



The International  
Association for  
Computational Mechanics



The European Community  
on Computational Methods  
in Applied Sciences

**8th World  
Congress on  
Computational  
Mechanics**

**WCCM8**

**5th European Congress  
on Computational Methods  
in Applied Sciences  
and Engineering**

**ECCOMAS 2008**

Venice, Italy, 30 June - 4 July 2008

**B. A. Schrefler and U. Perego (Eds.)**

Department of Structural and Transport Engineering  
Faculty of Engineering, Università di Padova

Department of Structural Engineering  
Politecnico di Milano

**PROGRAMME**

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8th World Congress on Computational Mechanics WCCM8  
5th European Congress on Computational Methods in Applied Sciences  
and Engineering ECCOMAS 2008

B. A. Schrefler and U. Perego (Eds.)

First edition, June 2008

© International Center for Numerical Methods in Engineering (CIMNE)  
Gran Capitán s/n, 08034 Barcelona, Spain



[www.cimne.com](http://www.cimne.com)

Printed by: Artes Gráficas Torres S.L., Morales 17, 08029 Barcelona, Spain

Depósito legal: B-31470-08

ISBN: 978-84-96736-55-9

*Joint*  
**8th. World Congress on Computational Mechanics (WCCM8)**  
*and*  
**5th. European Congress on Computational Methods in Applied  
 Sciences and Engineering (ECCOMAS 2008)**

**IACM – ECCOMAS 2008**

*Lido Island, Venice, Italy*  
*30 June - 4 July 2008*

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Università degli Studi  
di Padova

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## Greetings from the Co-Chairmen of the Congress



Welcome to the joint **Eighth World Congress of Computational Mechanics and Fifth European Congress on Computational Methods in Applied Sciences and Engineering WCCM8-ECCOMAS 2008** in Venice. Welcome to Venice which is considered among the most beautiful and best preserved historical cities in the world, unique in the fact that it is the only city built on water. In Venice you will experience the impact of history and culture, enjoy the flavour of the Adriatic sea and witness the problems which the preservation of such a unique cultural heritage poses. At the same time you will have the opportunity to discuss the latest developments in all aspects of computational mechanics and computational sciences and their application to traditional fields and new computation oriented areas in engineering and sciences.

This is the first time that IACM and ECCOMAS have joint their effort to set up a common conference and the outcome is probably the largest conference ever held in the field of mechanical sciences in its broader sense, with some 2600 papers to be presented. Several actions intended to promote the participation of young researchers have been undertaken: 37 scholarships for doctoral students have been offered by Eccomas, 25 by the US Association for Computational Mechanics (USACM), 10 by the Associazione Veneziana Albergatori (AVA) and 79 more have been supported on the congress budget. In addition to this, USACM also sponsored 25 Young Investigators Scholarships and 13 Scholarships for Retired Researchers have been supported on the congress budget. As an outcome of these actions, almost 500 participants registered as students, probably the best result ever achieved in congresses of this type.

The local organizing committee has been working very hard to set up a high quality technical programme. The selected papers have been accepted after a strong selection procedure, starting from 3457 submitted abstracts. The papers will be presented throughout the week in 35 parallel oral sessions, scheduled both in the morning and in the afternoon. Furthermore, there will be 10 plenary and 16 Semi-plenary lectures. This is a very dense programme and it will be surely a very intense week for all of us. Nevertheless, we hope that you will also have a chance to relax and take part in the social activities we have prepared. In particular we hope to see you in the Welcome Reception on Sunday evening at the Hotel Excelsior, at the Award ceremony on the occasion of the Conference Opening and at the banquet on Thursday evening in the harbour (Stazione Marittima). You should also take some time to visit the beautiful city of Venice and its museums. We have prepared on Tuesday and Wednesday, after the sessions, a guided visit to the basilica of San Marco, with all mosaics lit up, something which usually is not easy to see.

The selected conference venue is the Congress Center, located in the complex formed by the Palazzo del Cinema and the former Venice Casino on the Lido di Venezia. The Lido di Venezia is an island which limits the lagoon of Venice towards the Adriatic sea. The Conference Center is located close to the sea front. You have just to cross the road and you will be able to stroll along the beach or swim in the Adriatic sea. If your Hotel is on the Lido-Island, you can simply walk to your Hotel after the sessions or take a local bus. If your Hotel is elsewhere in the city, there exist frequent links between the island and other parts of the city. In that case you will experience the life in a city without cars and with historical buildings everywhere you look. You will also learn how not to be lost in its many alleys and bridges.

The organizers would like to thank the authors for submitting their contributions and for their patience in respecting the deadlines. The list of those who have worked at various stages of the preparation of the conference is long. We want to express our gratitude to all of them. In particular we want to thank the students of the Specialization School for Secondary Teaching (SSIS Veneto) at University of Cà Foscari in Venice for providing assistance in the lecture rooms. Special thanks go to the almost 400 colleagues who contributed to the organization of the Minisymposia and of the other Technical Sessions and to the many Referees who, with their work, contributed to enhance the scientific quality of this congress. Without their help this congress would have not been possible. We also want to thank the sponsors who have contributed generously to this conference. We invite you to enjoy Venice and to experience an unforgettable week.

Bernhard Schrefler

Umberto Perego

May 2008.

## Greetings from the President of IACM



Dear Colleague,

It is my great pleasure to welcome you in Venice from June 30th to July 4 2008 to the joint WCCM/ECCOMAS congress. The congress merges the 8<sup>th</sup> edition of the World Congress on Computational Mechanics of IACM and the 5<sup>th</sup> European Congress on Computational Mechanics in Applied Sciences and Engineering of ECCOMAS. The success of this joint venture is clearly shown by large number of participants, close to 3000. This is a landmark in the history of past congresses of IACM and ECCOMAS.

The success of the WCCM/ECCOMAS congress is also reflected in the content of the technical programme. Some 170 Minisymposia and Technical Sessions have been organized by leading scientists and engineers in topics covering most disciplines in computational science and engineering, ranging from advances in fundamental and emerging areas of computational mechanics such as nano-mechanics and material modelling, to innovative applications in technological fields, such as aeronautics, industrial forming processes, civil engineering and bio-mechanical engineering among others. The congress programme, therefore, covers the state of the art on the theory and practice of computational methods in many areas of engineering and applied sciences.

I thank ECCOMAS, and in particular its President Prof. Herbert Mang, for accepting to merge the 8<sup>th</sup> WCCM with the 5<sup>th</sup> ECCOMAS congress. I hope that this positive experience will be repeated in the future for the benefit of the computational community worldwide.

Last but not least, I would like to thank the co-organizers of the WCCM/ECCOMAS Congress, and particularly the two Co-Chairmen Profs. Bernard Schrefler and Umberto Perego and their teams at the Universities of Padova and Milano in Italy for an excellent and outstanding work.

I hope that you will enjoy attending the WCCM/ECCOMAS 2008 congress in the wonderful and inspiring city of Venice.

Best wishes,

Yours Sincerely,

Eugenio Oñate

## Greetings from the President of ECCOMAS



It is fair to say that the Joint 8th World Congress on Computational Mechanics (WCCM 8) and the 5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008) is a mega-event in the history of these relatively young scientific fields at the forefront of technological progress. The organization of this Congress by the International Association for Computational Mechanics (IACM) and the European Community on Computational Methods in Applied Sciences (ECCOMAS) is a long-term consequence of an agreement signed by the former Presidents of ECCOMAS and IACM, Profs. Oskar Mahrenholtz and Alf Samuelsson. This co-operation shows that, irrespective of its geographic focus, ECCOMAS is acting globally to fulfill its mission to "encourage the exchange of information and to enable the transfer of knowledge between research and industry".

Today we are confronted with problems in engineering and in the applied sciences with levels of complexity never encountered before in the history of mankind. The solution of problems characterized e.g. by the interaction of fluids and structures, not to forget materials, is of paramount importance in a technical world of rapidly increasing sophistication, referred to as the *Leonardo World* by the eminent philosopher Jürgen Mittelstraß.

WCCM 8/ECCOMAS 2008 is the ideal forum to report on and discuss solutions of complex problems in engineering and in the applied sciences with special emphasis on interdisciplinary research activities. Not the least it is a place where researchers and practicing engineers of different age groups and from all parts of the globe can exchange their ideas on these problems and at the same time renew old friendships and establish new ones in one of the most beautiful cities in the world.

On behalf of ECCOMAS I wish to thank the Chairmen of the Joint IACM and ECCOMAS Congress, Profs. Bernhard A. Schrefler and Umberto Perego, for the excellent organization of the Congress. Their dedicated efforts guarantee that the participants of WCCM 8/ECCOMAS 2008 will return home from Venice under the impression of an unforgettable scientific and social event.

Prof. Herbert A. Mang

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**Room: CAS1.7**

**MS019 Computational Methods in Multibody Dynamics Simulation II**

Organizers: Dan Negrut, Carlo Bottasso and Rudranarayan M. Mukherjee

- 14:00 Ball-Beam System Modeling using Nonlinear State-Space Equations Approach aided by Bond-Graphs  
*Celso Negrao, Euler Barbosa and Nazem Nascimento*
- 14:20 Parallelization of the Spatial Operator Algebra for Dynamics of Multibody Systems  
*Rudranarayan Mukherjee and Abhinandan Jain*
- 14:40 Spatial Operator Algebra Perspective for Computational Multibody Dynamics  
*Abhinandan Jain*
- 15:00 Subsystem Based Recursive Formulation for Repeated Topology of Multibody Systems  
*Sung-Soo Kim, Chang Ho Lee and Seonghoon Kim*
- 15:20 Automated Modeling of Complex Mechanical Systems using Bond Graph  
*Ryotaro Magoshi and Hiroaki Yoshimura*
- 15:40 Design Optimization Procedures for the Validation of Generic Road Vehicles  
*Marta Carvalho, Jorge Ambrosio and Luis Sousa*

**Room: CAS1.8**

**MS102 Inverse Problems II**

Organizers: Bojan Guzina and Marc Bonnet

- 14:00 A Variational Approach to solve Cauchy Problem for Steady State Stokes Flow  
*Xavier Escriva and Thouraya Nouri Baranger*
- 14:20 Identification of Lumped Parameter Systems and Optimal Experiment Design  
*Oleg M. Alifanov, Aleksey V. Nenarokomov and Vivaldo M. Gonzales*
- 14:40 A Bayesian Inference Approach for Structural Dynamic Transfer Function Identification  
*Erliang Zhang, Pierre Feissel, Jérôme Antoni and Claude Blanzé*
- 15:00 A Direct Identification Algorithm for the Estimation of the Stiffness Distribution of Frame Structures  
*Yiska Goldfeld*
- 15:20 Nondestructive Measurement of LSI Electroplating Current Distribution using Magnetic Sensors  
*Yoshinao Kishimoto and Kenji Amaya*
- 15:40 The Multidimensional Refinement Indicators Algorithm for Adaptive Parameterization  
*Hend Ben Ameer, François Clément, Pierre Weis and Guy Chavent*

**Room: CAS2.1**

**MS074 Minisymposium on Inverse Problems in Heat Transfer II**

Organizers: Alain Kassab, Richard Bialecki and Eduardo Divo

- 14:00 An Original Inverse Method for Characterization of Heat Flux in Grinding  
*Alexandre Brosse, Pierre Naïsson, Alexandre Delalleau, Hedi Hamdi and Jean Michel Bergheau*
- 14:20 The Measurement of Radiant Heat Flux in Combustion Chambers of Large Steam Boilers  
*Tomasz Sobota and Dawid Taler*
- 14:40 Initial Inverse Problem in the Vacuum Paper Drying Process  
*Zbigniew Bulinski, Andrzej Nowak, Krzysztof Kasza and Lukasz Matysiak*
- 15:00 Thermal Optimization of Polymer Injection Mould : Application of Conformal Cooling Design  
*Jacques Duysens, Didier Delaunay, V. Sobotka, David Garcia and Steve Langlois*
- 15:20 Numerical Estimation for Intumescent Thermal Protection using One-Dimensional IHCP  
*Luis Mesquita, Paulo Piloto, Mario Vaz and Tiago Pinto*
- 15:40 Substitute Thermal Capacity of Alloy. An Inverse Problem Solution  
*Ewa Majchrzak, Bohdan Mochnecki and Jozef S. Suchy*

## NUMERICAL ESTIMATION FOR INTUMESCENT THERMAL PROTECTION USING ONE-DIMENSIONAL IHCP

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**Key Words:** *Intumescent Paint, Cone Calorimeter, Thermal Conductivity, IHCP, Finite Difference Method.*

### ABSTRACT

Intumescent coatings are an important group of passive fire protection materials, representing about one third of steel fire protection costs. This insulating system is made of four different chemical compounds that can be classified as: a carbonisation agent, an acid source, a foaming agent and a catalyst. When protecting a steel structure under fire conditions, the intumescent paint is heated, beginning to melt, to bubble and to swell, forming a multi-cellular barrier which decreases the heat transfer from the fire to the substrate. The film behaviour is characterized by an expansion and mass loss, producing a foam char with a geometry that varies from 5 to 200 times its original volume. In order to design this type of protection, the intumescence physical and thermal behaviour must be acknowledged, being the thickness and the effective thermal conductivity the key parameters during this process.

The performance of a commercial water-based intumescent paint is assessed by a set of experimental tests, conducted in a cone calorimeter, which enables the mass loss rate calculation, the substrate temperature and the intumescence thickness variation with time.



Fig. 1 – Coated steel plates, with fixed thermocouples, cone calorimeter setup and intumescence development.

The samples are made of 100 [mm] squared steel plates, coated in one side with different dry film thicknesses and tested in a cone calorimeter as prescribed by the standard E1354-04 [1], considering different heat fluxes. Substrate temperatures are measured by means of four thermocouples, type k, welded at the plate in the heating side and at the opposite side, at two different positions, see Figure 1. Using discrete

frames, obtained from the camera during tests and by image processing techniques, the intumescence profile development was measured over time.

Although the problem of solving energy equation on each side of the intumescence moving boundary is considered as a generalized Stefan problem, in which the moving boundary and the free boundary locations must be determined as part of the proposed problem, [2], in this work the intumescence is treated as one homogenous layer of constant specific mass and constant specific heat. The development of the intumescence may be considered as a one-dimensional heat conduction problem, where the heat flows through the coating layer. The governing equation and the corresponding boundary conditions for the problem are:

$$c\rho \frac{\partial T}{\partial t} = \frac{\partial}{\partial x} k_{eff} \frac{\partial T}{\partial x} \quad 0 < x < L(t) \quad (1)$$

$$k_{eff} \frac{\partial T}{\partial x} \Big|_{x=L(t)} = \varepsilon \dot{q}_r - h_c (T - T_a) - \varepsilon \sigma (T^4 - T_a^4) \quad x = L(t) \quad (2)$$

$$k_{eff} \frac{\partial T}{\partial x} = d_s c_s \rho_s \frac{\partial T_s}{\partial t} \quad x = 0 \quad (3)$$

The solution for the effective thermal conductivity and the temperature field, defined by equations 1-3, may be considered an inverse heat conduction problem (IHCP), being ill-posed, since it will not, in general, have a unique solution. Such problems are extremely sensitive to measurement errors, [3]. The proposed numerical solution is obtained by the finite difference method, considering a single temperature sensor, corresponding to the thermocouple at the plate top surface, and using the function specification method, comparing the single future time step and  $r$  future time steps methods, as proposed by Beck, [3].

The intumescence effective thermal conductivity will be estimated by solving the IHCP, considering the influence of: (1) initial dry thickness, (2) incident heat flux, (3) substrate thickness and (4) intumescent coating type.

## REFERENCES

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