Annual Report 2001

Dynamics and Control Technology Group

Department of Mechanical Engineering
Eindhoven University of Technology
The Netherlands

Report 2002.001

Address
Lia Neervoort
Eindhoven University of Technology
Dynamics and Control Technology
P.O. Box 513
5600 MB Eindhoven
The Netherlands
Tel.: +31.40.2474817
Fax.: +31.40.2461418
E-mail: c.m.neervoort@tue.nl

1 Sections: Dynamics & Control and Control Systems Technology
CONTENTS

Preface

1. Employees

2. Education

3. Research Dynamics and Control Technology

4. Internal Reports
The Dynamics and Control Technology (DCT) Group comprises the two sections Dynamics & Control and Control Systems Technology within the Department of Mechanical Engineering of the Eindhoven University of Technology. A number of changes occurred during 2001.

The largest change was the merging of part of the former Power Transmission and Tribology section within the Control Systems Technology section.

The restructuring of the department of Mechanical Engineering has resulted in the new Dynamical Systems Design (DSD) Division. It comprises the two DCT sections and the sections Systems Engineering and Precision Engineering. Its primary purpose is to define a joint master track programme. In addition, the DCT group actively takes part in the new master track Automotive.

Another change that was effectuated in 2001 has been the ending of the bio-mechanics activities within the Dynamics and Control section. Given the changing focus of the section, the injury bio-mechanics and cardiac mechanics have moved to other groups within the Department of Mechanical Engineering and the Department of Biomedical Engineering.

This annual report should particularly demonstrate the fact that the two sections aim at profound and intimate interaction. For that reason the research activities in both sections are coherently presented together in this report.
1. EMPLOYEES OF THE GROUP (per 31 December 2001)

1.1. Co-workers

Full professors : Dr. H. Nijmeijer
Dr. Ir. M. Steinbuch
Dr. Ir. D.H. van Campen (PM Dean TU/e-W)
Dr. Ir. J.J. Kok (0.6)

Part-time professors : Ir. N.J.J. Liebrand (0.4; 0.6 VDT)
Dr. Ir. M.J.W. Schouten (0.2; 0.8 ID)
Dr. Ir. J.W. Verheij (0.2; 0.8 TNO-TPD)
Dr. Ir. J.S.H.M. Wismans (0.2; 0.8 TNO-WT)

Senior research staff : Dr. Ir. R.M. v. Druten (NWO)
Dr. Ir. H.A. van Essen
Ir. H.J. Giesen (0.3; 0.7 TU/e-W)
Dr. Ir. A.G. de Jager
Ir. L. Kodde
Dr. Ir. A. de Kraker (0.3; 0.7 TUE-W)
Dr. Ir. M.J.G. v.d. Molengraft
Ir. P.W.J.M. Nuij
Dr. A. Pogromsky
Dr. Ir. W.J.A.E.M. Post
Dr. J.J.M. Rijpkema
Dr. Ir. A.J.G. Schoofs (0.2)
Dr. Ir. F.E. Veldpaus (0.8)
Dr. Ir. G. Verbeek (0.3)
Dr. Ir. N. v.d. Wouw

Supporting staff : R. v.d. Bogaert
Ing. T.J.A.G. v. Duppen (0.8)
C.A. Hofkens (0.4)
K.T.M. Koekkoek
C.R. v.d. Laan
H.C.T. v.d. Loo
Ing. E. Meinders
C.M. Neervoort-Sanders (0.9)
Ing. N.R. Olthuis (0.9)
Ing. D. Steman
J.G.M. de Vries

Ph.D Students

Resource 1 : Ir. N.P.J. Aneke
Ir. R.P.B.J. Dollevoet
Ir. R. Dubbeldam (0.2; 0.8 Delphi)
Ir. L. Geerts-Ossevoort
Ir. R.H.A. Hensen
Ir. R.J. Hesseling (0.5; 0.5 BMW)
M.Sc. D. Kostic
M.Sc. N. Mihajlovic
M.Sc. D. Putra
Ir. R.A. v. Rooij
M.Sc. A.V. Pavlov

Resource 3: Ir. D.W.A. Brands (TNO-PML)  
M.Sc. F.X. Debiesme (TNO-EM)  
Ir. W.J. Dijkhof (TNO-EM)  
Ir. R.C.P. Kerckhoffs (Medtronic)  
M.Sc. A. Rodriguez (Conacyt, Mexico)  
Ir. M.G.E. Schneiders (IOP)

Post-docs: Dr. M. Lemmen (Duisburg)  
Dr.Ir. R.I. Leine (EM)  
Dr.Ir. D.A. Lizarraga  
Dr. G. Santoboni (NWO)  
Dr.Ir. A.F.A. Serrarens (NWO)  
Dr.Ir. B. Vroemen (NWO)

TWAIO’S: Ir. C.V. Vottis (SAI)  
Ir. V. Ivanov (SAI)

Guests: Dr. P.A. Veenhuizen (VDT)

1.2. Personal matters

Appointed

Dr.Ir. P. De Leenheer 01-01-01 Post-Doc  
Dr. A. Pogromsky 01-01-01 UD  
Ir. R. Dubbeldam 01-01-01 AIO-1 (0.2)  
R. v.d. Bogaert 01-09-01 from Section Power Transmission and Tribology  
Ir. R.P.B.J. Dollevoet 01-09-01 from Section Power Transmission and Tribology  
Dr.Ir. R.M. v. Druten 01-09-01 from Section Power Transmission and Tribology  
D.R. v.d. Laan 01-09-01 from Section Power Transmission and Tribology  
Prof.Ir. N.J.J. Liebrand 01-09-01 from Section Power Transmission and Tribology  
Dr.Ir. W.J.A.E.M. Post 01-09-01 from Section Power Transmission and Tribology  
Prof.Dr.Ir. M.W.J. Schouten01-09-01 from Section Power Transmission and Tribology  
J.G.M. de Vries 01-09-01 from Section Power Transmission and Tribology  
Ir. M.G.E. Schneiders 01-10-01 AIO-3

Leaving office

Dr.Ir. R. Happée 01-01-01 End of contract  
Ir. M.J. v.d. Horst 01-01-01 End of contract  
Dr. J. Zhang 15-01-01 End of contract  
Dr.Ir. P.H.L. Kessels 31-01-01 PhD Thesis  
Dr.Ir. G.Z. Angelis 28-02-01 End of contract  
Mak Müh M.E. Dukul 01-04-01 Retired  
Ir. J. Hartgers 01-04-01 to industry  
Dr.Ir. P.H.M. Bovendeerd 01-05-01 Mate  
Prof.Dr.Ir. M.G.J. Arts 01-06-01 Mate  
Ir. J.P.A. Banens 01-07-01 Retired
<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Ir. P. De Leenheer</td>
<td>01-08-01</td>
<td>End of contract</td>
</tr>
<tr>
<td>Ing. M.W.B.M. Leensen</td>
<td>15-08-01</td>
<td>End of contract</td>
</tr>
<tr>
<td>Ir. A. Cuellar</td>
<td>31-08-01</td>
<td>SAI diplom</td>
</tr>
<tr>
<td>Dr. S. Shen</td>
<td>17-09-01</td>
<td>End of contract</td>
</tr>
<tr>
<td>L. Garninto</td>
<td>31-09-01</td>
<td>SAI diplom</td>
</tr>
<tr>
<td>Ir. B.L. v.d. Vrande</td>
<td>12-12-01</td>
<td>PhD Thesis</td>
</tr>
</tbody>
</table>
2. EDUCATION OF THE GROUP

2.1. Compulsory undergraduate courses

<table>
<thead>
<tr>
<th>Trimester</th>
<th>Lecturers</th>
<th>Course code</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>Giesen/Rijpkema/Verbeek/Nijmeijer/Veldpaus</td>
<td>4A230</td>
<td>Dynamica</td>
</tr>
<tr>
<td></td>
<td>Rijpkema/Verbeek</td>
<td>4Q220</td>
<td>Dynamische systemen</td>
</tr>
<tr>
<td>1.3</td>
<td>v. Essen/Veldpaus/v.d. Wouw/Rijpkema</td>
<td>4A320</td>
<td>Systeemanalyse</td>
</tr>
<tr>
<td>2.1</td>
<td>de Kraker/v.d. Wouw</td>
<td>4A460</td>
<td>Mechanische trillingen</td>
</tr>
<tr>
<td>2.2</td>
<td>v. Campen/Rijpkema/Bovendeerd</td>
<td>4Q520</td>
<td>Dynamica in de BMT</td>
</tr>
<tr>
<td>2.2</td>
<td>Steinbuch/Veldpaus/Rijpkema/Pogromsky</td>
<td>4A550</td>
<td>Regeltechniek</td>
</tr>
<tr>
<td>3.1</td>
<td>Kok/de Jager</td>
<td>4A560</td>
<td>Regelen van multi-variabele systemen</td>
</tr>
</tbody>
</table>

2.2. Selective courses

<table>
<thead>
<tr>
<th>Trimester</th>
<th>Lecturers</th>
<th>Course code</th>
<th>Titel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>4K300</td>
<td>Data-acquisitie</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4K130</td>
<td>Signaalanalyse</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4N820</td>
<td>Oriëntatie Voertuigtechn.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4T700</td>
<td>Engineering Optimization: Advanced Topics</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4N630</td>
<td>Hydraulische aandrijftechniek</td>
</tr>
<tr>
<td>3.2 &amp; 4.2</td>
<td>de Kraker</td>
<td>4J560</td>
<td>Numerieke experimentele analyse van lineaire dynamische systemen</td>
</tr>
<tr>
<td></td>
<td>Nijmeijer/v. Essen/v.d. Wouw/de Jager/Liebrand/v. Druten</td>
<td>4J100</td>
<td>Regelen van niet lineaire mechanische systemen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4J820</td>
<td>Geavanceerde regeltechniek</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4N810</td>
<td>Voertuigaandrijvingen</td>
</tr>
<tr>
<td>3.3 &amp; 4.3</td>
<td>Giesen/Koppens/Etman/Rijpkema/Schoofs</td>
<td>4J400</td>
<td>Multibody dynamica</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4J530</td>
<td>Engineering Optimization: concept and application</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4J700</td>
<td>Parameterschatten</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4K410</td>
<td>Digital Motion Control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4L810</td>
<td>Basiskennis geluidarm construeren</td>
</tr>
</tbody>
</table>
2.3. **Number of graduated students per professor**

- v. Campen : 2
- Liebrand : 4
- Nijmeijer : 2
- Steinbuch : 8
- Verheij : 1
- Wismans : 1

2.4. **Graduated students**

In 2001 18 students of the DCT Group have been graduated. For the titles of the engineering theses the reader is referred to chapter 4: internal reports.

<table>
<thead>
<tr>
<th>Name</th>
<th>Professor</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.G.M. Hendriks</td>
<td>Steinbuch</td>
<td>29 January</td>
</tr>
<tr>
<td>R. Tebbens</td>
<td>Steinbuch</td>
<td>29 January</td>
</tr>
<tr>
<td>P.T.M. Bax</td>
<td>v. Campen</td>
<td>19 March</td>
</tr>
<tr>
<td>P.L. Knapen</td>
<td>Verheij</td>
<td>19 March</td>
</tr>
<tr>
<td>L. v. Rooy</td>
<td>Wismans</td>
<td>25 June</td>
</tr>
<tr>
<td>R.P.P. Roelands</td>
<td>Steinbuch</td>
<td>25 June</td>
</tr>
<tr>
<td>R.M. Westerhof</td>
<td>Steinbuch</td>
<td>25 June</td>
</tr>
<tr>
<td>P.R. v.d. Jagt</td>
<td>Liebrand</td>
<td>24 September</td>
</tr>
<tr>
<td>F.A.C.M. Jongenelen</td>
<td>Liebrand</td>
<td>24 September</td>
</tr>
<tr>
<td>D.H. Swinkels</td>
<td>Liebrand</td>
<td>24 September</td>
</tr>
<tr>
<td>H.M.A. v.d. Akker</td>
<td>Steinbuch</td>
<td>24 September</td>
</tr>
<tr>
<td>M.G.W. Schneiders</td>
<td>Steinbuch</td>
<td>24 September</td>
</tr>
<tr>
<td>I.A.C. Soute</td>
<td>Steinbuch</td>
<td>24 September</td>
</tr>
<tr>
<td>R.P.G.T. v.d. Velde</td>
<td>Nijmeijer</td>
<td>24 September</td>
</tr>
<tr>
<td>A.H. Koevoets</td>
<td>Nijmeijer</td>
<td>24 September</td>
</tr>
<tr>
<td>C.F. Janssens</td>
<td>v. Campen</td>
<td>26 November</td>
</tr>
<tr>
<td>H.J.A. Peeters</td>
<td>Liebrand</td>
<td>26 November</td>
</tr>
<tr>
<td>M.W.T. Koot</td>
<td>Steinbuch</td>
<td>26 November</td>
</tr>
</tbody>
</table>
3. RESEARCH DOCUMENTATION OF THE DYNAMICS AND CONTROL TECHNOLOGY GROUP

3.1 Full title of the research programmes
Dynamics and Control
Control Systems Technology

3.2 Subsidiary programmes
1) Nonlinear dynamics of mechanical systems
2) Structural acoustics
3) Structural optimization
4) Motion systems
5) Process-control and hydraulic systems
6) Automotive and power transmission systems
7) Injury biomechanics
8) Cardiac mechanics

3.3 Programme members

<table>
<thead>
<tr>
<th>Name</th>
<th>Employment</th>
<th>Research input (fte) in 2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prof. Dr. H. Nijmeijer</td>
<td>full Professor</td>
<td>0.4</td>
</tr>
<tr>
<td>Prof. Dr. Ir. M. Steinbuch</td>
<td>full Professor</td>
<td>0.4</td>
</tr>
<tr>
<td>Prof. Dr. Ir. D.H. van Campen</td>
<td>full Professor (PM)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>main position Dean TU/e-W</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr. Ir. J.J. Kok</td>
<td>full Professor (0.6)</td>
<td>0.2</td>
</tr>
<tr>
<td>Prof. Ir. N.J.J. Liebrand</td>
<td>part-time Prof. (0.4)</td>
<td>0.1</td>
</tr>
<tr>
<td>Prof. Dr. Ir. M.J.W. Schouten</td>
<td>part-time Prof. (0.2)</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>main position dean ID</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr. Ir. J.W. Verheij</td>
<td>part-time Prof. (0.2)</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>main position at TNO-TPD</td>
<td></td>
</tr>
<tr>
<td>Prof. Dr. Ir. J.S.H.M. Wismans</td>
<td>part-time Prof. (0.2)</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>main position at TNO-Automotive</td>
<td></td>
</tr>
<tr>
<td>Dr. Ir. A.G. de Jager</td>
<td>UHD</td>
<td>0.4</td>
</tr>
<tr>
<td>Dr. Ir. A. de Kraker</td>
<td>part-time UHD (0.3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>main position Dir. Education Mech. Eng. program. W</td>
<td></td>
</tr>
<tr>
<td>Dr. Ir. F.E. Veldpaus</td>
<td>UHD</td>
<td>0.4</td>
</tr>
<tr>
<td>Dr. Ir. R.M. v. Druten</td>
<td>UD since Sept. 2001</td>
<td>0.1</td>
</tr>
<tr>
<td>Dr. Ir. H.A. van Essen</td>
<td>UD</td>
<td>0.4</td>
</tr>
<tr>
<td>Dr. Ir. M.J.G. van de Melingraft</td>
<td>UD</td>
<td></td>
</tr>
<tr>
<td>Ir. P.W.J.M. Nuij</td>
<td>UD</td>
<td>0.4</td>
</tr>
<tr>
<td>Dr. Ir. W.J.A.E.M. Post</td>
<td>UD since Sept. 2001</td>
<td>0.1</td>
</tr>
<tr>
<td>Dr. J.J.M. Rijpkema</td>
<td>part-time UD, main position Gen. Manager Research School EM</td>
<td>0.2</td>
</tr>
<tr>
<td>Dr. Ir. A.J.G. Schoofs</td>
<td>part-time UD (0.2)</td>
<td>0.1</td>
</tr>
<tr>
<td>Dr. Ir. G. Verbeek</td>
<td>part-time UD (0.3)</td>
<td>0.2</td>
</tr>
<tr>
<td>Dr. Ir. N. van de Wouw</td>
<td>UD</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Total fte 4.5
3.4 PhD-projects per December 2001: name, source of financing and project title

**Nonlinear Dynamics of Mechanical Systems**
M.Sc. N. Mihajlovic (PhD 1) Limit cycling in mechanical systems
M.Sc. A.V. Pavlov (PhD 2) Robust regulation of complex dynamical systems

**Structural Acoustics**
M.Sc. F.X. Debiesme (PhD 3) Design tools for low noise products with uncertain parameters
Ir. W.J. Dijkhof (PhD 3) Analysis methods for low noise products with uncertain parameters

**Structural Optimization**
Ir. R.A. v. Rooij (PhD 2) Sequential approximate design optimisation including uncertainties, discontinuities and discrete design variables

**Motion Systems**
Ir. N.P.I. Aneke (PhD 1) Underactuated Systems
Ir. R.H.A. Hensen (PhD 1) Friction Modelling and Control
M.Sc. D. Kostic (PhD 1) Data-based control
M.Sc. D. Putra (PhD 1) Control of Limit Cycles
M.Sc. A. Rodriguez (PhD 2) Synchronization of mechanical systems
Ir. M.G.E. Schneiders (PhD 3) Overactuated Systems

**Automotive and Power Transmission Systems**
Ir. R.P.B.J. Dollevoet (PhD 1) Coatings for Hydraulic Systems
Ir. R.J. Hesseling (PhD 1/3) Passive Car Safety

**Injury Biomechanics**
Ir. H.L.A. v.d. Bosch (PhD 2) Modelling of helmet/head system under impact
Ir. D.W.A. Brands (PhD 3) Wave propagation in brain tissue due to blunt impacts
Ir. R. Dubbeldam (PhD 1) (0.2) Mathematical lower extremity model for counter measure evaluation

**Cardiac Mechanics**
Ir. L. Geerts-Ossevoort (PhD 1) Remodelling of the left ventricle
Ir. R.C.P. Kerckhoffs (PhD 3) Dynamic shape changes of the heart

3.5 Postdocs: name, country, project title and period of stay

Dr.Ir. R.I. Leine, NL Numerical methods for non-smooth systems, June 2000 – December 2001
Dr. M. Lemmen, Germany Nonlinear Modelling, March 1999 – December 2001
Dr. D.A. Lizarraga, Mexico Control of underactuated systems, June 2000- June 2002
Dr. G. Santoboni, Italy Mathematical modelling and control of constrained mechanical systems, October 2000 – April 2002
Dr. S. Shen, China Simulation of CVT, Sept. 1999 – Sept. 2001
3.6 Research in the Dynamics and Control Technology Group

The general research objective of the Dynamics and Control Technology group is the study of all aspects related to dynamics and control of high-performance mechanical systems. This covers the full range of topics such as modelling and analysis of systems, controller synthesis, signal and performance analysis. Practical and experimental validation is, where possible, part of the research. A crucial role in this is played by the Dynamics and Control Technology Laboratory, where various (new) experimental set-ups serve as test-bed for advanced research studies, and which are also used in graduate teaching.

The increasing requirements on accuracy, energy consumption, environmental aspects, and human comfort for many technical products urge the need for a better understanding, modelling, analysis, and control synthesis to improve performance. This requires an accurate modelling of the dynamics, preferably in a form suitable for analysis and, where possible, also for the synthesis of control systems. From a modern systems and control perspective the performance demands are tackled using a model-based controller design, which takes into account the available knowledge on the dynamics of the system and of its disturbances. In particular for mechanical systems such an approach is feasible and promising, due to the existing broad experience in the modelling of these systems. In other physical disciplines the situation is different and first principles are usually not so well developed. The inherent dynamic properties of mechanical systems are physical and geometric nonlinearities, possibly a large number of degrees of freedom, interactions between the degrees of freedom and, often, a relatively high speed of operation. The combination of these properties easily leads to difficulties in the modelling and analysis, and thereby also in bringing a model-based controller design to a successful end in practice. This is the basic challenge throughout the research in the DCT-Group, thereby aiming at methods and tools of practical value. Clearly, it is the ambition of the group to work at the forefront of present-day technology and to aim at a highly recognisable research stature within the department, but also within and outside the Netherlands.

The research in the Dynamics and Control Technology group comprises research in the following areas.
1. Nonlinear dynamics of mechanical systems
2. Structural acoustics
3. Structural optimization
4. Motion systems
5. Process-control and hydraulic systems
6. Automotive and power transmission systems
7. Injury biomechanics
8. Cardiac mechanics

Before surveying the results and developments in this research programme, a description is given of our DCT Lab, and of the structure of cooperation within research schools, and with other groups both in academea and industry.
### 3.7 Dynamics and Control Technology Laboratory

This year an ongoing effort has been put in re-vitalisation of the **Dynamics & Control Technology Laboratory**. The drill-string, the H-drive pick-and-place system, the RRR robot manipulator, the inverted pendulum, and the one-sided impact flexible beam are actively being used as test-bed for research. New experimental set-ups are now operational and various projects are running on them: a copier and a printer provided by OCE, three Compact Disc mechanisms provided by Philips CFT, five ‘fourth-order’ systems to be used in education and PATO courses, four mechanical pick-and-place units (‘Pizza steppers’), originally from the LCD factory of Philips Electronics, and provided by Fontys; new are also a small scale mobile robot, an SMA-based medical manipulator with force feedback, a ultra-precision mechanical set-up for slip detection, a laser scanner motion system (with TNO industry), electrical circuits for emulating the Duffing equation and for generating chaos (Chua circuit), and a vertical lift system to be used in education.

Our technical staff (mechanical and electrical) is key in providing support and creating a stimulating environment for PhD and MSc students to do their experiments in the Lab. The real-time hardware, data acquisition and measurement equipment is now at a mature level, including over 10 dSpace systems, 5 SigLab measurement systems, and over 10 TU/e DACS systems which enable students to use their own notebook computers as real-time control processors.

Besides the DCT Lab at floor –1 in building WH the automotive activities took place at our **Ecodrive Lab facility**. Also the **Hydraulics lab** is now part of the DCT group.
3.8 Structure of cooperation

*Department of Mechanical Engineering*

Within the Department of Mechanical Engineering the Dynamics and Control Technology Group has a fruitful interaction with various other research groups. Recently, in preparation for the new BSc and MSc curriculum, the teaching activities of the group are being merged into the newly established Dynamical Systems Design (DSD) Division, together with the sections Systems Engineering and Precision Engineering. In this way an MSc. Track ‘Dynamical Systems Design’ within the Master of Mechanical Engineering program has been defined. The group also participates actively in the MSc. Track ‘Automotive’ within the Master of Mechanical Engineering program.
Besides the cooperation with the sections of the DSD division, also with the Energy & Combustion group common projects are running.

**Eindhoven University of Technology**

Local inter-faculty cooperation exists in particular with the Department of Biomedical Engineering, Department of Electrical Engineering (Control Systems group, Electro-mechanics and Power Electronics group), and with the Department of Mathematics and Computing Science.

**National Research Schools**

The Dynamics and Control Technology group takes part in the National Research School DISC (Dutch Institute for Systems and Control) to enable a co-operation between the groups locally as well as countrywide. The common interest in systems and control theory is the central theme here. On the level of applications, however, each group within DISC, needs a full imbedding in its own faculty. Within Eindhoven we have organized the DISC groups within ‘Eindhoven Control’.

The DCT group also takes part in the National Research School EM (Engineering Mechanics). The secretariat of this Research School is in the DCT group and one of the staff members of the DCT group (Dr. Rijpkema) acts as General Manager of the Research School.

**National inter-university co-operation**

As far as national inter-university co-operation is concerned, substantial co-operation exists with Maastricht University in the field of bio-mechanics, where among others joint PhD projects are involved. Additional inter-university co-operation is realized through the Research School on Engineering Mechanics, in particular with Delft University of Technology in the field of structural optimization under a joint STW-project, and also with Delft University of Technology in the field of Systems and Control.

**National research institutes**

As far as national research institutes are concerned, important co-operation exists with the following major TNO-Institutes: with TNO industry in the field of Mechatronics, with TNO-Automotive and with TNO- Prins Maurits Laboratory in the field of injury bio-mechanics and in the field of automotive power trains, with TNO-Applied Physics in the field of structural acoustics and compressor dynamics & control, and with TNO-Building & Construction Research in the field of nonlinear dynamics and multi-phasic materials. In this context it should be mentioned that senior staff members of TNO-Crash Safety Centre (Prof. Wismans, injury bio-mechanics) and TNO-Applied Physics (Prof. Verheij, structural acoustics) are appointed in the Dynamics and Control Technology group as part-time professors.

**Industrial Contacts**

Co-operations with industrial partners exist in the form of a number of PhD projects. Research started mid 1997 in an EETU project on the development and control of a hybrid drive-line; partners are Van Doorne’s Transmissie and TNO Automotive. The program was successfully finished in 2001. With BMW a PhD program is running on the use of active control for vehicle passive safety systems. Together with Ford Research Aachen and the Control Systems group of TU/e, EE, a project has been started on vehicle electric
power management. With Philips Optical Storage Singapore and Eindhoven a co-operation is running on control of optical drives. On the level of student final thesis work (1st and 2nd phase) other industrial contacts exist with Océ, Philips Electronics N.V., VDT, DAF and others.

International co-operation
Next, the international co-operation is mentioned, mostly with sister universities. Our group participated in a recently finished BRITE-EURAM project on interdisciplinary optimization and still participates in two more or less recently started EC-COST programmes on Injury Criteria and on Structural Dynamics. In these programmes quite a number of European universities and research institutes are involved, the co-operation with Liège University (Belgium) in the field of structural optimization and the co-operation with Ford-US in the field of injury bio-mechanics, the latter resulting in an annual grant.
We also take part in the Danish program WAVES, on the use of Wavelets in control. In the year 2001 a substantial number of students went abroad for their 14 weeks training period, to various colleagues in the field (Singapore, Australia, New Zealand, Turin, San Diego, Buffalo, Mexico, Japan)

3.9 Overview of results and future developments

In the following an overview is given of results and future developments for each of the eight major research areas mentioned earlier.

Nonlinear dynamics of mechanical systems (research area 1)
Within this theme, the following more specific research topics are investigated:
a) Numerical and experimental study of non-smooth mechanical systems, like systems with friction, impacts, or constraints, is a mainstream topic within the group. The research on these phenomena is highly relevant in many engineering applications (friction in high performance/high precision systems, drill-strings, hybrid control systems etc.). Numerical aspects are notably difficult, but with the increasing computer power, become more and more feasible. Interesting and important results involve the study of bifurcation's in non-smooth systems.

b) Development of accessible (numerical) procedures for the steady-state response under periodic excitation. In particular, a nonlinear dynamics toolbox with time-discretization and shooting methods and a path-following procedure has been integrated in the commercial finite element package DIANA and in the general-purpose package MATLAB. Nonlinear dynamics phenomena for mdof structural engineering systems have also been studied by experiments on a laboratory scale. Applications to industrial systems (aircraft landing gear, solar array system, rotor-bearing systems, etc.) have been successfully carried out. A fairly new topic is the development of an efficient strategy in the case of stochastic excitation. Even for moderate nonlinear mdof dynamic systems, stochastic linearization fails and only the very time-consuming Monte-Carlo simulation seems to remain. For an elementary laboratory system, the similarity has been evaluated both numerically and experimentally between the broad-band stochastic and the periodic response. This similarity can be used as a key to evaluate equivalent linear or equivalent nonlinear
models of such strongly nonlinear systems. Such models will be of major importance for application in engineering practice. Still a lot of fundamental and application-oriented research has to be performed.

c) Additionally, increased attention is paid to parameter identification methods for specific subsystems, e.g. roller-bearings as used in gear boxes. This information is very important for the prediction of noise radiation by such subsystems.

In the future, the research in the above three topics is expected to tend to integrate, including the development of optimization strategies.

**Structural acoustics (research area 2)**

The research in this area is concentrated on topics related to low-noise design. The emphasis in recent years and in the forthcoming period will be on computational methods for application in design tools in an engineering environment:

a) By recent research the group has made significant progress in realizing fast computational tools for the vibrations and sound radiation of (nearly) axisymmetric structures. The primary application of this work, financed by STW, is low-noise design of Magnetic Resonance Imaging systems. However, other applications, e.g. in the areas of wheel noise from trains or sound radiation of carillon bells are of interest as well. The research is split into modelling of the vibrations of inhomogeneous, but (nearly) axisymmetric structures under non-axisymmetric loading, and of their sound radiation. Those sub-topics are being joined together in numerical optimization procedures, which are adapted for a designer’s environment. Interested users of these tools are currently found at Philips Medical Systems, Philips CFT, TNO-Institute of Applied Physics and SKF.

b) A recently started research topic involving two PhD students is the modelling of 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 wavelengths are 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. TNO-Institute of Applied Physics participates significantly in this long-term research and industrial partners will be sought as well.

**Structural optimization (research area 3)**

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 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’ has been started. It was awarded by the Technology Foundation STW. 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 multibody systems, composite structures and manufacturing systems.

**Motion Systems (research area 4)**

*a) Vibration control.*

A new (IOP-Precision technology) project was started this year on the development of a light-weight motion system with more actuators than rigid body degrees of freedom, together with the Precision Engineering section (ME) and the Electro-mechanics and Power Electronics group (EE). Optimization strategies are being developed for the design of tensegrity structures, including I/O selection and optimization. A new activity started this year with preliminary investigations into bio-robotics, or more specifically, surgical robotic systems. Together with the Department of Biomedical Engineering we have realized a (test) laparoscopic instrument (slave) using smart (active) materials as actuator, and a master operated by the operator (surgeon).

*b) Data-based control and disturbance identification.*

The goal of this research line is to explore signals (data) in control system design. Classification, detection, adaptation are key issues. Various project are running or are initiated within this field. (i) the RRR project is about data based control of a robot-like mechanical system with three rotational degrees of freedom. Identification has been used to build a detailed model on the non-linear rigid body dynamics, and identification in the frequency domain has been used to build models for the linear dynamics. Based on these non-linear and linear models, feedback linearization has been applied in combination with loop-shaping and robust controllers, as well as friction compensation using LuGre models. (ii) Research has been continued in the field of Iterative Learning Control (ILC). This method is based on finding iteratively the best feed forward signal for repeated motions. Experiments are being done on the `H-drive’, which is an XY positioning system with three linear motors. Attention is focussed on finding approximate inverses of the closed-loop plant model and on robustification for changing operating point and for (small) changes in the motion path. (iii) In the same area repetitive control and adaptive sine cancellation have been applied to optical storage systems, and (iv) playability has been investigated using analytical models of optical disc defects, as well as experimentally using feature detection with wavelets.

*c) Identification of friction in high-performance motion systems*

In high-performance motion systems, like pick-and-place machines, friction
can cause severe side effects, such as limit-cycling. A model of the friction phenomena is developed for the prediction and analysis of friction-related problems in closed-loop. This model can also be exploited by the controller itself, e.g. in the form of adaptive direct friction compensation. It is expected that many of today’s high-performance motion systems will gain both speed and accuracy if friction is taken into account in the controller design. A grey-box friction model has been identified and successfully used for on-line friction compensation for a rotating inverted pendulum set-up, as well as for the H-drive and the RRR robot. Also, progress has been made with prediction of limit cycling behaviour (event mapping tools). Work has been started on slip-detection using dedicated measurements of the changing dynamics during stick/slip.

d) Gain scheduling
For a large class of nonlinear systems a natural approach for control design is local linearisation and feedback. The interconnection of controllers and corresponding scheduling with operating point is subject of research. One approach is the use of polytopic linear models. These models constitute a convex combination of linear models, which enables extension of known linear system theory to nonlinear problems. The identification of both the polytopic model structure and its parameters on the basis of experimental data has been done for the friction experiment above. Based on this, a gain scheduled controller has been successfully implemented. A start is made with the investigation of LPV2 gain scheduling control design. Emphasis was put on generating LPV models from experiments; the H drive is used for this purpose.

e) Tracking control of underactuated mechanical systems
This project emphasizes tracking control of underactuated systems, i.e. systems with less independent control inputs than degrees of freedom. Typically this includes certain flexibilities in robot-like constructions as well as nonholonomic systems like mobile robots, vehicles and ships. An illustrative example forms the RRR robot with only two actuators active. The H drive set-up has been modified to be able to carry an underactuated manipulator on the X sledge.

f) Mobile robot structures
This new research line in the Dynamics & Control Technology Laboratory has been initiated in 2000. Mobile, autonomous, structures are very attractive for numerous application areas (space travelling, mail delivery, cleaning, inspections in hazardous environments etc.). Apart from mechanical design issues, these systems exhibit specific control challenges, especially because the systems are often underactuated and not enough accurate measurement information is available. The aims for this research line are: (i) development of an experimental set-up for validation of (theoretical) non-linear control concepts, (ii) development and validation of non-linear models, controllers, and observers, (iii) development of a representative demonstration object for mobile and underactuated mechanical structures.

g) Synchronisation of nonlinear systems
In this new project fundamental methods are investigated for the design of synchronising mechanical systems, and the robustness and stability of
synchronised controllers are studied. Synchronisation, or co-ordination as it is often called, is relevant in various mechanical systems, for instance in case two or more robots are asked to work in synchrony. As a test-bed the Pizza steppers are used.

**Process Control and Hydraulic Systems (research area 5)**

*a) Model Predictive Control*

The aim of this research line is the development and implementation of new strategies in model based control, especially related to the areas of Nonlinear Model Predictive Control, i.e. using nonlinear models and non-convex optimisation methods, Mixed Integer Model Predictive Control, i.e. incorporating logic decisions (discrete control inputs), Model Predictive Control with stochastic models, i.e. stochastic prediction and optimisation. Motivated by useful industrial applications, in these areas a flexible real-time implementation, favorable in the Matlab/ Simulink/ dSpace environment and supported by experimental validation in the Dynamics & Control Technology Laboratory will be aimed at. Current applications we are working on include: real time MPC on fast mechanical systems like robot manipulators, nonlinear MPC on nonholonomic mobile robots, control of re-configurable diesel engines (STW project in co-operation with the Energy Technology Group), control of manufacturing processes (duo project in co-operation with the Systems Engineering Group)

*b) Flow control of turbomachinery*

The operational flexibility and efficiency of compressors is limited by the occurrence of unstable flow phenomena, in particular rotating stall and surge. Traditionally these instabilities are avoided by recycling or bleed. However, such measures also hamper the operational flexibility and efficiency of the compressor system. This project - a co-operation with Energy & Combustion - is aimed at developing an active control strategy based on detailed knowledge of the fluid flow inside the compressor. In the previous years the (duo) project has shown that active surge control of the compressor can shift the surge region and so enlarge the region of feasible operating points. A new (duo) project has been formulated, in co-operation with TNO/TPD, Delft and Demag-deLavalle, focussing on further investigation into surge control, and initiating research on stall instabilities.

*c) Symbolic computation and Genetic Programming*

The aim of the project is to use symbolic computation as an aid in the analysis and design of nonlinear control systems, and to implement design methods for (robust) nonlinear controllers as a structured computer aided design tool. This has resulted in a computer program called NonLinCon. It can be used for process control systems as well as for mechanical positioning devices and for automotive systems.

In 2001 an interesting and successful investigation has been done on using genetic programming for finding Lyapunov equations for nonlinear stability assessment.

*d) Hydraulic Systems*

The transfer of the Hydraulics activities to the CST section enables a further development of system theoretic and control engineering issues for hydraulic systems. It is our belief that within the Netherlands there is a need for
academic research in hydraulic servo systems. One focus will be on Learning Hydraulic systems.

e) Tissue Engineering
New research is defined together with the Department of Biomedical Engineering. It is part of a European research project IMBIOTOR, and focuses on the development of an intelligent bioreactor for tissue engineering.

Automotive and Power Transmission Systems (research area 6)

a) Design and Control of a hybrid drive line
The project concentrates on the development of a hybrid drive line with an internal combustion engine, a flywheel and a continuously variable transmission (CVT). The aim of the research is to achieve a significant reduction in fuel consumption and in exhaust gas emissions without a decrease in comfort or driveability. Models are developed and used for the design of local controllers for the CVT and the clutches. An advanced test bench is realized. The analysis of many possible layouts for the hybrid drive line has resulted in a practical, more or less optimal layout. The design and manufacturing of the components (flywheel, clutches and fixed ratio transmissions) is finished. The hybrid driveline has been realised in a commercially available car. For the control of the total system a drive line manager (DLM) is developed and tested, using an advanced model. The Dutch governmental programme EET (Economy, Ecology and Technology) sponsors the research. Partners in the project are Van Doorne’s Transmissie, TNO Automotive and the TUE. The project started mid 1997 and has been finished with 3 PhD theses in 2001.

b) Energy efficient Continuously Variable Transmissions
A new project (3 PhDs) has been granted (BTS/VDT) with emphasis on alternative actuation principles for CVT’s and slip detection algorithms for force control, in order to improve efficiency of CVTs.

c) Passive Car Safety Systems
Passive car safety systems are for instance air-bags and safety belts. The project is a co-operation with BMW, and is focussed on the possible use of active control (feedback/feedforward) elements in passive safety systems. During the initial phase of the project a start was made with modelling the occupant dynamics and that of airbag and belt using elementary models. Identification has been used to extract linear models from the complex models. These linear models have been successfully used to design feedback controllers for the airbag and belt, showing a significant improvement of the performance (less peak decelerations of the body) of those systems.

d) Electric Power Management Systems
With Ford Research Aachen, and in co-operation with the Control Group of the Department of Electrical Engineering, a new project has been started on on-line optimal control of electrical power distribution and management in vehicles.

Injury biomechanics (research area 7)
The aim of the injury biomechanics research is to provide or improve insight into the mechanisms through which a transient load (contact force or
acceleration) on the human body results into injury, and, eventually, to use
this insight to set up guidelines for protection measures and to improve injury
diagnosis and treatment. The injury mechanics research is carried out in close
co-operation with TNO Crash Safety Centre and is also sponsored by Ford
Motor Company.
In a PhD project, sponsored by STW, the protective functioning of helmets is
investigated, and new guidelines are developed for design and testing of
helmets. Here, the numerical head model is extended with a helmet model.
Also, a novel physical head model is developed, containing a brain simulant,
made of a silicone gel, in a flexible skull. The behaviour of this head model is
assessed in a testing facility. Biplane X-ray is used to measure deformation of
the artificial brain and skull.
The activities in this area will be continued in 2002 within the Mechanics of
Materials group.

Cardiac mechanics (research area 8)
The aim of the research in cardiac mechanics is, firstly, to analyse the
relationship between the pump function of the heart as a whole and the
functioning of the individual muscle cells in the cardiac wall, using
experimentally validated mathematical models. Next, these models are used
to obtain insight into the adaptation properties of cardiac tissue, and to predict
the short-term and long-term response of the heart to pathological or surgical
interventions.
The activities in this area will be continued in 2002 within the Department of
BioMedical Engineering.

3.10 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 J. of Robust and Nonlinear Control
- Member Editorial Board J. of Applied Mathematics Computer Science
- Member Editorial Board J. of Dynamical Control Systems
- Member Editorial Board International J. of Control
- Member Editorial Board J. of Stability and Control
- Member Editorial Board European Journal of Control

Prof. Dr. Ir. M. Steinbuch:
- Editor-at-Large European Journal of Control
- Associate editor IEEE Control Systems Magazine

Prof. Dr. Ir. J. W. Verheij:
- 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)
Prof. Dr. Ir. J.S.H.M. Wismans:
- Member SAE Readers Cie (SAE Transactions)
- Member Editorial Board, J. of Crashworthiness

3.11 **Keynote & general lectures; seminars (duration ~ 40 min. or more)**

Prof. Dr. Ir. D.H. van Campen:

Prof. Dr. H. Nijmeijer
- ‘Recent advances in nonlinear observer design’, CINVESTAV, Mexico DF, 30 August 2001.
- DISC-course Nonlinear Systems and Control Theory (together with prof. dr. A.J. van der Schaft)

3.12 **Membership of 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.
- Council member Dutch Technology Foundation (STW) since 1993.
- Member EUROMECH Nonlinear Oscillation Conference Committee from 2000.

Dr. Ir. A. de Kraker:

Prof. Dr. H. Nijmeijer:
- Part-time professor Department of Mathematics and Computer Science, TU/e
• Member Board Dutch Institute of Systems and Control (DISC)
• Member IPC European Control Conference, 2001, Porto (P)
• Member IPC IFAC conference NOLCOS 2001, St. Petersburg (Russia)
• Member EU Marie Curie Network ‘Control Training Site’
• Member EU Marie Curie Network ‘MASTER’
• Member thesis committee B.L.J.Brown, Univ.Cape Town, South-Africa
• Member Overleg Onderzoekscholen Wiskunde (OOW)

Prof.Dr.Ir. M. Steinbuch:
• Chairman of the Danish Research Programme WAVES (2001-2004).

Prof.Dr.Ir. J.W. Verheij:
• Member Scientific Committee of Eight Int. Congress on Sound Vibration, Hong-Kong, 2-6 July, 2001.
• President of The Acoustic Society of the Netherlands.
• Secretary of the International Institute of Acoustics and Vibration.
• Scientific Advisory Board member of The Maritime Research Institute of The Netherlands.

Prof.Dr.Ir. J.S.H.M. Wismans:
• Board member IRCOBI (International Research Council for Biomechanics of Impacts)
• Member Advisory Board Stapp Car Crash Conference
• Member Scientific Advisory Board, Dutch Society of Whiplash Patients (NSWP)
• Chairman Working Group 12 of the “European Enhanced Vehicle Safety Committee” (EEVC) on advanced adult crash dummies
• Co-ordinator of the European Passive Safety Network (A thematic network supported by the European Commission DG12)
• European representative in the IHRA-Biomechanics working group (International Harmonised Research Agenda on injury biomechanics)
• Member of the Commission Road Transport (Kamer Wegverkeer) of the Dutch Traffic Safety Board (Raad voor de Transport Veiligheid)
• Member of the Dutch Traffic Safety Board (Raad voor de Transport Veiligheid)

3.13 Awards and patents

C.R. v.d. Laan, *Inrichting voor het meten van een radiale contactkracht tussen een elastische afdichting van een as*. Patentnr.: 1018039

PhD theses

<table>
<thead>
<tr>
<th>Name</th>
<th>Angelis, G.Z.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>System Analysis, Modelling and Control with Polytopic Linear Models</td>
</tr>
<tr>
<td>Advisors</td>
<td>Prof.Dr.Ir. J.J. Kok and Prof.Dr. H. Nijmeijer</td>
</tr>
</tbody>
</table>
Co-advisor: Dr.Ir. M.J.G. van de Molengraft

Name: Druten, R.M.
Title: Transmission design of The Zero Inertia Powertrain
Eindhoven University of Technology, November 2001
Advisors: Prof.Dr.Ir. M.J.W. Schouten and Prof.Dr.-Ing. B.-R. Höhn
Co-advisor: Dr.Ir. P.C.J.N. Rosielle

Name: Kessels, P.H.L.
Title: Engineering toolbox for structural-acoustic design
Advisors: Prof.Dr.Ir. J.W. Verheij and Prof.Dr.Ir. D.H. v. Campen
Co-advisor: Dr.Ir. G. Verbeek

Name: Serrarens, A.F.A.
Title: Coordinated Control of The Zero Inertia Powertrain
Advisors: Prof.Dr.Ir. M. Steinbuch and Prof.Dr.Ir. P.P.J. v.d. Bosch
Co-advisor: Dr.Ir. F.E. Veldpaus

Name: Vrande, B.L. v.d.
Title: Nonlinear Dynamics of Elementary Rotor Systems with Compliant Plain Journal Bearings
Eindhoven University of Technology, December 2001
Advisors: Prof.Dr.Ir. D.H. van Campen and Prof.Dr.Ir. E.A. Muijderman
Co-advisor: Dr.Ir. A. de Kraker

Name: Vroemen, B.G.
Title: Component Control for The Zero Inertia Powertrain
Advisors: Prof.Dr.Ir. M. Steinbuch and Prof.Ir. N.J.J. Liebrand
Co-advisor: Dr.Ir. F.E. Veldpaus
3.15 Academic publications

Refereed journals:


V. Potkonjak, D. Kostic, S. Tzafestas, M. Popovic, M. Lazarevic, G. Djordjevic, *Human-Like


A. Rodríguez-Angeles, H. Nijmeijer, Coordination of two robot manipulators based on position measurements only, Int. J. of Control, 74 , 1311-1323, (2001)


Books/Book-chapters:


Refereed proceedings:

P. De Leenheer, D. Aeyels, Stabilization results for positive systems with first integrals, in 5th IFAC Symposium Nonlinear Control Systems; Editors: IFAC, St. Petersburg, Russian Federation, 925-930, (2001)


R.J. Hesseling, F.E. Veldpaus, M. Steinbuch, T. Klisch, Control Design for Safety Restraint


A. Rodriguez-Angeles, H. Nijmeijer, *Co-ordination of two robot manipulators via nonlinear
estimated state feedback, in 5th IFAC Symposium Nonlinear Control Systems; Editors: IFAC, St. Petersburg, Russian Federation, 231-236, (2001)


A.F.A. Serrarens, Driveability control of the ZI powertrain, in Integrated Powertrains and their Control; Editors: N.D. Vaughan, Bath, United Kingdom, 19--30, (2001)


Other Technical publications:
C.R. v.d. Laan, Ontwerp van een contactkrachtmeter voor radiale afdichtingen, deel 1, De Constructeur, No. 7/8, 28-31 (2001)

C.R. v.d. Laan, Ontwerp van een contactkrachtmeter voor radiale afdichtingen, deel 2, De Constructeur, 9, 48-51 (2001)
3.16 Overview of research input and output

Research input

<table>
<thead>
<tr>
<th>Sources of financing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3</td>
</tr>
<tr>
<td>Senior academic staff</td>
<td>20   -</td>
</tr>
<tr>
<td>Supporting staff</td>
<td>9 2</td>
</tr>
<tr>
<td>PhD</td>
<td>9 4</td>
</tr>
<tr>
<td>Twaio</td>
<td>2</td>
</tr>
<tr>
<td>Postdocs</td>
<td>1 3</td>
</tr>
<tr>
<td>Total</td>
<td>39 7</td>
</tr>
</tbody>
</table>

1 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
4 No research input involved for Twaio-students because they perform a designers programme

Research output

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific publications: refereed journals and Books</td>
<td>29</td>
</tr>
<tr>
<td>Scientific publications: refereed proceedings</td>
<td>27</td>
</tr>
<tr>
<td>PhD theses</td>
<td>6</td>
</tr>
</tbody>
</table>

3.17 Special Activities

The 6 day PATO course ‘Motion Control Tuning’ was again organized twice this year, jointly with the Systems and Control group of Delft University of Technology. Since the interest from industry is encouraging, we intend to give this course at least twice every year.

Dr. Ir. A.G. de Jager spend a second period of two months at the University of San Diego, in the group of Prof. Skelton, working on input/output selection of flexible structures.

Dr. Ir. R.I. Leine spend from Nov. 2000 until April 2001 at the Technische Universität München, Lehrstuhl B für Mechanik (Prof. Pfeiffer), Germany, STW grant EWO 5531 and from June 2001-Nov. 2001 at the Commande des Systèmes Electromécaniques et Robotiques (Dr. Brogliato), Laboratoire d’Automatique de Grenoble, France, STW grant EWO 5647.

4. INTERNAL REPORTS

2001.01  Annual Report 2000                              L. Neervoort
2001.03  Pressure wave propagation in tissue model material after ballistic impact. Masters Thesis  P.T.M. Bax
2001.08  Evaluation of (unstable) non-causal systems applied to iterative learning control. Report of apprenticeship M. Schneiders
2001.18  Imbiotor. Control oriented investigation of tissue engineering of cartilage              S.H.H.M. Buijsen
<table>
<thead>
<tr>
<th>Year</th>
<th>Title</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001.28</td>
<td>Dynamics of an Automatic Dry Ball Balancer applied to a Disk System. Masters Thesis</td>
<td>A.H. Koevoets</td>
</tr>
<tr>
<td>2001.31</td>
<td>How to make frames less sensitive to sound induced vibration. Report of apprenticeship</td>
<td>H.M.J. Keunen</td>
</tr>
<tr>
<td>2001.35</td>
<td>Friction induced limit cycling; An experimental case study. Report of apprenticeship</td>
<td>B.H.M. Bukkems</td>
</tr>
<tr>
<td>2001.39</td>
<td>Finding lyapunov functions using genetic programming</td>
<td>I.A.C. Soute</td>
</tr>
<tr>
<td>2001.43</td>
<td>Solving stochastic differential equations using the polynomial chaos decomposition</td>
<td>W. Dijkhof</td>
</tr>
<tr>
<td>2001.44</td>
<td>Simulation research into the event detection method</td>
<td>H.M.A. v.d. Akker</td>
</tr>
<tr>
<td>2001.46</td>
<td>Assessment of the method presented by Ghanem Spanos for the analysis of stochastic acoustical systems</td>
<td>F.X. Debiesme</td>
</tr>
<tr>
<td>2001.47</td>
<td>Motion planning for underactuated manipulators. Master’s Thesis</td>
<td>R. Verhoeven</td>
</tr>
<tr>
<td>2001.52</td>
<td>Application of the sound substructure modification</td>
<td>A.A.A. Peeters</td>
</tr>
<tr>
<td>Year</td>
<td>Title</td>
<td>Author</td>
</tr>
<tr>
<td>------</td>
<td>----------------------------------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>2001.56</td>
<td>Meten aan een Duffing systeem. Stageverslag</td>
<td>K. Willems</td>
</tr>
</tbody>
</table>