MINI element, among other applications; the design of the basic strategy for proving stability of finite element approximations of Reissner-Mindlin plates, and the relationship with the Stokes problem (he claims this idea was suggested to him by a friend in a dream!); the introduction of BDM (Brezzi-Douglas-Marini) elements for mixed approximations of elliptic problems, such as Darcy flow; the introduction of Mixed Exponential Fitting methods for semiconductor device simulation; the introduction of Residual-Free Bubbles and the analysis of their relationship with SUPG methods and the capturing of subgrid scales; the concept of stabilizing subgrids; and the analysis of the fundamental mechanisms governing the behaviour of Discontinuous Galerkin methods.

Franco includes among the honours bestowed upon him membership in the Istituto Lombardo, Accademia di Scienze e Lettere, and corresponding membership in the Accademia Nazionale dei Lincei. Since birth (!) he has been a loyal supporter of the Juventus football club of Turin.

Roger Owen received his Bachelor's and Master's degrees in Civil Engineering from the University of Wales Swansea in 1963 and 1964, respectively. He received his Ph.D. from North-western University in 1967, after which he returned to Swansea to join his mentor, Prof. Olek Zienkiewicz, and pursue an academic career. He received his D.Sc. from the University of Wales in 1982.

Roger is an international authority on finite element and discrete element techniques, and is the author of seven textbooks and over 350 scientific publications.
In addition to being the editor of over 30 monographs and conference proceedings, he is also the editor of the International Journal for Engineering Computations and is a member of several Editorial Boards. His involvement in academic research has led to the supervision of over sixty Ph.D. students. Of these, a significant number have contributed prominently to research – and subsequently became academic colleagues and leaders in their own right. In this regard Djordje Peric and Eduardo de Souza Neto, who are now his colleagues at Swansea, may be especially recognized. His research, in the field of solid and structural mechanics, has largely centered on the development of solution procedures for nonlinear problems encountered in engineering practice. Roger has contributed prominently to the development of computational strategies for plastic deformation problems and to the introduction of parallel processing concepts to finite element analysis. Over the last decade or so, his work has focused on the development of discrete element methods for particulate modeling and the simulation of multi-fracturing phenomena in materials. Areas of application have included rock blasting simulations, deep level mining operations, defense problems, structural failure predictions for impact, seismic and blast loading, and the simulation of industrial forming processes for metals, plastics and glass. In all these areas, he has been able to solve extremely difficult problems and, in many cases, he has obtained truly spectacular results.

His research interests have led to extensive industrial involvement. In 1985 he co-founded Rockfield Software Ltd., of which he is Chairman, for the specific purpose of providing a computational technology service to industry. The company, which is located in the Technium Centre, Swansea, has grown into one of the foremost UK computational R&D companies with offices in Australia and the USA. Rockfield has an established world-wide reputation for leading-edge engineering activities and in 2002 received the Queen's Award for Enterprise.

Figure 2:
Franco Brezzi

Roger plays a leading role in national and international organizations. He is a member of several committees regulating research activities and standards within the UK and Europe. He is a member of the Executive Council of IACM and is also Past Chairman of the UK Association for Computational Mechanics in Engineering, which is the national association affiliated to IACM. Due to his industrial involvement, he has served for over ten years as elected Council Member of NAFEMS, which is an international organization aimed at establishing standards and quality assurance procedures for the safe use of finite element methods.

Figure 3
Roger Owen

Roger is also a Fellow of the Royal Academy of Engineering. In 1998 he was awarded an Honorary D.Sc. by the University of Porto, Portugal. He is also a Fellow of IACM and in 2002 received the Computational Mechanics Award of IACM for "outstanding contributions in the field of computational mechanics." In 2003 he was awarded the Warner T. Koiter Medal of the American Society of Mechanical Engineers for "contributions to the field of theoretical and computational solid mechanics." ●

The Modelling of Discontinuous Processes

by
Roger Owen
Civil & Computational Engineering Centre
University of Wales Swansea
IACM 2004 Gauss-Newton Medal

Since the early days of computational mechanics numerical methods have focused on the solution of continuum problems. However, over the last decade or so, considerable interest has emerged in the development of techniques suited to the modelling of engineering problems that exhibit strong discrete/discontinuous phenomena. The problems concerned may be broadly classified into three categories: the progressive separation/failure of continua, inherently discrete systems and a combination of continuous and discrete media.

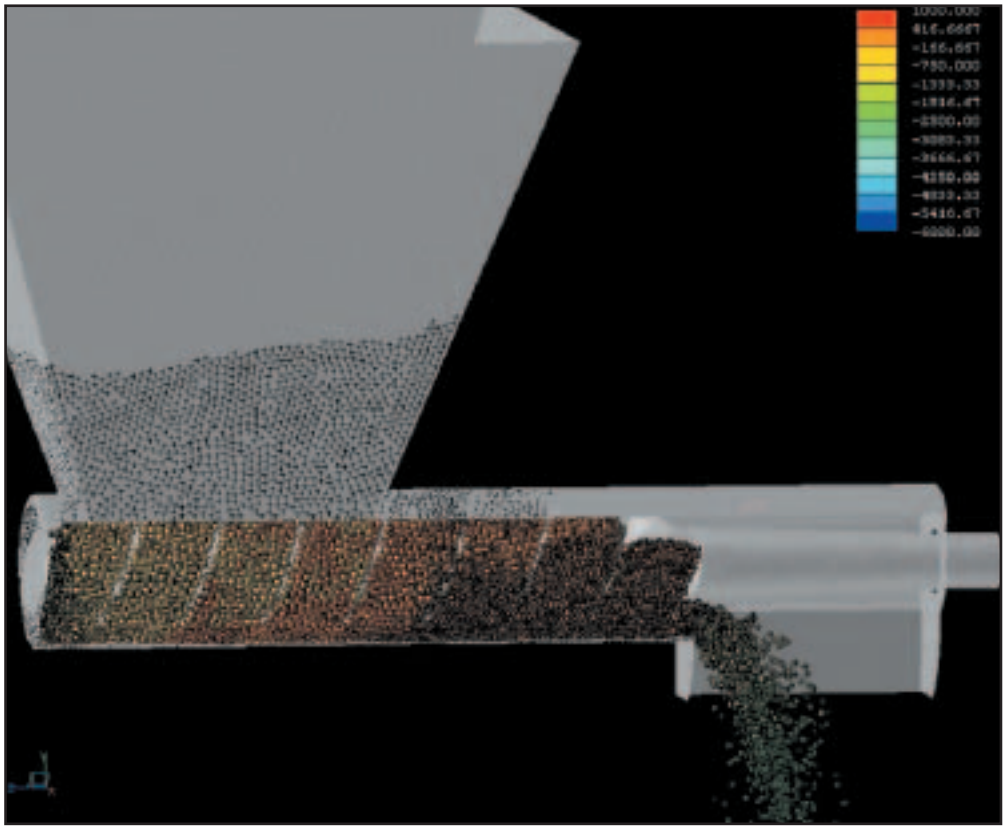


Figure 1: *Screw extruder*

Multi-fracturing solids*:* Many industrial and scientific problems are characterised by a transformation from a continuum to a discontinuous state. The problems are initially represented by a small number of continuous regions prior to the deformation process. During the loading phase, the bodies are progressively damaged and modelling of the subsequent fragmentation may result in possibly 3-4 orders of magnitude more bodies by the end of the simulation.The overall system response is governed firstly by appropriate constitutive mechanisms that control the material separation process, followed by description of the inter-element interaction forces that govern the subsequent motion of particles.These phenomena can be found in many applications such as masonry or concrete structural failure, particle comminution and grinding in high pressure grinding and ball mills, rock blasting in open and underground mining and thefracture of ceramic or glass-like materials under high velocity impact.

Discrete systems: Granular and particulate materials in process engineering and geomechanics are typical examples of systems with an inherent discrete nature. The systems often consist of an excessively large number of individual particles

in which the overall behaviour is determined by the motion of these particles that involves interaction mainly through adhesive/cohesive/frictional contact.

Combination of continuous and discrete media: In other situations, e.g. shot peening and peen shape forming operations, in which the residual stress and deformation states in a component are controlled by impacting the surface with, usually, steel shot, both a continuous region (workpiece) and a large number of discrete bodies (shot) are simultaneously present [1]. The deformation of the continuous region is a result of a coupled dynamic interaction between the two types of media.

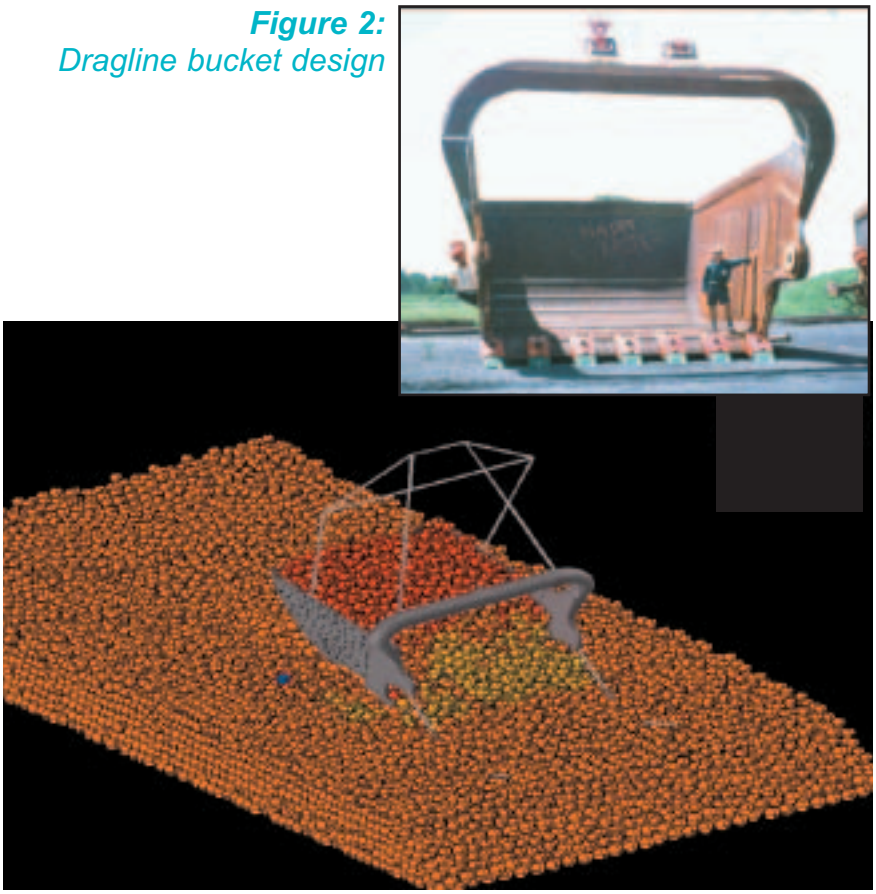
For modelling multi-fracturing phenomena in particular, current strategies range from continuum-based finite element approaches [2-4], including cohesive zone models, XFEM methods, to discontinuum-driven formulations, such as discrete discontinuous analysis (DDA) techniques [5] and distinct/discrete element approaches [6]. For problems in which interest is restricted to relatively small deformations, the use of continuum-based methods may be suitable, but not for situations involving large topological changes, such as the modelling of particle flow behaviour post-fracture.

Additionally, by modelling the continuous to discrete transformation involved in material fracture explicitly, it may be argued that a physically more realistic representation is obtained. This results in the significant advantages that the constitutive description of the entire process becomes more tractable and requires a reduced number of material parameters that can all be identified from standard experimental tests. This is important for many quasi-brittle materials, such as rocks and concrete, where the acquisition of reliable material data is difficult.

In view of the above, there is a compelling advantage in employing combined finite/discrete element solution strategies to model discrete/discontinuous systems. Discrete methods (DEM) are based on the concept that individual material elements are considered to be separate and are (possibly) connected only at discrete points along their boundaries by appropriate physically based interaction laws. Originally, each element was assumed to be rigid in the classic DEM [6], but the more recent incorporation of deformation kinematics into the discrete element formulation has lead naturally to combined finite/discrete element approaches [7,8].

Besides their discrete/discontinuous nature, the problems concerned are often characterised by the following additional features: they are often highly dynamic with rapidly changing domain configurations, sufficient resolution is required; and multi-physics phenomena are involved. The domination of contact/impact behaviour also gives rise to a very strongly non-linear response. These factors dictate that there is almost no alternative to employing time integration schemes of an explicit nature to numerically simulate such problems. For problems exhibiting multi-fracturing phenomena, the necessity of frequent

Figure 2:
Dragline bucket design



" DEM are based on the concept that individual material elements are considered to be separate and are ... connected only at discrete points along their boundaries by appropriate physically based interaction laws ..."

"... parallel implementation of the solution procedures is an obvious option for significantly increasing existing computational capabilities ..."

introduction of new physical cracks and/or adaptive re-meshing at both local and global levels adds another dimension of complexity.

All these factors make the simulation of a realistic application to be extremely computationally intensive.

Consequently, parallel implementation of the solution procedures is an obvious option for significantly increasing existing computational capabilities, which also becomes feasible due to significant advances in the development of parallel computer hardware, particularly the emergence of commodity PC clusters. However, parallel implementation is not trivial due to the continually evolving problem topology and dynamic domain decomposition strategies based on incremental migration of data between processors must be employed to maintain load balancing.

Examples of application of the technology, employing the commercial code ELFEN, include the following.

Figure 1 shows the flow of a particulate material through a screw extruder. Some 250,000 spherical particles are contained in a hopper and are then fed into the extruder system. This example illustrates, in particular, the complexity of the contact detection requirements.

Figure 2 shows the simulation of a dragline bucket operation. The bucket is modelled using 3D finite elements and the rock material is represented by locally clumped spherical particles, to provide the angularity necessary to represent the correct physical response. The aim is to improve both the design life and the payload of the bucket.

Figure 3 illustrates the 2D representation of a block caving operation. In many instances mineral ore of suitable strength existing in faulted geological strata can be efficiently mined by driving access galleries, or stopes, beneath the rock mass and creating draw points at selected locations. Due to disturbance of the initial tectonic stress state, extensive fracturing of the ore occurs resulting in free flow into the stopes for removal and processing.

Finally, *Figure 4* shows the replication of the Sugano test in which a reinforced concrete plate is dynamically loaded by a lumped mass-spring system, intended to simulate the impact of the components of an aircraft engine.

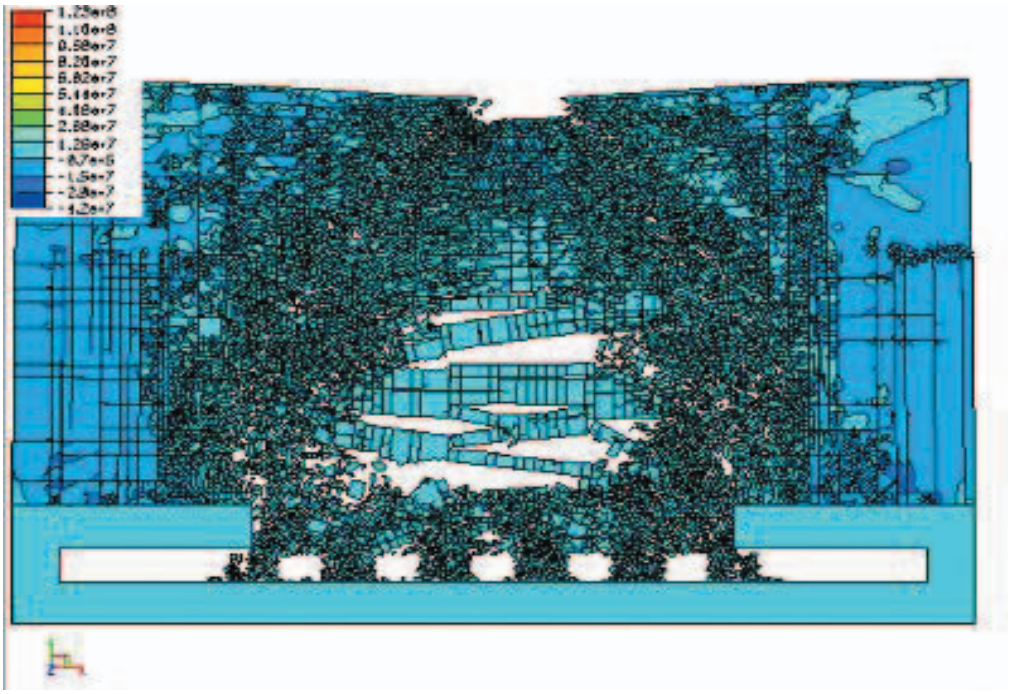


Figure 3:
Block caving mining operation

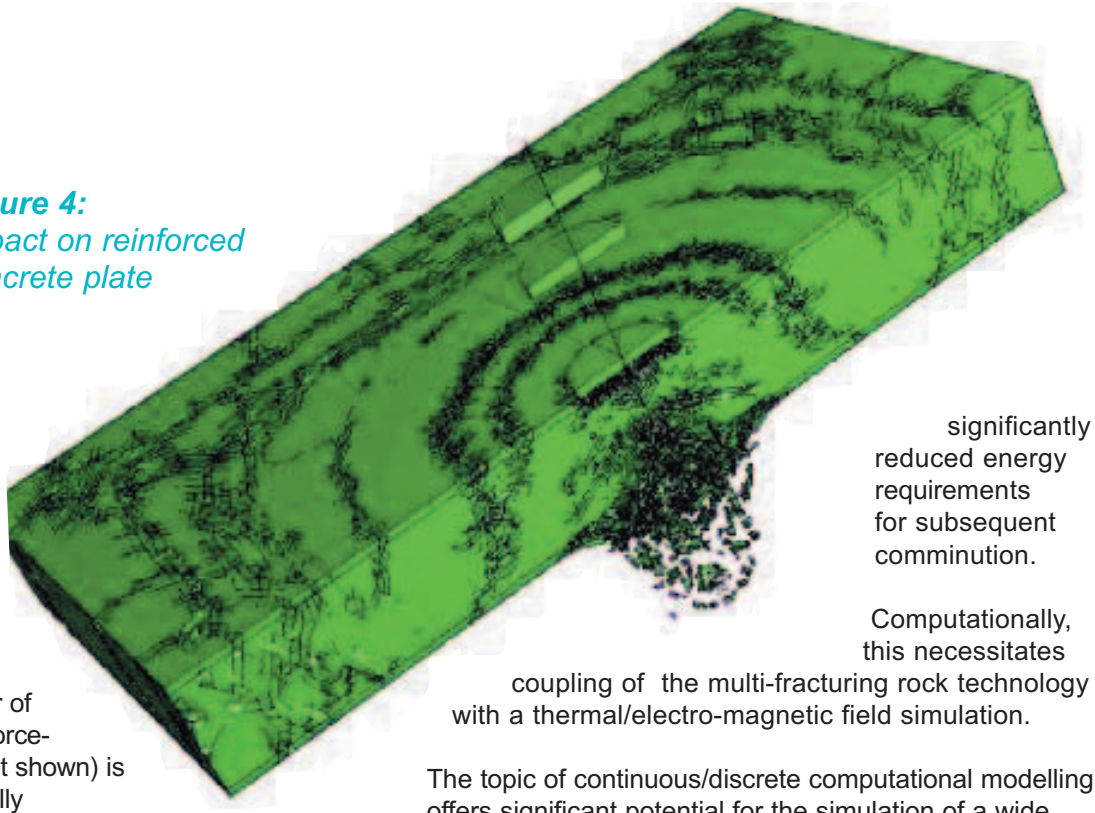


Figure 4:
Impact on reinforced concrete plate

Each bar of the reinforcement (not shown) is individually modelled as an elasto-plastic beam and the resulting fracture patterns and failure mode correspond well with experimental observations.

Current developments are being undertaken to couple FE/DE technology with other physics fields. Specific applications include coupling with gas detonation models to simulate the fracture of rock masses due to explosive quarrying/mining operations. A separate Eulerian mesh is used to model the gas flow, accounting for the equations of state of the detonating explosive, to provide the pressure distribution based on the local porosity of the fractured rock. This gas pressure is then applied to the mechanical Lagrangian based rock model to further drive the material fracture. Another form of fluid interaction involves low velocity fluid flow both along fracture surfaces and through semi-intact porous rock blocks. Again the basic requirement is the coupling of the fluid pressure distribution with the progressive deformation of the fracturing rock mass.

A further current topic of interest involves the preconditioning of mineral ore, prior to comminution, by microwave treatment. Essentially, the application of microwave pulses to the material promotes the breakdown of intergranularbonds due to differential thermal expansion, resulting in significantly reduced energy requirements for subsequent comminution.

Computationally, this necessitates coupling of the multi-fracturing rock technology with a thermal/electro-magnetic field simulation.

The topic of continuous/discrete computational modelling offers significant potential for the simulation of a wide range of scientific and engineering problems, ranging over many physics length scales, and promises to be an exciting area of future research activity. ●

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Mathematical Advances in Optimal Shape Design

by
Olivier Pironneau
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France
IACM 2004
IACM Fellow Award

Shape optimization is a well-understood and much practiced branch of optimization for systems governed by partial differential equations.

In mathematical terms if Ω denotes the domain, u the solution of a partial differential equation in Ω then the problem is to minimize a criteria J(u) with respect to a part S of the boundary of Ω. Mathematics contributed very significantly to the practical solutions of such problems because:

Existence of solution is intimately linked to the presence of numerical oscillations in the computed solutions. Indeed, the first criteria given by Chenais for existence was to restrict the class of domains to those with uniformly Lipschitz S (see Pironneau [2]); now the modern way is to use a Tikhonov regularization in terms of the length of S and replace J by J(u)+a|S| with a <<1. (see Allaire-Henrot [1] for example).

Gamma-convergence and homogenization theory have shown how ill-posed shape optimization problems really belong to a larger class of optimization problems with composite structures (Tartar [3]) and lead to topological optimization (Kikuchi [4], Sokolovski [5]).

Regularity is also connected to numerical efficiency and it is known now that smoothing S improves very much the performance of gradient algorithms (Dicesare et al [6], Jameson[7], Mohammadi et al[8]).

Spectacular results have been obtained for linear elasticity with topological derivatives

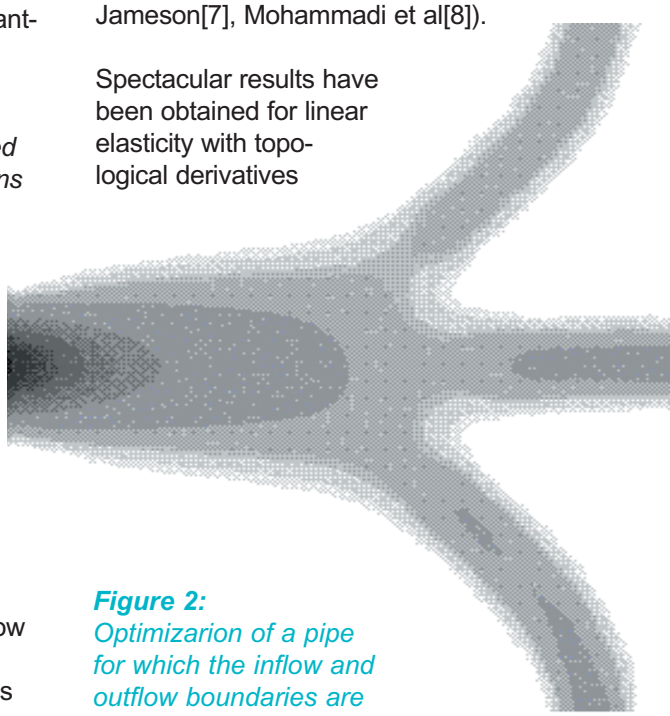

Figure 2:
Optimizarion of a pipe for which the inflow and outflow boundaries are prescribed; the problem is to maximize the flux (Courtesy of M. Hassine et al).

Figure 1:
Optimization of a car suspension triangle by topological optimization (courtesy of F. Jouve)

(Allaire et al [9], Masmoudi [10], *figure 1*) and application of the technique to microfluidic and MEMS is promising (see *figure 2*) while the classsical approach of shape deformation can be made to work efficiently on very large problems such as the optimization of the sonic boom of an airplane (Jameson et al[11], Mohammadi [12]) by using automatic differentiation, CAD-free mesh generators with adaptivity and incomplete gradients (*figure 3*).

The next generation of applications is likely to be with time dependent shapes.

It is an old problem in fact; deformable airplanes have been studied at NASA in the seventies; it was shown also that flagellated microorganisms swim in an optimal fashion by minimizing their energy (Pironneau-Katz [13]), it remains to show that fish do the same! Flying drones efficiency could also be analyzed in this fashion.

For low Reynolds number flows the inertial effects are small so their optimization is a succession of independent optimization at each time step; is it possible to apply this idea for the computation of cell motions as in Verdier [14] where the motion of anautono-mous cell penetratng through a tissue is computed by solving the large displacement nonlinear elasticity equations?

Time dependent optimization problems are plagued with memory gluttony as an optimal control must take into account the whole trajectory of the system. So there is much room for sub-optimal strategies for instance by minimizing for the shape at every snap shot in time after discretization of the system. ●

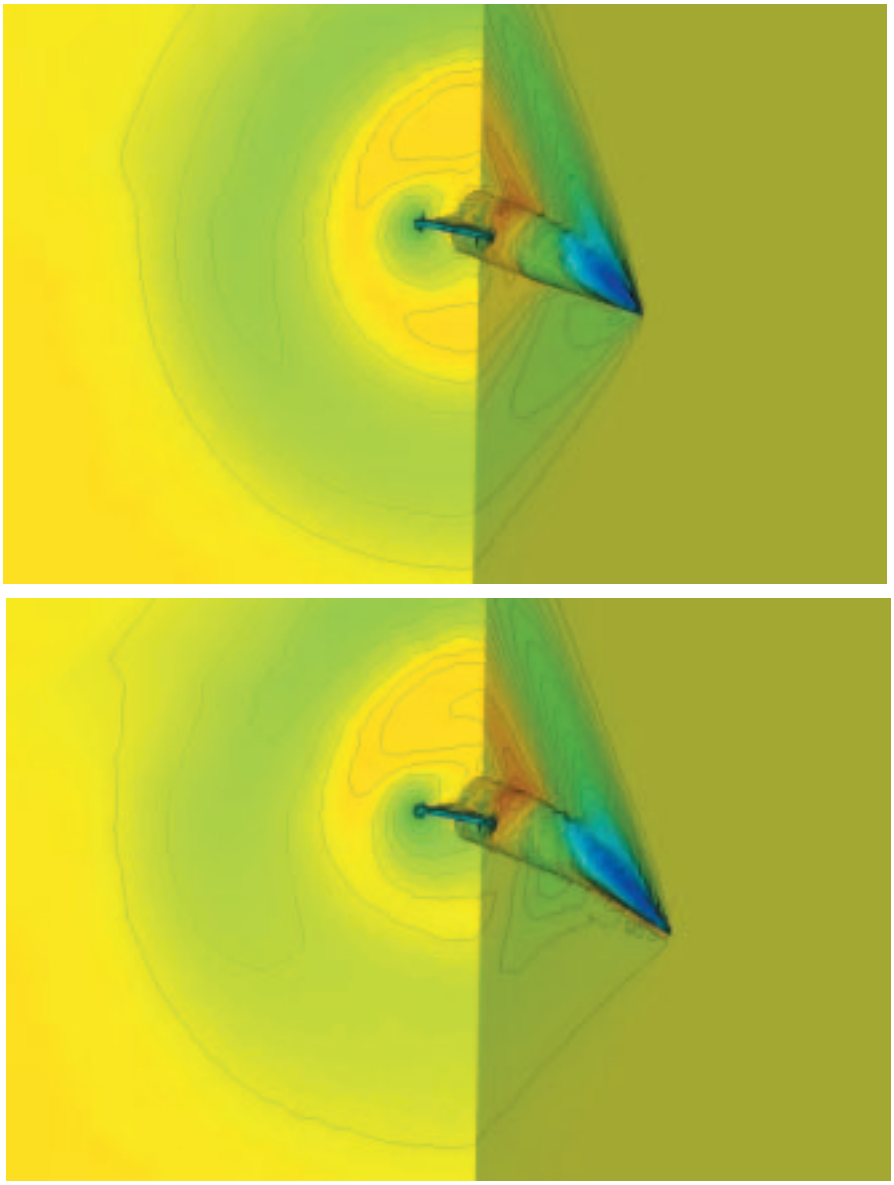

Figure 3:
Optimization of business jet to minimize the sonic boom at ground level while retaining lift drag and cross section areas. (courtesy of B. Mohammadi)

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Three Examples of Numerical Modelling of Flows in Time Dependent Domains

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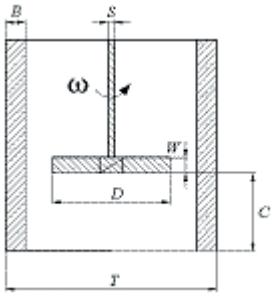
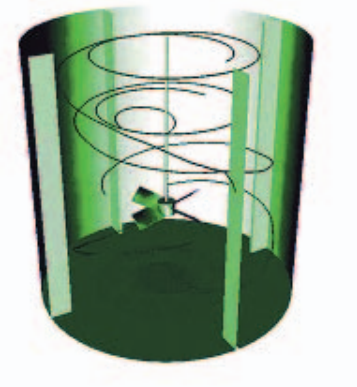
To say that many applications in computational fluid dynamics involve time dependent domains is an evidence that does not deserve to be the starting sentence of any text. However, unless one faces different real life problems, it is difficult to understand how diverse are the difficulties encountered in each case. In this note we will try to explain some of the problems we have encountered, as well as our way to approach them.

Perhaps the most well known way to treat time dependent domains is the Arbitrary Eulerian Lagrangian (ALE) method. This is a well known technique, useful in many applications, but with severe shortcomings in others. Let us describe three cases in which we have found convenient to use other approaches or modifications of the standard ALE method.

Many engineering applications involve rotating devices. Since rotation is usually very fast, it would be unfeasible or extremely expensive to use an ALE strategy. The natural way to cope with this situation is to use a rotating frame of reference attached to the rotating components of the domain and to write the flow equations in this non-inertial frame of reference.

Figure 1:
Left: *stirring tank geometry.*
Right: *particle tracking.*





This is enough, as far as there are not fixed components in the domain. This, of course, is the most likely situation. An example is shown in *Figure 1*, showing a cylindrical stirring tank with a rotating impeller and four fixed baffles (usually designed to increase the flow turbulence and thus its mixing capacity). Our way to deal with this problem has been to use different domains, one surrounding the rotating impeller and the other enclosing the baffles, with different frames of reference, the former rotating with the blades and the latter fixed. If the geometry is simple enough, it is possible to couple both domains using for example the so called sliding mesh technique. However, for general situations we have developed a Chimera strategy, coupling both subdomains via mixed transmission conditions [1]. The classical Chimera method employs a Dirichlet-Dirichlet coupling. In an iteration-by-subdomain implementation, this has the severe drawback that convergence depends on the overlapping region. In applications such as the one described, this is very narrow, leading to a poor convergence behaviour. On the other hand, mixed Dirichlet-Neumann coupling without overlapping requires matching subdomains (or a matching strategy). We have preferred to use these mixed conditions with overlapping, after showing that this is theoretically sound.

The coupling of rotating or, more generally, moving and fixed subdomains is not always possible. *Figure 2* shows an example of this situation, again for a rotating device. In this rotary pump, the two gears rotate in opposite senses, and it is impossible to assign a rotating subdomain to each because they would intersect the other subdomain near the contact zone. On the other hand, the use of a standard ALE method, even if one accepts to remesh as often as needed, has in this case the inconvenience of the lack of mesh

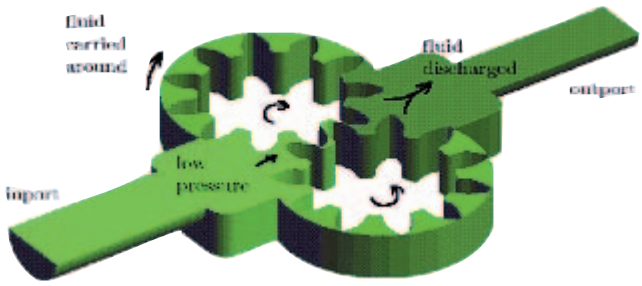
control in the gap between the gears and the casing, which in this application is extremely narrow. To sort out this difficulty we have used a modified ALE approach, which basically consists of fixing a priori the mesh to be used at each time step, thus having complete control on it. We call this strategy Fixed Mesh ALE. The difference with the standard approach is that the mesh used in each time step does not correspond with the one obtained from the classical nodal movement, and therefore an additional projection step is needed, similar to what happens when remeshing is done. The details of this approach can be found in [2].

We have found the use of the Fixed Mesh ALE approach useful in the modeling of the lost foam casting (LFC) process. In this process, before the molten metal is poured into the mould of the piece to be casted, this mould is filled with a foam (expandable polystyrene, EPS) that burns and evaporates when the hot metal contacts it.This often yields better casting qualities.The geometrical setting is depicted in *Figure 3*, together with the velocity vectors obtained in a
numerical simulation.

From the point of view of numerical modeling, the LFC is a peculiar problem involving time dependent domains. Contrary to classical casting, it is not a free surface problem, for the velocity of the interface between the metal and the foam is not governed directly by the flow equations, but by the rate at which the foam burns. A simple energy budget can be used to obtain an expression for the front velocity in terms of the temperatures of the foam and the metal and the material properties.

Since the fluid domain constantly increases, a standard ALE method would require constant remeshing. We have treated this problem by using always the same mesh, covering the whole computational domain, metal and foam. At a given time step, the flow equations are solved only in the metal region. When the front advances, new nodes appear in the computational domain, whose shape has changed. The Fixed Mesh ALE method in this case consists of moving the mesh of a given time step to follow the deformation of the domain but then, instead of using the resulting mesh, projecting the results to the fixed one and using this tosolve the flow equations. Details can be found in [3].

Another aspect that deserves special attention in this problem is the way to represent the interface metal-foam. We have used a level set technique [4], representing this interface as the isovalue of a function which is advected with the front velocity.
In spite of the fact that the way to deal with the moving flow domain may be considered independent of the numerical approximation of the flow equations, the success of the numerical simulation relies basically on this approximation. It is crucial to have a robust flow solver, particularly in this type of applications. Our experience with stabilized finite element methods, in the version described in [5], has been always satisfactory.
Let us also remark that this numerical approach fits nicely with the standard ALE



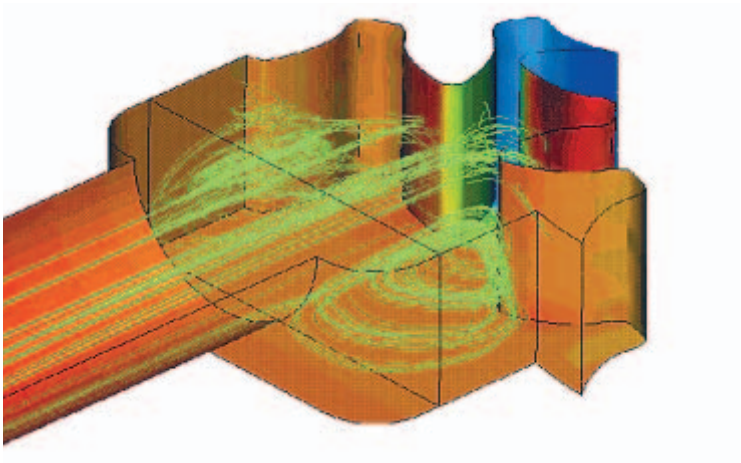
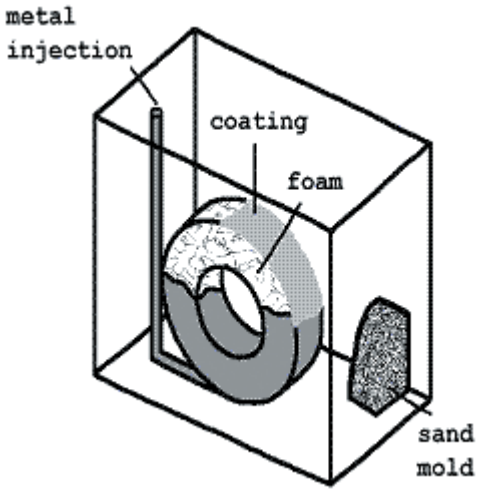


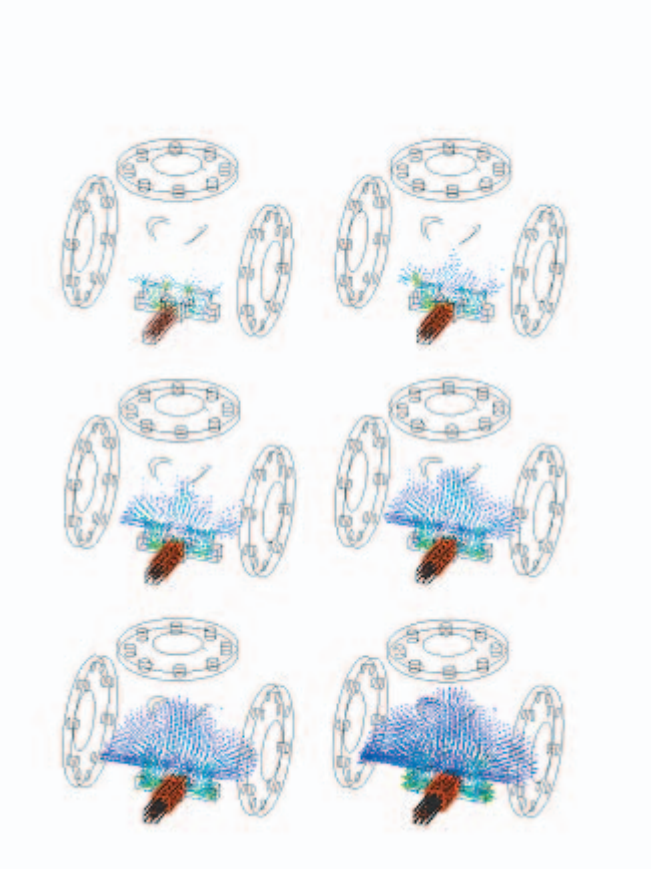
Figure 2.
Above: *Rotary pump schematic.*
Below: *Particle tracking.*

"Perhaps we are not yet in a position to say that a particular numerical approximation is better than the others."

method or its variants (see, for example, [6]). Let us conclude by noting that there are several other approaches to deal with time dependent domains in flow problems. Apart from classical ALE and the well known level set and Volume of Fluid (VOF) methods to deal with free surface problems, other possibilities with attractive potential applicability are fictitious domain methods [7] (combined perhaps with the use of Lagrange multipliers or mortar elements) or Lagrangian methods of particle type [8]. Perhaps we are not yet in a position to say that a particular numerical approximation is better than the others. What is clear is that the variety of ways to treat time dependent domains and, above all, the variety of flow situations involved, make the knowledge on the subject completely problem dependent. ●

Figure 3.
Below: *Schematic of a LFC process.*
Right: *Velocity vectors obtained in a numerical simulation at different time steps*





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" ... the variety of ways to treat time dependent domains ... make the knowledge on the subject completely problem dependent. "

The Amusing History of Shear Flexible Beam Elements

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Earnest Engineers

Having been largely created by engineers, Computational Mechanics (CM) and its subset: the Finite Element Method (FEM) are not particularly funny topics. There have been comedies about wacky scientists ("Young Frankenstein") and even undertakers ("Six Feet Under"). But I cannot recall comedies about engineers per se.The strip "Dilbert" confuses engineering with nerd culture as in *"a well dressed engineer has no credibility."* According to my Rhett and Scarlett emails, the sequel "Tacoma-Narrows: Gone with the Wind 2" was never released by MGM.

There are some, mostly lame, jokes about engineers: *"Ohm resisted the idea at first."* Googling "engineer jokes" does gather 16400 hits. But the good ones rely on other professions, like lawyers and bartenders, for the punch line.

The only FEM text that systematically attempts humor is [1]. Much of it, however, relies on insider knowledge plus dated themes from the sixties, such as *"shape functions are the new morality,"* as well as in-your-face statements: *"useful insight is always physical."* From the opposite *"math is all you need"* camp Truesdell [2] narrates the *"tragicomedy of thermodynamics"* with clueless founders bumbling Calculus. The setting here will be more informal. The humor will be in the fact that even a humble element can be endlessly rediscovered over five decades.

Figure 1:
Ukraine commemorative stamp in honor of S. P.Timoshenko. Courtesy of Prof. Roman D. Hryciw, University of Michigan.

The Timoshenko Beam

Flashback to the 1920s. Stepan (Stephen) Prokofyevich Timoshenko (1878-1972) is one of the fathers of modern engineering mechanics. Born in Ukraine, he graduated from the St. Petersburg Institute of Civil Engineering in 1901. He became a Professor at Kyev from 1907 through 1920, when he left for Yugoslavia. In 1922 he emigrated to the US, first working at the Westinghouse Research Laboratory and later joining the faculty of the University of Michigan in 1927. In 1936 he moved to Stanford, retiring in 1960. Besides making major contributions to theoretical and experimental applied mechanics, he revolutionized the teaching of structural engineering. His 12 textbooks, translated into 35 languages, remain ageless.

His "bottom up" approach to teach-through-problem-solving was unique at the time. (When I need to understand a specific problem in mechanics, or prepare an exam, I go to Timoshenko first.) One of his famous equations can be discerned in the Ukrainian commemorative stamp shown in *figure 1*.

In 1921 Timoshenko published [3] the beam model that now bears his name. This was intended as a refinement of the classical Bernoulli-Euler (BE) beam model. It introduced first-order shear effects by releasing the "plane sections remain plane" constraint of the BE model, as well as including rotational inertia in the kinetic energy. The model was presented in the context of vibration and dynamics. And indeed that was the area in which it has found heavy use since. Especially in transient dynamics and control. Its virtue for those applications is that the equation of motion is hyperbolic and possesses a finite wavespeed.On the other hand the BE model is parabolic: it has an wavespeed, which can lead to paradoxical results.

Matrices Appear in the Menu

As narrated in [4] significant advances in Matrix Structural Analysis (MSA) were made during the early 1930s by A. R. Collar and W. J. Duncan at the National Physical Laboratory in Teddington (UK). Their first journal article [5] came out in 1934. The chief goal of this effort was to organize aeroelastic computations on desk calculators. Mass, stiffness and flexibility matrices were written out in what is now known as assembled or master form. I have found no published evidence of use of matrices at the disconnected element level prior to 1950.

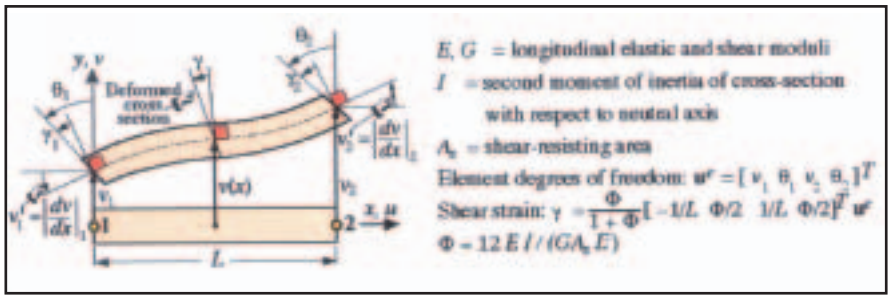

Figure 2: The shear flexible plane beam element with 4 degrees of freedom.

During 1952-1953 the eventual winner in the Force versus Displacement tug-of-war: the Direct Stiffness Method, emerged through the efforts of a small but high-caliber research team at Boeing under the direction of Jon Turner. This group developed stiffness matrices of axial and flexural one-dimensional members and two continuum based plane stress elements [6].
Concurrent events were the formal energy unification of the Force and Displacement Methods by Argyris in his classical serial [7] and the rising (but ephemeral) popularity in Europe of the Transfer Matrix Method covered in the textbook of Pestel and Leckie [8]. This "first FEM generation" period may be considered closed by Melosh's influential article [9], as well as Turner's definitive exposition of the DSM [10]. Melosh's paper, a summary of his 1962 thesis, clarified the link between conforming displacement models and Rayleigh-Ritz. Conforming elements guaranteed lower bounds to influence coefficients. By then the catalog of element matrices was growing swiftly.

The Exact Stiffness

The catalog included the Timoshenko beam element by 1956. For conciseness I will focus here on the stiffness matrix of the 2-node, 4 DOF plane beam. The element geometry and properties are defined in *figure 2*. From Timoshenko's governing equations one can derive the stiffness $\mathbf{K}^e_E$ shown in *figure 3(a)*, which is copied from eqn. (5.119) of Przemieniecki [11].
(The spatial beam case as well as the consistent mass matrix of Archer [12] are also presented in that book.) The dimensionless coefficient $\Phi = 12EI/(G A_s L^2)$ characterizes the importance of the mean-shear correction. If $\Phi \to 0$ the well known Hermitian-cubic beam element for the BE model is recovered.

The stiffness $\mathbf{K}^e_E$ was first presented in [6] but in a different context. It is worked out there as a spar-web element for airplane structures, with 4 translational degrees of freedom.

Figure 3: Stiffnesses for the shear flexible prismatic plane beam element of figure 2, in order of historical appearance: (a) Timoshenko-exact; (b) shear-moment spar-web, same as 1-point integrated LDLR iso-P; (c) fictitious edge beam stiffness for Melosh triangular shell facet, (d) exactly integrated LDLR iso-P, (e) template form that includes (a)-(d) as instances.

$$\text{(a)}\ \mathbf{K}^e_E = \frac{EI}{L(1+\Phi)}\begin{bmatrix} 12/L^2 & 6/L & -12/L^2 & 6/L \\ 6/L & 4+\Phi & -6/L & 2-\Phi \\ -12/L^2 & -6/L & 12/L^2 & -6/L \\ 6/L & 2-\Phi & -6/L & 4+\Phi \end{bmatrix} \qquad \text{(b)}\ \mathbf{K}^e_R = \frac{EI}{L\Phi}\begin{bmatrix} 12/L^2 & 6/L & -12/L^2 & 6/L \\ 6/L & 3+\Phi & -6/L & 3-\Phi \\ -12/L^2 & -6/L & 12/L^2 & -6/L \\ 6/L & 3-\Phi & -6/L & 3+\Phi \end{bmatrix}$$

$$\text{(c)}\ \mathbf{K}^e_F = GA_fL\begin{bmatrix} 12/L^2 & 6/L & -12/L^2 & 6/L \\ 6/L & 3 & -6/L & 3 \\ -12/L^2 & -6/L & 12/L^2 & -6/L \\ 6/L & 3 & -6/L & 3 \end{bmatrix} \qquad \text{(d)}\ \mathbf{K}^e_X = \frac{EI}{L\Phi}\begin{bmatrix} 12/L^2 & 6/L & -12/L^2 & 6/L \\ 6/L & 4+\Phi & -6/L & 2-\Phi \\ -12/L^2 & -6/L & 12/L^2 & -6/L \\ 6/L & 2-\Phi & -6/L & 4+\Phi \end{bmatrix}$$

$$\text{(e)}\ \mathbf{K}^e_T = \frac{\alpha EI}{L}\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & -1 \\ 0 & 0 & 0 & 0 \\ 0 & -1 & 0 & 1 \end{bmatrix} + \frac{3\beta EI}{L}\begin{bmatrix} 4/L^2 & 2/L & -6/L^2 & 6/L \\ 2/L & \psi & -2/L & \psi \\ -6/L^2 & -2/L & 6/L^2 & -6/L \\ 2/L & \psi & -2/L & \psi \end{bmatrix}$$

Instead of end section rotations, [6] takes as freedoms the displacements, along the spar axis, of the cover plate attachment points. ("Offset nodes" in current terminology.) In transfer matrix form it appears in Section 5-1 of [8], where it is derived for a harmonically vibrating beam. Therein credit is given to German books and articles of the mid-1950s. So $\mathbf{K}^{\circ}_{E}$ is certainly a first-FEM-generation product.

How "exact" is it?
The static equilibrium equation of a prismatic Timoshenko beam transversally loaded by $q(x)$ and deflecting by $v(x)$ is $E I v'''' = q + \Phi L^2 q''/12$, in which primes denote differentiation with respect to x. If $q(x) = 0$ over the segment covered by the element, $E I v'''' = 0$, whose exact solution is a cubic polynomial determined by four end conditions. This is how $\mathbf{K}^{\circ}_{E}$ is built in [11]. It follows that this stiffness gives a nodewise exact solution for any prismatic beam discretization loaded at the nodes. Using the modified equation method of Warming and Hyett [13] more can be proven as regards accuracy: the stiffness $\mathbf{K}^{\circ}_{E}$ is nodally exact for a repeating element lattice for any loading $q(x)$ as long as consistent loading is used [14].

In summary, for modeling a Timoshenko beam attached only at discrete joints this element cannot be improved upon. As a spar-web element, however, it tends to be too flexible because spars are usually welded or bonded to cover plates. The overflexibility was addressed by Melosh and Merritt at Boeing in the late 1950s. In [15] they derived the stiffness $\mathbf{K}^{\circ}_{R}$ of *figure 3(b)* for a "shear-moment spar." (Subscript R stands for "reduced integration", which is a clone discussed later.) This model maintained displacement compatibility with the cover plates and thus provided lower bounds on deflections.

Road to Shell Paved with Good Intentions

The linkage of conforming elements to Rayleigh-Ritz in [9] gave mathematical credibility to finite elements. In this context Timoshenko had played a major albeit indirect role.Through his books, especially [16-19], he had popularized the use of energy methods in problem solving, and introduced the direct variational methods of Rayleigh-Ritz and Galerkin to the US structural engineering community. Since 1962 there is a noticeable bias: in Conformity there is Safety. The more important question of completeness came up later.

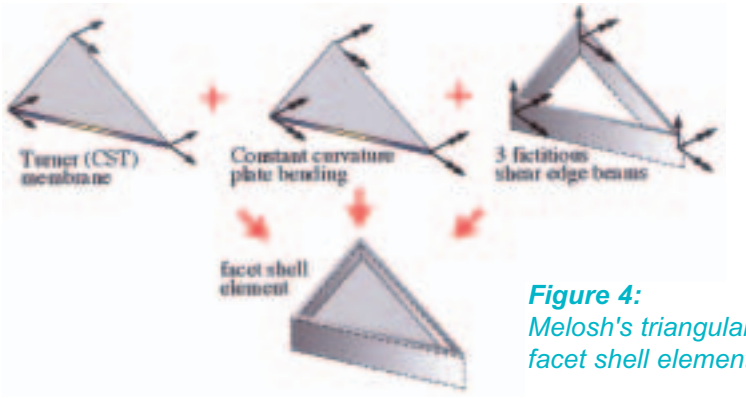

Figure 4:
Melosh's triangular facet shell element.

One noticeable gap in the DSM element collection was a thin shell element. The plane stress elements of [6] were used for cover plates (e.g., aircraft or rocket skins) and did not include plate bending effects. By the late 1950s Melosh, working at Boeing while a doctoral student at U. Washington, set out to fill that gap. He made four decisions: (I) flat triangular facet geometry, (II) membrane component taken care of by Turner's triangle (aka CST), (III) plate bending split into a constant curvature component and a transverse shear component, (IV) the latter realized by three fictitious shear beams. As shown in *figure 4*, the beams are placed along the triangle edges and are energy-orthogonal with respect to the constant-curvature component. Decision (IV) was perhaps influenced by Hrennikoff and McHenry "framework analogy" of the 1940s [20,21]. The original shell formulation appeared in [22] and was improved upon in [23].

In the FEM zoo this element is a curious chimera, mixing continuum and lattice ingredients. The innovative idea was the set of edge beams. Melosh chose linear displacements and linear rotation (LDLR) for all components.

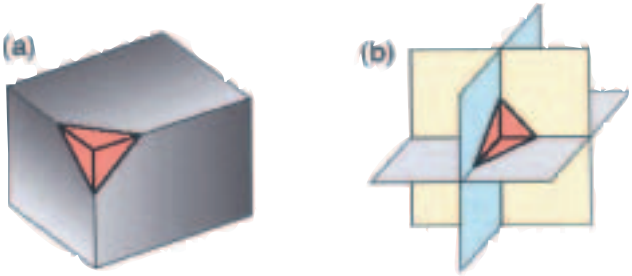

Figure 5:
Full conformity of facet shell elements meeting at finite-angle intersections mandates LDLR kinematics. In (a) and (b) 3 and 12 triangles, respectively, meet at a point.

" So many beam models, so little time. Can they be wrapped into a single package? "

For the shear beams the constant moment response was excised. Over each side the edge aligned stiffness $\mathbf{K}^{\circ}_{F}$ is that of *figure 3(c)*, in which A_f is a fictitious shear area to be determined by a matching-to-continuum procedure. A weird result from the matching was that the shear area opposite a 90-degree angle is zero, and becomes negative when opposite an obtuse angle. The latter problem was "cured" in [23] by taking the absolute value. But the fact is that a right-angled triangle would exhibit rank deficiency.

What accounted for those decisions? Recall that when the facet element was being formulated, Conformity was next to Godliness: the Rayleigh-Ritz Valhalla. A serious concern was that the element had to maintain full kinematic compatibility when used in plate-shell intersections such as those pictured in *figure 5*. These are common in aircraft structures. If this goal is enforced, linearly varying deflections in all element directions, as well as transverse shear inclusion, are mandatory.

Figure 6: *The Boeing 747 was the one of the first commercial aircraft extensively analyzed by finite element methods.*

So far as I know, the only industry-level program that implemented the facet shell was the SAMECS Boeing code developed in the late 1960s. An early application described in the 2nd Wright-Patterson conference was the analysis of the wing-body intersection of the Boeing 747 [24]. In SAMECS four triangles were combined to form a generally-warped quadrilateral shell macroelement. Taking the absolute value of the fictitious shear areas was not reason for worry. These beams act essentially to produce a stabilization matrix. In a well designed aircraft structure, such as the 747 *(figure 6)*, plate/shell transverse shear is unimportant. Injecting random numbers in the fictitious areas, as long as numerical stability is maintained, would hardly change the results.

Baby's Got New Clothes

The first FEM generation (1950-1962) was dominated by physical modeling. The second generation (1962-1973) was driven by variational methods and the isoparametric (iso-P) formulation. The third one (1973-1984) initially focused on how to improve iso-P elements by techniques of varying respectability. Among them reduced and selective integration were particularly successful because they simplified code reuse. Although initially viewed as "variational crimes" [25], those devices were eventually legalized largely through the work of Malkus and Hughes [26].

If the shear-flexible plane beam is formulated as an iso-P element with LDLR kinematics and exact integration used, the stiffness $\mathbf{K}^{\circ}_{X}$ of *figure 3(d)* results. This one is useless. It fails the constant moment patch test and blows up as the beam gets thin: $\Phi \rightarrow 0$. A significant improvement was found by Hughes, Taylor and Kanoknukulchai [27]: one-point reduced integration, which reproduces the stiffness $\mathbf{K}^{\circ}_{R}$ found in 1958 by Melosh as a spar-web element. This element still has flaws as an ordinary (not spar-web) beam: it does not reduce to the Hermitian beam as $\Phi \rightarrow 0$, and in fact it blows up if that limit is attempted. However it passes the constant moment patch test, and displays convergence for fixed EI.

Comparing *(a) and (b) in figure 3* a clever trick emerges. Replace by fiat Φ in (b) by $1 + \Phi$ and then remove the underline. This morphs $\mathbf{K}^{\circ}_{R}$ to $\mathbf{K}^{\circ}_{E}$ and recovers the exact Timoshenko element. The procedure is MacNeal's Residual Bending Flexibility (RBF) correction [28], which he has credited to a 1950 Ph.D. thesis at CalTech. So we are back to [6] traversing a different path through the-woods. In the words of Yogi Berra, *"it's deja vu all over again".*

Templates as Wrappers

So many beam models, so little time. Can they be wrapped into a single package? Yes, by using templates [29]. These are parametrized algebraic forms that produce specific elements as instances. If a template produces all

possible elements of given type, it is called universal. For a prismatic plane beam, a stiffness template that includes those in *figure 3(a-d)* is shown in *figure 3(e)*. It has three free parameters: α, β and ψ. If $\alpha=\psi=1$ and $\beta = 1/(1+\Phi)$ one obtains $\mathbf{K}^{\circ}_{E}$. Getting the other three is left to the reader as exercise.

Is there a way to customize this beam element to be the best for a given class of applications without going through months or years of analysis and experimentation? There is. Find the modified differential equation satisfied by the template over a repeating element lattice or patch, a process exemplified in[14]. Compare to the governing differential equation and set parameters to match or approximate that target. Voilá. Implementing the template as a single programming module with free parameters as arguments simplifies customization, benchmarking and validation.It automatically weeds out clones. And closes the chapter on that particular element.

A Blade Runner Future

The patient reader who has endured to here may now wonder. OK, all of that fiddling was done decades ago: water under the bridge. Since with templates one can systematically produce and customize elements while weeding out clones, the joy of what Feynman the iconoclast calls "the pleasure of finding things out" will be diminished for finitelementologists. *Right?*

Wrong. Reinventing the wheel is human second nature. An affirmation of life and ego, helped by printed and e-journals multiplying like rabbits. Even the humble plane beam elements featured in this story have been periodically cloned, like Replicants in Blade Runner. In this context, a shocking event I recall was receiving a paper (just two years ago!) from a distant land to review. Matrices *(a), (b) and (d) of figure 3* were derived by yet another method and claimed as new discoveries! And not a single reference to previous work. Even Timoshenko, renowned in his time for just citation and temperate respect for discoverers, was ignored. So we can confidently expect the comic FEM muse to inspire further spawning over the new millenium.
Happy cloning. ●

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Implicit Material Modeling

- A Challenge to Reliable Inelastic Finite Element Analysis -

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IACM 2004
Young Investigator Award

The computer simulation is replacing mechanical experiments in many cases due to its cost-effectiveness and improved accuracy. Nevertheless, its application fields are still limited to elastic analysis, as there exists a significant amount of model error in present inelastic material models. The present models can improve their accuracy by describing them in more detail, but the model error cannot be eliminated as far as the model is described explicitly. In this article, we will introduce an implicit material model, which has the ability to describe various material behaviors accurately without any complication.

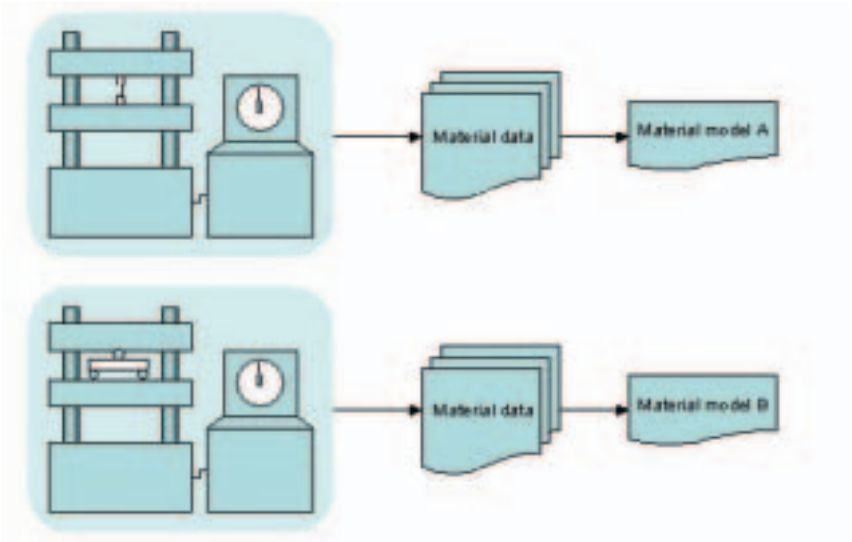

Figure 1:
Conventional material characterization

Introduction

Computer simulation, most popularly Finite Element Analysis (FEA), has a number of distinct advantages over the execution of mechanical experiments in the development process of mechanical systems in terms of cost, flexibility of analysis and many others [1]. Nowadays, much improvement has been achieved in the accuracy of finite elements and large scale analysis, which resultantly improves the accuracy of the geometry model of a mechanical system to be analyzed.This has allowed the simulation to replace a number of mechanical experiments for elastic solid analysis in various industrial areas accordingly [2].

In order to enable it for inelastic analysis, indispensable in addition to the geometrical model is the material model which can describe nonlinear material behaviour accurately. *Figure 1* illustrates the conventional material modeling process, which is typically characterized as follows:

- The core technique for the conventional material modeling is the explicit formulation where the resulting material model is formulated explicitly with a set of state variables and material parameters.
- The explicit modeling involves manual handling of material data obtained from experiments, so the explicit material model is created from a small number of material data.
- Because a small number of material data cannot contain a variety of material behaviour, the explicit material model describes only a small range of material behaviour.
- Because a small range of material behaviour can be described, many explicit material models are created even for a single material.

The conventional material modeling process can be in summary characte-rized by the core technique of explicit formulation and the resulting existence of many material models [3-9].

Two significant problems arise in the conventional material modeling by observing these characteristics; the lack of generality and the inaccuracy. The lack of generality, or the existence of many material models for a single material, is due to the fact that the explicit model is created from a small number and range of material data.The inaccuracy of the explicit model also can be caused by its mo-deling from a small number and range of material data, but the additional bottle-neck lies in the explicit formulation itself. As far as the model is formulated explicitly, model errors cannot be eliminated [10].

This article first describes the concept of automatic material characterization proposed by the authors [11]. The great advantage of the proposed characterization is that a generic model for a material can be created automatically from a variety of experiments. The model can describe a wide range of material behaviour, which may also include unsolved problems such as geometrical and sizing effects of materials. The article further presents the implicit material model, which can be created in the framework of automatic material characterization and describe material behaviour accurately without model errors [12,13].

Automatic Material Characterization

Figure 2 shows the schematic diagram of the proposed automatic material characterization. As opposed to the conventional one, the proposed material characterization can be summarized as follows:

- The core technique is the use of a computer to create a material model and control experiments. In addition to the automatic operations, it allows the on-line planning of experiments during the modeling so that an effective number of material data can be created and used for modeling.
- Because a large number of material data can be handled, the material model can describe a large range of material behaviour.
- Because a large range of material behaviour can be described, there is no necessity for creating more than one material model.

With these features, the successful implementation of the proposed modeling depends upon the achievement of the following developments:

- A material testing machine that can feed and fix test specimens, execute various experiments on the test specimens and save material data automatically.
- A methodology to create a material model that is not subject to model errors and that can be created from a large number of material data automatically.

The former automation issue has been dealt with by the materials and mechatronics community. For instance, Michopoulos et al. [14] developed a six-axis material testing machine to investigate the geometrical effects of composite materials. The latter is the computational issue of concern in the article, and, to overcome the computational issue, an implicit material model is described in the next section together with its automatic modeling technique.

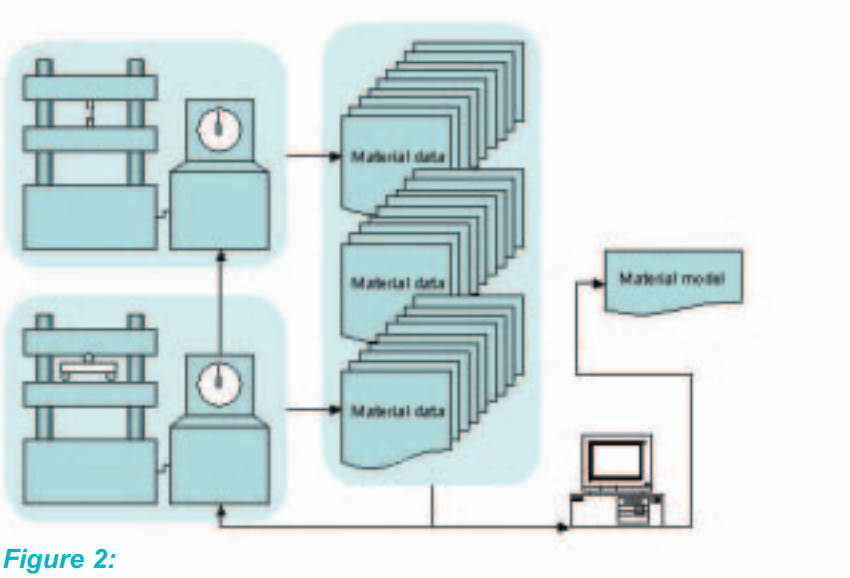

Figure 2:
Automatic material characterization

Implicit Material Model

Unlike the explicit material models, implicit material models are defined as those which do not have explicit expressions with parameters [12]. *Figure 3* compares the modeling processes of explicit and implicit models. Because the implicit material model does not involve explicit formulation and subsequent parameter identification, the only manual technique becomes the selection of independent state variables, which is unavoidable in the creation of a model that can describe a wide range of material behaviour including path-dependent, rate-dependent and temperature dependent behaviors.

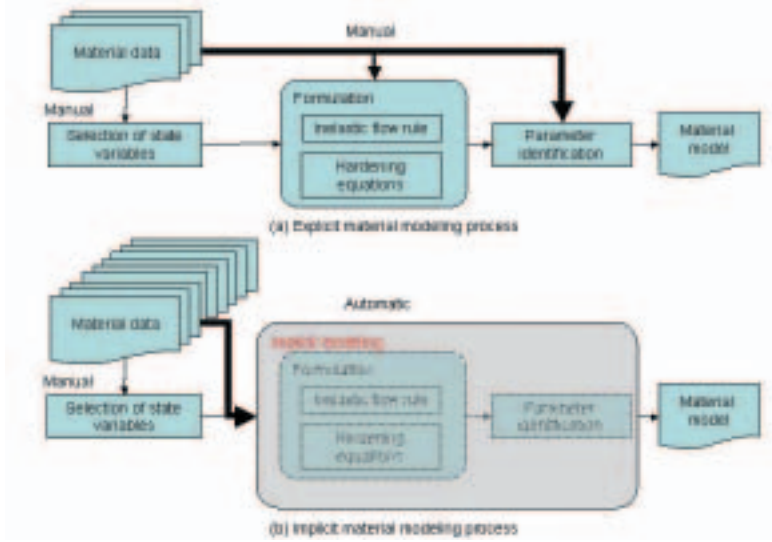

Figure 3:
Explicit and implicit material modeling

The remaining process, the creation of an implicit material model from a large number of material data, is conducted automatically

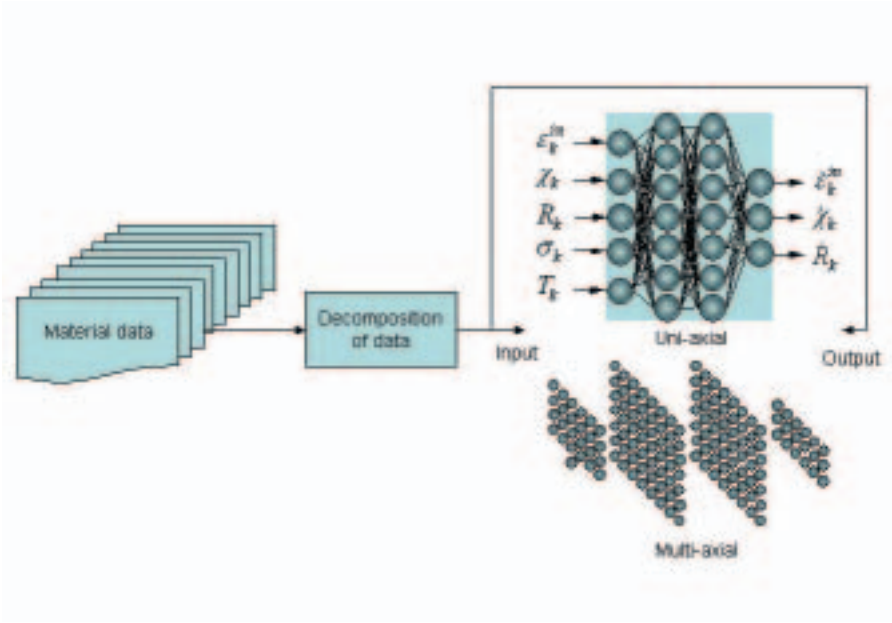

Figure 4:
Detailed implicit material modeling and configurations of implicit material models

> *"Implicit material modeling has been introduced as a technique for reliable inelastic FEA."*

Figure 4 shows the internal processes of implicit material modeling and configurations of the implicit material models. There are two automatic processes; (1) the decomposition of material data into a set of input-output data and (2) the creation of an implicit material model from the input-output data set.

Because of the complexity of material behaviour, the implicit material model is represented by state space equations, the mapping of which consists of multiple inputs and multiple outputs. In sanction with the selection of independent state variables, the inputs and the outputs are the values of the state variables and the rates of change of state variables, respectively [15]. If a uni-axial model is to be constructed, the inputs become the inelastic strain, back stress, drag stress, total stress and temperature, while the outputs are the rates of change of the inelastic strain, back stress and drag stress. In the multi-axial case, the state variables are represented in three-dimensional space, thereby yielding more inputs and outputs.

The automatic construction of such a multi-input multi-output mapping can be performed by a universal function approximator. The authors have used multi-layer neural networks as an approximator as shown in the figure [12]. The neural networks use input-output data as training data to create a material model. *Figure 5* shows the training of a neural network material model using JavaNNS, which is freeware for neural network simulation.

Numerical and Experimental Results

Superiority to existing models
To demonstrate its superiority to existing viscoplastic models, the implicit material model was first applied to describe 2 1/4 Cr-1 Mo steel behaviour at a temperature of 400 °C.

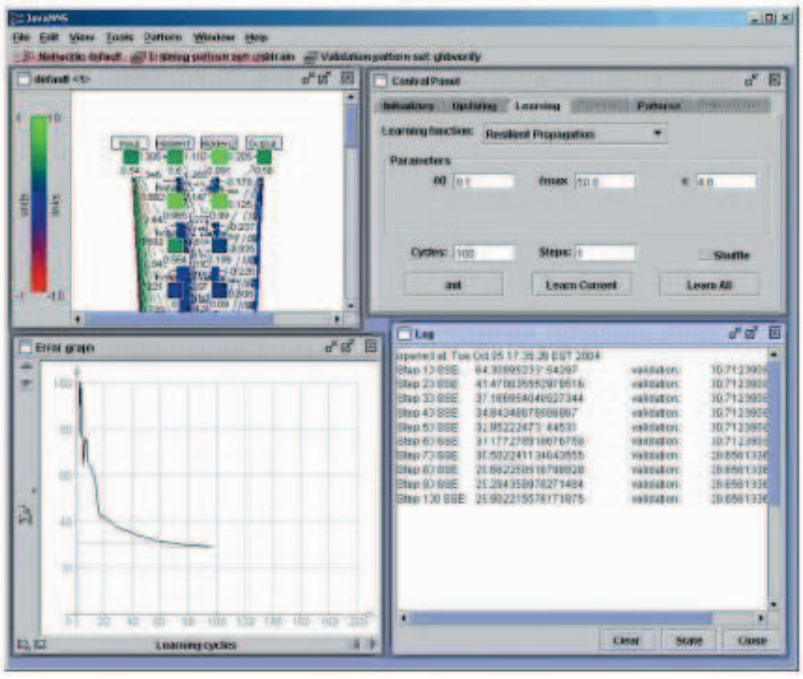

Figure 5:
Training of neural network material model

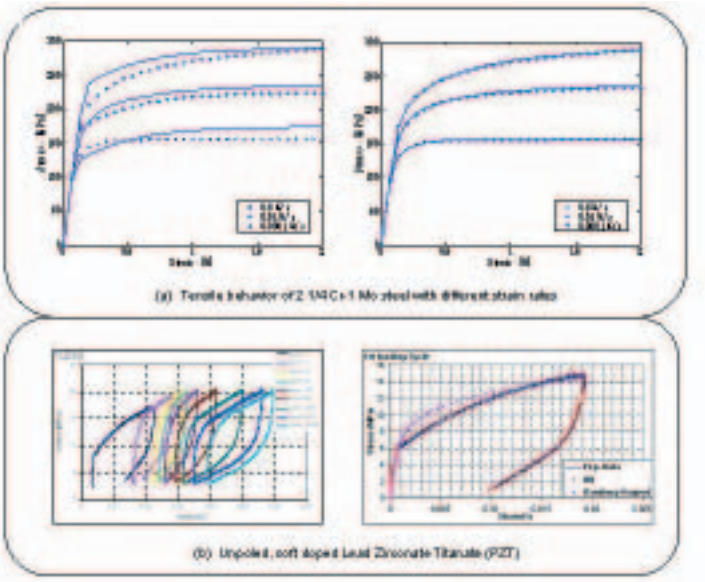

Figure 6:
Tensile behaviour of 2 1/4 Cr-1 Mo steel with different strain rates

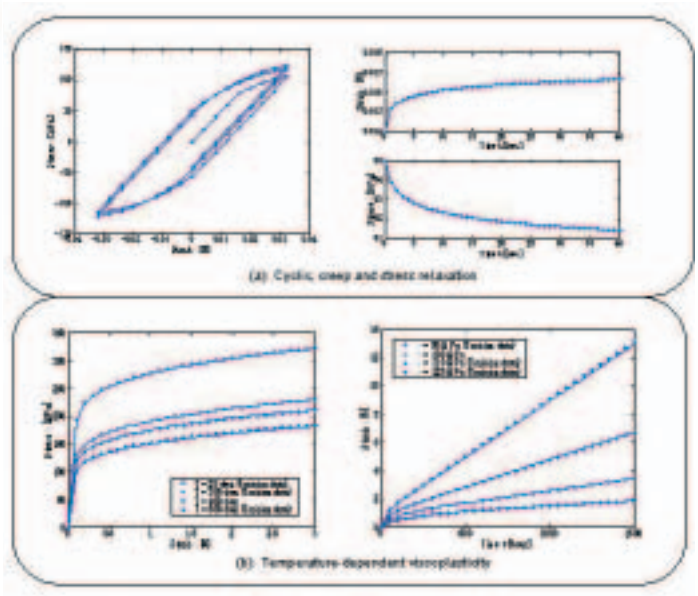

Figure 7:
A wide range of material behaviour

The experimental data used to create a neural network model include three sets of tensile data up to 2 %, each with a strain rate of 0.5 %/s, 0.01 %/s and 0.0001 %/s.

Figure 6(a) shows the experimental data and the corresponding simulation by Chaboche model (left) [9] with best-fit material parameters and the proposed neural network model (right). While Chaboche model shows errors inherent in explicit models, it is clearly seen that the responses of the proposed model well match with the experimental data. *Figure 6(b)* shows the modeling of a piezo-electric material as another example. The behaviour of this material, as shown in the left graph, is significantly complicated. The right graph compares the neural network model to the well-known Ramburg-Osgood model. The neural network model is seen to show almost no model errors.

Capability of describing a wide range of viscoplasticity

The ability of the proposed model to describe a variety of viscoplasticity was secondly investigated by training the model with cyclic plastic, creep and stress relaxation data. Pseudo-experimental data, created from Chaboche model, was used for training. *Figure 7(a)* shows the resultant behaviors of the proposed model together with the corresponding pseudo-experimental data. Clearly, the responses of the proposed model well coincide with the corresponding data.

Capability of describing temperature-dependent viscoplasticity

Finally, the proposed model was constructed to describe a variety of viscoplasticity at different temperatures. The material modeled was SUS304, and the experimental data used to construct the model include tensile data at temperatures of 20, 300 and 650 °C and creep data with constant stresses of 90, 110 and 120 MPa. *Figure 7(b)* shows the training data as well as the corresponding responses of the proposed model created. In spite of the wide variety of experimental data, the proposed model could reproduce all material behaviors very accurately. The figure also shows the experimental data (tensile at 450 °C and creep with 100 MPa) and the corresponding simulation results of the proposed model. Although they were not used for training, the proposed model predicts these untrained material behaviors accurately due to its capability of interpolation.

Reliable Inelastic Finite Element Analysis

Figure 8 illustrates the schematic framework of the reliable inelastic FEA, which is being developed under ADVENTURE project [16]. The ADVENTURE project concerns the reliability of the FEA in terms of both the geometrical and the material models. The reliability of the geometrical model is achieved by tackling issues commonly discussed in other FEA systems, such as the developments of higher-order finite elements and a reliable

mesh generator, but the noticeable innovation of the ADVENTURE system is its capability in large-scale FEA. Being built to suit to parallel computation, the system has enabled the elastic FEA of more than 100 million DoFs. The results shown in the figure are the pressure vessel for ABWR reactor and the knuckle joint of automotive suspension, which were successfully analyzed in the order [17]. In order to handle material models for inelastic FEA, the proposed material modeling technique is used. Numerical results have shown that the accuracy of inelastic FEA with a neural network model exceeds that with an existing inelastic material model in three orders.

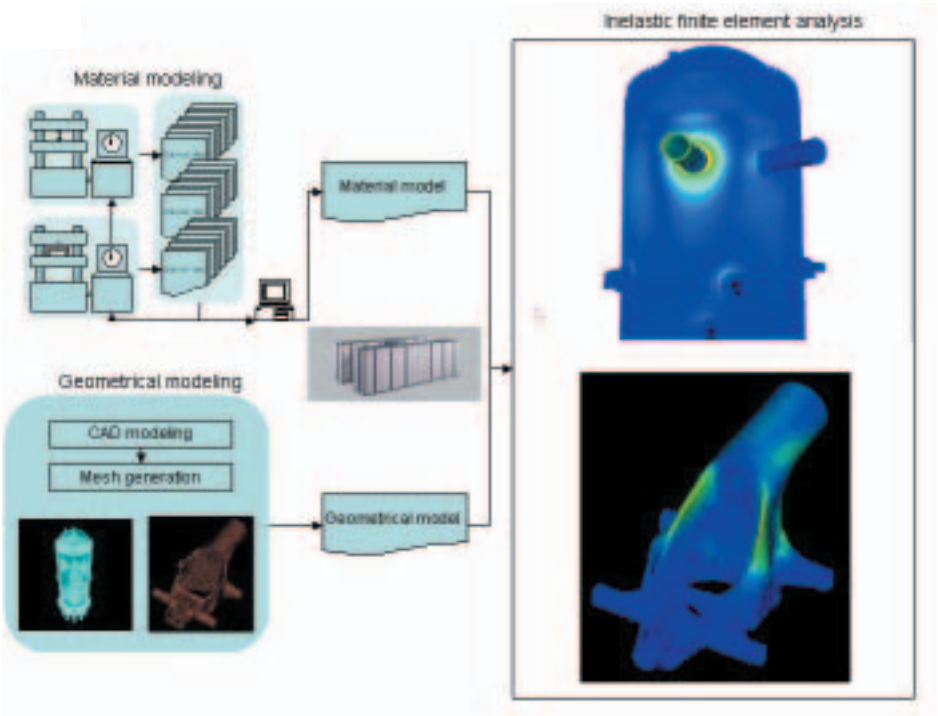

Figure 8
Inelastic finite element analysis using implicit material modeling

Conclusions

Implicit material modeling has been introduced as a technique for reliable inelastic FEA. The technique creates an accurate material model that can describe a wide range of material behaviour automatically from a large number of material data. The technique not only assists material scientists to analyze material behaviour but also links the material modeling to reliable inelastic FEA in one stream. The accuracy of the implicit material model will clearly contribute to the accelerated replacement of mechanical experiments by inelastic FEA in the near future. ●

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Computational Solid Mechanics in the Netherlands

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Netherlands Mechanics Committee (NMC)

Historical perspective

Computational Mechanics in the Netherlands was most probably pioneered at the Department of Mechanical Engineering of Delft University of Technology with the contributions of Hans Besseling, who, in the 1960s, developed a version of the finite element method that was closely related to Argyris' so-called natural approach. His work has had a profound influence in the Netherlands and most of the individuals who are currently active in the Dutch scene of computational mechanics, were either his pupils,have done their doctorate with one of his pupils, or have followed his lectures. His vision about computational inelasticity has been well documented in [1].

Another major contribution to (nonlinear) computational mechanics that has come from the Dutch community in the early 1970s is the landmark contribution of Eduard Riks on path-following techniques (also named arc-length methods) for controlling nonlinear computations [2]. An account can be found in the chapter on "Buckling", which he has contributed to the recently published Encyclopedia on Computational Mechanics [3].

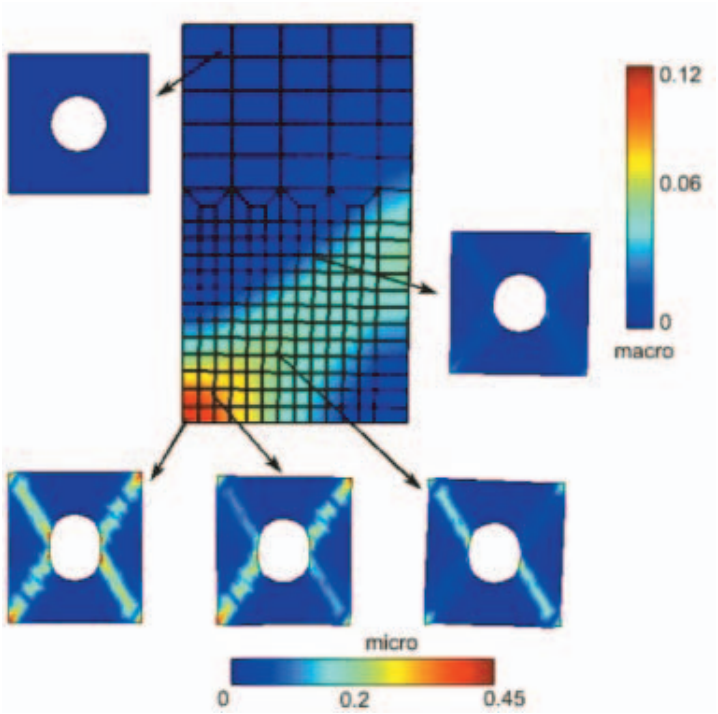


Figure 1: *Equivalent strain distribution in the homogenized structure and Representative Volume Elements obtained with a second-order computational homogenization scheme [4].*

The present scene

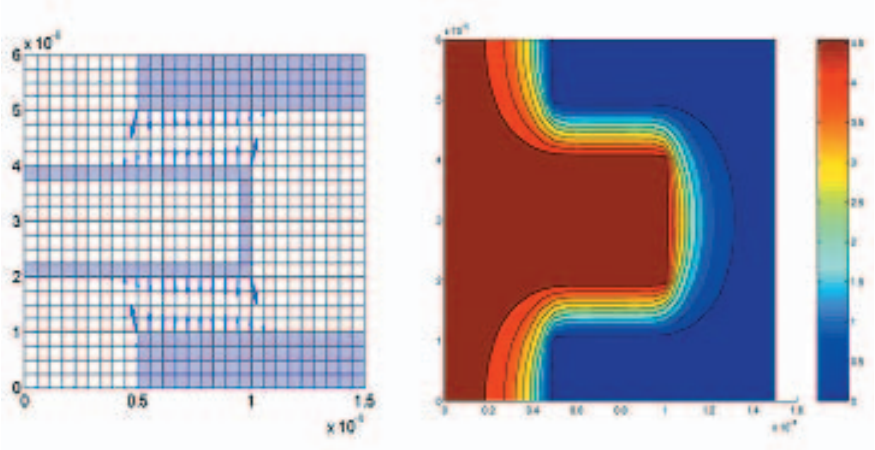
Since these early days, a major expansion has taken place in the Dutch computational solid mechanics community, with sizeable research groups working at Delft University of Technology, at Eindhoven University of Technology and at the University of Twente.

At Eindhoven University of Technology the research activities in the Department of Mechanical Engineering concentrate on the fundamental understanding of macroscopic problems in materials processing and engineering at different length scales, which emerge from the physics and the mechanics of the underlying material microstructure. Multiscale techniques are an important tool and Figure 1 shows an example of the use of a newly developed second-order computational homogenization scheme. Another important activity at this university relates to porous media, especially soft biological tissues, where electro-chemo-hydro-mechanical couplings pose significant challenges to the development of robust algorithms.

At the Department of Mechanical Engineering of the University of Twente computational research is mainly directed towards the development and validation of numerical methods to simulate forming and production processes of metals. Problems associated with new algorithms, the inclusion of phenomena like contact and friction between tool and product, and the deformation of flexible tools are of particular interest. Applications include processes such as rubber pad forming, hydroforming, rolling and extrusion.

At Delft, computational mechanics groups are working in the Departments of Mechanical., Civil, and Aerospace Engineering. At the Department of Mechanical Engineering research is performed on shell problems, on optimization and, more and more, on computational methods for MEMS. Figure 2 gives an example of a vibration analysis of an electrostatically coupled microsystem. Furthermore, the research on reduction methods for dynamic analysis and on parallel computing should be mentioned.

Figure 2: *Application of a consistent vibration analysis to an electrostatically coupled microsystem [5].*



At the Department of Civil Engineering and Geosciences activities are focused on the modeling of typical civil engineering materials like concrete and soils under extreme loading conditions such as impact, low or very high temperatures, chemical attack (e.g., salt), as well as the development of computational models for the use of advanced materials (fibre reinforcement, high-strength concrete) in high-performance or critical civil engineering applications.

The group at the Department of Aerospace Engineering has two main lines: computational solid mechanics and fluid-structure interaction, the latter being a more recent, but quickly growing activity. The activities in computational solid mechanics are grouped around four focal points: multi-scale methods, multi-physics, stochastic methods and reliability, and the simulation of evolving discontinuities, such as cracks, shear bands, phase transformations and discrete dislocation dynamics.

With respect to the latter theme, the group is organizing, jointly with Alain Combescure (INSA de Lyon) and Ted Belytschko (Northwestern University), a IUTAM symposium “Discretization Methods for Evolving Discontinuities” in Lyon from 4-7 September, 2006. Some examples of crack propagation using the partition-of-unity methodology are given in Figures 3 and 4. Figure 3 gives the crack evolution in a Single-Edge Notched beam under static loading conditions, while Figure 4 presents a simulation of dynamic crack propagation. In both cases, the experimentally recorded crack pattern was captured very closely.Organizational Structure

As has become clear from the above, the research in (computational) solid mechanics is concentrated at five places in the Netherlands: the departments of Mechanical Engineering, Civil Engineering and Geosciences, and Aerospace Engineering at Delft University of Technology, and the departments of Mechanical Engineering at Eindhoven University of Technology and at the University of Twente. For the PhD education, these groups have jointly founded the graduate school Engineering Mechanics, which organizes two high-level course in a concentrated format each year. Furthermore, it has an annual two-day symposium which is opened by a keynote lecture of a distinguished foreign scientist, and is accredited by the Royal Dutch Academy of Arts and Sciences.

Figure 3: *Simulation of crack propagation under quasi-static loading conditions using the cohesive-segments method [6].*

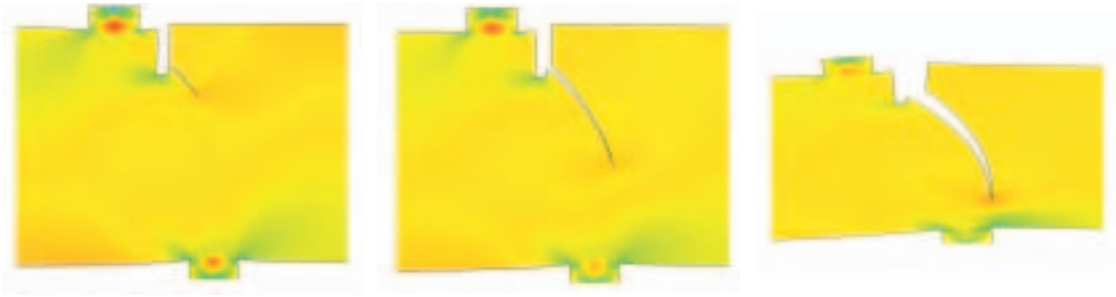


Figure 4: *Simulation dynamic crack propagation in a Kalthoff specimen using the cohesive-segments method [6].*

In a similar fashion, the fluid mechanics community in the Netherlands is organized in the J.M. Burgers Centre. Research and development engineers who work in industry, for example in the R&D establishments of large companies like Philips or Shell, or in semi-governmental laboratories like the National Aerospace Laboratory (NLR) or the Netherlands Organization for Applied Scientific Research (TNO), are represen-ted by the Mechanics Chamber of the Royal Dutch Institute of Engineering (KIVI). Recently, these three organizations have established the Netherlands Mechanics Committee (NMC) as their sole representative on the international level. In this context it is noteworthy that IACM has recently accepted the NMC as the affiliated organization for the Netherlands. ●

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[4] **V. Kouznetsova, M.G.D. Geers, W.A.M. Brekelmans**, *Multi-scale second-order computational homogenization of multi-phase materials: a nested finite element solution strategy*. Computer Methods in Applied Mechanics and Engineering, 193, 5525-5550, 2004.

[5] **V. Rochus, D.J. Rixen, J.C. Golinval**, *Monolithic modeling of electro-mechanical coupling in micro-structures*, submitted for publication.

[6] **J.J.C. Remmers, R. de Borst, A. Needleman**, *A cohesive segments method for the simulation of crack growth*. Computational Mechanics, 31, 69-77, 2003.

iacm news

ECCOMAS President

Prof. Herbert A. Mang, from University of Vienna (Austria) has been recently elected the new *President of the European Community on Computational Methods in Applied Sciences (ECCOMAS)*. He takes over the position held by **Prof. Eugenio Oñate** during the last four years.

ECCOMAS - the following awards were delivered at the annual congress in Finland:

- *ECCOMAS award for the best PhD thesis 2003* was presented to **Dr. Furio Lorenzo Stazi** (Università di Roma "La Sapienza")
  Title of the thesis: Finite Element Methods for Cracked and Microcracked Bodies.
- *J. L. Lions Award to Young Scientists in Computational Mathematic* was awarded to **Mark Ainsworth**, Strathclyde University, Scotland, UK.
- *O. C. Zienkiewicz Award to Young Scientists in Computational Engineering Sciences* was given to **Perumal Nithiarasu**, University of Wales Swansea - UK.

GACM Executive Council Changes

At the general meeting on occasion of the ECCOMAS conference in Jyväskylä, Finland, **Wolfgang A. Wall**, Professor for Computational Mechanics within the Department of Mechanical Engineering at Technische Universität München has been elected member of the executive council of GACM.

Wolfgang A. Wall

Manfred Bischoff

His successor as Secretary General is **Manfred Bischoff**, currently working at Lehrstuhl für Statik (Chair of Structural Analysis), also at TU München.

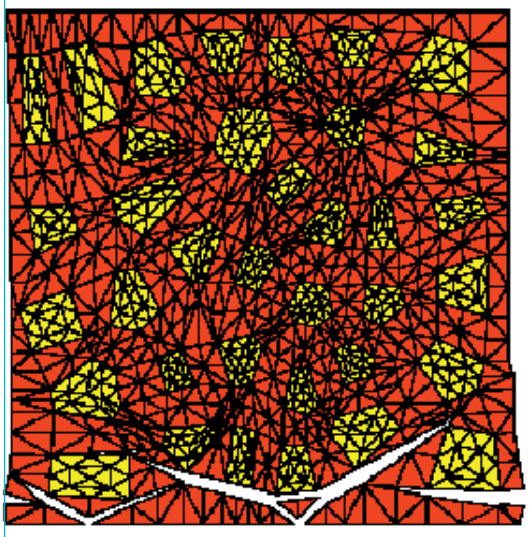
Professor **Günther Kuhn** from Erlangen, a charter member of the organization, resigned from the executive council. GACM thanks him for his long-lasting commitment.

Computational Solids Mechanics at the Centre for Computational Methods, National University of Tucumán

Victorio Sonzogni
National University of Tucumán
Argentina

The research group at the Center for Computational Methods (CEMNCI) of the National University of Tucumán in Argentina is advocated to the development of constitutive models for cohesive-frictional materials like soils, concrete, mortar, rock, and to the analysis of localized failure processes in structural systems. The research activities are close related to the graduate programs Master in Numerical and Computational Methods in Engineering and PhD of the Faculty of Exact Sciences and Technology. The group is composed by the academic staff of the CEMNCI, Guillermo Etse, Ricardo Schiava and Marcela Nieto as well as the research assistants Ricardo Lorefice, Sonia Vrech, Juan Parnás, Marcia Rizo Patrón and Hernán Kunert.

a)



b)

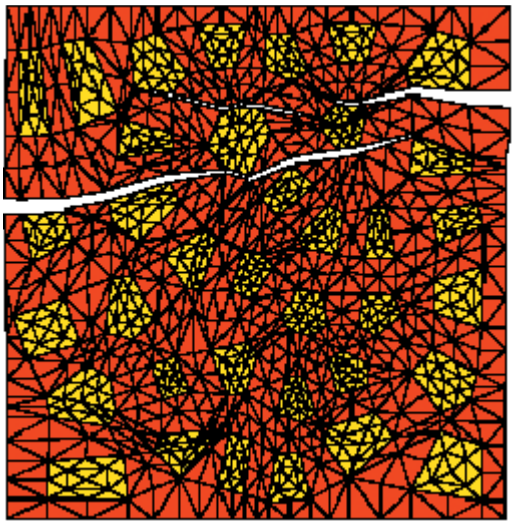


Figure 1:
Uniaxial tensile test - Deformed meshes at strain rates: 1.E-2 seg-1 (a), and 1.E-1 seg-1 (b).

The present research fields in non-linear computational solid mechanics at CEMNCI, National University of Tucumán, are:

Dynamic behaviour of concrete material: analysis at multi-scale levels

Constitutive theories are developed and computationally implemented to evaluate the time-dependent response behaviour of concrete at both the macroscopic and mesoscopic levels of analysis.
The main objective of the investigations is the evaluation of the mesomechanical components (mortar, aggregate and interface) influence in the overall rheological behaviour of concrete at low and high strain rates. Elasto-viscoplastic and viscoelastic models are considered for the mortar, interface mortar-aggregate and the aggregates. This is a joint investigation with Prof. Ignacio Carol and Dr. Carlos López of the Technical University of Catalonia, Spain.
The computational analysis at the macromechanical level of observations are directed toward the development of rate-dependent constitutive theories that involve the fundamental parameters of the material meso-structure.

The figures above show the failure pattern predictions of concrete at the mesomechanical level obtained for two different velocities of the applied loads.

" ... the development of non-local material formulations for localized failure analysis of quasi-brittle materials ... "

Gradient-dependent Plasticity computational analysis

One other important aspect of the computational researches at the CEMNCI, is the development of non-local material formulations for localized failure analysis of quasi-brittle materials in the framework of the smeared-crack concept. Non-local theories considered in these investigations are the micropolar Cosserat theory, the viscoplastic theory, the fracture energy-based plasticity and, more recently, the gradient-dependent plasticity.

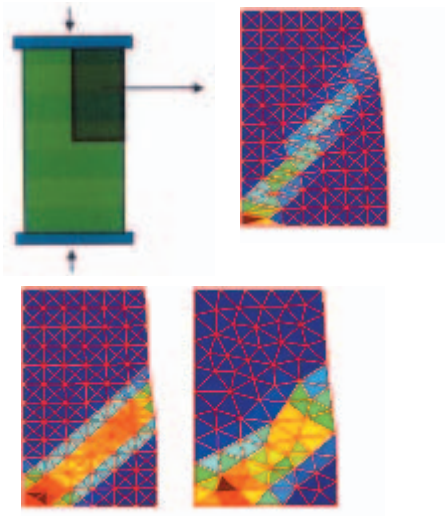


Figure 2
Uniaxial ompression-test. Deformed meshes for classical (a) and gradient-dependent (b) Plasticity.

Drucker-Prager and more complex plasticity models where reformulated to account for strain gradient dependency. The figures below show predictions of localized failure modes with Drucker-Prager, local and gradient-dependent plasticity, that demonstrate the regularization capabilities of the non-local theory.

Presently the analyses and developments in this field at CEMNCI focus on to extension of the capabilities of the gradient-dependent theory to reproduce both ductile and brittle failure modes that characterized concrete behaviour in the high and low confinement regime, respectively.

Another research fields at the National University of Tucumán are simulation of concrete behaviour at early stages and of partial saturated soils. To this end, appropriate constitutive theories and models are being considered and developed. ●

iacm Awardees

Congress Medal
(Gauss-Newton Award)
Franco Brezzi D. R. J. Owen

IACM Award
Y. K. Cheung Roger Ohayon

Computational Mechanics Award
Genki Yagawa Pierre Ladevèze

Young Investigator Award
Ramón Codina Tomonari Furukawa
Kenneth Jansen

Fellows 2004
Jaime Peraire Alfio Quarteroni
Patrick Le Tallec Isaac Harari
Ken Morgan Djordje Peric
Mingwu Yuan Francisco Armero
Mary Wheeler Hermann G. Matthies
Greg Hulbert Olivier Pironneau

J. Argyris Award
Marcus Wagner

for more information: **www.iacm.info**

USACM Chronicle

United States Association for Computational Mechanics

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IUSNCCM VIII

Eighth US National Congress on Computational Mechanics

Austin Convention Center, Austin, Texas

July 24-28, 2005

The Congress, hosted by the Institute for Computational Engineering and Sciences (ICES) at The University of Texas at Austin, will feature the latest developments in all aspects of computational mechanics, and will broaden the definition of the discipline to include many other computation oriented areas in engineering and sciences. From applications in nanotechnology and bioengineering, to recent advances in numerical methods and high-performance computing, the technical program will reflect the Congress theme - ``**Spanning Computational Engineering and Sciences''.** In addition to plenary lectures and minisymposia that highlight the latest trends in computational mechanics, pre- andpost-conference short courses will address validation and verification, advances in higher order methods, moving boundaries and interfaces and computational electromagnetics. Numerous vendor exhibits reflecting the richness of Austin's ``Silicon Hills'', and a cyber caf\'{e} are also planned. Detailed information on USNCCM VIII can be found at **http://compmech.ices.utexas.edu/usnccm8.html.**

Minisymposia

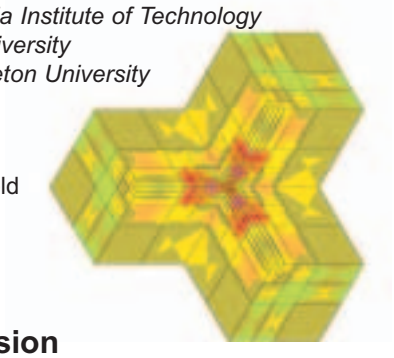
In addition to these talks, 63 minisymposia have been acceptedand registered with the Congress by the following authors:

Brian Carnes * Yijun Liu *
Florin Bobaru * Kent Danielson *
Tayfun Tezduyar* David J. Benson *
Zhanping You * Susanne Brenner *
Erwin Stein * Mark Ainsworth *
Robert C. Kirby * Ivan Yotov *
Geiser Juergen * Suvranu De *
Peter Wriggers * Richard Regueiro *
Thomas Impelluso * Herbert A. Mang *
N.R. Aluru * Richard Regueiro *
J.P. Pontaza * Murthy Guddati *
Graham Carey * Shen Wu *
Bernardo Cockburn * John Williams *
Ismael Herrera * Carlos Felippa *
Frank Ihlenburg * Roger Ohayon *
B N Rao * Arcady Dyskin *
Gregory Rodin * Norbert Gebbeken *
Carter Edwards * Bojan Guzina *
Bojan Jiang * Jiun-Shyan Chen *
Uday Banerjee * Alan Shih *
Ted Belytschko * Janusz Orkisz *
Dennis Parsons * David Gartling *
Wing Kam Liu * Krishna Garikipati *
Shahrouz Aliabadi * Robert Haber *
Jakob S.Jensen * Walter Richardson *
Jack Chessa * Senthil Vel *
Jacob Fish * Saikat Dey * Jie Shen *
Arif Masud * Zhimin Zhang *
Ernst P. Stephan * John Aidun *
Bernhard A Schrefler * Rui Huang *
Roger Ghanem * Barna Szabó *

Plenary Lectures

The Congress will feature three plenary and six semi-plenary lectures by leading experts, including:

Weng Cho Chew, *University of Illinois*
Jacob Fish, *Rensselaer Polytechnic Institute*
Omar Ghattas, *Carnegie Mellon University*
James Glimm, *SUNY at Stony Brook*
George Karniadakis, *Brown University*
Patrick Le Tallec, *Ecole Polytechnique*
Michael Ortiz, *California Institute of Technology*
Tetsuya Sato, *Keio University*
David Srolovitz, *Princeton University*

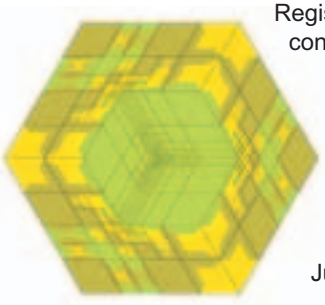


Short courses

Pre- and post-congress short courses will be held on July 24th and 28th, respectively

Registration and abstract submission

The deadline for print-ready abstracts is **May 1** and the deadline for early registration is **June 1**.



Registration fees include the conference proceedings, a welcome reception on Sunday July 24, continental breakfasts and breaks, and a dinner banquet on Tuesday, July 26.

The organizing committee would like to extend aninvitation to everyone interested in the continually evolving field of computational mechanics to participate in this exciting conference.

Congress Organizers

Honorary Congress Chair
J. Tinsley Oden, *director of ICES, The University of Texas at Austin*
Congress Co-Chairs
Leszek Demkowicz, *ICES*
Clint Dawson, *ICES*
Joe Flaherty, *Rensselaer Polytechnic Institute*
Local Organizing Committee
Tom Hughes, Graham Carey, Jon Bass , Yusheng Feng

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Report from
Japan Associaton for Computational Mechanics

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The JACM organized 17 minisymposia that include 184 papers at WCCM, Beijing last September. On that occasion, the JACM meeting was held to discuss the prospect of JACM and present JACM awards.More than 40 members got together including special guests Prof.Tayfun Tezduyar, Prof.Gretar Tryggvason and Dr.Richard Sun from Chrysler.

Figures 1 and 2:
JACM meeting in Beijing

The JACM Award for Computational Mechanics was presented to Prof.Yagawa and Prof.Satofuka.

Figure 3:
Genki Yagawa

Figure 4:
Nobuyuki Satofuka

The JACM Award for Young Investigators in Computational Mechanics was presented to M.Tanahashi, A.Nakatani and T.Himeno. ●

CDM
Computational Mechanics Division of JSME

CMD(Computational Mechanics Division) of **JSME**(Japan Society of Mechanical Engineers) is the JACM affiliated organization. The membership of JSME is about 40,000 and among them 5000 members are registered in CMD.

JSME CMD established two awards in 1990 – Computational Mechanics Award and Computational Mechanics Achievement Award. These awards are presented to domestic and international researchers who contributed to the field of computational mechanics. The 2004 Computational Mechanics Award is presented to Takashi Yabe(Japan) and Wing Kam Liu (US). Some of the researchers to whom these awards were given in the previous years are O.C.Zienkiewicz, J.T.Oden, T.J.R.Hughes, T.Kawai and G.Yagawa.

The 2004 Computational Mechanics Achievement Award is given to: S.Koshiduka (Univ.of Tokyo) and H.Okuda(Univ.of Tokyo). ●

Figure 1:
Wing Kam Liu

Figure 2:
Takashi Yabe

ENIEF'2004

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XIV Congress on Numerical Methods and their Applications

ENIEF Conferences on the Rise!

Attendance and scientific quality are rising steadily in ENIEF conferences. The fourteenth edition took place in beautiful San Carlos de Bariloche between November 8 and 11, 2004. It was organized by the Centro Atómico Bariloche, Comisión Nacional de Energía Atómica, having as Organizing Committee: Gustavo Buscaglia (President), Claudio Padra and Luis Guarracino (Vice-Presidents), Fernando Basombrío and Sergio Idelsohn (Honorary Presidents), and Daniela Arnica, Enzo Dari, Jorge Leiva, Claudio Mazufri, Nicolás Silin and Oscar Zamonsky as members.

Figure 1:
Participants at ENIEF 2004

Facts about ENIEF'2004:

Some numbers:
Participants: 270 (from 16 countries), Minisymposia: 2, Sessions: 62(Talks: 240), Student posters: 30

Plenary lectures
Oscar Bruno, Caltech (New high-order, high-frequency methods in computational electromagnetism)
Ramon Codina, Univ. Politécnica de Catalunya (Finite element approximation of thermal models for low speed flows)
Horacio Espinosa, Northwestern Univ. (Plasticity size effects in freestanding thin films: Experiments and modeling)
Rainald Lohner, George Mason Univ. (Adaptive embedded unstructured grid methods)
Paul Sorensen ABAQUS (Finite elements for industry, research and teaching)

Keynote lecturers
Guy Bayada, Gino Bella, Onno Bokhove, Fabián Bombardelli, Néstor Calvo, Alberto Cardona, Juan Cebral, Diego Celentano, José Corberán Salvador, Jorge Crempien Laborie, Marcela Cruchaga, Alberto Cuitiño, Francesco D'Auria, Guillermo Etse, Fernando Flores, Pablo Jacovkis, Mohammed Jai, Gerhard Jirka, Axel Larreteguy, Ricardo Lebensohn, Adrián Lew, Norberto Mangiavacchi, Ángel Menéndez, Jean-Philippe Ponthot, Gustavo Sánchez Sarmiento, Pablo Tarela, Marcelo Vénere, Carlos Vionnet, Bassam Younis, Pablo Zavattieri.

Minisymposia
Water resources, Automobile industry, Nuclear CFD and CSM, Industrial heat transfer, Hemodynamics, Constitutive modeling, Moving interfaces, Multiscale modeling, Solids and structures, Large scale computing, Atmospheric dispersion, Petroleum reservoirs, Discontinuous Galerkin, Interdisciplinary mathematics, Slender structures, Numerical analysis, Multiphase flows, Turbulent flows, Dynamics, Aerospace, Concrete, Fracture and Damage, Meshes.

Proceedings
Mecánica Computacional, Vol. XXIII, edited by G. Buscaglia, E. Dari and O. Zamonsky. ISSN 1666-6070. 3389 pages.

Post-conference
Most of the material (program, abstracts, papers, pictures) is available from the web page, www.cab.cnea.gov.ar/enief, or contact AMCA **(www.amcaonline.org.ar).**

Figure 2:
The Hotel where ENIEF'2004 took place.

Highlights of ENIEF'2004

The place: The lakes, the mountains, the sun, the people.
The lectures: Plenary, keynote and ordinary talks were of excellent level and carefully presented. Oscar Bruno's theatrical representation of how one stands on a 3D surface to flatten it against the floor so as to allow for a 2D FFT will be remembered.
The poster session: A poster session during the Cocktail (on Tuesday night) was such a good idea! Plenty of people kept the students busy with their questions and comments. The students were happy with the feedback when the session ended by 11 pm. They were also hungry, so many questions did not allow them to get much of the excellent food.
The awards: During the conference banquet on Thursday night there was food, there was wine and there was music, and they were all great. There were also several awards: Guillermo Etse and Juan Carlos Ferreri received the Senior AMCA awards, while Adrián Cisilino received the Junior one. Then it was time to announce the winners of the Student Posters Competition. They were Pablo García Martínez (1st), Fernanda Caffaratti (2nd) and Daniel Lanzillotti Kimura (3rd) among the undergrads, and Nora Paoletti (1st), Silvina Serra (2nd) and Mariano Febbo (3rd) among the graduate students. Tables were put aside to make room for some dancing until 3 am. The congress was over, it was time to celebrate.

Do ENIEF conferences have a secret?

ENIEF conferences are not just a meeting of friends. They are a meeting of friends who get together to learn from each other, to establish collaborations, to discuss hot topics... and also to criticize, question and object each other's work. Scientific discussions are informal but deep in ENIEF, and they do get harsh but never personal. Arguments do take place, you hear "That is wrong" in the sessions, you hear "Sorry, I was wrong" too. And then people go have lunch together. This may be one of ENIEF's secrets. Consider coming to Argentina for the next one. ●

Figure 3:
Guillermo Etse (far left) and Juan Carlos Ferreri (far right) receiving their AMCA awards from Alberto Cardona and Gustavo Sánchez Sarmiento.

Figure 4:
Rolando Granada (Head of the Centro Atómico Bariloche), Gustavo Buscaglia (Chairman of ENIEF'2004) and Sergio Idelsohn (President of AMCA) during the opening ceremony

Figure 5:
Guillermo Etse, Adrian Cisilino and Juan Carlos Ferreri, winners of the AMCA Awards 2004.

Figure 6:
Ramon Codina, Juan Cebral and Claudio Padra during a coffee-break

Figure 7:
Ricardo Lebensohn and colleagues at lunch time.

news

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The Bachelor and Master Fever

In 1999 the Ministers of Education of 29 European countries signed the so-called Bologna Declaration in order to reform and unify the structure of their higher education system. As a consequence of this declaration the individual national university curricula and degrees ought to be adapted to the Anglo-American bachelor and master system. In Germany, where certain universities had already introduced master programs in selected fields, this process was finally legalized in October 2003 when the Ministries of Sciences of the federal government and of the 16 states agreed that from 2010 on only bachelor and master degrees can be awarded, changing from a one degree system to a consecutive system with two degrees. The resolution comes along with the political intention to set a quota on the number of master students. In other words, the by far bigger portion of the student population should leave university with a bachelor degree after three to four years, leaving two ore one years for a smaller group pursuing a master degree, thus reducing duration of study.

The development was partially supported by industry, although not really discussing the content of the necessary curricula. An additional, maybe superficial argument was to abandon the name "Diploma" in engineering (cf. "Diplom-Ingenieur") having a rather trivial meaning in the English speaking world. To compound matters in Germany, a parallel system of higher education exists in many fields:

- "Fachhochschule", a kind of polytechnics, officially called Universities of Applied Sciences, with a more practice oriented education as the name says.
- "Universität", university with an emphasis on science and research.

In the matter of introducing bachelor and master both are treated in the same way by legislation.

Similar to other European countries also in Germany the Bologna Declaration caused a "bachelor/master fever", a process complicated by the strong federal system with 16 + 1 political opinions on the one hand and the aforementioned two tracks of education (Universität, Fachhochschule) on the other hand. First of all, there are a couple of well-founded arguments to introduce the bachelor/master system. Experience of many countries in the world (not only the Anglo-American countries) can serve as a guideline. Students may leave a field or a university after obtaining the bachelor and study in a different area or at another university, maybe even in another country. In turn, foreign students holding abachelor degree can easily enter the system to continue for a master; this was always a big obstacle in the past. Industry might be interested in graduates with a bachelor to continue with a "training on the job"; to mention but a few arguments.

Having adapted their curricula to the requirements of modern society anyway, universities claim that the quality of their present degrees, e.g. the "Diplom-Ingenieur" , has to be preserved by all means. At universities this one and only degree, up to now with 9 to 10 semesters, has been classified in most cases as "master equivalent" and accepted as a highly qualified education all over the world. This means that the master degree has to be introduced as a rule, in particular at universities. This statement is supported by the intense discussion in the US (partially also in other countries like the UK) under the keyword "one-degree policy", introducing a five years program for a master without the bachelor and the increased requirements in science and practice, see e.g. Statement 465 on the "Body of Knowledge" (B+M/30&E program) of the American Society of Civil Engineers (www.asce.org). Some universities did already introduce these one-degree master programs or ease the transfer from the bachelor to the master program (see e.g. the Co-terminal Degree Program in Stanford), and thus, strange enough in view of the above discussion, copy theprevious European system.

So where to go? First of all, we should accept the more flexible bachelor/master system. Secondly, we urgently need to keep a qualified standard; industry and practice would not accept a low level training in a world with more and more requirements. This means that we should allow studying directly towards a five year master program. Introducing more so-called soft-skills is necessary but not on the account of technical and scientific knowledge in the respective fields. There is a certain incubation period, also for our students. On the other side, despite their efforts, also Europeans should accept that there is no such thing as the one unique bachelor and master education. Experience in other countries in the world shows a large variety in kind and quality. The rules of evolution will also enter here.

Ekkehard Ramm

Honorary Doctorates

On January 30, 2004, Udo F. Meißner, Professor of computer science in civil engineering, at Technische Universität Darmstadt and President of the Ingenieurkammer (Chamber of Engineers) of the State of Hessen, Germany, was awarded an honorary doctorate "Doktor-Ingenieur Ehren halber" (Dr.-Ing. E.h.) by the Department of Civil Engineering of Bauhaus-Universität Weimar. He received the decoration for his credits in bringing together the disciplines of computer science and civil engineering which eventually formed a symbiosis today called "Bauinformatik" in Germany.

Even two honorary doctorates in a row have been conferred to Professor Ekkehard Ramm, head of the Institute of Structural Mechanics at the University of Stuttgart and currently President of GACM.

On June 8, 2004 he received the Doctor of Law h.c. by the University of Calgary for his scientific achievements in computational mechanics and his extraordinary engagement in an exchange program between both universities which exists since 25 years.

Later, on July 16, the Department of Civil Engineering and Geodesy, Technische Universität München, added the honorary degree Dr.-Ing. E.h. in recognition of Ramm's outstanding achievements in the development of structural mechanics and for establishing computational mechanics as an independent scientific discipline within engineering sciences. The laudatory speech was delivered by Robert L. Taylor from UC Berkeley, his long time companion and contemporary finite element pioneer.

Figure 1:
Professor Udo F. Meißner (left) receives the honorary doctor certificate from the dean, Professor Jochen Stark (center) and the president of the Bauhaus-Universität, Professor Walter Bauer-Wabnegg (right)

Figure 2:
W.A. Herrmann (president of TU München), E. Ramm, R. Rummel (dean of the Dept. of Civil Engineering and Geodesy), from left to right

from young people for young people

1st GACM Colloquium for Young Scientists on Computational Mechanics

October 5-7, 2005
Bochum, Germany

The main objective of the colloquium is to provide a forum for young scientists engaged in research in computational mechanics, to present and to discuss results of recent research efforts, to foster the exchange of ideas among various fields in computational mechanics and to support the progress of ongoing research. Advanced computational methods and models for the numerical analysis of materials and of structures and the assessment of their suitability and robustness are in the main focus of the colloquium. The presentation of work in progress is welcome. The organizers hope, that the colloquium will also help to identify promising new research directions.

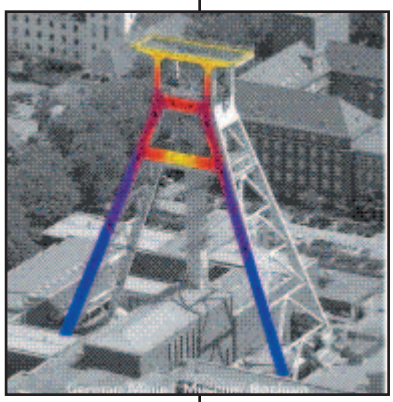


Figure 1:
Mining Museum

According to the colloquium objectives, young scientists are invited to present results of their scientific work at the colloquium. Thematically arranged sessions and organized minisymposia, complemented by social events, will provide ample opportunities for discussions in an informal atmosphere. Presentations may be given in English or German.

GACM colloquium chairpersons:
K. Hackl, G. Meschke and S. Reese

Young scientists are invited to submit one page abstracts to the local organizing committee
U. Hoppe, D. Kuhl and O. Schilling
Ruhr University Bochum, Faculty for Civil Engineering
Universitätsstr. 150 IA6/127
44780 Bochum, Germany
E-Mail: ***gacm05@rub.de***
homepage: ***www.rub.de/gacm05***

Early registration before ***1 May 2005*** for reduced fees.. Abstract deadline is ***28 February 2005***.

For further information see **www.rub.de/gacm05**

Chilean Society for Computational Mechanics

CSCM

For all inclusions under CSMC please contact:

Marcela Cruchaga
mcruchag@lauca.usach.cl

The CSCM was founded in 1995 by a group of professionals and academics with the objective to promote the development of computational mechanics in its different aspects from basic research to industrial applications. The Society is devoted to join people from different Chilean universities and areas of sciences.

Figure 1: *Workshop on Computational Mechanics Universidad de Los Andes, September 2003. Participants together with the Invited Speaker: Prof. Sergio Idelsohn.*

During the Workshops organized by the CSCM, engineers, physicists and mathematicians have found a place to present their works and to discuss their ideas. Several students from different levels have also attended such meetings. The postgraduate students had the opportunity to present their first research works.

The Workshops were hosted by Universidad de Concepción at Concepción, Universidad de Los Andes and Universidad de Santiago de Chile USACH both in Santiago de Chile. The next one will be held at Universidad Técnica Federico Santa María in Valparaiso during 2005. In addition to the mentioned universities, others have been represented during the meetings: Universidad de Chile, Pontificia Universidad Católica, Universidad de La Serena, Universidad del Bio Bio, Universidad de Temuco can be mentioned as references. Information about the CSCM (SCMC in Spanish) and its activities could be found in the web site: http://www.dim.udec.cl/scmc/

Figure 2: *Workshop on Computational Mechanics Universidad de Santiago de Chile – USACH, August 2004. Participants together with the Invited Speaker: Prof. Fernando Quintana.*

The CSCM thanks all the people that support and encourage it. CSCM also hopes that the number of people interested in join the Society will increase in the near future. The plurality and interdisciplinary are the compromise of CSCM and this would be reflected in their members and people interested to join the Society. ●

Indian Association for Computational Mechanics

A REVIEW

Indian Institute of Technology Bombay
tkant@iitb.ac.in

Prof Kant giving lecture at R&DE(E) at Pune, India

Dr. Gangan Prathap

Dr. Sudhakar Marur

Computers, Materials & Continua Journal

Prof Kant having a chat with Fellows of the Indian Academy of Sciences

The Department of Civil Engineering, Indian Institute of Technology Bombay) tkant@iitb.ac.in"

The summer of 2004 saw a lot of training/ lectures series rolled out for the practicing engineers and active researchers. Some program highlights and other Items of Interest are captured here.

Finite Element Course for Defense R&D Engineers
Research and Development Establishment (Engineers) - R&DE (Engrs), located at the eastern Indian city of Pune, is a defense establishment involved in the development of engineering solutions such as mobile bridges, robotic vehicles etc for the Indian armed forces. This organization wanted its young scientists to gain greater insights into the intricacies of solving engineering problems through proper exposure to the Finite Element Method, its developments and applications.

Professor Tarun Kant from the department of civil engineering of Indian Institute of Technology Bombay, Powai, Mumbai-400 076 was invited to give a lecture series for four days, during the first two week ends of April, this year.

The course prepared by Professor Kant covered various topics such as historical overview, various approaches to formulations, elementology, steady state and transient problems and stability analysis. Given the gap between two sessions to have hands on experience on problem solving coupled with the theoretical grinding, the course received excellent feedback from the participants.

Invited Lectures
Center for Mathematical Modeling and Computer Simulation at Bangalore, led by Dr. Gangan Prathap, has hosted a couple of lectures in its campus.

The first one was on the *Numerical Studies on Elastodynamics of Plates and Beams* by Muralikrishnan, a research scholar with the center.

The second was on *Performance and evaluation of R&D Institutes* by Professor Kaujalgi from the Indian Institute of Management, Bangalore.

E-mail group operational
An e-mail group formed for this association with all its members is fully functional. It enables rapid dissemination of information amongst the members. Mails addressed to indiacom@yahoogroups.com would reach all the members.

The moderator of the group, Dr Sudhakar Marur can be contacted at srmarur@iitiim.com for new membership.

New journal
A new journal launched recently by Tech Science Press *Computers, Materials & Continua* – has one of the life members of this association, Dr. Gangan Prathap, as its Editor-in-Chief.

Honours
Professor Tarun Kant of the Indian Institute of Technology Bombay and the Founder President of the Association was elected as a Fellow of Indian Academy of Sciences.

As a Fellow, he gave a lecture on *Two-dimensional modeling of fiber reinforced composite laminates*, during the 15th mid-year meeting of the academy at Bangalore on 2-3 July 2004. ●

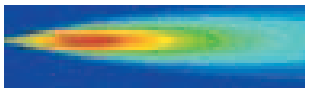
Thematic Conferences 2005

As the econd edition of the ECCOMAS Thematic Conferences in 2005
Fifteen Thematic Conferences will take place in Europe in 2005, covering a wide range of topics in the theoretical and applied aspects of computational methods in engineering and applied sciences.
Further information is available on www.eccomas.org

Coupled Problems

Computational Methods for Coupled Problems in Science and Engineering

Santorini, Greece
25-28 May 2005
http://congress.cimne.upc.es/coupledproblems



Combustion

International Conference on Computational Combustion
Lisbon, Portugal
21-24 June 2005
http://navier.ist.utl.pt/compcomb05

Multi-body Dynamics

II International Conference on Advances in Computational Multi-body Dynamics

Madrid, Spain
21-24 June 2005

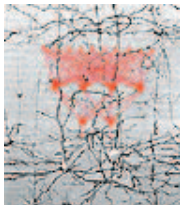
Marine Engineering

Computational Methods in Marine Engineering

Oslo, Norway
27-29 June 2005
http://congress.cimne.upc.es/marine05

Neural Networks

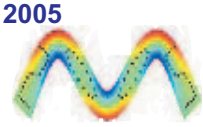
International Conference on Neural Networks and Soft Computing in Structural Engineering (NNSF-2005)



Cracow, Poland
June 30 - July 2 2005
www.pk.edu.pl/nnsc

Meshless Methods

International Conference on Meshless Methods 2005



Lisbon, Portugal
11-14 July 2005
http://www.math.ist.utl.pt/meshless2005

Smart Structures

II International Conference on Smart Structures and Materials

Lisbon, Portugal
18-21 July 2005
www.dem.ist.utl.pt/~smart05

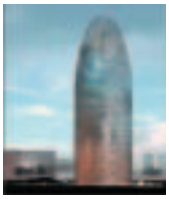
NMCM

10th International Conference on Numerical Methods in Continuum Mechanics (NMCM) & 4th Workshop on Trefftz Methods

Zilina, Slovakia
23-26 August, 2005
http://mppserv.utc.sk/NMCM2005

COMPLAS VIII

VIII International Conference on Computational Plasticity (COMPLAS VIII)



Barcelona, Spain
5-8 September 2005
http://congress.cimne.upces/complas05

Adaptive Modelling

II International Conference on Adaptive Modelling Simulation (ADMOS II)

Barcelona, Spain
8-10 September 2005
http://congress.cimne.upc.es./admos05

EUROGEN 2005

Evolutionary Methods for Design, Optimisation and Control with Applications to Industrial Problems (EUROGEN 2005)

Munich, Germany
12-14 September 2005
http://www.lhm.mw.tu-muenchen.de/EUROGEN05

ICCB 2005

International Conference on Computational Bioengineering (ICCB 2005)
Lisbon, Portugal
14-16 September 2005
http://www.dem.ist.util.pt/

EMG08

8th European Multi-grid Conference (EMGO08)
Delft, The Netherlands
27-30 September 2005
Organized by Delft University of Technology

Structural Membranes

II International Conference on Textile Composites and Inflatable Structures (Structural Membranes 2005)

Stuttgart, Germany
2-4 October 2005
http://congress.cimne.upc.es/membranes05

AI-METH 2005

VI Symposium on Methods of Artificial Intelligence (AI-METH 2005)

Gliwice, Polan
16-18 November 2005
http://www.ai-meth.polsl.pl

ECCOMAS 2004

The fourth European Congress on Computational Methods in Applied Sciences and Engineering took place in J**yväskylä, Finland** on **24 - 28 July 2004**. The Congress was hosted by the Jyväskylä Paviljonki International Congress Centre and the University of Jyväskylä.

Following the success of the three previous ECCOMAS Congresses (Brussels 1992, Paris 1996 and Barcelona 2000), this edition of ECCOMAS congress was attended by over 1.000 delegates, from many different countries. The different topics covered developments and applications of computational methods to a wide range of problems in science and engineering. They included: Computational Solid and Structural Mechanics, Computational Fluid Mechanics, Computational Acoustics, Computational Electromagnetics, Computational Chemistry, Computational Mathematics and Numerical Methods, Inverse Problems, Optimization and Control, Computational Methods in, Life Sciences, Industrial Applications

Ekkehard Ramm, Pekka Neittaanmäki (ECCOMAS Congress Chairman), Eugenio Oñate, Herbert Mang and Jacques Périaux

Plenary lectures were:
Recent Advances in Computational Modeling of Material Failure by **Javier Oliver**, Mathematical and Numerical Models for the Simulation of Cardiovascular Flow by **Alfio Quarteroni**, Why Should We Use Multiobjective Optimization when Solving Real-life Problems? by **Kaisa Miettinen**, The Topological Asymptotic Expansion and Its Applications to Optimal Design and Shape Inversion by **Mohammed Masmoudi**, Regularization for Ill-posed Problems: Linear to Non-linear to Non-differentiable to Non-convex by **Otmar Scherzer**
Efficient Solvers in Computational Electromagnetics by **Ulrich Langer**
Modelling and Simulation of Multi-Scale Systems in Biosciences by **Willi Jäger**
Designing Smaller Computers Requires Bigger Computers by **Yrjö Neuvo**

Complete information is available on **http://www.mit.jyu.fi/eccomas2004/**

Delegates enjoying leisure time and the Finish country
Photographer: Markku Könkkölä

ECCOMAS CFD 2006

The next European Conference on Computational Fluid Dynamics will take place in Egmond aan Zee, **The Netherlands**, on **September 5-8, 2006**. It will take place under the auspices of ECCOMAS and organised by the institute is Delft University of Technology, Delft, The Netherlands.
Chairman of the Conference is P. Wesseling (Delft University of Technology, The Netherlands) and co-vice-chairmen are E. Oñate (Technical University of Catalonia, Spain) and J. Périaux (Dassault Aviation, France).

The goal of the ECCOMAS CFD conferences is to periodically bring together researchers, industrialists and students working in broad parts of computational science and engineering. The focus is on computational fluid dynamics, computational acoustics, computational electromagnetics, computational mathematics and related fields in the computational sciences. Further information is available on **http://pcse.tudelft.nl/eccomas2006/**

ECCOMAS CSSM 2006

ECCOMAS and the Associação Portuguesa de Mecânica Teórica, Aplicada e Computacional (APMTAC) organize the III European Conference on Computational Solid and Structural Mechanics that will take place in the Laboratório Nacional de Engenharía Civil (LNEC) in **Lisbon, Portugal**, on **June 4 - 8, 2006**. Co-chairmen of the Conference are Prof. Carlos A. Mota Soares (Technical University of Lisbon, Portugal) and Prof. Manolis Papadrakakis (National Technical University of Athens, Greece).

The Conference will include many different topics in the areas of Computational Methods, Computational Solid Mechanics, Computational Structural Mechanics, Coupled Problems and Industrial Applications.
http://www.dem.ist.utl.pt/~cssm2006/

debrief

WCCM VI Sixth World Congress on Computational Mechanics

September 5 - 10, 2004

Beijing, China

Figure 1:
Opening Ceremony at Beijing Hotel

The **Sixth World Congress on Computational Mechanics, WCCM VI** was held in conjunction with **Second Asian Pacific Congress on Computational Mechanics**, APCOM'04 in **Beijing, China** during **September 5-10, 2004**. The Beijing venue is the first time that both congresses were held together and it was a unique occasion for the world community of researchers in computational mechanics to get together. The Beijing Congress was also the most successful congress in the WCCM series which started with Austin (1986), Stuttgart (1990), Chiba (1994),Buenos Aires (1998) and Vienna (2002), attracting more than 1200 delegates from 57 countries and regions only after two years of Vienna congress.

WCCM VI in conjunction with APCOM'04 was organized jointly by the International Association for Computational Mechanics and Asian Pacific Association for Computational Mechanics. The local organization comprised of Chinese Association for Theoretical and Applied Mechanics, Chinese Association for Computational Mechanics, Peking University, Tsinghua University, Dalian University of Technology and Institute of Mechanics, Chinese Academy of Sciences. The chairmen of the congress was Professor Mingwu Yuan and Zhong Wanxie. The Secretary General was Professor Zhenhan Yao.

The scientific program for the combined congress consisted of 3 plenary lectures representing the three regions[Belytschko*(Americas)*, Ohayon *(Europe)*,Zhong *(Asia-Australia)*], 21 semi plenary lectures, 172 mini-symposia sessions and 85 regular sessions. The average number of presentations in mini-symposia and regular sessions weresix.

The Local Organizing Committee was responsible for planning not only an efficient technical program but also a wonderful social program. The Opening Ceremony in the Banquet Hall of Beijing Hotel included addresses by C.G.Feng *(Chief Guest)*, W. X. Zhong, M. W. Yuan, E. Onate and S. Valliappan. The Social Events included the Reception Dinner at the Banquet Hall of Beijing Hotel, VIP Dinner at Summer Palace, APACM Awards for Senior Scientists at the Roast Duck Restaurant and the magnificent Congress Banquet at Golden Palace. The highlights of the Congress Banquet were the IACM and APACM Awards presented to a number of scientists for their contributions in computational mechanics.



Figure 2, 3 and 4:
Yuan, Oñate and Valliappan´s Address

The major IACM Award, Gauss-Newton Medal was presented to Franco Brezzi *(Italy)* and Roger Owen *(UK)*. The major APACM Award, Zienkiewicz Medal was presented to S. Valliappan *(Australia)*.

The Congress Proceedings have been published in two volumes of abstracts and another volume containing 3 plenary lectures, 11 semi-plenary lectures and 108 keynote lectures. The volumes of abstracts consist of 650 abstracts of papers presented in mini-symposia and 545 abstracts of papers presented in regular sessions. A CD Rom containing all the full papers was also produced and distributed to the participants.

The selection of Beijing as the venue for WCCM VI/APCOM'04 indicated the recognition of world community about the progress made by Chinese scientists in computational mechanics.

The success of the combined congress proved that China had made a significant growth in the field of computational mechanics along with its fast economic growth during the past 25 years.

The organizers would like to acknowledge the financial support received from various institutions, especially National Natural Science Foundation of China, Ministry of Science and Technology of China and Ministry of Education of China. Finally, the organizers would like to express their sincere thanks to all participants, authors, members of various committees, sponsors and other individuals who have made significant contributions to the immense success of the combined **WCCM VI/APCOM'04** Congress.

S.Valliappan
Vice President (Asia-Australia) IACM and Secretary General, APACM
Mingwu Yuan
Chairman, WCCMVI/APCOM'04
Zhenhan Yao
Secretary General,WCCMVI/APCOM'04

Figure 5:
Valliappan replying to the award of APCOM Congress (Zienkiewicz) Medal

Figure 6:
Roger Owen replying to the award of Congress (Gauss-Newton) Medal

Figure 7:
Yuan, Hughes, Idelsohn, Mrs Idelsohn and Mrs Yuan at the Banquet

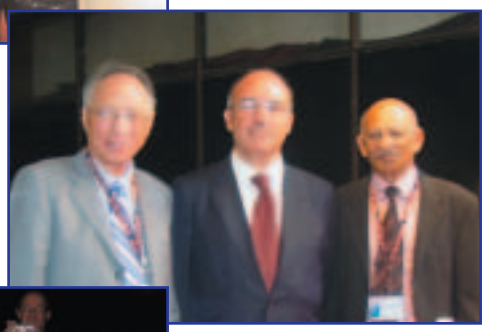


Figure 8:
Yuan, Oñate and Valliappan at the Banquet

Figure 9:
Lion Dance at the table

Figure 10:
Mang and Hughes at the reception

Figure 11:
Belytschko with delegates at the reception

Figure 12:
Participants at the reception

WCCM 2006
Seventh World Congress on Computational Mechanics

In 1986, when the IACM was formally established, the General and Executive Councils were confirmed and the Constitution approved. The Constitution giving equal emphasis to the three geographical Regions of America, Euro-Africa and Australia-Asia a rotation of such World Congresses between the regions on a two year cycle was established. After the success of China, we return to the USA for our National Congress, to **Los Angeles, California** from **16 - 22 July 2006.**

Important Dates:
May 1, 2005 Deadline for pre- and post-congress workshop proposal
July 1, 2005 Deadline for receipt of 1-page abstracts
Advisory Board:
Wing Kam Liu - General Chairman
J. S. Chen - Technical Chairman
Co-hosted by:
T. Belytschko , B. Moran, J.W. Ju, E. Taciroglu, L. Keer, H. Espinosa S. Osher, N. Ghoniem

Congress Themes are: Computational Mathematics, Computational Bio-sciences, Computational Material Sciences, Computational Nanotechnology, High Performance Computing in Mechanics and Applied Mathematics.

Congress Topics are: Computational solid and structural mechanics, fluid mechanics, materials science, biomechanics, nanotechnology, MEMS and bio-MEMS, engineering sciences and physics, nonlinear dynamics, adaptive materials systems, structures and smart materials, advances in composite machining, geomechanics, inverse problems and optimization, environmental science, damage mechanics, dynamic failure and fracture, ice mechanics, NDE and wave propagation, infrastructures and aging structures, polymers and polymer composites, microtribology and micromechanics, CAD,CAM and CAE, Scientific visualization, Data and signal processing, Parallel computing, Artificial intelligence and expert systems, Mesh less and wavelet methods andMultiple-scale physics and computation

For further information:
http://www.wccm2006.northwestern.edu ●

Third MIT Conference on Computational Mechanics

June 14 - 17, 2005
Massachusetts Institute of Technology
Cambridge, U.S.A.

Our aim is to bring together researchers and practitioners from around the world to assess the latest frontiers of high performance compu-ting and to set important directions for further research and development.
The following broad areas will be addressed: Computational Fluid Dynamics, Computational Mechanics of Solids and Structures, Computational Multi-Physics Dynamics including Fluid Flows with Structural Interactions, The focus will be on the state of the art of the numerical procedures used, software development and industrial usage.

The focus of the Conference will be on computational fluid dynamics, computational solid and structural mechanics, and in particular on the interdisciplinary areas of multi-physics phenomena. Formulations, solution procedures, mathematical analyses, error estimations and adaptivity, model validations, optimization in design and advanced applications are of interest. Finite element, finitevolume, finite difference, boundary element, meshless methods,... will be presented.

For further information:
http://thirdmitconference.org ●

GRACM 05
5th GRACM Congress on Computational Mechanics

29 June - 1 July 2005
Linassol, Cyprus

GRACM 05 is dedicated to the memory of Professor John H. Argyris.

The aim of GRACM05 is to provide a forum for discussion of both academic and industrial research in the various areas of computational mechanics which combine computer applications, numerical methods and mechanics.Early registration ends on 30 April 2005.

For further information:
http://www.ucy.ac.cy/~gracm05 ●

conference diary planner

18 - 22 April 2005	**ICRA05 - IEEE International Conference on Robotics andAutomation**		
	Venue: Barcelona, Spain	*Contact:*	*http://www.irca2005.org*
4 - 6 April 2005	**FEF05 - 13th Conference on Finite Element for Flow Problems**		
	Venue: Swansea, Wales	*Email:*	*o.hassan@swansea.ac.uk*
		Contact:	*http://www.swansea.ac.uk/fef05*
25 - 28 May 2005	**Computational Methods for Coupled Problems in Science and Engineering**		
	Venue: Santorini, Greece	Contact:	*http://congress.cimne.upc.es/coupledproblems*
1 - 4 June 2005	**IASS IACM - 5th Int. Conference on Computation of Shell & Spatial Structures**		
	Venue: Salzburg, Austria	*Email:*	*info@iassiacm2005.de*
		Contact:	*http://www.iassiacm2005.de/*
6 - 10 June 2005	**Nonlinear Finite Element Analysis Short Course by T.J.R. Hughes and T. Belytschko**		
	Venue: Paris, France	*Contact:*	*www.zace.com*
14 - 17 June 2005	**Third M.I.T. Conference on Computational Fluid and Solid Mechanics**		
	Venue: Massachusetts Institute of Technology, Cambridge, U.S.A.		
		Contact:	*http://www.thirdmitconference.org*
21 - 24 June 2005	**ECCOMAS Thematic Conference on Computational Combustion**		
	Venue: Lisbon, Portugal	*Contact:*	*www.eccomas.org*
21 - 24 June 2005	**II International Conference on Advances in Computational Multibody Dynamics**		
	Venue: Madrid, Spain	*Contact:*	*www.eccomas.org*
27 - 29 June 2005	**Computational Methods in Marine Engineering**		
	Venue: Oslo, Norway	*Contact:*	*http://congress.cimne.upc.es/marine05*
29 June - 1 July 2005	**GRACM05 - 5th GRACM Congress on Computational MEchanics**		
	Venue: Limassol, Cyprus	*Email:*	*gracm05@ucy.ac.cy*
		Contact:	*www.ucy.ac.cy/~gracm05*
30 June - 2 July 2005	**NNSC2005 - International Symposium on Neural Networks and Soft Computing in Structural Engineering**		
	Venue: Cracoe, Poland	*Contact:*	*www.pk.edu.pl/nnsc*
4 - 7 July 2005	**VII Congreso de Métodos Numéricos en Ingeniería**		
	Venue: Granada, Spain	*Contact:*	*www.semni.org*
11 - 14 July 2005	**ECCOMAS Thematic Conference on Meshless Methods**		
	Venue: Lisbon, Portugal	*Contact:*	*www.eccomas.org*
18 - 21 July 2005	**II ECCOMAS Thematic Conference on Smart Structures and Materials**		
	Venue: Lisbon, Portugal	*Contact:*	*www.eccomas.org*
24 - 28 July 2005	**USNCCM'05 - 8th US National Conference on Computational Mechanics**		
	Venue: Austin, Texas, USA	*Contact:*	*www://www.ices.utexas.edu/usnccm8.html*
23 - 26 August 2005	**NMCM - 10th International Conference on Numerical Methods in Continum Mechanics and 4th Workshop on Trefftz Methods**		
	Venue: Slovakia	*Contact:*	*http://congress.cimne.upc.es/NMCM2005*
5 - 8 September 2005	**COMPLAS VIII - VIII International Conference on Computational Plasticity**		
	Venue: Barcelona, Spain	*Contact:*	*http://congress.cimne.upc.es/complas05*
8 - 10 September 2005	**ADAMOS II - International Conference on Adaptive Modelling Simulation**		
	Venue: Barcelona, Spain	*Contact:*	*www.cimne.com*
12 - 14 September 2005	**EUROGEN 2005 - Evolutionary Methods for Design, Optimisation and Control with Applications to Industrial Problems**		
	Venue: Munich, Germany	*Contact:*	*www.eccomas.org*
14 - 16 September 2005	**ECCOMAS Thematic Conference on Computational Bioengineering**		
	Venue: Lisbon, Portugal	*Contact:*	*www.eccomas.org*
27 - 30 September 2005	**EMG08 - 8th European Multigrid Conference**		
	Venue: Delft, The Netherlands	*Contact:*	*p.wesseling@ewi.tudeft.nl*
2 - 4 October 2005	**II International Conference on Textile Composites and Inflatable Structures**		
	Venue: Stuttgart, Germany	*Contact:*	*http://congress.cimne.upc.es/membranes05*
16 - 18 November 2005	**AL-METH 2005 - VI Symposium on Artificial Intelligence**		
	Venue: Gliwice, Poland	*Contact:*	*http://www.al-meth.polst.pl*
4 - 8 June 2006	**CSSM 2006 - III European Congress on Computational Solid and Structural Mechanics**	*email:*	*carlosmotasoares@dem.ist.utl.pt*
	Venue: Lisbon, Portugal	*Contact:*	*www.dem.ist.utl.pt/~cssm2006*
16 - 22 July 2006	**WCCM7 - VII World Congress on Computational Mechanics**		
	Venue: California, USA	*Contact:*	*WCCM7@mail.mech.northwestern.edu.*
5 - 8 September 2006	**Computational Fluids Dynamics - ECCOMAS CFD 2006**		
	Venue: Rotterdam, The Netherlands	*Contact:*	*www.eccomas.org*

The 2006 Seventh IACM World Congress on Computational Mechanics

The Century Plaza Hotel & Spa
Century City, California, USA
July 16 – 22, 2006

Co-hosted by

Northwestern University

W. K. Liu, T. Belytschko
B. Moran, L. Keer, H. Espinosa

UCLA

J. S. Chen, J. W. Ju, E. Taciroglu
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