Research documentation per participating group
2. RESEARCH DOCUMENTATION OF THE GROUP
SYSTEM 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
2.3 Structural Optimization
2.4 Automotive Technology
2.5 Mechanical Design
2.6 Systems Design Optimization
2.7 Control of Manufacturing Systems
2.8 Nonlinear and Hybrid Dynamics

3. Group directors
Prof.Dr. H. Nijmeijer
Prof.dr.ir J.E. Rooda
Prof.Dr.Ir. M. Steinbuch

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

Besselink, Dr.Ir. J.J.M. UD (0.4) main position at TNO-TPD 0.2
Campen, Prof.Dr.Ir. D.H. van Full Professor (PM) main position Dean TU/e-W p.m.
Etman, Dr.ir L.F.P. UD 0.4
Fey, Dr.Ir. R.H.B. UD 0.4
Kraker, Dr.Ir. A. de Part-time UHD (0.3) main position Dir. p.m.
Lefeber, Dr.ir E. UD 0.4
Lopez, Dr.Ir. I. UD 0.1
Nijmeijer, Prof.Dr. H. Full Professor 0.2
Nuij, Ir. P.W.J.M. UD 0.2
Pogromsky, Dr. A.Y. UD 0.4
Rijpkema, Dr. J.J.M. DU 0.1
Rosielle, Dr.Ir. P.C.J.N. UHD 0.4
Rooda, Prof.dr.ir J.E. Full Professor 0.2
Roozen, Prof.Dr.Ir. N.B. Part-time Prof. (0.2) main position at Philips 0.1
Steinbuch, Prof.Dr.Ir. M. Full Professor 0.1
Veenhuizen, Dr. P.A. UD 0.1
Veldpaus, Dr.Ir. F.E. UHD 0.1
Verheij, Prof.Dr.Ir. J.W. Part-time Prof. (0.2) main position at TNO-TPD p.m.

1 Per 2002 the activities of the previous EM groups “TU/e – Dynamics and Control Technology” and “TU/e – Systems Engineering” are combined within the new EM group “TU/e – Systems, Dynamics and Control”.

Annual Report Engineering Mechanics 2005 2.1
5. **PhD-projects related to research school EM per December 2005: name, source of financing, project title and research theme EM**

5.1 *Nonlinear Dynamics of Mechanical Systems*

Faassen, Ir. R.P.H. (PhD 3)
- Chatter in high-speed Milling

Mallon, Ir. N.J. (PhD 2)
- Dynamic stability of thin walled structures

Mestrom, Ir. R.M.C. (PhD 1)
- Dynamics of multiphysics systems

5.2 *Structural Acoustics and Noise Control*

Debiesme, M.Sc. F.X. (PhD 3)
- Design tools for low noise products with uncertain parameters

Dijkhof, Ir. W.J. (PhD 3)
- Analysis methods for low noise products with uncertain parameters

Scholte, Ir. R. (PhD 2)
- Acoustic holography

5.4 *Automotive Technology*

Bonsen, Ir. B. (PhD 3)
- Modelling and control of slip in a push-belt

Hofman, Ir. T. (PhD 2)
- Hybrid Vehicle Topology

Meerakker, Ir. K.G.O. vd (PhD 3)
- Alternative variator actuation

5.5 *Mechanical Design*

Bedem, Ir. L.J.M. v.d. (PhD 2)
- Medical Robotics

Hamelinck, Ir. R.F.M.M. (PhD 3)
- Adaptive Optics

Henselmans, Ir. R. (PhD 3)
- Fee-form optics measurement instrument

Seggelen, Ir. J.K. v. (PhD 3)
- Nano measurement machine

Veggel, Ir. A.A. van (PhD 3)
- Design of a metrology system for GAIA

Werner, Ir. C. (PhD 3)
- Large stroke AFM

5.6 *Systems Design Optimization*

Tosserams, Ir. S. (PhD 1)
- Analytical Target Cascading

Kock, Ir. A.A.A. (PhD 2)
- Effective Process Time

5.7 *Control of Manufacturing Systems*

Eekelen van, Ir. J.A.W.M. (PhD 1)
- Control of Manufacturing Systems

Hendriks, Ir. R.M.P. (PhD 3)
- Modeling, Control, and Optimization of Warehousing Systems

5.8 *Nonlinear and Hybrid Dynamics*

Berg van de, Ir. R. (PhD 1)
- Performance based design of hybrid systems

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

Dr.Ir. R.M. v. Druten
- Power train design
- NL 2002 – 2007

Dr.Ir. A.J.C. Schmeitz
- Vehicle dynamics & tyres
- NL May 2004 – May 2005
7. Short description of sub programmes related to research school EM

7.1 Non-linear dynamics of mechanical systems

Within this theme, the following research topics are investigated:

Numerical and experimental study of non-smooth mechanical systems, like systems with friction, impacts, or constraints. The research on these phenomena is highly relevant in many engineering applications (friction in high performance/high precision systems, drillstrings, hybrid control systems etc.). Numerical aspects are notably difficult, but with increasing computer power, become more and more feasible. Interesting and important results involve the study of bifurcations in non-smooth systems. Cooperation with Remco Leine (ETH, Zürich) has resulted in a monograph on this subject as well as several other publications. A further development along the line of non-smooth systems consists of the study of active control of non-smooth mechanical systems. This is part of the EU sponsored project, SICONOS and is linked with the European Network of Excellence HYCON (Hybrid Control Network). Additionally, possibilities for both active and passive control of piecewise linear systems are studied.

Development of accessible (numerical) procedures for the steady-state response under periodic excitation. In particular, a non-linear dynamics toolbox with time-discretization, shooting methods and a path-following procedure has been integrated in the commercial finite element package DIANA and in the general-purpose package MATLAB. Non-linear dynamics phenomena such as bifurcations have been studied both experimentally and numerically. Among others, a PhD thesis combining numerical and experimental bifurcation analysis on the drillstring set up in the DCT lab, demonstrates the value of our analysis.

Related to research theme “Structural Dynamics and Control”

7.2 (Structural) acoustics and noise control

Two PhD students are completing their thesis on the modelling and optimization of uncertainty in structural vibrations and the associated sound radiation. Important examples for low-noise design are road vehicles, railway carriages, aircraft, ships and MRI-scanners. With respect to structural-acoustic modelling, these examples have two characteristic problems in common. These are the enormous size of numerical models needed to describe their physics correctly and their uncertainty behaviour. The first topic refers to the frequency range in which structural wavelength is small compared to the characteristic geometrical dimensions. The latter characteristic means that nominally identical structures show a large and rather unpredictable scatter in acoustic behaviour. This is true for new products and may even increase after some years of use. Therefore, much interest is shown in improving predictive capabilities and in optimization for robust designs, i.e. designs which do not deteriorate easily during their life cycle.

The research topic Tyre-road noise currently focuses on modeling the acoustically relevant structural vibrations of rolling tyres. A student has recently finished his MSc. thesis and a second student has continued in this direction.

On the subject “Acoustic holography” an STW-project proposal is running on the subject of the inverse acoustic holography method.

Tyre-road noise

The research topic “Tyre-road noise” is focused upon the development of numerical prediction procedures for structure borne noise transmission from the tyre vibrations due to tyre-road contact to the interior noise in a car. This structure borne noise transmission path is dominated by frequencies below 500 Hz. The numerical prediction procedures involves an efficient procedure to take the dynamics of a rotating tyre into account on the basis of structural modes of the tyre that are obtained from non-rotating tyre model. This
procedure reduces the computer resources in terms of both computer memory and
computation time drastically, from being non-feasible to acceptable resources. A
graduation student has recently finished his MSc. Thesis on this topic. A second student
has continued using this modeling procedure, and focuses now on the modeling of the
tyre-road contact models.

Acoustic Imaging: Measurement Techniques and Signal Processing
Focus has been on realization of a measurement facility for acoustic holography, which
facilitates a semi-anechoic room with a fully controllable traverse system and integrated
control and post-processing software. Since October 2005 it is possible to conduct
holographic measurements on stationary sources and produce acoustic images with
millimeter range spatial resolutions.
Fundamental research has been conducted on regularization of Planar Near-field Acoustic
Holography (PNAH), spatial sampling and aliasing. Both topics have been published and
presented on international congresses. Regularization of PNAH focuses on handling the
ill-posed-ness of PNAH and finding the correct parameters for the low-pass filters that are
applied. The result of this could mean a way to fully automate the PNAH process. Spatial
sampling and aliasing is a very important topic where many mistakes are made, especially
in measurement set-ups. A tool has been developed to exactly determine microphone and
hologram distances with respect to the source and for a given signal-to-noise ratio of the
measurement.

Related to research theme “Structural Dynamics and Control”

7.3 Structural optimization
The research in this area concerns the development of tools for the optimization of the
dynamic behaviour of constructions, where the engineering optimization problem is
considered as an interrelated combination of an Optimal Design Problem (ODP) and an
Optimal Control Problem (OCP). Particular attention is paid to the development and
utilization of both approximation concepts in the optimization process and of strategies for
the combination, integration and coordination of effective approaches for (uncertain) ODP
and OCP. In co-operation with the Systems Engineering section and the Structural
Optimization and Computational Mechanics group from TUD an inter-university research
project ‘ADOPT: Sequential Approximate Design Optimization including uncertainties,
discontinuities and discrete design variables’, sponsored by the Technology Foundation
STW, is running. The aim of the project is to develop design optimization tools for
problems exhibiting simultaneously discrete design variables, uncertainties, and
discontinuous response functions. Applications are foreseen in the design of (automotive)
multibody systems, composite structures and manufacturing systems. In particular, the
Automatic Balancing Unit (ABU) donated by Philips CFT is used as an experimental
carrier in this project.

Related to research theme “Structural Dynamics and Control”

7.4 Automotive Technology
Advanced Power Trains
The first project in this area is on accurate and robust control of the torques in power
trains. In innovative (hybrid) power trains often mode changes occur. These are to be
controlled accurately, in order not to adversely affect drivability and comfort. Therefore,
research is focused on gaining superior control over the power train components, leading
to optimal drive torque combined with minimal fuel consumption. Power trains often are
over-actuated, multi-input-multi-output (MIMO) systems, requiring advanced control
techniques. Slip control of CVTs is a new and very promising line of research. A second
project concentrates on servomotor based actuation systems (EMPACT). New
transmissions, like the CVT and the double clutch transmission, still rely on hydraulic
actuation, leading to compromised transmission efficiencies and requiring a complex and expensive hydraulic unit. The third project focuses on validation and test facility development. Power train components are being developed and tested on the available test facilities. Further facilities are developed. Newly developed components are demonstrated in state-of-the-art test vehicles, using modern controllers, so they can be validated under real life conditions.

**Vehicle Dynamics and Tyres**

In the beginning of 2005 the first group of Master students in the field of Vehicle Dynamics has been graduated. During the year about 10 students have been working on internal and external (TNO, DAF, LMS, Vredestein) master thesis projects. Several Bachelor projects and internal and external (BMW, DAF, Daimler-Chrysler, Goodyear, Intec) traineeships have been performed. The courses "Vehicle Dynamics" and "Advanced Vehicle Dynamics" have been attended well, about 80+ and 30+ students, respectively. For the course "Orientation in Automotive Technology" lecture notes have been written.

In the AES lab the Flat Plank Tyre Tester has been used for various experiments (e.g. motorcycle tyre measurements, stiffness measurements, cleat tests). A four wheel steered vehicle has been obtained from TNO and several students have been working on this vehicle to design a suitable controller. The Tyre Measurement Tower with strain gauge measuring hub has been obtained from Delft University of Technology and work has been done to get the Tyre Measurement Tower and large drum facility in the AES lab operational. This work will continue in 2006.

Research has been done in three main areas: tyre modelling, truck modelling and vehicle control. In December the first PhD project has been started on active cabin suspension. This project is a joint research project with TNO and DAF.

Finally, for the TUE Formula Student Racing Team a multibody vehicle model has been built that is used as a tool for designing the 2006 racing car.

**Related to research theme “Structural Dynamics and Control”**

### 7.5 Mechanical Design

The mechanical design group C&M from the C&M lab is involved in 8 PhD projects directly, such as the EMPACT project, and the Gaia project. There is a project for design of a fast measurement machine with nanometer capability. As a successor to the Zeiss F25, a commercial startup is made within this Nano CMM. Furthermore, there is a project to design a measurement machine with nanometer accuracy for free form optics. Also a project on adaptive optics is running, addressing the complexity question as well as design issues. This is done together with TNO and the Technische Universiteit Delft (TUD). ANanoned design project with NMI for a metrologic AFM. New activities concentrate on medical robotics, in particular on minimally invasive robotic surgery systems.

Further designs for experimental set-ups were made for PhD projects on drill string with vibrations, synchronisation of robots, dynamic stability of thin structures, friction in the Loop controlled mechanisms, turbulent flow velocity measurement, Biomedical applications.

Master thesis project designs for instruments & machinery: motion system for flat structures, Vehil Moving base, Robot Eye, Mars robotics, Optical nm probe, mirror actuation system, plate-press 400T 7 m, Hydraulic Spreader, Large printer design, Hydraulic Robot for off-shore platform removal, Material tester ASML. Also technical advising on mechanical design and engineering for industry and Institutes was done.

**Related to research theme “Structural Dynamics and Control”**
7.6 **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 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 themes "Structural Mechanics" and "Structural Dynamics and Control".

7.7 **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”

7.8 **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 constitutes 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


Besselink, I.J.M., experiences with the TYDEX standard tyre interface and file format, Vehicle System Dynamics, 43s, 63-75, (2005)


Ron, A.J. de; Rooda, J.E.: Fab Performance. IEEE Transactions on Semiconductor Manufacturing, 18, 399-405, 2005


Veld, F. ter, R.P.H. Faassen, K. Nicolay, Mitochondrial affinity for ADP is twofold lower in creatine kinase knock-out muscles. Possible role in rescuing cellular energy homeostasis, FEBS J., 272, 956-965, (2005)


8.2 Books, chapters in book


8.3 Refereed proceedings


Hofman, T., R.M. van Druten, Concept design for hybrid vehicle power systems, in American Control Conference; Editors: AACC, Portland, Oregan, United States, 5, (2005)


2.8 Annual Report Engineering Mechanics 2005


Lopez, I., H. Nijmeijer, How important is the friction model on the modeling of energy dissipation?, in Proceedings of the 5th EUROMECH Nonlinear Dynamics Conference (ENOC); August 7-12, Editors: D.H. van Campen, M.D. Lazurko, W.P.J.M. van den Oever, Eindhoven, Netherlands, on CDROM, (2005)


Oguchi, T., H. Nijmeijer, State prediction based on synchronization and an application, in SICE Annual Conference on Control Systems; Editors: SICE, Sendai, Japan, 433-436, (2005)

Oguchi, T., H. Nijmeijer, Control of non-linear systems with time-dealy using state predictor based on synchronization, in Proceedings of the 5th EUROMECH Nonlinear Dynamics Conference (ENOC); August 7-12, Editors: D.H. van Campen, M.D. Lazurko, W.P.J.M. van den Oever, Eindhoven, Netherlands, on CDROM, (2005)


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

Name: N. Mihajlovic
Title: Torsional and Lateral Vibrations in Flexible Rotor Systems with Friction, PhD. Thesis, June 2005, TU/e
Advisor: H. Nijmeijer, D.H. van Campen
Co-advisor: N. van de Wouw
Current position: Philips Research
10. Membership editorial boards international journals

Prof. Dr. Ir. D.H. van Campen:
• Contributing Editor Multibody Systems Dynamics
• Member Advisory Board Nonlinear Dynamics

Prof. Dr. H. Nijmeijer:
• Editor in Chief Journal of Applied Mathematics
• Associate editor AUTOMATICA
• Corresponding editor SIAM J Control Optimization
• Subject editor International Journal of Robust and Nonlinear Control
• Member Editorial Board Journal of Applied Mathematics Computer Science
• Member Editorial Board Journal of Dynamical Control Systems
• Member Editorial Board International Journal of Control
• Member Editorial Board Journal of Stability and Control
• Member Editorial Board European Journal of Control

Prof. Dr. Ir. M. Steinbuch:
• Member Editorial Board Advanced Manufacturing Technology

Prof. Dr. Ir. J.E. Rooda:
• Member Editorial Board Int. Journal of Acoustics and Vibration
• Member Editorial Board of E-mail Noise and Vibration Digest
• Member Editorial Board Handbook of Noise and Vibration Control (to be published by John Wiley & Sons, New York)

11. Keynote lectures and seminars

Prof. Dr. H. Nijmeijer:
• Synchronization/coordination in mechanical systems; 2005 International Symposium on Nonlinear Theory and its Applications (NOLTA), October 18-21, Brugge, Belgium.

Prof. Dr. Ir. M. Steinbuch:
• Advanced Motion Control. Plenary talk at the Advanced Process control Workshop, Vancouver Canada, May 2005

12. Membership international scientific committees

Prof. Dr. Ir. D.H. van Campen:
• Secretary-General of the International Union on Theoretical and Applied Mechanics (IUTAM) since November 2000
• Member EUROMECH Nonlinear Oscillation Conference Committee since 2000; chairman since 2004
• Chairman Fifth EUROMECH Nonlinear Dynamics Conference, Eindhoven, 7-12 August 2005
Dr.ir. L.F.P. Etman:
• Member scientific committee of 2005 IEEE/SEMI Advanced Semiconductor Manufacturing Conference and Workshop, 11-12 April, Munich

Prof.Dr. H. Nijmeijer:
• Member EU Marie Curie Network ‘Control Training Site’
• Member EU Marie Curie Network ‘MASTER’
• Member of various International Program Committees
• Member EU project HYCON (Hybrid Control)

Prof.dr.ir J.E. Rooda:
• Member scientific committee of 2005 IEEE/SEMI Advanced Semiconductor Manufacturing Conference and Workshop, 11-12 April, Munich

Prof.Dr.Ir. M. Steinbuch:
• Chairman of the Danish Research Programme WAVES (2001-2005)
• Member Board of the European Association of Control

Prof.Dr.Ir. J.W. Verheij:
• Secretary of the International Institute of Acoustics and Vibration

13. Awards and patents

Awards:
Ir. S. Tosserams was nominated in 2005 for the Mignot prize of the best M.Sc thesis of Eindhoven University of Technology over the year 2004.

Patents:

14. Overview of research input and output

14.1 Input “Systems, Dynamics and Control” related to EM, 2005

<table>
<thead>
<tr>
<th></th>
<th>Sources of financing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Supporting staff</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>PhD</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Postdocs</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>29</td>
<td>6</td>
</tr>
</tbody>
</table>

Sources of financing:
1: University
2: STW, SON, NWO, FOM, EM
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, etc.

2 No research input involved for supporting staff. 3 Research input per PhD per year: 0.8 fte
14.2 Output “Systems, Dynamics and Control” related to EM, 2005

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals</td>
<td>15</td>
</tr>
<tr>
<td>Scientific publications: books, chapters in book</td>
<td>1</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>44</td>
</tr>
<tr>
<td>PhD theses</td>
<td>1</td>
</tr>
</tbody>
</table>

* In cooperation with other EM-groups.

15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte

Project Title: ADOPT: Sequential Approximate Design Optimization including uncertainties, discontinuities and discrete design variables.

Participating Groups: Systems, Dynamics and Control (TU/e), Structural Optimization and Computational Mechanics (TUD), Aerospace Structures and Computational Mechanics (TUD)

Participants: Dr.Ir. L.F.P. Etman (TU/e), Ir. S.P. Gurav (TUD), Ir. J.H. Jacobs (TU/e), Prof. Dr. Ir. A. van Keulen (TUD), Dr. J.J.M. Rijpkema (TU/e), Ir. R.A. van Rooij (TU/e), Prof. Dr. H. Nijmeijer (TU/e), Ir. K. Vervenne (TUD).

Research Input in fte: 1.6

Project Title: STW project TW 6618, Inverse Acoustics

Participating Groups: Applied Mechanics (UT), Systems, Dynamics and Control (TU/e)

Participants: Prof. Dr. Ir. A. de Boer (UT), Dr. Ir. Y.H. Wijnant (UT), Ing. A. Winkel (UT), Ir. J. Wind (UT), Prof. Dr. Ir. N.B. Roozen (TU/e), Dr. I. Lopez (TU/e), Ir. R. Scholte (TU/e)

Research Input in fte: 2.8
3. 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 Structure-Property relations and Constitutive Modelling
2.2 Microscopic Aspect of Deformation
2.3 Micromechanics of Functional Devices
2.4 Multi-scale Mechanics, Damage and Fracture in Metals
2.5 Impact Protection and Injury Biomechanics
2.6 Biomechanics
2.7 New Processes and Devices for Micro- and Nano- Scales

3. Group directors

Prof.Dr.Ir. F.P.T. Baaijens
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

Baaijens, Prof.Dr.Ir. F.P.T. Full Professor 0.1
Bellouard, Dr., Y. UD 0.1
Brekelmans, Dr.Ir. W.A.M. UHD 0.4
Dietzel, Prof.Dr. A.H. Full Professor 0.2
Dommelen, Dr.Ir. J.A.W. UD 0.4
Geers, Prof.Dr.Ir. M.G.D. Full Professor 0.4
Hoefnagels, Dr.ir. J.P.M. UD 0.4
Homburg, Ir., F.G.A. UD 0.2
Huyghe, Dr.Ir. J.M.R.J. UHD 0.1
Kouznetsova, Dr.ir. V.G. NIMR-fellow 0.4
Oomens, Dr.Ir. C.W.J. UHD 0.1
Peerlings, Dr.Ir. R.H.J. UD 0.4
Wismans, Prof.Dr.Ir. J.S.H.M. Part-time Professor 0.1
Witteman, Dr.Ir. W.J. UD 0.2

Total fte: 3.5
5. PhD-projects related to research school EM per December 2005: name, source of financing, project title and research theme EM

5.1 Structure-Property Relations and Constitutive Modelling

- Boers, Ir. S.H.A. (PhD 1) Discrete multi-path forming StMe
- Bosch, Ir. M.J. v. d. (PhD 3) Deformation limits of polymer coated metal sheets CoMe/ MeMa

5.2 Microscopic Aspect of Deformation

- Janssen, Ir. P.J.M. (PhD 3) Miniaturisation and forming micro-parts MeMa
- Yalcinkaya M.Sc. T. (PhD 3) Strain path dependent material models for forming and crash MeMa

5.3 Micromechanics of Functional Devices

- Erinç, M.Sc. M. (PhD 2) Solder joint fatigue MeMa

5.4 Multi-scale Mechanics, Damage and Fracture in Metals

- Kasyanyuk, M.Sc. Y. (PhD 3) Fatigue damage in metals CoMe/ MeMa
- Balmachnov, M.Sc. A. (PhD 2) Computational characterization and tailoring of metastable steel MeMa
- Tasan, M.Sc. C. (PhD 3) Forming the limits of damage prediction CoMe/ MeMa
- Ozdemir, M.Sc. I. (PhD 3) Multi-scale modelling of thermoshock: from microstructure to failure MeMa

5.5 Impact Protection and Injury Biomechanics

- Hrapko, Ir. M. (PhD 1) Determination of the mech. behaviour of brain tissue for impact conditions MeMa

5.6 Biomechanics

- Driessen, Ir. N.J.B. (PhD 1) Heart valve tissue differentiation CoMe
- Roos, Ir. R.W. (PhD 3) Mechanics of hydrogels MeMa
- Schroeder, Dipl.Ing. Y. (PhD 3) Degeneration of the intervertebral disc MeMa

5.7 New Processes and Devices for Micro- and Nano- Scales

- Petousis, Ir, I. (PhD 3) Preconcentration and micro channel devices StMe
- Bos, Ir., E.J.C. (PhD 3) 3D taster StMe
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 of Stay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. A. Roy</td>
<td>Mesoscopic Modeling of Dislocation Patterning</td>
<td>CoMe/MeMa</td>
<td>CoMe</td>
<td>01-11-2005</td>
</tr>
<tr>
<td>Dr. J. Zeman</td>
<td>Nonlocal computational homogenization</td>
<td>MeMa</td>
<td></td>
<td>01-11-2005</td>
</tr>
</tbody>
</table>

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

### 7.1 Structure-Property Relations and Constitutive Modelling

This subprogramme focuses on the mechanical behaviour of solids, with a particular emphasis on micromechanics, where the microstructural morphology is of major influence. Typical topics addressed are (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. The ultimate goal is to arrive at a physically based constitutive description, which can be numerically implemented, enabling an accurate analysis of engineering products or product manufacturing processes.

Related to research themes “Computational Mechanics” and “Mechanics of Materials”.

### 7.2 Microscopic Aspects of Deformation

This subprogramme aims to provide a sound experimental basis for the computational efforts in the group, by trying to take into account 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), multi-phase materials (e.g. micro-electronics solders), multi-layered structures (e.g. flexible displays), microsystems, etc.

Related to research themes “Computational Mechanics” and “Mechanics of Materials”.

### 7.3 Micromechanics of Functional Devices

This subprogramme focuses on the micromechanics of devices upon miniaturization. In miniaturized products, materials cannot be trivially considered as continua. Furthermore, boundary, surface and interface effects start to 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 the influence on the performance of microsystems.

Related to research themes “Computational Mechanics” and “Mechanics of Materials”.

### 7.4 Multi-scale Mechanics, Damage and Fracture in Metals

This subprogramme focuses on mechanical failure as an important design criterion for metallic products and components. Both prevention and control of damage are thereby of relevance. The correct prediction of this ultimate behaviour offers many challenges, both numerically and experimentally. 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.

Related to research themes “Computational Mechanics” and “Mechanics of Materials”.

### 7.5 Impact Protection and Injury Biomechanics for Automotive Safety

This subprogramme focuses on passive safety research for automotive applications, i.e. prevention of injuries caused by an accident. Important topics are:

- Smart vehicle structures and restraint systems
- Improvement of (impact)compatibility of different vehicles
• Use of light-weight materials
• Use of electronics in pre-crash sensing
• Characterisation of the mechanical behaviour of biological materials under impact conditions

Related to research theme “Mechanics of Materials”.

7.6 Biomechanics
Within the program Biomechanics and Tissue Engineering we apply principles from engineering mechanics and biology, to a variety of biomedical problems and devices. In particular, prevention, diagnosis and treatment of medical conditions and diseases of the cardio-vascular and the musculoskeletal systems are examined. Treatment may result in the engineering of living tissues and artificial implants, such as heart-valves, small diameter blood vessels, orthopaedic implants, and extracorporal systems and devices. These developments critically rely on the availability of various technologies, such as bioreactors and testing procedures, which are subjects of research. In all cases, numerical and experimental techniques offer powerful tools for biologically and clinically relevant research in these areas.

Related to research themes “Mechanics of Materials” and “Structural Mechanics”.

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 f the polymer devices and the required fabrication processes.

Precision Machining and Engineering. This research is centred about the design of an ultra fast large stroke rotary fast tool servo intended for the manufacture of asymmetric polymeric optical surfaces. The tool will be placed on the group’s Colath high precision optical lathe. Research topic is the combination of high stiffness, nanometer resolution and high acceleration in the rotary tool post design.

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 nanoscale 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.

Related to research theme “Structural Mechanics”.

8. Refereed scientific publications

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: Engelen, R.A.B.  
Title: Plasticity-induced Damage in Metals - nonlocal modelling at finite strains, TU/e May 2005  
Advisors: Prof.dr.ir. M.G.D. Geers, Prof.Dr.Ir. F.P.T. Baaijens  
Co-Advisor: Dr.Ir. R.H.J. Peerlings  
Current position: Employee Philips

Name: Hendriks, F.M.  
Title: Mechanical Behaviour of Human Epidermal and Dermal Layers, TU/e March 2005  
Advisors: Prof.dr.ir. F.P.T. Baaijens, Prof.dr.ir. D.L. Bader  
Co-Advisor: Dr.ir. C.W.J. Oomens  
Current position: Employee TNO

Name: Matin, A.  
Title: Microstructure evolution and thermomechanical fatigue of solder materials, TU/e November 2005  
Advisors: Prof.dr.ir. M.G.D. Geers  
Co-Advisor: Dr.ir. W.P. Vellinga  
Current position: Employee IMEC, Leuven

Name: Mediavilla, J.  
Title: Continuous and discontinuous modelling of ductile fracture, TU/e April 2005  
Advisors: Prof.dr.ir. M.G.D. Geers  
Co-Advisor: Dr.ir. R.H.J. Peerlings  
Current position: Employee TNO
Name: Peeters, E.A.G.
Title: Biomechanics of single cells under compression, TU/e April 2004 (not included in AR 2004)
Advisor: Prof.dr.ir. E.P.T. Baaijens, prof.dr. D.L. Bader
Co-Advisor: Dr. C.V.C. Bouten
Current position: ASML

Name: Ubachs, R.L.J.M.
Title: Thermomechanical modelling of microstructure evolution in solder alloys, TU/e December 2005
Advisor: Prof.dr.ir. M.G.D. Geers
Co-Advisor: Dr.ir. P.J.G. Schreurs
Current position: Post-doc TU Delft

Name: Viatkina, E.M.
Title: Micromechanical modelling of strain path dependency in FCC metals, TU/e December 2005
Advisor: Prof.dr.ir. M.G.D. Geers
Co Advisor: Dr.ir. W.A.M. Brekelmans
Current position: Employee Takumi-Tech

10. **Membership editorial boards international journals**

Prof.Dr.Ir. F.P.T. Baaijens:
- Advisory editor of Comp. Meth. Appl. & Eng.
- Member editorial board Journal of Non-Newtonian Fluid Mechanics

Prof.dr.ir. M.G.D. Geers:
- Editorial board International Journal for Multiscale Computational Engineering

11. **Keynote lectures and seminars**


12. **Membership international scientific committees**

Prof.Dr.Ir. M.G.D. Geers
- Member CNRS Visiting Committee LASMIS, Université de Troyes
• Member of the Technical Committee of EuroSimE

Prof. Dr. A.H. Dietzel
• Member of Scientific Committee 1st Int. Conf. on Multi-Material Micro Manufacture, 4M 2005

13. **Awards and patents**

-----

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

14.1 *Input “Materials Technology” related to EM, 2005*

<table>
<thead>
<tr>
<th>Sources of financing</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>number</td>
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<tr>
<td>1</td>
<td>2</td>
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<tr>
<td>Senior academic staff</td>
<td>15</td>
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<td>Supporting staff</td>
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<td>PhD</td>
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<td>Postdocs</td>
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<tr>
<td>Total</td>
<td>22</td>
</tr>
</tbody>
</table>

^1 Sources of financing: 1: University  
2: STW, SÖN, NWO, Fom  
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, NIMR, DPI etc.

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

14.2 *Output “Materials Technology” related to EM, 2005*

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

* In co-operation with other EM-groups.
### 15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte

<table>
<thead>
<tr>
<th>Project Title:</th>
<th>Multiscale Methods in Computational Mechanics</th>
</tr>
</thead>
</table>
| Participating Groups: | Engineering Mechanics (1) (TUD)  
| | Structural Optimization and Computational Mechanics (TUD)  
| | Materials Technology (TU/e) |
| Participants: | Prof.Dr.Ir. R. de Borst (TUD), Prof.Dr.Ir. F. van Keulen (TUD), Dr.Ir. J.M.R.J. Huyghe (TU/e) |
| Research Input in fte: | |

<table>
<thead>
<tr>
<th>Project Title:</th>
<th>NIMR-project MC1.03158, Strain path dependent materials models for forming and crash</th>
</tr>
</thead>
</table>
| Participating Groups: | Applied Mechanics and Polymer Engineering (UT)  
| | Materials Technology (TU/e) |
| Participants: | Prof.Dr.Ir. J. Huétink, Dr.Ir. A.H. van den Boogaard, Ir. M. van Riel (MIMR/UT), Prof.Dr.Ir. M.G.D. Geers, Dr.Ir. W.A.M. Brekelmans, T. Yalcinkaya (TU/e/NIMR) |
| Research Input in fte: | 2.0 |

<table>
<thead>
<tr>
<th>Project Title:</th>
<th>FOM-project 02EMM30, Tailoring of processable metastable steels</th>
</tr>
</thead>
</table>
| Participating Groups: | Applied Mechanics (UT)  
| | Materials Technology (TU/e)  
| | Fundamentals of advanced materials (TUDelft, not EM member) |
| Participants: | Prof.Dr.Ir. J. Huétink, Dr.Ir. H. Geijselaers (UT), S. Perdahcioglu (FOM/UT), Prof.Dr.Ir. M.G.D. Geers (TU/e), Dr. V. Kouznetsofa (NIMR/TU/e), A. Balmachov (FOM/TU/e), Prof Dr.Ir. S. van der Zwaag (TUD), Dr. D. san Martin (FOM/TUD) |
| Research Input in fte: | 2.5 |

<table>
<thead>
<tr>
<th>Project Title:</th>
<th>NIMR-project MC1.04205, Forming the limits of damage prediction</th>
</tr>
</thead>
</table>
| Participating Groups: | Applied Mechanics (UT)  
| | Materials Technology (TU/e) |
| Participants: | Prof.Dr.Ir. J. Huétink, Dr. ir. H.H. Wisselink  
| | Prof.Dr.Ir. M.G.D. Geers, Dr.Ir. R. Peerlings (TU/e), C. Tasan (NIMR/Tue) |
| Research Input in fte: | 2.0 |
4. RESEARCH DOCUMENTATION OF THE GROUP
ANALYSIS SCIENTIFIC COMPUTING AND APPLICATIONS (CASA) 

1. University/Department

Eindhoven University of Technology
Department of Mathematics and Computing Science

2. Subprogrammes related to research school EM

2.1 Scientific Computing
2.2 Applied Analysis

3. Group directors

Prof.dr.ir. J. de Graaf
Prof.dr. R.M.M. Mattheij

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>Aarts, Mevr.dr. A.C.T.</td>
<td>UD</td>
<td>0.1</td>
</tr>
<tr>
<td>Graaf, Prof.dr.ir. J. de</td>
<td>Full Professor</td>
<td>0.2</td>
</tr>
<tr>
<td>Maten, Dr. E.J.W. ter</td>
<td>UD, main position at Philips-Research</td>
<td>0.1</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>UD</td>
<td>0.3</td>
</tr>
<tr>
<td>Morsche, Dr. H.G. ter</td>
<td>UHD</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>0.1</td>
</tr>
<tr>
<td>Tijsseling, Dr.ir. A.S.</td>
<td>UD</td>
<td>0.1</td>
</tr>
<tr>
<td>Ven, Dr.ir. A.A.F. van de</td>
<td>UHD</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Total fte: 1.6

5. PhD-projects related to research school EM per December 2004:
name, source of financing, project title and research theme EM

5.1 Scientific Computing

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Research Input in fte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aa, Ir. N.P. van der</td>
<td>(PhD 3) Field based parameter estimation for lithography</td>
<td>CoMe</td>
</tr>
<tr>
<td>Allaart-Bruin, Drs. S.M.A.</td>
<td>(PhD 3) Blowing of Glass</td>
<td>CoMe</td>
</tr>
<tr>
<td>Ilievski, Z., M.Sc.</td>
<td>(PhD 2) COMSON</td>
<td>CoMe</td>
</tr>
</tbody>
</table>

\[1\] Per 2004 the name of the previous EM-group “TU/e – Computational Science and Engineering” has been changed to “TU/e – Centre for Analysis, Scientific computing and Applications (CASA)
5.2 Applied Analysis

Dijkstra, Ir. W. (PhD 1) Boundary Element methods CoMe
Kakuba, ir. G. (PhD 1) Local Defect Correction CoMe
Kraaij, Ir M.G.M.M. v. (PhD 3) Rigorous Coupled-Wave Analysis CoMe
Patricio Dias, M.J.M., M. Sc. (PhD 2) Structural integrity CoMe
Shcherbakov, E., MSc (PhD 1/2) Model Reduction Techniques CoMe
Verhoeven, Ir. A. (PhD 3) Circuit Simulation CoMe

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

Giannopapa, Dr. C. Blowing of glass 2.1 CoMe
Kagan, Dr. P., Israel Problems in glass industry 2.1 CoMe
March 2003 – March 2006

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 application, 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 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. Special points of attention are:
  - Research to origins of instabilities/distortions occurring in these processes;
  - Modelling of boundary conditions (slip or stick);
  - Influences of thermal effects and pressure (compressibility);
  - Residual stresses and/or deformations in final products (e.g. compact discs);
  - Morphology of polymer mixtures; break-up of liquid threads.
- **Biomechanical foot model**: The development of a biomechanical foot model, which can be used in clinical gait analysis, to analyse foot motion during locomotion.
- **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.
- Analysis and numerical simulation of electromagnetic systems for design of antennas and gradient coils in MRI-scanners.

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 probe.

7.2.4 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 books


8.3 Refereed proceedings


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

Name: I. E.M. Severens
Title: DEM Simulations of toner behaviour in the development nip of the Océ direct imaging print process, TU/e, 19-4-2005
Current position: Océ-Technologies B.V.

Name: H.J.J. Gramberg
Title: Flow front instabilities in injection moulding process, TU/e, 9-5-2005
Advisors: J. Molenaar, C.J. van Duijn, A.A.F. v.d. Ven
Current position: Oxford Centre for Industry and Applied Mathematics

Name: J.M.B. Kroot
Title: Analysis of eddy currents in a gradient coil, TU/e, 23-6-2005
Current Position: Directorate General RTD, European Commission

Name: F. Hagman
Title: Can plantar pressure predict foot motion, TU/e, 9-11-2005
Advisors: S.J.L. van Eijndhoven, A.A.F. v.d. Ven
Current Position: University of Brussels, Human Biometry and Biomechanics Lab

Name: P. Heres
Title: Robust and efficient Kaylov subspace methods for model order reduction, TU/e, 13-12-2005
Advisors: W.H.A. Schilders, H.A. van der Vorst
Current Position: ASML

10. Membership editorial boards international journals

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 International Journal of Nonlinear Modelling in Sciences and Engineering
- Editor Springer series on Mathematics for Industry

Prof.dr. W.H.A. Schilders:
- Editor of COMPEL, the international journal for computation and mathematics in electrical and electronic engineering
- Editor of special volume Numerical Methods in Electromagnetics in series Handbook of Numerical Analysis (Elsevier)

Dr.Ir. A.A.F. van de Ven:
- Editor Journal of Engineering Mathematics

11. Keynote lectures and seminars

Dr. J.M.L. Maubach:
- Spacefilling curves for a simplex-bisection-refined 2-dimensional tensor meshes, Seminarium, Technische Universität Darmstadt, Germany, January 6, 2005
- Spacefilling curves for 2-dimensional meshes, Colloquium, Universita di Catania, Sicily, Italy, May 16, 2005
- Parallel methods for convection diffusion problems with PETSC, Universita di Catania, Sicily, Italy, May 23, 2005
- Dirichlet degrees of freedom need not be eliminated, Workshop on Numerical Methods for Convection Dominated Convection Diffusion Problems, Amsterdam, November 4, 2005

Prof.dr. R.M.M. Mattheij:
- Mathematics of Glass, Magical, Frankfurt, January 27-28, 2005
- Computational Science & Engineering, Technical University Istanbul, February 22-24, 2005
- Blowing of glass bottles, Glass Days, Kaiserslautern, April 14-15, 2005
- Local Defect Correction for time dependent problems, SciCalDE, Nagoya, May 22-24, 2005

12. Membership international scientific committees

Prof. dr. R.M.M. Mattheij:
- Member Scientific Committee BeTeq 2005.

Prof. dr. W.H.A. Schilders:
- Member Programme Committee of series SCEE-conferences.
- Member Advisory Committee of SEMIC conference series.

Dr. ir. A.A.F. v.d. Ven:

13. Awards and patents

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14. Overview of research input and output

14.1 Input "Computational Science and Engineering" related to EM, 2005

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<th>Sources of financing</th>
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<td>1</td>
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<tr>
<td>Senior academic staff</td>
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<tr>
<td>Supporting staff</td>
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<tr>
<td>PhD</td>
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<td>Postdocs</td>
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</table>

1 Sources of financing: 1: University
2: STW, SON, NWO, FOM
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, NIMR, DPI, etc.
2 No research input involved for supporting staff.
3 Research input per PhD per year: 0.8 fte

14.2 Output "Computational Science and Engineering" related to EM, 2005

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

15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte

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5. RESEARCH DOCUMENTATION OF THE GROUP
ENGINEERING MECHANICS (1)

1. University/Department

Delft University of Technology
Department of Aerospace Engineering

2. Subprogrammes related to research school EM

2.1 Composite Materials
2.2 Advanced Computational Procedures
2.3 Fluid-Structure Interaction
2.4 Advanced Materials

3. Group director

Prof. Dr. Ir. R. de Borst

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

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
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<th>FTE</th>
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<tbody>
<tr>
<td>Borst, Prof. Dr. Ir. R. de</td>
<td>full Professor, Director Research School EM</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Brummelen, Dr. Ir. E.H. van</td>
<td>UD</td>
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</tr>
<tr>
<td>Gutiérrez, Dr. Ir. M.A.</td>
<td>UHD</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Hulshoff, Dr. S.J.</td>
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<td>Remmers, Ir. J.C.J.</td>
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<td>Suiker, Dr. Ir. A.S.J.</td>
<td>UD</td>
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<td>Turteltaub, Dr. S.R.</td>
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</table>

5. PhD-projects related to research school EM per December 2003:
name, source of financing, project title and research theme EM

<table>
<thead>
<tr>
<th>Name</th>
<th>Source of Financing</th>
<th>Project Title</th>
<th>Research Theme EM</th>
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<tbody>
<tr>
<td>Akkerman, ir. I.</td>
<td>(PhD 2)</td>
<td>Multiscale adaptive methods for LES computations</td>
<td>CoMe</td>
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<tr>
<td>Chung, Ir. D.B.</td>
<td>(PhD 1)</td>
<td>Reliability of fibre-metal laminate structures</td>
<td>CoMe</td>
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<tr>
<td>Cid Alfaro, mw M.V.</td>
<td>(PhD 2)</td>
<td>Multiscale models for GLARE</td>
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<tr>
<td>Lopez de la Cruz, mw ir. J.</td>
<td>(PhD 2)</td>
<td>Modelling of corrosion</td>
<td>CoMe</td>
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<tr>
<td>Hille, Dipl.-Ing. T.</td>
<td>(PhD 3)</td>
<td>Thermal barrier coatings</td>
<td>MeMa</td>
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<tr>
<td>Munts, Ir. E.A.</td>
<td>(PhD 2)</td>
<td>Fluid-structure interactions using multiscale LES techniques</td>
<td>CoMe</td>
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<tr>
<td>Nawijn, Ir. M.</td>
<td>(PhD 2)</td>
<td>Meshless methods in design processes</td>
<td>CoMe</td>
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<tr>
<td>Shi, MSc Y.</td>
<td>(PhD 3)</td>
<td>Solid-state phase transformations</td>
<td>MeMa</td>
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<tr>
<td>Tjahjanto, ir. D.</td>
<td>(PhD 2)</td>
<td>Modelling of TRIP steels</td>
<td>MeMa</td>
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<tr>
<td>Vaders, ir. J.A.A.</td>
<td>(PhD 3)</td>
<td>Impact loading of composites</td>
<td>MeMa</td>
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</table>
6. Postdocs: name, country, project title, research theme EM and period of stay

Rethoré, Dr J.; France
Discontinuities in Fluid-Saturated Media, September-December 2005
2.2 CoMe

Stan, Dr. F.; Romania
Discontinuous Galerkin Methods for Fracture, April, July 2005
2.2 CoMe

7. Short description of subprogrammes 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 "Mechanics of Materials"

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 Mechanics"

7.3 Fluid-structure interaction
The interaction of thin structures and (air) flows is becoming increasingly important. On one hand do composite materials offer the possibility to design wings and rotor blades with specific deformation capacities. On the other hand do contemporary numerical techniques and hardware configurations offer the possibility to analyse the behaviour of such thin composite structures in transient, three-dimensional flows, including full interaction between fluid and structure. It is the aim of this programme to develop such an integrated approach, including the development of proper numerical methodologies for the various length and time scales that play a role in this problem.
Related to the research theme "Computational Mechanics"

7.4 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 themes “Mechanics of Materials” and “Computational 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: Hagenbeek, M
Title: Characterisation of fibre metal laminates under thermo-mechanical loadings, TUD November 2005
Advisors: Prof.dr.ir. R de Borst
Current position: Hogeschool Inholland

Name: Michler, C
Title: Efficient numerical methods for fluid-structure interaction, TUD June 2005
Advisors: Prof.dr.ir. R de Borst
Current position: NWO Talent Fellowship at University of Texas at Austin

10. Membership editorial boards international journals

Prof.Dr.Ir. R. de Borst:
- Editor-in-Chief “International Journal for Numerical and Analytical Methods in Geomechanics”
- Editor-in-Chief "Encyclopedia of Computational Mechanics"
- Associate Editor "International Journal for Numerical Methods in Engineering"
- Associate Editor “The Aeronautical Journal”
- Member Editorial Board “Archive of Applied Mechanics (Ingenieur-Archiv)”
- Member Editorial Board “European Journal of Mechanics / A: Solids”
- Member Editorial Board “Structural Engineering and Mechanics”
- Member Editorial Board “Engineering Computations: An International Journal”
- Member Editorial Board "International Journal of Multiscale Computational Engineering”
- Member Editorial Board “Computer Modelling in Engineering & Sciences”
- Member Editorial Board "Journal of Computational Methods in Applied Sciences and Engineering”
- Member Editorial Board "Computer Methods in Applied Mechanics and Engineering"
- Member Editorial Board "Communications in Numerical Methods in Engineering"
11. **Keynote lectures and seminars**

Prof. Dr. Ir. R. de Borst:
- “Jules Verne als Ingenieur”, Maison Descartes & Royal Netherlands Academy of Arts and Sciences, Amsterdam, Netherlands, 14 April, 2005.
- “Localisation and Failure in Softening Multi-Phase Media”, 8th International Conference on Computational Plasticity, Barcelona, Spain, 5-8 September, 2005.
- “Stability and Dispersion in Damaging Two-Phase Media”, Workshop on Reactive Flow and Transport through Complex Systems, Oberwolfach, Germany, 1-5 November, 2005.
- “Rekenen aan het bezwijken van materialen en constructies”, Royal Netherlands Academy of Arts and Sciences, Amsterdam, Netherlands, 19 December, 2005.

Dr. Ir. M.A. Gutiérrez

12. **Membership international scientific committees**

Prof. Dr. Ir. R. de Borst:
- 5th International Conference on Computation of Shell & Spatial Structures, Salzburg, Austria, 1-4 June, 2005.
- 16th International Conference on Computer Methods in Mechanics, Czestochowa, Poland, 14-17 June, 2005.
- 8th International Conference on Computational Plasticity, Barcelona, Spain, 5-8 September, 2005.
Dr. ir. E.H. van Brummelem

8th International Conference on Computational Modelling and Experimental Measurements of Free and Moving Boundary Problems, La Coruna, Spain, 21-23 September 2005

13. Awards and patents

Prof. Dr. Ir. R. de Borst:

- Elected Member Royal Netherlands Academy of Arts and Sciences (KNAW)

14. Overview of research input and output

14.1 Input “Engineering Mechanics (1)” related to EM, 2005

<table>
<thead>
<tr>
<th>Sources of financing</th>
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<td>fte</td>
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</table>

1 Sources of financing:
1: University
2: STW, SON, NWO, FOM
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, NIMR, DPI etc.

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

14.2 Output “Engineering Mechanics (1)” related to EM, 2005

<table>
<thead>
<tr>
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<tr>
<td>Scientific publications: refereed proceedings</td>
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<td>PhD theses</td>
<td>2</td>
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</table>

* In co-operation with other EM-groups.

15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte

Project Title: Multiscale Methods in Computational Mechanics
Participating Groups: Engineering Mechanics (1) (TUD)
Structural Optimization and Computational Mechanics (TUD)
Materials Technology (TU/e)
Participants: Prof. Dr. Ir. R. de Borst (TUD), Prof. Dr. Ir. F. van Keulen (TUD), Dr. Ir. J. M. R. J. Huyghe (TU/e)
Research Input in fte:
6. RESEARCH DOCUMENTATION OF THE GROUP 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

Abdalla, Dr. M.M.  
Arbocz, Prof. Dr. J.  
Gürdal, Prof. Dr. Z.  
Hol, Ir. J.M.A.M.  
Jansen, Dr. Ir. E.L.  
Vries, Ir. J. de  
Abdalla, Dr. M.M.  
Arbocz, Prof. Dr. J.  
Gürdal, Prof. Dr. Z.  
Hol, Ir. J.M.A.M.  
Jansen, Dr. Ir. E.L.  
Vries, Ir. J. de  

Total fte: 1.4

5. PhD-projects related to research school EM per December 2005: name, source of financing, project title and research theme EM

5.1 Structural Tailoring, and Design and Optimization

Alhaj Ahmad, M.Sc. A.  
Blom, Ir. A.W.  
Lopes, Ir. C.  

5.2 Stability and Vibrations of Imperfect Composite Shells

Tiso, M.Sc. P.  
Rahman, M.Sc. T.  

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

Dzyuba, Dr. V.V.; Ukraine
Interaction between the cylindrical shells with the spherical inclusions in a flowing ideal liquid, April 2005 – June 2005

Abdalla, Dr. M.M.; Egypt

Setoodeh, Dr. S.; Iran

7. Short description of subprogrammes related to research school EM

7.1 Structural Tailoring, and Design and Optimization
New demands of structural integrity, durability, low weight and minimum cost pose an unprecedented challenge to the structural designer. New materials may assist in satisfying some of these demands, but at the same time give rise to significant new problems for the designer. Furthermore the design of the structure 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 here, 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 - a process sometimes termed structural synthesis and sometimes computer-aided design.

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 theme Structural 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 (read advanced composites), it frequently happens that stability behavior dictates the choice of some of the critical dimensions of the structure. This implies the need to investigate the different loading cases quite accurately by carrying out extensive numerical calculation and/or experimental verification.

The central goal of the shell research being carried out is the development of Improved Shell Design Criteria, incorporating all the theoretical knowledge accumulated in the last, say, 25 years through intensive research in the aerospace, the nuclear and the offshore field, and making efficient use of the currently available interactive and (super-) computing facilities.

It has been demonstrated in the past that reliable buckling loads predictions for imperfection sensitive structures depend mainly on the availability of a sufficiently detailed statistical sample of the expected initial imperfections and on the appropriate choice of the
nonlinear model used for the buckling load calculations. The latter, in turn, requires considerable knowledge by the user of the physical behavior of imperfect shell structures. The analogy between buckling and vibration has stimulated the use of vibration tests to obtain information that is important to assess the buckling behavior, like the so-called vibration correlation technique. Moreover, in certain stability problems inertia plays an essential role. Part of the ongoing shell research is therefore concerned with the vibration behavior and dynamic stability behavior of shells.

The subprogramme includes the following topics:

- Theoretical, numerical, and experimental studies of the collapse behavior and nonlinear vibration behavior of imperfect composite shells under combined 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 Mechanics and Structural 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: S. Setoodeh
Advisors: Prof.dr. Z. Gürdal, Prof.dr.ir. M.J.L. van Tooren, Prof.ir. A. Beukers

10 Membership editorial boards international journals

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11. Keynote lectures and seminars

-----
12. Membership international scientific committees

-----

13. Awards and patents

-----

14. Overview of research input and output

14.1 Input Aerospace Structures related to EM, 2005

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<tr>
<th>Sources of financing¹</th>
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<th>3</th>
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<tr>
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<td>Supporting staff</td>
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¹ Sources of financing: 1: University  
2: STW, SON, NWO, Fom  
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, NIMR, DPI etc.  
² Research input for PhD per year: 0.8 fte

14.2 Output Aerospace Structures related to EM, 2005

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

* In co-operation with other EM-groups

15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte.

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7. RESEARCH DOCUMENTATION OF THE STRUCTURAL OPTIMIZATION AND COMPUTATIONAL MECHANICS GROUP

1. University/Department

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

2. Subprogrammes related to research school EM

2.1 Structural Optimization and Computational Mechanics (SOCM)

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>Research Input in fte</th>
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<tbody>
<tr>
<td>Booij, M.Sc. J.</td>
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<td>Goosen, Dr. Ir. J.F.L.</td>
<td>UD</td>
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<tr>
<td>Keulen, Prof. Dr. Ir. F. van</td>
<td>Full Professor</td>
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<tr>
<td>Linden, Dr. Ir. J.C. van der</td>
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<td>Rijn, Dr. C.J.M. van der Rijn</td>
<td>Associate Researcher</td>
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Total fte: 1.0

5. PhD-projects related to research school EM per December 2004: name, source of financing, project title and research theme EM

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<tr>
<td>Andreykiv, Ir. A.</td>
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<tr>
<td>Broomans, Ir. P.</td>
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<td>3D Numerical simulation of bone ingrowth for glenoid component design of shoulder prostheses</td>
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<td>Cerulli, Ir. C.</td>
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<td>Support of the software development process concerning structure in the context of the Awiat Project</td>
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<tr>
<td>Langelaar, Ir. M.</td>
<td>StMe</td>
<td>Development and design of Micro-Electrical Mechanical Systems</td>
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<tr>
<td>Lau, Ir. G.</td>
<td>StMe</td>
<td>Electrostatic actuators with embedded sensing</td>
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<td>MacKay, Ir. J.</td>
<td>CoMe</td>
<td>Buckling of pressure hull</td>
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<tr>
<td>Poort, Ir. G.</td>
<td>StMe</td>
<td>Development of improved endoprostheses for the upper extremities</td>
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</table>
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 biomedical 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.

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 made available for day-to-day practice. For this purpose we are collaborating with more application-oriented groups and companies.

Related to the research themes “Computational Mechanics” and “Structural 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 supervisors

Name: Gurav, S.P.
Title: Uncertainty-based Design Optimization of Structures with Bounded-But-Unknown Uncertainties.
Delft University of Technology, December 2005.
Advisors: Prof.dr.ir. A. van Keulen.
Current position: Senior researcher at AOES, Leiden, The Netherlands.

Name: Ruiter, M.J. de
Title: Topology Optimization using a Topology Description Function Approach.
Delft University of Technology, December 2005.
Advisor: Prof.Dr.Ir. A. van Keulen
Current position: Senior researcher at Huisman Itrec, Schiedam, The Netherlands.

Name: Vervenne, K.
Title: Gradient-based Approximate Design Optimization.
Delft University of Technology, November 2005.
Advisor: Prof.Dr.Ir. A. van Keulen
Current position: Senior researcher at ALE, Delft, The Netherlands.

10. Membership editorial boards international journals

Prof.Dr.Ir. A. van Keulen:
- Book review editor for Structural and Multidisciplinary Optimization
11. **Keynote lectures and seminars**

Prof. Dr. Ir. A. van Keulen:
Keynote at Eurosim 2005, Berlin

12. **Membership International Scientific Committees**

Prof. Dr. Ir. F. van Keulen:
- EPSRC review panel

13. **Awards and patents**

None

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

14.1 *Input “Structural Optimization and Computational Mechanics” related to EM, 2005*

<table>
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<th>Sources of financing</th>
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¹ Sources of financing:
1: University
2: STW, SON, NWO, FOM
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, NIMR, DPI etc.

² Research input per PhD per year: 0.8 fte

14.2 *Output “Structural Optimization and Computational Mechanics” related to EM, 2005*

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* In co-operation with other EM-groups
15. **Co-operation with other EM-groups: project title, participating groups, participants and research input in fte**

**Project Title:** ADOPT: Sequential Approximate Design Optimization including uncertainties, discontinuities and discrete design variables.

**Participating Groups:** Systems, Dynamics and Control (TU/e)  
Structural Optimization and Computational Mechanics (TUD)  
Aerospace Structures and Computational Mechanics (TUD)

**Participants:**  
Dr.Ir. L.F.P. Etman (TU/e), Ir. S.P. Gurav (TUD),  
Ir. J.H. Jacobs (TU/e), Prof.Dr.Ir. A. van Keulen (TUD),  
Dr. J.J.M. Rijkemka (TU/e), Ir. R.A. van Rooij (TU/e),  
Prof.Dr. H. Nijmeijer (TU/e), Ir. K. Vervenne (TUD).

**Research Input in fte:** 1.6

**Project Title:** Multiscale Methods in Computational Mechanics

**Participating Groups:** Engineering Mechanics (1) (TUD)  
Structural Optimization and Computational Mechanics (TUD)  
Materials Technology (TU/e)

**Participants:**  
Prof.Dr.Ir. R. de Borst (TUD), Prof.Dr.Ir. F. van Keulen (TUD),  
Dr.Ir. J.M.R.J. Huyghe (TU/e)

**Research Input in fte:**
8. RESEARCH DOCUMENTATION OF THE GROUP ENGINEERING MECHANICS (2)

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 Mechanics of Materials
2.2 Dynamic Behaviour of Mechanical Systems

3. Group director

Prof.Dr.Ir. L.J. Ernst

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

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
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<tbody>
<tr>
<td>Ernst, Prof.Dr.Ir. L.J.</td>
<td>Full Professor</td>
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<tr>
<td>Jansen, Dr.Ir. K.M.B.</td>
<td>UHD</td>
<td>0.6</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>UD</td>
<td>0.6</td>
</tr>
<tr>
<td>Woerkom, Dr.Ir. P.Th.L.M. van</td>
<td>UHD</td>
<td>0.2</td>
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</table>

Total fte: 2.6

5. PhD-projects related to research school EM per December 2005:
name, source of financing, project title and research theme EM

5.1 Mechanics of Materials

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Project Title</th>
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<tr>
<td>Hof, Ir. C. van 't</td>
<td>PhD 3</td>
<td>Process dependent packaging polymer characterization: development of a constitutive model</td>
</tr>
<tr>
<td>Yang, Ir. D.</td>
<td>PhD 1/3</td>
<td>Process dependent packaging polymer characterization: study of (micro-) damage, initiated during the curin process</td>
</tr>
</tbody>
</table>

MeMa
5.2 Dynamic Behaviour of Mechanical Systems

Conza, Ir. N. (PhD 2) Doppler Imaging of Vibration System for detection of musculoskeletal disorders StDy
Fransen, Ir. S.H.J.A. (PhD 3) Dynamics Substructuring Techniques for Stress Prediction in Launchers StDy
De Kraker, A (PhD 2) Shape optimization under condition of partial hydro elastic lubrication StDy
Delhaes, G.M.J. (PhD 2) Distributed piezo-control of vibration modes in air-bearings StDy

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

Yuan, C., Taiwan, Prediction of interfacial strength of the wafer backend stack by molecular dynamics and finite element methods 2 years

7. Short description of subprogrammes related to research school EM

7.1 Mechanics of Materials

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.

Two areas of industrial interest and application have been chosen as carriers for the present and future research projects: “Fiber reinforced plastics and flexible fiber systems” and “Micro electronic components and mechanical systems”.

Related to the research themes “Mechanics of Materials” and “Structural Mechanics”.

7.2. Dynamic Behaviour of Mechanical Systems

Tremendous advances have been achieved during the last two decades in the field of mechanical engineering thanks to innovation in materials, production techniques and analysis tools. New designs are better optimized leading to better designs. In that context, predicting and controlling the dynamical behavior of systems has become more important than ever before. Structures have become lighter and therefore more flexible. 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 has a strong background in multi-body dynamics, in vibration analysis, substructuring methods, parallel algorithms, and in non-linear stability and bifurcation studies.

Related to the research themes “Computational Mechanics” and “Structural Dynamics and Control”.

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

8.1 Refereed journals


8.2 Books, chapters in book


8.3 Refereed proceedings


8.4 Annual Report Engineering Mechanics 2005


Wang, L (Ch. IC Technology), Bartek, M (Ch. Integrated Sensing Devices), Poliakov, A (Ch. Integrated Sensing Devices), Jansen, KMB., & Ernst, LJ. (2005). Flexibility studies on ultra-thin silicon substrates. In Proceedings of the STW annual workshop on semiconductor advances for future electronics and sensors (SAFE 2005) (pp. 175-180).


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

Name: Prasenjit Mohanty
Title: Operational Modal Analysis in the Presence of Harmonic Excitations, TUD, January, 2005
Advisor: Prof.dr.ir. D.J. Rixen
Current position: University of Sheffield, UK

10. Membership editorial boards international journals

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11. Keynote lectures and seminars

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12. Membership international scientific committees

Prof.Dr.Ir. L.J. Ernst:
• Member of the Technical Committee of the 11th Int. Conf. on Mechanics and Technology of Composite Materials.

Dr.Ir. P.Th.L.M. van Woerkom:
• American Institute of Aeronautics and Astronautics (AIAA): International Advisor for Guidance, Control and Dynamics.
13. Awards and patents

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14. Overview of research input and output


<table>
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<th>Sources of financing</th>
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<td>Postdocs</td>
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1 Sources of financing: 1: University
2: STW, SON, NWO, FOM
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, NIMR, DPI etc.

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


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<td>PhD theses</td>
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- in co-operation with other EM-groups

15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte.

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9. 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
2.4 Soil mechanics
2.5 Soil dynamics

3. Group directors

Prof.dr.ir. F. Molenkamp
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>Research Input in fte</th>
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<tbody>
<tr>
<td>Al-Khoury, Dr. R.I.N.</td>
<td>Associate Researcher</td>
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<tr>
<td>Brinkgreve, Dr.ir. R.B.J.</td>
<td>UD</td>
<td>0.1</td>
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<tr>
<td>Heeres, Dr.ir. O.</td>
<td>UD</td>
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<tr>
<td>Metrikine, Dr. A.V.</td>
<td>UHD</td>
<td>0.5</td>
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<tr>
<td>Molenkamp, Prof.dr.ir. F.</td>
<td>Professor</td>
<td>0.5</td>
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<tr>
<td>Simone, Dr. A</td>
<td>Associate Researcher</td>
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<tr>
<td>Sluys, Prof.dr.ir. L.J.</td>
<td>Professor</td>
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<tr>
<td>Stroeven, Dr.ir. M.</td>
<td>Associate Researcher</td>
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<tr>
<td>Wells, Dr. G.N.</td>
<td>UHD</td>
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Total fte: 2.5

5. PhD-projects related to research school EM per December 2004: name, source of financing, project title and research theme EM

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<thead>
<tr>
<th>Name</th>
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<tr>
<td>Dung, MSc. N.T.</td>
<td>Computational modelling of laminated structures CoMe</td>
</tr>
<tr>
<td>Gareau, MSc. L.</td>
<td>Engineering geology of glaciate soils CoMe</td>
</tr>
<tr>
<td>Gitman, BSc. I.M.</td>
<td>Micro-macro modelling of fracture in partially saturated materials MeMa</td>
</tr>
<tr>
<td>Hommels, Ir. A.</td>
<td>Inverse modelling of soil behaviour during Construction StDy</td>
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<td>Name</td>
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<tr>
<td>Hoving, Ir. J.</td>
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<tr>
<td>Iacono, MSc. C.</td>
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<td>Lloberas, MSc. O.</td>
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<td>Mathijssen, Ir. F.A.J.M.</td>
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<td>Oelgaard, MSc K.</td>
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<td>Pannachet, MSc. T.</td>
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<td>Pedersen, MSc R.R.</td>
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<td>Pel, Ir. S.</td>
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<tr>
<td>Radtke, MSc F.</td>
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<tr>
<td>Rohe, Ir. A.</td>
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<td>Vegt, Ir. I.</td>
<td>PhD 2</td>
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</table>

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

- **Molari, Dr. L.; Italy**
  Analysis of Discontinuous Galerkin Techniques, August – December 2005
- **Septanika, Dr.ir. E.G.; Indonesia**

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 "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 Mechanics".

7.3 **Structural Dynamics:**
The development of analytical procedures for moving loads in railway transport and offshore engineering applications. Related to the research theme "Structural Dynamics and Control".

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*Annual Report Engineering Mechanics 2005*
7.4 **Soil mechanics**
Experimentation, modelling, computation and monitoring of thermo-hydro-geomechanical processes with large deformation. Multi-phase constitutive models, unsaturation, swelling-shrinking, quasi-static liquefaction, shear bands, cracks, stochastic heterogeneity, reliability.

7.2. **Soil dynamics**
Experimentation, modelling, computation and monitoring of dynamic hydro-geomechanical processes. Multi-phase constitutive models, wave propagation, liquefaction, vibration hinder.

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

10. Membership editorial boards international journals

Prof. Dr. Ir. L.J. Sluys
- Editor-in-Chief “Heron”
- Member Editorial Board “Computers and Concrete”.

11. Keynote lectures and seminars

Dr. A.V. Metrikine
- ‘Wave phenomena in modern civil engineering’ at APM 2005 (Advanced Problems of Mechanics), St. Petersburg, Russia, June 2005

Prof. Dr. Ir. L.J. Sluys
- ‘Computational modelling of failure processes’, Special colloquium at the Gdansk University of Technology, Gdansk, Poland, 28 juni, 2005

Dr. G.N. Wells
- ‘Discontinuous Galerkin formulation for a strain gradient dependent damage model.Chalmers’, University of Technology (Sweden), February 2005
• ‘Finite Element Model for Phase Separation Problems’, University of Stuttgart, June 2005

12. Membership international scientific committees

Dr. G.N. Wells
• Member of the international scientific committee of ‘Centre of Study and Research on the Identification of Materials and Structures (CIMEST)’, University of Bologna.

13. Awards and patents

Prof. Dr. Ir. L.J. Sluys
• Special STW-grant recipient on Computational Modelling of High-performance Materials, 2005

14. Overview of research input and output

14.1 Input “Computational Mechanics, Structural Mechanics and Dynamics” related to EM, 2005

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<td>Supporting staff</td>
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1 Sources of financing: 1: University  
2: STW, SON, NWO, Fom  
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, NIMR, DPI etc.

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

14.2 Output “Computational Mechanics, Structural Mechanics and Dynamics” related to EM, 2005

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<tr>
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* In co-operation with other EM-groups.

15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte.

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10. RESEARCH DOCUMENTATION OF GROUP APPLICATION MECHANICS

1. University/Faculty

University of Twente
Faculty of Engineering Technology

2. Subprogrammes related to research school EM

2.1 Structural Dynamics
2.2 Mechanics of Forming Processes

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 0.4
Boogaard, Dr.Ir. A.H. van den UHD 0.2
Geijselaers, Dr.Ir. H.J.M. UD 0.2
Hoogt, Dr.Ir. P.J.M. van der UD 0.3
Huétink, Prof.Dr.Ir. J. Full Professor 0.2
Meinders, Dr.Ir. V.T. UD 0.2
Spiering, Ir. R.M.E.J. UD 0.3
Wijnant, Dr.Ir. Y.H. UD 0.4

Total fte: 2.2

5. PhD- projects related to research school EM per December 2005: name, source of financing, project title and research theme EM

5.1 Structural Dynamics

Hannink, Ir. M.H.C. (PhD 3) Fluid-structure interaction and acoustics StDy
Huls, Ir. R. (PhD 3) Fluid-structure interaction and acoustics StDy
Kampinga Ir. W.R. (PhD 3) Fluid-structure interaction and acoustics StDy
Nijhof, Ir. M.J.J. (PhD 3) Fluid-structure interaction and acoustics StDy
Oosterhuis, Ir. E.J. (PhD 2) Inverse Structural Dynamics StDy
Sloetjes, Ir. P.J. (PhD 2) Structural Dynamics StDy
Wind Ir. J.W. (PhD 2) Fluid-structure interaction and acoustics StDy

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1 Per 2003 the former group “Applied Mechanics and Polymer Engineering” has been split up in two separate groups; “Applied Mechanics” and “Production Technology”
5.2. **Mechanics of Forming Processes**

<table>
<thead>
<tr>
<th>Name</th>
<th>Project Title</th>
<th>Research Theme</th>
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<tbody>
<tr>
<td>Avetisyan, Ir. M.</td>
<td>Sheet metal forming/springback</td>
<td>CoMe</td>
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<td>Bonte, Ir. M.H.A.</td>
<td>Optimization of Forming processes</td>
<td>CoMe</td>
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<tr>
<td>Burchitz, Ir. I.</td>
<td>Sheet metal forming</td>
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<td>Haaren, Ir. L. van</td>
<td>Warm forming of Aluminium</td>
<td>CoMe</td>
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<td>Koopman Ir. A.J.J.</td>
<td>Aluminium Extrusion</td>
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<td>Lingbeek Ir.R.</td>
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<td>Perdahciooglu E.S.</td>
<td>Processing Meta Stable Steels</td>
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<td>Owczarek, P.</td>
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6. **Postdocs: name, country, project title, research theme EM and period of stay**

<table>
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<tr>
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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 structural dynamics and fluid-structure interaction, with emphasis on acousto-elastic coupling of plate-type structures and the accompanying noise production. The aim of these studies is to develop and validate numerical and measuring methods to analyze and reduce (passively as well as actively) responses of vibrating and noise radiating structures. For the latter attention is focused on models for the interaction of vibrating structures with the surrounding air.

Topics of special interest are:

**Structural Dynamics**

1) **Robust Inversion of Nonlinear Dynamic Systems**

For fatigue analyses one needs to know the load spectra that are applied to the structure or a part of it. In the case the load is not known it has to be derived from other information such as responses in the structure. Once these responses are known the load can be determined with inverse dynamics. For nonlinear systems this inversion is complex. This project, which is carried together with the Systems and Control group of prof. Verhaegen at the TUDelft, focus on the development of inverse methods for nonlinear structural dynamic structures. In principle this project is related with the source localisation method mentioned below however in this case structural sources (loads) have to be localised instead of acoustic sources (see point 4 of the section Fluid Structure Interaction and acoustics). The part of the research at the Structural Dynamics and Acoustics group will be the subject of the PhD-thesis of Ekke Oosterhuis.

(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. The latter may jeopardize the overall system integrity and eventually lead to severe damage and possible failure. Furthermore the vibrating parts of the machine (e.g. the housing) can radiate unwanted noise which must be limited to meet the legal regulations on noise emission and the growing consumer demands for quiet design.

The life of the machinery (parts) can be extended and the radiated noise minimized by applying vibration reduction measures. The life time can be extended too, when a structural part with potential fatal damage is repaired or replaced in time. At present, this requires off-line inspections which is time consuming and expensive since the machinery is inactive at those times. This can be avoided through on-line monitoring of the condition of the (rotating) machinery. Weight can be reduced by using composite materials instead of metals. An additional advantage of composites is that the production process makes it possible to integrate monitoring and vibration reduction systems in the material. This research will be the subject of the PhD-thesis of Peter Sloetjes.

**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 vibrational behaviour of a structure was shown and it appeared possible to generate a considerable amount of damping.

   Further studies are performed towards practical applications more specifically for computers. In 2005 source localisation measurements were carried out on cooling fans in computer housings. Based on the obtained data and the developed theory treatments for noise reduction have been proposed and are now worked out in detail. This research will be the subject of the PhD-thesis of Martin Nijhof. In 2005 a new study in this field has been started on modelling the acoustic behaviour of receivers in hearing aids using the theory on viscothermal wave propagation. This research will be the subject of the PhD-thesis of Ronald Kampinga.

2. **Sound-absorbing materials**
   
   A closely related part of the research program, involves the development and validation of a model to predict and optimise the impedance of sound-absorbing materials. Emphasis is put on the development of highly efficient sound-absorbing configuration of bores, arranged in an optimal way. Further studies are under way to design optimised acoustic panels for aircraft cabins, which is carried out within the European project FACE (Friendly Aircraft Cabin Environment). In 2005 a new method on reduction of noise radiation/transmission within a predefined frequency band has been developed. A patent on this method has been submitted. This research will be the subject of the PhD-thesis of Marieke Hannink.

3. **Active and passive vibration damping**
   
   A third method to reduce the noise emitted from vibrating structures is to damp the structural vibrations, which cause the noise. This can be carried out by damping the vibrations of the structure directly or by isolating the source that excites the structure (e.g. engine in a car). Vibration damping and isolation can be performed with passive means like viscous layers or rubber springs and active means like a linear motor or an electromagnet. A combination of passive and active means is possible too. This is called hybrid damping.

   This research has been the subject of the PhD-thesis of Clemens Beijers which was defended on the 2nd of June 2005.

4. **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 “Efficiente 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 TUe 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. This research will be the subject of the PhD-thesis of Jelmer Wind.

(5) 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 2005 vibration measurements have been carried on the combustion chamber during burner tests. These results have been used for the validation of the numerical models. This research will be the subject of the PhD-thesis of Rob Huls which will be defended on the 17th of May 2006.

(6) 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. This research is the subject of the post-doc Marco Oude Nijhuis.

There is deliberation with prof. N.B. Roozen from the TUe on this research subject.

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, e.g. rubber pad forming, hydro-mechanical forming, and incremental sheet forming. Therefore these processes will serve for benchmarking of software tools. Processes as rolling, extrusion and also laser hardening can be approximately modelled as continuous (steady state)
processes. Hence special attention is paid to (fast) solution algorithm for finding directly a steady state solution.

The sub programme is to a large extent part of the Research programme of the Netherlands Institute for Metals Research (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, and crash condition 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.

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 Loes van Haaren). With the TU/e and TUDelft a joint FOM-NIMR project "Tailoring of processable metastable steels" is started (PhD researcher Semih Perdañıcıoğlu). The project will result into constitutive equations for FEM simulations, including the phase transitions during forming. At the TU/e micro level FEM models are developed. These numerical micro scale models cannot directly be applied on macro-scale. A Multi Level Finite Element Method (MLFEM) procedure is being developed to bridge the gap between micro and macro scale models. Via homogenization steps using Representative Volume Elements (RVE), constitutive relations are generated on integration point level of the macro model. For small two-dimensional academic problems this approach shows promising results. However the computation time of this kind of methods is still too high for application in full-scale three dimensional forming process simulations. As long as these MLFEM procedures are too much computer time consuming, approximations have to be used in which micro-structural phenomena are translated into averaged continuum constitutive relations.

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 to make quantitative predictions of ductile damage and fracture in industrially relevant materials and applications (researcher Harm Wisselink).

- **Springback after forming**
  The problems related to spring back are becoming more pronounced due to the increasing use of materials such as aluminium alloys and high strength steels. A disadvantage is that they are highly sensitive to spring back phenomena due to the high yield stress/Young’s modulus ratio. Therefore it is hard to obtain the nominal shape of components formed with these materials. Nevertheless aluminium alloys and high strength steels are desirable in many industrial products because of their high strength/weight ratio, especially in transport industry.
In the springback project a detailed study of the numerical predictability is being carried out on 4 sheet metal parts of various complexity, known to be sensitive to spring back. The study includes a full sensitivity analysis of both numerical and physical factors on the springback behaviour, using several finite element codes (Abaqus/Standard, DiekA, MSC.MARC and Pamstamp/Optris). The following items are varied: Normal contact definition, Friction, Numerical damping, Material models and Material properties, Sheet discretisation, Deformable tools, Tool discretisation, Method of unloading, Plane strain elements versus shell elements, Thickness integration, Tool velocity (explicit codes) and, Plastic anisotropy. Besides the effect of a sequence of forming steps, including trimming, is investigated.

A rather paradoxical conclusion is that for an accurate prediction of elastic springback after forming an accurate plasticity model is more important than for the simulation of the preceding plastic forming. (PhD researchers Marianna Avetisyan, Igor Burchitz, Roald Lingbeek)

- Optimisation

Attention is paid to Springback compensation in die design for sheet metal forming

In cooperation with the new NIMR partner INPRO (Berlin) a project is started with the aim to compensate the tool design, based on predicted springback after forming. The project should result into a software that can optimise the tool-set automatically, using the results of a FE simulation. The tool can also be used earlier in the process, integrating structural and geometrical design right from the start. The application of ‘design for manufacturing’ opens up new possibilities for creating parts with high performance materials and complex shapes

Optimisation of Forming processes

A project is being carried out on optimisation of the structural component to be formed and optimisation of the process conditions. The project should result into guidelines for industry, more optimal process conditions, shorter lead-through times and less material waste (PhD researcher Martijn Bonte).

- Improvement of solution algorithms for specific parts of the numerical simulation.

Extensions to the meshing algorithms for ALE applications, evaluation of remeshing and field mapping techniques are evaluated for the analysis of cutting processes; implementation of local stress fields resulting from cutting and hemming processes in subsequent forming analysis will be explored. In addition continued research will be performed on dynamic-implicit algorithms in combination with direct and iterative solvers. Yuhong Yu finished her PhD thesis on a solution method for steady state processes.

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

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


Zuiderduin, W.C.J., Vlasveld, D.P.N., Huetink, J., Gaymans, R.J. Influence of sample thickness on fracture behaviour of polyketone and polyketone-rubber blends. Polymer, 10321-10330, 2005

### 8.2 Books, chapters in books

### 8.3 Refereed proceedings


Bonte, M.H.A., Boogaard, A.H. van den, Huetink, J. Solving optimisation problems in metal forming using Finite Element simulation and metamodelling techniques. In D. Buch & N. Hofmann (Eds.), Apomat (pp. 242-251). Morschach, Switzerland. 2005


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

Name: Beijers, C.A.J.
Title: A modelling approach to hybrid isolation of structure-borne sound, 17 June 2005, ISBN 90-365-2189-0
Advisor: Prof. Dr.Ir. A. de Boer, Prof. Dr. Ir. J.W. Verheij
Current position: Scientific Researcher at ASML, Velthoven

Name: Yu, Y
Advisor: Prof. Dr.Ir. J. Huétink, Dr. Ir. H.J.M. Geijselaers
Current position:

10. **Membership editorial boards international journals.**

Prof. Dr. Ir. J. Huétink:
- Member of scientific advisory committee of International Journal of Forming Processes

11. **Keynote lectures.**

Dr. Ir. A.H. Van den Boogaard:
- Do advanced material models contribute to accuracy in industrial sheet forming simulations; Shemet conference, Erlangen 2005

12. **Membership 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
- Member of the Numisheet scientific committee

Prof. Dr. Ir. A. de Boer:
- Netherlands representative in the Programme Committee of ICAS (International Counsel of Aerospace Sciences).
- Member of the accreditation committee for the departments of Electrical-Mechanical Engineering at the Flemish universities of Brussel, Gent and Leuven.
- Member of the Scientific committee of ISMA (International Seminar on Modal Analyses), KU Leuven.

13. **Awards and patents**


M. A.H. Bonte, Award for best presentation, Apomat conference 2005, Morschach, Switzerland "Solving optimisation problems in metal forming using Finite Element simulation and metamodelling techniques"
14. Overview of research input and output

14.1 Input “Applied Mechanics” related to EM, 2005

<table>
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1 Sources of financing: 1: University 2: STW, SON, NOW, FOM 3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, etc.

2 No research input involved for supporting staff.

3 Research input per PhD per year: 0.8 fte

14.2 Output “Applied Mechanics” related to EM, 2005

<table>
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<th>Scientific publications</th>
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* In co-operation with other EM-groups

15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte

**Project Title:** STW project TW 6618, Inverse Acoustics  
**Participating Groups:** Applied Mechanics (UT), Dynamics & Control (TUe)  
**Participants:** Prof. Dr. Ir. A. de Boer (UT), Dr. Ir. Y.H. Wijnant (UT), Ir. J.W. Wind (UT), Prof. Dr. Ir. N.B. Roozen (TUe), Dr. I. Lopez (TUe), Ir. R. Scholte (TUe)  
**Research Input in fte:** 2.0

**Project Title:** Hybrid Isolation of Construction noise (HIC)  
**Participating Groups:** Applied Mechanics (UT), Mechanical Automation (UT)  
**Participants:** Prof. Dr. Ir. A. de Boer (UT), Prof. Dr. Ir. B. Jonker (UT), Ir. C.A.J. Beijers (UT), Ir. H. Super (UT), Dr.Ir. J. van Dijk (UT)  
**Research Input in fte:** 1.9

**Project Title:** Rotor Dynamics  
**Participating Groups:** Applied Mechanics (UT), Mechanical Automation (UT)  
**Participants:** Prof. Dr. Ir. A. de Boer (UT), Prof. Dr. Ir. B. Jonker (UT), Ir. P. Sloetjes (UT), Ir. P.J.M. van der Hoogt (UT)  
**Research Input in fte:** 1.0
Project Title: Friction and roughness transfer in rolling and metal forming processes.
Participating Groups: Applied Mechanics (UT), Surface Technology and Tribology (UT)
Participants: Prof. Dr.Ir. J. Huétink (UT), Ir. E.C. Dillingh (TNO), Prof. Dr.Ir. D.J. Schipper (UT)
Research Input in fte: 1.0

Project Title: NIMR-project MC1.03158, Strain path dependent materials models for forming and crash
Participating Groups: Applied Mechanics (UT)
Materials Technology (TU/e)
Participants: Prof. Dr.Ir. J. Huétink, Dr.Ir. A.H. van den Boogaard, Ir. M. van Riel (MIMR/UT), Prof. Dr.Ir. M.G.D. Geers, Dr.Ir. W.A.M. Brekelmans, T. Yalcinkaya (TU/e/NIMR)
Research Input in fte: 2.0

Project Title: FOM-NIMR-project 02EMM30, Tailoring of processable metastable steels
Participating Groups: Applied Mechanics (UT)
Materials Technology (TU/e)
Fundamentals of advanced materials (TUDelft, not EM member)
Participants: Prof. Dr.Ir. J. Huétink, Dr.Ir. H. Geijselaers (UT), S. Perdahcioglu (FOM/UT), Prof. Dr.Ir. M.G.D. Geers (TU/e), Dr. V. Kouznetsofa (NIMR/TU/e), A. Balmachov (FOM/TU/e), Prof. Dr.Ir. S. van der Zwaag (TUD), Dr. D. san Martin (FOM/TUD)
Research Input in fte: 2.5

Project Title: NIMR-project MC1.04205, Forming the limits of damage prediction
Participating Groups: Applied Mechanics (UT)
Materials Technology (TU/e)
Participants: Prof. Dr.Ir. J. Huétink, Dr. ir. H.H. Wisselink, Prof. Dr.Ir. M.G.D. Geers, Dr.Ir. R. Peerlings (TU/e), C. Tasan (NIMR/TU/e)
Research Input in fte: 2.0

Project Title: NIMR-project MC1.01100 Static friction in metal forming
Participating Groups: Applied Mechanics (UT), Surface Technology and Tribology (UT)
Participants: Prof. Dr.Ir. J. Huétink (UT), Prof. Dr.Ir. D.J. Schipper (UT) Dr. Ir. M.B. de Rooij (UT) Mrs E.L. Deladi (NIMR/UT)
Research Input in fte: 1.0

Project Title: NIMR-project MC1.03160 Galling performance indicator
Participating Groups: Applied Mechanics (UT), Surface Technology and Tribology (UT)
Participants: Prof. Dr.Ir. J. Huétink (UT), Prof. Dr.Ir. D.J. Schipper (UT) Dr.Ir M.B. de Rooij (UT). Ir. G. van der Linde (NIMR/UT)
Research Input in fte: 1.0

Project Title: High Precision Rubber Forming
Participating Groups: Production Technology (UT), Applied Mechanics (UT)
Participants: Prof. Dr. ir. R. Akkerman, Prof. Dr.Ir. J. Huétink Dr. ir V.T. Meijniders, Ir. S. Wijskamp
Research Input in fte: 1.0
Project Title: Draping Simulation of Non Crimp Fabric in Composite forming
Participating Groups: Production Technology (UT), Applied Mechanics (UT)
Participants: Prof. Dr. ir. R. Akkerman, Prof. Dr. Ir. J. Huétink, Dr. ir V.T. Meijnders, Ir. R. ten Thije
Research Input in fte: 1.0
11. 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

3. Group director

Prof.dr.ir. D.J. Schipper

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

Rooij, Dr.Ir. M.B. de UD 0.3
Schipper, Prof.Dr.Ir. D.J. Full Professor 0.3
Total fte: 0.6

5. PhD- projects related to research school EM 2005: name, source of financing, project title and research theme EM

5.1 Tribology

Deladi, Msc. E.L. (PhD 3) Static friction StDy
Sloetjes, Ir. J.W. (PhD 3) Micro-EHL StDy

5.2 Surface Technology and Roughness

Dillingh, E.C (PhD 3) Friction and roughness transfer MeMa
Jamari, Ir. J. (PhD 3) Running-in of surfaces StDy

5.3 Materials and coatings

Moodij, Ir. E. (PhD 3) Hydrostatische Magnesium Extrusie StDy
5.4 Experimental Validation

Linde, Ir. G. v.d. (PhD 3) Gallina Performance Indicator MeMa

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

Heide, Dr.Ir. E. van der The Netherlands Friction and Wear; 12 months 5.3 MeMa
Pasaribu, Dr.Ir. H.R. Indonesia Thin film lubrication, 10 months 5.1 StDy

7. Short description of subprogrammes related to research school EM

The subject of research in surface technology and tribology is the interaction of material 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 the regimes with respect to friction and wear. The modelling is aimed at design tools for reliable and accurate prediction of tribological behaviour in practical applications. The main subjects are I) Lubricated systems: (elasto-) hydrodynamic lubrication, mixed- and boundary lubrication, II) Special materials and Coatings: ceramics, MMC’s, PMC’s, lasertreated surfaces and PVD and III) Surface Textures: human-product interaction.

7.1 Tribology

The research conducted in this subprogramme deals with the frictional behaviour in lubricated concentrated contacts. Special attention is paid to the rheology of the lubricant, shear thinning effects and starvation, on film formation and frictional behaviour. Besides this the local interaction between the opposing surfaces is studied by developing elastic-plastic contact models. On the basis of the models developed one is able to predict for line- and point contacts the Stribeck curve for I) heavily loaded contacts, II) shear thinning of the lubricant and III) starved 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. For systems set in motion or set still friction is determining the position of a system in time and space. Therefore, in this subprogramme attention is paid to this phenomenon (static friction). Special attention is paid to rubber-metal contact. Related to research theme “Structural Dynamics and Control”.

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 model is developed for the contact between a 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. It is, for instance, possible to generate micro-EHL instead of boundary lubricated micro-contacts. In certain applications the surface roughness should not change too much in order to maintain a certain friction level. The change in surface roughness
roughness cannot be detected in the traditional way (profile measurements). By matching and stitching several images before and after a tribological experiment the change in surface roughness can be determined in a quantitative way (deterministic and statistically). 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. The research also includes the phenomenon “galling” occurring during deep drawing and extrusion.
Related to research themes “Mechanics of Materials” and “Structural Dynamics and Control”.

7.3 Materials

Oxide ceramics (alumina, zirconia and their composites) are studied because of their specific properties. The research focuses on the development of nano-scale oxide ceramic couples with low friction. The reason for this is that in previous research it was shown that nano-scale oxide ceramics are highly wear resistant. However, the application of these materials is hampered by the fact that the coefficient of friction is too high, 0.5 and higher likewise for other ceramics. Therefore, metal oxides are added during the material processing of oxide ceramics. The basis for this idea is that the additive forms a thin interfacial layer between the opposing surfaces during rubbing. Initial experiments showed that the coefficient of friction could be reduced to a value of 0.2 for a sliding distance up to 4 km. The mechanism of the interfacial layer formation will be studied as well as the friction will be modeled in order to optimize the ceramic material. The friction model is based upon ploughing and adhesion.
In sheet metal forming processes coatings are becoming more and more important. This because lubricants are more and more omitted for environmental reasons. Large tools in sheet metal forming are made of cast iron. By locally re-melting, by using a laser, and subsequently applying a layer, by means of PVD, a duplex coating for these applications is studied. The modeling with respect to friction and wear focuses on local ploughing, cutting and wedge formation. The abrasive wear is experimentally studied with a surface force apparatus and will be compared with the model. The galling phenomenon is studied for the hydrostatic magnesium extrusion process. The influence of the fluid is studied extensively. Related to research theme “Mechanics of Materials” and “Structural Dynamics and Control”.

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 paid to measure 1) semi on line micro-wear by using an interference microscope, 2) friction during cold rolling in the roll-bite by means of a special designed friction sensor and 3) 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. Related to research theme “Structural Dynamics and Control” and “Mechanics of Materials”.

8. Refereed scientific publications related to research school EM

8.1 Refereed journals


8.2 Books, chapters in book

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8.2 Refereed proceedings


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

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<td>Pasaribu, H.R.</td>
<td>Friction and Wear of Zirconia and Alumina Ceramics Doped with CuO</td>
<td>University of Twente</td>
<td>February 2005</td>
<td>90-365-2143-2</td>
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<td>Advisors:</td>
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10. **Membership editorial boards international journals**

Prof. dr.ir. D.J. Schipper
- Member editorial board Industrial Lubrication and Tribology
- Member editorial board Tribotest
- Member editorial board Lubrication Science

11. **Keynote lectures**

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12. **Membership International Scientific Committees**

Prof.dr.ir. D.J. Schipper:
- Secretary of the International Research group on Wear of Materials, IRG-OECD.
- Member University Grants Committee of the University of Hong Kong.

13. **Awards and patents**

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14. Overview of research input and output

14.1 Input “Tribology” related to EM, 2005

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\(^1\) Sources of financing: 1: University
2: STW, SON, NOW, FOM
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, etc.

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

14.2 Output “Tribology” related to EM, 2005

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<td>PhD theses</td>
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15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte

Project Title: Friction and roughness transfer in rolling and metal forming processes.
Participating Groups: Applied Mechanics (UT) Surface Technology and Tribology (UT)
Participants: Prof. Dr.Ir. J. Huetink (UT), Ir. E.C. Dillingh (TNO), Prof.dr.ir. D.J. Schipper (UT)
Research Input in fte: 1.0

Project Title: NIMR-project MC1.01100 Static friction in metal forming
Participating Groups: Applied Mechanics (UT), Surface Technology and Tribology (UT)
Participants: Prof. Dr.Ir. J. Huetink (UT), Prof. Dr.Ir. D.J. Schipper (UT) Dr. Ir. M.B. de Rooij (UT) Mrs E.L. Deladi(NIMR/UT)
Research Input in fte: 1.0

Project Title: NIMR-project MC1.03160 Galling performance indicator
Participating Groups: Applied Mechanics (UT), Surface Technology and Tribology (UT)
Participants: Prof. Dr.Ir. J. Huetink (UT), Prof. Dr.Ir. D.J. Schipper (UT) Dr. Ir M.B. de Rooij (UT). Ir. G. van der Linde (NIMR/UT)
Research Input in fte: 1.0
12. 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
2.3 Laser machining of materials

3. Group director

Prof. Dr. Ir. J.B. Jonker

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

<table>
<thead>
<tr>
<th>Name</th>
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<tr>
<td>Aarts, Dr. Ir. R.G.K.M.</td>
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5. PhD-projects related to research school EM per December 2005: name, source of financing, project title and research theme EM

5.1 Robotics and Micro Mechatronic Systems

<table>
<thead>
<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Brouwer, Ir. D.M.</td>
<td>Multi Axis Micro Stage (MAMS)</td>
<td>StDy</td>
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<tr>
<td>Graaf, Ir. M.W. de</td>
<td>Seam-tracking for robotized laser welding</td>
<td>StDy</td>
</tr>
<tr>
<td>Hakvoort, Ir. W.B.J.</td>
<td>Iterative Learning Control for Robotized Laser Welding</td>
<td>StDy</td>
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<tr>
<td>Hardeman, Ir. T.</td>
<td>Model Based Beam Manipulation Control</td>
<td>StDy</td>
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<tr>
<td>Waiboer, Ir. R.R.</td>
<td>Off-Line Programming for laser welding</td>
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5.2 Vibration isolation control

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<tr>
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<td>State-space based active vibration isolation control algorithms</td>
<td>StDy</td>
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<tr>
<td>Poel, Ir. G.W. van der</td>
<td>Design of smart mount for application of vibration isolation in precision machinery</td>
<td>StDy</td>
</tr>
<tr>
<td>Super, Ir. H.</td>
<td>Hybrid isolation of structure borne noise</td>
<td>StDy</td>
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</table>
5.3 Laser machining of materials

Aalderink, Ir. B.J. (PhD 3) Multivariable weld pool control for double spot laser welding

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

Lange, Dr.Ir. D.F. de Unsteady meltpool and keyhole modelling for laser welding; Feb 2002-Feb 2007

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 is investigated in order to get a better understanding of the achievable performance and to enlarge the industrial applicability especially for robotised laser welding. The research deals with the modelling of the robotic manipulator, the identification of the dynamic parameters, simulations of the closed-loop system of manipulator and its controller, enhancements of the (industrial) controller and the integration of sophisticated sensors. The robot models take into account all aspects of the inertia properties, friction, flexibility and the control system. For 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. Furthermore, the linearization and subsequent use of modal techniques resulted in a computationally efficient simulation algorithm.

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. 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.

For laser welding it is important that the focussed laser beam is guided along the seam to be welded with sufficient accuracy at the specified welding speed. The required accuracy is quite demanding for industrial six axes robots. In the UT/NIMR-project on “Improved laser beam manipulation control for robotized laser welding” two independent solutions for the reduction of tracking errors are being investigated.

In “Model Based Beam Manipulation Control for Robotized Laser Welding” the laser beam will be manipulated with an additional lightweight manipulator mounted at the robot tip. Experiments with a first prototype of such a scanner system have been quite satisfactory. However, it also appeared that even with a seam detection sensor operating at about a kHz, the performance is limited due to signal delays. The next step is to analyse the actual robot motion in real-time in order to estimate future errors. As the real tip motion has to be simulated, the existing rigid robot models will have to be extended with elastic
components. The research so far concentrated on the development of the models, possibilities to increase the speed of the simulations and identification techniques for the parameters in the models with elasticity. It appeared to be quite complicated to determine the correct model structure from experimental data. A new framework for the parameter identification has been designed. It has been tested with simulations, but experimental results are not yet available.

In "Iterative Learning Control for Robotized Laser Welding" it is attempted to improve the tracking accuracy by adding an Iterative Learning Controller to the standard industrial (feedback) robot controller. In a first implementation only the joint motion has been considered. Tracking errors measured in the past are used to modify the reference trajectory for the robot motion during subsequent trials of a repetitive motion. The path corrections are computed using a straightforward model of the controller and (rigid) robot. A next step has been the use of synchronised measurements from a tip mounted seam sensor. This ILC algorithm has also been tested and proved to be capable of correcting errors in a frequency range up to about the lowest natural frequency of the robot. In the future ILC algorithms will be developed in which the actual tip motion will be corrected in a larger frequency range.

The application of such a seam sensor has also been investigated in a European project on “Seam-tracking for robotized laser welding” as in many practical situations robotized laser welding cannot be successful without using a seam-tracking sensor. Such a sensor measures the relative position and orientation of the robot tip and laser head with respect to the seam. From such data the actual seam position with respect to the robot coordinate system has to be calculated. At the end of that project it was demonstrated that it was possible to teach the robot to track an unknown seam and to weld it successfully. Since then the procedures for the calibration of the sensor and laser tool centre point (TCP) have been improved further. In addition a protocol for accurate synchronisation between sensor and robot controller has been defined and implemented in order to be able to use sensor data that is measured while the robot is moving. This way, it becomes possible to apply real-time seam tracking, i.e. the actual seam position is measured by the seam sensor and the robot motion is adjusted just in time before the seam is welded. At all stages of the development and testing of advanced seam tracking algorithms, the non-ideal behaviour of the robot has to be taken into account. The continuous effort invested in combining simulations and experimental results appeared to be indispensable.

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

7.2 Vibration isolation control

The tendency towards miniaturisation in precision technology leads to a constant decrease in accuracy specifications for precision machines. Disturbances, often produced by vibrations of the floor or machine parts, 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 and the formulation of design principles for mechanical realizations of mounts. The systems (mounts) to design consist of an active sub-system of actuators, sensors and a control strategy next to the mechanical structure. The active subsystem uses measurements to generate antiforces in the mount which are opposite to the excitation forces.

For investigating control strategies in vibration control a set-up has been built. This set-up consists of a source plate excited by a shaker. Vibrations from the source pass through the three mounts to the receiver plate. Without control this receiver is vibrating. In the case the control system is active, the accelerations are measured by 6 accelerometers...
and 6 piezo actuators produce forces that counteract the forces due to vibrations. In this manner the source is isolated from the receiving construction.

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

7.3 Laser machining of materials

During laser welding with high laser intensity the laser penetrates deep into the material creating a so-called keyhole. The keyhole is a narrow and deep crater formed by the pressure of the evaporating metal. In keyhole laser welding of metals, in particular aluminium, the occurrence of porosity and holes in the weld and spatter are serious problems. These phenomena are closely related to the stability of the keyhole and the surrounding liquid metal in the melt pool during the welding process. In two NIMR projects the laser welding process is being investigated both by simulations and experimentally.

Simulations of the unsteady three-dimensional behaviour of keyhole and melt pool are the goal in the project “Unsteady melt pool and keyhole modelling for laser welding”. The research aims at the development of a simulation tool that includes the heat balance, radiation (e.g. from the laser), fluid dynamics (in the liquid and vapour domain and at the interface) and material properties. A two-dimensional unsteady model of the interaction of the laser beam with the material proved to be successful for the analysis of laser drilling. Current focus is on three-dimensional models for the simulation of the stationary geometry of the melt pool during laser cladding. Numerical results are compared with experimental observations using thermal images during laser cladding and measurements of realised clad layers. For laser keyhole welding a three-dimensional unsteady model will have to be developed.

The experimental work on laser welding is concentrated in the project on “Multivariable weld pool control for double spot laser welding”. The goal of this project is to obtain reliable process conditions for laser welding of aluminium sheets. Process stability as mentioned previously is one concern. Furthermore, the weld quality depends strongly on the gap width of the seam to be welded. During welding experiments it was found that for perfect seams the process could be stabilised by using sufficiently high laser power or by using a double spot beam delivery system. With such a system the laser power is focussed in two spots. It can also be used in combination with filler wire to obtain good weld quality for a larger range of gap widths. A sensor system is needed to monitor the welding process in real-time in the presence of intense optical emissions from the aluminium welding process. A visualisation system has been developed based on a CMOS camera with a high dynamic range. In addition an illumination laser and optical filtering are applied to obtain sufficiently clear images. With this visualisation system a number of sources for process instability could be traced and avoided. Ongoing research focuses on the development of a smart wire feeding system in which the wire speed is controlled depending of the requirements of the welding process. Furthermore the link between numerical simulations and the camera images should be established.

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

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8.3 Refereed proceedings


Brouwer, D.M.; Jong, B.R. de; Soemers, H.M.J.R.; Dijk, J. van: Sub-nanometer stable precision MEMS clamping mechanism maintaining clamp force un-powered for TEM application; The 16th workshop on micromachining, micromechanics and Microsystems, Göteborg, September, 4-6, 2005, 4 pages [CDROM].


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

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10. Membership editorial boards international journals

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11. Keynote lectures

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12. Membership international scientific committees

Prof.Dr.Ir. J.B. Jonker:

- Member of the ICINCO 2005 Programme Committee of the 2nd International Conference on Informatics in Control, Automation and Robotics, Sebútal, Portugal.
• IFToMM member technical Committee for Robotics and Mechatronics.

13. Awards and patents

14. Overview of research input and output

14.1 Input “Mechanical Automation” related to EM, 2005

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<td>Postdocs</td>
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<sup>1</sup> Sources of financing: 1: University  
2: STW, SON, NWO, FOM  
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, NIMR, etc.

<sup>2</sup> No research input involved for supporting staff.

<sup>3</sup> Research input per PhD per year: 0.8 fte

14.2 Output “Mechanical Automation” related to EM, 2005

<table>
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<tr>
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<td>Scientific publications: books, chapters in book</td>
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<tr>
<td>Scientific publications: refereed proceedings</td>
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<tr>
<td>PhD theses</td>
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</table>

15. Co-operation with other EM-groups: project title, participating groups, participants and research input in fte

Project Title: Hybrid Isolation of Construction noise (HIC)  
Participating Groups: Applied Mechanics (UT), Mechanical Automation (UT)  
Participants: Prof. Dr. Ir. A. de Boer (UT), Prof. Dr. Ir. B. Jonker (UT), Ir. C.A.J. Beijers (UT), Ir. H. Super (UT), Dr. Ir. J. van Dijk (UT)  
Research Input in fte: 1.9

Project Title: Rotor Dynamics  
Participating Groups: Applied Mechanics (UT), Mechanical Automation (UT)  
Participants: Prof. Dr. Ir. A. de Boer (UT), Prof. Dr. Ir. B. Jonker (UT), Ir. P. Sloetjes (UT), Ir. P.J.M. van der Hoogt (UT)  
Research Input in fte: 1.0
13. 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 Composites

3. Group director

Prof.dr.ir. R. Akkerman

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

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<th>Name</th>
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<tr>
<td>Akkerman, Prof.Dr.Ir. R.</td>
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<td>Bor, Dr.Ir. T.C.</td>
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<td>Warnet, Dr.Ir. L.</td>
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5. PhD-projects related to research school EM per December 2005: name, source of financing, project title and research theme EM

5.1. Composites

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<td>Kruijer, Ir. M.</td>
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<td>Reinforced Thermoplastic Pipes</td>
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<td>Loendersloot, Ir. R.</td>
<td>PhD 3</td>
<td>Resin Transfer Moulding</td>
<td>CoMe</td>
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<tr>
<td>Thije, Ir. R.H.W. ten</td>
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<td>Villa-Rodriguez, Ir. B.H.</td>
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6. Postdocs: name, country, project title, research theme EM and period of stay

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<th>Project Title</th>
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<td>Wijskamp, Dr.Ir. S.</td>
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<td>Transverse Reinforcement</td>
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7. Short description of subprogrammes related to research school EM

7.1 Composites
The Composites Group conducts research into the mechanisms and modelling of deformation and failure of continuous fibre composites under different rates of loading. This modelling is combined with an experimental programme (for identifying the mechanisms operating) to establish material property data for the modelling and to test the modelling accuracy. Dr.ir. T.C. Bor is setting up research on lightweight metallic materials along similar lines. Some efforts were put into self healing composite materials by means of shape memory alloys.

Composite Damage Development
These studies are aimed at gaining insight into damage development in continuous fibre reinforced plastics in order to optimise materials and structures with respect to impact performance. Most efforts were devoted to the “Large Diameter Reinforced Thermoplastic Pipe” programme.
This Eureka funded programme is a co-operation with Pipelife NL, Seaflex AS (N), Bekaert (B). Most efforts were directed towards steel cord reinforced polyethylene pipes for larger diameters than the currently commercially available 4" aramide reinforced pipe. The mechanical properties (stiffness and strength) of the steel cords can be predicted from micromechanical considerations. The properties of the cord reinforced tape follow when the cord properties are combined with an appropriate nonlinear viscoelastic model for the HDPE matrix. The long term strength of the RTPs can be predicted when these constitutive laws are implemented in a model for a thick walled pipe. A design method was developed applying these models. The work was reported in a number of scientific publications and in thesis of ir. Kruijer, to be defended in 2006.
A project funded by the IMPACT institute was performed on Transverse Reinforcement, in which carbon nanofibres were grown on a carbon microfibre substrate. The resulting composite properties are promising. The result of the post-doc project (performed by dr.ir. Wijskamp) will be used in a proposal for further research funding.
Finally, the research on impact of composite (Glare) structures was intensified by a revival of interest in impact (in particular bird strike) on wing leading edges. This work is performed in collaboration with Stork-Fokker, the NLR and the Structural Dynamics group of prof. de Boer (UT).

High Precision Composites Moulding
The NIVR funded programme on High Precision Rubber Press Forming of Thermoplastic Laminates was concluded with the PhD thesis of S. Wijskamp (May 2005). A new initiative was started in cooperation with the TUDelft (Design and Production of Composites Structures group), Ten Cate AC and Stork-Fokker, resulting in two PhD positions in 2006. The UT group will work on friction between successive composite layers and between the laminate and the tools.

Resin Transfer Moulding
The major part of the research work on Resin Transfer Moulding is performed in collaboration with the National Aerospace Laboratory (NLR). The investigations on permeability focused on the analysis of statistical effects. The micro-geometry of carbon Non Crimp Fabrics was analysed to find the distribution of flow channel dimensions. These were subsequently used to predict the effects of these distributed properties on the overall macroscopic permeability, by means of a mesoscopic network analysis. The variation in properties and their spatial distribution lead to a significant variation in the permeability, compared with the results for a network with a uniform averaged geometry only. Further work was devoted to other textile structures, i.e. biaxial woven fabrics and triaxial braids. The work was reported in a number of scientific publications and in thesis of ir. Loendersloot, to be defended in 2006.
The NIVR funded national round robin exercise on permeability measurements was carried
out in collaboration with the Centre of Lightweight Structures and the NLR. Permeability is a material property which is recognized as very difficult to measure in a reproducible manner, not only within a single laboratory but even more between different labs. The UT coordinated the out-of-plane permeability measurements.

Further work on NCFs was performed within the Framework 5 programme FALCOM (Failure, Performance and Processing Prediction for Enhanced Design with NCF Composites), which was concluded in May 2005. Fundamental issues in terms of accuracy and convergence of finite element simulations of anisotropic materials were identified and solved.

All activities within the programme are related to the research themes “Mechanics of Materials” and “Computational Mechanics”.

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

8.1 **Refereed journals**


8.2 **Books, chapters in books**

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8.3 **Refereed proceedings**


R.H.W. ten Thije, R. Akkerman, Finite element simulation of draping with non-crimp fabrics, 15th ICCM conference, Durban (South Africa), 2005, on cd-rom


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

Name: Wijskamp, S.
Title: Shape Distortions in Composites Forming, PhD thesis University of Twente, May 2005, ISBN 90-365-2175-0
Advisor: Prof. Dr.Ir. R. Akkerman, Prof.Dr.Ir. J. Huétink
Current position: Vredestein, Tyre Materials and Processing
10. Membership editorial boards international journals

Prof. Dr. Ir. R. Akkerman
- Member of the editorial board of Composite Structures

11. Keynote lectures

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Dr. Ir. L. Warnet
- Member of the organising committee of the ESIS TC4 conference on Fracture of Polymers, Composites and Adhesives.

13. Awards and patents

-----

14. Overview of research input and output 2005

14.1 Input “Production Technology” related to EM, 2005

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Sources of financing:
1: University
2: STW, SON, NOW, FOM
3: Industry, TNO, Brite-Euram, Nuffic, Min. Econ. Affairs, etc.

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

14.2 Output “Production Technology” related to EM, 2005

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<td>PhD theses</td>
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* In co-operation with other EM-groups
15. **Co-operation with other EM-groups: project title, participating groups, participants and research input in fte.**

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