Emerging User Community in Industrial Mathematics

Svetozar Margenov

Institute for Information and Communication Technologies, Bulgarian Academy of Sciences, Acad. G. Bonchev Str. Bl. 25-A, 1113 Sofia, Bulgaria

1. Industrial mathematics

”Industrial mathematics focusses on problems which come from industry and aims for solutions which are relevant to industry, including finding the most efficient way to solve the problem.”

Virginia Postrel, Boston Globe. June 27, 2004

International Societies:

- **Society for Industrial and Applied Mathematics (SIAM)**
  The Bulgarian Section of SIAM was established in January 2007.
  The current Annual Meeting of BG SIAM will take place in Sofia, December 18-19, 2013.
- **European Consortium for Mathematics in Industry (ECMI)**
- **Oxford Center for Computational and Applied Mathematics:**
  Study Groups with Industry (OCCAM SGI).
  The European SGI 95 took part in September 23-27, 2013 in Sofia.

SGI'95

European Study Group with Industry'95 http://esgi95.fmi.uni-sofia.bg/

- Home
- Organization
- What is SGI
- SGI format
- For Companies
- For academic participants
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- Important dates
- Problems
- Program
- Participants
- Presentation of prof. Wil Schilders

European Study Group with Industry'95 (ESGI'95)

September 23 - 27, 2013, Sofia, Bulgaria

The 95th European Study Group with Industry

ESGI'95

September 23 - 27, 2013, Sofia, Bulgaria
is organized by

Faculty of Mathematics and Informatics, Sofia University "St. Kliment Ohridski",

in cooperation with

Institute of Information and Communication Technologies, Bulgarian Academy of Sciences,

Institute of Mathematics and Informatics, Bulgarian Academy of Sciences,

and

ECMI
European Consortium for Mathematics in Industry

OCCAM
Oxford Centre for Collaborative Applied Mathematics

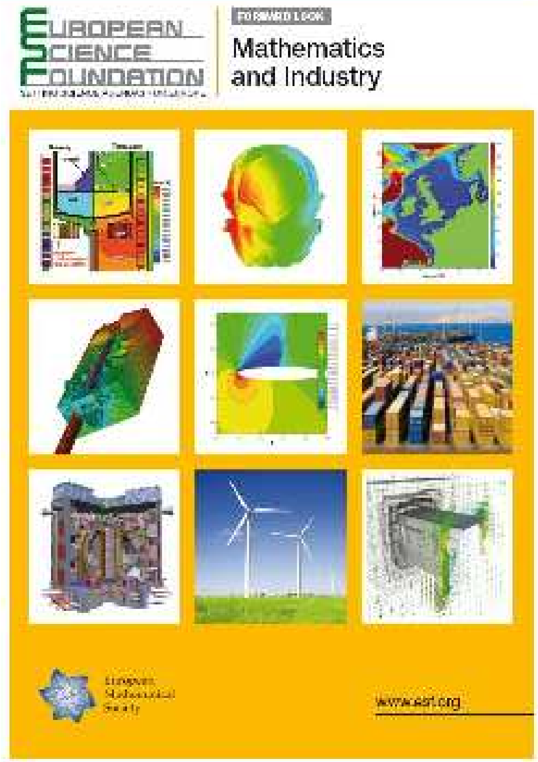
SGI'95

- Participants: 50
- Problems:
  - Compressed representation of a partially defined integer function over multiple arguments
  - Estimation of errors in text and data processing
  - Optimization of the charging process in zinchydrometallurgy
  - Mini-Max wallpaper
  - Laboratory calibration of a MEMS accelerometer sensor
  - Prediction of sanding in subsurface hydrocarbon reservoirs
- Support: OCCAM and ECMI
- Official Reprepresentatives:
  - OCCAM: Prof. Hilary Ockendon, Oxford University
  - ECMI: Prof. Wil Schilders, TU Eindhoven

W. Schilders (ECMI)

"Mathematics and Industry" Forward Look (2011)

- ECMI has played an important role in the Forward Look project on "Mathematics and Industry" organized by the European Mathematical Society and the European Science Foundation



http://www.ceremade.dauphine.fr/FLMI/

Technische Universiteit Eindhoven University of Technology

ACOMIN SIM'2013

SEMINAR on INDUSTRIAL MATHEMATICS

Sofia, December 19, 2013

- **10:30 - 12:00 AComIn SmarthLab Equipment**
- **13:30 - 14:30 Mathematics as technology: good practices in various industrial applications: Oleg Iliev, Fraunhofer ITWM, Kaiserslautern**
- **14:30 - 15:30 On-going activities in industrial mathematics at IICT**
- **15:30 - 16:30 Panel discussion**

Participant from innovative companies are expected to take part in the event, including representatives of national branch chambers and industrial clusters.

Fraunhofer ITWM

Flow and Material Simulation - Fraunhofer-Institut... http://www.itwm.fraunhofer.de/en/departments/flo...

Fraunhofer ITWM

Home > Departments > Flow and Material Simulation

Flow and Material Simulation

Fraunhofer Institute for Industrial Mathematics ITWM

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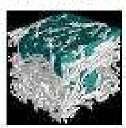
The department of FLOW AND MATERIAL SIMULATION deals with the modeling and simulation of fluid dynamical and structure elastic processes for the optimization of materials and components. One of our main competences is the efficient numerical solution of multiscale and multiphysical problems occurring in Material Simulation.
Our clients are producers of technical textiles and composite materials, metal and plastic processing companies, particularly foundries, as well as subsequent processing branches, such as filter producers and system suppliers in the field of automobile technology.

Competences

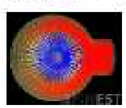
Microstructure Simulation and Virtual Material Design



The work within the group of microstructure simulation and virtual material design can be summarized by the overall concept of "GeoDict ", we are developing and marketing software for the optimization of complex three-dimensional geometric structures of porous materials and composites.

Further Information

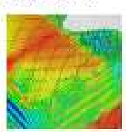
Hydrodynamics



The subject Hydrodynamics deals with flows wich are relevant for industrial as well as for ecological applications. Usually, we have to solve multiphysical problems, partly with free surfaces.

Further Information

Complex Fluids



The Complex Fluids group deals with rheological complex fluid flow problems and analysis of physical complex processes relevant for industrial applications. Our competences include mathematical physical modelling of material properties and industrial processes as well as development of fast, robust and efficient numerical algorithms for performing computer simulations of the identified models.

Further Information

IM activities at IICT

Numerical Simulation Of The Cooling Process In A Porous Inert Media Gas Burner

Svetozar Margenov, Yavor Vutov
Institute of Information and Communication Technologies
Bulgarian Academy of Sciences

Henning Bockhorn, Jordan A. Denev, and Ilian Dinkov
Engler-Bunte-Institute
Karlsruhe Institute of Technology

1. Introduction

Premixed combustion in porous inert media (PIM) burners is a promising alternative to the traditional free and swirl-stabilized flames [1, 2, 3]. The increased heat recirculation due to solid-solid radiation, solid conduction and dispersion results in considerably higher burning velocities, less pollutant emissions, higher radiant heating rates.

The process of understanding of the physics behind the combustion phenomenon in PIM faces challenging difficulties due to problems with optical accessibility, the complexity of the phenomena involved and the randomness of PIM. Therefore, continuous research is necessary in the areas of fluid mechanics and heat transfer within PIM and PIM property data. The burner investigated is made of a porous Siliconized Silicon Carbide (SiSiC).

Geometry

The computational domain consists of a porous SiSiC material and gas phase. A computed tomography (CT) scan of the SiSiC porous material is used to obtain the geometry (see Fig. 1 and Fig. 2). The scan was performed at the Institute of Geonics, Ostrava. We want to thank professor Radim Blaheta and his group for the CT scans.

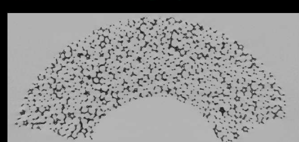


Fig. 1. Slice of the SiSiC scan

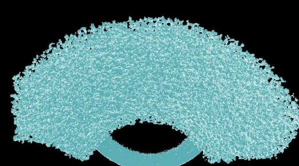


Fig. 2. 3D reconstruction of CT scan

The complexity of the domain leads to big discrete problems. A parallel FEM solver is developed for the simulation. The presented results are obtained on an IBM Blue-Gene/P system.

2. Effective heat conductivity coefficient

Our first goal was to obtain effective homogenized heat conductivity coefficient for the porous SiSiC material. To do so, we cut a parallelogram piece ($4.57cm \times 6.09cm \times 6.09cm$, $192 \times 256 \times 256$ voxels) from the scan (see Fig. 3). We solve the steady state heat transfer equation:

$$-\kappa \Delta T = 0, \tag{1}$$

where T is the temperature and κ is the heat conductivity of a solid SiSiC material. Dirichlet boundary condition (BC) of 800 °C is put on one of the sides of the piece and Dirichlet BC of 820 °C – on the opposite one. Our domain consisted *only* of the SiSiC material extracted from the CT scan. We use the finite element method (FEM) with linear tetrahedral elements for the computations. The finite element mesh is obtained directly from the voxel image dividing each voxel into 6 tetrahedrons. For the solution we use MPI parallelized preconditioned conjugate gradient method with a BoomerAMG preconditioner. BoomerAMG is an implementation of a parallel multigrid method, part of the software package HYPRE [4, 5]. The mesh is partitioned using ParMETIS library[6].
We use formula

$$\kappa_{eff} = |\phi| \frac{dx}{dT} \tag{2}$$

to compute the effective conductivity coefficient κ_{eff}, where with ϕ is denoted the averaged heat flux, with dT — the temperature difference and dx is the thickness of the piece.
In Table 1 are shown the obtained effective conductivity for three specimens with different porosity (obtained via segmentation with different cutoff value). In the experiments $\kappa = 47$ was used. Since κ depends nonlinearly on the temperature for the SiSiC material, of particular interest is the ratio κ/κ_{eff}, which is also shown in the table.

porosity	κ_{eff}	κ/κ_{eff}
10%	9.30	5.05
15%	15.66	3.00
20%	18.04	2.61

Table 1. Effective conductivity coefficients

3. Cooling process

We use the 3D finite element method to simulate the cooling process of a stopped porous burner. The flammability limit of the methane-air mixture is approximately 600 °C. We are interested in the time needed for the burner to cool bellow this limit. The cooling time is of practical interest for safety reasons and for the purpose of reigniting the burner without an external spark.

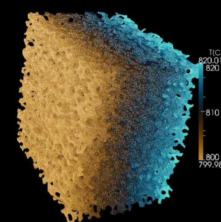


Fig. 3. Temperature field in a SiSiC cut

This time the computational domain contains solid SiSiC material and a fluid (air) phase. The whole cylindric SiSiC burner is reconstructed from the CT scan data using symmetry (see Fig. 4).
We solve the general heat conduction equation

$$\frac{\partial T}{\partial t} - a \Delta T = \frac{S}{\rho c}, \tag{3}$$

where T is the temperature, t is the time, S is the heat sink $[W/m^3]$, a is the thermal diffusion coefficient:$a = \kappa/(\rho c)$, ρ is the material density, κ — its thermal conductivity and c is its specific heat.
A volumetric heat sink for the gas-phase only is prescribed. This heat sink accounts for the cooling effect of non-burning air flowing through the porous media during the cool-down process. It is computed from the following equation:

$$S = -m_{air} c(T)(T(x_{i+1}, t) - T(x_i, t))/Vol_{x_i}, \tag{4}$$

where $m_{air} = 0.011[kg/s]$ is the air flowing rate through our experimental setup at Engler-Bunte institute, x is the radius cylindrical coordinate of the point; $T(x_i, t)$ is the azimuthal temperature average with radius x_i at time T, and Vol_{x_i} is the volume of the gas phase in the cylinder between x_i and x_{i+1}. Density of the solid is $3150[kg/m^3]$, its specific heat is $800[j/(kg.K)]$. SiSiC heat conductivity coefficient is interpolated from values in a table (see Fig. 6). Gas heat conductivity coefficient κ_g is 0.025 $[w/(m.K)]$, Gas density and specific heat depend on the temperature. They are taken from the experimentally obtained table. The initial temperature was experimentally obtained (see Fig. 7 and Fig. 8).

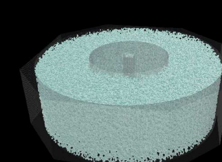


Fig. 4. Reconstructed porous burner

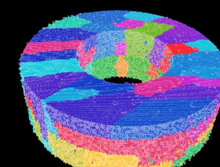


Fig. 5. Sample partitioning on 64 processors

For the time discretization backward Euler method was used.

On Fig. 8 are shown the solution at different radii and times. The azimuthally averaged values are shown.

The computations were performed on an IBM BlueGene/P computer. The mesh consists of 824 640 000 tetrahedrons and 138 700 288 vertices. The machine was used in DUAL mode, utilizing 512 processors on 256 compute nodes. Sample partitioning is shown on Fig. 5. The computation took 3 hours. Timestep was chosen to be 5s and 21 timesteps were performed for a total simulation time of 105 seconds.

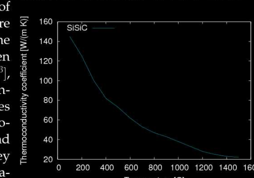


Fig 6. Manufacturer data of SiSiC

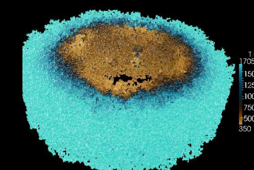


Fig 7. Initial temperature in PIM

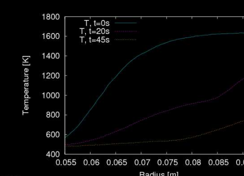


Fig 8. Average temperatures

References

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[6] G. Karypis and V. Kumar, *A coarse-grain parallel multilevel k-way partitioning algorithm*, In Proceedings of the 8th SIAM conference on Parallel Processing for Scientific Computing, 1997.

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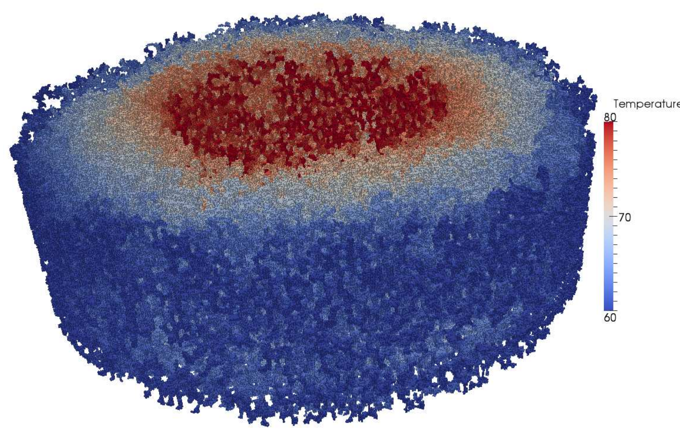
- **μ-FEM analysis of combustion in porous inert media (PIM)**

  The computational domain consists of a porous SiSiC material and gas phase. A computed tomography (CT) scan of the SiSiC porous material is used to obtain the geometry.



Microstructure geometry of the PIM burner