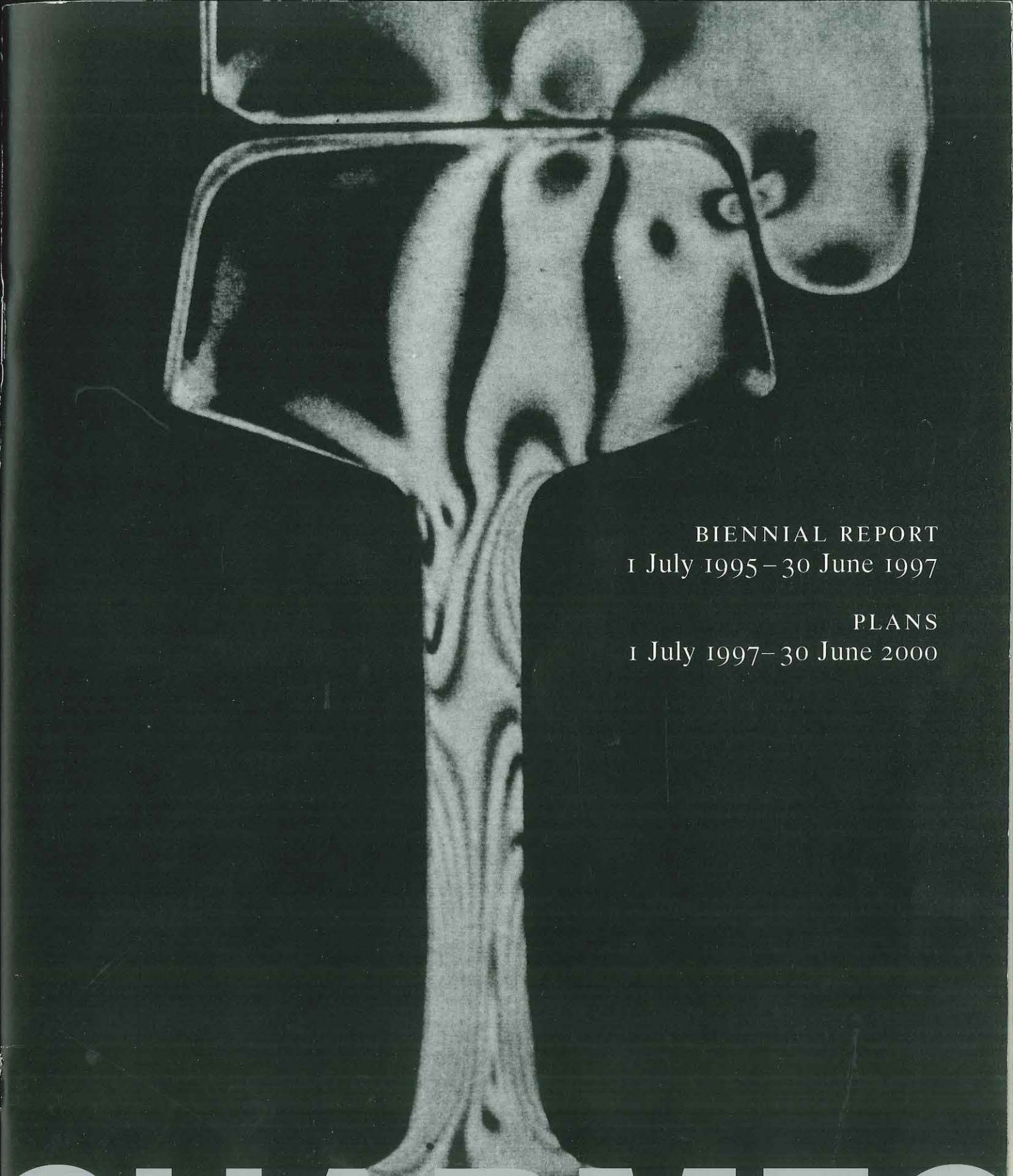
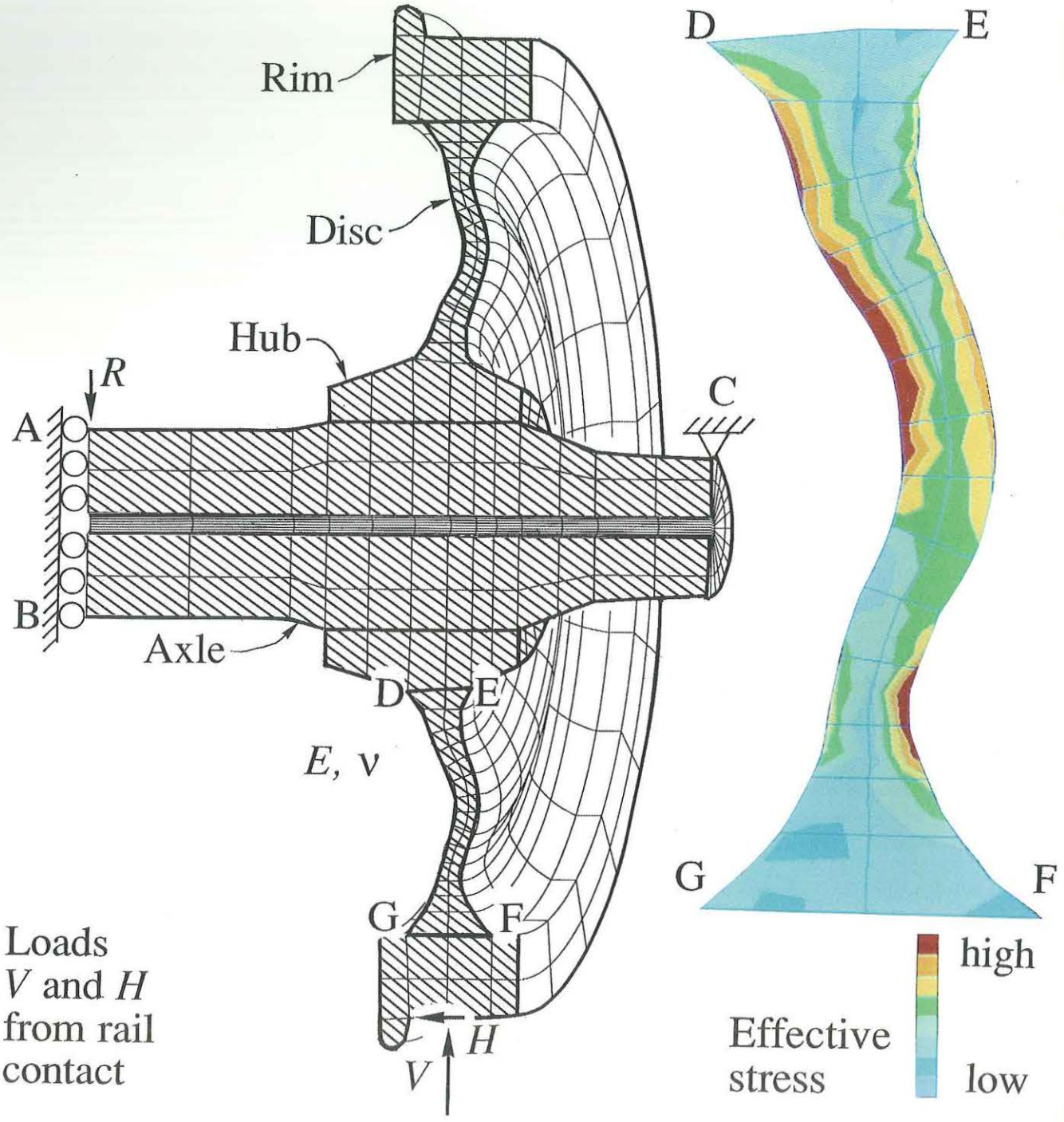


BIENNIAL REPORT
1 July 1995 – 30 June 1997

PLANS
1 July 1997 – 30 June 2000

CHARMEC

Chalmers Railway Mechanics – a NUTEK Competence Centre
Chalmers University of Technology



Left-hand figure shows a three-dimensional computer model used in 1992 at Chalmers Solid Mechanics for strength analysis of a railway wheel. The reactive loads from the rail are the vertical force V and the horizontal force H, both including dynamic contributions.

Right-hand figure shows a calculated result for the wheel disc DEFG. The three-dimensional tensorial stress field is here summarized in a scalar field, the so-called effective stress. Knowledge of this scalar measure is useful when the risk of material yielding or fatigue should be estimated for different parts of the rolling wheel.

The two figures are to be found in the Swedish National Encyclopaedia (Nationalencyklopedin) under the entry Strength of Materials (Hållfasthetslära)

CONTENTS

Front cover: Photoelastic experiment illustrating stress fields arising during contact between wheel and rail

Design: Yngve Nygren / Anders Kornestedt
Printed by Palmeblads, Göteborg 1998

INTRODUCTION

A Centre of Excellence, or Competence Centre (in Swedish: Kompetenscentrum), in Railway Mechanics has been established at Chalmers University of Technology. The formal agreement was signed at The Swedish National Board for Industrial and Technical Development (NUTEK) in Stockholm on 7 July 1995. Joint funding of Stage 1 (1 July 1995 – 30 June 1997) with a sum of MSEK 20.5 was agreed upon. It is intended that the Centre shall operate for a period of 10 years.

The acronym CHARMEC stands for CHAlmers Railway MEChanics. At the end of this report of CHARMEC's Stage 1, a brief outline is given of CHARMEC's Stage 2, which runs 1 July 1997–30 June 2000 with a budget of MSEK 58.9. The three parties to the agreement on Stage 1 are

The Industrial Interests Group

Adtranz Wheelset
an Adtranz subsidiary and wheelset manufacturer located in Surahammar

Abetong Teknik
a Scancem Group company and concrete sleeper manufacturer with headquarters in Växjö

Banverket
the Swedish National Rail Administration (infrastructure authority) with headquarters in Borlänge

SJ Maskindivisionen
the Swedish State Railways (rolling stock operator) with Machine Division headquarters in Stockholm

Chalmers University of Technology

The Swedish National Board for Industrial and Technical Development (NUTEK)

BOARD AND DIRECTOR

Anders Sjöberg, President of Chalmers University of Technology, in consultation with the Industrial Interests Group and NUTEK, appointed the following to be members of the Board of the Competence Centre during Stage 1:

Björn Paulsson (chairman)
Banverket Headquarters
Lennart Nordhall
Adtranz Wheelset
Stefan Westberg
Abetong Teknik
Hugo von Bahr
SJ Maskindivisionen
Evert Andersson
The Royal Institute of Technology (KTH), Railway Engineering, Stockholm
Hans Andersson
The Swedish National Testing and Research Institute (SP), Borås
Lars Sjöstedt
Chalmers University of Technology, Transportation and Logistics, Göteborg

Professor *Bengt Åkesson* of Chalmers Solid Mechanics was appointed Director of the Competence Centre.

Left-hand column from top: Hans Andersson of SP (1+2) and Hugo von Bahr of SJ (1+2).

Middle column from top: Kjell Sundwall of Inexa Profil (2) and Stefan Westberg of Abetong Teknik (1+2).

Group photo from left: Nils Lennart Nilsson of Cardo BSI Rail (2), Birgitta Johanson of Chalmers (secretary), Evert Andersson of KTH (1+2), Bengt Åkesson of Chalmers (initiator and former Director of CHARMEC), Roger Lundén of Chalmers (present Director), Lars Sjöstedt of Chalmers (1+2), Björn Paulsson of Banverket (1+2, Chairman), Lennart Nordhall of Adtranz (1+2) and Lennart Olofsson of Duroc (2).

1 = Board member Stage 1 2 = Board member Stage 2

VISION AND GOALS

Within its area of competence the Centre should work for a long-term build-up of knowledge that is relevant to the needs of the industry as regards railway infrastructure and rolling stock. The choice and orientation of the individual research projects should be decided on the basis of overall assessments of technology, economy, safety and environmental factors.

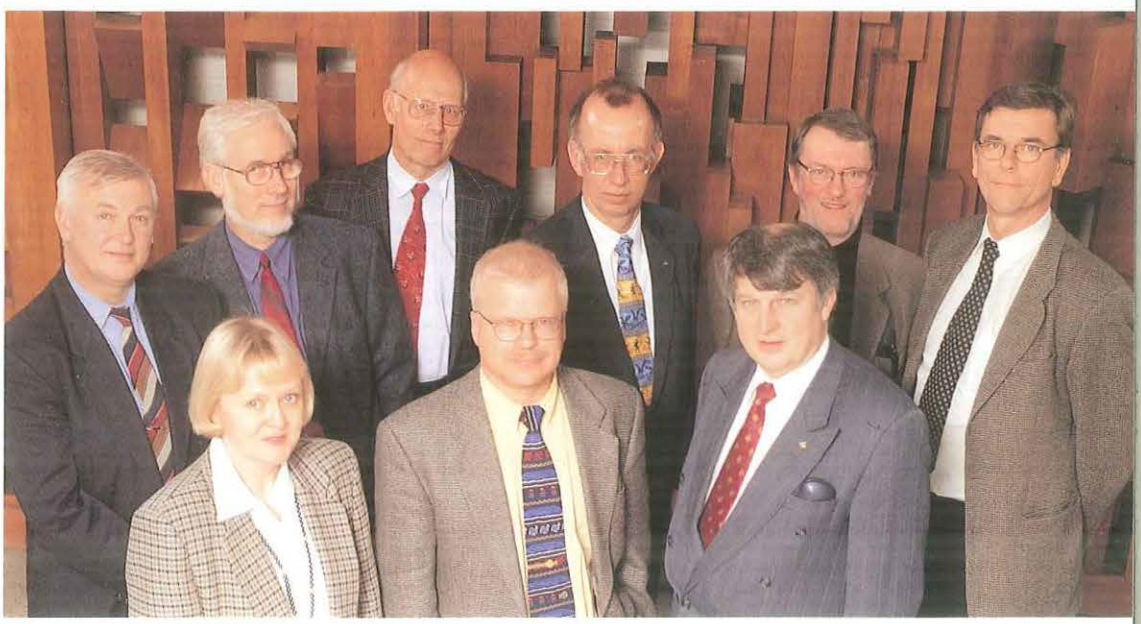
The overall goal of the Competence Centre is to achieve increased quality in railway transportation and at the same time to lower production, maintenance, operational and environmental costs. The interaction of various railway mechanical components should be given special consideration. Specific goals are life-cycle optimized components and systems for track structure and running gear. These should result in slower degradation of ballast, increased lifetime of sleepers and pads, improved track alignment stability, reduced rail and wheel wear, and lower levels of vibration and noise in trains and tracks and in their surroundings.

QUALITY ASSESSMENT AND KNOWLEDGE TRANSFER

The scientific quality of research results should be assured through public exposure and criticism at national licentiate's seminars and defence of doctor's dissertations, as well as through presenting papers at recognised international conferences and publishing papers in recognised international journals.

The transfer of knowledge to industry is to take place by means of regular personal contacts and exchange of staff, through orientation and summarizing at seminars, and through informative reports and the handing over of test results and computer programs. An extremely important aspect of this transfer of knowledge will be the employment in the industry of those who have gained licentiate's and doctor's degrees at the University.

Each individual research project within the Centre should correspond to work for a licentiate's thesis or doctor's dissertation. This is to be formulated in general terms as regards orientation and goals. A detailed specification of each step of a project (such as when an agreement is drawn up for ordering project work or when consultancy services are purchased) should be avoided.



SUMMARY OF CHARMEC STAGE 1

Research within the Centre has been carried out in accordance with its vision and goals and its operational plans. Board meetings were held on 29 November 1995, 26 February 1996, 28 May 1996, 26 November 1996, 24 February 1997 and 13 May 1997. At the first of these meetings, the content and funding of nine main projects during the whole of CHARMEC's Stage 1 of operations were decided.

An agreement was reached between Chalmers University of Technology and Banverket (the Swedish National Rail Administration Infrastructure Authority) on Banverket's participation in the CHARMEC Competence Centre, in accordance with the main agreement with NUTEK.

Roger Lundén succeeded Bengt Åkesson as Director of CHARMEC on 1 April 1997. Bengt Åkesson retired as Professor of Solid Mechanics at Chalmers at the end of May 1997.

An international evaluation of the organisation of CHARMEC's activities was undertaken in March 1997, with good results (NUTEK's Report R 1997:18). The Competence Centre as a form of co-operation venture has functioned well and provided added value to the development of contacts between university and industry at both the national and the international levels.

The work of the Centre has run according to plan during the two academic years 1995/96 and 1996/97. The staff intended for the Centre, both at Chalmers (five supervisors and nine doctoral candidates) and in the Industrial Interests Group (R&D management and experimental staff), have been involved. Several new contacts for co-operation have been established. There have been frequent meetings between university researchers and those working in industry, and these meetings have resulted in increased involvement in industrial long-term knowledge development as well as in providing deeper insights into the working potential of the university, respectively. Several concrete results have been achieved in the business activities of the industrial partners, see page 19.

Two licentiate's theses and two doctor's dissertations in railway mechanics have been presented by CHARMEC's researchers. Furthermore, 16 articles have been published (or accepted for publication) in international scientific journals with a referee system, 11 papers have been published in the proceedings of international conferences with a referee system, 13 research reports have been edited in our own series of research publications (in English), 8 master's theses have been edited in our own series of student reports (in English), and 9 other works have been published. For further information on these publications, see the lists under the projects described in the next section.

As from the second board meeting, four seminars are usually held on the morning of the same day as the board meeting in the afternoon. All the CHARMEC board members, supervisors, researchers and others (approximately 25 persons) are present at the seminars and at the lunch that follows. The seminars, at which all supervisors and doctoral candidates present and discuss their projects, follow a rolling annual schedule decided by the board.

A measure of the scientific standard achieved by the activities of the university and industry at Chalmers Railway Mechanics on the international arena is the high level of acceptance of articles for journals and contributions to conferences. Furthermore, a number of international co-operation projects have been established with CHARMEC as their base.

A measure of the scientific and industrial status enjoyed by Chalmers Railway Mechanics on the European arena can be the positive treatment given to our applications to Brite-EuRam III within the Fourth Framework Programme (together with industries, institutes, administrations and universities in Sweden, UK, France, Germany, Italy, Spain, Holland, Switzerland and others). Altogether we are today participating in five current EU railway mechanics projects, see page 22. The total budget for these five EU projects is MECU 16.3. Our total investment is 108 man-months and our EU funds in these projects amount to KECU 710. The duration of each project is about three years.

PROGRAMME AREAS STAGE 1

According to the agreement of 7 July 1995, the Competence Centre should work within three overall programme areas during Stage 1, as set out below. The choice of projects within each area has been decided by the Board of the Centre.

Programme area 1
Interaction of train and track
(Samverkan Tåg/Spår, TS)

A rolling train is a mobile dynamic system that interacts with the stationary track structure, which in its turn is a dynamic system. This interaction is a key area within all railway research. The mechanisms behind vibration, noise and wear depend on the interplay of the rolling train and the track structure. The activities of this programme area are directed towards being able to better understand, model and predict the dynamic interaction for different types and conditions of trains, tracks and operations. Theoretical, numerical and experimental methods are required.

Programme area 2
Vibration and noise
(Vibrationer och Buller, VB)

A considerable reduction in vibration and noise from railway traffic seems to be of crucial importance for the future acceptance of this type of transportation. The generation and spreading of vibrations in trains and tracks and the emission of noise are phenomena that are both theoretically and experimentally difficult to approach. The activities of this programme area are directed towards being able to better understand the underlying mechanisms. Advanced analytical and numerical tools and well-planned laboratory and field experiments and measurements are required. The goal is to be able to put forward effective modifications and counter-measures against vibration and noise in trains and tracks and in their surroundings.

Programme area 3
Materials and maintenance
(Material och Underhåll, MU)

Suitable and improved materials for axles, wheels, rails, pads, sleepers, ballast and embankment are a prerequisite for good mechanical performance, reduced wear, lower maintenance costs and increased technical/economic lifetime of the components mentioned. The activities of this programme area are directed towards analysing existing materials and developing new materials. There will be created a knowledge base for the rational maintenance of train and track components. Co-operation between several different competences are required for this research.

PROJECTS AND RESULTS AS OF 30 JUNE 1997

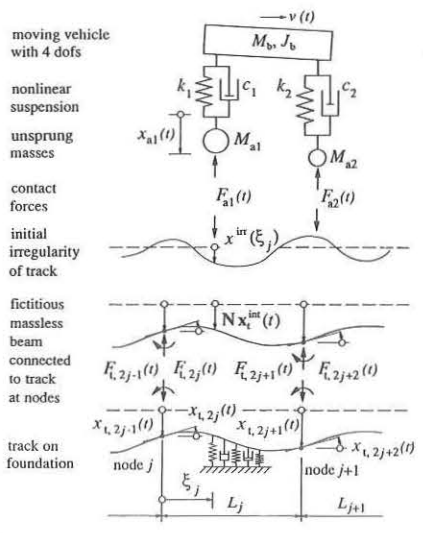
By "Chalmers budget" below is meant the funding in cash, thus excluding the in-kind contribution from the university (its so-called basic resources). The "Industrial interests budget" means the contributions in kind of these industrial interests. Both budgets refer to the whole of Stage 1, that is from 1 July 1995 to 30 June 1997. The memoranda (PM) mentioned below are available as supplements to the CHARMEC board meeting minutes of 29 November 1995. The total annual cost of a normal doctoral project at Chalmers is estimated to be KSEK 850–900. Comprehensive physical experiments in the laboratory and/or field increase the cost. A newly appointed doctoral candidate, who already holds a Master's degree (MSc), is nowadays estimated to take his/her doctor's degree within five years. The degree of Licentiate of Engineering (Lic Tech) is an intermediate one.

TS1. CALCULATION MODELS OF TRACK STRUCTURES

Supervisor	Dr Tore Dahlberg, Associate Professor, Solid Mechanics
Doctoral candidate	Johan Oscarsson, MSc (appointed January 1996)
Period	1996-01-01 – 1997-06-30 (– 2000-12-31)
Chalmers budget (excluding university basic resources)	KSEK 1400 + 200
Industrial interests budget (Banverket)	KSEK 400
Research programme	PM 1995-11-10 (6 pages)

Remarks: Tore Dahlberg left Chalmers on 1 January 1997. Dr Jens Nielsen gradually took over supervision of the project during the spring (which is the reason for the supplementary funding of KSEK 200).

Johan Oscarsson (photo on page 27) has made himself familiar with our earlier theories, measurements and computer programs (Tore Dahlberg, Jens Nielsen, Annika Igeland, et al). He took part in the evaluation of the Goose Hill measurements in 1995. Andrew Peplow, a visiting researcher from ISVR in Southampton, has participated in searches of the literature. Undergraduates working on their degree papers have also been engaged in the work. Among them, Clas Andersson (a doctoral candidate of CHARMEC from August 1997), together with Annika Igeland and in consultation with Abetong Teknik, has studied the dynamics of railway turnouts with the aid of our DIFF program. Reports during Stage 1 from the research group are listed below:



Visualized mathematical model of a running bogie interacting with an irregular track as used in Projects TS1 and TS2

Tore Dahlberg: Vertical dynamic train/track interaction – verifying a theoretical model by full-scale experiments, *Proceedings of the 3rd Herbertov Workshop on Interaction of Railway Vehicles with the Track and Its Substructure,* Herbertov, Czech Republic, September 1994. Published as supplement to *Vehicle System Dynamics,* vol 24, 1995, pp 45-57

Mikael Fermér and Jens Nielsen: Vertical interaction between train and track with soft and stiff railpads – full-scale experiments and theory, *Proceedings IMechE, Part F: Journal of Rail and Rapid Transit,* vol 209, no F1, 1995, pp 39-47

Andrew Peplow, Johan Oscarsson and Tore Dahlberg: Review of research on ballast as track substructure, *Chalmers Solid Mechanics,* Report F189, Gothenburg 1996, 39 pp

Johan Oscarsson and Tore Dahlberg: Dynamic train/track/ballast interaction – computer models and full-scale experiments, *Proceedings 15th IAVSD Symposium Dynamics of Vehicles on Roads and Tracks,* Budapest, August 1997, 12 pp (in press)

Thomas Broberg, Patrik Johansson, Per Anders Jönsson, Stefan Larsson and Ulf Lång: Railway track vibrations – a benchmark test and a sleeper vibration study, Student Report, *Chalmers Solid Mechanics,* Gothenburg 1995, 46 pp

Ulf Mårtensson: Railway crossing vibrations, Student Report T138, *Chalmers Solid Mechanics,* Gothenburg 1996, 27 pp

Johan Ivarsson and Anders Johansson: Finite element model of a railway turnout, Student Report T144, *Chalmers Solid Mechanics,* Gothenburg 1996, 70 pp

Clas Andersson: Railway turnout vibrations, MSc Thesis EX 1997:1, *Chalmers Solid Mechanics,* Gothenburg 1997, 53 pp

Tore Dahlberg and Clas Andersson: Vibration due to a wheelset passing a railway turnout crossing, *Proceedings WCRR'97 (World Congress on Railway Research),* Florence, Italy, November 1997, vol E (Environment), pp 413-419

Clas Andersson and Tore Dahlberg: Wheel/rail impacts at a railway turnout crossing, *Proceedings IMechE, Part F: Journal of Rail and Rapid Transit* (in press)

Annika Igeland and Johan Oscarsson: Modelling of railway track for computer simulation of dynamic train/track interaction, *Proceedings XVth IMAC (International Modal Analysis Conference),* Tokyo, September 1997, pp 464-470

Johan Oscarsson, Jens Nielsen and Annika Igeland: Dynamic train/track interaction – theory and full-scale experiments, *Proceedings WCRR'97 (World Congress on Railway Research),* Florence, Italy, November 1997, vol B (Infrastructure and Track), pp 123-129

TS2. RAILHEAD CORRUGATION FORMATION

Supervisor	Dr Tore Dahlberg, Associate Professor, Solid Mechanics
Doctoral candidate	Annika Igeland, Lic Tech (appointed August 1991)
Period	1995-07-01 – 1997-06-30
Chalmers budget (excluding university basic resources)	KSEK 200
Industrial interests budget (Banverket)	KSEK 200
Research programme	PM 1995-11-10 (6 pages)

Remarks: Remaining costs have been paid by Banverket direct. Annika Igeland left Chalmers on 31 January 1997.

Doctoral candidate Annika Igeland of Project TS2 and Dr David Thompson of ISVR at the defence of her dissertation (examination in public) in January 1997

Annika Igeland successfully defended her doctor's dissertation on 24 January 1997, with Dr David Thompson of ISVR (Institute of Sound and Vibration Research) in Southampton as the faculty-appointed "opponent" (external examiner).

During 1996, Annika was a visiting researcher for three months with Professor Klaus Knothe at the Technical University (TU) Berlin, where she worked together with Dr-Ing Heike Ilias. Annika has also participated in conferences and visits to industries in Europe, North America and Japan. The results of the Goose Hill measurements have continued to be used and Banverket staff have been engaged. Reports during Stage 1 from the research group are listed below:

Jens Nielsen and Annika Igeland: Vertical dynamic interaction between train and track – influence of wheel and track imperfections, *Journal of Sound and Vibration,* vol 187, no 5, 1995, pp 825-839

Annika Igeland: Time domain solution of the dynamic interaction between railroad structures and moving loads, *The Third International Congress on Industrial and Applied Mathematics, ICIAM/GAMM95,* Hamburg, July 1995. Published in *ZAMM (Zeitschrift für Angewandte Mathematik und Mechanik),* vol 76, supplement 4, 1996, pp 137-140

Annika Igeland: Dynamic train/track interaction – parametric study and comparisons with full-scale experiments, *Engineering Foundation Conference Vehicle-Infrastructure Interaction IV,* San Diego CA, June 1996, 14 pp

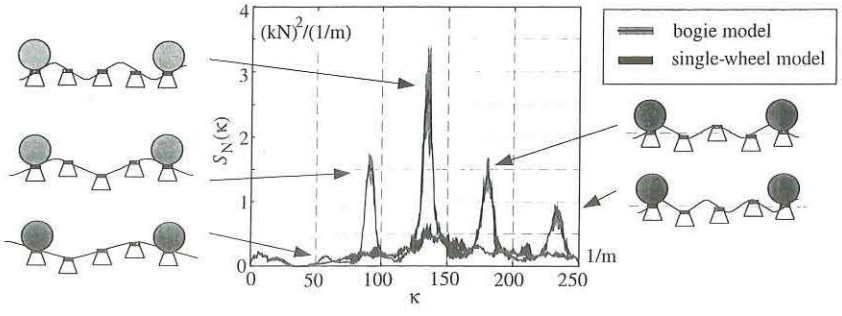
Annika Igeland and Heike Ilias: Railhead wear calculations based on high frequency wheelset/track interaction – a comparison between different models, *Proceedings 2nd MiniConference on Contact Mechanics and Wear of Rail/Wheel Systems,* Budapest, July 1996, pp 304-314

Annika Igeland: Railhead corrugation growth explained by dynamic interaction between track and bogie wheelsets, *Proceedings IMechE, Part F: Journal of Rail and Rapid Transit,* vol 210, no F1, 1996, pp 11-20

Annika Igeland: Railhead wear calculations based on high frequency vehicle/track interaction, *Chalmers Solid Mechanics,* Report F196, Gothenburg 1996, 9 pp

Annika Igeland and Heike Ilias: Railhead corrugation growth predictions based on non-linear high frequency vehicle/track interaction, *Wear* (in press)

Annika Igeland: Dynamic train/track interaction – simulation of railhead corrugation growth under a moving bogie using mathematical models combined with full-scale measurements, Doctoral Dissertation, *Chalmers Solid Mechanics,* Gothenburg 1997 (summary and five appended papers)



From Project TS2: Calculated spectral density $S_N(\kappa)$ of vertical contact force N between wheel and rail, versus wave number $\kappa = 2\pi/\lambda$ of railhead corrugation, for a bogie model of a vehicle running on a track with a random vertical waviness (only right-hand half of two-sided spectrum is shown). Speed of vehicle is v = 150 km/h. Calculated resonance modes of the coupled system bogie/track are illustrated and are related to the peaks of the spectrum. An important observation is that these modes and peaks are missed when single-wheel models of the vehicle are used. The existence of the peaks may gradually change the frequency content of the railhead waviness

TS3. SLEEPER AND RAIL PAD DYNAMICS

Supervisor	Dr Tore Dahlberg, Associate Professor, Solid Mechanics
Doctoral candidate	Åsa Fenander, Lic Tech (appointed August 1991)
Period	1995-07-01 – 1997-06-30
Chalmers budget (excluding university basic resources)	KSEK 1200
Industrial interests budget (Abetong)	KSEK 300
Research programme	PM 1995-11-10 (6 pages)

Remarks: Åsa Fenander left Chalmers on 30 September 1997.

Åsa Fenander successfully defended her doctor's dissertation on 23 May 1997, with Professor George A Lesieutre of Pennsylvania State University as the faculty-appointed "opponent" (external examiner). In 1996, with the help of Abetong Teknik, she carried out dynamic testing of rail pads at the TNO Institute of Applied Physics in Holland. She has worked in co-operation with Dr Mikael Enelund from the materials group at Chalmers Solid Mechanics, and with Professor Peter Olsson at Chalmers Mechanics. Åsa has continued to use the results of our Goose Hill measurements and she has taken part in conferences in Europe and the United States. Reports during Stage 1 from the research group are listed below (sleeper testing and sleeper calculations have been performed and reported earlier):

PhD student Åsa Fenander (doctorate earned in May 1997) inspecting an instrumented wheelset in the laboratory of Chalmers Solid Mechanics. For photo of Dr Tore Dahlberg, see page 25

Åsa Fenander: Modal synthesis when modeling damping by use of fractional derivatives, *AIAA Journal,* vol 34, no 5, 1996, pp 1051-1058

Tore Dahlberg, Jan Köhler and Åsa Fenander: Ett järnvägsspårs dynamiska egenskaper – Gåsakullamätningarna 1995 (The dynamic properties of a railway track – the Goose Hill measurements 1995, in Swedish). *Seminarium Samverkan Fordon-Bana,* VTI, Linköping, April 1996, 11 pp

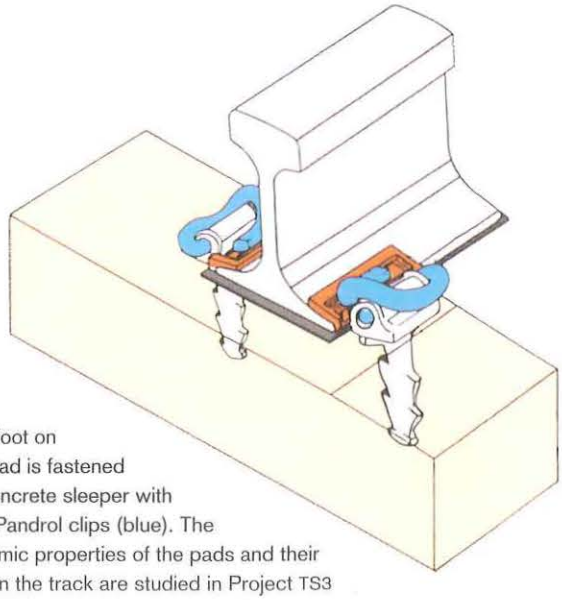
Åsa Fenander: Fractional derivatives in damping descriptions, Proceedings *ESA International Workshop on Advanced Mathematical Methods in the Dynamics of Flexible Bodies,* Noordwijk NL, June 1996, pp 159-166

Mikael Enelund, Åsa Fenander and Peter Olsson: Fractional integral formulation of constitutive equations of viscoelasticity, *AIAA Journal,* vol 35, no 8, 1997, pp 1356-1362

Åsa Fenander: Frequency-dependent stiffness and damping of railpads, *Proceedings IMechE, Part F: Journal of Rail and Rapid Transit,* vol 211, no F1, 1997, pp 51-62

Åsa Fenander: A fractional derivative railpad model included in a railway track model, *Journal of Sound and Vibration* (in press)

Åsa Fenander: Modelling stiffness and damping by use of fractional calculus with application to railpads, Doctoral Dissertation, *Chalmers Solid Mechanics,* Gothenburg 1997 (summary and four appended papers)



Rail foot on rail pad is fastened to concrete sleeper with two Pandrol clips (blue). The dynamic properties of the pads and their role in the track are studied in Project TS3

VB1. STRUCTURAL VIBRATIONS FROM RAILWAY TRAFFIC

Supervisor	Professor Sven Ohlsson, Dynamics in Design
Doctoral candidate	Johan Jonsson, MSc (appointed June 1995)
Period	1995-09-01 – 1997-06-30 (– 2001-12-31)
Chalmers budget (excluding university basic resources)	KSEK 1400
Industrial interests budget (Banverket)	KSEK 400
Research programme	PM Sept 1995 (2 pages)

Remarks: The purchase of extensive experimental equipment for vibration measurements principally in field trials has been funded by the Research Council FRN (approximately MSEK 2).

Knowledge on excitation mechanisms for buildings caused by the passage of a train is to be established. Mechanisms for the internal spreading of building vibrations, as well as criteria for maintaining levels of comfort, function and safety in the building, are also to be studied. Johan Jonsson has tested the applicability of various suggested models to the generation of mechanical waves in the ground by a train. An experimental study has been carried out in Halmstad with parallel measurement of train-generated vibrations in the ground and in a nearby building. Field tests of homogeneous clay subjected to controlled impact loads have been carried out north of Göteborg.

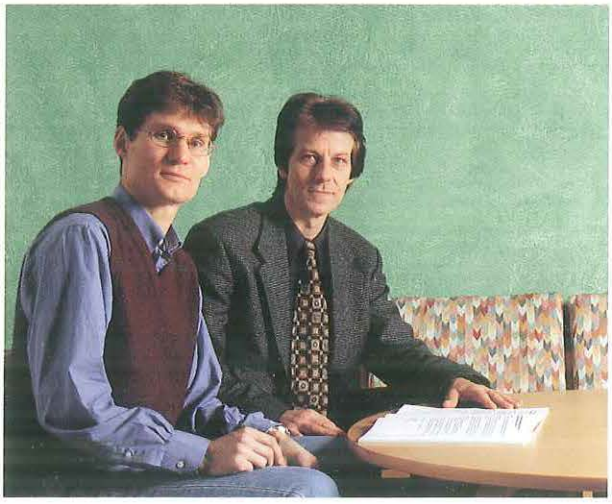
A linear elastic finite element model has been established for the volume of ground in question. A comparison between the transmission functions measured and calculated shows reasonable agreement in the frequency range studied up to about 12 Hz.

Investments to a value of approximately MSEK 2 have been made in new measuring equipment at Chalmers Dynamics in Design with support from the Research Council FRN. Considerable work has been put into adapting the sensor equipment so that it can also be used for measurement below ground surface. Extensive three-dimensional measurements of vibration fields at and below ground surface have been planned (and have been carried out) in homogeneous clay at Alvhem during the autumn of 1997. Banverket's loading wagon was used to generate concentrated dynamic forces to the track. Measurements of ground vibration fields caused by the actual passage of trains are also included in the project. Reports from the work during Stage 1 are listed below:

Johan Jonsson: A literature survey of railway induced ground vibrations into buildings, *Chalmers Dynamics in Design,* Report D96:2, Gothenburg 1996, 16 pp

Johan Jonsson: Measurements of railway induced building vibrations at the Furet block in Halmstad, *Chalmers Dynamics in Design,* Report D96:3, Gothenburg 1996, 60 pp

Johan Jonsson: Ground vibrations – field measurements and prediction using finite element technique, *Proceedings XVth IMAC (International Modal Analysis Conference),* Tokyo, September 1997, pp 594-600



PhD student Johan Jonsson (left) and his supervisor Professor Sven Ohlsson in Project VB1

Banverket's Track Loading Wagon (TLW) exciting the track during the field experiments at Alvhem in Project VB1

Sensor equipment designed and built by Chalmers Dynamics in Design for triaxial underground vibrational measurements in Project VB1

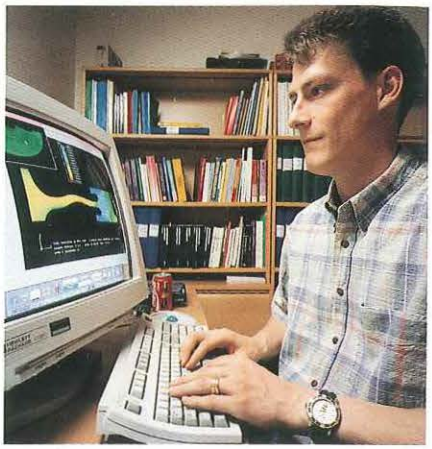
VB2. NOISE FROM TREAD-BRAKED RAILWAY VEHICLES

Supervisor	Dr Roger Lundén, Associate Professor, Solid Mechanics
Doctoral candidate	Tore Vernersson, MSc (appointed March 1994)
Period	1995-07-01 – 1997-06-30 (– 2000-06-30)
Chalmers budget (excluding university basic resources)	KSEK 600 + 100
Industrial interests budget (Adtranz)	KSEK 600
Research programme	PM 1995-11-10 (2 pages)

Remarks: Part of a larger project with parallel funding direct from Adtranz Wheelset and from NUTEK. The additional allocation of KSEK 100 was granted in November 1996 for the purchase of extra equipment.

Tore Vernersson gained his licentiate's degree on 29 September 1997. Dr Adam Blomberg (previously at Materials Technology/Tribology at the University of Uppsala, now at Volvo Technical Development) then acted as discussion leader. Part of this work was included in a parallel NUTEK project during 1995-96, a fact which contributed to the positive development of VB2.

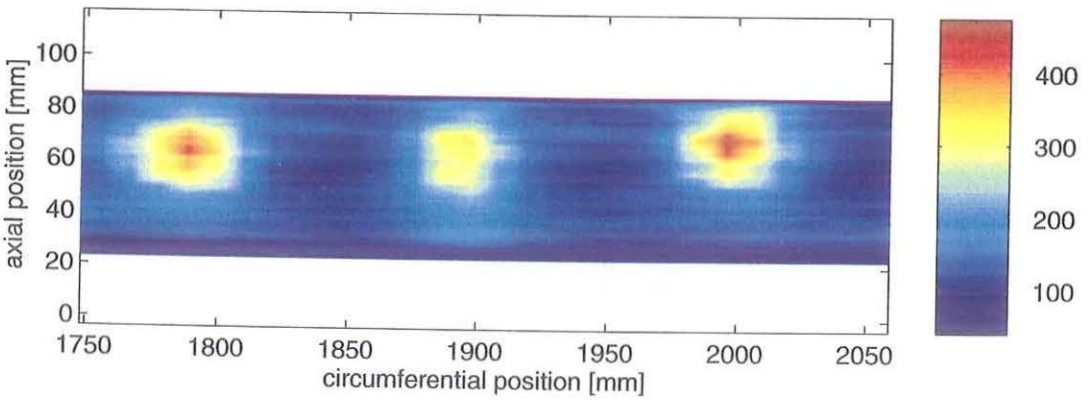
During the two-year period, work has been carried on together with Adtranz Wheelset in Surahammar on theories and experiments concerning the mechanisms behind the origin of non-roundness on the wheel tread caused by block braking. Staff from Chalmers Solid Mechanics (Erik Hult, MSc, and technician Hans Johansson), in co-operation with staff at Surahammar and consulting experts in temperature measurement (AGEMA Infrared Systems AB), have contributed to the planning and performance of the tests. Simultaneous registration of tread temperature and block dynamics is carried out, and unevenness on the tread is measured after braking and cooling. There has been co-operation with the EU project EuroSABOT in which, among others, KTH (Royal Institute of Technology) and NS (Nederlandse Spoorwegen) have taken part in the experiments. ABB Corporate Research have also been involved. An extensive study of the literature has been carried out and documented. Undergraduates working on their degree papers have been engaged. Olaf Kämmerling from TU Berlin has been a visiting foreign undergraduate working on his degree. Reports during Stage 1 from the research group are listed below:



PhD student Tore Vernersson analyzing the rim and disc of a wheel in Project VB2

Tore Vernersson and Roger Lundén: Stresses in Rc-locomotive tyres – on the influence of shrink-fit and braking stresses on rolling contact fatigue, *Chalmers Solid Mechanics,* Report F183, Gothenburg 1995, 45 pp

Tore Vernersson: Non-roundness of block-braked railway wheels – a literature survey, *Chalmers Solid Mechanics,* Report F186, Gothenburg 1996, 63 pp



The hot spots developed on the wheel tread during block braking were photographed with a scanning thermovision camera (2500 lines/sec) during the full-scale experiments in Project VB2

VB3. NOISE RIG

Project leader	Dr Roger Lundén, Associate Professor, Solid Mechanics	
Chalmers budget (excluding university basic resources)	KSEK 800	
Industrial interests budget	KSEK 200	*(Adtranz)*
	KSEK 200	*(Abetong)*
	KSEK 200	*(Banverket)*

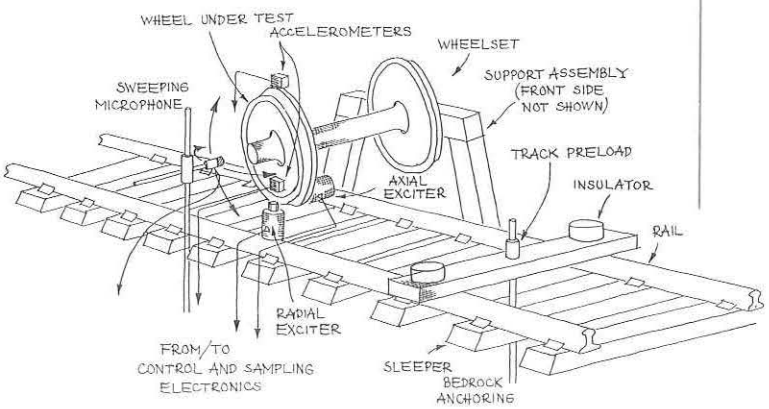
Remarks: ABB Corporate Research have also contributed to the noise rig both directly and through the EU project Silent Freight.

An agreement for the construction of a test rig for advanced noise measurements has been reached between seven parties. They are ABB Corporate Research, Abetong Teknik, Adtranz Wheelset, Banverket, Chalmers University of Technology, SJ and SP (the Swedish National Testing and Research Institute). CHARMEC contributes financially as above. The rig will be owned and administered by Adtranz Wheelset under the terms of a special agreement.

A stretch of full-scale track is being built outdoors on the Adtranz Wheelset's plant site. It will be possible to measure noise radiated from track and wheelsets separately. The excitation of track and wheels occurs separately at their respective contact points (but with the same counter-directed dynamic forces). Sweep microphones are used for the determination of sound levels and directivity. Computer equipment and software for control and data collection are being developed at Chalmers Solid Mechanics by Research Engineer Erik Hult. Reports from the work on the noise rig are listed below:

Urban Olin and Anneli Sandelius: Sinussvepsgenerator för bullermätsystem (Sine sweep generator for noise measuring systems, in Swedish), *Department of Electrical Engineering, Chalmers College of Applied Engineering and Maritime Studies,* Student Report 97:34, Gothenburg 1997, 22 pp

Leonard Hillkirk: Evaluation of a contact-free electromechanical exciter of train wheels, *Department of Electrical Power Engineering, Royal Institute of Technology,* Student Report (in preparation)



An early design sketch of the test rig for noise measurements in Project VB3

Olof Cato, Tomas Göransson, Peter Johansson and Anders Lindberg: Acoustically short-circuited railway wheels – a preliminary experimental study, Student Report, *Chalmers Solid Mechanics,* Gothenburg 1995, 39 pp

Olaf Kämmerling: Vibrational modes of railway wheels, Student Report, *Chalmers Solid Mechanics,* Gothenburg 1995, 32 pp

Kenth Ackemo: Flexible wheels for railway vehicles, Student Report T146, *Chalmers Solid Mechanics,* Gothenburg 1996, 88 pp

Martin Petersson, Tore Vernerson and Roger Lundén: Research on roughness generation and growth, Chapter 5 (pp 35-52) of State of the art – final report (editor G J Bazuin), *EuroSabot Technical Report 1N6G30T1.DA,* NS, Utrecht 1996, 65 pp (+ annexes)

Martin Petersson and Roger Lundén: Thermal buckling of railway wheels, *EuroSabot Technical Report 2H6O07TI.OA1,* Chalmers Solid Mechanics, Gothenburg 1996, 10 pp (availability restricted)

Martin Petersson, Tore Vernersson and Roger Lundén: Full-scale block braking of railway wheels – Experiments performed on the Adtranz/Chalmers inertia dynamometer to investigate the roughness growth of freight car wheels, *EuroSabot Technical Report 2H7U25T12.OB,* Chalmers Solid Mechanics, Gothenburg 1997, 55 pp (availability restricted)

Tore Vernersson: Thermally induced roughness of tread braked railway wheels – a noise-related problem, Thesis for the Degree of Licentiate of Engineering, *Chalmers Solid Mechanics,* Gothenburg 1997, 77 pp

Tore Vernersson, Martin Petersson and Martin Hiensch: Thermally induced roughness of tread braked railway wheels (to be presented at *12th International Wheelset Congress* in September 1998 in Qingdao, China)

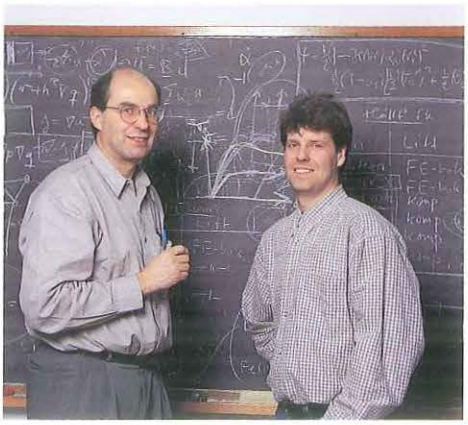
Tore Vernersson: Thermally induced roughness of tread braked railway wheels (submitted for international publication)

MU1. MECHANICAL PROPERTIES OF BALLAST

Supervisor	Professor Kenneth Runesson, Solid Mechanics
Doctoral candidate	Lars Jacobsson, MSc (appointed February 1996)
Period	1996-01-01 – 1997-06-30 (– 2001-12-31)
Chalmers budget (excluding university basic resources)	KSEK 1400 + 100
Industrial interests budget (Abetong)	KSEK 100
Research programme	PM 1995-11-20 (4 pages)

Remarks: Additional funding of KSEK 100 was granted in June 1997 to cover further experimental costs at the University of Colorado, USA.

Triaxial testing of scaled-down ballast specimens (crushed Swedish granite) in Project MU1 has been conducted at the University of Colorado, USA



PhD student Lars Jacobsson (right) and his supervisor Professor Kenneth Runesson in Project MU1

Lars Jacobsson has attended research courses and studied the literature on "the plasticity theory of granular materials". He has also compiled a report on work with the constitutive modelling of granular materials (published in 1998). Kenneth Runesson, supervisor of this programme, has made an inventory of test equipment for conventional as well as true triaxial experiments in Europe and the USA. Visits have been made to institutes in the USA. In March 1997, Lars Jacobsson and Johan Oscarsson visited the University of Colorado at Boulder (where Kenneth Runesson was visiting professor during the 1996/97 academic year) and AAR's test plant TTC at Pueblo, Colorado.

Within the project, an extensive series of tests in triaxial cells has been performed at the University of Colorado during 1996/97 in order to determine the mechanical properties of ballast under monotonic as well as repeated loading. In particular, the effect of scaling down the granular size (which is necessary in commercially available laboratory equipment) has been studied in both 100 mm and 150 mm triaxial cells. Very good correlation has been observed in these tests. Mathematical modelling has been undertaken in parallel with the tests and the next step is to use the test results for calibration. Reports from the work during Stage 1 are listed below:

Mustafa Kaya, Russ Jernigan, Kenneth Runesson and Stein Sture: Reproducibility of conventional triaxial tests on ballast materials, *Department of Civil, Environmental, and Architectural Engineering (CEAE), University of Colorado,* Report No 1 to CHARMEC, February 1997, 43 pp

Mustafa Kaya, Russ Jernigan, Kenneth Runesson and Stein Sture: Reproducibility of conventional triaxial tests on ballast materials, *Department of Civil, Environmental, and Architectural Engineering (CEAE), University of Colorado,* Report No 2 to CHARMEC, May 1997, 40 pp

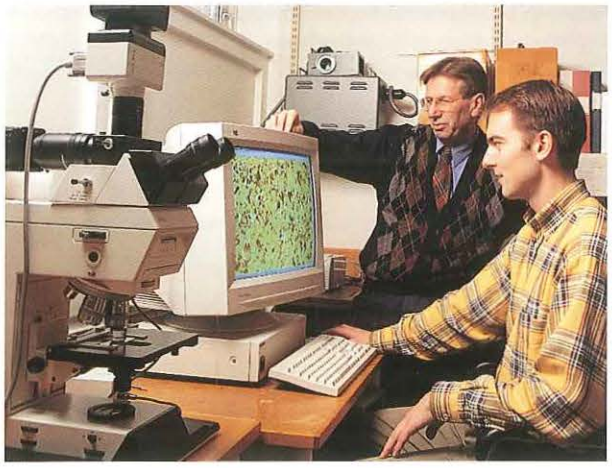
Lars Jacobsson: Review of research on railway ballast behaviour – experimental findings and constitutive models, *Chalmers Solid Mechanics,* Report F208, Gothenburg 1998, 32 pp

MU2. NEW MATERIALS IN WHEELS AND RAILS

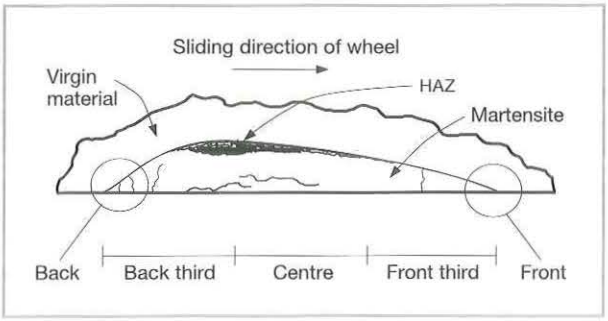
Supervisor	Professor Birger Karlsson, Engineering Metals
Doctoral candidate	Johan Ahlström, MSc (appointed November 1995)
Period	1995-07-01 – 1997-06-30 (– 2001-09-30)
Chalmers budget (excluding university basic resources)	KSEK 1400
Industrial interests budget (Adtranz)	KSEK 200
Research programme	PM 1995-11-13 (5 pages)

Johan Ahlström has attended research courses and worked with studies of the literature on phase transformations in thermal cycles in connection with the formation of wheel flats. The problem range has been identified together with laboratory staff at Adtranz Wheelset. The kinetics of austenitisation and austenite decay in rapid temperature increases and temperature falls have been studied experimentally by means of temperature-time control of small test samples in a salt bath. Preliminary transformation diagrams have been established. In these, wide deviations from conventional transformation diagrams have been observed. There has also been co-operation with Roger Lundén and Johan Jergéus in MU3 on temperature calculations, especially regarding appropriate boundary conditions. A report from the work during Stage 1 is given below:

Johan Ahlström: Phase transformations in railway wheel steels exposed to friction heating – problem and literature survey, *Chalmers Engineering Metals,* Report 776/96, Gothenburg 1996, 18 pp



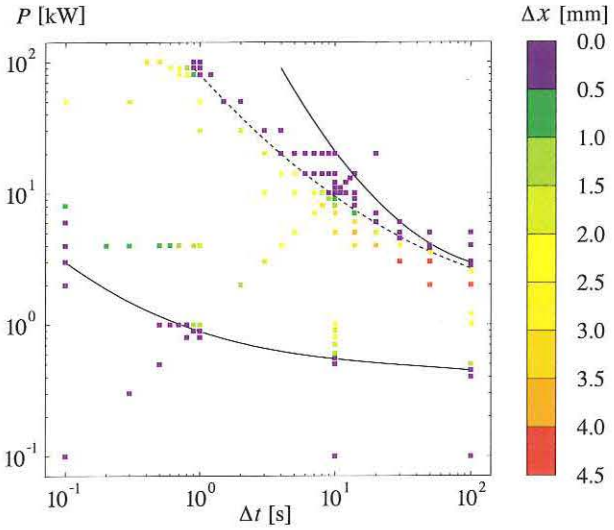
PhD student Johan Ahlström (right) and his supervisor Professor Birger Karlsson in Project MU2. Optical microscope examination of heat-treated SURA B82 steel is performed in the laboratory of Chalmers Engineering Metals. The amount of martensite formed after a certain thermal cycle is determined. The microscope in the foreground is connected to the computer in the background. The image from the microscope is recorded by a digital camera and transferred to an image analysis system



Sketch of part of a wheel rim with a typical flat on the tread. The martensite and HAZ (Heat Affected Zone) formed under a wheel flat are studied in Projects MU2 and MU3

MU3. MARTENSITE FORMATION AND DAMAGE AROUND RAILWAY WHEEL FLATS

One of about 240 wheel flats generated under controlled conditions in the field experiments at Silinge in Project MU3 (see also photo on page 19)



Calculated depth of the martensite formed under a wheel flat as a function of the duration Δt of sliding and the power P of braking for one wheel. One square represents the result of one computer run in Project MU3

Supervisor	Dr Roger Lundén, Associate Professor, Solid Mechanics
Doctoral candidate	Johan Jergéus, Lic Tech (appointed September 1991)
Period	1995-07-01 – 1997-06-30 (– 1997-12-31)
Chalmers budget (excluding university basic resources)	KSEK 1000 + 100
Industrial interests budget (SJ Maskin-divisionen)	KSEK 400
Research programme	PM 1995-08-25 (3+1 pages)

Remarks: Johan Jergéus has been on parental leave for 3 months. Additional funding of KSEK 100 was granted in November 1996 to cover further experimental costs.

Johan Jergéus (photo on page 24) will be defending his doctor's dissertation on 30 January 1998, with Professor Lennart Karlsson of Luleå Technical University as the faculty-appointed "opponent" (external examiner). Johan has worked with the theory and calculation of temperatures, stresses and material wear in co-operation with Per Gullers and others at SJ Maskindivisionen and the staff at SJ's Workshops. Experiments have been carried out in a test rig at Adtranz Wheelset in Surahammar. Extensive full-scale experiments on existing railroad were carried out at Silinge near Flen in September 1996 with the use of SJ's laboratory resources. Christer Odenmark, MSc, of Chalmers Solid Mechanics and Dr Peter Sotkovszki of Chalmers Engineering Metals have assisted in the evaluation of the experiments. The results of the project will lead to improved guidelines for wheel maintenance in regular railway traffic. Reports during Stage 1 from the research group are listed below:

Johan Jergéus, Roger Lundén and Per Gullers: Martensite formation around railway wheel flats, *Proceedings of the 11th International Wheelset Congress,* Paris, June 1995, pp 53-58

Johan Jergéus: Martensite formation and residual stresses around railway wheel flats, *Proceedings IMechE, Part C: Journal of Mechanical Engineering Science,* vol 212, no C1, 1998, pp 69-79

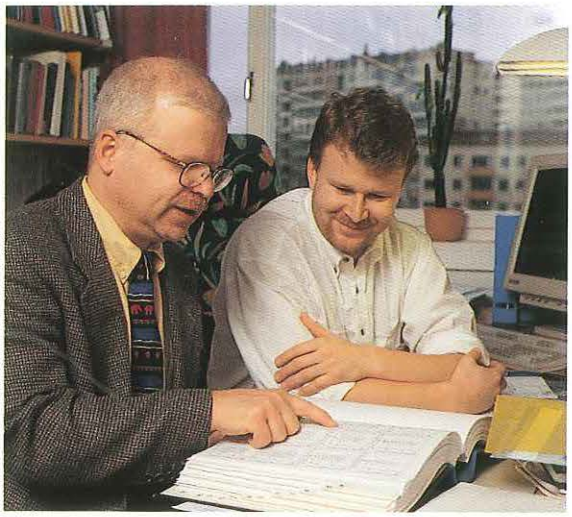
Johan Jergéus: Martensite formation and damage around railway wheel flats, *Proceedings of 6th International Heavy Haul Conference "Strategies beyond 2000",* Cape Town, April 1997, vol 2, pp 889-904

Christer Odenmarck and Markus Wallentin: Friction heat partitioning and martensite formation at wheel/rail sliding contacts, *Chalmers Solid Mechanics,* Report T145, Gothenburg 1996, 49 pp

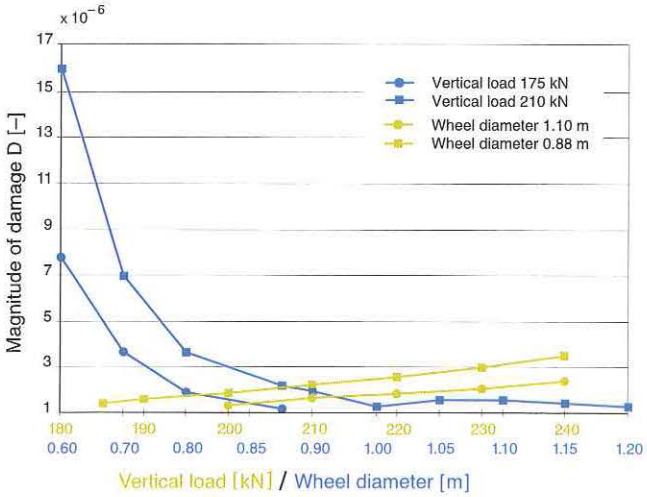
Johan Jergéus, Christer Odenmarck, Roger Lundén, Peter Sotkovszki, Birger Karlsson and Per Gullers: Full-scale railway wheel flat experiments (submitted for international publication)

Johan Jergéus: Railway wheel flats – martensite formation, residual stresses and crack propagation, Doctoral Dissertation, *Chalmers Solid Mechanics,* Gothenburg 1998 (summary and five appendes papers)

MU4. PREDICTION OF LIFETIME OF RAILWAY WHEELS



PhD student Anders Ekberg (right) and his supervisor Dr Roger Lundén in Project MU4



From Project MU4: Calculated fatigue damage of wheel tread per loading cycle (wheel revolution) as a function of vertical contact load F_z wheel/rail (including dynamic contribution) and wheel diameter, respectively (lifetime is estimated to be exhausted for $D = 1$)

Supervisor	Dr Roger Lundén, Associate Professor, Solid Mechanics
Doctoral candidate	Anders Ekberg, MSc (appointed April 1994)
Period	1995-07-01 – 1997-06-30 (– 1999-06-30)
Chalmers budget (excluding university basic resources)	KSEK 1000
Industrial interests budget (Adtranz)	KSEK 200
Research programme	PM 1995-11-10 (1+4 pages)

Anders Ekberg gained his licentiate's degree on 18 February 1997, with Dr Erland Yhland (previously of SKF) acting as discussion leader. Extensive studies have been made of the literature. Theory development and computer implementation have been undertaken. Use has been made of Adtranz's experience (design and production of wheels in Surahammar and of bogies in Helsingborg) and of SJ's statistics of wheel damage. Dr Hans Bjarnehed, a consultant from Prosolvia R&T AB, has been engaged. An operational computer model is being developed for the prediction of the lifetime of railway wheels with regard to surface (contact) fatigue. The Dang Van criterion is employed. There has been co-ordination with the other resources within the field of fatigue at Chalmers Solid Mechanics (Professor Hans Andersson and others). Reports during Stage 1 from the research group are listed below:

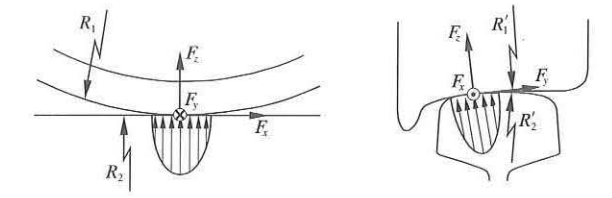
Anders Ekberg and Hans Bjarnehed: Rolling contact fatigue of wheel/rail systems – a literature survey, *Chalmers Solid Mechanics,* Report F182, Gothenburg 1995, 50 pp

Anders Ekberg, Hans Bjarnehed and Roger Lundén: A fatigue life model for general rolling contact with application to wheel/rail damage, *Fatigue & Fracture of Engineering Materials & Structures,* vol 18, no 10, 1995, pp 1189-1199

Anders Ekberg: Rolling contact fatigue of railway wheels – computer modelling and in-field data, *Proceedings 2nd MiniConference on Contact Mechanics and Wear of Rail/Wheel Systems,* Budapest, July 1996, pp 154-163

Anders Ekberg: Rolling contact fatigue of railway wheels – a parametric study, *Wear,* vol 211, 1997, pp 280-288

Anders Ekberg: Rolling contact fatigue of railway wheels, Thesis for the Degree of Licentiate of Engineering, *Chalmers Solid Mechanics,* Gothenburg 1997, 55 pp



$R_2 = \infty$	Young's modulus = 210 MPa	$a_{DV} = 0.32$
$R'_1 = \infty$	Poisson's ratio = 0.30	$\tau_f = 498.5$ MPa
$R'_2 = 0.30$ m		$\tau_c = 226$ MPa

Contact geometry of wheel/rail interface as used in the three-dimensional calculations of wheel tread fatigue under rotating principal stress directions in Project MU4

OTHER ACTIVITIES

Parallel support research

A method for the fracture mechanics study of three-dimensional cracks in damaged wheels and rails under moving loads (projects MU2, MU3 and MU4) has been developed, implemented and verified in the report

Bengt Åkesson, Hans Bjarnehed, Hans Andersson and Lennart Josefson: Routine FE determination of stress intensity factors at curved crack fronts using a Müller-Breslau influence function technique. Presented at *IUTAM Symposium on Innovative Computational Methods for Fracture and Damage,* University College Dublin, June-July 1996, 25 pp. Published in *Computational Mechanics,* vol 19, 1997, pp 481-489

A possible model for track and embankment analysis when considering the frequency-dependent damping of the macadam mass has been developed in the report (the numerical example in the paper refers to trains on tracks)

Mikael Enelund, Lennart Mähler, Kenneth Runesson and Lennart Josefson: Unified formulation and integration of the standard viscoelastic solid with integer and fractional order rate laws, *Chalmers Solid Mechanics,* Report F192, Gothenburg 1996, 26 pp. Presented at *19th ICTAM (International Congress of Theoretical and Applied Mechanics),* Kyoto, August 1996 (accepted for publication in *International Journal of Solids and Structures*)

Surveys and popular reports and articles

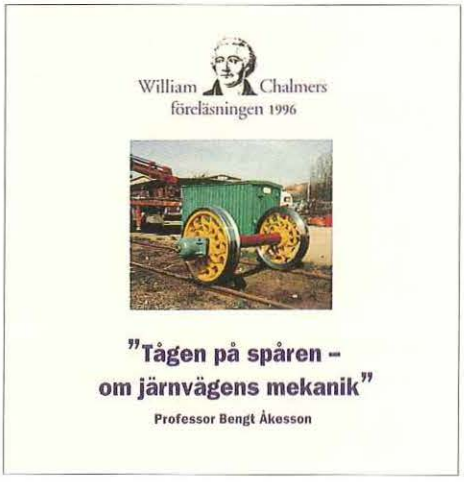
The following reports have been published during CHARMEC Stage 1. The first one lists references to 53 research papers, 20 other articles and 20 student reports produced at Chalmers Solid Mechanics.

Bengt Åkesson, Tore Dahlberg and Roger Lundén: Railway mechanics research 1987-1995 at Chalmers University in Gothenburg – dynamic train/track interaction and railway wheelsets, *Chalmers Solid Mechanics,* Report F185, Gothenburg 1996, 42 pp

Tore Dahlberg: Järnvägsforskning vid Chalmers hållfasthetslära (Railway research at Chalmers Solid Mechanics, in Swedish), *Modern Järnväg,* no 3, 1995, pp 10-11

Tore Dahlberg: Chalmers Railway Mechanics – CHARMEC, *The Cairn Tribune* (Chalmers Alumni International Resources Network), Chalmers, no 3, 1996, pp 15-16

Bengt Åkesson: Tågen på spåren – om järnvägens mekanik (The trains on the track – on the mechanics of railways, in Swedish), The William Chalmers Lecture of 5 November 1996, *Chalmers University of Technology,* 1997, 27 pp



A popular account of railway mechanics was given at the William Chalmers Lecture in November 1996 (the resilient wheel, shown in the photo, with its S-shaped spokes was developed in 1993 by Mikael Fermér. It was studied, theoretically and experimentally, in his doctoral project at Chalmers Solid Mechanics)

MANAGEMENT OF THE COMPETENCE CENTRE

Directors	Professor Bengt Åkesson (21 months) and Dr Roger Lundén, Associate Professor (3 months)
Period	1995-07-01 – 1997-06-30
Chalmers budget (excluding university basic resources)	KSEK 800 + 284
Industrial interests budget	–

According to the four members of the Industrial Interests Group, the CHARMEC Competence Centre has been appreciated by the companies participating as a knowledge resource that is available to them daily. As mentioned elsewhere, there have been frequent personal contacts and these contacts are now being continuously developed. The openings created towards Europe with our 30 or so partners in the five EU projects in railway mechanics, see page 22, have been especially valuable. Some selected examples of more concrete effects are, according to the Industrial Interests Group, the following:

Through the work in CHARMEC, Abetong Teknik have gained increased credibility and a better dimensioning base for their concrete sleepers and have used this when submitting tenders both nationally and internationally. Among Abetong Teknik's CHARMEC-related successes can be mentioned a renewed licensing agreement in South Africa, a design assignment for a new high-speed railway between Seoul and Pusang in South Korea, and the track construction (through its sister company SRS) for Copenhagen's Mini-Metro. By using CHARMEC's methods, Adtranz Wheelset have developed new types of wheels for their customers. One result is that all four bidders (one Swedish and three foreign) for the contract for new ore wagons for Malmbanan (Iron Ore Line in Sweden/Norway) use wheels from Adtranz Wheelset in their tenders.

Banverket have installed CHARMEC's DIFF computer program. This program has been used to evaluate the track system in the 30-tonne project for Malmbanan and also for the major upgrading to 25-tonne axle load on other lines in Sweden. Banverket have also used knowledge developed within CHARMEC in their revision of Swedish track regulations and in investigations carried out within Nordiskt Bantekniskt Samarbete (Nordic Technical Railway Track Co-operation). At SJ Maskindivisionen, there is now an increased understanding of railway wheel flat problems, a fact which is deemed to be of great economic importance. New wheel norms, exploiting work done in CHARMEC, are being developed. New instructions for the reprofiling of damaged wheels are being prepared.

Wheel flat experiments at Silinge near Flen in Södermanland were carried out in Project MU3 in a collaboration between Chalmers, SJ and Adtranz. About 240 flats on 15 wheelsets with 30 new wheels were created, measured and examined in the project. The test train consisted of an electric locomotive, one measuring wagon containing data sampling equipment, one wagon equipped for measuring the pulling force, and the test wagon. The tests were performed at constant train speed (5 to 80 km/h), at train retardation (0.1 to 1.0 m/s^2), and at train acceleration from zero speed (0.10 to 0.15 m/s^2). The axle loads were 6.2 (empty wagon), 10.1 and 18.9 tonnes. The duration of sliding with locked brakes in the first set of tests was 1 to 40 seconds. The coefficient of friction between wheel and rail was measured

Here are presented cash and in-kind investments both per party and per programme area. In-kind investments from the Industrial Interests Group and Chalmers have been calculated according to the principles stated in the main agreement with NUTEK.

Report per party

Budgeted cash and in-kind investments per party according to the main agreement for Stage 1 can be seen in Table 1.

Cash investments

In December 1995, an agreement was made between, on the one hand, Abetong Teknik AB, Adtranz Wheelset, SJ Maskindivisionen and Banverket, respectively, and, on the other, Chalmers University of Technology AB on how the Industrial Interests Group's payments to Chalmers Competence Centre in Railway Mechanics, CHARMEC, should be periodized. According to these four agreements, CHARMEC would invoice at the four points of time 1995-09-01, 1996-03-01, 1996-09-01, and 1997-03-01. All amounts for Stage 1 have been paid in as per the agreement, that is

4 x SEK 400 000	from Adtranz Wheelset
4 x SEK 425 000	from Abetong Teknik
4 x SEK 250 000	from SJ Maskindivisionen
4 x SEK 375 000	from Banverket

After sending quarterly invoices, CHARMEC has received

8 x SEK 737 500	from NUTEK

The total amounts are to be found in Table 1.

In-kind contributions

The in-kind contributions made by Abetong, Adtranz and Banverket consist partly of use of their equipment and work done by their staff according to the principles stated in the main agreement with NUTEK, and partly of services and equipment purchased by the companies. In addition to the kSEK 11 700 stated in Table 1, CHARMEC has revenues of kSEK 84 in interest during Stage 1. Total funds are therefore kSEK 11 784.

Table 1. Cash and in-kind contributions (kSEK) per party

Party	Cash		In-kind		Total	
	Budget	Paid	Budget	Performed/ Value	Budget	Paid/ Value
NUTEK	5 900	5 900	0	0	5 900	5 900
Chalmers	0	0	5 400	5 400	5 400	5 400
Adtranz	1 600	1 600	1 200	1 165	2 800	2 765
Abetong	1 700	1 700	600	635	2 300	2 335
SJ	1 000	1 000	400	400	1 400	1 400
Banverket	1 500	1 500	1 200	1 835	2 700	3 335
TOTAL	11 700	11 700	8 800	9 435	20 500	21 135

Report per programme area

The accounts for each project have been allocated funds according to budgets decided by CHARMEC's board (note that this also involves a decision taken at board meeting 1997:4, held on 21 October 1997). CHARMEC's total funds (KSEK 11 784) for Stage 1 have thereby been transferred to the projects. A compilation by programme area is given in Table 2, where in-kind contributions are also shown.

For the "Noise rig" project (VB3) decided by the CHARMEC board during Stage 1, only KSEK 352 had been used 1997-06-30. The in-kind contributions refer to what had been used 1997-12-12 and a further KSEK 77 for work still in progress (Adtranz). The majority of the in-kind work has been carried out (Abetong's construction work, Banverket's track building and Adtranz's control room, etc). Some work still remains to be done – for example on the software for control systems (Chalmers Solid Mechanics). All this will be reported to CHARMEC's board, but will not be formally included as activities during Stage 2.

Table 2. Budgeted and used funds and in-kind contributions (shown separately for the Industrial Interests Group and Chalmers) for each programme area and for management (and administration), as well as for the "Noise rig" project. The Stage 1 CHARMEC programme areas are TS = Interaction of train and track, VB = Vibration and noise, and MU = Materials and maintenance

Programme area	Cash		In-kind Industrial Interests		In-kind Chalmers		Total	
	Budget	Used	Budget	Used	Budget	Used	Budget	Used
TS	2 800	2 701	900	1 625	1 500	1 500	5 200	5 826
VB	2 100	2 332	1 000	515	880	880	3 980	3 727
MU	5 000	4 974	900	1 045	2 120	2 120	8 020	8 139
Management	1 084	1 085	0	0	800	800	1 884	1 885
Noise rig (VB3)	800	800	600	850	100	100	1 500	1 750
Total	11 784	11 892	3 400	4 035	5 400	5 400	20 584	21 327

PARALLEL EU PROJECTS IN RAILWAY MECHANICS

During Stage 1, the activities of CHARMEC have benefitted from the five parallel EU projects in railway mechanics which are being run at Chalmers Solid Mechanics under Brite-EuRam III within the Fourth Framework Programme. The projects are

EuroSABOT

(Sound Attenuation by Optimized Tread Brakes)

Totally	3724 KECU, 309 man-months
Chalmers	165 KECU, 13 man-months
Start	March 1996
Coordinator	NS (Paul de Vos)
Partners	ERRI, NS, DB, SBB, SLM, Metravib, FrenDo/ABEX, Talbot, FS, KTH, Chalmers, Ferodo, Politecnico di Torino
Chalmers/ CHARMEC project leader	Roger Lundén

Silent Freight

(Development of New Technologies for Low Noise Freight Wagons)

Totally	3196 KECU, 243 man-months
Chalmers	91 KECU, 17 man-months
Start	February 1996
Coordinator	ERRI (William Bird)
Partners	ERRI, Adtranz Sweden, CAF, Talbot, Valdunes, TNO, Vibratec, ISVR, Chalmers, CEIT, Jenbacher
Chalmers/ CHARMEC project leader	Roger Lundén

Silent Track

(Development of New Technologies for Low Noise Railway Infrastructure)

Totally	3747 KECU, 343 man-months
Chalmers	150 KECU, 28.5 man-months
Start	January 1997
Coordinator	ERRI (William Bird)
Partners	ERRI, SNCF, British Steel, Sogerail, Pandrol, Vibratec, TNO, Chalmers, ISVR, TU Berlin
Chalmers/ CHARMEC project leader	Jens Nielsen

ICON

(Integrated Study of Rolling Contact Fatigue)

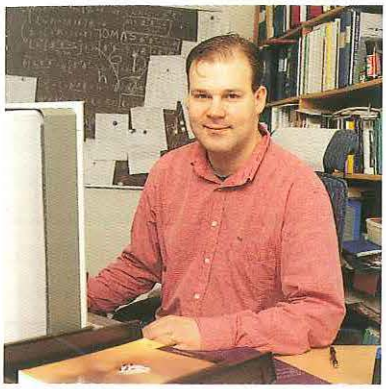
Totally	1523 KECU, 230 man-months
Chalmers	96 KECU, 16 man-months
Start	January 1997
Coordinator	ERRI (Dave Cannon)
Partners	ERRI, Chalmers, Univ of Sheffield, TU Berlin, INSA, Otto von Guericke Univ Magdeburg, KTH
Chalmers/ CHARMEC project leader	Lennart Josefson

EuroBALT II

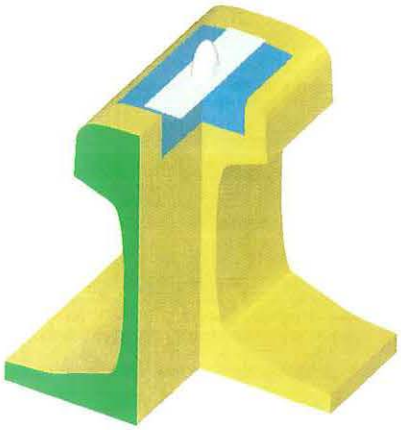
(European Research for Optimization of the Ballasted Track)

Totally	4154 KECU, 303 man-months
Chalmers	207 KECU, 34 man-months
Start	September 1997
Coordinator	SNCF (Jean-Pierre Huille)
Partners	DB, BR Research, Banverket, Chalmers, Cronau, SNCF, TSO, Kassel Univ, ERRI
Chalmers/ CHARMEC project leader	Tore Dahlberg

PARTNERS IN EU PROJECTS



PhD student Martin Petersson in Projects EU1 EuroSABOT and also VB2 of Stage 2



Finite element model of part of rail under contact load from wheel in Project EU4 ICON of Stage 2

PhD student Jonas Ringsberg (left) and his supervisor Professor Lennart Josefson in Projects EU4 ICON and also MU6 of Stage 2

Adtranz Sweden	Swedish section of the multinational company ADtranz (ABB Daimler-Benz Transportation) which designs and manufactures railway transportation systems and components
Banverket	The Swedish National Rail Administration (infrastructure authority and administrator)
BR Research	Research division of British Rail
BS	British Steel plc is a multinational steel producer with research facilities at several locations
CAF	Construcciones y Auxiliar de Ferrocarriles SA is a Spanish company designing and manufacturing trains
CEIT	Centro de Estudios e Investigaciones Tecnicas de Guipozcoa is a Spanish non-profit research organisation
Cronau	Cronau GmbH is a German company specializing in maintenance of railway infrastructure
DB	Deutsche Bahn AG (the German Railways)
ERRI	European Rail Research Institute, Utrecht, The Netherlands, is the research organisation within UIC (Union Internationale des Chemins de Fer)
FrenDo/ABEX	FrenDo/ABEX Rail produces frictional materials for brakes in Germany, Belgium and Italy
Ferodo	Ferodo Limited, Railway Division, Stockport, England. Company developing and manufacturing railway friction materials
FS	Ferrovie dello Stato spa, Rome, Italy. The Italian Railways represented by a department in Firenze
INSA	Institut National des Sciences Appliquées de Lyon. Engineering school and research institute in Lyon, France
ISVR	The Institute of Sound of Vibration Research at the University of Southampton, England
Jenbacher	Jenbacher Transportsysteme AG. Small Austrian company manufacturing components for railway vehicles
Kassel University	The Institute of Geotechnics at the Kassel University, Germany
KTH	The Royal Institute of Technology in Stockholm, Sweden
Metravib	Metravib RDS, Ecully. French private contract research organisation specialized in vibroacoustics
NS	NV Nederlandse Spoorwegen. The Dutch Railways represented by two departments in Utrecht
Pandrol	Multinational company manufacturing rail fastening components
Politecnico di Torino	Aeronautical and Space Engineering Department of Turin Polytechnic in Italy
SBB	Schweizerische BundesBahnen, Bern. The Swiss Railways represented by the department Zugförderung und Werkstätten
SLM	Schweizerische Lokomotiv- und Maschinenfabrik AG, Winterthur. SLM here involves Sulzer-Innotec (research organisation of Sulzer Corporation)
Sogerail	French manufacturer of rails. Subsidiary of Usinor Sacilor which is the third largest steel producer in the world
SNCF	Société Nationale des Chemins de Fer Français. The French Railways
Talbot	Waggonfabrik Talbot, Aachen, Germany. Rolling stock producer (freight wagons, passenger coaches and bogies)
TNO	Contract research organisation in Delft, The Netherlands
TSO	Travaux du Sud-Ouest. French company specializing in construction and maintenance of railway tracks
TU Berlin	The Technical University of Berlin
Valdunes	Wheelset manufacturer in France
Vibratec	Industrial RTD company in Lyon, France

AWARDS

It was encouraging for Chalmers railway mechanics research when, in London on 9 September 1996, Dr Mikael Fermér (who gained his doctorate at Chalmers Solid Mechanics in 1993) received the "William Alexander Agnew Meritorious Award/Clarence Noel Goodall Award 1995" from the Institution of Mechanical Engineers, Railway Division, for his paper "Optimization of a railway freight car wheel by use of a fractional factorial design method" (published in IMechE Proceedings, Part F, no 2, 1994). Furthermore, Johan Jergéus, Lic Tech, received an SKF scholarship in June 1997 as a reward for his work in the field of railway mechanics, see the project MU3 above. Finally, Clas Andersson, MSc (now a doctoral candidate), was awarded Swedtrain's prize for the best degree paper in railway technology in May 1997.

SKF President Peter Augustsson together with PhD student Johan Jergéus of Project MU3 after award ceremony at Slottsviken in June 1997

CHARMEC STAGE 2

The final meeting on Stage 2 of CHARMEC covering the period 1997-07-01 to 2000-06-30 was held at NUTEK in Stockholm on 10 October 1997. In addition to the previous members Abetong Teknik AB, Adtranz Wheelset and SJ Maskindivisionen of the Industrial Interests Group, Cardo BSI Rail AB, Duroc AB and Inexa Profil AB are also participating in Stage 2. New board members (in addition to those of Stage 1, see page 4) are Nils Lennart Nilsson of Cardo BSI Rail, Lennart Olofsson of Duroc, and Kjell Sundwall of Inexa Profil. As in Stage 1, a separate agreement has been drawn up for Banverket's participation. The funding of CHARMEC for the three-year period of Stage 2 is shown in the table below.

In their separate agreement with CHARMEC, Banverket have decided to raise their cash contribution from KSEK 3000 to KSEK 5250. This means that the total CHARMEC budget for Stage 2 has been increased to KSEK 58 900.

There are two additional programme areas for Stage 2, areas 4 and 5, as below:

1. Interaction of train and track (TS)
2. Vibration and noise (VB)
3. Materials and maintenance (MU)
4. Systems for monitoring and operations (SD)
5. Parallel EU projects (EU)

The addition of programme area 5 means that CHARMEC can part-fund the five EU projects (funds from the Commission in Brussels only cover about half of the total costs). Moreover, Chalmers has now decided centrally to provide approximately KSEK 600 towards the funding of the five EU projects.

	Cash	In-kind	Total
NUTEK	16 400	–	16 400 (32%)
Industrial interests group	9 950	6 450	16 400 (32%)
Chalmers	2 250	16 500	18 750 (36%)
Banverket	3 000	2 100	5 100
Total	31 600	25 050	56 650 KSEK

CONCLUDING REMARKS

It is the opinion of both the former and the present Director of the Centre that Stage 1 of operations of the NUTEK Competence Centre in Railway Mechanics has been a successful one. Any somewhat hesitant attitudes that may have been found in some parties at the beginning had already changed in a positive direction during the first year. Now there is a spirit of enthusiasm for, and a willingness to take an active part in, the tasks in hand. Some of the industrial interests members have emphasized how very important it is to have the "right of access" to the Competence Centre. This "access" has, among other things, led to a number of projects between members of the Industrial Interests Group outside of CHARMEC.

Gothenburg, 16 January 1998

Bengt Åkesson Roger Lundén

BENGT ÅKESSON ROGER LUNDÉN

Photo: Bo Håkansson, Kamerareportage

Associate Professors Tore Dahlberg (left)
and Roger Lundén (middle)
and Professor Bengt Åkesson
in the laboratory of
Chalmers Solid Mechanics

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Railway

MEC

Mechanics

CHARMEC

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