Research documentation per participating group


1. **RESEARCH DOCUMENTATION OF THE GROUP DYNAMICS AND CONTROL**

1. **University/Department**

   Eindhoven University of Technology
   Department of Mechanical Engineering

2. **Subprogrammes related to research school EM**

   2.1 Non-linear Dynamics of Mechanical Systems
   2.2 Structural Acoustics and Noise Control, Optimization
   2.3 Vehicle dynamics, tire dynamics and control
   2.4 Mechanical Design
   2.5

3. **Group directors**

   Prof.Dr. H. Nijmeijer

4. **Senior academic staff: name, position, research input in fte related to research school EM**

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Research Input</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Besselink, Dr.Ir. J.J.M.</td>
<td>Assistant Professor (0.4) main position at TNO-TPD</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Fey, Dr.Ir. R.H.B.</td>
<td>Assistant Professor</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Kraker, Dr.Ir. A. de</td>
<td>Associate Professor</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Lopez, Dr.Ir. I.</td>
<td>Assistant Professor</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Nijmeijer, Prof.Dr. H.</td>
<td>Full Professor</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Rosielle, Dr.Ir. P.C.J.N.</td>
<td>Associate Professor</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Roozen, Prof.Dr.Ir. N.B.</td>
<td>Part-time Prof. (0.2) main position at Philips</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Wouw, Dr.Ir. N. v.d.</td>
<td>Associate Professor</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

   **Total fte:**  1.9

5. **PhD-projects related to research school EM per December 2009:**

   **name, source of financing, project title and research theme EM**

5.1 **Nonlinear Dynamics of Mechanical Systems**

<table>
<thead>
<tr>
<th>Name</th>
<th>Degree</th>
<th>Source of Financing</th>
<th>Project Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mestrom, Ir. R.M.C.</td>
<td>(PhD 1)</td>
<td></td>
<td>Dynamics of multi physics systems</td>
</tr>
<tr>
<td>Steur, Ir. E.</td>
<td>(PhD 1)</td>
<td></td>
<td>Network Synchronization</td>
</tr>
</tbody>
</table>

5.2 **Structural Acoustics and Noise Control**

<table>
<thead>
<tr>
<th>Name</th>
<th>Degree</th>
<th>Source of Financing</th>
<th>Project Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debiesme, M.Sc. F.X.</td>
<td>(PhD 3)</td>
<td></td>
<td>Design tools for low noise products with uncertain parameters</td>
</tr>
</tbody>
</table>

5.3 **Vehicle dynamics, tire dynamics and control**

<table>
<thead>
<tr>
<th>Name</th>
<th>Degree</th>
<th>Source of Financing</th>
<th>Project Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steen, R. v.d.</td>
<td>(PhD 3)</td>
<td></td>
<td>FEM Tyre Modelling</td>
</tr>
</tbody>
</table>
5.4 Mechanical Design and Vision
Hendrix, Ir. R. (PhD 3) Eye Rhas StDy
Pieters, Ir. R.S. (PhD 3) High-performance Visual Servoing for micrometer positioning StDy
Zhenyu, Ir. Ye, (PhD 3) Embedded Vision Architecture (EVA) StDy

6. Postdocs: name, country, project title, subprogramme, research theme EM and period of stay
Dr.Ir. R.M.C. Mestrom November 2009 - (StDy)

7. Short description of sub programmes related to research school EM
7.1 Non-linear dynamics of mechanical systems
The numerical and experimental study of non-linear and in particular non-smooth mechanical systems, such as systems with friction, impacts or other constraints are key activities in this sub-theme, and play an essential role in the modeling and analysis of advanced mechanical systems. The research on these phenomena is highly relevant in many engineering applications (friction in high-performance/high-precision systems, drill strings, high-speed milling, hybrid control systems etc.). Numerical aspects are notably difficult, but are becoming more and more feasible with increasing computer power.

Related to research theme “Structural Dynamics and Control”

7.2 (Structural) acoustics and noise control, optimization
This sub-theme deals with various structural vibrations and the associated sound radiation. The focus is on the one hand on numerical/computational tools for acoustic models, and on the other hand on the experimental validation of those tools. Subsequently, both passive and active means for acoustic noise suppression are investigated. Several mechanical applications are used as benchmark examples, particularly tire–road noise. The development of tools for optimization is essential in the dynamic behavior of mechanical constructions.

Related to research theme “Structural Dynamics and Control”

7.3 Vehicle dynamics, tire dynamics and control
Vehicle Energy Management Systems Topology Design
Research is done on energy management of the complete power train, including the design trade-offs for hybrid vehicles with an internal combustion engine and an electromotor. Advanced model-based optimisation methods, like dynamic programming, are used for the off-line generation of optimal trajectories for the variables that dictate the energy supply from the combustion engine and/or the electromotor. We started a new research project on a hybrid truck.

Vehicle Dynamics and Tyres
Since 2002, the group has been responsible for the research and teaching in vehicle dynamics. The research focuses on modeling, analysis and control of articulated vehicles, and modeling and analysis of vehicle tires. For the latter, extensive use is made of the flat plank tire tester. The tire research is linked to the tire–road noise research referred to above.
Mechanical Design and Vision
The mechanical design group Construction and Mechanism is jointly headed with Prof. Dr. Ir. M. Steinbuch (Control Systems Technology). Dr. ir. P. C. J. N. Rosielle leads the activities in the C&M lab., which at the moment comprises 7-8 PhD students and about 10 MSc students. Focal point in the lab is the Construction and Design of Advanced, Novel Mechanical Systems. A separate activity mostly directed by prof. dr. ir. P. P. Jonker (part-time professor at the TU/e) deals with Vision in advanced mechatronic systems. Two PhD students and a number of MSc students work in this field.

Systems Design Optimization
Optimization methods to support systematic design and improvement of complex engineering systems are investigated. We concentrate on simulation-based design optimization in the context of manufacturing system and distribution center networks, manufacturing machines, automotive systems, and micro-mechanical systems. Optimization methods and tools are being developed that can deal with typical governing characteristics such as: one or more computationally expensive computer simulation models in the loop, a mix of continuous and discrete design variables, stochastic design variables and responses, and dynamic response behavior. The development of techniques for approximation, meta-modelling, and lumped-parameter modelling that can be utilized in the optimization plays a central role in our research work. Furthermore, methods for design optimization of multidisciplinary and multi-level decomposed systems have our special interest.

Control of Manufacturing Systems
In this subprogramme two main streams can be considered. The first stream considers a class of manufacturing systems that can be approximately modelled by means of a continuous time fluid or flow model. For this approximate model, standard techniques from control theory can often be used to design controllers. As the manufacturing system has a discrete-event nature, a connection between the discrete event plant and the continuous time controller has to be developed. Continuous time signals have to be converted to discrete-events and measurements of discrete states need to be filtered for a better control performance. Currently available flow models often ignore variability, whereas queuing theory often considers only steady state behavior. For that purpose new (mathematical) models need to be developed that include both variability and dynamics. It is clear that preferably these models should be suited for applying standard control theory in order to control these systems. The second stream considers the control of a network of servers through which many types of jobs flow, where it is assumed that servers require a setup time when switching between types. Such networks can be used to model complex communication, traffic or manufacturing systems.

Nonlinear and hybrid dynamics
In this subprogram two main directions can be considered. First, general questions of nonlinear dynamics and control of mechanical systems including switched (hybrid) systems are studied. In recent years hybrid systems attracted a considerable attention due to possible applications in various fields of science and technology. The theory of
hybrid systems is far from its completeness. Therefore it is of interest to further develop methods of analysis and design for such systems. In this research particular attention is drawn to the following two questions: analysis of oscillations in hybrid systems and formalization of some mathematical models of hybrid systems using the formal languages approach. The formal language used is Chi developed in the Systems Engineering group.

The second direction of the research is to study applications for the theoretical results in the framework of systems engineering. Nowadays complex manufacturing machines contain discrete-event and continuous-time parts with interactions between the components. These interactions can result in nonlinear dynamical phenomena that should be taken into account during design and real-time control of the machine. This research theme has a strong relation with the topic Embedded Systems (within the Institute for Programming and Algorithmic).

Related to research theme “Structural Dynamics and Control”

8. **Refereed scientific publications related to research school EM**

8.1 **Refereed journals**


systems with backlash, Chaos, Solitons and Fractals, 41(1), 131-144


8.2 Books, chapters in book
- Book chapter
- 

8.3 Refereed proceedings


Pieters, RS, Jonker, PP, & Nijmeijer, H (2009). Real-time centre detection of an OLED structure, in ACIVS; Bordeaux, France, 9


Steur, E, Tyukin, I & Nijmeijer(2009). H Semi-passivity and synchronization of neuronal oscillators, in CHAOS 09; Editors: H. Huijbers, London, United Kingdom, 6

9. **Dissertations: related to research school EM: name, title, university, date and advisors**

Name: F.X. Debiesme  
Title: Averaged Velocity Boundary Element Method for Sound Radiation from Vibrating Structures  
Advisor: Prof.dr.ir. J.W. Verheij, Prof.dr. H. Nijmeijer  
Co-advisor: Dr. ir. R.H.B. Fey  
Date: May 14, 2009  
Current position: Researcher at ASML, Veldhoven

Name: R.M.C. Mestrom  
Title: Multiphysics modelling and experimental validation of microelectromechanical resonator dynamics  
Advisor: Prof.dr. H. Nijmeijer  
Co-advisor: Dr.ir. R.H.B. Fey  
Date: November 12, 2009  
Current position: Postdoc at Department Electrical Engineering, TU/e

10. **Keynote lectures and seminars**

Prof.Dr. H. Nijmeijer:
- The electronic brain: does it synchronize? University of Amsterdam, Mathematics Department 28-10-2009
- Convergency and regulation, 7th Workshop on Advanced Control and Diagnosis, Zielona Gora, Poland, 19-21 November 2009
- Coordination in Mechanical Systems, Mexican Automatic Control Conference, Zacatecas, 30 September – 2 October 2009.

11. **Memberships**

11.1 Editorial boards international journals
Prof. Dr. H. Nijmeijer:
- Editor in Chief Journal of Applied Mathematics
- Associate editor AUTOMATICA
- Corresponding editor SIAM J Control Optimization
- Subject editor International J. of Robust and Nonlinear Control
- Member Editorial Board J. of Applied Mathematics Computer Science
- Member Editorial Board J. of Dynamical Control Systems
- Member Editorial Board International J. of Control
- Member Editorial Board J. of Stability and Control
- Member Editorial Board European Journal of Control
- Member Editorial Board International Journal of Bifurcation en Chaos

11.2 International scientific committees

Prof. Dr. H. Nijmeijer:
- Board International Physics and Control Society (IPACS)

11.3 National Science Foundation and Academies

Prof. Dr. H. Nijmeijer:
- Board Member Dutch Institute of Systems and Control (DISC)

Prof. Dr. Ir. N.B. Roozen:
- President of the Acoustical Society of the Netherlands (NAG)
- Director of the International Institute of Acoustics and Vibration (IIAV).

12. Awards, patents and NWO grants

Patents:

13. Overview of research input and output

13.1 Input “Systems, Dynamics and Control” related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing 1)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>8</td>
</tr>
<tr>
<td>Supporting staff 2)</td>
<td>8</td>
</tr>
<tr>
<td>PhD 3)</td>
<td>5</td>
</tr>
<tr>
<td>Postdocs</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University  
2: STW, NWO, FOM  
3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte
13.2 Output “Systems, Dynamics and Control” related to EM, 2009

<table>
<thead>
<tr>
<th>Type of Publication</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
<td>12</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>-</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>11</td>
</tr>
<tr>
<td>PhD theses</td>
<td>2</td>
</tr>
</tbody>
</table>

* In cooperation with other EM-groups.
2. RESEARCH DOCUMENTATION OF THE GROUP SYSTEMS ENGINEERING

1. University/Department

Eindhoven University of Technology
Department of Mechanical Engineering

2. Subprogrammes related to research school EM

2.6 Systems Design Optimization
2.7 Control of Manufacturing Systems
2.8 Nonlinear and Hybrid Dynamics
2.9

3. Group directors

Prof.dr.ir J.E. Rooda

4. Senior academic staff: name, position, research input in fte related to research school EM

Armbruster, Prof.dr. Part-time Professor 0.1
Etman, Dr.ir L.F.P. Assistant Professor 0.4
Lefeb, Dr.ir E. Assistant Professor 0.4
Pogromsky, Dr. A.Y. Assistant Professor 0.4
Rooda, Prof.dr.ir J.E. Full Professor 0.2

Total fte: 1.5

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

5.1 Systems Design Optimization
Andriansyah, Ir. R. (PhD 3) Aggregate modeling and optimization of automated distribution centers ReOp

5.2 Control of Manufacturing Systems

5.3 Nonlinear and Hybrid Dynamics
Ivanov, E. (PhD3) Pulse sequence optimization for MRI scanners StDy
Starkov, K (PhD3) Control of manufacturing networks StDy
6. Postdocs: name, country, project title, subprogramme, research theme EM and period of stay

<table>
<thead>
<tr>
<th>Name</th>
<th>Project Title</th>
<th>Subprogramme</th>
<th>Research Theme</th>
<th>Period</th>
</tr>
</thead>
</table>

7. Short description of sub programmes related to research school EM

7.1 Systems Design Optimization
Optimization methods to support systematic design and improvement of complex engineering systems are investigated. We concentrate on simulation-based design optimization in the context of manufacturing system and distribution center networks, manufacturing machines, and micro-mechanical systems. Optimization methods and tools are being developed that can deal with typical governing characteristics such as: one or more computationally expensive computer simulation models in the loop, a mix of continuous and discrete design variables, stochastic design variables and responses, and dynamic response behavior. The development of techniques for approximation, meta-modelling, and lumped-parameter modelling that can be utilized in the optimization plays a central role in our research work. Furthermore, methods for design optimization of multidisciplinary and multi-level decomposed systems have our special interest.

Related to research theme "Reliability and Optimization".

7.2 Control of Manufacturing Systems
In this subprogramme two main streams can be considered. The first stream considers a class of manufacturing systems that can be approximately modelled by means of a continuous time fluid or flow model. For this approximate model, standard techniques from control theory can often be used to design controllers. As the manufacturing system has a discrete-event nature, a connection between the discrete event plant and the continuous time controller has to be developed. Continuous time signals have to be converted to discrete-events and measurements of discrete states need to be filtered for a better control performance. Currently available flow models often ignore variability, whereas queuing theory often considers only steady state behavior. For that purpose new (mathematical) models need to be developed that include both variability and dynamics. It is clear that preferably these models should be suited for applying standard control theory in order to control these systems.

The second stream considers the control of a network of servers through which many types of jobs flow, where it is assumed that servers require a setup time when switching between types. Such networks can be used to model complex communication, traffic or manufacturing systems.

Related to research theme “Structural Dynamics and Control”

7.3 Nonlinear and hybrid dynamics
In this subprogram two main directions can be considered. First, general questions of nonlinear dynamics and control of mechanical systems including switched (hybrid) systems are studied. In recent years hybrid systems attracted a considerable attention due to possible applications in various fields of science and technology. The theory of hybrid systems is far from its completeness. Therefore it is of interest to further develop methods of analysis and design for such systems. In this research particular attention is drawn to the following two questions: analysis of oscillations in hybrid systems and formalization of some
mathematical models of hybrid systems using the formal languages approach. The formal language used is Chi developed in the Systems Engineering group. The second direction of the research is to study applications for the theoretical results in the framework of systems engineering. Nowadays complex manufacturing machines constitute of discrete-event and continuous-time parts with interactions between the components. These interactions can result in nonlinear dynamical phenomena that should be taken into account during design and real-time control of the machine. This research theme has a strong relation with the topic Embedded Systems (within the Institute for Programming and Algorithmic).

Related to research theme “Structural Dynamics and Control”

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


8.2 Books, chapters in book

Book chapter


8.3 Refereed proceedings

Etman, LFP, Groenwold, AA, Rooda, JE (2009). On diagonal QP problems for sequential approximate optimization, in 8th World Congress on Structural and Multidisciplinary Optimization; June 1-5, Lisbon, Portugal, CD-rom

Groenwold, AA, Etman, LFP (2009). Globally convergent SAO algorithms for large scale simulation-based optimization, in 8th World Congress on Structural and Multidisciplinary Optimization; June 1-5, Lisbon, Portugal, CD-rom

Ivanov, E, Pogromski, AY, Rooda, JE (2009). Scheduling with sequence dependent setup times in application to Magnetic Resonance Imaging scans processing, in Multi-conference on Systems and Control; St. Petersburg, Russian Federation, CD-ROM

Ivanov, E, Pogromski, AY, Rooda, JE (2009). Scheduling with dynamic constraints in application to Magnetic Resonance Imaging scans processing, in Multi-conference on Systems and Control; St. Petersburg, Russian Federation, CD-ROM


Pogromski, AY, Andrievsky, B, Rooda, JE (2009). Observer-based Production control of Manufacturing Machines, in 3th IFAC Symposium on Information Control Problems in Manufacturing (INCOM 2009); Moscow, Russian Federation, CD-ROM

Pogromski, AY, Andrievsky, B, Rooda, JE (2009). Aircraft flight control with anti-windup control strategy, in IFAC Workshop Aerospace guidance, navigation and flight control systems; Samara, Russian Federation, CD-ROM

Veeger, CPL, Etman, LFP, Herk, J van, Rooda, JE (2009). Predicting the mean cycle time as a function of throughput and product mix for cluster tool workstations using EPT-based aggregate modeling, in 20th Annual IEEE/SEMI Advanced Semiconductor Manufacturing Conference (ASMC 2009); Berlin, Germany, 80-85


9. Dissertations: related to research school EM: name, title, university, date and advisors

Name: M. Hendriks
Title: Multi-step optimization of logistic networks: strategic, tactical, and operational decisions
Advisors: J.T. Udding, J.E. Rooda
10. **Keynote lectures and seminars**

Prof. Dieter Armbruster:
- keynote speaker at the 2nd International Conference on Dynamics in Logistics (LDIC 2009) in Bremen, August 2009

11. **Memberships:**

11.1 Editorial boards international journals

Prof. Dr. Ir. J.E. Rooda:
- Member Editorial Board Advanced Manufacturing Technology

11.2 International scientific committees

Prof. dr. D. Armbruster:
- Co-organizer of the Sapporo Winter School: Networks of interacting machines, February 2009
- Member of the Organizing committee for SIAM conference on Mathematics for Industry, San Francisco, October 2009

Dr. Ir. L.F.P. Etman:
- Member of the scientific committee of the Advanced Semiconductor Manufacturing Conference 2009

Prof. Dr. Ir. J.E. Rooda:
- Member of the scientific committee of the Advanced Semiconductor Manufacturing Conference 2009

11.3 National Science Foundation and Academies

- 

12. **Awards, patents and NWO grants**

- 

13. **Overview of research input and output**

13.1 Input “Systems, Dynamics and Control” related to EM, 2009 (status 1\textsuperscript{st} December 2009)

<table>
<thead>
<tr>
<th>Sources of financing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>5</td>
</tr>
<tr>
<td>Supporting staff (2))</td>
<td>4</td>
</tr>
<tr>
<td>PhD (3))</td>
<td></td>
</tr>
<tr>
<td>Postdocs</td>
<td>1</td>
</tr>
<tr>
<td>----------</td>
<td>---</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

1) Sources of financing:  
1: University  
2: STW, NWO, FOM  
3: Industry, TNO, EC-funds, Nuffic, Senter, NIMR, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

13.2 Output “Systems, Dynamics and Control” related to EM, 2008

<table>
<thead>
<tr>
<th>Scientific publications: refereed journals</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>1</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>11</td>
</tr>
<tr>
<td>PhD theses</td>
<td>1</td>
</tr>
</tbody>
</table>

* In cooperation with other EM-groups.
3. RESEARCH DOCUMENTATION OF THE GROUP CONTROL SYSTEMS TECHNOLOGY

1. University/Department

Eindhoven University of Technology
Department of Mechanical Engineering

2. Subprogrammes related to research school EM

2.10 Vehicle power trains
2.11 Mechanical Design
2.12

3. Group directors

Prof. Dr. Ir. M. Steinbuch

4. Senior academic staff: name, position, research input in fte related to research school EM

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Research Input in fte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hofman, Dr. Ir. T.</td>
<td>Assistant Professor</td>
<td>0.4</td>
</tr>
<tr>
<td>Nuij, Dr. Ir. P.W.J.M.</td>
<td>Assistant Professor</td>
<td>0.2</td>
</tr>
<tr>
<td>Rosielle, Dr. Ir. P.C.J.N.</td>
<td>Associate Professor</td>
<td>0.2</td>
</tr>
<tr>
<td>Steinbuch, Prof. Dr. Ir. M.</td>
<td>Full Professor</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Total fte: 0.9

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

5.1 Vehicle power trains

<table>
<thead>
<tr>
<th>Name</th>
<th>Source of Financing</th>
<th>Project Title</th>
<th>Research Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aladagli, I., MSc</td>
<td>StDy</td>
<td>CVT</td>
<td>StDy</td>
</tr>
<tr>
<td>Keulen, Ir. T.A.C. van</td>
<td>StDy</td>
<td>Energy Management Hybrid trucks</td>
<td>StDy</td>
</tr>
<tr>
<td>Berkel, Ir. K. van</td>
<td>StDy</td>
<td>Hybrid powertrains</td>
<td>StDy</td>
</tr>
<tr>
<td>Ngo, D.V, MSc</td>
<td>StDy</td>
<td>Hybrid powertrains</td>
<td>StDy</td>
</tr>
</tbody>
</table>

5.2 Mechanical Design

<table>
<thead>
<tr>
<th>Name</th>
<th>Source of Financing</th>
<th>Project Title</th>
<th>Research Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedem, Ir. L.J.M. v.d.</td>
<td>StDy</td>
<td>Medical Robotics</td>
<td>StDy</td>
</tr>
<tr>
<td>Cau, Ir. R.</td>
<td>StDy</td>
<td>Medical Robotics</td>
<td>StDy</td>
</tr>
<tr>
<td>Meenink, Ir. H.C.M.</td>
<td>StDy</td>
<td>Eye Rhas</td>
<td>StDy</td>
</tr>
<tr>
<td>Naaijens, Ir. G.P.</td>
<td>StDy</td>
<td>Smart Optics</td>
<td>StDy</td>
</tr>
<tr>
<td>Ravensberger, Ir. S.</td>
<td>StDy</td>
<td>Adaptive Optics</td>
<td>StDy</td>
</tr>
<tr>
<td>Werner, Ir. C.</td>
<td>StDy</td>
<td>Large stroke AFM</td>
<td>StDy</td>
</tr>
</tbody>
</table>
6. **Postdocs: name, country, project title, subprogramme, research theme EM and period of stay**

7. **Short description of sub programmes related to research school EM**

7.1 **Vehicle power trains**
Vehicle Energy Management Systems Topology Design
Research is done on energy management of the complete power train, including the design trade-offs for hybrid vehicles with an internal combustion engine and an electromotor. Advanced model-based optimisation methods, like dynamic programming, are used for the off-line generation of optimal trajectories for the variables that dictate the energy supply from the combustion engine and/or the electromotor. We started a new research project on a hybrid truck.

Related to research theme “Structural Dynamics and Control”

7.2 **Mechanical Design**
The mechanical design section within the CST group is involved in various PhD projects on precision instrumentation, such as minimal invasive medical robotics: eye surgical slave-robot, slave for Laparoscopic and Endoscopic Surgery, and a robot for plastic reconstructive surgery. In metrology we have metrological AFM for NMI, and on adaptive optics and smart optics.

Related to research theme “Structural Dynamics and Control”

8. **Refereed scientific publications related to research school EM**

8.1 **Refereed journals**


Ravensbergen, SK, Rosielle, PCJN & Steinbuch, M (2009). Improving Maneuverability and Tactile Feedback in Medical Catheters, by Optimizing the Valve Towards Minimal Friction, J. of Medical Devices, 3(1), 011003

8.2 Books, chapters in book

8.3 Refereed proceedings


Bedem, LJM van den, Groen, JC, Rosielle, PCJN & Steinbuch, M (2009). Design of a Slave Robot for Minimally Invasive Surgery, in Proceedings of the 21st International Conference of Society for Medical Innovation and Technology; Sinaia, Romania, 52


Henselmans, R, Cacace, LA, Kramer, GFIJ, Rosielle, PCJN & Steinbuch, M (2009). Development and performance demonstration of the NANOMEFOS non-contact measurement machine for freeform optics, in Euspen Annual meeting 2009; San Sebastian, Spain, 164-168

Henselmans, R, Cacace, LA, Kramer, GFIJ, Rosielle, PCJN & Steinbuch, M (2009). Freeform optics measurements with the NANOMEFOS non-contact measurement machine, in SPIE Optifab 2009; Rochester, NY, United States


Ravensbergen, SK, Hamelinck, RFMM, Rosielle, PCJN, & Steinbuch, M (2009). Deformable mirrors: design fundamentals for force actuation of continuous facesheets, in SPIE Optics & Photonics 2009; Advanced Wavefront Control: Methods, Devices, and Applications VII; Editors: Richard A. Carreras; Troy A. Rhoadarmer; David C. Dayton, San Diego, United States, 74660G-8

Slob, JJ, Kuijpers, MRL, Rosielle, PCJN & Steinbuch, M (2009). A new approach to extended linear motion technology: the wall is the limit, in Driving Simulation Conference 2009; Editors: Monaco, Monaco, 6p

Werner, C, Rosielle, PCJN & Steinbuch, M (2009). Design and realization of a long-stroke translation stage for SPM, in Euspen 2009; San Sebastian, Spain, 4

9. **Dissertations: related to research school EM: name, title, university, date and advisors**

   Name: R. Henselmans  
   Title: Non-contact Measurement Machine for Freeform Optics  
   PhD. Thesis, 2 april 2009, TU/e  
   Advisors: M. Steinbuch  
   Co-advisors: P.C.J.N. Rosielle

   Name: L. Cacace  
   Title: An Optical Distance Sensor - Tilt Robust Differential Confocal Measurement with MM Range and NM Uncertainty, PhD. Thesis, 1 december 2009, TU/e  
   Advisors: Prof.dr.ir. M. Steinbuch,  
   Co-advisors: Dr.ir. P.C.J.N. Rosielle

10. **Keynote lectures and seminars**

11. **Memberships:**

11.1 **Editorial boards international journals**
Prof. Dr. Ir. M. Steinbuch:
Editor-in-Chief of Mechatronics

Dr. ir. T. Hofman:
Associate Editor of the Int. J. of Hybrid and Electric Vehicles (IJEHV).

11.2 International scientific committees

Prof. Dr. Ir. M. Steinbuch:
Member of various IPCs

Dr. ir. T. Hofman:
International Program Committee member of the IEEE Vehicle, Propulsion and Power Conference (VPPC).

11.3 National Science Foundation and Academies

- 

12. Awards, patents and NWO grants

- 

13. Overview of research input and output

13.1 Input “Control Systems Technology” related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing 1)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>4</td>
</tr>
<tr>
<td>Supporting staff 1)</td>
<td></td>
</tr>
<tr>
<td>PhD 2)</td>
<td>2</td>
</tr>
<tr>
<td>Postdocs</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University
2: STW, NWO, FOM
3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.
3) Research input for PhD per year: 0.8 fte

13.2 Output “Control Systems Technology” related to EM, 2009

<table>
<thead>
<tr>
<th>Source</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
<td>8</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>0</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>15</td>
</tr>
<tr>
<td>PhD theses</td>
<td>2</td>
</tr>
</tbody>
</table>
4. RESEARCH DOCUMENTATION OF THE GROUP MATERIALS TECHNOLOGY

1. University/Department

Eindhoven University of Technology
Department of Mechanical Engineering
Department of Biomedical Engineering

2. Subprogrammes related to research school EM

2.1 Multi-scale Mechanics & Structure-Property Modelling
2.2 Microscopic Aspects of Deformation
2.3 Micromechanics of Functional Devices
2.4 Damage, Fracture and Reliability
2.5 Manufacturing and Injury Biomechanics
2.6 Swelling Mechanics
2.7 New Processes and Devices for Micro- and Nano- Scales

3. Group directors

Prof.dr. A.H. Dietzel
Prof.dr.ir. M.G.D. Geers

4. Senior academic staff: name, position, research input in fte related to research school EM

Bellouard, Dr. Y. Assistant Professor 0.1
Brekelmans, Dr.ir. W.A.M. Associate Professor 0.4
Dietzel, Prof.dr. A.H. Part time Professor 0.1
Dommelen, Dr.ir. J.A.W. Assistant Professor 0.4
Geers, Prof.Dr.ir. M.G.D. Full Professor 0.4
Hoefnagels, Dr.ir. J.P.M. Assistant Professor 0.4
Huyghe, Dr.ir. J.M.R.J. Associate Professor 0.4
Homburg, Ir. F.G.A. Assistant Professor 0.2
Kouznetsova, Dr.ir. V.G. Assistant Professor 0.4
Peerlings, Dr.ir. R.H.J. Associate Professor 0.4

Total fte: 3.2
5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

5.1 Structure-Property Relations and Constitutive Modelling
Beex, Ir. L.A.A. (PhD 2) Multiscale mechanics of fibrous networks CoEM

5.2 Microscopic Aspects of Deformation
Poh, M.Sc. L.H. (PhD 1) Gradient enhanced plastic and damage constitutive models CoEM
Yalcinkaya M.Sc. T. (PhD 3) Strain path dependent material models for forming and crash CoEM

5.3 Micromechanics of Functional Devices
Bergers, Ir. L.I.J.C. (PhD 2) Size-effects in creep and fatigue in metallic MEMS CoEM
Ertürk, M.Sc. I. (PhD 2) Mechanics of dynamically loaded free-standing thin films CoEM
Kolluri, M.Sc. M. (PhD 3) Characterisation and prediction of interface delamination in integrated microsystems CoEM
Neggers, Ir. J. (PhD 2) Novel routes towards interfacial integrity in stretchable electronics CoEM
Samimi, M.Sc. M. (PhD 2) Numerical characterisation of delamination in integrated microsystems CoEM

5.4 Damage, Fracture and Reliability
Coenen, Ir. E.W.C. (PhD 3) Forming the limits of damage predictions. Microscopic-numerical part CoEM
Javani Joni, M.Sc. H. (PhD 3) Forming the limits of damage predictions. Macroscopic-numerical part CoEM
Pina, M.Sc. J.C. (PhD 3) Thermo-mechanical fatigue of cylinder heads CoEM
Tasan, M.Sc. C. (PhD 3) Forming the limits of damage prediction CoEM

5.5 Manufacturing and Injury Biomechanics
Cloots, Ir. R. (PhD 1) Multi-scale mechanics of traumatic brain injury CoEM

5.6 Swelling Mechanics
Pizzocolo, M.Sc. F. (PhD 2) Multiscale numerical modelling of crack propagation in poroelastic media CoEM
Mojra, M.Sc.A., (PhD 3) Modelling of tissue integrity of the intervertebral disc CoEM

5.7 New Processes and Devices for Micro- and Nano-Scales
Boustheen, Ir. A. (PhD 3) Plastic MEMS CoEM
Karade, M.Sc. Y. (PhD 3) Ion beam induced structuring on polymers & alloys CoEM
6. **Postdocs: name, country, project title, subprogramme, research theme EM and period of stay**

<table>
<thead>
<tr>
<th>Name</th>
<th>Project Title</th>
<th>Subprogramme</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y. Schroeder</td>
<td>In silico design of a nucleus replacement</td>
<td>CoEM</td>
<td>October 2009 – October 2010</td>
</tr>
<tr>
<td>F. Kraaijeveld</td>
<td>Hydraulic Fracture in tar sands</td>
<td>CoEM</td>
<td>January 2009 – March 2009</td>
</tr>
<tr>
<td>F. Madani-Grasset</td>
<td>Bio-inspired assembly of meso-scale components</td>
<td>CoEM</td>
<td>January 2007 – March 2010</td>
</tr>
<tr>
<td>M. Matteucci</td>
<td>Sensing and diagnostics on a chip</td>
<td>CoEM</td>
<td>May 2008 – May 2010</td>
</tr>
</tbody>
</table>

7. **Short description of subprogrammes related to research school EM**

7.1 *Multi-scale Mechanics & Structure-Property Modelling*
This research topic focuses on the mechanical behaviour of solids, with particular emphasis on (1) multi-scale aspects; (2) micromechanical aspects, involving a major influence of the microstructural morphology. Typical topics addressed are single- and poly-crystalline structures, dislocation networks in metals, structured single crystal alloys (turbine blades), structured ceramics, complex structured polymer-metal geometries (flexible displays), (semi-) crystalline polymers with various inclusions, and fibrous materials such as paper(board). The ultimate goal is to arrive at multi-scale solution schemes and physically based constitutive descriptions which can be numerically implemented, enabling an accurate analysis of engineering products or product manufacturing processes.

7.2 *Microscopic Aspects of Deformation*
This research topic aims to provide a sound experimental basis for the computational efforts in the group, through a range of specific set-ups spanning a hierarchy of interacting length scales. Research topics are mainly concerned with the analysis of microscopic aspects of deformation and adhesion at interfaces (e.g. polymer-metal interfaces), of multi-phase materials (e.g. micro-electronics solders), multi-layered structures (e.g. flexible displays), microsystems etc.

7.3 *Micromechanics of Functional Devices*
This research topic focuses on the micromechanics of devices on miniaturization. In miniaturized products, materials cannot be trivially considered as continua. Furthermore, boundary, surface and interface effects play a dominant role. Changes in deformation mechanisms and failure processes directly influence the lifetime of functional devices. Both numerical and experimental tools and techniques are being developed for the analysis of these phenomena and their influence on the performance of microsystems.

7.4 *Damage, Fracture and Reliability*
This research topic focuses on mechanical failure as an important design criterion for metallic products and components. Both prevention and control of damage are thereby relevant. The correct prediction of this ultimate behaviour presents many challenges of both a numerical and an experimental nature. Non-standard continuum theories are required to deal with intense
localization phenomena. The transition to discrete failure and the coupling with the underlying microstructure in a multi-scale setting is another goal pursued here.

7.5 **Manufacturing and Injury Biomechanics**
This partly more application-oriented research topic constitutes the group's link with the Manufacturing and Automotive Engineering Science activities in the Department. In the past period, it has focused mainly on optimal forming processes and passive safety research for automotive applications, i.e. prevention of injuries caused by accidents. The focus for the coming period is the development and use of high-performance materials in manufacturing and automotive applications and multi-scale injury mechanics.

7.6 **Swelling Mechanics**
The mechanics of swelling materials comprises applications in the geotechnical as well as the biomedical areas. Clays, shales, intervertebral disc, cartilage, hydrogels and living cells are a few examples. Mechanical deformations are inevitably coupled to fluid and ion diffusion-convection and to electrical potential gradients and currents in these media. Crack propagation and mechano-transduction are important themes of research.

7.7 **New Processes and Devices for Micro- and Nano- Scales**
The group research activities are currently clustered in the following activities:

Nano-patterning using Charged Particle Beams. In contrast to lithographic nano-structuring techniques using a resist as a pattern transfer medium, a direct modification of thin film materials through particle irradiation can be used. Such a process can lead to unique material properties and surface qualities. Charged particles can either to form small probe beams to be scanned over a surface or broad beam passing a stencil mask before being projected on a surface. The local beam modulation leads to nano-patterns by local conversion of material properties.

Micro- & Nano- technologies for bioapplications. In future molecular diagnostics very small quantities of specific biomolecules shall be detected in microliter volumes. In a bead based approach such biomolecules shall undergo a specific binding to nanobeads that can subsequently be detected. Efficient interactions between beads and the fluid can be forced by bead movement induced by magnetic fields or acoustic excitation. Functionalities like mixing of reagents and controlled flow/convection are investigated.

Polymer-based micro-devices. Microsystems are traditionally based on silicon technology. Some applications as micro fluidic devices and sensors benefit from the cheap mass production technologies for polymers (micro molding, embossing etc.). Special interest is paid to the design of actuator components which benefit from the possibility of massive parallel operation. This research encounters both the design aspect of the polymer devices and the required fabrication processes.

Micro-robotics. This research activity deals with the conception and design of systems and tools for manipulating, positioning and interacting with sub-millimeter size components and parts. It is a highly multidisciplinary discipline that benefits from new development in robotics, material science and micro-fabrication techniques. Our research is currently focused on the development of actuators and sensors for the micro- and nano-scale based on smart materials and on monolithic integration in various substrate.

System Integration at the Micro- and Nano- Scale. Scaling effect raises numerous issues for micro-system design: it not only implies the development of novel micro- / nano- fabrication techniques
but also requires new design strategies and means to successfully integrate sub-components that constitute the system. Our approach is based on monolithic integration. Multiple functionalities are introduced by locally tailoring material properties. For instance, in glass substrate, we use femtosecond lasers to locally increase the refractive index and the chemical selectivity which allow us to introduce both structural function like flexures or fluidic channels together with integrated optics.

Laser assisted carbon nanotube growth. Carbon nanotubes have high potential due to their outstanding electrical, thermal and mechanical properties. For synthesizing the carbon nanotubes a laser based chemical vapor deposition method is used. An advantage of this approach is a high flexibility of the process. The position of the carbon nanotube growth can be chosen and temperature sensitive materials can be used as well, since it is not necessary to heat the whole device. Our research is mainly focused on integrating the carbon nanotubes in flexible electronics as interconnects.

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


Boers, SHA, Geers, MGD & Kouznetsova, V (2009). Contactless and frictionless pure bending: principles, equipment and experimental opportunities, Experimental Mechanics, Published online


Derks, RJS, Frijns, AH, Prins, MWJ & Dietzel, A (2009). Multibody interactions of actuated magnetic particles used as fluid drivers in microchannels, Microfluidics and Nanofluidics,


Kolluri, M, Thissen, MHL, Hoefnagels, JPM, Dommelen JAW van & Geers MGD (2009). In-situ characterization of interface delamination by a new miniature of interface delamination by a new miniature mixed mode bending setup, Int. J. Fracture, 158(2), 183-195


Tasan, CC, Hoefnagels, JPM, Horn, CHLJ ten & Geers, MGD (2009), Experimental analysis of strain path dependent ductile damage mechanics and forming limits, Mech. Mat., 41(11), 1264-1276,


8.2 Books, chapters in book

ISBN 10: 142006195X


8.3 Refereed proceedings


Hoefnagels, JPM, Tasan, CC & Geers, MGD (2009). Direct damage quantification techniques - comparative study, in Proceedings of the SEM annual conference; Editors: TW Prouls, Albuquerque, United States, on cd-rom


Javani Joni, HR, Peerlings, RHJ & Geers, MGD (2009). Non-local ductile damage implementation using three field low order tetrahedral element, in Proceedings of the 12th International Conference on Fracture; Ottawa, Canada, on cd-rom


Peerlings, RHJ, Kleijne, ED, Veenendaal, E van & Bouten PCP (2009). On the mechanics of buckling-delamination in compliant laminates, in Proceedings of the 12th International Conference on Fracture; Ottawa, Canada, on cd-rom


51
9. **Dissertations related to research school EM: name, title, university, date and advisors**

<table>
<thead>
<tr>
<th>Name</th>
<th>T. Tinga</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Multi-scale modelling of single crystal superalloys for gas turbine blades</td>
</tr>
<tr>
<td>Advisor</td>
<td>Prof.dr.ir. M.G.D. Geers</td>
</tr>
<tr>
<td>Co-Advisor</td>
<td>Dr.ir. W.A.M. Brekelmans</td>
</tr>
<tr>
<td>Date</td>
<td>May 7, 2009</td>
</tr>
<tr>
<td>Current position</td>
<td>Researcher at NLDA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>I. Özdemir</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Multi-scale modelling of thermal shock damage in refractory materials</td>
</tr>
<tr>
<td>Advisor</td>
<td>Prof.dr.ir. M.G.D. Geers</td>
</tr>
<tr>
<td>Co-Advisor</td>
<td>Dr.ir. W.A.M. Brekelmans</td>
</tr>
<tr>
<td>Date</td>
<td>July 2, 2009</td>
</tr>
<tr>
<td>Current position</td>
<td>Staff Researcher at Atilim University, Ankara, Turkey</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>F. Kraaijeveld</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>Propagation discontinuities in ionized porous media</td>
</tr>
<tr>
<td>Advisor</td>
<td>Prof.dr.ir. F.P.T. Baaijens</td>
</tr>
<tr>
<td>Co-Advisor</td>
<td>Dr.ir. J.M. Huyghe</td>
</tr>
<tr>
<td>Date</td>
<td>October 6th 2009</td>
</tr>
<tr>
<td>Current position</td>
<td>Associate Researcher Geomechanics</td>
</tr>
</tbody>
</table>

10. **Keynote lectures and seminars**

Prof.dr.ir. M.G.D. Geers

Multi-scale mechanics of material interfaces: delamination, cracking, buckling and hardening, Invited seminar, Politecnico di Milano, Italy, 23 April 2009.

Dr.ir. J.A.W. van Dommelen


Dr.ir. J.PM. Hoefnagels


Dr.ir. V.G. Kouznetsova

Multiscale computational homogenization for non-linear and evolving heterogeneous solids, International Workshop on Computational Multiscale Methods, University of Twente, Netherlands, 2009

Upscaling techniques for evolving microstructures, International Workshop ‘Scale transitions in space and time for materials’, Lorentz Center, Leiden, Netherlands, 2009

Computational homogenization for non-linear heterogeneous solids, Invited seminar at RWTH Aachen University, Germany, 2009

Multiscale computational homogenization for bridging microscale damage and macroscale failure, 1st International Conference on Material Modelling ICMM, Dortmund, Germany, 2009


Computational homogenization for heterogeneous shells. 80th Annual Meeting of the International Association of Applied Mathematics and Mechanics (GAMM), Gdansk, Poland, 2009

Dr.ir. R.H.J. Peerlings


Homogenisation of dislocation interactions towards a mesoscopic plasticity framework, invited presentation, 1st International Conference on Material Modelling Dortmund, Germany, 15 March 2009

Mesoscopic modelling of thin film plasticity using an implicit gradient formulation, invited presentation, ASME International Mechanical Engineering Congress and Exposition Lake Buena Vista, Florida, USA, 18 November 2009

Dr.ir. J.M.R.J. Huyghe


Plenary lecture: Symétrie des relations constitutives des milieux poreux biologiques
11. **Memberships**

11.1 **Editorial boards international journals**

Prof.dr.ir. M.G.D. Geers
- Associate editor of the *ASME Journal of Applied Mechanics*
- Editorial Board of *Computational Mechanics*
- Editorial Board of the International Journal of Multiscale Computational Engineering
- Editorial Board of the *International Journal of Multiscale Modelling and Computation* (Imperial College Press)
- Editorial Board of the *ASCE Journal of Nanomechanics and Micromechanics*
- Editorial Board of the International Journal of Automotive and Mechanical Engineering

Dr.ir. J.M. Huyghe
- ASME Journal of Biomechanical Engineering
- *Biorheology*
- Transport in Porous Media

11.2 **International scientific committees**

Prof.dr.ir. M.G.D. Geers:
- Chairman of the EUROMECH Mechanics of Materials Conference Committee (EMMCC)
- Member of the Scientific Committee of ESAFORM
- Member of the Technical Committee of EuroSimE
- Member of the GAMM research committee on Multiscale Material Modelling
- Member of the Scientific Advisory Board of the Belgian IAP Physics based multilevel mechanics of metals
- Member of the assessment committee of Mechanics of the Ecole Polytechnique, Paris, France
- Member Scientific Committee of 18th International Conference on Computer Methods in Mechanics, Zielona Góra, Poland, 18-21 May 2009.
- Member Scientific Committee THERMEC, Sixth International Conference on Processing & Manufacturing of Advanced Materials, Berlin, Germany, 25-29 August 2009.

11.3 **National Science Foundation, Academies**

Prof.Dr.Ir. M.G.D. Geers
- Member of the Board of Governors of FOM (Foundation for Fundamental Research on Matter)
- Member NWO Theme Group Complexity

12. **Awards, patents and NWO grants**
13. Overview of research input and output

13.1 Input “Materials Technology” related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>9</td>
</tr>
<tr>
<td>Supporting staff</td>
<td>2</td>
</tr>
<tr>
<td>PhD</td>
<td>2</td>
</tr>
<tr>
<td>Postdocs</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
</tr>
</tbody>
</table>

1) Sources of financing:
   1: University
   2: STW, NWO, FOM
   3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

13.2 Output “Materials Technology” related to EM, 2009

<table>
<thead>
<tr>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Scientific publications: refereed journals</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
</tr>
<tr>
<td>PhD theses</td>
</tr>
</tbody>
</table>

* In co-operation with other EM-groups.
5. DOCUMENTATION OF THE GROUP NUMERICAL METHODS IN ENGINEERING

1. University/Department

Eindhoven University of Technology
Department of Mechanical Engineering

2. Sub programmes related to research school EM

2.1 Evolving Discontinuities
2.2 Computational Multiscale Methods
2.3 Computational Multiphysics

3. Group director

Prof.dr.ir. R. de Borst

4. Senior academic staff: name, position, research input in fte related to research school EM

Borst, Prof.dr.ir. R. de  
Full Professor  
0.2

Campen, Prof.dr.ir. D.H. van  
Emeritus Professor  
0.1

Remmers, Dr.ir. J.J.C.  
Assistant Professor  
0.4

Total fte: 0.7

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

Irzal, Ir. F.  
(PhD 2)  
Multiscale Computational Poromechanics  
CoEM

Opstal, Ir. T.M. van  
(PhD 2)  
Adaptive Multiscale Methods  
CoEM

6. Postdocs: name, country, project title, research theme EM and period of stay

Zee, K.G. van der  
Goal-Adaptive Discretization of Fluid-Structure Interaction  
CoEM

The Netherlands  
March – June 2009

7. Short description of subprogrammes related to research school EM

7.1 Evolving Discontinuities

Most physical phenomena are described by differential equations that hold on a finite domain. During the past half century computational physics has developed a host of numerical tools to
solve these differential equations, the finite element method being the most prominent. The equations that hold at (moving) interfaces between these domains cannot be solved equally well. Given the ongoing miniaturisation and the wish to understand and to predict the behaviour of materials and devices from more fundamental physical principles, the proper description and simulation of interface phenomena becomes increasingly important. A main thrust of the group is to contribute fundamentally to the development of novel computational techniques for capturing evolving discontinuities.

Related to the research theme “Computational and Experimental Mechanics”.

7.2 Computational Multiscale Methods

The response of physical systems at the level of practical interest, often called the macroscale, is to a large extent determined by processes that occur at scales which are one to several orders of a magnitude smaller: meso, micro and nanoscales. Two main approaches can be distinguished: (i) upscaling and downscaling, and (ii) computational multiscale methods. In the first category we have computational homogenisation and Reynolds Averaged Navier-Stokes methods as examples for solids and fluids, respectively. The group concentrates on the second approach, including those based on variational or projection concepts, either in solids, fluids, or in interaction problems. Related to the research theme “Computational and Experimental Mechanics”.

7.3 Computational Multiphysics

Increasingly, engineering is confronted with cases where different physical phenomena simultaneously play a role. Examples include durability problems, joining technologies (welding), and many problems in biomaterials. While the stable and efficient solution of the governing equations that describe these phenomena is already difficult, this holds a fortiori in the presence of discontinuities or interfaces. First, the physics of the transport processes in the interface/discontinuity must be captured properly. Secondly, the equations in the interface must be discretised in a manner that is consistent with the discretisation of the surrounding continuum, ensuring compatibility between the continuous and discrete parts. This, in itself, is again a multiscale problem. To keep computational times acceptable, algorithms are being developed that possess a high degree of efficiency.

Related to the research theme “Computational and Experimental Mechanics”.

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


8.2 Books, chapters in book


8.3 Refereed proceedings


Borst, R de, (2009) Computational Multi-Scale Methods and Evolving Discontinuities, in Computational Structural Engineering. In proceedings of the International Symposium on Computational Structural Engineering, held on June 22–24, Editors: Yong Yuan, Junzhi Cui and Herbert A. Mang, HA, Shanghai, China, 3-9


9. Dissertations: related to research school EM: name, title, university, date and advisors

Name: I. Akkerman
Title: Adaptive Variational Multiscale Formulations using the Discrete Germano Approach
Advisors: Prof.dr.ir. R. de Borst  
Date: 10 March 2009  
Current position: Post-doctoral researcher, University of California at San Diego

Name: T.S. Hille  
Title: Lifetime Modeling of Thermal Barrier Coatings  
Advisors: Prof.dr.ir. R. de Borst, dr. S.R. Turteltaub  
Date: 8 May 2009  
Current position: Siemens

Name: K.G. van der Zee  
Title: Goal-Adaptive Discretization of Fluid-Structure Interaction  
Advisors: Prof.dr.ir. R. de Borst, prof.dr.ir. E.H. van Brummelen  
Date: 5 June 2009  
Current position: Post-doctoral researcher, University of Texas at Austin

Name: J. Shi  
Title: Discrete Modelling of Plasticity and Martensitic Transformations  
Advisors: Prof.dr.ir. R. de Borst,  
Date: 4 September 2009

Name: C.V. Verhoosel  
Title: Multiscale and Probabilistic Modelling of Micro Electromechanical Systems  
Advisors: Prof.dr.ir. R. de Borst,  
Date: 12 October 2009  
Current position: Post-doctoral researcher, University of Texas at Austin & TU/e

10. Keynote lectures and seminars

R. de Borst:

- “Computational Methods for Evolving Discontinuities”, Plenary Lecture, 18th International Conference on Computer Methods in Mechanics, Zielona Gora, 18 – 21 May 2009
- “Computational Multi-Scale Methods and Evolving Discontinuities”, Plenary Lecture, Symposium on Computational Structural Engineering, Shanghai, 22 – 24 June 2009

11. Memberships

11.1 Editorial boards international journals

R. de Borst:

- Editor “Encyclopedia of Computational Mechanics”
- Editor “International Journal for Numerical Methods in Engineering”
- Editor “International Journal for Numerical and Analytical Methods in Geomechanics”
- Associate Editor “The Aeronautical Journal”
D.H. van Campen:
- Member Advisory Board Nonlinear Dynamics

11.2 International scientific committees

R. de Borst:
- Corresponding Member Executive Council International Association of Computational Mechanics (IACM)
- Member General Assembly International Union of Theoretical and Applied Mechanics (IUTAM)
- Member Scientific Council, Academic Assembly and Board of Directors of the International Centre for Mechanical Sciences (CISM)
- Member Euromech Solid Mechanics Conference Committee
- Member Physics and Engineering Sciences Research Council of the European Science Foundation (ESF)
- Member Scientific Committee 1st African Conference on Computational Mechanics (AfriComp'09), Sun City, 7 – 11 January 2009
- Member Scientific Committee 15th International Conference on Finite Elements in Flow Problems (FEF09), Tokyo, 1 – 3 April 2009
- Member Scientific Committee 18th International Conference on Computer Methods in Mechanics, Zielona Gora, 18 – 21 May 2009
• Member Scientific Committee Colloque National en Calcul des Structures, Giens, 25 – 29 May 2009
• Member Scientific Committee Symposium on Computational Structural Engineering, Shanghai, 22 – 24 June 2009
• Member Scientific Committee 10th US National Congress on Computational Mechanics, Columbus, Ohio, 16 – 19 July 2009
• Topic Organizer on Computational Mechanics 12th International Conference on Fracture, Ottawa, 12 – 17 July 2009
• Member Scientific Committee 10th International Conference on Computational Plasticity, 2 – 4 September 2009
• Member Scientific Committee ECCOMAS Thematic Conference From the Atom to the Part: Models and Computational Methods, Nantes, 21 – 23 October 2009

D.H. van Campen:
• Member-at-Large of IUTAM
• Member of IUTAM’s Congress Committee and of its Executive Committee
• Chairman EUROMECH Nonlinear Oscillation Conference Committee.
• Member Scientific Committee IUTAM Symposium on Emerging Trends in Rotor Dynamics, New Delhi, 23-26 March 2009
• Member Scientific Committee IUTAM Symposium on The Vibration Analysis of Structures with Uncertainties, St. Petersburg, 6-10 July 2009
• Member Managing Board of ECCOMAS

11.3 National Science Foundation and Academies

R. de Borst:
• Member Royal Netherlands Academy of Arts and Sciences (KNAW)
• Member Governing Council Dutch Technology Foundation

12. Awards and patents

13. Overview of research input and output


<table>
<thead>
<tr>
<th>Sources of financing 1)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>3</td>
</tr>
<tr>
<td>Supporting staff 2)</td>
<td></td>
</tr>
<tr>
<td>PhD 3)</td>
<td>2</td>
</tr>
<tr>
<td>Postdocs</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University  
2: STW, NWO, FOM  
3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

| Scientific publications: refereed journals       | 5 (3*) |
| Scientific publications: books, chapters in book | 1      |
| Scientific publications: refereed proceedings   | 7 (6*) |
| PhD Theses                                       | 5 (5*) |

* In co-operation with other EM-groups.
6. DOCUMENTATION OF THE GROUP ANALYSIS SCIENTIFIC COMPUTING AND APPLICATIONS (CASA)

1. University/Department

Eindhoven University of Technology
Department of Mathematics and Computer Science

2. Subprogrammes related to research school EM

2.1 Scientific Computing
2.2 Applied Analysis

3. Group directors

Prof.dr. R.M.M. Mattheij
Prof.dr. M.A. Peletier

4. Senior academic staff: name, position, research input in fte related to research school EM

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Research Input in FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hochstenbach, Dr. M.E.</td>
<td>Assistant Professor</td>
<td>0.2</td>
</tr>
<tr>
<td>Maten, Dr. E.J.W. ter</td>
<td>Assistant Professor, main position at Philips-Research</td>
<td>0.0</td>
</tr>
<tr>
<td>Mattheij, Prof.dr. R.M.M.</td>
<td>Full Professor</td>
<td>0.2</td>
</tr>
<tr>
<td>Maubach, Dr. J.M.L.</td>
<td>Assistant Professor</td>
<td>0.3</td>
</tr>
<tr>
<td>Morsche, Dr. H.G. ter</td>
<td>Associate Professor</td>
<td>0.1</td>
</tr>
<tr>
<td>Muntean, Dr. A.</td>
<td>Assistant Professor</td>
<td>0.2</td>
</tr>
<tr>
<td>Peletier, Prof.dr. M.A.</td>
<td>Full Professor</td>
<td>0.2</td>
</tr>
<tr>
<td>Schilders, Prof.dr. W.H.A.</td>
<td>Part time Professor, main position at Philips-Research</td>
<td>0.2</td>
</tr>
<tr>
<td>Tijsseling, Dr.ir. A.S.</td>
<td>Assistant Professor</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Total fte: 1.5

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

5.1 Scientific Computing and Applied Analysis

<table>
<thead>
<tr>
<th>Name</th>
<th>Source of Financing</th>
<th>Project Title</th>
<th>Research Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilievski, M.Sc. Z.</td>
<td>COMSON</td>
<td></td>
<td>CoMe</td>
</tr>
<tr>
<td>Kakuba, Ir. G.</td>
<td>(PhD 2)</td>
<td>Local Defect Correction</td>
<td>CoMe</td>
</tr>
<tr>
<td>Lutowska, M.Sc. A.</td>
<td>(PhD 2)</td>
<td>Model reduction</td>
<td>CoMe</td>
</tr>
<tr>
<td>Machyshyn, M.Sc. I.</td>
<td>(PhD 3)</td>
<td>Growth for Aneurysms</td>
<td>CoMe</td>
</tr>
<tr>
<td>Pisarenco, M.Sc. M.</td>
<td>(PhD 3)</td>
<td>FEM for diffraction problems</td>
<td>CoMe</td>
</tr>
<tr>
<td>Renger, M.Sc. M.</td>
<td>(PhD 1)</td>
<td>Fundaments of Non-equilibrium Thermodynamics</td>
<td>CoMe</td>
</tr>
<tr>
<td>Rudnaya, M.Sc. M.</td>
<td>(PhD 3)</td>
<td>CONDOR</td>
<td>CoMe</td>
</tr>
</tbody>
</table>
6. Postdocs: name, country, project title, research theme EM and period of stay

Harutyunyan, Dr. D. Operational model order reduction CoMe
February 2007 – February 2010

Savcenco, Dr. V. Simulation and state estimation of smart electricity CoMe
transmission networks July 2008 – July 2011

Hlod, Dr. A. RCWA Impact of model errors and numerical CoMe
approximations October 2009 - December 2010

Kho, Dipl.Ing. S.C. Derivative-free optimization for grating profile CoMe
reconstruction October 2009 – December 2010

7. Short description of subprogrammes related to research school EM

7.1 Scientific Computing
The main emphasis in this programme is on analysis and numerical simulation of problems arising in technology. Research is often induced by specific applications, yet being seen as part of a larger area where mathematical tools and in particular numerical methods can be applied. Hence both fundamental (numerical) research and applying the results to specific applications are typical for Scientific Computing. The following areas specify the actual research:

7.1.1 Glass Morphology
Analysis and simulation of the glass flow in (partially) confined areas, such as in mould for producing jars and bottles. Flows in a glass tank (oven). Investigating the heat transport by various phenomena, like diffusion and convection.
Co-operation in this research is with TNO-TPD ceramics and glass. The research is embedded in an EU project “MAGICAL” Furthermore there exists cooperation with the departments of Mechanical Engineering and Chemistry (TU/e).
Related to research themes “Computational Mechanics” and “Mechanics of Materials”.

7.1.2 Ordinary Differential Equations and DAE
Problems that exhibit an evolutionary character will result in ODE after spatial discretisation. Moreover problems in control and mechanics often lead to such equations more directly. Quite often they are coupled with some (algebraic) constraint equations, resulting in DAE. Matters like stability and accuracy of numerical methods still provide for important questions. Co-operation exists with the TU/e-department of Mechanical Engineering.
Related to research theme “Computational Mechanics”.

7.1.3 Large Scale System Solving
In solving partial differential equations numerically, one encounters complex larger (non) linear systems which exhibit a sparsity structure. In order to be able to solve them one need special iterative solvers, like multigrid. In this area one can also often employ parallel architectures fruitfully. Co-operation exists with TNO-TPD and the TU/e-department of Computer Science.
Related to research theme “Computational Mechanics”.
7.1.4 **Modelling and Finite Element Applications**

Although there exists a variety of FEM packages, it is often necessary to tailor methods for specific problems. Further development and improving them is a core activity. A particular aspect is the visualisation, which is increasingly important due to the ever increasing complexity of problems to be solved.

Related to research theme “Computational Mechanics”.

7.1.5 **Boundary Element Methods and Approximation**

The research on BEM is concentrating on the quality of approximations of non-homogeneous problems. In particular it is investigated how various basic approximation methods like radial basis functions lead to convergence and therefore efficient methods.

Related to research theme “Computational Mechanics”.

7.1.6 **Wave Analysis for lithography**

Analysis of diffraction gratings that are used to determine the position of a wafer in a waferstepper. Numerical methods like RCWA (Rigorous Coupled-Wave Analysis) are investigated to solve these equations in a stable and accurate way. New software tools will be developed for sensors that have the improved RCWA algorithm incorporated.

Related to research theme “Computational Mechanics”.

7.2 **Applied Analysis**

The main emphasis in this programme is on mathematical analysis of technological problems. Research is often fostered by specific applications, after which it may trigger more fundamental, and thus more generally applicable research:

7.2.1 **Mathematical Methods in Continuum Physics**

- Slow viscous flow of polymeric melts: considered is the mathematical simulation of manufacturing processes for polymers such as fiber spinning, extrusion and injection moulding. These processes are considered as slow viscous (Stokes-) flows. The polymeric melts are described as nonlinear thermoviscoelastic fluids. Analytical and numerical evaluation of the resulting system of partial differential equations is looked for.

- Modelling of direct imaging processing in photocopiers: Description of the toner particles between drum and dip roller, including collision, friction, and electromagnetic forces. Modelling of the toner as a granular medium or as a conglomerate of many rigid particles. Numerical simulation on basis of discrete element analysis.

7.2.2 **Fundamental Analysis of (Non-Linear) Evolution Problems**

Our research in functional analysis is concentrated on evolution equations. An inspiring source of inspiration are non-linear evolution equations arising from free boundary value problems in quasi-stationary fluid dynamics (Stokes flow, Hele-Shaw flow, polymer flow).

7.2.3 **Mathematical Methods for Impacting Oscillators**

In this subprogramme the dynamics of oscillating systems with impacts is studied. These systems show universal bifurcation behaviour, such as ‘period-adding’ bifurcations. Applications of the theory are found in atomic force microscopy, an experimental method to scan the detailed structure of surfaces from interactions between the surface and an oscillating problem.

7.2.4 **Stability of thin-walled structures**
A variational criterion for the hurt of stability of thin-walled shell structures provides a new lower bound for the loading capacity. We are investigating the implications of this criterion for the classical case of an axially loaded cylinder.

7.2.5 Industrial Mathematics
Problems and questions from industry.

All subprogrammes within 7.2 are related to research theme “Mechanics of Materials”.

8. Refereed scientific publications related to research school EM
8.1 Refereed journals


8.2 Books, chapters in book


8.3 Refereed proceedings


9. Dissertations: related to research school EM: name, title, university, date and advisors

Name: Hlod, A.
Title: Curved jets of viscous fluid: Interactions with a moving wall, TU/e September 2009
Advisors: Prof.dr. M.A. Peletier
Current position: KWR-project AMSL

10 Keynote lectures and seminars

Dr. M.E. Hochstenbach:
• Eigenvalue problems and DDE stability, Voorjaarsbijeenkomst Werkgemeenschap Scientific Computing, Eindhoven, April 24, 2009, the Netherlands
• Recent advances in computing specific eigenvalues, Universitat Politecnica de Valencia, December 11, 2009, Spain
• Recent advances in matrix eigenvalue problems, Universität Düsseldorf, December 17, Germany

Dr. E.J.W. ter Maten:
• Compound-fast multirate time integration for IC simulation, SIAM-CSE (Computational Science and Engineering), Miami FL, MiniSymposium MS 50, March 3, 2009
• Importance sampling Monte Carlo simulations for SRAM yield and margin analysis, NXP Semiconductors, PDM-GWO, Sept. 15, 2009 & AMSRF-Meeting, October 5, 2009
• Initial conditions for Harmonic Balance, ICESTARS Public Project Workshop, Fachhochschule Ober Österreich (FHO) Hagenberg/Linz, Ober Österreich, Austria, October 9, 2009

Prof.dr. R.M.M. Mattheij:
• IISc Bangalore, 21-01-09, Numerical Conservation of mass under symmetry
• IIT Kanpur 22-01-09, Laser drilling

Dr. J.M.L. Maubach:
• COMSON Rom Workshop, Cetraro, Calabria, Italia, September 7 – 11, 2009
• COMSON PMB and Workpackages, Universita di Calabria, Italia September 12 – 25, 2009
• Future Developments in Model Order Reduction, Terschelling, The Netherlands, September 12 – 25, 2009
• De vijfendertigste conferentie v.d. Werkgemeenschap Scientific Computing, Woudschoten, The Netherlands, October 7 – 9, 2009
• STW/Oofelie workshop, Liege, Belgium, November 2 – 4, 2009

Dr. A. Muntean:
• A hybrid model for the financial industry (jointly with Martin van der Schans, Simone Munao, Harrie Hendriks, Tasnim Fatima) SWI Wageningen, January 27-30, 2009, the Netherlands
• A reaction-diffusion system with distributed microstructure: homogenization and fast-reaction asymptotics, CASA Minisymposium on Multiscale Problems and Homogenization, February 23, 2009, Eindhoven, the Netherlands
• A reaction-diffusion system with distributed microstructure: homogenization and fast-reaction asymptotics SIAM conference of Geosciences, June, 2009, Leipzig, Germany
• Modeling reaction zones as free interfaces: application to predicting chemical corrosion of concrete, Workshop “Permeable Media”, May 14, 2009, Eindhoven, the Netherlands
• Fast-reaction asymptotics for gas-liquid reactions in structured porous media (invited talk in the Oberseminar of the Institute of Applied Analysis (head Prof. dr. W. Jaeger), Department of Mathematics, Univ. Heidelberg, Germany), June 6, 2009, Heidelberg, Germany
• Asymptotic homogenization in locally periodic media, Workshop on “Microstructures and scale transitions”, Academisch Genootschap, October 2009, Eindhoven, the Netherlands
• Multiscale model for gas-liquid transfer and structured transport in porous media: modeling, analysis and simulation, RIMS Conference on “Nonlinear evolution equations and mathematical modeling, Kyoto, October 21 – 23, 2009, Japan
• Analysis of a two-scale reaction-diffusion system with nonlinear micro-macro transmission condition, Oberseminar Analysis AG Schweizer, Fachbereich Mathematik, University Dortmund, December 3, 2009, Germany
Prof.dr. M.A. Peletier:
- Unification of chemical reactions and diffusion as a Wasserstein gradient flow, Dortmund, February 5, 2009
- Many-spike structures in block copolymers, CASA Minisymposium, Eindhoven University of Technology, March 10, 2009, the Netherlands
- Many-spike structures in block copolymers, Université catholique de Louvain, March 19, 2009, Belgium
- Variational methods for the analysis of patterns, Lipschitz Lectures, Universität Bonn, April 20 – May 8, 2009, Germany
- Many-droplet solutions in block copolymer melts, Bath University, June 8 – 10, 2009, United Kingdom
- Many-droplet solutions in block copolymer melts, Vancouver, July 6 – 10, 2009, Canada
- Variational analysis of a striped-pattern model, Workshop on Energy-driven systems, Pittsburgh, August 27 – 29, 2009, United States
- Chemical reactions as a type of diffusion, Université Libre de Bruxelles, September 2 – 4, 2009, Belgium
- Energy driven pattern formation via competing long and short range interactions, Vrije Universiteit Amsterdam, October 7, 2009, the Netherlands
- Unification of diffusion and reaction as a Wasserstein gradient flow, Weierstrass Institute for Applied Analysis and Stochastics, Berlin, October 14 – 16, 2009, Germany
- Variational analysis of a striped-pattern model, Amsterdam Dynamics of Patterns, November 4, 2009, the Netherlands
- Understanding the origins of the Wasserstein gradient flows, Dortmund University, November 5, 2009, Germany
- Probing the origin of Wasserstein gradient flows, Oxford University, November 6, 2009, United Kingdom
- Variational analysis of a striped-pattern structure in block copolymer, Materiel theories workshop Oberwolfach, December 14 – 19, 2009, Germany

W.H.A. Schilders:
- Preconditioning techniques in linear model order reduction, MATHMOD 2009, Vienna, February 11 - 13, 2009
- Model order reduction using new concepts from graph theory and numerical analysis, SIAM CSE09 Conference, Miami, March 2 - 6, 2009
- Model order reduction in the electronics industry, Nederlands Mathematics Congres, Groningen, April 15, 2009
- On passivity of the supernode algorithm, Dublin Institute for Advanced Studies, April 20, 2009
- Order Reduction Techniques for Coupled Multi-Domain Electromagnetic based Models, Conference “Coupled Problems”, Ischia Island (I), June 8 - 10, 2009
- Comprehensive High-Accuracy Modelling of Electromagnetic Effects in Complete Nanoscale RF blocks, SIAM Annual Meeting, Denver, July 6 - 10, 2009
- Mathematical challenges in the electronics industry, Hamilton Institute, Maynooth (IRL), October 19, 2009
- Model order reduction, Utrecht University, Mathematics Insitute, Staff Colloquium, November 26, 2009
- Toegepaste wiskunde, Presentation for Science Alliance in Deurne, December 15, 2009
11. Memberships:

Dr. M.E. Hochstenbach:
- Co-organizer Autumn School on Future Developments in Model Order Reduction, Terschelling, September 21 - 25, 2009, the Netherlands

Prof.dr. E.J.W. ter Maten:
- Programme Committee SCEE-2009
- Scientific Committee ECMI-2009
- Member Wiskundig Genootschap, SIAM

Prof.dr. R.M.M. Mattheij:
- SIAM
- KWG

Prof.dr. W.H.A. Schilders:
- Vice-president of ECMI
- Member of Scientific Organizing Committee ESF-EMS Forward Look project “Mathematics and Industry”
- Member of programme Committee SCEE Conference Series
- Chairman of organising committee Autumn School on Model Order Reduction, Terschelling, September 21 - 25, 2009
- Chairman of track D17 for DATE Conference Series
- Chairman of EMS-committee for Felix Klein prize
- Member of Scientific Advisory Committee on Linear Algebra for ESPL project at Rutherford Appleton Laboratories
- Advisory Committee for the ISSNLA (department of SIAM Special Interest Group on Linear Algebra)

11.1 Editorial boards international journals

Dr. M.E. Hochstenbach:
- SIAM Journal on Matrix Analysis and Applications

Prof.dr. R.M.M. Mattheij:
- Associate editor SIAM News
- Associate editor Surveys on Mathematics for Industry
- Associate editor Electronic Journal of Boundary Elements
- Editor Boundary Element Technology
- Editor Springer series on Mathematics for Industry
- Editor MESA

Prof.dr. M.A. Peletier:
- Associate editor IMA Journal of Applied Mathematics
- Editor European Journal of Applied Mathematics
- Editor Mathematics in Industry Case Studies

W.H.A. Schilders:
- COMPEL
• Reviews done for several other journals (Numerical Linear Algebra, Computers and Mathematics with Applications, Applied Mathematical Modeling)

11.2 International scientific committees

Prof.dr. R.M.M. Mattheij:
• Member Scientific Committee BeTeq 2009
• Applied Mathematics Committee of the European Mathematical Society

11.3 National Science Foundation and Academies

Prof.dr.R.M.M. Mattheij:
• Member NWO Programme Committee Computational Science
• Member of OOW (Council of Dutch “Onderzoekscholen”)
• Member NWO Programme Committee “Computational Science”
• Chairman KNAW programme “Computational Science”

Prof.dr. M.A. Peletier:
• Lorentz Center Scientific Board on the Life Sciences
• NWO Programme Committee Computational Life Sciences II
• Member of De Jonge Akademie of the KNAW

12. Awards and patents

- 

13. Overview of research input and output

13.2 Input “Computational Science and Engineering” related to EM, 2009

<table>
<thead>
<tr>
<th></th>
<th>Sources of financing 1)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>9</td>
<td>-</td>
</tr>
<tr>
<td>Supporting staff 2)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PhD 3)</td>
<td>2+14</td>
<td>2</td>
</tr>
<tr>
<td>Postdocs</td>
<td>3 +15</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

1) Sources of financing:
   1: University
   2: STW, NWO, FOM
   3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

4) Research input for PhD per year: 0.6 fte

5) Research input for Postdocs per year: 0.2 fte
### Output “Computational Science and Engineering” related to EM, 2009

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
<td>16</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>1</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>12</td>
</tr>
<tr>
<td>PhD theses</td>
<td>1</td>
</tr>
</tbody>
</table>

*In co-operation with other EM-groups*
7. RESEARCH DOCUMENTATION OF THE GROUP ENGINEERING MECHANICS

1. University/Department

Delft University of Technology
Department of Aerospace Engineering

1. Sub programmes related to research school EM

2.1 Composite Materials
2.2 Advanced Computational Procedures
2.3 Advanced Materials

3. Group director

Dr.ir. A.S.J. Suiker

4. Senior academic staff: name, position, research input in fte related to research school EM

Suiker, Dr.ir. A.S.J.  Associate Professor     0.3
Turteltaub, Dr. S.R. Associate Professor     0.3

Total fte: 0.6

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

Yadegari, M.Sc. S.   (PhD 2)  Dynamic multiscale performance of multiphase steels CoEM
Zwieten, Ir. G.J. van  (PhD 2)  Quantitative fault discontinuity modeling using the Partition of Unity Method CoEM

6. Postdocs: name, country, project title, research theme EM and period of stay

Herbst, Dr. O. “Modelling of repeated self-healing processes in materials” Germany CoEM
January 2009 – March 2009
7. **Short description of sub-programmes related to research school EM**

7.1 **Composite Materials**
Research within the group is primarily directed to developing damage-based models for predicting delamination and matrix-cracking, particularly for fibre-metal laminates such as Glare. These are being applied to the prediction of fatigue durability and thermal behaviour, as well as the analysis of crack stoppers, splices and combined buckling/delamination phenomena. Related to the research theme “Computational and Experimental Mechanics”.

7.2 **Advanced Computational Procedures**
This sub-programme relates to the development of computational models for the simulation of the behaviour of materials and structures. For this purpose accurate and robust models are made for the temporal and spatial discretization and algorithms are constructed for the efficient, accurate and robust solution of the ensuing non-linear algebraic equations. Another main thrust is the development of advanced computational mechanics strategies for stochastic phenomena. Related to the research theme “Computational and Experimental Mechanics”.

7.3 **Advanced Materials**
The research of the group in this area is focused on (i) a better understanding of the underlying physics of coating systems under ambient and elevated temperatures, (ii) the numerical simulation of phase transformations and dislocation movement and the development of efficient numerical techniques to generate the microstructures, and (iii) the development of robust methods for simulating crack growth in heterogeneous materials and under dynamic loading conditions. Related to the research theme “Computational and Experimental Mechanics”.

8. **Refereed scientific publications related to research school EM**

8.1 **Refereed journals**


8.2 Books, chapters in book

8.3 Refereed proceedings


9. **Dissertations: related to research school EM: name, title, university, date and advisors**

Name: Akkerman, I.
Title: Adaptive variational multiscale formulations using the discrete Germano approach
Advisors: Prof.dr.ir. R. de Borst
Date: March 10, 2009
Current position: Post-doc at University of California, San Diego

Name: Hille T.S.
Title: Lifetime modelling of thermal barrier coatings
Advisors: Prof.dr.ir. R. de Borst, Dr. S.R. Turteltaub
Date: May 8, 2009
Current position: Stress Engineer at Siemens, Germany

Name: Van der Zee, K.G.
Title: Goal-adaptive discretization of fluid-structure interaction
Advisors: Prof.dr.ir. R. de Borst, Dr. E.H. van Brummelen
Date: June 5, 2009
Current position: Post-doc at University of Texas, Austin

Name: Shi, J.
Title: Discrete modelling of plasticity and martensitic transformations
Advisors: Prof.dr.ir. R. de Borst, Dr. S.R. Turteltaub
Date: September 4, 2009
Current position: Stress Engineer at Huisman B.V., Schiedam

Name: Verhoosel, C.V.
Title: Multiscale and probabilistic modelling of micro electromechanical systems
Advisors: Prof.dr.ir. R. de Borst, Prof.dr. M.A. Gutierrez
Date: October 12, 2009
Current position: Post-doc at Eindhoven University of Technology

10 **Keynote lectures and seminars**

Dr.ir. A.S.J. Suiker:
Martensitic transformations in TRIP-assisted carbon steels. Cambridge University, U.K.
11. Memberships:

11.1 Editorial boards international journals

Dr.ir. A.S.J. Suiker:
Member of editorial board “Journal of Composite Materials”,
Member of editorial board “The Open Industrial and Manufacturing Engineering Journal”
Member of editorial board “Recent Patents on Materials Science”
Member of editorial board “Journal of Mechanics and MEMS”

11.2 International scientific committees

Dr.ir. A.S.J. Suiker:
Board member of the “Granular Materials Technical Committee” of the ASCE
Member of Euromech (European Mechanics Society)

11.3 National Science Foundation and Academies

- 

12. Awards and patents

- 

13. Overview of research input and output


<table>
<thead>
<tr>
<th>Sources of financing 1)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>2</td>
</tr>
<tr>
<td>Supporting staff 2)</td>
<td>1</td>
</tr>
<tr>
<td>PhD 3)</td>
<td>2</td>
</tr>
<tr>
<td>Postdocs</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University
2: STW, NWO, FOM
3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

<table>
<thead>
<tr>
<th>Type of Publication</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific journals</td>
<td>10(6*)</td>
</tr>
<tr>
<td>Books/chapters</td>
<td>-</td>
</tr>
<tr>
<td>Proceedings</td>
<td>9(8*)</td>
</tr>
<tr>
<td>PhD theses</td>
<td>5(5*)</td>
</tr>
</tbody>
</table>

* In co-operation with other EM-groups.
8. RESEARCH DOCUMENTATION OF THE TECHNICAL CHAIR AEROSPACE STRUCTURES (AeS)

1. University/Department

Delft University of Technology
Faculty of Aerospace Engineering

2. Subprogrammes related to research school EM

2.1 Structural Tailoring, and Design and Optimization
2.2 Stability and Vibrations of Imperfect Composite Shells

3. Group director

Prof.dr. Z. Gürdal

4. Senior academic staff: name, position, research input in fte related to research school EM

Dr. M.M. Abdalla                        Assistant Professor       0.4
Prof. J. Arbocz                         Professor Emeritus        0.1
Ir. R. de Breuker                       Research Associate        0.2
Prof. Z. Gürdal                         Professor                   0.1
Ir. J.M.A.M. Hol                        Assistant Professor        0.1
Dr. E.L. Jansen                         Assistant Professor        0.4
C. Kassapoglou, M.Sc                    Associate Professor        0.1

Total fte: 1.4

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

Structural Tailoring, and Design and Optimization

Alharbi, MSc M.                        (PhD 3)  Aeroelastic design of morphing winglets
Bin Syed Abu Bakar, MSc S.N.           (PhD 3)  Resonant frequency tuning of synthetic jet actuators
Blom, Ir. A.W.                         (PhD 3)  Design and optimization of composite cylindrical shells using tow-placement
Campen, Ir. J.M.J.F. van               (PhD 3)  Global/local modeling and design of tow-placed composite laminates
Dillinger, Ir. J.                      (PhD 3)  Multilevel aeroelastic design of composite wings
Fagiano, Ir. C                         (PhD 1)  Computational modeling of fabrication

ReOp
ReOp
ReOp
ReOp
ReOp
CoEM
features of tow-placed composite laminates using layerwise theory

Aeroelastic design of wind turbine blades

Efficient design optimization scheme for multi-layered laminates

Tailored composite blades for turbines under combined loads

Damage Tolerance of Non-Conventional Laminates

Isogeometric design and analysis of tow-placed composites

Damage detection and identification in composite cylindrical structures

Micro-mechanical modelling of fatigue behaviour of wind turbine composites

Mortar finite element method for coupling non-matching meshes using virtual work

Virtual testing of advanced composites

Aeroelastic tailoring on thin-walled variable stiffness composite laminates

Advanced cross-sectional modelling for aeroelastic tailoring of wings

Postdocs: name, country, project title, research theme EM and period of stay

7. Short description of subprogrammes related to research school EM

7.1 Structural Tailoring, and Design and Optimization

The demands of high-performance, structural integrity, durability, low weight, and minimum cost pose an important challenge to structural designers. New materials may assist in satisfying some of these demands, but at the same time give rise to significant new problems for the designers. Furthermore the structural design can no longer be seen as an isolated activity, but must play its part in a multi-disciplinary approach to the design of the aircraft or spacecraft as a whole. The traditional approach to design is no longer adequate unless it can be supplemented by a numerical, computer-based approach in which the trade-off between conflicting design requirements can be quantified, and many more alternatives evaluated. Optimization plays an important role in this process, by providing a tool to identify the active design constraints and to steer the design towards some required goal such as minimum weight or cost. The goal of the research efforts in this area is the development of efficient and robust design and optimization tools for a variety of challenging structural design problems, which meet the needs that industry is facing.

The subprogramme includes the following topics:
• Development of design and optimisation procedures for specific structural design problems;
• Theoretical optimisation including multi-level procedures and optimisation of structural shape and layout;
• Tailoring of advanced fibre reinforced composite structures;
• Design and optimisation of actively sensed and actuated structures.

Related to the research themes “Reliability and Optimization” and “Computational and Experimental Mechanics”.

7.2 Stability and Vibrations of Imperfect Composite Shells
In modern designs, which are often obtained by use of one of the structural optimization codes and which may be of new high strength materials such as advanced composites, structural response is often dictated by the stability and vibration behaviour. This is due to the drive for achieving light weight structures which result in thin-walled constructions. Such structures are also imperfection sensitive and display nonlinear response characteristics. This implies the need to investigate and understand the response characteristics of thin-walled structures under different loading conditions by carrying out extensive numerical calculation and/or experimental verification. A key issue is the development of fast and accurate analysis capability for thin-walled structures, incorporating all the theoretical knowledge accumulated in the last decades through intensive research in the aerospace, nuclear, and offshore fields, and making efficient use of the currently available interactive and (super-) computing facilities. Part of the ongoing thin-walled structures research is therefore concerned with the buckling, post-buckling, vibration and dynamic stability behaviour of shells. The goal of the research efforts in this area is the availability of improved design criteria and the necessary analysis tools.

The subprogramme includes the following topics:
• Theoretical, numerical, and experimental studies of the collapse behaviour and nonlinear vibration behavior of imperfect composite shells under static and dynamic loading;
• Development of an International Imperfection Data Bank and DISDECO (Delft Interactive Shell DEsign COde);
• Development of efficient semi-analytical and Finite Element based tools (reduced-basis methods) for the nonlinear static and dynamic analysis of slender and thin-walled structures.

Related to the research themes “Computational and Experimental Mechanics” and “Reliability and Optimization”.

8. Refereed scientific publications related to research school

8.1 Refereed journals


Irizarri, FX, Bassir, DH, Maire, JF & Carrere, N (2009). Multiobjective stacking sequence optimisation strategy for laminated composite structures. Composites science and technology, 69(7-8), 983-990


Totaro, G & Gurdal, Z (2009). Optimal design of composite lattice shell structures for aerospace applications. Aerospace science and technology, 13(4-5), 157-164


8.2 Books, chapters in book

Book:


Chapter:


Editorial:

8.3 Refereed proceedings


Abdalla, MM & Kassapoglou, C (2009). Formulation of Composite Laminate Robustness Constraining in Lamination Parameters Space. In C.E.S. Cesnik, D.M. Pitt (Eds.), Proceedings of the


Breuker, R de, Abdalla, MM & Gurdal, Z (2009). Analysis and design of morphing wings. In Olivier Polit & Michele D'Ottavio (Eds.), Book of Abstracts DeMEASS III (pp. 2-1). Vernon, France: Université Paris Ouest Nanterre La Defense


Breuker, R de, Hol, JMAM & Smits, GN (2009). The use of Wiki-Pages as a Course Reader: Conclusions after a One-Year Wiki Experiment. In M. van den Boogaard, E. de Graaff & G. Saunders-Smith (Eds.), 37th SEFI-conference 2009- proceedings (pp. 1-7). Delft: Delft university of technology


Kat, R de & Saunders-Smits, GN (2009). 3,2,1, Launch. In M. van den Bogaard, E de Graaff, G.N. Saunders-Smits (Eds.), proceedings of the 37th SEFI conference (pp. 1-7). Delft: Delft University of Technology


Smits, GN (2009). Engineering Heroes Wanted. In M. van den Bogaard, E. de Graaff & G.N. Saunders-Smits (Eds.), proceedings of the 37th SEFI conference (pp. 1-7). Delft: Delft University of Technology


9. Dissertations: related to research school EM: name, title, university, date and advisors

Name: T. Rahman
Title: A Pertubation Approach for Geometrically Nonlinear Structural Analysis Using a General Purpose Finite Element Code
University: Delft University of Technology
Date: December 21, 2009
Promotor: Prof. dr. Z. Gürdal
Co-promotor: Dr. ir. E. Jansen

Name: C. S. Lopes
Title: Damage and failure of non-conventional composite laminates
University: Delft University of Technology
Date: June 23, 2009
Promotors: Prof. dr. Z. Gürdal and Prof. dr. P. Camanho (University of Porto, Portugal)
Name: R. Zakhama
Title: Multigrid Implementation of Cellular Automata for Topology Optimisation of Continuum Structures with Design-Dependent Loads
University: Delft University of Technology
Date: June 8, 2009
Promotors: Prof. dr. Z. Gürdal and Prof. dr. ir. H. Smaoui (Ecole Nationale d'Ingenieurs de Tunis, Tunisia)
Co-promotor: Dr. M. Abdalla

Name: J. de Vries
Title: The Imperfection Data Bank and its Applications
University: Delft University of Technology
Date: May 11, 2009
Promotors: Prof. dr. Z. Gürdal and Prof. dr. ir. A. de Boer (TU Twente)
Current position: Researcher Nederlandse Defensie Academie

10. **Keynote lectures and seminars**

11. **Memberships:**

11.1. Editorial boards international journals

11.2. International scientific committees

Prof. Z. Gürdal:
- International Conference on Adaptive Structures and Technologies (ICAST)
- Association for Simulation and Multidisciplinary Optimisation (ASMDO)

11.3. National Science Foundation and Academies

10. **Awards and patents**

Ir. A.W. Blom: CACSMA-ASC student poster competition first prize

11. **Overview of research input and output**

Input Aerospace Structures related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>7</td>
</tr>
<tr>
<td>Supporting staff</td>
<td>-</td>
</tr>
<tr>
<td>PhD</td>
<td>2</td>
</tr>
</tbody>
</table>
1) Sources of financing:  
1: University  
2: STW, NWO, FOM  
3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

Output Aerospace Structures related to EM, 2009

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
<td>19</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>9</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>43</td>
</tr>
<tr>
<td>PhD theses</td>
<td>4</td>
</tr>
</tbody>
</table>

*In co-operation with other EM-groups
9. RESEARCH DOCUMENTATION OF THE GROUP APPLIED MECHANICS (PME)

1. University/Department

Delft University of Technology
Faculty of Mechanical, Maritime and Materials Engineering (3mE)
Department of Precision and Microsystems Engineering

2. Subprogrammes related to research school EM

2.1 Structural Optimization and Computational Mechanics
2.2 Mechanics of Materials & Microsystems Reliability
2.3 Dynamic Behaviour of Mechanical Systems
2.4 Reliability of Structures and Processing

3. Group director

Prof.dr.ir. F. van Keulen

4. Senior academic staff: name, position, research input in fte related to research school EM

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Booij, M.Sc. J.</td>
<td>Assistant Professor</td>
<td>0.1</td>
</tr>
<tr>
<td>Driel, Dr.ir. W. van</td>
<td>Associate Researcher</td>
<td>0.2</td>
</tr>
<tr>
<td>Ernst, Prof.dr.ir L.J.</td>
<td>Full Professor</td>
<td>0.6</td>
</tr>
<tr>
<td>Goosen, Dr.ir J.F.L.</td>
<td>Assistant Professor</td>
<td>0.2</td>
</tr>
<tr>
<td>Gutiérrez, Prof.dr.ir M.A.</td>
<td>Full Professor</td>
<td>0.6</td>
</tr>
<tr>
<td>Jansen, Dr.ir K.M.B.</td>
<td>Associate Professor</td>
<td>0.6</td>
</tr>
<tr>
<td>Keulen, Prof.dr.ir F. van</td>
<td>Full Professor</td>
<td>0.4</td>
</tr>
<tr>
<td>Rixen, Prof.dr.ir D.J.</td>
<td>Full Professor</td>
<td>0.6</td>
</tr>
<tr>
<td>Schwab, Dr.ir A.L.</td>
<td>Assistant Professor</td>
<td>0.6</td>
</tr>
<tr>
<td>Zhang, Prof.dr. G.Q.</td>
<td>Part-time Professor</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Total fte: 4.1

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

5.1 Structural Optimization and Computational Mechanics

<table>
<thead>
<tr>
<th>Name</th>
<th>Source of Financing</th>
<th>Project Title</th>
<th>Research Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolsman, Ir. C.T.</td>
<td>CoEM</td>
<td>Micro-actuation for flapping wings</td>
<td>CoEM</td>
</tr>
<tr>
<td>Dijk, Ir. N.P. van</td>
<td>ReOp</td>
<td>Multi-field design optimization of microsystem components</td>
<td>ReOp</td>
</tr>
<tr>
<td>Li, Ir. Q.</td>
<td>CoEM</td>
<td>Thin film micro-cavities for MEMS packaging</td>
<td>CoEM</td>
</tr>
<tr>
<td>MacKay, Ir. J.</td>
<td>CoEM</td>
<td>Buckling of pressure hull</td>
<td>CoEM</td>
</tr>
<tr>
<td>Sadeghian, Ir. H.</td>
<td>CoEM</td>
<td>Surface and interface effects</td>
<td>CoEM</td>
</tr>
<tr>
<td>Name</td>
<td>Degree</td>
<td>Title</td>
<td>Conference</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------</td>
<td>------------------------------------------------------------------------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Saputra, MSc. O.</td>
<td>PhD 3</td>
<td>Model validation and experimental testing of multi-physical interaction in MEMS</td>
<td>CoEM</td>
</tr>
<tr>
<td>Suarez, Ir. D.R.</td>
<td>(PhD 3)</td>
<td>Modeling and evaluation of cementless glenoid implants</td>
<td>CoEM</td>
</tr>
<tr>
<td>Akram, Ir. M.</td>
<td>(PhD 3)</td>
<td>Surface treatment of metals for improving adhesive bond strength and durability of adhesive bonds</td>
<td>CoEM</td>
</tr>
<tr>
<td>Chen, Ir. X.P.</td>
<td>(PhD 2)</td>
<td>Functional and reliability modeling of nanowire sensors</td>
<td>CoEM</td>
</tr>
<tr>
<td>Heru Utomo, Ir. B.H.</td>
<td>(PhD 3)</td>
<td>High impact testing of composites</td>
<td>CoEM</td>
</tr>
<tr>
<td>Liao, N.</td>
<td>(PhD 3)</td>
<td>Multi-scale modeling of interfaces</td>
<td>CoEM</td>
</tr>
<tr>
<td>Ma, Ir. X.</td>
<td>(PhD 3)</td>
<td>Fast Reliability qualification of System-in-Package</td>
<td>CoEM</td>
</tr>
<tr>
<td>Nakka, J.S.</td>
<td>(PhD 3)</td>
<td>Viscoelasticity of its cured product epoxy resin</td>
<td>CoEM</td>
</tr>
<tr>
<td>Noijen, S.</td>
<td>(PhD 3)</td>
<td>Multi-scale damage modeling of interface</td>
<td>CoEM</td>
</tr>
<tr>
<td>Rezaie Adli, Ir. A.R.</td>
<td>(PhD 3)</td>
<td>Joint equipment and materials for System-in-Package and 3D integrations</td>
<td>CoEM</td>
</tr>
<tr>
<td>Sadeghinia, Ir. M.</td>
<td>(PhD 3)</td>
<td>Experimental investigations on the delamination of the metal-oxide-polymer, nano-interfaces</td>
<td>CoEM</td>
</tr>
<tr>
<td>Saraswat, Ir. M.</td>
<td>(PhD 2)</td>
<td>Shrinkage and stress reduction</td>
<td>CoEM</td>
</tr>
<tr>
<td>Schlottig, Ir. G.</td>
<td>(PhD 3)</td>
<td>Interface characterization and failure modelling for semiconductor packages-2</td>
<td>CoEM</td>
</tr>
<tr>
<td>Soestbergen, Ir. M. van</td>
<td>(PhD 3)</td>
<td>Ion transport related failures</td>
<td>CoEM</td>
</tr>
<tr>
<td>Vreugd, Ir. J. de</td>
<td>(PhD 3)</td>
<td>Ageing characterization of moulding compounds and its modeling</td>
<td>CoEM</td>
</tr>
<tr>
<td>Wang, Ir. L.</td>
<td>(PhD1/3)</td>
<td>Flexible substrate</td>
<td>CoEM</td>
</tr>
<tr>
<td>Xiao, Ir. A.</td>
<td>(PhD 3)</td>
<td>Interface characterization and failure modelling for semiconductor packages-1</td>
<td>CoEM</td>
</tr>
<tr>
<td>Zaal, Ir. J.J.M.</td>
<td>(PhD 3)</td>
<td>MEMS packaging and reliability</td>
<td>CoEM</td>
</tr>
<tr>
<td>Hannot, Ir. S.D.A.</td>
<td>(PhD 3)</td>
<td>Multiphysical modeling of microsystems</td>
<td>CoEM</td>
</tr>
<tr>
<td>Kooijman, Ir. J.D.G.</td>
<td>(PhD 1)</td>
<td>Theoretical and experimental analysis of the stability of bikes</td>
<td>StDy</td>
</tr>
<tr>
<td>Ozbek, Ir. M.</td>
<td>(PhD 1)</td>
<td>Experimental dynamics and monitoring of wind turbines in operation</td>
<td>StDy</td>
</tr>
<tr>
<td>Steenhoek, Ir. A.M.</td>
<td>(PhD 3)</td>
<td>Model reduction for microsystem simulations</td>
<td>StDy</td>
</tr>
<tr>
<td>Tabak, Ir. U.</td>
<td>(PhD 2)</td>
<td>Model reduction of multiphysical high-tech systems</td>
<td>StDy</td>
</tr>
<tr>
<td>Voormeereren, Ir. S.</td>
<td>(PhD 3)</td>
<td>Dynamic modeling of wind turbine components</td>
<td>StDy</td>
</tr>
<tr>
<td>Vries, Ir. E.J.H. de</td>
<td>(PhD 1)</td>
<td>Smart braking strategies including tire</td>
<td>StDy</td>
</tr>
</tbody>
</table>
5.4 Reliability of Structures and Processes
Zwieten, Ir. G.J. van (PhD 2)
Earthquake hazard assessment through computational stochastic failure mechanics and satellite observations

6. Postdocs: name, country, project title, subprogramme, research theme EM and period of stay

Andreykiv, Dr.ir. A.
2004-2009
Length scales in MST modelling
Ukraine
CoEM

Langelaar, Dr.ir M.
2006-2010
Nederland, Design optimization of reliable microsystem components
Netherlands
CoEM

Tiso, Dr.ir. P.
2009
Non-linear Model Reduction. Application to Microsystems
Italy
StDy

Yuan, Dr. C.
2005-2009
Prediction of interfacial strength of the wafer backend stack by molecular dynamics and finite element methods
Taiwan
CoEM

7. Short description of subprogrammes related to research school EM

7.1 Structural Optimization and Computational Mechanics
Analytical modelling is only possible for a very limited number of structures or parts of structures. With the development of high-performance computer facilities, however, an increasing number of mechanical problems can be modelled and analysed numerically. The finite element method is the method that is often made use of in these cases. Analysis on the basis of numerical techniques is complicated by nonlinearities, caused by material behaviour, geometric effects, contact and/or friction. Moreover, multidisciplinary interaction may be important. This is especially the case for Micro-Electrical-Mechanical Systems (MEMS) and high-tech applications. Because of these aspects, the analysis of practical problems takes a tremendous effort. Therefore, further development of efficient, multidisciplinary numerical modelling techniques is required. These techniques should be tailored for high-performance computer architectures. The aim is to develop such techniques using approaches that strengthen and exploit the fundamentals of engineering mechanics.

Once numerical techniques are incorporated in a design process, for which often many intermediate designs and corresponding design sensitivities must be evaluated, the efficiency requirements are even more demanding. This holds for a design process in which intermediate designs are evaluated "manually", but becomes more important for (partially) automated optimization processes. Improvement of structural optimization techniques cannot be achieved independently from new developments in Computational Mechanics. Only a close integration of structural optimization techniques and numerical analysis strategies can yield the most efficient design tools. Clearly, manufacturing constraints impose additional challenges on the optimization. Within this theme, the fundamentals for modelling, analysis, design sensitivities and optimization of structures will be developed. The focus will be on the multidisciplinary links between these aspects. Furthermore, new developments will be translated in prototype designs, ready for laboratory testing and ultimately made available for day-to-day practice. For this purpose we are collaborating with more application-oriented groups and companies. Related to the research theme "Computational and Experimental Mechanics"

7.2 Mechanics of Materials & Microsystems Reliability
Demands on functionality and reliability of mechanical products, processes and systems and the needs for continuing improvement of product and process quality are of major concern for the worldwide industry. Traditional experience based design approaches, i.e. trial & error methods (designing, production and testing of a multiplicity of prototypes) can no longer be considered as competitive. Therefore, there is an urgent need to develop innovative design methods. As one of the promising alternatives for the traditional design method, virtual (= simulation-based) prototyping is beginning to draw attention from both industries and the academic world.

Adequate virtual prototyping involves a variety of aspects such as mathematical modeling, numerical simulation, functionality and reliability judgement, appropriate optimization tools and adequate experimental verification techniques. Presently, various modeling, simulation and optimization abilities have become available through continuing research and developments in physics, mathematics and engineering. Extension and improvement of these abilities and understanding of the underlying physics have been subject of research and development of many Engineering Mechanics programs. By virtue of the continuing developments in microelectronics and consequently continuing improvement of computational capabilities, an increasing number of mechanical problems can now be modeled and analyzed numerically. Therefore application of virtual prototyping is becoming an increasingly realistic possibility for future design of mechanical products, processes and systems.

One of the important building blocks in the process of virtual prototyping concerns "reliable and efficient (mostly FEM-based) mechanical modeling". Within this building block some bottlenecks (or challenges) are presently remaining, while new ones are emerging, despite the tremendous research effort worldwide. Those bottlenecks are mainly driven by the increasing demands on product complexity (application of new complex materials, continuing miniaturization, function integration), reliability and short-time-to-market demands. Examples of identified bottlenecks are:

- Characterization and modeling methodologies for process and geometric dependent material properties for various materials.
- Damage (and damage evolution) modeling (models & criteria) for various materials.
- Reliable experimental techniques for (material-) model parameter identification.
- Reliable experimental methods for FEM-model verification.

The orientation of the recent (and near future) “Mechanics of Materials” research projects is mainly directed to the elimination of the above bottlenecks and thus to improvement of the “virtual prototyping” chain. The necessary research requires combined experimental and numerical mechanics methods. The understanding and subsequent modeling of materials behavior requires the study and description of physical phenomena, ranging from macro to micro scales.

As a main research area with both rich scientific challenges and important industrial interest and application, Microsystems Reliability has been chosen. Reliability is the probability that a product in operation will survive under certain conditions during a certain period in time. Failure is the probability that a product is not functioning as designed. Moore’s law and More than Moore drive micro/nanoelectronics into an unknown level of complexity, characterized by miniaturization down to nano scale, multi and heterogeneous functionality, multi-discipline, multi-scale (in both geometry and time), multi-process, multi-technology, multi-variability, multi-material and interface, multi-damage and failure modes. These technology development trends, in combination with business trends, lead to increased design complexity, dramatically decreased design margins, increased chances and consequences of failures, decreased product development and qualification times, increased difficulties to meet quality, robustness and reliability requirements. As the consequence, product field failure rates and qualification effort are unacceptably high and yield is low, leading to very high cost of non-quality. Industries are losing billions in potential profits because of the field failures and delays in product development, due to
many unsolved challenges covering design methods, reliability practices, tools, standardization protocols, and especially the underlying fundamental knowledge. Industries have no appropriate

- Designing methods. The currently used ones are
  - Experience and trial-error based
  - Empirical, phenomenological and case dependent
  - Sub-optimization with limited capability for integrated co-design
  - Associated with high development costs

- Reliability qualification methods. The currently used ones are
  - Time and money consuming
  - Unclear correlation between application profiles with specifications and between application profiles with accelerated testing
  - No guarantee for extrapolating to outside of the specifications
  - No satisfied coverage for quality, robustness and reliability

To meet the development needs of micro/nanoelectronics, knowledge-based new reliability paradigm is a must. The scientific successes of many micro/nano-related technology development cannot lead to a business success without innovation & breakthroughs in the way that we address reliability through the whole value chain.

As an active player in the worldwide micro/nano reliability arena, and one of the founding members for EUCEMAN (European Center for Micro and Nanoreliability), our research focus is to develop fundamental knowledge, methodologies and advanced industry practices that enable industries to predict, qualify, design and optimise the reliability of micro/nano process and products upfront, prior to major manufacturing investments, physical prototyping and qualification tests. Our research scopes cover

- Multi-scale (from MD to continuous), multi-physics and multi-parameter based material/process/product characterization and modeling
- Damage, reliability and failure prediction and modeling, covering failure modes such as cracks, delamination, fatigue, moisture, degradation, buckling, warpage, various types of migrations, plastic yielding, etc.
- Virtual design prototyping/optimization/design rules, and virtual reliability qualification
- Advanced failure analysis, test strategy/methods and accelerated reliability qualification tests.

Related to the research theme “Computational and Experimental Mechanics”

7.3 Dynamic Behaviour of Mechanical Systems

Predicting and controlling the dynamical behavior of systems has become more important than ever before since new material and design techniques render structures lighter, more complex, more flexible and multi-functional. Thus predicting their dynamic performance with accuracy is crucial (e.g. response of constructions to surrounding perturbations, positioning of flexible manipulators, dynamic load analysis on machines,). Also the advent of new materials such as piezoelectric ceramics and the development of novel mechanical structures such as Micro-Electro-Mechanical systems (MEMS) require modern dynamic analysis to take into account the coupling between different physical fields, treated separately in earlier days. Tackling multi-physical problems and analyzing fully coupled systems (thermal, acoustic, electric, fluid and structural for instance) is one of the essential challenges underlying the development of new analysis tools and innovative design approaches in mechanical dynamics.

The objective of the research work in the Engineering Dynamics group is on one hand to develop numerical tools that allow analysis of complex systems, and on the other hand to improve the understanding of dynamical behavior (e.g. vibration analysis and measurement, stability prediction). The research is centered on the development of novel numerical methods and
advanced algorithms for efficient computing and testing. Specifically, the section is centering its research around the fields of expertise

- Multibody Dynamics,
- Numerical methods for dynamics,
- Multiphysical modeling
- Experimental Dynamics

and application fields usually considered are bio-medical, automotive, aerospace and aeronautics and Microsystems.

Related to the research theme “Structural Dynamics” and also “Computational and Experimental Mechanics”

7.4 Reliability of Structures and Processing

Even the most sophisticated analysis and design procedures traditionally use a deterministic approach, often based on (arbitrary) safety factors. A new dimension is introduced by taking into account the variability in material properties, geometry and operation conditions and to quantify it by means of probabilistic descriptions. The recent ability to operate inexpensive PCs in a parallel network and the development of specific algorithms for computational stochastic methods in a multiscale context, often with the added complication of non-linearities and multiphysics, have brought within reach a systematic incorporation of the probabilistic aspects in the modelling of engineering materials and systems. A direct consequence of this is the possibility of predicting the reliability of an object or system with respect to a performance requirement in a rational fashion. These advances also have relevance for many problems in processing, where a proper modelling of manufacturing introduced defects is a conditio sine qua non for a proper design of a system.

Related to the research theme “Reliability and Optimization”.

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


Driel, WD van, Silfhout, RBR van & Zhang, GQ (2009). On Wire Failures in Microelectronic Packages. Ieee transactions on device and materials reliability, 9(1), 1-7


Liu, Y, Kessels, FJHG, Driel, WD van, Driel, JAS van, Sun, FL & Zhang, GQ (2009). Comparing drop impact test method using strain gauge measurements. Microelectronics and reliability, 49, 1299-1303


Zhang, GQ & Driel, WD van (2009). Quo Vadis, Micro/NanoReliability. Micromaterials and nanomaterials, 09, 14-17

8.2 Books, chapters in book


8.3 Refereed proceedings


Hannot, SDA & Rixen, DJ (2009). Coupling plate deformation, electrostatic acruation and squeeze folm damping in a fem model of a micro switch. In E. Onate M. Papadrakakis B. Schrefler (Ed.), Int. conf. on computational methods for coupled problems in science and engineering (pp. 1-4). Barcelona: CIMNE


Klerk, D de (2009). Determining the signifinant number of singular values in experimental dynamic sybstructuring. In s.n., s.n. & s.n (Eds.), Proceedings of the IMAC-XXVII: a conference & exposition on structural dynamics 2009 (pp. 1-6). s.l.: SEM


Ozbek, M, Rixen, DJ & Verbruggen, TW (2009). Remote monitoring of wind turbine dynamics by laser interferometry phase 1. In s.n., s.n. & s.n (Eds.), Proceedings of the IMAC-XXVII: a conference & exposition on structural dynamics 2009 (pp. 1-16). s.l.: SEM


Rixen, DJ (2009). Dual craig-bampton with enrichment to avoid spurious modes. In s.n., s.n. & s.n (Eds.), Proceedings of the IMAC-XXVII: a conference & exposition on structural dynamics 2009 (pp. 1-14). s.l.: SEM


Steenhoek, AM, Rixen, DJ & Nachtergaele, P (2009). Model order reduction for thermomechanically coupled problems. In s.n., s.n. & s.n (Eds.), Proceedings of the IMAC-XXVII: a conference & exposition on structural dynamics 2009 (pp. 1-20). s.l.: SEM


9. Dissertations related to research school EM: name, title, university, date and supervisors

| Name:       | D. de Klerk                        |
| Title:      | Dynamic response characterization of complex systems through operational identification and dynamic substructuring. |
| Advisor:    | Prof.dr.ir. D.J. Rixen            |
| Date:       | 18 March 2009                      |
| Current position: | TUD                            |

| Name:       | C.V. Verhoosel                     |
| Title:      | Multiscale and probabilistic modeling of micro electromechanical systems |
| Advisors:   | Prof.dr.ir. R. de Borst and Prof.dr.ir. M.A. Gutiérrez |
Date: 12 October 2009
Current position: TU/e

Name: A.J. de Wit
Title: A unified approach towards decomposition and coordination for multi-level optimization
Advisor: Prof.dr.ir. F. van Keulen
Date: 30 November 2009
Current position: NLR

10 Keynote lectures and seminars

Prof. D.J. Rixen:
- Seminar on Modeling of Electro-static coupling in MEMS (Colorado University at Boulder), February 2009
- Kivi Niria seminar “Engineering Dynamics in Delft: joggling with Science, Industry and administration, June 2009

Prof. F. van Keulen
- Seminar on Nano cantilevers (UFL, Gainesville, FL, USA, November 2009)
- Seminar on Nano cantilevers (Nortwestern University, Evanston, IL, USA, November 2009)

11. Memberships:

11.1 Editorial boards international journals

11.2 International scientific committees

Prof.dr.ir. F. van Keulen:
- Member of EPSRC review panel
- Scientific Committee EngOpt 2010

Prof.dr.ir. L.J. Ernst:
- EuroSimE – Int.Conf. on Thermal and Mechanical Simulation and Experiments in Microelectronics and Microsystems – Technical Chair
- EPTC: Electronics Packaging Technology Conference, Singapore – Member of Technical Committee + Session Chair
- ECTC: Electronics Components and Technology Conference, USA – Member of Technical Committee + Session Chair

Prof. G.Q. Zhang:
- EuroSimE – Int.Conf. on Thermal and Mechanical Simulation and Experiments in Microelectronics and Microsystems – Technical Chair
Prof. D.J. Rixen:
- Advisory committee of FEMTO-ST (Université de Franche-Comté)
- Scientific committee of the ISMA conference (Leuven)

11.3 National Science Foundation and Academies

12. Awards and patents


13. Overview of research input and output

13.1 Input “Applied Mechanics (PME)” related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Total Fte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior academic staff</td>
<td>10</td>
<td></td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>Supporting staff</td>
<td></td>
<td>3.5</td>
<td>4</td>
<td>24.5</td>
</tr>
<tr>
<td>PhD</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Postdocs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University
                        2: STW, NWO, FOM
                        3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte
13.2 Output “Applied Mechanics (PME)” related to EM, 2009

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
<td>25</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>3</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>69</td>
</tr>
<tr>
<td>PhD theses</td>
<td>3</td>
</tr>
</tbody>
</table>

* In co-operation with other EM-groups
10. RESEARCH DOCUMENTATION OF THE GROUP
COMPUTATIONAL MECHANICS, STRUCTURAL MECHANICS
AND DYNAMICS

1. University/Department

Delft University of Technology
Faculty of Civil Engineering and Geosciences

2. Sub programmes related to research school EM

2.1 Computational Modelling of Failure
2.2 Advanced Computational Procedures
2.3 Structural Dynamics

3. Group director

Prof.dr.ir. L.J. Sluys

4. Senior academic staff: name, position, research input in fte related to research school EM

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-Khoury, Dr. R.I.N.</td>
<td>Associate Researcher</td>
<td>0.2</td>
</tr>
<tr>
<td>Metrikine, Prof.dr. A.V.</td>
<td>Associate Professor</td>
<td>0.4</td>
</tr>
<tr>
<td>Simone, Dr. A.</td>
<td>Associate Researcher</td>
<td>0.4</td>
</tr>
<tr>
<td>Sluys, Prof.dr.ir. L.J.</td>
<td>Professor</td>
<td>0.4</td>
</tr>
<tr>
<td>Stroeven, Dr.ir. M.</td>
<td>Associate Researcher</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Total fte: 1.5

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

<table>
<thead>
<tr>
<th>Name</th>
<th>Project Title</th>
<th>Research Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmed, MSc A. (PhD 3)</td>
<td>Computational modelling of laminated composites under impact loading</td>
<td>CoEM</td>
</tr>
<tr>
<td>Hoving, Ir. J.S. (PhD 1)</td>
<td>Nonlinear soil vibrations induced by high-speed trains</td>
<td>StDy</td>
</tr>
<tr>
<td>Lloberas, MSc. O. (PhD 2)</td>
<td>Multi-scale modelling of discrete fracture</td>
<td>CoEM</td>
</tr>
<tr>
<td>Mandapalli, MSc P.R. (PhD 3)</td>
<td>Multi-physics computational modelling of damage development in heterogeneous materials under plane impact loading.</td>
<td>CoEM</td>
</tr>
<tr>
<td>Meer, Ir. F.P. van der (PhD 2)</td>
<td>Computational modelling of laminated composites</td>
<td>CoEM</td>
</tr>
<tr>
<td>Nguyen, MSc. V.P. (PhD 1)</td>
<td>Hierarchical methods for brittle materials</td>
<td>CoEM</td>
</tr>
</tbody>
</table>
Nikbakht, MSc. M. (PhD 2) Computational modelling of failure mechanisms in geomechanics CoEM
Oelgaard, MSc. K.B. (PhD 2) Discontinuous Galerkin methods for solid mechanics CoEM
Ogink, Ir. R.H.M. (PhD 3) Nonlinear hydroelastic dynamics of deep-water risers StDy
Pedersen, MSc. R.R. (PhD 2) Computational study of the dynamic behaviour of concrete CoEM
Radtke, MSc. F.K.F. (PhD 2) Computational modelling of fibre-reinforced concrete CoEM
Shan, MSc. X. (PhD 3) Coupled thermal, reservoir flow and geomechanical modeling CoEM
Shabir, MSc. Z. (PhD 3) Reliability of Engineering Materials CoEM
Talebian, MSc M. (PhD 3) Multidomain numerical tools for environmental impact assessment and monitoring of CO2 sequestration CoEM

6. Postdocs: name, country, project title, research theme EM and period of stay

7. Short description of sub programmes related to research school EM

7.1 Computational Modelling of Failure
Simulation of failure and the associated phenomenon of strain localisation for a range of materials. Activities focus on improved computational procedures and on the integration of experimental methods and sophisticated computational procedures. Related to the research theme "Computational and Experimental mechanics of Materials".

7.2 Advanced Computational Procedures
This research topic is concerned with the development of computational models for the simulation of the behaviour of materials and structures. For this purpose accurate and robust models are made for the temporal and spatial discretization and algorithms are constructed for the efficient, accurate and robust solution of the ensuing non-linear algebraic equations. Related to the research theme "Computational and Experimental mechanics of Materials".

7.3 Structural Dynamics
The development, experimental validation, and numerical implementation of prediction models of (i) ground vibration from high-speed trains and (ii) vibration of submerged flexible offshore structures in waves and currents. Related to the research theme "Structural Dynamics and Control".

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


Stroeven, P, He, H, Guo & Z Stroeven, M (2009). Particle packing in a model concrete at different levels of the microstructure: Evidence of an intrinsic patchy nature. Materials characterization, 60, 1082-1087


8.2 Books, chapters in book


8.3 Refereed proceedings


He, H, Guo, Z, Stroeven, M, Stroeven, P & Sluys, LJ (2009). Particle packing characteristics in concrete assessed by a DEM. In E. Onate, E. Owen (Eds.), Int. conference on Particle-Based Methods, PARTICLES 2009 (pp. 394-397). Barcelona, Spain: CIMNE


Meer, FP van der & Sluys, LJ (2009). A computational model for splitting and delamination in laminates. In s.n. (Ed.), 12th International conference on fracture (pp. 1-10). Ottawa - Canada


Meer, F.P. van der & Sluys, L.J. (2009). Simulation of complex failure mechanisms in composite laminates with the phantom node method and a dissipation based arclength method. In M.A.N. Hendriks, S.L. Billington (Eds.), Computational Modeling on Concrete, Masonry and Fiber-reinforced Composites (pp. 41-44). Delft: TU Delft

Meer, FP van der & Sluys, LJ (2009). Simulation of multiple cracking in laminates. In T.P. Fries, A. Zilian (Eds.), Int. conf. on extended finite element methods - recent developments and applications, XFEM 2009 (pp. 221-224). Aachen, Germany


Metrikine, A (2009). Parametric instability of a wheelset of high-speed train caused by the spatial periodicity of a railway track. In M. Papadrakakis, N.D. Lagaros & M. Fragiadakis (Eds.), Computational methods in structural dynamics and earthquake engineering (pp. 104-104). Athens: National Technical University of Athens


Stroeven, P (2009). Methodology of damage assessment in concrete - Scope and restrictions. In s.n. (Ed.), 12th Concereence on fracture (pp. 1-10). Ottawa - Canada


9. **Dissertations: related to research school EM: name, title, university, date and advisors**

Name: P.F.P. Moonen
Title: Continuous-discontinuous modelling of hygrothermal damage processes in porous media.
Advisors: Prof.dr.ir. L.J. Sluys, Prof. J. Carmeliet
Date: 2009-06
Current position: ETH Zürich
10. **Keynote lectures and seminars**

**Prof.dr.ir. Sluys:**
Keynote lecture:
- "Enhanced Domain Decomposition techniques for the modelling of softening materials", 1st Int. Conference on Computational Technologies in Concrete Structures (CTCS'09), May 2009, Jeju, Korea

**Prof. dr. A.V. Metrikine:**
Keynote lectures:
- "Derivation of isotropic gradient elastic continua from a regular lattice: procedure, uniqueness and causality", EUROMECH 512, May 2009, Paris, France and Advanced Problems in Mechanics, June 2009, St.Petersburg, Russia (I delivered the same lecture twice)
- "Intermittence of the self-excited vibrations of a submerged cantilever pipe aspirating water" recent Advances in Nonlinear Mechanics, August 2009, Kuala Lumpur, Malaysia

Seminars:
- "Vibration and stability of flexible structures interacting with moving loads and flows" January 2009, TU Eindhoven, Netherlands
- "The main mechanisms of generation of elastic waves by moving loads: Theory and application to high-speed trains", October 2009, SPARKS seminar, TU Delft, Netherlands
- "Dynamics of submerged pipes" November 2009, IHC Merwede, Kinderdijk, Netherlands
- "Wave mechanics and nonlinear dynamics of structures and structural materials", December 2009, NTNU, Trondheim, Norway

11. **Memberships**

11.1 **Editorial boards international journals**

**Prof. dr. L.J. Sluys:**
- Editor-in-Chief “HERON”
- Member Editorial Board “Computers & Concrete”
- Member Editorial Board “Journal of Multiscale Modelling”

**Prof. dr. A.V. Metrikine:**
- Deputy Editor-in-Chief “Journal of Sound and Vibration”

11.2 **International scientific committees**

11.3 **National Science Foundation and Academies**

12. **Awards and patents**

13. **Overview of research input and output**

13.1 Input “Computational Mechanics, Structural Mechanics and Dynamics” related to EM, 2009
### Sources of financing

<table>
<thead>
<tr>
<th>Sources of financing 1)</th>
<th>Total number</th>
<th>Fte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior academic staff</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>Supporting staff 2)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>PhD</td>
<td>6</td>
<td>10.8</td>
</tr>
<tr>
<td>Postdocs</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6</td>
<td>12.3</td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University  
2: STW, NWO, FOM  
3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

4) Joint project with SoMe; input 0.4 fte

### 13.2 Output “Computational Mechanics, Structural Mechanics and Dynamics” related to EM, 2008

<table>
<thead>
<tr>
<th>Scientific publications: refereed journals</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>4</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>37</td>
</tr>
<tr>
<td>PhD theses</td>
<td>1</td>
</tr>
</tbody>
</table>

* In co-operation with other EM-groups.
11. RESEARCH DOCUMENTATION OF GROUP APPLIED MECHANICS

1. University/Faculty

University of Twente
Faculty of Engineering Technology

2. Subprogrammes related to research school EM

2.1 Structural Dynamics and Control
2.2 Computational and Experimental Mechanics
2.3

3. Group directors

Prof.dr.ir. A. de Boer
Prof.dr.ir. J. Huétink

4. Senior academic staff: name, position, research input in fte related to research school EM

De Boer, Prof.dr.ir. A. Full Professor 0.3
Boogaard, Dr.ir. A.H. van den Assistant Professor 0.2
Ellenbroek, Dr.ir. M.H.M. Lease docent (0% BPM) 0.1
Geijselers, Dr.ir. H.J.M. Associate Professor 0.2
Hoogt, Dr.ir. P.J.M. van der Associate Professor 0.2
Huétink, Prof.dr.ir. J. Full Professor 0.2
Loendersloot, Dr.ir. R. Assistant Professor 0.3
Meinders, Dr.ir. V.T. Assistant Professor 0.2
Wijnant, Dr.ir. Y.H. Assistant Professor 0.4

Total fte: 2.1

5. PhD- projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

5.1 Structural Dynamics and Control
Akçay Perdahcióglu, MSc D. (PhD 3) Structural Dynamics and Optimization StDy
Altunlu, MSc A.C. (PhD 3) Fatigue of Gas Turbine Liners StDy
De Guido, MSc S. (PhD 3) Structural Dynamics and Optimization StDy
Dikmen, MSc E. (PhD 3) Rotor Dynamics StDy
Jong, Ir. P.H. de (PhD 3) Power Harvesting StDy
Kampinga Ir. W.R. (PhD 3) Fluid-structure interaction and acoustics StDy
Kuipers, Ir. E.R. (PhD 3) Fluid-structure interaction and acoustics StDy
Nijhof, Ir. M.J.J. (PhD 3) Fluid-structure interaction and acoustics StDy
Paternoster, MSc A.R.A. (PhD 3) Rotor blade Dynamics StDy
5.2. Computational and Experimental Mechanics

Schutte, Ir. J.H. (PhD 3) Tire road noise
Wind, Ir. J.W. (PhD 2) Inverse acoustics

5.2. Computational and Experimental Mechanics

Assaad, W., MSc (PhD 3) Die performance and productivity in aluminium extrusion
Hadoush, A., MSc (PhD 3) Modelling of incremental sheet forming
Hilkhuizen, Ir. P. (PhD 3) Plasticity in stainless steel and TRIP steels at non proportional strain paths
Hol, Ir. J. (PhD 3) Friction modelling on multiple scales
Koopman, Ir. A.J. (PhD 3) Aluminium Extrusion
Kurukuri, S., MSc (PhD 3) Thermo-mechanical aluminium sheet forming
Niazi, M.S. MSc (PhD 3) Damage
Owczarek, P., MSc (PhD 2) Lubricant free piston compressor
Quak, Ir. W. (PhD 1) Meshless Methods
Riel, Ir. M. van (PhD 3) Strain path dependent material models
Snippe Ir. Q.H.C. (PhD 2) Thin Structures for Vertex detectors
Stelt, Ir. A. van der (PhD 3) Friction stir welding
Wiebenga Ir. J.-H. (PhD 3) Robust Forming

6. Postdocs: name, country, project title, research theme EM and period of stay

Arora, Dr. V. (India) Inverse Acoustics December 2009 - December 2010
Martinez Lopez, Dr. A. Effect of bending on forming December 2009 – December 2011
Perdahcioğlu, Dr. E.S. Processing Meta Stable Steels December 2009 – December 2011
Wisselink, Dr. ir. H.H. Material Modeling, Damage (indefinite)

7. Short description of subprogrammes related to research school EM

7.1 Structural Dynamics and Acoustics (Prof. dr. ir. A. de Boer)

The research in this discipline is directed towards:
- Fluid-structure interaction and acoustics, with emphasis on thermal viscous wave propagation and acousto-elastic coupling and the accompanying noise production.
- Structural dynamics, involving rotating components in machinery and optimisation and actuation of vibrating structures.
- Material behaviour under dynamic loading, covering condition monitoring based on vibration based methods, impact behaviour and rubber modelling.

The research of the group aims at generation of new, fundamental knowledge by combining numerical and experimental techniques. Based on this knowledge engineering tools are validated and made ready for application in key industrial problems. A characteristic feature of all themes is the innovative use of advanced numerical simulation methods in a design environment. Crucial
information that is difficult or even impossible to obtain from experiments is added through numerical models.

Current topics are:

Structural Dynamics

(1) Optimization of Dynamic Systems
Optimization problems concerning complex structures with many design variables may entail an unacceptable computational cost. This problem can be reduced considerably with a multi-level approach; a structure consisting of several components is optimized as a whole (global) as well as on component level. Optimizing the dynamic behaviour of a structure in this way gives an extra complication because the interaction loads for each of the components are frequency dependent. The objective of the research is to develop robust and fast methods to address this kind of dynamic problems for large complex structures using neural networks and genetic algorithms in combination with component mode synthesis and making use of repetitive patterns in the structure. The research in 2009 has been focussed on re-analysis methods for reduction methods. This research will be the subject of the PhD-thesis of Didem Akçay Perdahcioğlu which will be defended on July the 9th, 2010. A new project has been started on the optimization of thermoplastic structures in the framework of the Dutch TAPAS (Thermoplastic Affordable Primary Aircraft Structure) programme. The research of the UT part within TAPAS will be the subject of the PhD-thesis of Samuele De Guido.

(2) Rotor Dynamics
Rotating parts in machinery are sources of vibrations and can therefore affect the life time of the rotating part itself and the whole machine drastically. The tendency to optimize the functional performance of structures results in modern designs which often exhibit a minimal weight and very tight safety factors. For high speed rotating micro systems, a well-known rule is that with decreasing scale, surface effects begin to dominate volume effects. This means that friction (e.g. in the support system of the rotors), aerodynamic damping, thermal effects become very important and have to be taken into account in the models. Therefore the type of models used will be typical for the multi-field microsystems setting. A model has been developed to calculate the aerodynamic loads in the containment between rotor and housing and coupled with the rotor dynamics and thermal model. Further an experimental set-up has been designed and built to validate the developed multiphysics model. This research is the subject of the PhD-thesis of Emre Dikmen. In 2009 a separate project has been carried out with the objective to develop identification methods for special bearings in the support system of high speed rotor systems. This research was carried out by post-doc Vikas Arora.

Fluid-structure interaction and acoustics

(1) Viscothermal wave propagation
New, analytical models, which include the effects of inertia, viscosity and thermal conductivity, led to the development of a new finite element for viscothermal wave propagation in narrow gaps. Coupling of this acoustic element with finite elements for the structure enables fully coupled acousto-elastic calculations for a complex geometry to be made. The models were validated with specially designed experiments. The enormous effect that the presence of air can have on the vibration behaviour of a structure was shown and it appeared possible to generate a considerable amount of damping. In 2009 the computation speed of the viscothermal finite elements has been increased drastically and validation
experiments have been carried out. This research will be the subject of the PhD-thesis of Ronald Kampinga which will be defended on June the 23rd 2010.

Further studies are performed towards practical applications more specifically for computers. 2D and 3D finite elements have been developed which make it possible to apply the viscothermal wave propagation theory for arbitrary geometries. This research will be the subject of the PhD-thesis of Martin Nijhof.

(2) Sound-absorbing materials.

A closely related part of the research program, involves the development of methods and models concerning sound-absorbing materials. In 2009 emphasis is put on a new method of measuring the absorption of materials in-situ. This research is carried out by Erwin Kuipers.

(3) Efficient analysis and measuring methods for source localisation

Acoustic source localisation concerns a combination of measuring and numerical analysis methods with the goal to detect the parts of a structure that are responsible for the generation of noise. The idea is to measure the sound pressure or particle velocity on a grid around the radiating object and to determine the radiating source with inverse analysis methods.

In 2005 the STW project TWO 5154 “Efficiënte akoestische reken- en meet-technieken” was finished and the new STW project TWO 6618 “Inverse Akoestiek” was started. This project is carried out together with Prof. Slump of the UT Department of Electrical Engineering, Signals and Systems group and Prof. N.B. Roozen of the TU/e Department of Mechanical Engineering, Section Dynamics and Control. The goal of this project is to develop fast methods to localize noise sources with acoustic sensor arrays. In 2009 a method to localize moving noise sources has been investigated and developed. This research was the subject of the PhD-thesis of Jelmer Wind which was defended on November the 18th, 2009.

(4) Thermo-acoustic structural interaction

During combustion in a gasturbine noise is generated which can interact with the gasturbine wall. Due to this interaction undesirable acoustic pressure fields can be generated that disturb the flame. The latter can affect the efficiency of the combustion process. The objective of this study is to investigate the interaction between the gasturbine structure and the thermo-acoustic pressure generated in the combustion chamber. This study is carried out in close collaboration with the Thermal Mechanics group of the University of Twente. In 2009 a new (Marie Curie) project focussed on fatigue of the liners has been started on this subject. This research is carried out by Can Altunlu.

(5) Tyre/road noise

Traffic road noise is a serious environmental problem and effective countermeasures are needed to reduce noise. The main components of the radiated noise are engine noise and tyre/road noise, where engine noise dominates at low speeds. Road noise is generated through the interaction between a rolling tyre of a vehicle and the road surface. Many different mechanisms contribute to the generation of tyre/road noise. Because most generation mechanisms originate from the contact region, modelling of the interaction between tyre tread and road surface is crucial for an accurate prediction of tyre/road noise.

With such a complete model, one can study the effect of modifications to the tyre or road, and ultimately design quieter tyre/road combinations. The objective is to develop numerical tyre/road models with emphasis on what is happening in the contact region and the material models for rubber. In 2009 an analysis procedure has been developed such that the radiated tyre noise can be calculated. This research will be the subject of the PhD-thesis of Arjan Schutte.
Dynamic material behavior

(1) Structural Health Monitoring
This project is in collaboration with Production Technology, Prof.dr.ir. R. Akkerman. See chapter 13 ‘Production Technology’ for more details.

(2) TTIW Wetsus Distribution.
The research program of the Technological Top Institute Water, financed by the Dutch government and Dutch industry, covers a wide range of projects, amongst which the remaining life time assessment of water distribution pipes. Premature failure can result in high maintenance costs and public inconveniences, whereas premature replacement of large parts of the water distribution network is logistically impossible and extremely costly. Previous researches on PVC gas pipes revealed the effect of physical aging on the type of failure. Moreover, the dynamics of the ground in which the pipes are embedded can cause extreme deformations and depending on the level physical aging to damage. Ultrasonic measuring technologies are being developed (see InnoWator project) to measure the dynamic response of a water pipe during service. The relation between the dynamic response, the age of the material and the resulting remaining life time estimation are subject of the Wetsus theme program Distribution. The current focus is on PVC material. Complicating factors involve the unknown initial material properties, such as the level of gelation, and non-linearities in the (dynamic) material properties. Artificial rejuvenation and aging are employed to investigate the physical aging kinetics and their relation to physical material properties. Beginning 2010, Mahmoud Ravanah started his PhD research on this project.

(3) InnoWator
This project is in collaboration with Production Technology, Prof.dr.ir. R. Akkerman. See chapter 13 ‘Production Technology’ for more details.

(4) Rotor Blade Dynamics
Green Rotor Craft (GRC) is one of the research projects within the European funded Joint Technology Initiative research program “Clean Sky”. The objective of the GRC project is to reduce the environmental impact of helicopters. A smart use of resources, in terms of vibrations of the rotary system, and an optimisation of the rotor blade performance are set as the main research activities. Two PhD position are defined in this project.
The first part of the research is focussed on power harvesting methods. The energy of vibrations in the rotor’s lag damper and of the rotor blade itself can be extracted by employing for example piezo patches. Design and development of the electrical circuits in order to maximise the power output from a complex dynamic system such as a rotor blade is a challenging and relatively unexplored problem. February 2009, Pieter de Jong started his PhD research on this project. First activities involved an study on the available power harvesting methods and circuits, which are collected in a Initial Technology Review. The review is assessed by the GRC project task leader (Agusta Westland) in December and is issued as a deliverable in January 2010. The first results will also be presented at ICSV-17 (July 2010).
The second part involves smart shaping of the blade in order to optimise the performance during different flight conditions. The main interest is the development of a suitable activator principle and design for a model rotor blade. The dynamic loading on the blade, which varies during advancing and retreating motion of the blade is a complicating factor. The demands on the actuator performance and the coupling between actuation of a shape morphing mechanism and the rotor blade dynamics require a fundamental understanding of actuator behaviour. Additional challenges are found in the scale of the model rotor and the impossibility to either upscale or downscale solution from model rotor to a full scale blade and vice versa. Generic solution technology need to be developed to bridge this gap, resulting in a robust full scale smart blade design. February 2009, Alexandre Paternoster started as a PhD on this project. A technology review, assessed by the GRC project task leader (Agusta
Westland), was finished in December (issued in January 2010 as a deliverable). It incorporates an extensive overview of available technologies and a new selection methodology based on a comparison of work per weight versus actuation time rather than force versus displacement.

7.2 Mechanics of forming processes (Prof.dr.ir. J. Huétink)

The research in this discipline is directed towards the development and validation of numerical methods to simulate forming and production processes. Industrial application of numerical simulations of forming processes is gradually finding its way in industry. For specific forming processes commercially available software packages can provide predictive answers. There is a strong need for more accurate macroscopically based descriptions of material behaviour during specific parts of the forming process, more accurate descriptions of the process conditions such as friction and heat transfer between tools and workpiece and above all, experimental verification of the capability of the models to describe the phenomena with sufficient accuracy.

The fundamental problems associated with new algorithms, the inclusion of relevant boundary conditions like contact and friction between tool and product, and the deformation of flexible tools are addressed. These fundamental problems obviously occur in very important technologies that have attracted (renewed) attention in recent years.

The sub programme is to a large extent part of the Research programme of the Materials Innovation Institute (M2i) (previously NIMR). Several research projects are joint activities of the UT, TU/e and TUD.

Increased demands for accuracy of these simulations and computationally efficient simulations require that a number of topics have to be addressed:

- Improved macroscopic models for describing the material. Accurate constitutive equations are required including (evolution of) sheet metal anisotropy in order to predict the final shape after forming and subsequent “spring back”.

  In particular the effect of the initial sheet anisotropy, the changes in loading path as present in multi-stage forming processes and through process modelling, the strain rate dependency, the consequences of temperature changes in warm forming processes, the effects of annealing periods between successive forming steps and strain rate effects have to be properly accounted for. Material properties are commonly determined from uni-axial and/or proportional deformation test. In forming processes the stress state is not uniaxial, and the deformation path is not proportional. In order to develop and validate material models under multiaxial stress state and arbitrary deformation paths, a biaxial test facility is developed. The test facility allows for biaxial loading under simultaneous bi-directional shear and tension/compression of sheet metal, including strain path changes and strain rate changes. In the project on strain path dependent material models this equipment is further developed and the results are used to validate and to improve macroscopic material models (PhD researcher Maarten van Riel).

The Project “Simulation of thermo-mechanical forming of aluminium sheet” addresses both the material hardening aspects during warm forming and the effect of annealing periods (PhD researcher Srihari Kurukuri). The project is jointly executed with TU/e and TUDelft a joint FOM-NIMR project “Tailoring of processable metastable steels” is running. The project has resulted into constitutive equations for FEM simulations, including the phase transitions from austenite to martensite during forming. At the TU/e micro level FEM models are developed that can foster the development of the macroscopic models that are necessary in full-scale three dimensional forming process simulations. PhD researcher Semih Perdahcioglu has defended his thesis December 2008, has continued his work in a valorisation project in
cooperation with Philips and started as a post-doc on a project “Mechanically induces martensite in stainless steel and TRIP steel”. The project “Plasticity in stainless steel and TRIP steels at non-proportional strain paths” aims to continue the development of a general (constitutive) deformation model to describe the behaviour of single and dual phase steels with or without phase (austenite to martensite) transformations. The deformation model should be able to describe the effects of texture and phase transformation during forming operations. The model will be an extension of the ‘stress induced transformation’ model (PhD researcher Peter Hilkhuijsen).

The project “Forming the Limits of Damage Predictions – From fundamentals to application” is also a joint activity of the TU/e ant UT. The aim is to develop computational tools which allow one sites to make quantitative predictions of ductile damage and fracture in industrially relevant materials and applications (researcher Harm Wisselink). A project on anisotropic damage has been started in 2007 (PhD researcher Muhammad Sohail Niazi). The effect of bending on the formability limits is studies in a two years post doc project (researcher Alejandro Martínez Lopez).

**Optimisation**

Superplastic forming of aluminium foils is investigated and the optimisation towards constant final thickness considered (PhD researcher Corijn Snippe). The optimisation is geometrically based rather than process based, since the overall costs of the foil product will be the result from development time and not from the chosen material or production process (low mass production).

In the project on ‘Lubricant free piston compressor’ the thermo-mechanical conditions, especially in the start-up phase for a free piston compressor are optimised. Small tolerances and thermal expansion are the main topics here (PhD researcher Pawel Owczarek). In 2009 a project is started on “Design of robust forming processes”, (PhD researcher Jan-Harmen Wiebenga).

**Advanced solution algorithms for forming processes**

In the project ‘modelling of incremental sheet forming’ the focus is on efficient modelling techniques for a process in which only a very small part of the work piece experiences plastic deformation at a particular time. Considered methods are refinement and de-refinement and sequential (dynamic) substructuring (PhD researcher Ashraf Hadoush). This research is carried out in cooperation with RWTH Aachen. In addition continued research will be performed on dynamic-implicit algorithms in combination with direct and iterative solvers.

For aluminium extrusion, full 3D simulations of the bearing area are still very time consuming. Equivalent bearing areas and improved steady state simulations are investigated by Bert Koopman and Wissam Assaad.

A project on the applicability of meshless methods for forming process simulations is started in 2007 (PhD researcher Wouter Quak).

**Joining, surfaces, contact and friction**

The project “Local Alloying and Cladding of Advanced Al-Alloys Employing Friction Stir Welding” is aimed to develop an innovative modified tool for the Friction Stir Welding (FSW) process. Contrary to regular FSW, filler material is supplied to the weld area during welding through an adapted FSW tool. This is a joint project with the production Technology group (PhD researcher Arnoud van der Stelt).

A project jointly with the Surface Technology group is “Friction modelling in sheet metal forming on multiple scales”. The aim of the project is to provide a friction model that describes the effects
of the surface topology on the micro scale in FE simulations on the macro scale. The algorithm incorporating the model must be applicable to full-scale automotive sheet metal forming simulations (PhD researcher Johan Hol).

All activities within the sub programme “Mechanics of Forming Processes” are related to the research theme “Computational and Experimental Mechanics”.

8. **Refereed scientific publications related to research school EM**

8.1 Refereed journals


Assaad, W & Geijselaers, HJM (2009). Boundary conditions applied on bearing corner in direct aluminum extrusion. Int. j. mater. form., (ISSN 1960-6206), 2(Supplement 1), 77-80


Emmens, WC & Boogaard, AH van den (2009). Incremental forming by continuous bending under tension—An experimental investigation. J. mater. process. technol., (ISSN 0924-0136), 209, 5456-5463


8.2 Books, chapters in book


8.3 Refereed proceedings


9. **Dissertations: related to research school EM: name, title, university, date and advisors**

Name: Vries, J. de  
Title: The imperfection data bank and its applications.  
Advisor: Prof.dr.ir. A. de Boer & Prof.dr. Z Gürdal  
Date: 2009, May 11  
Current position: NDLA, Den Helder. NL

Name: Wind J.W.  
Title: Acoustics source localization: Exploring theory and practice  
Advisor: Prof.dr.ir. A. de Boer & Dr.ir. M.H.M. Ellenbroek  
Date: 2009, November 18  
Current position: MicroFlown, Zevenaar, NL

Name: Koopman, A.J.  
Title: Analysis tools for the design of aluminium extrusion dies.  
Date: 2009, June 11  
Current position: Alko Engineering, Enschede, NL

Name: Riel, M. van  
Title: Strain path dependency in sheet metal. Experiments and models.  
Advisor: Prof.dr.ir. J. Huetink & Dr. ir. A.H. van den Boogaard (ISBN 978-90-77172-50-6). (134 pag.)  
Date: 2009, August 28.  
Current position: Movaris, Utrecht, NL

10. **Keynote lectures and seminars**

Wijnant Y.H.  
Invited lecturer at seminar 'Energy Dissipating Materials for Vibration Damping' organized by IOP Institute of Physics, UK at Rolls Royce in Derby, UK, June 17th 2008.

11. **Memberships:**

11.1 **Editorial boards international journals**

Prof.Dr.ir. J. Huétink:  
- International Journal of Material Forming
11.2 International scientific committees

Prof. Dr. ir. J. Huétink
- Member of the NUMIFORM Steering Committee
- Member Board of directors ESAFORM, European Scientific Association for Material Forming
- Chairman of the Esaform 2009 conference.
- Member of the ECCOMAS Scientific Committee
- Member of the METAL FORMING Conference Scientific Committee
- Member of the NUMISHEET Conference Scientific Committee

Prof. Dr. ir. A. de Boer
- Netherlands representative in the Programme Committee of ICAS (International Council of Aerospace Sciences).
- Member of the Scientific committee of ISMA (International Seminar on Modal Analyses), KU Leuven.
- Member of Advisory committee IOP ‘Self Healing Materials’
- Member of the ‘Huygens Scholarship Programme’ selection committee

Dr. ir. A.H. van den Boogaard
- Member Board of directors ESAFORM, European Scientific Association for Material Forming
- Chairman of the Esaform 2009 conference organising committee.
- Member of the Scientific Committee of ESAFORM,
- Member of the NUMIFORM Scientific Committee
- Member of the NUMISHEET Conference Scientific Committee

Dr. ir. V.T. Meinders
- Member of the Scientific Committee of ESAFORM, European Scientific Association for Material Forming
- Member of the NUMISHEET Conference Scientific Committee
- Member of the ESAFORM conference organising committee

Dr. ir. H.J.M. Geijselaers
- Member of the NUMIFORM Scientific Committee
- Member of the ESAFORM conference organising committee

11.3 National Science Foundation and Academies

Prof. Dr. ir. J. Huétink
- Member of the Hollandsche Maatschappij der Wetenschappen,
- Cluster Co-ordinator of the Materials Innovation Institutes, M2i
- Member of the M2i program committee.

12. Awards and patents

Ooijevaar T.H.
- Corus jong talent prijsuitgereikt door Koninklijke Hollandsche Maatschappij der Wetenschappen
13. Overview of research input and output

13.1 Input “Applied Mechanics” related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior academic staff</td>
<td>9</td>
<td>-</td>
<td>-</td>
<td>9 2.1</td>
</tr>
<tr>
<td>Supporting staff 2)</td>
<td>1.5</td>
<td>-</td>
<td>0.5</td>
<td>2 -</td>
</tr>
<tr>
<td>PhD 3)</td>
<td>1</td>
<td>3</td>
<td>20</td>
<td>24 18.4</td>
</tr>
<tr>
<td>Postdocs</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4 3.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11.5</strong></td>
<td><strong>3</strong></td>
<td><strong>24.5</strong></td>
<td><strong>38 23.7</strong></td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University 2: STW, NWO, FOM 3: Industry, TNO, EC-funds, Nuffic, Senter, M2i/NIMR, DPI etc.
2) No research input involved for supporting staff.
3) Research input for PhD per year: 0.8 fte

13.2 Output “Applied Mechanics” related to EM, 2009

<table>
<thead>
<tr>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
</tr>
<tr>
<td>Scientific publications: Books, chapters in book</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
</tr>
<tr>
<td>PhD theses</td>
</tr>
</tbody>
</table>

* In co-operation with other EM-groups
12. RESEARCH DOCUMENTATION OF GROUP SURFACE TECHNOLOGY and TRIBOLOGY

1. University/Faculty

University of Twente
Faculty of Engineering Technology

2. Subprogrammes related to research school EM

2.1 Tribology
2.2 Surface Technology and Roughness
2.3 Materials and Coatings
2.4 Experimental Validation
2.5 Bio-Tribology

3. Group director

Prof.dr.ir. D.J. Schipper

4. Senior academic staff: name, position, research input in fte related to research school EM

Heide, Prof.dr.ir. E. van der
Professor
0.1
Masen, Dr.ir. M.A.
Assistent Professor
0.3
Rooij, Dr.ir. M.B. de
Associate Professor
0.3
Schipper, Prof.dr.ir. D.J.
Full Professor
0.3

Total fte: 1.0

5. PhD- projects related to research school EM 2009: name, source of financing, project title and research theme EM

5.1 Tribology
Bosman, Ir. R. (PhD 3) Bosch-mild-Wear CoEM
Cracaoano, MSc. I. (PhD 3) CVT-Wear CoEM
Popovici, MSc. R.I. (PhD 3) AdRem Slippery Tracks ReOp
Tauviqirrahman, MSc. M, (PhD 1) Lubricated MEMS CoEM
Woldman, Ir. M. (PhD 3) Abrasive wear ReOp

5.2 Surface Technology and Roughness
Dillingh, Ir. E.C (PhD 3) Friction and Roughness Transfer CoEM
Ismail, MSc R. (PhD 1) Running-in ReOp
Yaqoob, MSc A. (PhD 2) Stick-slip single asperity CoEM

5.3 Materials and coatings
 Arnaldo del Cerro, MSc D  (PhD 3) Hydrophobic/hydrophlic surfaces  CoEM
 Dollevoet, Ir. R.P.B.J.  (PhD 3) Head checks  CoEM
 Ma, MSc X.  (PhD 2) Aluminium extrusion  CoEM
 Moodij, Ir. E.  (PhD 3) Hydrostatische Magnesium Extrusie  ReOp
 Valefi, MSc M.  (PhD 2) Self-healing surfaces  CoEM
 Rodriguez, MSc N.  (PhD 3) Reinforced Rubber  CoEM

5.4 Experimental Validation
Karupannasamy, Msc D.  (PhD 3) Friction multiple scale  CoEM
Linde, Ir. G. v.d.  (PhD 3) Galling Performance Indicator  CoEM
Vries, Ing. E.G. de  (PhD 1) Cryogenic Tribology  CoEM

5.5 Bio-Tribology
Veijgen, drs.ing. N.  (PhD 3) Skin-object friction device  ReOp
Kuilenburg, Ir. J. van  (PhD 3) Comfort  CoEM

6. Postdocs: name, country, project title, research theme EM and period of stay
Dr. ir. J. Jamari  Indonesia, Running-in of surfaces  7 months  CoEM
Dr. ir. J. Song  China, Self healing ceramics  6 months  CoEM

7. Short description of subprogrammes related to research school EM

The subject of research of the surface technology and tribology group is the interaction of surfaces and engineering practices related thereto. The nature of the interaction between the opposing surfaces depends on the operational conditions. Therefore: different lubrication regimes are distinguished: A) full film lubrication, mixed lubrication and boundary lubrication and B) unlubricated or dry contact. The physics describing the interaction is quite different. Since in most mechanical engineering applications all regimes are encountered, research is conducted in all these areas, with special attention for the transitions between regimes with respect to friction and wear. Based on modelling design tools are developed for reliable and accurate prediction of tribological behaviour in practical applications. The main subjects are I) Lubricated systems, II) Materials and Coatings and III) Skin-Tribology. In 2009 A new topic is initiated: Tribology Based Maintenance.

7.1 Tribology
The research conducted in this subprogramme deals with the frictional behaviour in lubricated contacts. The local interaction between the opposing surfaces is studied by developing elastic-plastic contact models. On the basis of the models developed Strubeck curves can be predicted for lubricated contacts. With these models one is able, in combination with the critical contact temperature hypothesis, to predict the load carrying capacity of lubricated systems. Also with this model the influence of wear (a few micrometer wear depth) on friction in lubricated concentrated contacts can be predicted. For systems set in motion or set still friction is determining the position of a system. Within this subprogram attention is paid to single and multi-asperity contact. Related to research theme: “Computational and Experimental Mechanics”.

7.2 Surface technology and Surface Roughness
Surface roughness has a significant influence on the tribological behaviour (friction and wear) of a system. Therefore, the prediction of the change in roughness, running-in, as a function of the operational conditions is one of the topics which is under investigation by the surface technology
and tribology group. A deformation model is developed for the contact between a rolling hard spherical body in contact with a rough soft surface. On the basis of this model one can determine what the initial roughness should be to generate a certain roughness level during operation. This model will be extended for a rolling/sliding ball on a flat situation. In certain applications the surface roughness should not change too much in order to maintain a certain friction level. This change in roughness is the result of local deformation and the wear mechanism involved. For certain applications, as for instance in sheet metal forming, transfer of sheet material to the tool changes the micro-geometry of the tool significantly and as a result friction changes during operation.

Related to research themes: “Computational and Experimental Mechanics” and “Reliability and Optimization”.

7.3 Materials
The research focuses on the development of self healing nano-scale oxide ceramic (alumina, zirconia and their composites) couples with low friction by adding metal oxides to the ceramics during material processing. A thin interfacial layer forms between the opposing surfaces during rubbing. The mechanism of the interfacial layer formation is studied in order to optimize the ceramic material with respect to self healing.

In sheet metal forming processes the type of lubricant and coatings are becoming more and more important. The modeling with respect to friction and wear focuses on local ploughing, cutting and wedge formation. Wear is experimentally studied with a surface force apparatus and will be compared with the model. The galling phenomenon is studied for the aluminium extrusion and hydrostatic magnesium extrusion process. For the latter process the influence of the fluid is studied extensively. Related to research themes “Computational and Experimental Mechanics” and “Reliability and Optimization”.

7.4 Experimental Validation
Different friction and wear models are developed which are validated by experiments. For certain processes, as for instance cold rolling, models are available which are not validated by experiments yet. In this research measurement techniques will be developed to measure friction and wear under specific operational conditions. Attention is for instance paid to measure 1) semi on line micro-wear by using a tribotester connected to an interference microscope and 2) friction in wheel rail contact. Next, measurement techniques are developed to measure the material transfer of the sheet to the tool by using interference microscopy and a surface force apparatus. Further, research takes place with respect to the tribological behaviour of materials in systems operating under cryogenic circumstances. A cryogenic tribotester is build for this purpose as well as a high vacuum single asperity tribotester. Related to research themes “Computational and Experimental Mechanics” and “Reliability and Optimization”.

7.5 Bio-Tribology
Research is started on the topic “skin - object interaction”. To design a product based on comfort, in which contact takes place between skin and product like artificial grass or a shaver, the designer has no “tools”. In this research a design comfort diagram will be developed based on a thermal-, mechanical- and skin parameter. As a start a non-isotropic visco-elastic elastic contact model as well as a portable friction device is developed. Related to research theme “Computational and Experimental Mechanics”.

133
8. Refereed scientific publications related to research school EM

8.1 Refereed journals


Popovici, RI & Schipper, DJ, 2009, ”Modelling contact phenomena and those influenced by greases”, Eurogrease, pp. 17-26


8.2 Books, chapters in book

-  

8.3 Refereed proceedings


Popovici, RI & Schpper, DJ (2009). ”Modelling contact phenomena and those influenced by greases”, Eurogrease, pp. 17-26


Contact on Multilayered Solids,” The 6th International Conference on Numerical Analysis in Engineering, Mataram, Nusa Tenggara Barat, Indonesia, Proceeding will be available Dec 2009


Li, Z, Arias Cuevas, O & Dollevoet, RPBJ (2009). Relation between Head Checks Initiation, Growth and Operational Loading Conditions, 9th International Heavy Haul Association (IHHA) Specialist Technical Session, Shanghai China


9. Dissertations: related to research school EM: name, title, university, date and advisors
   -

10 Keynote lectures and seminars
   -

11 Memberships

11.1 Editorial boards international journals

   D.J. Schipper:
   - Editorial board: Lubrication Science (ISSN 0954-0075)
   - Editorial board: TriboTest (ISSN 1354-4063)
   - Editorial board: Industrial Lubrication and Tribology (ISSN 0036-8792)

11.2 International scientific committees

   E. v.d. Heide:

   M.A. Masen:
   Member committee of the Institute of Physics Tribology group.
   Member CEN ISO TR11811 Guidance on Conducting NanoTribology Experiments.

   D.J. Schipper:
   International research group on wear of engineering materials (IRG-OECD).
   Member CEN ISO TR11811 Guidance on Conducting NanoTribology Experiments.

11.3 National Science Foundation and Academies

   D.J. Schipper, chairman “Bond van Materialenkennis, Tribologie sectie”.
   M.B. de Rooij, secretary “Bond van Materialenkennis, Tribologie sectie”.

12. Awards and patents

   Wallenberg award.

13. Overview of research input and output

13.1 Input “Tribology” related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing</th>
<th>Total</th>
</tr>
</thead>
</table>

---

136
<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>number</th>
<th>Fte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Senior academic staff</td>
<td>4</td>
<td></td>
<td></td>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>Supporting staff</td>
<td>2</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>PhD</td>
<td>3</td>
<td>3</td>
<td>13</td>
<td>19</td>
<td>15.2</td>
</tr>
<tr>
<td>Postdocs</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>4</td>
<td>14</td>
<td>27</td>
<td>17</td>
</tr>
</tbody>
</table>

1) Sources of financing:  
   1: University  
   2: STW, NWO, FOM  
   3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

4) Research input for PhD per 0.5 year: 0.4 fte

13.2 Output “Tribology” related to EM, 2009

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
<td>4</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>-</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>19</td>
</tr>
<tr>
<td>PhD theses</td>
<td>-</td>
</tr>
</tbody>
</table>

* In co-operation with other EM-groups.
13. RESEARCH DOCUMENTATION OF GROUP MECHANICAL AUTOMATION

1. University/Faculty

University of Twente
Faculty of Engineering Technology (CTW)

2. Subprogrammes related to research school EM

2.1 Robotics and Micro Mechatronic Systems
2.2 Vibration isolation control

3. Group director

Prof. Dr. C. De Persis
Prof. Dr. ir. J. B Jonker

4. Senior academic staff: name, position, research input in fte related to research school EM

Aarts, Dr.ir. R.G.K.M.        Associate Professor          0.2
Dijk, Dr.ir. J. van        Assistant Professor          0.2
Jonker, Prof.dr.ir. J.B.        Full Professor          0.2

Total fte: 0.6

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

5.1 Robotics and Micro Mechatronic Systems
Boer, Ir. S.E.        (PhD 3)        MOtion in Vacuum by Elastic mechanisms and Tribology (MOV-ET)

6. Postdocs: name, country, project title, research theme EM and period of stay

Dr.ir. J.P. Meijaard        CLEMPS project, TheNetherlands        StDy
October 2008 –March 2011

7. Short description of subprogrammes related to research school EM

The research topics of the group Mechanical Automation related to the speciality of Engineering Mechanics can be summarised as:
7.1  **Robotics and Micro Mechatronic Systems**

The dynamic behaviour of (industrial) robots and (micro) mechatronic systems is investigated. For analyses and efficient simulations the computer program “SPACAR” has been developed. It is based on a non-linear finite element method to analyse and simulate the kinematics and dynamics of mechanisms and manipulators or, more generally, multibody systems with non-linear behaviour due to large displacements and/or rotations. In this approach mechanisms may be composed of both rigid and flexible components. Locally linearised models can be derived to study e.g. natural frequencies and vibration modes.

The low-dimensional models that are obtained in this way appear to be particularly suited to obtain prototype models of the mechanical part of a mechatronic system. For control synthesis of such systems it is essential to make use of simple prototype models with a few degrees of freedom that nevertheless capture the relevant three-dimensional system dynamics.

Manipulators in Micro Electro-Mechanical Systems (MEMS) typically make use of elastic members for predictable behaviour as elastic mechanisms are characterised by low hysteresis, zero backlash and no friction. The main goals of the CLEMPS project are the mechatronic design, realisation and validation of a closed loop system with a MEMS device.

MEMS are manufactured in a clean room. Therefore the cost of prototyping and the time consumed in the clean room is high compared to ordinary devices. Consequently modelling should be used to reduce the cost and time of making the device. The mechanical structures in MEMS are created in silicon or silicon nitride. These materials allow much larger strains than metals. Therefore relatively large deformation of the elastic members is allowed. The above mentioned finite element approach implemented in the computer program “SPACAR” has proved to be particularly suited for the analysis of (lateral) buckling and stiffness decrease of elastic mechanism members in MEMS.

In the MOV-ET project manipulator concepts are investigated to realise high precision motion in vacuum. Our contribution to this project focuses on the use of elastic (or compliant) manipulators. These offer the advantages of motion with low friction and no backlash. However, to realise relatively large strokes, the elastic joints will exhibit non-linear behaviour. In particular the support stiffness decreases significantly which causes a deterioration of the system’s performance. SPACAR models are applied to optimise the design of new joint concepts such that a high support stiffness is combined with a low actuation stiffness in the full operating range and with acceptable stresses in the elastically deformed parts. Furthermore, these models can detect overconstraint or underconstraint system design and offer insight to avoid these conditions.

Related to the research theme "Structural Dynamics and Control".

7.2  **Vibration isolation control**

The tendency towards miniaturization in precision technology leads to a constant decrease in accuracy specifications for precision machines. Disturbances, often produced by vibrations of the floor, machine parts or acoustics, are becoming an increasing problem. In order to cope with future accuracy demands for precision machinery a (better) solution for these vibrations is required.

The aim of the research project on “Design of smart mount for application of vibration isolation in precision machinery” is to increase the isolation performance by the application of different concepts of active vibration isolation control and active damping as well as the formulation of design principles for mechanical realizations of mounts. The mounts consist of an active subsystem of actuators, sensors and a control strategy next to the mechanical structure. The active subsystem uses measurements to generate anti-forces in the mount which are opposite to the excitation forces.
Control strategies in vibration control have been investigated experimentally with a three dimensional set-up. This set-up consists of a source plate excited by piezo-actuators. Vibrations from the source pass through the three mounts to the receiver frame. Source plate and receiver frame accelerations are measured by 12 accelerometers and 6 actuators produce forces based on the sensor signals that counteract the forces due to vibrations. In this manner the source is isolated from the receiving construction. Next to the described feedforward control strategy a feedback strategy is added to provide damping of the internal modes of the receiver frame.

This project will be concluded with a PhD defence in 2010.

Related to the research theme "Structural Dynamics and Control".

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


8.2 Books, chapters in book

Dijk, J van (2009). Mechatronic design of hard-mount concepts for precision equipment, in Motion and Vibration Control, Ulbrich, H, Ginzinger, L (Eds.) 315-324, Springer München, Book Chapter

8.3 Refereed proceedings


9. **Dissertations: related to research school EM: name, title, university, date and advisors**

- 

10. **Keynote lectures and seminars**

Poel, GW van der. Active vibration isolation using stiff supports, Philips Conference on Applications of Control Technology (PACT), Hilvarenbroek, February, 3-4, 2009.

11. **Memberships:**

- 

  11.1 **Editorial boards international journals**

- 

  11.2 **International scientific committees**

- 

  11.3 **National Science Foundation and Academies**

- 

12. **Awards and patents**

- 

13. **Overview of research input and output**

13.1 **Input “Mechanical Automation” related to EM, 2009**

<table>
<thead>
<tr>
<th>Sources of financing 1)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>3</td>
</tr>
<tr>
<td>Supporting staff 2)</td>
<td>-</td>
</tr>
<tr>
<td>PhD 3)</td>
<td>-</td>
</tr>
<tr>
<td>Postdocs</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
</tr>
</tbody>
</table>

1) Sources of financing: 1) Total, 2) Senior academic staff, 3) Supporting staff, PhD, Postdocs.
1) Sources of financing:  
1: University  
2: STW, NWO, FOM  
3: Industry, TNO, EC-funds, Nuffic, Senter, M2i, DPI etc.  

2) No research input involved for supporting staff.  
3) Research input for PhD per year: 0.8 fte

13.2 Output “Mechanical Automation” related to EM, 2009

<table>
<thead>
<tr>
<th>Scientific publications: refereed journals</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>1</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>6</td>
</tr>
<tr>
<td>PhD theses</td>
<td>-</td>
</tr>
</tbody>
</table>

*In co-operation with other EM-groups
14. RESEARCH DOCUMENTATION OF GROUP PRODUCTION TECHNOLOGY

1. University/Faculty

   University of Twente
   Faculty of Engineering Technology

2. Subprogrammes related to research school EM

   2.1 Automated Composites Manufacturing
   2.2 Performance of Advanced Materials

3. Group director

   Prof.dr.ir. R. Akkerman

4. Senior academic staff: name, position, research input in fte related to research school EM

   Akkerman, Prof.dr.ir. R.  
   Bor, Dr.ir. T.C.  
   Dijk, Dr.ir. D.J. van  
   Warnet, Dr.ir. L.

   Full Professor  0.4
   Assistant professor  0.3
   Assistant professor  0.1
   Assistant professor  0.3

   Total fte:  1.1

5. PhD-projects related to research school EM per December 2009: name, source of financing, project title and research theme EM

   5.1 Automated Composites Manufacturing

      Cornelissen, Ir. B (PhD 2)  
      Grouve, Ir. W.J.B. (PhD 3)  
      Haanappel, Ir. S.P. (PhD 3)

      Tow Mechanics  CoEM
      Laser Assisted Tow Placement  CoEM
      Complex Stamp Forming  CoEM

   5.2 Performance of Advanced Materials

      Ooijevaar, ir. T. (PhD 3)  
      Paternoster, A.R.A. (PhD 3)  
      Ravanan, M. (PhD 3)  
      Sridhar, Ir. A. (PhD 3)  
      Stelt, ir. A.A. van der (PhD 3)  
      Visser, Ir. H.A. (PhD 3)

      Vibration based Structural Health Monitoring  CoEM
      Intelligent Rotor Blades  CoEM
      Ultrasonic Inspection of Thermoplastics  CoEM
      Long term performance of inkjet printed electronics  CoEM
      Friction Stir Processing  CoEM
      Long Term Performance of Thermoplastics  CoEM

6. Postdocs: name, country, project title, research theme EM and period of stay
6.1. \textit{Automated Composites Manufacturing}
Thije, Dr.ir. R.H.W. ten. Transverse shear in composites forming October 2007 – December 2009 CoEM

6.2. \textit{Performance of Advanced Materials}
Parlapalli, Dr. M. Self Healing Materials July 2007 – Jan 2009 CoEM
Christoulis, Dr. D. Friction Stir Processing December 2008 – November 2010 CoEM
Demcenko, Dr. A. Ultrasonic Inspection of Thermoplastics June 2009-May 2011 CoEM
Ivanov, Dr. S. Self Healing Materials July 2009-June 2011 CoEM
Koissin, Dr. V. Transverse Reinforcement of Composite Materials May 2009-April 2012 CoEM
Perdahcioglu, Dr. S. Self Healing Materials January 2009-November 2009 CoEM

7. \textbf{Short description of subprogrammes related to research school EM}

Research in the Production Technology group addresses the technical issues of new products and new processes. The group focuses on the optimisation of both the manufacturing process and the product performance.

‘Processing’ and ‘Product performance’ of lightweight materials in structural applications characterise the main research themes of the Production Technology group. In our view processing and performance can be optimised after thorough analysis and modelling in combination with a firm experimental programme. The experiments identify the operating mechanisms, establish relevant material property data for the modelling and provide data to test the accuracy of the models proposed. An integral approach is pursued, taking into account the interrelations between the geometric design, the production process and the material properties.

In the year 2009, many new research projects were started. Various PhD students started within the EU Clean Sky initiative, developing technologies for greening air transportation: less fuel consumption and less noise. In this year also the ThermoPlastic composite Research Centre TPRC was founded in Twente by Boeing, Stork Fokker, Ten Cate and UT. TPRC aims to advance TPC technology towards automated processing with controlled repeatable product quality, supported by novel CAE tools to include process constraints in the design phase.

Two subprogrammes are distinguished: Automated Composites Manufacturing and Performance of Advanced Materials.

7.1 \textit{Automated Composites Manufacturing}
The first research theme is concerned with the cost-effective application of advanced continuous fibre reinforced composites. The breakthrough of this type of materials in various applications has occurred to a smaller extent than might have been expected, mainly due to their high costs of manufacturing. Thermoplastic composites in particular have the potential to overcome these hurdles.

In general, research in the PT group starts from of a thorough analysis of the deformation and flow mechanisms involved during manufacturing and the modelling of these mechanisms. Design tools are developed to support the production of composite structures with modern techniques.
The aim of these design tools is mostly to optimise the process settings in order to obtain a composite component having a prescribed shape or combination of materials properties.

**High Precision Composites Moulding**

Friction in composite forming processes, both between successive composite layers and between the laminate and the tools, was characterised experimentally, as part of a post-doctoral research project. Multiscale models (solving Reynolds’ equation at the meso level) appear to capture the phenomena observed during the experiments. After redesigning the friction test set-up, Dr. ten Thije determined accurate friction data (as a function of pressure, sliding velocity and temperatures up to 400°C), implemented an appropriate model in the FE code and validated the model with press forming experiments.

After concluding the project on thermoplastic composite consolidation Ir. W. Grouve continued research on the laser assisted tape placement process within the Clean Sky initiative. Here, the aim is to consolidate the thermoplastic tape ‘in situ’ after rapid local heating by means of fibre lasers.

The mechanical behaviour of fibre bundles during textile composite processing is subject of the PhD research by Ir. Cornelissen. The microscale phenomena between the filaments are being investigated in order to predict the mesoscopic behaviour of the bundles during e.g. tension, bending, shear and compaction of technical textiles.

Ir. Haanappel started on a project within the TPRC on ‘complex stamp forming’, focusing on press forming of locally reinforced (i.e. tailored) thermoplastic composite blanks, manufactured by a tape placement process. Constitutive models have to be developed for these unidirectionally reinforced materials at forming temperatures, implemented in a robust manner and characterised accurately.

### 7.2 Performance of Advanced Materials

The second research theme involves a better understanding of the mechanics of new materials, focusing on the physical properties of the component and taking into account the production process used. An increasing range of properties is being considered, from thermomechanical properties such as stiffness and structural integrity, to optical and electromagnetic properties on the short and the long term. Materials with ‘added functionality’ (e.g. composite with integrated sensors and actuators or even self-healing capacity) receive growing interest.

The current research projects in this theme are:

- long term performance of thermoplastics
- active composites
- transverse reinforcement of composite materials
- long term performance of inkjet printed electronics
- friction stir processing of light metals

**Long term performance of thermoplastics**

The PT group investigates the long term performance of non-reinforced pipework. Condition Monitoring in plastic pipe gas distribution networks can assist in ‘smart maintenance’, replacing gas pipes (at the end of their design lifetime) only when necessary. Physical ageing decreases the fracture toughness which can lead to premature failure. The long term performance as measured with pressurised pipe tests can be predicted using models (dr. Govaert, TU/e) fitted with elementary experiments such as tensile and compression testing on specimens of different ages. It was shown that the brittle-to-ductile transition temperature increases with the physical age of PVC. Ir Visser finalised his PhD thesis on this subject before the end of the year. In addition, Dr Demcenko started on ultrasonic methods to determine this physical age, funded via the MEA.
Further research on this topic is funded via the TTI Wetsus. Recruiting a PhD student for this position and settling the legal formalities took considerable time, such that this project could not start before January 2010.

**Active Composites**
Dr. Perdahcioglu continued the post-doctoral research project on self healing thermoplastic composites. A finite element implementation was developed for shape memory alloy wires to simulate the self healing mechanism, combining local clamping and melting while heating and thus re-consolidating delaminated regions in the thermoplastic composite component. Another 2-year post doctoral position was filled by dr Ivanov, working on the use of supramolecular polymers (in co-operation with the group of prof. Sybesma, TU/e). The very low viscosity of these materials can be used to repair composite damage by means of heating and by filling cracks and delaminations.

Composite damage may be difficult or impossible to detect visually during regular inspection. Composite materials are, however, well suited to embed strain sensors such as fibre optics. These can in turn be employed to record changes in the dynamic response of composite structures. This information can be used to detect and localise damage, as is investigated and elaborated by ir. Ooijevaar in his Clean Sky funded project on structural health monitoring.

In addition to sensing, also actuation mechanisms can be incorporated in composite materials, leading to active light weight structures. This is investigated in the Clean Sky funded project of Paternoster MSc for the application of intelligent helicopter rotor blades. Both Clean Sky projects are conducted in co-operation with the Structural Dynamics and Acoustics group of prof. de Boer.

**Transverse reinforcement**
Carbon nanofibres can be grown on microfibres by means of catalytic deposition. This can be used in composite materials to improve the properties transverse to the fibre orientation. The four research positions within the two participating groups (PT and CPM, prof. Lefferts) were filled in the course of the year. The first efforts were devoted to scale up the CNF deposition process.

**Long term performance of inkjet printed electronics**
Phased Array Communication antenna for Mass-market Application Needs (PACMAN) aims to develop integral low cost implementations of complex technologies developed in defense and astronomy applications. The project is a co-operation with Thales, Astron and the TU/e. Ink jet printing of electronic circuits is seen as a novel cost effective enabling technology in this respect. The PT group concentrates on the mechanical performance of the deposited structures, on both the short and the longer term. Ir. Sridhar’s finalised his thesis in the end of the year.

**Friction Stir Processing**
Friction Stir Welding is a semi-solid forming process, suited for low temperature joining of e.g. aerospace Aluminium alloys. It proves to be possible to extend this process by means of adding an extra material during stir welding. Dr. Christoulis developed a set-up to realize this concept on the FSW equipment installed in the course of the year. Related to this, the PhD project of Ir. Van der Stelt focuses on process modeling in order to achieve better understanding and process optimization.

All activities within the programme are related to the research theme “Computational and Experimental Mechanics”.

8. **Refereed scientific publications related to research school EM**
8.1 Refereed journals


Visser, HA, Warnet, LL & Akkerman, R (2009). *An attempt to use scratch tests to predict the residual lifetime of unplasticised poly(vinyl chloride) pipes* Engineering Fracture Mechanics, 76(18), pp. 2698-2710


Sridhar A, Perik, MA, Reiding, J, Dijk, DJ van & Akkerman, R *Fabrication of RF Circuit Structures on a PCB Material Using Inkjet Printing-Electroless Plating and the Substrate Preparation for the Same* Transactions of The Japan Institute of Electronics Packaging, 2(1)

8.2 Books, chapters in book

- 

8.3 Refereed proceedings

Visser, HA, Bor, TC, Wolters M & Govaert LE (2009). *The influence of physical ageing on yielding and failure of unplasticised poly(vinyl chloride) pipes* Proceedings of DYFP, Rolduc Kerkrade, the Netherlands


9. Dissertations: related to research school EM: name, title, university, date and advisors

10. Keynote lectures and seminars

11. Memberships:

11.1 Editorial boards international journals

Prof.dr.ir. R. Akkerman:
Composites Structures

11.2 International scientific committees

Prof.dr.ir. R. Akkerman:
Secretary of the European Association of Material Forming ESAFORM, organising committee Esaform 2009 conference

Dr.ir. L. Warnet:
organising committee of the ESIS TC4 Conference on the Fracture of Polymers, Composites and Adhesives

Dr.ir. T.C. Bor:
organising committee of the International Conference on Self Healing Materials, organising committee Esaform 2009 conference

11.3 National Science Foundation and Academies

Prof.dr.ir. R. Akkerman:
Koninklijke Hollandse Maatschappij der Wetenschappen

12. Awards and patents

A Shridhar: Best Author Award at the 3rd Int. Conf. on Print & Media Technology in Chemnitz (Germany), “Substrate modification of a PCB substrate for better adhesion of inkjet printed circuit structures”.

T. Ooijevaar: Corus Young Talent Award, ‘Vibration based Structural Health Monitoring in fibre reinforced composites’ (co-operation with prof. de Boer).


13. Overview of research input and output 2009

13.1 Input “Production Technology” related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing 1)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>4</td>
</tr>
<tr>
<td>Supporting staff2)</td>
<td>2</td>
</tr>
<tr>
<td>PhD3)</td>
<td>1</td>
</tr>
<tr>
<td>Postdocs</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University  
2: STW, SON, NWO, FOM  
3: Industry, TNO, EC-funds, Nuffic, Senter, NIMR, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

13.2 Output “Production Technology” related to EM, 2009

<table>
<thead>
<tr>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
</tr>
<tr>
<td>PhD theses</td>
</tr>
</tbody>
</table>

* In co-operation with other EM-groups
15. RESEARCH DOCUMENTATION OF GROUP MULTI SCALE MECHANICS

1. University/Faculty
   University of Twente
   Faculty of Engineering Technology

2. Subprogrammes related to research school EM
   2.1 MultiScale Simulation Techniques
   2.2 Instability in multiScale materials
   2.3 Structural Dynamics and Acoustic
   2.4 Mechanics of Forming Processes
   2.5 Discrete particle self-healing material models

3. Group directors
   Prof.dr. S. Luding

4. Senior academic staff: name, position, research input in fte related to research school EM
   Bertoldi, Dr. K. Assistant Professor 0.50
   Thornton, Dr. A. Assistant Professor 0.25
   Steeb, Dr. H. Visiting Professor 0.10
   Luding, Prof.dr. Full Professor 0.50
   Total fte: 1.35

5. PhD- projects related to research school EM per December 2009: name, source of financing, project title and research theme EM
   5.1 MultiScale Simulation Techniques
      Yazdchi, K PhD (2) Hierarchical Multi-Scale Modeling CoEM
   5.2 Instability in multiScale materials
      Göncü, F PhD (3) Instability induced pattern switches in granular crystals CoEM

6. Postdocs: name, country, project title, research theme EM and period of stay
   Srivastava, Dr. S. Hierarchical Multi-Scale Modeling CoEM
      August 2009 - August 2011
   Weinhart, Dr. T. Computational multi-scale modeling CoEM
7. Short description of subprogrammes related to research school EM

7.1 MultiScale Simulation Techniques

7.1.1 Hierarchical MultiScale Modeling
This research will be at the junction of three areas: Dynamic unstructured grids and their refinement, hierarchical data structures for coarsening and micro-macro methods, and coupling of various techniques and fields across the scales. The idea is to provide new ways of coupling between particle and continuum methods, for multi-scale modeling, not only relying on a future increase of available computing power, but also keeping massive parallelization in mind. At present, hierarchical hash tables for efficient simulation of poly-disperse systems and FEM/DEM coupling for fluid particle interaction problems e.g. porous media, fluidized beds is being explored.

7.1.2 Computational methods for scale bridging in composite materials
The computational modeling of fracture in composites, concrete, and other cohesive granular materials will be performed and analyzed following a hierarchical multi-scale approach, involving parallelization and tree-data-structures for both the particle analysis and the continuum analysis. A question from the mechanics side is the understanding of the formation of cracks and the ability to predict the conditions (mechanical, environmental) under which they occur or are triggered. Are the small scales more important than the large ones? This makes crack growth (from its initial micro-state up to dimensions leading to failure of a material or a structure) a research issue of paramount importance – and a challenge from the algorithmic and numerical point of view.

7.1.3 Jamming and Creep in Granular Materials
The project is addressed to probe the connections between jamming, creep, shear banding and microstructures in numerical simulations of Brownian and non-Brownian systems with various interaction forces, shear rates, stress regimes at multiple scales.

7.1.4 Computational multi-scale modelling of super-dispersed multiphase flows
The goal of the research is the development of good numerical models for dry granular flow, which is of interest in many industrial processes and geophysics. Granular material shows both solid and fluid behavior. Closed continuous models for granular flow only exist for certain cases, while Discrete Particle Models (DPM) are unfeasible for large-scale simulations. Therefore the work focuses on a DG finite element model for heterogeneous multiscale modelling of polydisperse, nonuniform dry granular flows, which allows both efficient and reliable numerical simulations.

7.2 Instability in multiScale materials
Traditionally instabilities have been viewed as an inconvenience, with research focusing on how to avoid them. Instead they can be exploited to create new materials with improved and
switchable properties. Many technological applications, including acoustics, optics and electronics, require the development of new materials with improved and possibly even tunable properties. Particular attention is reserved to materials characterized by a regular micro-structure. Both Nature and technological applications make extensive use of materials to achieve different properties and attributes. Examples are given by phononic/photonic crystals, sensors, superhydrophobic surfaces and the surface structure of beetles and fishes. We explore the nonlinear microscopic behavior and failure of such materials. This investigation will pave the road to the use of the pattern switch occurring at instability for creating a new class of materials with switchable functionalities.

7.2.1 Instability induced pattern switches in granular crystals
The specific project refers to the investigation of large deformation behavior of two and three-dimensional granular crystals consisting of elastic and rigid particles. The investigation takes the form of numerical and experimental tests, which confirm the existence of global pattern transformation triggered by the applied load. The findings have consequences for the fabrication of tunable granular meta-materials and energy and shock absorbers. The implementation of a continuum model able to describe the evolution of the material structure is a further goal of the project.

7.3 Structural Dynamics and Acoustic (Prof.dr. S. Luding)
In this project sound wave propagation through different types of dry confined granular systems is studied with three-dimensional discrete element simulations, theory and experiments. The influence of several micro-scale properties: friction, dissipation, particle rotation, and contact disorder, on the macro-scale sound wave propagation characteristics are investigated. Experiments, analyzed with the “Spectral Ratio Technique”, make it possible to extract frequency-dependent propagation velocities and attenuation. An improved set-up for future investigations is proposed in order to better understand dispersion and propagation of sound in granular materials. The full dispersion relation of a Face-Centered-Cubic lattice is derived from a theoretical analysis that involves translations, tangential elasticity, and rotations. The additional displacement and rotation modes and the energy conversion between them is studied using discrete element simulations. Simulations and theory are in perfect quantitative agreement for the regular lattices examined. As a first small step away from order, systems with weak geometrical disorder (system structure) but strong contact disorder, i.e. with an inhomogeneous contact force distribution, are studied next. They reveal nicely the dispersive nature of granular materials and show strong frequency filtering. Low frequencies propagate, whereas high frequencies vanish exponentially. A more detailed study of how energy is transferred between different wavenumber bands shows linearly increasing transfer rates for increasing wavenumbers. A first theoretical approach using a linear Master Equation leads to a quantitative prediction of the energy evolution per band for short times.

A bigger second step in complexity is made by investigating the sound propagation in a realistic tablet made of a sintered frictional and cohesive polydisperse powder and prepared in different ways. These simulations nicely display history dependence and the effect of different material parameters on sound propagation in particulate solids.

7.4 Mechanics of Forming Processes

7.4.1 Non-Newtonian behavior of granular flows in nano-channels
Highly confined fluid or particle flows typically show strongly non-Newtonian behavior. A channel geometry is often used to study the inhomogeneous behavior of strongly confined fluids. The understanding of these non-Newtonian fluid problems is still very limited, while gaining a deeper insight into these systems is becoming increasingly important with the rise of microfluidic and
nanofluidic applications, such as lab-on-a-chip device. Very similar phenomenology (i.e. layering, anisotropy) is observed in many particle systems. The goal of the study is to investigate the non-Newtonian transport properties of granular flows, investigate the effect of wall-fluid interaction, surface roughness and wall-morphology on the material behavior. Molecular dynamics simulations are used to investigate various physical properties.

### 7.4.2 Size segregation in dense granular avalanche flows

Dense, dry granular avalanches are very efficient at sorting the larger particles towards the free surface of the flow, and finer grains towards the base, through the combined processes of kinetic sieving and squeeze expulsion. This generates an inversely graded particle-size distribution, which is fundamental to a variety of pattern formation mechanisms, as well as subtle size-mobility feedback effects, leading to the formation of coarse-grained lateral levees that create channels in geophysical flows, enhancing their run-out. A continuum model of size segregation for dense granular free surface flows have been developed. A large number of analytical and numerical solutions to these equation have been constructed and compared to experiments. The focus of this research is now on using this model to explain phenomena caused by segregation. These include pattern formation in rotation drums, levee formation in geophysical flows, particle size structure of a flowing finite mass of material in avalanches and axial segregation in long rotating cylinders.

### 7.4.3 Modeling of Long-range interaction forces and clustering

Clustering in granular material is since long a hard topic. It is a generic and paradigmatic example for the special behavior and properties of granular matter: long and high densities co-exist, large gradients and shocks occur, both solid and liquid-like behaviors are observed inside the clusters. The objective of the project is to develop a three dimensional Molecular Dynamics (MD) environment and hydrodynamic theory for modeling long-range interaction forces based on hierarchical algorithms, to reproduce clustering of particles.

### 7.5 Discrete particle self-healing material models

Using an advanced history dependent contact model for DEM simulations, including elasto-plasticity, viscosity, adhesion, and friction, pressure-sintered tablets are formed from primary particles. These tablets are subjected to unconfined uni-axial compression until and beyond failure. For fast and slow deformation we observe ductile-like and brittle softening, respectively. We propose a model for local self-healing that allows damage to heal during loading such that the material strength of the sample increases and failure/softening is delayed to larger strains. Local healing is achieved by increasing the (attractive) contact adhesion forces for those particles involved in a potentially breaking contact. We examine the dependence of the strength of the material on

(a) the damage detection sensitivity,
(b) the damage detection rate, and
(c) the (increased) adhesion between healed contacts.

The material strength is enhanced, i.e. the material fails at larger strains and reaches larger maximal stress values, when any of the parameters (a) – (c) is increased. For moderate damage detection sensitivities, the material strength increases with both increasing healing rate and increasing adhesion of the healed contacts. For very large adhesion between the healed contacts
an interesting instability with strong (brittle) fluctuations of the healed material’s strength is observed.

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


8.2 Books, chapters in book


8.3 Refereed proceedings


9. Dissertations: related to research school EM: name, title, university, date and advisors

Name: Mouraille, O.J.P.
Title: *Sound propagation in dry granular materials: discrete element simulations, theory and experiments*
Advisor: Prof. dr. S. Luding
Date: 2009, 27 February
Current position: ASML – Eindhoven
10. **Keynote lectures and seminars**


Melchels, FPW. (Polymer Chemistry and Biomaterials (PBM)), Bertoldi, K. (Multiscale mechanics (MSM)), Feijen, J. (Polymer Chemistry and Biomaterials (PBM)) & Grijpma, D. W. (Polymer Chemistry and Biomaterials (PBM)) (2009). Mechanical properties of advanced tissue engineering scaffold architectures. 2nd Netherlands biomedical engineering conference: Egmond aan Zee (NL) (2009, January 23).

11. **Memberships:**

11.1 **Editorial boards international journals**

Prof.dr. S. Luding
- Multiscale mechanics (MSM) Managing Editor in Chief (2009). *Granul. matter, (ISSN 1434-5021), 11(1-6).*

11.2 **International scientific committees**

Prof.dr. S. Luding
- 2009-2009 Int.Congres International Conference for Conveying and Handling of Particulate Solid.: Queensland Australia (2009, August 2)
- 2009-2009 Int.Congres Organisation Lorentz Center Conference
- 2009-2009 Int.Congres Organisation Powders and Grains 2009
- 2002- Member Board VDI-GVC Fachausschuss Agglomerations und Schuettguttechnik
- AEMMG - Association pour L'Etude de la Micromecanique des Milieux Granulaires
- 2006- Member Board IFMCGM - Intl. Federation of Measurement and Control of Granular Media
11.3 National Science Foundation and Academies

12. Awards and patents

13. Overview of research input and output

13.1 Input “Multi Scale Mechanics” related to EM, 2009

<table>
<thead>
<tr>
<th>Sources of financing</th>
<th>Total</th>
<th>Fte</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Supporting staff</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>PhD</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Postdocs</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

1) Sources of financing: 1: University  
2: STW, SON, NWO, FOM  
3: Industry, TNO, EC-funds, Nuffic, Senter, NIMR, DPI etc.

2) No research input involved for supporting staff.

3) Research input for PhD per year: 0.8 fte

13.2 Output “Multi Scale Mechanics” related to EM, 2009

<table>
<thead>
<tr>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
</tr>
<tr>
<td>Scientific publications: Books, chapters in book</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
</tr>
<tr>
<td>PhD theses</td>
</tr>
</tbody>
</table>

* In co-operation with other EM-groups