TRIENNIAL REPORT
1 July 1997–30 June 2000

REVIEW
1 July 1995–30 June 1997

PLANS
1 July 2000–30 June 2003

CHARMEC

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

CONTENTS

FOREWORD

This is a report of the organisation, operation and financing of the NUTEK Competence Centre CHARMEC during its Stage 2. Summaries of the research performed within the Centre are presented. A review of Stage 1 and a look forward at Stage 3 are also given. The foldout on pages 3–4 contains an overview of all CHARMEC projects since the start of the Centre on 1 July 1995.

Gothenburg in February 2001

ROGER LUNDÉN
Director of CHARMEC

A continuously updated list of our railway mechanics reports is to be found under www.charmec.chalmers.se/achievements

Photo: Bo Håkansson, Kamerareportage

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

Above: "How it all started in 1995". Associate Professors Tore Dahlberg (left) and Roger Lundén (middle) together with Professor Bengt Åkesson in the laboratory of Chalmers Solid Mechanics

EXECUTIVE SUMMARY

CHARMEC *has established itself as a widely known and recognizable, world-class Centre of Excellence in railway mechanics. Industry-University collaboration works very well and very effectively. The caliber of the students graduating from* CHARMEC *is outstanding.* This is a quotation from the conclusions drawn by NUTEK's international evaluators in March 2000.*

The Competence Centre *CHA*lmers *R*ailway *MEC*hanics was established in July 1995 at Chalmers University of Technology in Gothenburg, Sweden. Its annual budget during the three years of Stage 2 has been MSEK 20.5 (2.2 million USD). Each one of three parties has contributed one third to the financing: the University, the governmental research agency NUTEK, and an Industrial Interests Group comprising 7 partners. More than 20 research projects have been run during Stage 2 within the five programme areas, see the foldout on pages 3–4 of the present report,

Interaction of Train and Track
Vibrations and Noise
Materials and Maintenance
Systems for Monitoring and Operation
Parallel EU Projects

At Chalmers, 35 persons (project leaders, academic supervisors, doctoral candidates and senior researchers) from 7 Departments in 3 Schools have been involved. They have published more than 50 scientific reports in international journals and conference proceedings during Stage 2. A total of 15 licentiate's degrees and 8 doctor's degrees in railway mechanics have up to now (February 2001) been awarded at Chalmers. The number of partners in our 7 European projects during Stage 2 has been 43 (industries, universities, institutes, administrations, consultancies) from 9 countries.

CHARMEC strives at combining academic excellence and industrial relevance. Our work includes mathematical modelling, numerical studies, laboratory experiments and full-scale in-field measurements. The co-operation with the Industrial Interests Group has been close. The transfer of knowledge, in both directions, has taken place in advisory groups and during industrial site visits, regular seminars and brain-storming meetings and also in the form of co-authored journal papers, co-ordinated conference participation and joint in-field experimental campaigns. One inertia dynamometer for braking experiments and one railway noise rig for acoustic experiments on the Adtranz Wheelset plant site have been designed, set up and developed. The activities continue during Stage 3.

* The evaluators were Professor John S Baras (University of Maryland, USA), Professor Tom M Husband (UKERNA, UK), Dr Marshall M Lih (National Science Foundation, USA), Professor Roderick A Smith (University of Sheffield and Advanced Railway Research Centre, UK) and Dr Robert D Fröhling (Spoornet Engineering, RSA), see NUTEK's Report R:2009.

International evaluators Robert D Fröhling and Roderick A Smith at Chalmers in March 2000

INTRODUCTION

CHARMEC is the acronym for *CHA*lmers *R*ailway *MEC*hanics. This Centre of Excellence, or Competence Centre (in Swedish: Kompetenscentrum), was established at Chalmers University of Technology in 1995. 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 then agreed upon between NUTEK, the University and the four industrial partners Abetong Teknik, Adtranz Wheelset, Banverket and SJ. On a small scale, research in railway mechanics had started at Chalmers Solid Mechanics already in 1987 when a first bilateral contract between Bengt Åkesson of that Department and Åke Hassellöf of Adtranz Wheelset (then Sura Traction AB) was signed.

CHARMEC's Stage 2 (1 July 1997 – 30 June 2000), which has been running with a budget of MSEK 59.6, was agreed upon at a meeting in Stockholm on 10 October 1997. Cardo Rail, Duroc and Inexa Profil then came in as new industrial partners. At the end of this report, a brief outline is given of CHARMEC's Stage 3, which runs 1 July 2000 – 30 June 2003 with a total budget of MSEK 69.3 and with Adtranz Sweden as a new industrial partner in parallel to the seven previous ones.

The three parties to the agreement on Stage 2 were

Chalmers University of Technology

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

The Industrial Interests Group

Abetong Teknik – a Heidelberger Zement Group company and concrete sleeper manufacturer with headquarters in Växjö

Adtranz Wheelset (now *Lucchini Sweden*) – a wheelset manufacturer (the only one in the Nordic countries) located in Surahammar

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

Cardo BSI Rail (now *Cardo Rail*) – an international manufacturer of braking systems (trademark SAB WABCO) with headquarters in Malmö

Duroc – an engineering industry and development company (specializing in surface treatments by use of laser technology) with headquarters in Umeå

Inexa Profil – with a rolling mill for rails (the only one in the Nordic countries) located in Luleå

SJ – the Swedish State Railways (rolling stock operator) with headquarters in Stockholm (see page 51 about the division of SJ into separate companies)

Dr Jens Nielsen at his presentation before the international evaluators (from left) Marshall M Lih, Tom M Husband and John S Baras in March 2000. In the background (from left): Professor Lennart Josefson, Dean of School of Mechanical and Vehicular Engineering, and Dr Lars Sonnerup, Head of Department of Solid Mechanics at Chalmers

BOARD AND DIRECTOR

Anders Sjöberg, President of Chalmers University of Technology of that time, in consultation with the Industrial Interests Group and NUTEK, appointed the following to be members of the Board of the Competence Centre CHARMEC during Stage 2:

Björn Paulsson (chairman)	Banverket Headquarters
Stefan Westberg	Abetong Teknik
Lennart Nordhall	Adtranz Wheelset
Nils Lennart Nilsson	Cardo BSI Rail
Lennart Olofsson	Duroc
Kjell Sundwall	Inexa Profil
Hugo von Bahr	SJ
Evert Andersson	The Royal Institute of Technology (KTH), Railway Group, Stockholm
Hans Andersson	The Swedish National Testing and Research Institute (SP), Borås
Lars Sjöstedt	Chalmers University of Technology, Transportation and Logistics, Göteborg

Later during Stage 2, Alf Göransson, Olof Nilsson and Stefan Östlund replaced Nils Lennart Nilsson, Kjell Sundwall and Evert Andersson, respectively, from the same organisations.

Professor Roger Lundén of Chalmers Solid Mechanics was appointed Director of the Competence Centre from 1 April 1997. He succeeded the Centre's first Director Bengt Åkesson, now Professor Emeritus of Solid Mechanics.

VISION AND GOALS

The overall vision of CHARMEC is to successfully combine the identification, formulation and solution of industrially relevant and important problems with an academically high-standard and internationally viable research. Concrete objectives are the national education and examination of Licentiates and Doctors, the international publication of research papers, and the continued participation in European and other international conferences. CHARMEC will have a strong position in the international railway mechanics community. The active co-operation with leading research centres in the world will be further developed and strengthened. Among the national obligations of the Competence Centre are the close collaboration with the industrial partners and the implementation in their industrial environment of the solutions arrived at.

The overall goal of CHARMEC 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 optimised components and systems for track structure and running gear. These should result in slower degradation of ballast and embankment, increased lifetime of sleepers and pads, improved track alignment stability, reduced rail and wheel wear, lower levels of vibration and noise in trains and tracks and in their surroundings, and better systems for monitoring and operation of brakes, bearings, wheels etc.

QUALITY ASSESSMENT AND KNOWLEDGE TRANSFER

In our opinion, an assessment of the quality and quantity of the results and effects achieved by a Competence Centre like CHARMEC should take the following points into consideration:

- The ability to understand, formulate and "make scientific" the current problems and aims of the Industrial Interests Group
- The ability to initiate and run general future-oriented projects within the area of activity of the Centre
- The publication of scientific works in recognised international journals
- The publication of read papers in the proceedings of recognised international conferences
- The conferring of licentiate's and doctor's degrees
- The transfer to the Industrial Interests Group of information about the results achieved and the implementation of those results at their sites
- The development, nationally and internationally, of the role of the Centre as a partner for dialogue, as an information hub, and as a network builder.

During Stage 2, the scientific quality of CHARMEC's research results has been 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 relevance of our research has been secured through discussions at the Board meetings, at the seminars at Chalmers with the industrial partners, and at frequent visits with brain-storming etc to the industrial sites. Also our participation in worldwide congresses, conferences, workshops and seminars in railway technology has contributed to the calibration of CHARMEC's research.

The transfer of knowledge to industry has taken 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 important aspect of this transfer of knowledge is the employment in the industry, directly or through consultant companies, of those who gave gained licentiate's and doctor's degrees at the University.

Each individual research project within the Centre should, normally, 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 in an academic environment.

Opposite page:
From left: Stefan Westberg of Abetong Teknik (1+2+3), Henrik Tengstrand of Adtranz Sweden (3), Olof Nilsson of Inexa Profil (2+3), Lennart Nordhall of Adtranz Wheelset/Lucchini Sweden (1+2+3), Birgitta Johanson of Chalmers (secretary), Björn Paulsson of Banverket (1+2+3, Chairman), Roger Lundén of Chalmers (Director of CHARMEC), Bengt Åkesson of Chalmers (initiator and former Director of CHARMEC), Mats Önner of Duroc (3), Hugo von Bahr of SJ (1+2+3), and Hans Andersson of SP (1+2+3). Photo taken at main entrance to the Chalmers campus

1 = Board member Stage 1
2 = Board member Stage 2
3 = Board member Stage 3

Evert Andersson of KTH (1+2)

Lars Sjöstedt of Chalmers (1+2)

Lennart Olofsson of Duroc (2)

Kjell Sundwall of Inexa Profil (2)

Nils Lennart Nilsson of Cardo Rail (2)

Stefan Östlund of KTH (2+3)

Mats Svensson of Cardo Rail (3)

PROGRAMME AREAS CHARMEC STAGE 2

According to the agreement of 10 October 1997, the Competence Centre CHARMEC should work within five overall programme areas during Stage 2, as set out below. The choice of projects within each area is decided on by the Board of the Centre. The programme areas 4 and 5 were added when Stage 2 started.

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

A rolling train is a mobile dynamic system that interacts, via the wheel/rail interface, with the stationary track structure, which in its turn is a dynamic system. This interaction is a key area within all railway mechanics research. The mechanisms behind vibrations, 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
Vibrations and noise
(Vibrationer och Buller, VB)

A considerable reduction in vibrations 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, tracks and environment 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 in-field experiments and measurements are required. The goal is to be able to put forward effective modifications and countermeasures against vibrations 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 should 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.

Programme area 4
Systems for monitoring and operation
(System för övervakning och Drift, SD)

Brakes, bearings, axles, wheels and bogies are important mechanical components of a train in what concerns its operational economy and safety. As to both passenger and freight trains, there seems to be a large potential for improvements. New components and new ways of improving and supplementing existing functions should be studied. A systems approach is emphasized and the work is performed in a cross-disciplinary environment drawing on several different academic and industrial competences. Among them are solid mechanics, machine elements, signal analysis, control theory and computer engineering.

Programme area 5
Parallel EU projects
(Parallella EU-projekt, EU)

During Stage 2, Chalmers University of Technology has been a partner, through CHARMEC, in five EU (European Union) projects in railway mechanics within the Fourth Framework Programme. Two new EU projects within the Fifth Framework Programme have been initiated, accepted and started. All these projects are closely related to CHARMEC's ongoing research in the programme areas 1, 2, 3 and 4. CHARMEC contributes to the financing of the EU projects. It should be observed that the legal entity signing the EU contracts on our part is Chalmers University of Technology AB.

SUMMARY OF CHARMEC STAGE 2

Research within the Centre during Stage 2 has been carried out as planned. Three new members have joined the Industrial Interests Group and have been represented on the Board. An agreement was reached between Chalmers University of Technology and Banverket (the Swedish National Rail Administration, which is a governmental Authority) on Banverket's participation in the CHARMEC Competence Centre, in accordance with the main agreement with NUTEK. Board meetings were held on

9	September	1997	11	February	1999
21	October	1997	1	June	1999
4	December	1997	24	September	1999
4	March	1998	8	December	1999
27	May	1998	15	March	2000
6	October	1998	7	June	2000

Detailed minutes have been taken at all meetings. Early decisions were made on the content and funding of the projects carried over from Stage 1 and of the new projects started during Stage 2. In addition to the three programme areas of Stage 1, two new ones have been established as of Stage 2: "Systems for Monitoring and Operation" and "Parallel EU Projects". Five new Departments at Chalmers University of Technology have been involved in the CHARMEC research: Computer Engineering, Machine and Vehicle Design, Mechatronics, Structural Engineering/Concrete Structures, and Structural Mechanics. The two full-scale outdoor teststands in Surahammar for braking experiments and noise measurements have been further developed and used. Test campaigns with in-field measurements have been run at Alvhem, Gåsakulla (Goose Hill) and Grundbro (located on three different railway lines in Sweden) and also in the Netherlands.

An international evaluation of CHARMEC was undertaken in March 2000 (NUTEK's Report R 2000:9). It reviewed the Centre with respect to technical and scientific achievements and industrial relevance and benefits. The conclusion by the evaluators in their written report is that "CHARMEC has established itself as a widely known and recognizable, world-class Centre of Excellence in railway mechanics. Industry-University collaboration works very well and very effectively. The caliber of the students graduating from CHARMEC is outstanding".

The staff intended for the Centre, both at Chalmers (12 project leaders/principal advisors, 15 doctoral candidates and 8 senior researchers) 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. For concrete results achieved in the business activities of the industrial partners, see page 46.

CHARMEC's secretary Birgitta Johanson taking down notes in shorthand at a Board meeting

Seven licentiate's theses and three doctor's dissertations in railway mechanics have been presented by CHARMEC 's researchers during Stage 2 up to June 2000. Furthermore, 27 articles have been published (or accepted for publication) in international scientific journals with a referee system, 24 papers have been published in the proceedings of international conferences with a referee system, more than 15 EU reports have been delivered, 14 research reports have been edited in our own series of research publications (in English), 9 master's theses have been edited in our own series of student reports (in English), and several other works have been published. For further information on these publications, see the lists under the projects described in the next section.

As during Stage 1, four seminars are usually held on the morning of the same day as the board meeting in the afternoon. All the CHARMEC board members, project leaders, researchers and others (approximately 35

persons) are invited to the seminars and to the lunch that follows. The seminars, at which all project leaders/supervisors and doctoral candidates present and discuss their projects, follow a rolling annual schedule.

The continued participation by the CHARMEC researchers in EU projects (Fourth and Fifth Framework Programmes) has widened the co-operation with industries, universities, institutes, administrations and consultancies all over Europe. CHARMEC's network coupled to the EU projects now comprises 43 institutions in 9 countries, see page 52.

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 of contributions to conferences. A remarkable fact is that no less than 16 articles in railway mechanics have now been published by the Chalmers/CHARMEC researchers in Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit, which is a leading scientific journal in the field.

CHARMEC does not run any special courses, undergraduate or graduate, in railway mechanics as such. However, a very positive consequence of the CHARMEC activities with their industrial problems has been the fact that several new areas of practical application have been exposed and exploited in the traditional disciplines and courses at Chalmers (solid mechanics, structural mechanics, engineering metals, concrete structures, machine elements, mechatronics, computer engineering etc). This important impact on the regular courses raises the motivation of the students. Further, about 100 undergraduate students have been involved, over the years, in project work and/or have written their master's thesis in railway mechanics.

For special events and achievements during Stage 2, see page 54. It is obvious, in retrospect, that without the framework and support established through the NUTEK Competence Centre concept, the rather small university/industry collaboration in railway mechanics already existing at Chalmers in 1994/95 could most likely not have expanded, intramurally and extramurally, as it has now done during CHARMEC's Stages 1 and 2 (and is doing during Stage 3).

From left: Professor Thomas Abrahamsson, PhD student Clas Andersson, Docent Jens Nielsen and PhD student Johan Oscarsson of projects TS1, TS4, EU2, EU3 and EU5. Photo taken in the laboratory of Chalmers Solid Mechanics

PROJECTS AND RESULTS

The publications below are all those not previously registered in CHARMEC's Biennial Report 1 July 1995 – 30 June 1997 (Stage 1), or which at that time were incomplete (not yet printed). Several minor reports have not been listed. Internal reports that later resulted in international publication have also been excluded.

The EU1 – EU5 projects belong to Brite/EURAM III under the European Union's Fourth Framework Programme. The total scope of the projects and their partners are shown in the CHARMEC Biennial Report for Stage 1. The EU6 and EU7 projects belong to the Fifth Framework Programme and are both to be found under Specific Research Programme "Competitive and Sustainable Growth" and Key Action "Land Transport and Marine Technologies". The total scope and partners are given below. Only some of our EU reports have been listed. It should be noted that access for outsiders to EU documents supplied by us and by others is often limited.

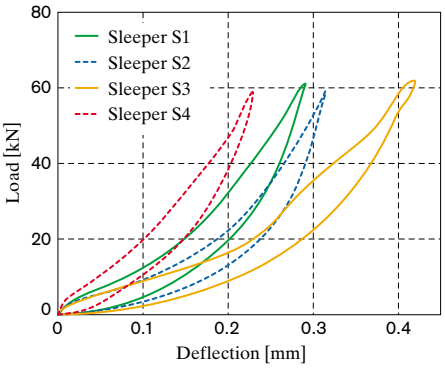
TS1. CALCULATION MODELS OF TRACK STRUCTURES

Beräkningsmodeller för spårkonstruktioner
Berechnungsmodelle für Gleiskonstruktionen
Modélisation de constructions des voies ferrées

Project leader and supervisor	Professor Thomas Abrahamsson, Solid Mechanics/ Structural Dynamics
Doctoral candidate	Johan Oscarsson, Lic Eng (from 1996-01-01; Lic Eng in March 1999)
Period	1996-01-01 – 2000-06-30 (– 2001-06-30)
Chalmers budget (excluding university basic resources)	Stage 1: KSEK 1400 Stage 2: KSEK 2000+200 Stage 3: KSEK 650
Industrial interests in-kind budget (Banverket)	Stage 1: KSEK 400 Stage 2: KSEK 700 Stage 3: –

The analysis and dimensioning of the whole track structure with rails, railpads, fasteners, sleepers, ballast and substructure is an area of central interest to CHARMEC. Our earlier developed calculation model in the DIFF (Swedish acronym for Dynamic Interaction of Vehicle and Track) computer program has been expanded in the TS1 project so as to better reproduce the dynamics of the ballast and substructure. Measured non-linearities in railpads and ballast/substructure have been taken into consideration. One result is that these non-linearities proved to be of relatively small importance to the total dynamic behaviour of the track structure. New full-scale measurements have been carried out together with Banverket at Goose Hill on the West Coast Line and at Grundbro on the Svealand Line. One goal was to obtain a statistical basis for some track parameters. There proved, for example, to be a very large spread in vertical stiffness between the sleepers in a track. In parallel, DIFF has been supplemented so that stochastic realisations of track models can be made. There has been co-ordination between the TS1, TS4 and TS5 projects. A new project plan for TS1 was approved by the CHARMEC Board on 11 June 1999. The original plan is dated 1995-11-10.

At an early stage of the TS1 project, railway turnout vibrations were also studied with the assistance of Clas Andersson (see TS4) and Abetong Teknik. Up to January 1997, the TS1 project was headed by Dr Tore Dahlberg (then Associate Professor at Chalmers Solid Mechanics, now Professor at Linköping Institute of Technology) and later by Dr Jens Nielsen during a transitional period. Thomas Abrahamsson took up his chair at Chalmers on 1 October 1997.



Registered load-displacement curves of four adjacent sleepers at Grundbro showing the statistical spread in vertical stiffness. The frequency is 2 Hz

Johan Oscarsson gained his Licentiate of Engineering (Lic Eng) on 12 March 1999. At the licentiate seminar, the discussion was introduced by Sten Hammarlund, MSc, who is research co-ordinator at Banverket's headquarters. It is planned that Johan Oscarsson will take his PhD in April 2001.

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 (Hungary) August 1997, pp 73-84. Also in *Vehicle System Dynamics,* vol 29, 1998, pp 73-84

Clas Andersson and Tore Dahlberg: Wheel/rail impacts at a railway turnout crossing, *IMechE Journal of Rail and Rapid Transit,* vol 212, no F2, 1998, pp 123-134

Johan Oscarsson: Dynamic train/track/ballast interaction – linear and state-dependent track models, Licentiate Thesis 1999:3, *Chalmers Solid Mechanics,* Gothenburg March 1999, 66 pp

Clas Andersson and Johan Oscarsson: Dynamic train/track interaction including state-dependent track properties and flexible vehicle components, *Proceedings 16th IAVSD Symposium – Dynamics of Vehicles on Roads and Tracks,* Pretoria (South Africa) August-September 1999, pp 11-14. Full-length paper in *Vehicle System Dynamics,* vol 33, 2000, pp 47-58

Measurements in project TS1 at Grundbro on the Svealand Line in April 2000.The rail has been unfastened from the sleepers. The two loads on a sleeper are applied close to the two rail seats. The acceleration is registered and integrated twice. See also photo on page 17

TS2. RAILHEAD CORRUGATION FORMATION

Räffelbildning på rälhuvud
Riffelbildung auf der Schienenoberfläche
Formation de l'usure ondulatoire sur les rails

The TS2 project was completed with Annika Igeland's (now Annika Lundberg) defence of her doctoral dissertation in January 1997, when she also left Chalmers. Associate Professor Tore Dahlberg was her supervisor. The faculty-appointed external examiner was Dr David J Thompson of the Institute of Sound and Vibration Research (ISVR) in Southampton, England. An important feature of the TS2 project was the interaction via the track structure between the two wheelsets in the same bogie. New resonance phenomena were discovered. See further the CHARMEC Biennial Report from Stage 1.

Annika Igeland and Heike Ilias: Railhead corrugation growth predictions based on non-linear high frequency vehicle/track interaction, *Wear,* vol 213, 1997, pp 90-97

PhD student Annika Igeland of project TS2 and Dr David Thompson of ISVR at the defence of her doctoral dissertation (examination in public) in January 1997. For photo of Tore Dahlberg, see page 41

TS3. SLEEPER AND RAILPAD DYNAMICS

Sliprarnas och mellanläggens dynamik
Dynamik der Schwellen und Zwischenlagen
Dynamique de traverses et de semelles

The project was completed with Åsa Fenander's (now Åsa Sällström) defence of her doctoral dissertation in May 1997 and her continued work up to September the same year, when she left Chalmers. Associate Professor Tore Dahlberg was her supervisor. The faculty-appointed external examiner at the defence of her dissertation was Professor George A Lesieutre of Pennsylvania State University, USA. A central feature of the TS3 project was the use of fractional time derivatives in the constitutive modelling of the railpads. See further the CHARMEC Biennial Report from Stage 1.

Åsa Fenander: A fractional derivative railpad model included in a railway track model, *Journal of Sound and Vibration,* vol 212, no 5, 1998, pp 889-903

PhD student Åsa Fenander (doctorate gained in May 1997) inspecting an instrumented wheelset in the laboratory of Chalmers Solid Mechanics. For photo of Tore Dahlberg, see page 41

TS4 LATERAL TRACK DYNAMICS

Lateraldynamik och korrugering
Lateraldynamik der Gleiskonstruktionen
Dynamique latérale de voies ferrées

Project leader and supervisor	Professor Thomas Abrahamsson, Solid Mechanics/ Structural Dynamics
Doctoral candidate	Clas Andersson, MSc (from 1997-01-01; Lic Eng in November 2000)
Period	1998-01-01 – 2000-06-30 (– 2002-12-31)
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 2000 Stage 3: KSEK 1300
Industrial interests in-kind budget (Banverket)	Stage 2: KSEK 700 Stage 3: KSEK 200

For photo of Thomas Abrahamsson and Clas Andersson, see page 12

Railhead corrugation leads to wear, vibration and noise, and the regrinding required of rails on a track involves substantial costs. The mechanisms for the origin of railhead corrugation are most probably related to concurrent vertical, lateral and longitudinal interaction between train and track in the wheel/rail interface, and the CHARMEC DIFF calculation model (see under TS1) has therefore been extended to become a tool for the analysis of this interaction in the frequency range up to 1000 Hz. Like DIFF, the new computer program works in the time domain and it has been called DIFF 3D. The model of the vehicle in DIFF 3D allows large rigid body movements (important to running dynamics) simultaneously with small elastic deformations of the components. The coupling to the track includes wheel/rail contact zone detection. Both elasticity and creep in the contact zone are taken into consideration. A suitable FE model of a bogie wheelset has been established. The running surface of the rails is also modelled with finite elements while the rails as a whole are analysed by means of beam theory. The experimental basis of the track model used has been developed in full-scale measurements in co-operation with Banverket (see under TS1 above). There has been co-ordination with the EU3 project.

At an early phase of Stage 2, Clas Andersson worked with railway turnouts, among other things, under the supervision of Associate Professor Tore Dahlberg (see under TS1 in the Biennial Report from Stage 1). The final project plan for TS4 is dated 1998-02-23 and was approved by the CHARMEC Board on 4 March 1998. Clas Andersson gained his Licentiate on 17 November 2000. At the licentiate seminar, the discussion was introduced by Dr Mats Berg of KTH Railway Technology.

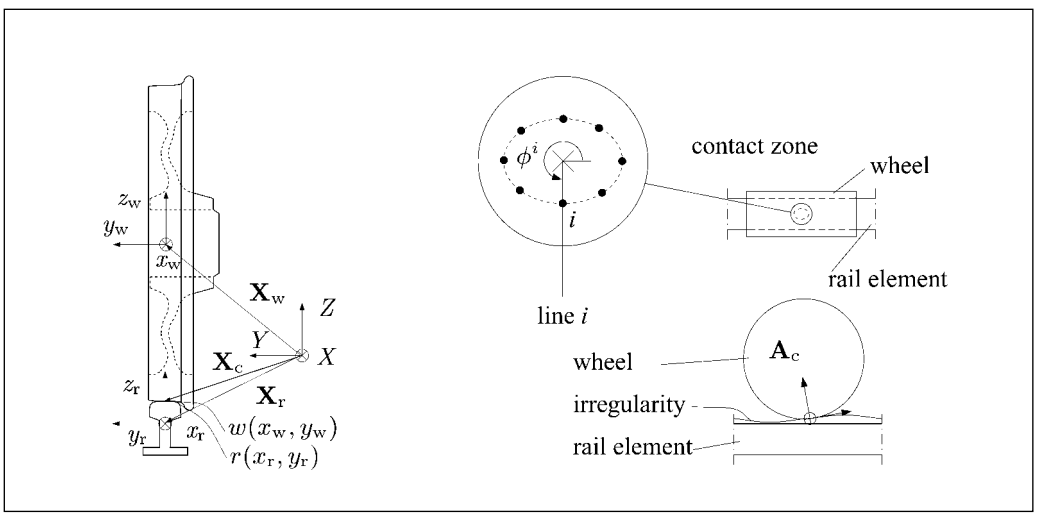
Jeanette Lavery: 2-D rail-wheel contact in train-track interaction, MSc Thesis EX 1999:16, *Chalmers Solid Mechanics,* Gothenburg 1999, 49 pp

Clas Andersson and Tore Dahlberg: Load impacts at a railway turnout crossing, *Vehicle System Dynamics,* vol 33, 2000, pp 131-142

Mikael Hallqvist: Track/vehicle simulation with explicit FE-code, MSc Thesis EX 2000:5, *Chalmers Solid Mechanics,* Gothenburg 2000, 58 pp

Clas Andersson: Modelling and simulation of general train/track interaction, Licentiate Thesis 2000:1, *Chalmers Solid Mechanics,* Gothenburg November 2000, 45 pp

Clas Andersson and Johan Oscarsson: Dynamic train/track interaction including state-dependent track properties and flexible vehicle components, see TS1



Location of the contact zone wheel/rail as calculated in project TS4

TS5. OUT-OF-ROUND WHEELS – CAUSES AND CONSEQUENCES

Orunda hjul – orsaker och konsekvenser
Unrunde Räder – Ursachen und Konsequenzen
Défauts de rondeur des roues – causes et conséquences

Project leader and supervisor	Docent Jens Nielsen, Solid Mechanics/ Railway Mechanics
Assistant supervisor	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Doctoral candidate	Anders Johansson, MSc (from 2000-08-01)
Period	1998-05-01 – 2000-06-30 (– 2005-06-30)
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 1300+150 Stage 3: KSEK 2150+850
Industrial interests in-kind budget (Banverket + SJ + Duroc)	Stage 2: KSEK 300+200+100 Stage 3: KSEK 300+50+100

Railway traffic with out-of-round wheels leads to increased dynamic stresses in both track and vehicle with fatigue fracture as the utmost consequence. In the TS5 project, the causes and consequences of long-wave out-of-roundness of the wheel tread (from only one wave up to a total of five waves around the circumference of the wheel) will be the primary subject of investigation. Both field studies and parameter studies are to be performed. A database of the most commonly occurring wheel damage in Sweden is to be created with regard to wheel type, train speed, axle load and type of traffic. The aim of the project is to determine which amplitudes and wavelengths in the out-of-roundness that are important in the interaction between train and track, and to study how these should relate to appropriate criteria in wheel damage detectors. It should be possible to set limits for permissible out-of-roundness. The project was started during 1998–1999 with a comprehensive study of the literature. A project plan dated 1999-05-11 was presented to the CHARMEC Board on 1 June 1999.

Full-scale tests with a freight train provided with a number of deliberate types of wheel damage (wheel flats, local spalls, long waves) took place in the spring of 2000 at Grundbro on the Svealand Line. The tests were carried out in co-operation with Banverket, SJ and Adtranz Wheelset. Two different axle loads were studied in combination with speeds in the range of 30 to 100 km/h. Contact forces between wheel and rail were registered by means of a strain gauge based wheel damage detector mounted on the track. Stresses and movements in rails and sleepers were measured with strain gauges and accelerometers. In conjunction with the tests, the stiffness of the track was also measured with Banverket's test wagon. Evaluation of the tests and comparison with DIFF calculations is in progress. An FE model of a rotating wheelset is being developed in which both centripetal and Coriolis acceleration will be considered.

Jens Nielsen and Anders Johansson: Out-of-round railway wheels – a literature survey, *IMechE Journal of Rail and Rapid Transit,* vol 214, no F2, 2000, pp 79-91. This is a condensed version of Report 210, *Chalmers Solid Mechanics,* Gothenburg 1998, 46 pp

PhD student Anders Johansson (left) and his supervisor Docent Jens Nielsen in project TS5

Loaded wagons with out of-round wheels at Grundbro during the test campaign in project TS5

TS6. IDENTIFICATION OF DYNAMIC FORCES IN TRAINS

Identifiering av dynamiska krafter i tåg
Identifizierung von dynamischen Kräften in Zügen
Identification des forces dynamiques dans les trains

Project leader and supervisor	Professor Thomas Abrahamsson, Solid Mechanics/ Structural Dynamics
Assistant supervisor	Dr Peter Möller, Senior Lecturer, Solid Mechanics
Doctoral candidate	Lars Nordström, MSc (from 2000-09-01)
Period	2000-07-01 – 2003-06-30 (– 2005-06-30)
Chalmers budget (excluding university basic resources)	Stage 3: KSEK 2150
Industrial interests in-kind budget (Adtranz Sweden)	Stage 3: KSEK 600

The time-variant contact forces between wheels and rails dimension wheels, bogies, wagon bodies and tracks. They cause wear and fatigue and they also affect coach comfort and lead to ground vibrations. A good knowledge of the dynamic contributions to the contact forces is important for both train manufacturers and track builders. Up to now, it is mainly special measuring wheels with strain gauges that have been used to register the magnitude and variation of the contact forces.

The TS6 project is aimed at solving a so-called inverse problem. Starting from a basis of measured accelerations and other responses in appropriate positions and directions on board a running wagon, attempts will be made to determine which exciting contact forces act on the wagon wheels. Internal forces in a running vehicle may also be identified. This will require a very good system description of the wagon based on both mathematical modelling and experimental measurement, together with certain a priori assumptions. It is planned to use a scanning laser interferometer in the initial laboratory tests on model structures.

From left: PhD student Lars Nordström, Dr Peter Möller, Dr Johan Jonsson (sitting) and Professor Thomas Abrahamsson of projects TS6, VB1 and VB6. A newly acquired scanning laser vibrometer Polytec PSV300H is seen

The practical possibilities of performing load measurement by means of indirect methods will be elucidated. In an extension of the TS6 project, it is possible that the sensors may be supplemented with actuators and an active mechatronic control system be developed for an increase in comfort, for example, in real time in a passenger coach. By using the conditions that are special to moving vehicles, it may be possible to identify the causes of the time-variance of the registered contact forces, that is irregularities in wheels and tracks. A research plan dated 2000-09-11 was approved by the CHARMEC Board on 21 September 2000.

The site at Grundbro on a newly built stretch of the Svealand Line before the measurements in projects TS1, TS4 and TS5

TS7. DYNAMICS OF TRACK SWITCHES

Spårväxlars dynamik
Dynamik von Eisenbahnweichen
Dynamique des aiguilles de voies ferrées

Project leaders and supervisors	Professor Tore Dahlberg and Docent Jens Nielsen
Doctoral candidate	To be recruited
Period	–
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 100 Stage 3: KSEK 1000 (preliminary)
Industrial interests in-kind budget (Banverket)	Stage 3: KSEK 200

For photos of Tore Dahlberg and Jens Nielsen, see pages 41 and 12

The CHARMEC Board discussed the proposed TS7 project at its meeting on 15 March 2000 and decided to reserve funds for a study of the state-of-the-art in this field. Further discussion took place at the board meeting on 7 June 2000. It had been preceded by an international seminar arranged by Banverket and CHARMEC at KTH on 30 May 2000 attended by participants from twelve different organisations and companies, the proceedings of which were recorded. At its meeting on 29 November 2000, the Board decided that project descriptions of research into the dynamics of, and fatigue in, track switches should be compiled. The research is to provide a basis for the development of track switches that require less frequent inspection and demand less maintenance, as well as leading to fewer traffic disruptions than present track switches. Track switches have previously been studied in connection with project TS1, see the literature list there.

VB1. STRUCTURAL VIBRATIONS FROM RAILWAY TRAFFIC

Byggnadsvibrationer från järnvägstrafik
Gebäudeschwingungen durch Eisenbahnverkehr
Vibrations de bâtiments par le trafic ferroviaire

Project leader and supervisor until February 1999	Professor Sven Ohlsson, Structural Engineering/ Dynamics in Design
Project leader and supervisor from February 1999	Professor Thomas Abrahamsson, Solid Mechanics/ Structural Dynamics
Doctoral candidate	Johan Jonsson, Lic Eng (from 1995-06-01; Lic Eng in May 1998, PhD in June 2000)
Period	1995-07-01 – 2000-06-30
Chalmers budget (excluding university basic resources)	Stage 1: KSEK 1400 Stage 2: KSEK 1980
Industrial interests in-kind budget (Banverket)	Stage 1: KSEK 400 Stage 2: KSEK 100

For photo of Thomas Abrahamsson and Johan Jonsson, see page 17

New railway traffic travelling at higher speeds and with higher axleloads than earlier causes an increase in vibrations in nearby buildings. People are disturbed, machines can be damaged and buildings can be affected by cracks and subsidence. In the VB1 project, the mechanisms for the transmission of vibrations via the ground from the passage of a train to a nearby building have been studied theoretically and experimentally. Johan Jonsson has carried out his work at the Chalmers School of Civil Engineering and the Chalmers School of Mechanical and Vehicular Engineering, as well as at the Department of Civil Engineering at the University of Tokyo.

Both two- and three-dimensional analytical and numerical models of the ground have been developed and used. Calibration against experiments has been performed. An important outcome is that only the transmission of low-frequency vibrations is of significance.

Extensive multi-channel field measurements (in three directions both at ground surface level and at a depth of 6 m below the ground surface) were performed, with apparatus developed by ourselves, in a field beside the railway at Alvhem north of Göteborg. Clay is to be found there down to a depth of ca 40 m. The measurements produced important qualitative and quantitative results, see further the CHARMEC Biennial Report for Stage 1. At the same site, a concrete slab (0.12 m x 9.00 m x 10.00 m) was cast on a gravel bed in the spring of 1998. On this base were mounted four specially adapted steel frames. After measuring vibrations on this construction from passing trains, the slab was lifted from the ground (by means of compressed air in hoses that had been placed in advance under the slab) so that the dynamic properties of the separate construction could be determined. An important finding was that the slab on the ground on the whole followed the ground surface deformations that wander out over the free ground (when there is no slab there) in the surface wave field from the passing train.

Johan Jonsson gained his Licentiate on 13 May 1998. The discussion at the seminar was introduced by Dr Anders Bodare of KTH Soil and Rock Mechanics. The VB1 project was completed when Johan Jonsson defended his doctoral dissertation on 9 June 2000. The faculty-appointed external examiner was Dr-Ing Christian Madshus of the Norwegian Geotechnical Institute (NGI) in Oslo. From 1 October 2000, Johan Jonsson has been employed as an assistant professor at Chalmers Structural Engineering (School of Civil Engineering) with a continued involvement in CHARMEC, see project VB6.

Johan Jonsson: Ground vibrations with reference to railway traffic, Licentiate Thesis D98:1, *Chalmers Dynamics in Design,* Gothenburg May 1998, 70 pp

Johan Jonsson: Comments to "Ground vibration generated by a load moving along a railway track" (paper by X Sheng, C J C Jones and M Petyt in Journal of Sound and Vibration, vol 228, no 1, 2000, pp 129-156), *Journal of Sound and Vibration,* vol 236, no 2, 2000, pp 359-361

Johan Jonsson: On ground and structural vibrations related to railway traffic, Doctoral Dissertation, *Chalmers Structural Engineering/Division of Steel and Timber Structures,* Gothenburg 2000, 184 pp

Johan Jonsson: Measurements and numerical simulations of surface waves using a plane model, *Géotechnique,* vol 50, no 4, 2000, pp 339-348

← Lifting, by use of hoses with compressed air, of the concrete slab with its steel frames at Alvhem in June 1999 in project VB1

VB2. NOISE FROM TREAD BRAKED RAILWAY VEHICLES

Buller från blockbromsade järnvägsfordon
Rollgeräusche von Zügen mit Klotzbremsen
Émissions sonores de trains freinés par sabot

Project leader and supervisor	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Assistant supervisor	Dr Peter Möller, Senior Lecturer, Solid Mechanics
Doctoral candidates	Tore Vernersson, Lic Eng (from March 1994 until 31 December 1997; Lic Eng in September 1997)
	Martin Petersson, Lic Eng (from January 1998; Lic Eng in October 1999)
Period	1995-07-01 – 2000-06-30 (– 2001-06-30)
Chalmers budget (excluding university basic resources)	Stage 1: KSEK 700 Stage 2: KSEK 900 Stage 3: KSEK 325
Industrial interests in-kind budget (Adtranz Wheelset)	Stage 1: KSEK 600 Stage 2: KSEK 900 Stage 3: KSEK 200

Note: VB2 is part of a larger project with parallel funding direct from Adtranz Wheelset (now Lucchini Sweden).

Freight trains run to a large extent at night-time and, moreover, have proved to make more noise than passenger trains. The reason is that freight trains are nearly always tread braked, while passenger trains are disc braked. Thermal and dynamic interaction between the brake blocks and the wheel cause a corrugated tread on the wheel. For the running train, this results in vibrations in the wheel and rail, with noise radiation as a consequence. The aim of the project is to understand the mechanisms behind the growth of tread corrugation and to try to reduce this.

Extensive braking experiments have been performed in the test rig at Surahammar, see pages 36 and 38. In parallel with these, mathematical modelling and numerical calculations have been carried out. Brake blocks of cast iron, sintered material and composite material have been investigated. Various braking programmes have been carried out. There has been co-ordination with the EU1 and EU2 projects, in which both Tore Vernersson and Martin Petersson have taken part. It was possible to assign a suitable selection of parameters for tread brakes.

Martin Petersson gained his Licentiate on 12 October 1999. At the licentiate seminar, the discussion was introduced by Dr Sven Ödeen of SJ Teknik.

PhD student Martin Petersson (left) and his supervisor Professor Roger Lundén in projects VB2 and EU1.
For photo of Peter Möller, see page 17

Tore Vernersson, Martin Petersson and Martin Hiensch: Thermally induced roughness of tread braked railway wheels, *Proceedings 12th International Wheelset Congress,* Qingdao (China) September 1998, pp 68-75

Per Kron: Spoked railway wheels – an optimization for low radial stiffness combined with low fatigue stresses, MSc Thesis EX 1998:5, *Chalmers Solid Mechanics,* Gothenburg 1998, 59 pp

Martin Petersson: Noise-related roughness of railway wheels – testing of thermomechanical interaction between brake block and wheel tread, Licentiate Thesis 1999:4, *Chalmers Solid Mechanics,* Gothenburg 1999, 40 pp

Tore Vernersson: Thermally induced roughness of tread braked railway wheels, Part 1: Brake rig experiments, *Wear,* vol 236/1-2, 1999, pp 96-105

Tore Vernersson: Thermally induced roughness of tread braked railway wheels, Part 2: Modelling and field measurements, *Wear,* vol 236/1-2, 1999, pp 106-116

Patrik Nordberg: A model for computation of the transient temperature field during block braking of railway wheels, MSc Thesis EX 1999:9, *Chalmers Solid Mechanics,* Gothenburg October 1999, 48 pp

Martin Petersson: Noise-related roughness of railway wheel treads – full-scale testing of brake blocks, *IMechE Journal of Rail and Rapid Transit,* vol 214, no F2, 2000, pp 63-77

Martin Petersson and Tore Vernersson: Noise-related roughness of tread braked railway wheels – experimental measurements and numerical simulations, *Proceedings 5th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems,* Tokyo (Japan) July 2000, pp 293-299 (to appear in *Wear*)

VB3. TEST RIG FOR RAILWAY NOISE

Provrigg för järnvägsbuller
Prüfstand für Schallfelder von Eisenbahnen
Banc de mesure pour bruits ferroviaires

Project leader	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Co-workers	Tore Vernersson, Lic Eng, Erik Hult, MSc (until December 1998) and Carl Fredrik Hartung, MSc (from April 1999)
Period	1995-07-01 – 2000-06-30
Chalmers budget (excluding university basic resources)	Stage 1: kSEK 800 Stage 2: kSEK 1000
Industrial interests in-kind budget (Abetong Teknik + Adtranz Wheelset + Banverket)	Stage 1: kSEK 200+200+200 Stage 2: –

PhD students Tore Vernersson (left) and Carl Fredrik Hartung (right) together with their project leader and supervisor Professor Roger Lundén in projects VB3 and VB4

The test rig has now been designed and constructed as planned, and the VB3 project is thus finished. The rig has been used and further developed in project VB4. It is built outdoors on the Adtranz Wheelset factory site at Surahammar and was inaugurated in June 1999 in the presence of, among others, the CHARMEC Board. Eight parties have signed an agreement undertaking to contribute jointly to the development, marketing and use of the test rig for technical development within the field of noise and vibration. The parties are ABB Corporate Research, Abetong Teknik, Adtranz Sweden, Adtranz Wheelset (now Lucchini Sweden), Banverket, Chalmers Solid Mechanics, SJ and the Swedish National Testing and Research Institute (SP). A steering group for the noise rig has been constituted.

A special feature of the noise rig is that wheels and track can be excited both together and each one separately (three different tests with the same excitation). The level and directivity of sound from wheelsets and track can therefore be established both in total and separately. See further the CHARMEC Biennial Report from Stage 1.

Part of test rig for noise measurements in projects VB3 and VB4. The perforated prototype wheel in project EU2 is here being investigated

VB4. VIBRATIONS AND EXTERNAL NOISE FROM TRAIN AND TRACK

Vibrationer och externbuller från tåg och spår
Schwingungen und externe Geräusche von Zug und Gleis
Vibrations et bruits émis par le train et la voie

Project leader and supervisor	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Assistant supervisor	Dr Anders Frid, Adtranz Sweden/ Vehicle Technology
Doctoral candidate	Carl Fredrik Hartung, MSc (from 1999-04-01)
Period	1998-07-01 – 2000-06-30 (– 2003-06-30)
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 1200 Stage 3: KSEK 1950
Industrial interests in-kind budget	Stage 2: KSEK 200+200+200 *(Abetong + Adtranz Wheelset + SJ)* Stage 3: KSEK 300+600 *(Adtranz Sweden + Adtranz Wheelset)*

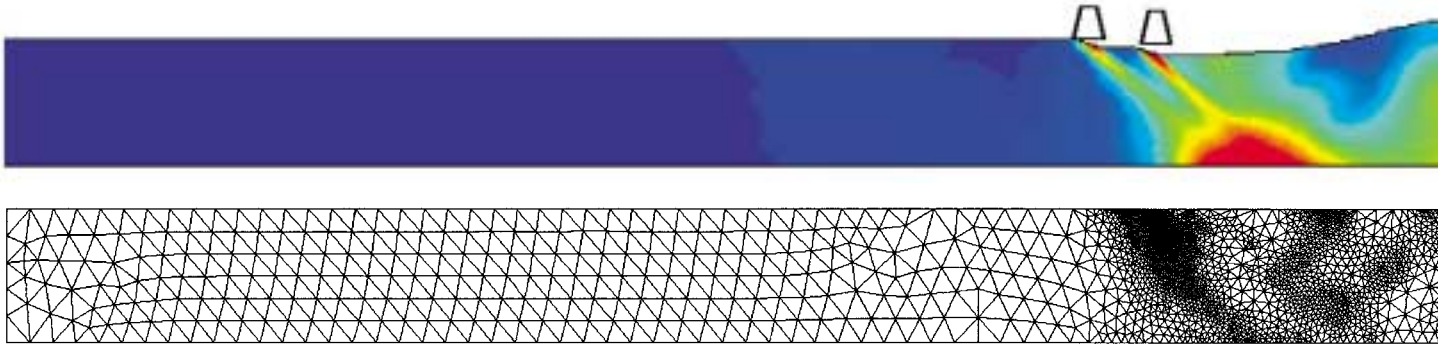
The VB4 project is to use and develop the noise rig, see VB3. By means of tests in the rig, the project will demonstrate how the vibration and noise properties of various track and on-board components can be predicted for the running train. Carl Fredrik Hartung has carried out literature studies, studied measurement techniques and performed pilot tests. Tore Vernersson has contributed to the project. A project description dated 1999-05-17 was approved by the CHARMEC Board on 1 June 1999.

Co-operation in project VB4 with Dr Anders Frid of Adtranz Sweden. For photo of Roger Lundén and Carl Fredrik Hartung, see page 21

Carl Fredrik Hartung: Vibrations and external noise from train and track – a literature survey, *Chalmers Solid Mechanics,* Report F227, Gothenburg 2000, 27 pp

PhD student Torbjörn Ekevid (left) and his supervisor Professor Nils-Erik Wiberg in project VB5

Example in project VB5 of a two-dimensional simulation of wave propagation by use of an adaptive finite element mesh 250 m x (4+20) m. Two distributed loads move from right to left on a soft two-layer ground at the supersonic speed 60 m/s. The critical train speed for the material parameters studied is about 50 m/s



VB5. WAVE PROPAGATION UNDER HIGH-SPEED TRAINS

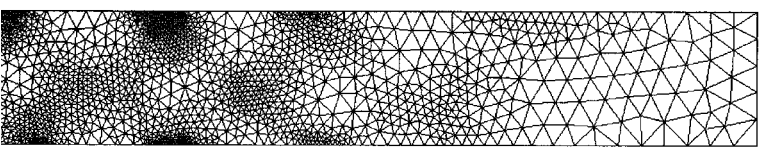
Vågutbredning under höghastighetståg
Wellenausbreitung unter Hochgeschwindigkeitszügen
Propagation d'ondes sous des trains à grande vitesse

Project leader and supervisor	Professor Nils-Erik Wiberg, Structural Mechanics
Doctoral candidate	Torbjörn Ekevid, MSc (from 1999-01-01; Lic Eng in December 2000)
Period	1999-01-01 – 2000-06-30 (-2003-12-31)
Chalmers budget (excluding university basic resources)	Stage 2: kSEK 710 Stage 3: kSEK 1585
Industrial interests in-kind budget (Banverket)	Stage 2: kSEK 500 Stage 3: kSEK 300

Note: VB5 has an additional annual funding of kSEK 250 for the first four years from the National Graduate School in Scientific Computation (NGSSC) of the Swedish Foundation for Strategic Research (SSF).

At places in Sweden where ground conditions are bad with, for example, loose clays, high vibration levels have been observed on the embankment and surrounding ground when high-speed trains have passed. The vibrations are reinforced when the speed of the train approaches the shear wave speed in the ground and probably passes this speed. On certain stretches of track, the maximum permitted speed of the train has had to be reduced. By means of numerical simulations and parallel field measurements, the VB5 project aims at providing an understanding of which factors affect vibration levels. It will then be possible to make proposals for action to reduce these levels.

Models have been developed based on a so-called time-Discontinuous Galerkin Finite Element (DGFE) method in combination with an adaptive element mesh.



Simulations in two dimensions have been carried out. The implementation of routines for three-dimensional calculation has been commenced. During the spring of 2000, field measurements were made together with Banverket at Ledsgård south of Göteborg.

Project VB5 was initiated by the submission of a special application on 10 September 1998 by Nils-Erik Wiberg to Banverket. A project plan for the years 1999–2003 was included. According to a letter of 17 December 1998 announcing their decision, Banverket contributed kSEK 930 for the first two years. An additional kSEK 250 per year for the first four years will come from the Strategic Research Foundation, see above. After consultation with Banverket and Nils-Erik Wiberg, the CHARMEC Board decided on 11 February 1999 to arrange for the project to be included in the Competence Centre.

Torbjörn Ekevid and Nils-Erik Wiberg: Wave propagation in soils related to high-speed trains, *Proceedings 12th Nordic Seminar on Computational Mechanics,* NSCM-12, Helsinki (Finland) October 1999, pp 51-54

Nils-Erik Wiberg, Torbjörn Ekevid and Xiangdong Li: Wave propagation in solids by adaptive DG-FE procedure, Keynote Lecture at *European Conference on Computational Mechanics, ECCM'99,* Munich (Germany) August- September 1999. See also *Chalmers Structural Mechanics,* publ 99:19, Gothenburg 1999, 17 pp (submitted for international journal publication)

Torbjörn Ekevid, Martin X D Li and Nils-Erik Wiberg: Adaptive finite element analysis of wave propagation under moving loads induced by high-speed trains, Keynote Lecture at *European Congress on Computational Methods in Applied Science and Engineering, ECCOMAS 2000,* Barcelona (Spain) September 2000. See also *Chalmers Structural Mechanics,* publ 00:3, Gothenburg 2000, 19 pp (submitted for international journal publication)

Torbjörn Ekevid and Nils-Erik Wiberg: Wave propagation – explicit code for parallel computing, *Proceedings European Congress on Computational Methods in Applied Science and Engineering, ECCOMAS 2000,* Barcelona (Spain) September 2000. See also *Chalmers Structural Mechanics,* publ 00:4, Gothenburg 2000, 18 pp

Torbjörn Ekevid and Nils-Erik Wiberg: Parallel computing of wave propagation problems, *Proceedings 13th Nordic Seminar on Computational Mechanics, NSCM-13,* Oslo (Norway) October 2000, pp 167-170

Torbjörn Ekevid and Nils-Erik Wiberg: Wave propagation related to moving loads close to critical speed, *Proceedings 2nd International Workshop on Wave Propagation, Moving Loads and Vibration Reduction, WAVE2000,* Bochum (Germany) December 2000, pp 43-52

Torbjörn Ekevid: On computational wave propagation in solids – with emphasis on high-speed train related to ground vibrations, Licentiate Thesis, *Chalmers Structural Mechanics,* Gothenburg December 2000, 95 pp

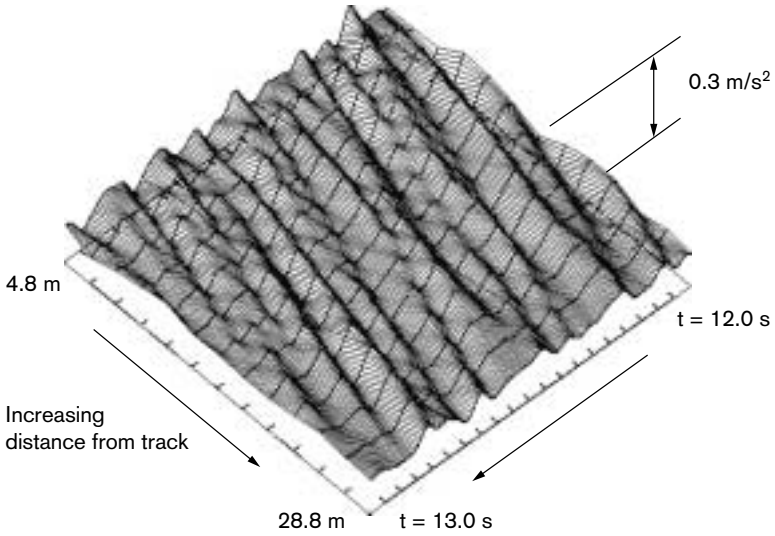
VB6. INTERACTION OF TRAIN, SOIL AND BUILDINGS

Interaktion mellan tåg, mark och byggnader
Wechselwirkung von Zug, Boden und Gebäuden
Interaction entre train, sol et bâtiments

Project leader	Dr Johan Jonsson, Assistant Professor, Structural Engineering/ Applied Structural Dynamics
Advisors	Professor Thomas Abrahamsson, Solid Mechanics/ Structural Dynamics
	Professor Kent Gylltoft, Structural Engineering/ Concrete Structures
Period	2000-07-01 – 2003-06-30 (–2004-06-30)
Chalmers budget (excluding university basic resources)	Stage 3: KSEK 2700
Industrial interests in-kind budget (Banverket)	Stage 3: KSEK 300

For photos of Johan Jonsson, Thomas Abrahamsson and Kent Gylltoft, see pages 17 and 29

This project is partly a continuation of VB1 in which efforts will now be more oriented towards constructive measures for the reduction of vibrations in buildings beside the track. A research programme dated 2000-05-24 was approved by the CHARMEC Board on 7 June 2000. It concerns a combination of methods development, computer analyses and physical experiments, the latter in both laboratory and field. The project is located at the School of Civil Engineering (V) and is reckoned to last for four years.



Measured vertical acceleration time histories on the soil surface at Alvhem along a line perpendicular to the railway track. The train speed is lower than the soil surface wave speed. Note that the axis along the track has the dimension time. A similar registration was made at a depth of 6 m below the surface, see project VB1

VB7. VIBRATION TRANSMISSION IN RAILWAY VEHICLES

Vibrationsöverföring i järnvägsfordon
Übertragung von Vibrationen in Eisenbahnfahrzeugen
Transmission de vibrations dans les véhicules ferroviaires

Project leader and supervisor	Docent Thomas McKelvey, Signals and Systems/ Signal Processing
Assistant supervisor	Professor Thomas Abrahamsson, Solid Mechanics/ Structural Dynamics
Doctoral candidate	To be recruited
Period	2001-07-01 – 2003-06-30 (–2006-06-30)
Chalmers budget (excluding university basic resources)	Stage 3: KSEK 1500
Industrial interests in-kind budget (Adtranz Sweden)	Stage 3: KSEK 300

Vibrations are generated at the contact between wheel and rail. The transmission paths through the running gear into the car-body will be studied. The aim is to bring down vibrations and noise in passenger coaches. A project plan dated 2001-02-12 was discussed and approved by the CHARMEC Board on 20 February 2001.

MU1. MECHANICAL PROPERTIES OF BALLAST

Ballastens mekaniska egenskaper
Mechanische Eigenschaften des Schotters
Propriétés mécaniques du ballast

Project leader and supervisor	Professor Kenneth Runesson, Solid Mechanics/ Mechanics of Materials
Doctoral candidate	Lars Jacobsson, Lic Eng (from 1996-04-01; Lic Eng in January 1999)
Period	1996-01-01 – 2000-06-30 (– 2001-06-30)
Chalmers budget (excluding university basic resources)	Stage 1: KSEK 1500 Stage 2: KSEK 2465 Stage 3: KSEK 650
Industrial interests in-kind budget	Stage 1: KSEK 100 *(Abetong Teknik)* Stage 2: KSEK 300 *(Banverket)*

The mechanical properties of ballast are of great importance to its ability to distribute the load carried down to the substructure in such a way as to prevent detrimental deformation of the track. Ballast may be described as a coarse-grained frictional material whose properties have so far been poorly known. Project MU1 aims to set up a constitutive model for the ballast mass which in terms of continuum mechanics describes the relationship between stresses and deformations in a representative volume element in an essentially arbitrary triaxial condition. An updated project plan of 1999-02-01 was approved by the CHARMEC Board on 11 February 1999.

Extensive experiments with scaled-down ballast material (Swedish granite) have been performed in triaxial cells at the University of Colorado in Boulder, USA, during both Stage 1 (monotonic loading) and Stage 2 (repeated loading) of the project. Volumetric strain was also measured. Lars Jacobsson has participated in the tests and last spent the period from March to May 2000 in Boulder. On the basis of the test results, constitutive models have been developed for both monotonic and repeated loading. With these models, it is possible to study both the behaviour of the ballast mass when it is first rolled over and long-term effects such as subsidence and conditioned elasticity properties after being rolled over many times. The models have been integrated into a commercial finite element program.

Lars Jacobsson gained his Licentiate on 28 January 1999. The discussion at the licentiate seminar was introduced by Professor Kennet Axelsson of LTU Soil Mechanics and Foundation Engineering. It is planned that Lars Jacobsson will take his PhD in the autumn of 2001.

Russel Jernigan: The physical modeling of soils containing oversized particles, PhD Thesis, *University of Colorado, Department of Civil, Environmental and Architectural Engineering,* Boulder CO 1998, 501 pp

Lars Jacobsson: A plasticity model for cohesionless material with emphasis on railway ballast, Licentiate Thesis 1999:1, *Chalmers Solid Mechanics,* Gothenburg 1999, 93 pp

Lars Jacobsson and Kenneth Runesson: Integration and calibration of a plasticity model for granular materials, *Proceedings IUTAM Symposium on Theoretical and Numerical Methods in Continuum Mechanics of Porous Materials,* Stuttgart (Germany) September 1999, pp 215-220

Yu-Ning Ge, Lars Jacobsson, Kenneth Runesson and Stein Sture: Cyclic behaviour and elastic shake-down of coarse-sized granular materials, *ASCE 14th Engineering Mechanics Conference,* Austin TX May 2000, 5 pp

PhD student Lars Jacobsson (left) and his supervisor Professor Kenneth Runesson in project MU1. Photo taken in the laboratory of Chalmers Solid Mechanics

MU2. NEW MATERIALS IN WHEELS AND RAILS

Nya material i hjul och räler
Neue Werkstoffe in Rädern und Schienen
Nouveaux matériaux pour roues et rails

Project leader and supervisor	Professor Birger Karlsson, Engineering Metals
Doctoral candidate	Johan Ahlström, Lic Eng (from 1995-11-01; Lic Eng in December 1998)
Period	1995-07-01 – 2000-06-30 (– 2001-06-30)
Chalmers budget (excluding university basic resources)	Stage 1: KSEK 1400 Stage 2: KSEK 1800 Stage 3: KSEK 325
Industrial interests in-kind budget (Adtranz Wheelset)	Stage 1: KSEK 200 Stage 2: KSEK 300 Stage 3: KSEK 100

PhD student Johan Ahlström (left) and his supervisor Professor Birger Karlsson in project MU2. Low-cycle fatigue testing of a potential wheel material is performed in the laboratory of Chalmers Engineering Metals

The material in wheels and rails is subject to wear and fatigue, and can present unstable fracture patterns. The microstructure of the steel and its inner defects play a role here, together with loads and subsequent stresses. As regards the wheels, it is both the action of the normal cyclical mechanical contact forces and the thermal load that occurs temporarily in connection with unintentional wheel locking and sliding, with surface heating, crack formation and wheel flats as consequences. The MU2 project aims at looking for material structures that can better resist the loads in question. An updated project plan dated 1999-02-10 was discussed by the CHARMEC Board on 11 February 1999, and a revised version dated 1999-03-12 approved by the Board on 1 June 1999.

Detailed calculations and evaluations have been performed on selected wheel flats from the Silinge experiments in project MU3. Heat flows, phase transformations, plastic yielding and crack formation have been studied. Basic data have thereby been obtained for an improved selection of material.

Together with Adtranz Wheelset (now Lucchini Sweden), SJ Teknik and Scana Björneborg, a series of two different microalloyed steels (V and N alloyed) were cast. Apart from the alloy variations, non-conventional homogenisation heat treatment of the castings (two charges with a total of 36 castings) was used in one variant. Different forging procedures were applied, among others at a lower temperature than usual. Changes in the microstructure during the manufacturing process were followed. Test pieces were taken from the finished forged wheels and their fatigue properties under strain-controlled excitation were established. Improvements were found for certain variants.

There has been co-ordination with, and following-up of, the MU3 project. Johan Ahlström gained his Licentiate on 11 December 1998. It is planned that he will take his PhD in March 2001.

Johan Ahlström: Phase transformations in railway wheels during wheel slide, Licentiate Thesis, *Chalmers Engineering Metals,* Gothenburg December 1998, 71 pp

Johan Ahlström and Birger Karlsson: Microstructural evaluation and interpretation of the mechanically and thermally affected zone under railway wheel flats, *Wear,* vol 232, 1999, pp 1-14

Johan Ahlström and Birger Karlsson: Analytical 1D model for analysis of the thermally affected zone during railway wheel skid, *Wear,* vol 232, 1999, pp 15-24

Johan Ahlström and Birger Karlsson: Fatigue crack nucleation induced by surface shearing of railway wheels, *Proceedings Fatigue '99, 7th International Fatigue Congress,* Beijing (China) June 1999, pp 2609-2614

Johan Ahlström and Birger Karlsson: Modelling of heat conduction and phase transformations during wheel sliding – theoretical predictions and comparison with results of full-scale experiments, *Proceedings 5th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems,* Tokyo (Japan) July 2000, pp 287-292

Johan Ahlström and Birger Karlsson: Cyclic deformation and fatigue behaviour of microalloyed carbon steels for use in railway wheels, *Proceedings Euromat 2000: Advances in Mechanical Behaviour, Plasticity, and Damage,* Tours (France) November 2000, pp 1021-1026

MU3. MARTENSITE FORMATION AND DAMAGE AROUND RAILWAY WHEEL FLATS

Martensitbildning och skadeutveckling kring hjulplattor
Martensitbildung und Beschädigung an Radplatten
Formation de martensite et dommage aux roues dans les zones de plats

Project leader and supervisor	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Doctoral candidate	Johan Jergéus, Lic Eng (from 1991-09-01; PhD in January 1998)
Period	1995-07-01 – 1997-12-31 (original project start in March 1992)
Chalmers budget (excluding university basic resources)	Stage 1: kSEK 1100 Stage 2: kSEK 300
Industrial interests in-kind budget (SJ Teknik)	Stage 1: kSEK 400 Stage 2: –

The MU3 project was completed with Johan Jergéus's defence of his doctoral dissertation on 30 January 1998, after which he also left Chalmers. The faculty- appointed external examiner was Professor Lennart Karlsson of LTU Computer Aided Design. See further the CHARMEC Biennial Report from Stage 1.

The results of the field trials at Silinge (ca 240 wheel flats were created under controlled conditions) have been evaluated and documented. The earlier developed numerical model for the formation of a wheel flat and its possible martensite layer has been modified after calibration against the experimental results. Better guidelines have been developed for the turning of wheels with wheel flats. Work on wheel flats has to some extent been continued in project MU2.

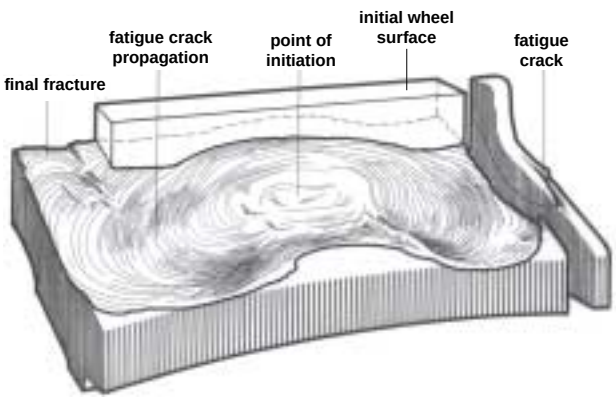
One of about 240 wheel flats generated under controlled conditions in September 1996 during the field experiments at Silinge in project MU3

Johan Jergéus: Railway wheel flats – martensite formation, residual stresses, and crack propagation, Doctoral Dissertation, *Chalmers Solid Mechanics,* Gothenburg January 1998, 111 pp (summary and five appended papers)

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

Johan Jergéus, Christer Odenmarck, Roger Lundén, Peter Sotkovszki, Birger Karlsson and Per Gullers: Full-scale railway wheel flat experiments, *IMechE Journal of Rail and Rapid Transit,* vol 213, no F1, 1999, pp 1-13

PhD student Johan Jergéus of project MU3. For photo of Roger Lundén, see page 20



Sketch of the morphology of a real fatigue crack in a railway wheel as studied in project MU4. The initiation is some 4 mm below the running surface and the circumferential extension some 300 mm. The maximum depth of the crack below the surface is about 14 mm. Drawing by Ulla Kjellgren. See also the photo of a wheel tread on page 50 →

MU4. PREDICTION OF LIFETIME OF RAILWAY WHEELS

Prediktering av livslängd hos järnvägshjul
Vorhersage der Lebensdauer von Eisenbahnrädern
Prédiction de la durée de vie des roues ferroviaires

Project leader and supervisor	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Doctoral candidate	Anders Ekberg, Lic Eng (from 1994-04-15; PhD in March 2000)
Period	1995-07-01 – 2000-06-30 (original project start in January 1994)
Chalmers budget (excluding university basic resources)	Stage 1: KSEK 1000 Stage 2: KSEK 2250
Industrial interests in-kind budget	Stage 1: KSEK 200 *(Adtranz Wheelset)* Stage 2: KSEK 200+200 *(Adtranz Wheelset + SJ Teknik)*

The lifetime and wear of a railway wheel are determined by the mechanical and thermal loads that especially the tread of the wheel is subjected to. The mechanisms behind the degradation of the wheel material are fatigue, wear, phase transformations, etc. Current trends within the railway industry are towards increased speeds and axleloads at the same time as the size of wheels is reduced and tracks are straightened out. Taken together, these factors have led to the result that many wheels, which previously would have been worn down, are now being taken out of operation due to crack formation caused by material fatigue. The rolling contact load means that traditional methods for fatigue dimensioning are no longer applicable. Complicating factors are a high compressive load and a multi-axial stress condition with rotating principal directions.

In the MU4 project, a modern computer-based analysis program WLIFE (WheelLife) has been developed. This is intended as an efficient tool for design work. The results from this part of the project show the effect of load levels and contact geometry. This kind of knowledge is also of great use in the optimisation of wheel maintenance.

Laboratory experiments to evaluate material strength have been carried out together with Adtranz Wheelset (now Lucchini Sweden), the Swedish National Testing and Research Institute, and Chalmers Engineering Metals. It has been possible to draw conclusions on how the strength of the wheel material varies with the direction of the loading and the position in the wheel. A new

Drs Elena Kabo and Anders Ekberg in projects MU4, MU9 and MU10

wheel material has been developed and tested with very good results. In-field measurements on the X2 train have been carried out.

The statistical distribution of loads and material stresses is of great importance to railway wheel fatigue. Statistical simulation has been performed with a neural network for fast fatigue analyses based on the (relatively slow) deterministic simulations from WLIFE. See also the CHARMEC Biennial Report for Stage 1.

During the spring of 1999, Anders Ekberg was a guest researcher at Spoornet in Pretoria, South Africa. In a study together with Johan Marais, various types of wheel breakdowns involving heavy loads were investigated with a special focus on material defects. Dr Elena Kabo has also been working within project MU4 since June 1999. She is a graduate of St Petersburg State Technical University, where she gained her PhD in October 1998.

Anders Ekberg defended his doctoral dissertation on 7 April 2000. The faculty-appointed external examiner was Professor Michael W Brown of the Department of Mechanical Engineering at the University of Sheffield, England. Since 16 April 2000, Anders Ekberg has been employed as an assistant professor at Chalmers Solid Mechanics. He and Elena Kabo are still involved in CHARMEC, see projects MU9 and MU10.

Anders Ekberg: Fatigue – a survey, *Chalmers Solid Mechanics,* Report U67, 2nd edition, Gothenburg 1998, 70 pp

Anders Ekberg: Random multiaxial fatigue initiation – 13 annotated references 1991-1998, *Chalmers Solid Mechanics,* Report F 209, Gothenburg 1998, 17 pp

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MU5. MECHANICAL PROPERTIES OF CONCRETE SLEEPERS

Mekaniska egenskaper hos betongsliprar
Mechanische Eigenschaften von Betonschwellen
Propriétés mécaniques de traverses en béton

Project leader and supervisor	Professor Kent Gylltoft, Structural Engineering/ Concrete Structures
Doctoral candidate	Rikard Gustavson, Lic Eng (from 1997-12-01; Lic Eng in May 2000)
Period	1997-07-01 – 2000-06-30 (– 2002-12-30)
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 2000 Stage 3: KSEK 1625
Industrial interests in-kind budget	Stage 2: KSEK 600+100 *(Abetong Teknik + Banverket)* Stage 3: KSEK 150 *(Abetong Teknik)*

There is a demand for new concrete products for building tracks where increased speeds and axleloads make higher demands than previously. The MU5 project aims at developing methods for the analysis and dimensioning of concrete sleepers subjected to both static and dynamic loads.

Non-linear analysis of a sleeper has been performed with three-dimensional finite elements where the parameters included were calibrated against results from laboratory tests performed on six half-sleepers in co-operation with Abetong Teknik. Crushing of concrete and crack formation and propagation in sleepers under increasing loads have been followed numerically. There has been an exchange of experience between projects TS1 and MU5. The vertical displacement calculated with the DIFF computer program was used as the prescribed "load" on the sleeper on the ballast bed. The reduced stiffness in a partially cracked sleeper proved, with the aid of the established FE model and DIFF, to have only a small effect on the total behaviour of the track construction. A three-dimensional bonding model for the pre-stressed tendons is under development.

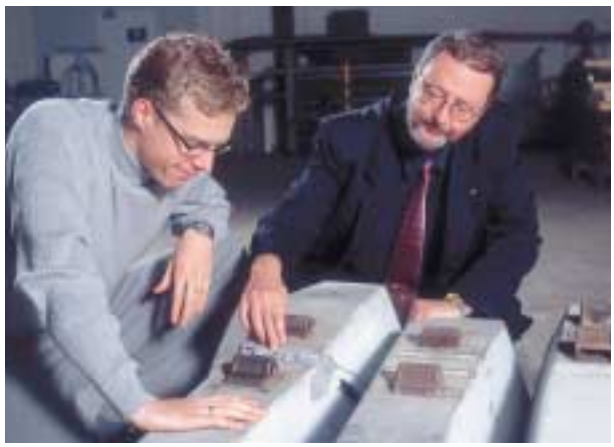
Rikard Gustavson gained his Licentiate on 11 May 2000. The discussion at the licentiate seminar was introduced by Docent Lennart Ågårdh from Sweden's Defence Research Establishment (FOA) in Tumba. Rikard Gustavson is continuing with his studies for a PhD. A revised research plan dated 2000-09-13 was approved by the CHARMEC Board on 21 September 2000.

Rikard Gustavson: Static and dynamic loading of a floating slab structure with embedded monoblock sleepers, *Chalmers Concrete Structures,* Report 98:10, Gothenburg 1998, 8 pp

Rikard Gustavson: Concrete sleeper subjected to static loading – an experimental study, *Chalmers Concrete Structures,* Report 99:4, Gothenburg 1999, 32 pp

Rikard Gustavson, Kent Gylltoft and Magnus Åkesson: Concrete sleepers for railways, *Proceedings Nordic Concrete Research Meeting,* Reykjavik (Iceland) August 1999, pp 196-198

Rikard Gustavson: Static and dynamic finite element analysis of concrete sleepers, Licentiate Thesis, *Chalmers Concrete Structures,* publ 2000:3, Gothenburg May 2000, 69 pp



PhD student Rikard Gustavson (left) and his supervisor Professor Kent Gylltoft in project MU5. Photo taken in the laboratory of Chalmers Concrete Engineering

Anders Ekberg, Reine Lindqvist and Martin Olofsson: Multi-axial fatigue – a probabilistic analysis of initiation in cases of defined stress cycles, *Proceedings Fatigue '99, 7th International Fatigue Congress,* Beijing (China) June 1999, pp 923-928

Anders Ekberg: Rolling contact fatigue of railway wheels – towards tread life prediction through numerical modelling considering material imperfections, probabilistic loading and operational data, Doctoral Dissertation, *Chalmers Solid Mechanics,* Gothenburg April 2000, 128 pp (summary and six appended papers)

Anders Ekberg and Johan Marais: Effects of imperfections on fatigue initiation in railway wheels, *IMechE Journal of Rail and Rapid Transit,* vol 214, no F1, 2000, pp 45-54

Elena Kabo and Anders Ekberg: Fatigue initiation in railway wheels – on the influence of defects, *Proceedings 5th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems,* Tokyo (Japan) July 2000, pp 17-22 (to appear in *Wear*)

Anders Ekberg and Peter Sotkovszki: Anisotropy and rolling contact fatigue of railway wheels, *International Journal of Fatigue,* vol 23, no 1, 2000, pp 29-43

MU6. ROLLING CONTACT FATIGUE OF RAILS

Rullkontaktutmattning av järnvägsräl
Ermüdung von Schienen durch Rollkontakt
Fatigue de contact des rails au roulement

Project leader and supervisor	Professor Lennart Josefsson, Solid Mechanics
Doctoral candidate	Jonas Ringsberg, Lic Eng (from 1998-01-01; PhD in September 2000)
Period	1998-01-01 – 2000-06-30 (– 2000-09-30)
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 1350
Industrial interests in-kind budget (Inexa Profil)	Stage 2: KSEK 450

The rolling contact between railway wheels and rails often results in fatigue damage in the railhead. Increased traffic intensity and higher axle loads have accentuated the problem. The MU6 project deals particularly with the surface cracks called head checks and which, especially on curves, arise in a plastic shear-deformed surface layer on the railhead without any possible material defects having had any influence. A project plan dated 1997-11-27 was approved by the CHARMEC Board on 4 December 1997.

A combined global (the track structure) and local (the contact area) calculation model has been developed and validated. This describes the initiation and early growth of surface cracks taking into account time-variant normal and tangential loads and isotropic and kinematic hardening of the rail material. At high friction, successively growing plastic deformation may occur, so-called ratchetting, which gradually leads to such an accumulation of damage that material fracture and cracks ensue.

PhD student Jonas Ringsberg (left) and his supervisor Professor Lennart Josefson in project MU6. See also the figure on page 40 and the photo on page 51

Calibration of the calculation model has been performed against other researchers' laboratory experiments of the twin disc type and against field results from a test stretch with suburban traffic at Älvsjö in Stockholm. This work has been carried out in close conjunction with the EU4 project, where there has been co-operation with, among others, KTH, TU Berlin, Universität Otto-von-Guericke in Magdeburg and the University of Sheffield.

The work carried out in the MU6 project has made it possible to estimate in advance the time that will elapse until head checks arise on a new or re-ground rail during a given traffic programme. Contact fatigue has proved to be a mainly local process on the railhead, in which the way that the rail is placed on the sleepers plays a very small role.

Jonas Ringsberg defended his doctoral dissertation on 15 September 2000. The faculty-appointed external examiner was Professor Roderick A Smith of the Department of Material and Process Engineering, the University of Sheffield, England. He is also head of the Advanced Railway Research Centre, ARRC, at the same university. Roderick Smith took up the post of Dean of Mechanical Engineering at Imperial College, London, on 1 October 2000. Since 1 September 2000, Jonas Ringsberg has been employed as an assistant professor at Chalmers Solid Mechanics and is still involved in CHARMEC, see projects MU8 and EU7.

Anders Johansson and Hans Thorberntsson: Elastoplastic material model with nonlinear kinematic hardening for rolling and sliding contact fatigue, MSc Thesis EX 1997:15, *Chalmers Solid Mechanics,* Gothenburg November 1997, 82 pp

Lars Broman and Andreas Larsson: Rolling contact fatigue – residual stresses due to contact loads and cross sectional forces, MSc Thesis EX 1997:16, *Chalmers Solid Mechanics,* Gothenburg November 1997, 46 pp

Jonas Ringsberg and Lennart Josefson: Assessment of conditions for initiation of cracks in railheads due to rolling contact fatigue of rails, *Proceedings Fatigue '99, 7th International Fatigue Congress,* Beijing (China) June 1999, pp 2597-2602

Magnus Ekh, Anders Johansson, Hans Thorberntsson and Lennart Josefson: Models for cyclic ratchetting plasticity – integration and calibration, *ASME Journal of Engineering Materials and Technology,* vol 122, no 1, 2000, pp 49-55

Joakim Mattsson and Mattias Olsson: Rolling contact fatigue in rail heads – three-dimensional FE simulations of stresses and strains, MSc Thesis EX1999:12, *Chalmers Solid Mechanics,* Gothenburg 1999, 40 pp

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Jonas Ringsberg, Marianne Loo-Morrey, Lennart Josefson, Ajay Kapoor and John Beynon: Prediction of fatigue crack initiation for rolling contact fatigue, *International Journal of Fatigue,* vol 22, no 3, 2000, pp 205-215

Jonas Ringsberg, Hans Bjarnehed, Anders Johansson and Lennart Josefson: Rolling contact fatigue of rails – FE-modelling of residual stresses, strains and crack initiation, *IMechE Journal of Rail and Rapid Transit,* vol 214, no F 1, 2000, pp 7-19

Jonas Ringsberg: Cyclic ratchetting and failure of a pearlitic rail steel, *Fatigue & Fracture of Engineering Materials & Structures,* vol 23, no 9, 2000, pp 747-758

Jonas Ringsberg: Rolling contact fatigue of railway rails with emphasis on crack initiation, Doctoral Dissertation, *Chalmers Solid Mechanics,* Gothenburg September 2000, 130 pp (summary and five appended papers)

Lennart Josefson, Thomas Svensson, Jonas Ringsberg, Thomas Gustafsson and Jacques de Maré: Fatigue life and crack closure in specimens subjected to variable amplitude loads under plane strain conditions, *Engineering Fracture Mechanics,* vol 66, no 6, 2000, pp 587-600

Jonas Ringsberg and Lennart Josefson: Finite element analyses of rolling contact fatigue crack initiation in railheads, *IMechE Journal of Rail and Rapid Transit* (in press)

Torbjörn Lindbäck, Jonas Ringsberg, Mattias Olsson, Lennart Josefson and Mats Näsström: Rail rolling contact fatigue caused by heavy haul train transports in cold climates, *Luleå Technical University, Department of Computer Aided Design,* Luleå 2000, 18 pp

Jonas Ringsberg and Lennart Josefson: A method for prediction of fatigue crack initiation in railway rails, *6th International Conference on Biaxial/Multiaxial Fatigue and Fracture,* Lisboa (Portugal) June 2001 (accepted paper)

MU7. LASER TREATMENT OF WHEELS AND RAILS

Laserbehandling av hjul och räl
Laserbehandlung von Rädern und Schienen
Traitement au laser des roues et des rails

Project leader and supervisor	Professor Birger Karlsson, Engineering Metals
Doctoral candidate	Simon Niederhauser, Ingénieur diplomé, École Polytechnique Fédéral Lausanne, EPFL (from 2000-04-17)
Period	2000-01-01 – 2000-06-30 (– 2004-12-31)
Chalmers budget (excluding university basic resources)	Stage 2: kSEK 700 Stage 3: kSEK 2050
Industrial interests in-kind budget (Adtranz Wheelset + Duroc Rail + Inexa Profil)	Stage 2: kSEK 200+500+300 Stage 3: kSEK 200+500+300

The life of railway wheels and rails can in all probability be increased by melting on a suitable powder surface layer with the aid of laser technology. In the MU7 project, the influence of different material and process parameters will be studied with regard to the bonding of the surface layer to the base material and the strength of the surface layer when subjected to fatigue loading. Finally, the friction and wear properties of the new running surface will be investigated. The project is being run in close co-operation with Duroc.

PhD student Simon Niederhauser (left) and his supervisor Professor Birger Karlsson in project MU7. Tensile testing of a laser-coated wheel material is performed in the laboratory of Chalmers Engineering Metals

A search has been made of the literature. A test plate taken from a railway wheel has been coated by means of a multi-run process. Metallographic investigations of the surface and substrate have been performed.

MU8. BUTT-WELDING OF RAILS

Stumsvetsning av räl
Stumpfschweissen von Schienen
Soudure bout à bout de rails

Project leader and supervisor	Professor Lennart Josefson, Solid Mechanics
Assistant supervisor	Dr Jonas Ringsberg, Solid Mechanics
Doctoral candidate	Anders Salomonsson, Lic Eng (from 2001-03-01)
Period	2000-01-01 – 2000-06-30 (– 2003-06-30)
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 450+100 Stage 3: KSEK 1850
Industrial interests in-kind budget	Stage 2: – Stage 3: KSEK 200+400 *(Banverket + Inexa Profil)*

A research plan dated 1999-12-07 was presented to the CHARMEC Board on 8 December 1999 and they decided to start the project. A study of the literature has been carried out and seminars held with interested parties from Banverket and Inexa Profil. Both flash welding and thermite welding will be studied. The aim of the MU8 project is to enable a simulation of the welding process numerically. Thereby a good understanding should be obtained of the influence of various parameters on residual stresses and deformations in the weld joint, and on its fatigue strength and lifetime under rolling contact. A special problem is the strength of the thermite weld in a cold climate. Know-how and experience gained in previous projects such as TS1, MU6 and EU4 will be used. Co-operation with Luleå Technical University (LTU) will continue.

Jan Henrik Sällström: Literature survey on flash and thermite welding of rails, *Frontec R&T and Chalmers Solid Mechanics,* Gothenburg November 1999, 12 pp

MU9. ROLLING CONTACT FATIGUE OF RAILWAY WHEELS

Rullkontaktutmattning av järnvägshjul
Ermüdung von Eisenbahnrädern durch Rollkontakt
Fatigue de contact des roues ferroviaires au roulement

Project leaders	Dr Anders Ekberg, Assistant Professor, Dr Elena Kabo and Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Period	2000-07-01 – 2003-06-30 (– 2004-06-30)
Chalmers budget (excluding university basic resources)	Stage 3: KSEK 1350+800
Industrial interests in-kind budget (Adtranz Sweden + Adtranz Wheelset)	Stage 3: KSEK 200+200

A project plan dated 2000-09-19 was discussed (and given preliminary approval) at the CHARMEC Board meeting on 21 September 2000. Five part projects are included. Issues, know-how and experience gained from the MU4 project will be utilised. A special area of study will be the influence of material defects and criteria for their dangers. One conclusion from MU4 is that correct material specifications should take into consideration the mechanical properties of the defects and their absolute size, geometrical shape and physical location.

The WLIFE computer program will be further developed with regard to defects, anisotropy and plastic yielding, as well as residual stresses from manufacture and operation. With the aid of WLIFE, it will be possible to dimension wheels and to make an optimal selection of wheel materials and maintenance intervals. The design engineer will have access to a fatigue spectrum for a given train/ track configuration.

MU10. CRACK PROPAGATION IN RAILWAY WHEELS

Sprickfortplantning i järnvägshjul
Rissausbreitung in Eisenbahnrädern
Propagation de fissures dans les roues ferroviaires

Project leader and supervisor	Professor Hans Andersson, Solid Mechanics
Assistant supervisor	Dr Elena Kabo, Solid Mechanics
Doctoral candidate	To be recruited
Period	2001-07-01 – 2003-06-30 (– 2006-06-30)
Chalmers budget (excluding university basic resources)	Stage 3: KSEK 1500
Industrial interests in-kind budget (Lucchini Sweden)	Stage 3: KSEK 400

Fatigue cracks may be initiated at different positions in a wheel as studied in the MU9 project. Their propagation will be investigated in the present project. A preliminary project plan dated 2001-02-08 was discussed and approved by the CHARMEC Board on 20 February 2001.

SD1. BRAKING OF FREIGHT TRAINS – A SYSTEMS APPROACH

Bromsning av godståg - en systemstudie
Bremsen von Güterzügen - eine Systemstudie
Freinage de trains de marchandises - étude de systèmes

Project leader and supervisor	Professor Göran Gerbert, Machine and Vehicle Design
Doctoral candidate	Daniel Thuresson, MSc (from 1998-12-01)
Period	1998-12-01 – 2000-06-30 (– 2003-12-01)
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 1400 Stage 3: KSEK 1950
Industrial interests in-kind budget	Stage 2: KSEK 400+100 *(Cardo Rail + SJ Teknik)* Stage 3: KSEK 250 *(Cardo Rail)*

Higher speeds and increased axleloads of freight wagons put increasingly higher demands on brake performance. Furthermore, a considerable share of the maintenance costs for freight wagons falls on the wheels and their tread brakes. The performance of the brakes is determined by the interaction between the blocks and the wheel. The SD1 project aims at determining the limits for what the brake system can manage under different conditions and thereby identify critical parameters. A project description dated 1998-03-04 was discussed by the CHARMEC Board on 4 March 1998 and approved by them on 27 May 1998.

A thermomechanical model has been created in which the brake block is elastic while the wheel is considered to be rigid but thermally conductive. A finite element program has been written which solves the coupled problem. The model can handle wear and also temperature-dependent coefficients, etc. There is close co-operation with Cardo Rail (SAB WABCO in Landskrona) and SJ Teknik. Göran Gerbert formally left his chair at Chalmers on 31 December 2000, but informally continues as supervisor for Daniel Thuresson. There is co-ordination between this project and project VB2.

Daniel Thuresson: Thermomechanical analysis of friction brakes, *Proceedings of the 2000 Brake Colloquium and Engineering Display,* SAE\P-00/358, San Diego CA October 2000, pp 149-160

PhD student Daniel Thuresson (right) and his supervisor Professor Göran Gerbert in project SD1. Photo taken at a brake rig in the laboratory of Chalmers Machine and Vehicle Design

SD2. SONAR PULSES FOR BRAKING CONTROL

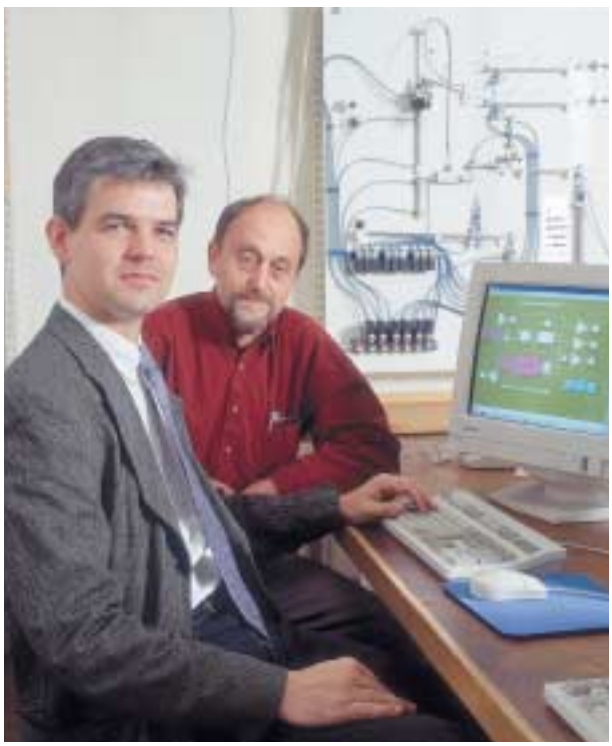
Ljudpulser för styrning av bromsar
Schallpulse für die Steuerung von Bremsen
Contrôle de freins par pulsions sonores

Project leader	Professor Bengt Schmidtbauer, Mechatronics
Co-worker	Hans Sandholt, MSc
Period	1998-07-01 – 2000-06-30
Chalmers budget (excluding university basic resources)	Stage 2: KSEK 395
Industrial interests in-kind budget (Cardo Rail + SJ Teknik)	Stage 2: KSEK 250+100

The brake systems in ordinary locomotive-drawn freight trains work on a purely mechanical-pneumatic basis, which in long trainsets leads to considerable delays from the initiation of a brake command in the locomotive to the braking effect being achieved in the last wagon. Apart from braking distances thus being considerably extended, an early deceleration in only the forward part of the train leads to a deterioration in stability and an increase in wear etc. The aim of the SD2 project is to provide conditions for better and safer control of deceleration in freight trains without having to make any appreciable modifications in the existing wagon fleet. Up to now, the project has been carried on as a prestudy.

Acoustic communication/sonar transmission (modulation of the pressure signal) through the main brake line of a trainset has been studied theoretically, numerically and experimentally. Scale-model experiments have been performed in our own laboratory and full-scale experiments with brake lines (including hoses, accumulators etc) up to 1200 m in length at SAB WABCO's brake system simulator in Piossasco, Italy, as well as on stationary and rolling freight trains in Sweden. Sensors, actuators and program software have been developed. The experiments verified the theoretical/numerical models.

The conclusion reached in project SD2 is that it is possible to transmit usable information in the pressurized brake line, but only at a low bandwidth, 5 to 10 Hz. A more efficient pneumatic actuator that is impedance adapted should be developed so that the signal level can be raised in relation to the noise level on board the rolling freight train. The future of the project is the subject of ongoing discussions. Bengt Schmidtbauer left his post at Chalmers on 31 December 2000.



Lecturer Hans Sandholt (left) and Professor Bengt Schmidtbauer in project SD2. A SIMULINK experiment has been set up

Hans Sandholt and Bengt Schmidtbauer: On sonar transmission through the train brake system: phase 1 – literature and baseline models, *Chalmers Mechatronics,* Report I-98/004, Gothenburg 1998, 10 pp

Hans Sandholt: On sonar transmission through the train brake system: progress report 1, *Chalmers Mechatronics,* Report I-98/005, Gothenburg 1998, 5 pp

Hans Sandholt and Bengt Schmidtbauer: On sonar transmission through the train brake system: progress report 2, *Chalmers Mechatronics,* Report I-99/001, Gothenburg 1999, 11 pp

Hans Sandholt: On sonar transmission through the train brake system: experimental notes from the tests on cargo wagons at SweMaint, *Chalmers Mechatronics,* Report I-99/002, Gothenburg 1999, 5 pp

Hans Sandholt and Bengt Schmidtbauer: On sonar transmission through the train brake system: test report from tests at SAB WABCO in Piossasco/Italy, *Chalmers Mechatronics,* Report I-99/003, Gothenburg 1999, 19 pp

Hans Sandholt: On sonar transmission through the train brake system – a noise characterizing experiment, *Chalmers Mechatronics,* Report I-00/001, Gothenburg 2000, 5 + 99 pp

Hans Sandholt and Bengt Schmidtbauer: Sonar transmission through the train brake system: final report of prestudy (phase 2), *Chalmers Mechatronics,* Report I-00/002, Gothenburg 2000, 9 pp

SD3. COMPUTER CONTROL OF BRAKING SYSTEMS FOR FREIGHT TRAINS

Datorstyrning av bromsar till godståg
Rechnersteuerung der Bremssysteme von Güterzügen
Contrôle par ordinateur du freinage des trains de marchandises

Project leader	Håkan Edler, MSc, Computer Engineering
Supervisor	Professor Jan Torin, Computer Engineering
Doctoral candidate	Roger Johansson, Lic Eng (from 1999-10-01; part-time)
Period	1998-07-01 – 2000-06-30 (– 2003-06-30)
Chalmers budget (excluding university basic resources)	Stage 2: kSEK 300+100 Stage 3: kSEK 1500
Industrial interests in-kind budget (Cardo Rail + SJ)	Stage 2: kSEK 250+200 Stage 3: kSEK 250+50

Today, computers connected in networks are used in the control of various processes. Each computer can be located near to sensors and actuators and can thus collect and process data near to sources and sinks. Electrical and mechanical interfaces are being replaced by data communication. Such distributed real-time systems provide many advantages as regards speed, flexibility and safety/security and they are the subject of intensive research.

For the last couple of decades, computers have been used for control of railway signals and for many years they have also been used on board trains. Railway signals and automatic train control put extreme demands on safety. Applications on board trains have not yet made corresponding demands, but as more and more functions become computerised, the need for reliability will increase. One example is train brakes, where a distributed computer system can give shorter response times and better means of controlling braking processes than pneumatic systems.

An important issue in project SD3 is how to achieve a satisfactory level of safety with today's technology. Products at present on the market are well suited to most automation applications, but are often found wanting when safety demands are high. Better knowledge is required about the demands on train computer systems and how they can be fulfilled. Methods of verifying the reliability of systems are required. The aim is for dependability (including availability, reliability, safety and security) and for a safety-critical application on top of existing technology.

Meetings have been held with Cardo Rail/SAB WABCO in Landskrona and Turin. A conceptual solution has been formulated and is being worked on. A steering group has been established consisting of representatives of Cardo Rail, SJ Teknik and the Swedish National Testing and Research Institute, SP. Håkan Edler formally left his post at Chalmers on 30 September 2000, but will continue to contribute as project leader. A project plan dated 1999-02-09 was discussed by the CHARMEC Board on 11 February 1999. The project was finally confirmed and approved by the Board on 20 February 2001. As of 1 January 2001, the project SD3 has been transferred to Chalmers Lindholmen University College (Chalmers Lindholmen högskola AB).

Professor Jan Torin is the supervisor of Roger Johansson in project SD3

PhD student Roger Johansson (right) and his project leader Mr Håkan Edler in project SD3

SD4. CONTROL OF BLOCK BRAKING

Reglering av blockbromsning
Steuerung von Klotzbremsen
Contrôle du freinage à sabot

Project leader and supervisor	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Doctoral candidate	Tore Vernersson, Lic Eng
Period	2001-03-01 – 2004-06-30
Chalmers budget (excluding university basic resources)	Stage 3: KSEK 1700
Industrial interests in-kind budget	Stage 3: KSEK 600+400+50 *(Lucchini Sweden + Cardo Rail + TrainTech Engineering)*

The project will focus on the maximum capacity of a block braking system of best design. In particular, the limitations put on the heating of the wheel rim will be studied. A project plan dated 2001-02-16 was discussed and approved by the CHARMEC Board on 20 February 2001.

The inertia dynamometer in Surahammar at its inauguration in 1989 in the presence of people from Chalmers, ABB and SJ.
See also page 38

Simulation of stop braking, drag braking and complete braking programs (sequences recorded in-field) is performed in an outdoor environment. Disc brakes and block brakes with a maximum wheel diameter of 1500 mm can be handled. An electric motor of maximum power 250 kW drives 2 to 12 fly-wheels, each at 630 kg and 267 kgm^2, with a maximum speed of 1500 rpm

Parameters controlled:
Braking air pressure (max 5 bar)
Train speed (max 250 km/h)
Axle load (max 30 tonnes)
Environment (heat, cold, water, snow…)

Results recorded:
Braking moment
Temperatures
Strains and stresses
Wear

Design for two extreme stop braking cases:

$2m$ tonnes	v_0 km/h	s_{sign} m	s_b m	t_b s	r m/s^2	Q_0 kW	E kWh	D m	n rpm	M Nm
30	140	1000	772	39.7	0.98	571	3.15	0.92	807	6760
16	250	3500	2837	81.7	0.85	472	5.36	0.88	1500	2990

SD5. ACTIVE AND SEMI-ACTIVE SYSTEMS IN RAILWAY VEHICLES

Aktiva och semiaktiva system i järnvägsfordon
Aktive und halbaktive Systeme in Eisenbahnfahrzeugen
Systèmes actifs et semiactifs dans les véhicules ferroviaires

Project leader and supervisor	Docent Jonas Sjöberg, Signals and Systems/ Control Engineering
Assistant supervisor	To be appointed
Doctoral candidate	To be recruited
Period	2001-07-01 – 2003-06-30 (– 2006-06-30)
Chalmers budget (excluding university basic resources)	Stage 3: KSEK 1500
Industrial interests in-kind budget (Adtranz Sweden)	Stage 3: KSEK 300

Sensors and actuators in the bogies of a vehicle may register and compensate for vibrations and impacts as induced by wheel and track imperfections. The aim is to improve the overall performance of the vehicle. In particular, passenger comfort should be increased. A project plan dated 2001-02-12 was discussed and approved by the CHARMEC Board on 20 February 2001.

Parallel EU projects – Parallella EU-projekt – Parallele EU-Projekte – Projets parallèles avec l'UE

EU1. EUROSABOT

EuroSABOT – Sound Attenuation by Optimised Tread Brakes
Schallverminderung durch optimierte Klotzbremsen
Atténuation du bruit par l'optimisation des freins à sabot

Project leader	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Co-workers	Tore Vernersson, Lic Eng, and Martin Petersson, Lic Eng, Solid Mechanics
Period	1996-02-01 – 2000-02-01
Budget EU	KEURO 122+42
Budget CHARMEC	Stage 2: KSEK 200

Tread braked railway vehicles radiate high rolling sound. The reason is that the brake blocks generate roughness (waviness, corrugation) on the wheel tread, which induces vibrations and noise. The objective of EuroSABOT and the EU1 project has been to develop new and better brake blocks that cause less roughness on the wheel tread than blocks used today. Chalmers' commitment to EuroSABOT was 13 man-months. The work was carried out in close co-operation with the CHARMEC VB2 project. Cédric Pouligny, a guest student from INSA in Lyon, has contributed. A great deal of experimental work has been done in the brake rig at Surahammar, see further the CHARMEC Biennial Report for Stage 1. Our work in EuroSABOT has now been completed. We have had particularly intensive co-operation with our partner NS in the Netherlands. The total budget for EuroSABOT is KEURO 3724.

Cédric Pouligny: Analysis of temperature and roughness of tread braked railway wheels, MSc Thesis EX 1998:3, *Chalmers Solid Mechanics,* Gothenburg 1998, 29 pp

Tore Vernersson: EuroSABOT WP3 benchmark study using the "Chalmers model", EuroSABOT Technical Report 3H9 J29T1 OA1, *Chalmers Solid Mechanics,* Gothenburg 1999, 29 pp

Martin Petersson, Roger Lundén and Cédric Pouligny: Full-scale block braking of railway wheels II – testing of block prototypes on the Adtranz/Chalmers inertia dynamometer, *EuroSABOT Technical Report 4H9 L21T1 OZ1, Chalmers Solid Mechanics,* Gothenburg 1999, 124 pp

P H de Vos and A A van Lier: EuroSABOT final report – technical part, *EuroSABOT Technical Report 6N9 O11T1 DA, NS Technical Research,* Utrecht (the Netherlands) 1999, 68 pp

EU2. SILENT FREIGHT

Silent Freight – Development of new technologies for low noise freight wagons

Entwicklung neuer Technologien für leise Güterwagen

Développement de nouvelles technologies pour des wagons de marchandises silencieux

Project leader	Docent Jens Nielsen, Solid Mechanics
Co-workers	Martin Petersson, MSc, and Markus Wallentin, MSc, Solid Mechanics
Period	1996-01-01 – 1999-01-01
Budget EU	kEURO 91
Budget CHARMEC	Stage 2: kSEK 200

For photos of Jens Nielsen and Martin Petersson, see pages 12 and 20

The aim of Silent Freight and the EU2 project has been to reduce the noise level from the rolling stock used in freight traffic by 10 dB(A). Chalmers' commitment to Silent Freight was 17 man-months. Our contribution aimed at investigating whether a proposal put forward by us for a standard wheel with a perforated wheel disc could be a cost-effective solution that would be applicable on existing types of freight wagon wheels. Our work in Silent Freight has now been completed.

A series of initial rough calculations and rig tests with perforations made in the wheel disc of already manufactured wheels has been followed by thorough strength calculations and the manufacturing of a new prototype wheel. CEN standards have been observed. Sound radiation was calculated by means of the commercial SYSNOISE computer program and was measured in the test rig. The outcome of the EU2 project shows that acoustic short-circuiting (between the front and rear sides of the wheel disc) via suitable holes is an effective method in the frequency range up to ca 1000 Hz. For frequency ranges above that, supplementary measures must be taken for noise reduction. We have had particularly intensive co-operation with ABB Corporate Research. A prototype wheelset made by Adtranz Wheelset was used in the final field tests at Velim in the Czech Republic. The total budget for Silent Freight is kEURO 3196.

Jens Nielsen was made Docent of Solid Mechanics (Railway Mechanics) on 9 November 2000.

Martin Petersson: Appendix 7 (25 pp) of Silent Freight – state-of-the-art study (G Haines, editor), *Brite/EuRam III Silent Freight Technical Report 1L6 Y14T1 DB, LUL Technology Services,* London 1996, 14 pp + appendices

Jens Nielsen and Markus Wallentin: Design of a perforated wheel, *Brite/EuRam III Silent Freight Technical Report 3H7 O28T1 DA, Chalmers Solid Mechanics,* Gothenburg 1998, 14 pp + appendices

Jens Nielsen: Acoustic short-circuiting in perforated Adtranz AD860 railway wheel – a parametric study, *Brite/EuRam III Silent Freight Technical Report 3H8 M08T1 DA, Chalmers Solid Mechanics,* Gothenburg 1998, 21 pp

Anders Daneryd, Jens Nielsen, Eva Lundberg and Anders Frid: On vibroacoustic and mechanical properties of a perforated railway wheel, *Proceedings 6th International Workshop on Railway Noise,* Île des Embiez (France) November 1998, pp 305-317

From left: PhD student Tore Vernersson together with Lennart Nordhall, Managing Director of Lucchini Sweden, and Hans Johansson, Technician of Chalmers Solid Mechanics. In the background: Inertia dynamometer in Surahammar used for braking experiments in projects VB2 and EU1. A slip ring device is seen in the middle. See also photo and data on page 36

EU3. SILENT TRACK

Silent Track – Development of new technologies for low noise railway infrastructure

Entwicklung neuer Technologien für leise Infrastruktur

Développement de nouvelles technologies pour des infrastructures ferroviaires silencieuses

Project leader	Docent Jens Nielsen, Solid Mechanics
Co-worker	Clas Andersson, MSc, Solid Mechanics
Period	1997-01-01 – 2000-02-29
Budget EU	KEURO 150
Budget CHARMEC	Stage 2: KSEK 1400

For photo of Jens Nielsen and Clas Andersson, see page 12

The aim of Silent Track and the EU3 project has been, for freight traffic, to reduce the noise level from the track by 10 dB(A). Chalmers' commitment to Silent Track was 28.5 man-months. Our contribution was partly to develop further the DIFF model (see project TS1) to study the origin of corrugation on the railhead, and partly to propose a new sleeper with reduced radiated sound power. Our work in Silent Freight has now been completed.

Simulation of corrugation growth in DIFF has been calibrated and verified against measurements of wave formation on rails used on the Netherlands railways. Studies have been made of the effect on wave formation in the rail of the parameters railpad stiffness, type of rail, sleeper distance and sleeper mass. During May and June 1999, at Velim in the Czech Republic, full-scale tests arranged by Silent Freight and Silent Track, and with the participation of CHARMEC, were carried out.

Our DIFF program has been used in a study to minimise noise radiation from track sleepers. Vibro-acoustic calculations were performed with the commercial SYSNOISE computer program. A lower sound power was obtained for a two-block sleeper than for a standard sleeper of the mono-block type. In co-operation with Abetong Teknik (a subcontractor in Silent Track), new optimised two-block sleepers were developed and manufactured, and also used in the full-scale tests at Velim. The total budget for Silent Track is KEURO 3747.

Tomas Fernström: Structural dynamics optimization of railway sleepers, MSc Thesis EX 1997:14, *Chalmers Solid Mechanics,* Gothenburg 1997, 41 pp

Jens Nielsen: Parametric study on low noise sleeper design, *Brite/EuRam III Silent Track Technical Report 80801/3/CHAL/T/A1/prel-sleepdesign, Chalmers Solid Mechanics,* Gothenburg 1998, 29 pp

Jens Nielsen: Acoustic optimisation of railway sleepers, *Proceedings 6th International Workshop on Railway Noise,* Île des Embiez (France) November 1998, pp 252-263. Also in *Journal of Sound and Vibration,* vol 231, no 3, 2000, pp 753-764

Jens Nielsen: Rail roughness generation and growth – influence of track parameters, *Silent Track Technical Report 92501/2/CHAL/T/A/RGGUPP, Chalmers Solid Mechanics,* Gothenburg 1999, 22 pp

Johan Oscarsson and Jens Nielsen: Dynamic train/track interaction with state-dependent track properties, *Silent Track Technical Report 92704/2/CHAL/T/Z/STATEDEP, Chalmers Solid Mechanics,* Gothenburg 1999, 19 pp (part of Johan Oscarsson's licentiate thesis)

Jens Nielsen: Rail roughness generation and growth in the Netherlands – simulation vs experiments, *Silent Track Technical Report 92009/2/CHAL/T/Z3/RGG-simulation Soest, Chalmers Solid Mechanics,* Gothenburg 1999, 26 pp

Martin Hiensch, Jens Nielsen and Edwin Verheijen: Rail corrugation in the Netherlands – measurements and numerical simulations, *Proceedings 5th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems,* Tokyo (Japan) July 2000, pp 81-88 (to appear in *Wear*)

Finite element model of a wheel with perforated disc as studied, both numerically and experimentally, in project EU2. See also photo of prototype wheel on page 21

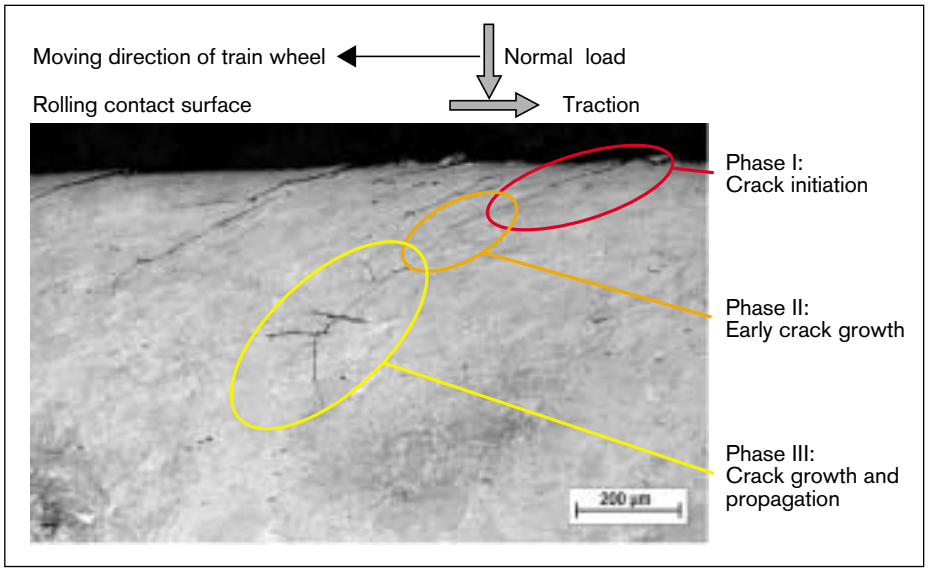
EU4. ICON

ICON – Integrated study of rolling contact fatigue
Integriertes Studium über Ermüdung durch Rollkontakt
Étude intégrée de la fatigue de contact au roulement40

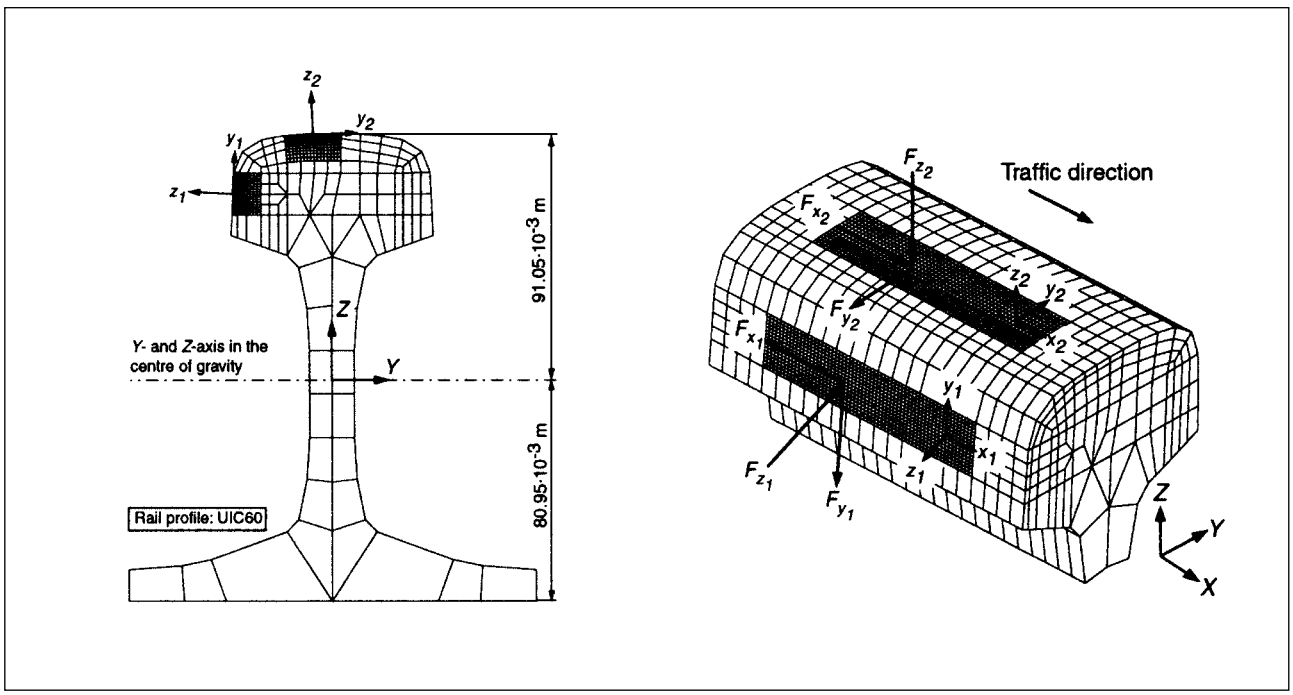
Project leader	Professor Lennart Josefson, Solid Mechanics
Co-worker	Jonas Ringsberg, Lic Eng, Solid Mechanics
Period	1997-01-01 – 1999-12-31
Budget EU	KEURO 96
Budget CHARMEC	Stage 2: KSEK 850

The aim of ICON and the EU4 project has been to develop and verify a calculation model that can describe the initiation and early growth of cracks in the railhead. Chalmers' commitment to ICON was 16 man-months. Our part in the project has now been completed. A final seminar for the whole of ICON was held in Utrecht on 22 March 2000.

The activities of projects EU4 and MU6 were similar and coincided to a great extent. Here we refer to the report under the MU6 project and the references given there. The total budget for ICON is KEURO 1523.



Three phases of crack development in the railhead under rolling contact load as simulated in a so-called twin disc laboratory experiment in project EU4, see also project MU6. The experiment was performed at the Otto-von-Guericke University in Magdeburg (Germany)



Our finite element study in the MU6 and EU4 projects of a two-point wheel contact on the high rail in an unlubricated curve at the Älvsjö test site (cf the front cover of this Triennial Report). The dark areas contain a very fine mesh

EU5. EUROBALT II

EUROBALT II – European research for an optimised ballasted track
Europäische Forschung für Optimiering von Gleisen auf Schotter
Recherche européenne pour l'optimisation des voies ferrées sur ballast

Project leaders	Professor Tore Dahlberg, IKP, Linköping University Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Co-worker	Johan Oscarsson, Lic Eng, Solid Mechanics
Period	1997-09-01 – 2000-06-30 (– 2000-08-31)
Budget EU	KEURO 207
Budget CHARMEC	Stage 2: KSEK 350

Chalmers' commitment to EUROBALT II was 34 man-months. Our aim in the EU5 project has been to develop a calculation model that well reproduces and predicts the dynamic interaction between train and track.

A literature study has been carried out in which over 1000 references to ballast were identified. Our DIFF calculation model has been expanded, see project TS1. A resonance frequency at 20 to 30 Hz in the ballast/substructure has been included. A calculation routine has been implemented for optimal selection of describing parameters, including among other things a frequency-dependent viscoelastic railpad stiffness. The influence of train and track parameters on the track deformation and on the contact forces between sleeper and ballast has been investigated. There has been co-ordination with the TS1 project. Tore Dahlberg has continued his work in the project after his move to the Linköping Institute of Technology on 1 January 1997. The total budget for EUROBALT II is KEURO 4154.

The work in the project was formally concluded on 31 August 2000.

Tore Dahlberg: Bibliography for EUROBALT II project on railroad ballast used as track substructure, *Linköping University, IKP,* Linköping (Sweden) 1997-1999: Part 1 – Literature review of research on railroad ballast used in track substructure (48 references), 19 pp, Part 2 – Bibliography for EUROBALT II projekt on railroad ballast used in track substructure, 91 pp, and Part 3 – Thesaurus to the Bibliography, 11 pp. See also http://www.solid.ikp.liu.se/research/tore.htm

Tore Dahlberg: Review of research on railroad ballast used in track substructure, *Proceedings VTI's and KFB's Transport-Forum,* Linköping (Sweden) January 13-14, 1999, 17 pp

Tore Dahlberg: Further developments of the DIFF train/track interaction model for the EUROBALT II project, *Report for the EUROBALT II meeting in York (UK),* March 8-9, 1999, Linköping University, IKP, 15 pp

Tore Dahlberg: The Goose Hill measurements, *Report for the EUROBALT II meeting in Malmö (Sweden),* June 21-23, 1999, Linköping University, IKP, 12 pp

Johan Oscarsson and Per Linusson: Verification of dynamic train/track interaction models, *Brite/EuRam III Project EUROBALT II, Technical Report 4C/991213/T1/DA, Chalmers Solid Mechanics,* Gothenburg 1999, 16 pp

Fredrik Månsson and Tore Dahlberg: Investigation of how track parameters influence the short-term dynamics of the train/track interaction with special emphasis on factors influencing the long-term deterioration, *Linköping University, IKP,* Linköping (Sweden) 2000: Part 1 – Non-linear track model, *EUROBALT Report 6C/000717/T1/OA,* 30 pp, and Parts 2 and 3 – Linear track model, *EUROBALT Report 6C/000405/T1/OA,* 30 pp

Tore Dahlberg: Some railroad settlement models – a critical review, *IMechE Journal of Rail and Rapid Transit* (in press)

Professor Tore Dahlberg (right) and his Master's student Fredrik Månsson in project EU5.
For photo of Johan Oscarsson, see page 12

EU6. HIPERWHEEL

HIPERWHEEL – Development of an innovative high performance railway wheelset

Entwicklung eines innovativen leistungsstarken Radsatzes

Développement d'un essieu monté innovent à haute performance

Project leader	Professor Roger Lundén, Solid Mechanics/ Railway Mechanics
Co-workers	Docent Jens Nielsen, Solid Mechanics
	Dr Anders Ekberg, Assistant Professor, Solid Mechanics
Period	2000-04-01 – 2000-06-30 (– 2004-03-31)
Budget EU	KEURO 130
Budget CHARMEC	Stage 3: KSEK 700 (preliminary)

In total, HIPERWHEEL comprises 280 man-months and has a budget of KEURO 1979. Chalmers' share is 13 man-months. Partners in the project are Centro Ricerche Fiat (Italy), Fraunhofer-Institut für Betriebsfestigkeit LBF (Germany), Lucchini (Italy), Valdunes (France), SNCF (France), Otto Fuchs Metallwerke (Germany), Chalmers Solid Mechanics (Sweden), University of Sheffield (England), Politecnico di Milano (Italy), Ferrovie dello Stato (Italy) and Mechanical Dynamics Italy (Italy).

Lower weight, longer maintenance intervals and less noise radiation are the properties of future wheelsets that the HIPERWHEEL project aims at attaining. It should be possible to achieve lower weight, for example, by manufacturing parts of the wheelset in other materials than steel. The mechanisms of damage such as rolling contact fatigue of the tread and fretting fatigue in the shrink-fit between wheel and axle are to be considered. CHARMEC's main work in the EU6 project is, together with the University of Sheffield, to study damage mechanisms and to act as work package leader for the part project on noise radiation.

Jens Nielsen took part in the kick-off meeting for the project at Fiat's research centre at Orbassano outside Turin on 18 April 2000. Furthermore, Anders Ekberg participated in a meeting at the Fraunhofer-Institute LBF in Darmstadt on Work Package 3: damage mechanisms. Work with state-of-the-art and identification of rolling contact damage mechanisms is in progress.

Some of CHARMEC's co-workers in EU projects. From left: Johan Iraeus, Jan Rydin, Anders Johansson and Lennart Mähler (sitting), and Hans Bjarnehed and Jan Henrik Sällström (standing). From the consultancy Frontec R&T (now HighTech Engineering) in Gothenburg. Mähler, Bjarnehed and Sällström all gained their doctorates at Chalmers Solid Mechanics. For photo of Jens Nielsen of the consultancy Ingemansson Technology, see page 12

EU7. INFRASTAR

INFRASTAR – Improving railway infrastructure productivity by sustainable two-material rail development

Verbesserte Produktivität der Eisenbahninfrastruktur durch Entwicklung haltbarer Schienen aus zwei Werkstoffen

Amélioration de la productivité de l'infrastructure ferroviaire par le développement des rails durables composés de deux matériaux

Project leaders	Professors Lennart Josefson and Roger Lundén, Solid Mechanics
Co-workers	Docent Jens Nielsen, Solid Mechanics
	Dr Jonas Ringsberg, Assistant Professor, Solid Mechanics
	Professor Birger Karlsson, Engineering Metals
Period	2000-05-01 – 2000-06-30 (– 2003-11-01)
Budget EU	KEURO 181
Budget CHARMEC	Stage 3: KSEK 700 (preliminary)

In total, INFRASTAR comprises 140 man-months and has a budget of KEURO 2160. Chalmers' share is 20 man-months. Partners are NSTO (the Netherlands), Chalmers Solid Mechanics (Sweden), University of Sheffield (England), Banverket (Sweden), RATP (France), Duroc (Sweden), Sogerail (France) and Inexa Profil (Sweden).

The aim of the INFRASTAR project is to increase the lifetime and reduce the noise level (including screeching sounds) of particularly exposed sections of railway track. This can, for instance, mean small-radius curves that are subject to large volumes of traffic and high axleloads. A thin surface layer of other material with favourable friction and fatigue properties will be applied to the railhead. Two different technologies will be studied: the melting of powder onto the surface by laser and the rolling-in of an extra layer of material. The objective of the EU7 project is to develop and validate a calculation model that can describe the initiation and early growth of rolling contact fatigue cracks in a so-called two-material rail (both in the railhead and in the interface between the base material and the applied surface layer). Furthermore, a calculation model is to be developed that can describe the dynamic interaction between train and track, including the two-material rail.

Rigid-body dynamic models of trains on the Malmbanan (Iron Ore Line) in Sweden/Norway and on the Paris underground are to be created. Dynamic simulations of trains running on curves will be performed with the aid of the GENSYS software program in order to calculate contact forces between wheels and rail. Contact pressure distributions will be calculated by means of the CONTACT software program. The influence of friction between wheel and rail on running dynamics and contact pressure is to be specially studied.

A literature study will provide information on residual stresses and fatigue properties in existing applications where a surface layer has been melted on by means of laser cladding. Such an application is the melting of stainless steel onto the inner surface of a reactor tank in a nuclear power station. There will also be an examination into the need for parameter values in connection with constitutive models of basic materials in rails (900A) and surface layers. Experiments are planned for the development of especially low-cycle fatigue data. Residual stresses and deformations when melting surface layers onto rails will be estimated. There is co-ordination with the parallel MU7 project. A kick-off meeting was held at Hindås, Sweden, on 26 May 2000.

Two-unit twelve-axle (Co)'(Co)'+(Co)'(Co)' locomotive (360 tonnes, 10.8 MW) for the Iron Ore Line as delivered by Adtranz in August 2000 →

Part of bogie of the new two-unit twelve-axle iron ore locomotive, see full photo on the previous page

Iron ore line

The 540 km iron ore line Malmbanan/Ofotbanen in Sweden and Norway (its major part runs north of the Arctic Circle) is presently being upgraded from 25 to 30 tonne axleload, from 52 to 68 wagons per train and from 50 to 60 km/h maximum speed of the loaded train. New locomotives and wagons have been procured by the transportation company MTAB (Malmtrafik i Kiruna AB) and reinforcing measures in the track are being taken by Banverket and its Norwegian counterpart Jernbaneverket. The knowledge generated in CHARMEC has here found broad application. Thomas Nordmark, Robert Fröhling and Tord Karlsson, the co-authors of the conference papers below, are employees of MTAB, the wagon manufacturer Transwerk in South Africa and the mining company LKAB in Kiruna, respectively.

Roger Lundén: LKAB invests in 30 tonne axleloads, *Railway Gazette International,* vol 154, no 9, 1998, pp 585-588 (extended reprints are available)

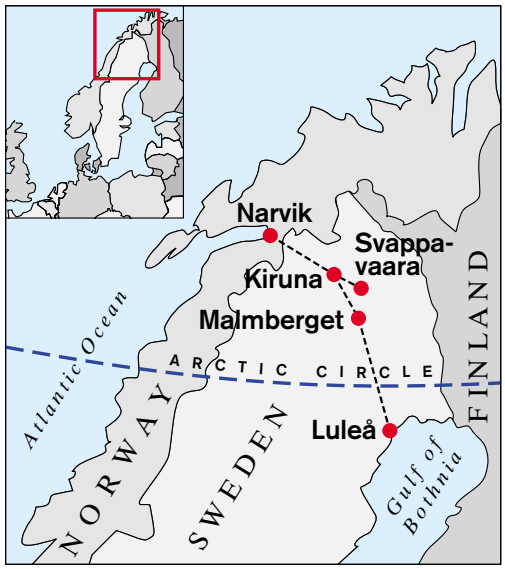
Björn Paulsson: Assessing the track costs of 30 tonne axleloads, *Railway Gazette International,* vol 154, no 11, 1998, pp 785-788 (extended reprints are available)

Jens Nielsen and Annika Stensson: Enhancing freight railways for 30 tonne axle loads, *IMechE Journal of Rail and Rapid Transit,* vol 213, no F4, 1999, pp 255-263

Roger Lundén and Bernt Andersson: Heavier and longer electric trains with higher axle loads – an example from the "Iron Ore Line" in the north of Sweden (in English and Russian), *Swedish/Russian Seminar at Petersburg State Transport University,* St Petersburg (Russia) May 2000, 37 pp

Roger Lundén, Thomas Nordmark and Björn Paulsson: Enhancing iron ore transportation in Sweden, Paper accepted for *7th International Heavy Haul Conference,* Brisbane (Australia) June 2001, 8 pp

Robert Fröhling, Tord Karlsson and Roger Lundén: New LKAB iron ore wagons with self-steering bogies and rapid unloading system, Paper accepted for *7th International Heavy Haul Conference,* Brisbane (Australia) June 2001, 6 pp



The 540 km Malmbanan links the iron ore production plants at Kiruna, Malmberget and Svappavaara with the ports of Narvik and Luleå. The highest point is 550 m above sea level and the steepest grade down to Narvik is 1.7 %. Most of the route is north of the Arctic Circle where severe winter conditions include snowstorms and temperatures of −40° C. The Norwegian section of the line is known as Ofotbanen

Surveys and popular reports and articles

Several oral and written surveys of the CHARMEC activities have been presented during Stage 2. A few of them are listed below.

Bengt Åkesson: Chalmers järnvägsmekanik – CHARMEC (Chalmers railway mechanics – CHARMEC, in Swedish), *SVIB VibrationsNytt* (Scandinavian Vibration Society), vol 15/16, no 4/1, December/January 1997/98, pp 20-25

Bengt Åkesson and Roger Lundén: CHARMEC Biennial Report 1 July 1995 – 30 June 1997/Plans 1 July 1997 – 30 June 2000, *Chalmers Solid Mechanics,* Gothenburg January 1998, 28 pp

Roger Lundén and Bengt Åkesson (editors): Sammanfattningar av föredrag vid Seminariet i Järnvägsmekanik i Göteborg 12-13 mars 1998 (Summaries of papers read at the Seminar in Railway Mechanics in Gothenburg 12-13 March 1998, in Swedish and English), *Chalmers Solid Mechanics,* Gothenburg March 1998, 43 pp

Bengt Åkesson: Eisenbahnforschung im Kompetenzzentrum CHARMEC an der TH Chalmers, *Railway Seminar Deutsche Bahn/Inexa Profil,* Berlin (Germany) June 1999, 5 pp

Roger Lundén: CHARMEC Intermediate Report 1 July 1997 – 30 September 1999, *Chalmers Solid Mechanics,* Gothenburg September 1999, 12 pp (for the fair "Nordic Rail 99" in Jönköping 5-7 October 1999)

Roger Lundén: Kompetenscentret CHARMEC (The Competence Centre CHARMEC, in Swedish), *Modern Järnväg,* no 2, 2000, pp 12-13

ACADEMIC AWARDS

The research in railway mechanics at Chalmers University of Technology has resulted in the conferring of the higher academic degrees (above the Master's level) listed below.

PhD student Anders Ekberg of project MU4 and Professor Mike Brown of Sheffield University at the defence of Anders Ekberg's doctoral dissertation (examination in public) in April 2000

Licentiate

Jens Nielsen	1991-02-19	Johan Ahlström	1998-12-11
Mikael Fermér	1991-04-09	Lars Jacobsson	1999-01-28
Åsa Fenander	1994-09-09	Johan Oscarsson	1999-03-12
Annika Igeland	1994-10-06	Martin Petersson	1999-10-12
Johan Jergéus	1994-11-22	Rikard Gustavson	2000-05-11
Anders Ekberg	1997-02-18	Clas Andersson	2000-11-17
Tore Vernersson	1997-09-29	Torbjörn Ekevid	2000-12-19
Johan Jonsson	1998-05-13		

Doctor (PhD)

Jens Nielsen	1993-12-16	Johan Jergéus	1998-01-30
Mikael Fermér	1993-12-17	Anders Ekberg	2000-04-07
Annika Igeland	1997-01-24	Johan Jonsson	2000-06-09
Åsa Fenander	1997-05-23	Jonas Ringsberg	2000-09-15

Docent (highest academic "degree" in Sweden)

Roger Lundén	1993-03-23	Jens Nielsen	2000-11-09

Pre-series LKAB iron ore wagon with Pneumatic Brake Unit (PBU), including brake cylinder, as delivered by Transwerk in October 2000

INTERNATIONAL CONFERENCES

Researchers from CHARMEC have participated during Stage 2 in the following important seminars, symposia and conferences:

The 15th IAVSD Symposium (International Association for Vehicle System Dynamics) in Budapest (Hungary) 25-29 August 1997

The 15th IMAC (International Modal Analysis Conference) in Tokyo (Japan) 1-4 September 1997

WCRR '97 (World Congress on Railway Research) in Florence (Italy) 16-19 November 1997

Nordic Seminar in Railway Mechanics in Gothenburg (Sweden) 12-13 March 1998

The 12th International Wheelset Congress in Qingdao (China) 21-25 September 1998

The 6th IWRN (International Workshop on Railway Noise) at Île des Embiez (France) 4-6 November 1998

Nordic Seminar in Railway Mechanics in Luleå (Sweden) 24-25 March 1999

Euromech Colloquium 392 Mechanics of Railway Interfaces in Sheffield (England) 25-27 March 1999

Fatigue '99 – the 7th IFC (International Fatigue Conference) in Beijing (China) 8-12 June 1999

The 7th IHHAC (International Heavy Haul Association Conference) in Moscow (Russia) 13-16 June 1999

The Nordic Concrete Research Meeting in Reykjavik (Iceland) 4-6 August 1999

The 16th IAVSD Symposium (International Association for Vehicle System Dynamics) in Pretoria (South Africa) 30 August – 3 September 1999

IUTAM (International Union for Theoretical and Applied Mechanics) Symposium on Theoretical and Numerical Methods in Continuum Mechanics of Porous Materials in Stuttgart (Germany) 5-10 September 1999

WCRR '99 (World Congress on Railway Research) in Tokyo (Japan) 19-23 October 1999

The 36th Annual Technical Meeting of SES (Society of Engineering Science) Symposium Wear of Materials – Modeling and Experiments in Austin (Texas) 25-27 October 1999

ECCM '99 (European Conference on Computational Mechanics) in Munich (Germany) 31 August – 3 September 1999

The 12th NSCM (Nordic Seminar on Computational Mechanics) in Helsinki (Finland) 12-23 October 1999

Euromech Colloquium 409 Dynamics and Long-Term Behaviour of Railway Vehicles, Track and Subgrade in Hannover (Germany) 6-9 March 2000

Seminar on High-Speed Lines on Soft Ground in Gothenburg (Sweden) 16-17 March 2000

Nordic Seminar in Railway Mechanics in Trondheim (Norway) 22-23 March 2000

The 5th International Conference on Contact Mechanics and Wear of Rail/Wheel Systems in Tokyo (Japan) 25-28 July 2000

ECCOMAS 2000 (European Congress on Computational Methods in Applied Science and Engineering) in Barcelona (Spain) 11-14 September 2000

The 13th NSCM (Nordic Seminar on Computational Mechanics) in Oslo (Norway) 20-21 October 2000

WAVE2000 (2nd International Workshop on Wave Propagation, Moving Loads and Vibration Reduction) in Bochum (Germany) 13-15 December 2000

At the end of CHARMEC's Stage 2, the partners in the Industrial Interests Group of that Stage have expressed the following views.

Abetong Teknik

Our participation in CHARMEC has provided us with a better understanding of the functioning of the entire track structure including all its components and the problems related to them. This understanding has significantly improved our ability to enter into professional discussions with the end users of our concrete sleepers. Considered as part of the integral track structure, the sleepers can now more effectively be optimised. New alternative designs have been evaluated in co-operation with the CHARMEC researchers. The Abetong licensees abroad have shown an increasing interest in the research results coming out from CHARMEC and initiatives have been taken to develop a further exchange of knowledge.

Adtranz Wheelset

Our railway wheelsets have to fulfil stringent requirements to achieve compliance with numerous national and international standards. This applies to freight wagons and passenger coaches as well as to locomotives and motor coaches. Special demands on the running wheelsets are made by the Nordic winter climate. The co-operation with CHARMEC has been of extreme value to us in our continuous work to build up a relevant knowledge of the many facets of wheelset behaviour. This knowledge is necessary when we now face requirements in Sweden for higher train speeds, increased axleloads and lower noise levels. The results of our joint efforts with CHARMEC are also valuable when Adtranz Wheelset tries to expand its market to new countries where similar requirements have to be met. In particular, this applies to countries with the same harsh winter conditions as in Sweden.

Banverket Headquarters

The knowledge that has been built up in our co-operation with CHARMEC meets several of the needs of Banverket. Many central questions regarding the track infrastructure can now be handled and answered with competence. Examples are maintenance and safety issues in connection with higher train speeds and increased axleloads. CHARMEC's research results on railhead corrugation and rail pad insulation have been of direct use for Banverket in enhancing codes used for the upgrading of existing tracks. A new project on the influence of out-of-round wheels has recently been initiated by Banverket. In the area of vibrations and noise, including our joint European projects, the results from CHARMEC are of great economic and environmental importance, and Banverket can now, on the international arena, present Sweden as one of the leading nations. We also appreciate the long-term basic research being performed by CHARMEC on track ballast and clay subgrade being exposed to loading from high-speed trains. Other projects that have contributed much valuable knowledge are those on wheel flats, block-braked vehicles and concrete sleepers. In total, CHARMEC has considerably raised the level of practically useful knowledge within Banverket and its collaborating sister organisations in Europe.

Cardo Rail

The ongoing renewal of braking systems for railway freight wagons is driven by requirements for higher train speeds, increased axleloads and lower noise levels. Our SAB WABCO is now developing a new generation of block braking equipment for the world market. A broad approach with theoretical models has been initiated by CHARMEC to optimise the block braking of freight wagons considering high braking power combined with low damage, low wear and low noise for the wheels. SAB WABCO is now also introducing modern computerised control systems for the braking of all kinds of locomotives, wagons and coaches. The corresponding CHARMEC project addresses the extremely high level of safety and security that will be required for these systems. The CHARMEC prestudy of the use of sonar pulses for information transfer in the main airbrake pipe has yielded interesting results in SAB WABCO's full-scale testing rig in Italy.

Duroc

Duroc's partnership in the Competence Centre has been of great value to the company. Through CHARMEC's national and international network, we have gained in our development work. Scientific reports and literature surveys have kept us informed in an effective manner. In particular, reports and results on wheel out-of-roundness, wheel flats, fatigue mechanisms and improved wheel materials have found practical application in our wheelset maintenance. A major strategy for Duroc, however, is to expand the company's activities in the area of laser treatment of the running surfaces of wheels and rails. A project formulated and recently started within CHARMEC addresses important issues such as the optimal

power and sweeping speed of the laser beam and the performance and endurance of the treated surfaces during operational loading. Together with us, CHARMEC is a partner in INFRASTAR which is a new European project within the Fifth Framework Programme started in April 2000. This project focusses on improving the rail in curves in order to achieve reduced maintenance costs and lower noise levels. Laser treatment is one of two main concepts to be investigated. CHARMEC's contribution to INFRASTAR with mathematical modelling and full-scale testing is deemed to be of great importance for Duroc.

Inexa Profil

Through our participation in CHARMEC, we have gained better knowledge about the initiation and development of rolling contact fatigue (RCF) of rails. This knowledge has strengthened our competence and has been of great value in our discussions with existing and potential customers. The recently started CHARMEC project on butt-welding of rails has raised our expectations. Increased straightness over the joints and an improvement of the fatigue properties of the weldments are sought for. Lately, this demand has been accentuated by the fact that Inexa now delivers welded long-rails (lengths up to 420 m) to certain customers.

SJ

Our co-operation in CHARMEC has led to new specifications for wheel materials and to new guidelines for the turning of worn wheels, this being based on an increased understanding of material fatigue in the wheel tread and of the development of wheel flats, respectively. Other concrete results are improved methods for the design and testing of freight wagon wheels. We also appreciate the insight we have gained together with CHARMEC into the mechanisms of noise emission from freight trains with tread-braked wagons. An interesting approach to an improved braking control for these trains is the CHARMEC project dealing with sonar pulses in the main pneumatic pipe along the whole train set.

Three doctoral dissertations submitted by CHARMEC researchers during 2000

MANAGEMENT AND ADMINISTRATION

Director	Professor Roger Lundén
Period	1997-07-01 – 2000-06-30 (– 2005-06-30)
Chalmers budget (excluding university basic resources)	Stage 1: KSEK 1084 Stage 2: KSEK 4000 Stage 3: KSEK 4200
Industrial interests budget (in-kind contributions)	–

Roger Lundén has devoted about one third of his full-time position to the management and administration of the CHARMEC Competence Centre during its Stage 2, the rest of his time tending to his duties as teacher, researcher and research supervisor in Solid Mechanics. Bengt Åkesson, Professor Emeritus of Solid Mechanics and Director of CHARMEC until April 1997, has assisted in the administration of CHARMEC during its Stage 2, together with Birgitta Johanson of Solid Mechanics who has also served as the Centre's secretary. For Stage 3, Anders Ekberg has joined Bengt Åkesson and Birgitta Johanson in the administration of the Centre. All three participate on a part-time basis.

Here are presented cash and in-kind investments both per party and per programme area. The information on the money received and used has been taken from Chalmers' accounts for the CHARMEC Competence Centre centrally, and from the accounts for each respective department's CHARMEC projects. The 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 2 can be seen in Table 1. Included are also a later cash contribution of KSEK 2250 from Chalmers and an additional cash contribution of KSEK 710 from Banverket.

Cash investments

In October/November 1997, agreements were made between, on the one hand, each of Abetong Teknik AB, Adtranz Wheelset, Cardo BSI Rail AB, Duroc AB, Inexa Profil AB and SJ Maskindivisionen (later SJ Teknik), respectively, and, on the other, Chalmers University of Technology AB on how the Industrial Interests Group's payments to CHARMEC should be settled. According to these six agreements, CHARMEC would invoice at the six points of time 1997-11-01, 1998-03-01, 1998-09-01, 1999-03-01, 1999-09-01 and 2000-03-01.

A corresponding agreement was reached in January 1998 between Banverket and Chalmers University of Technology AB in which Banverket's cash investment for the three-year period is KSEK 5250. According to this agreement, CHARMEC would invoice at the six points of time 1997-12-15, 1998-03-01, 1998-09-01, 1999-03-01, 1999-09-01 and 2000-03-01. The amounts to be paid are KSEK 1100 on 1997-12-15, KSEK 950 on 2000-03-01 and KSEK 800 on each of the remaining four invoicing dates.

Another agreement was reached in May 1999 between Banverket and Chalmers University of Technology AB on the VB5 project "Vibrations under high-speed trains" in which Banverket's cash contribution is KSEK 710 during Stage 2 and KSEK 220 during the first part of Stage 3. According to the agreement, CHARMEC would invoice during Stage 2 at the three points of time 1999-05-01, 1999-09-01 and 2000-03-01. The amounts are KSEK 245 on 1999-05-01 and 1999-09-01, and KSEK 220 on 2000-03-01. All amounts due for Stage 2 have been received as per the agreements, that is

KSEK 6 x 425	from Abetong Teknik
KSEK 6 x 500	from Adtranz Wheelset
KSEK 1100 + 4 x 800 + 950 + 2 x 245 + 220	from Banverket
KSEK 6 x 250	from Cardo BSI Rail
KSEK 6 x 150	from Duroc
KSEK 6 x 83.5	from Inexa Profil
KSEK 6 x 250	from SJ

Table 1. Cash and in-kind contributions (kSEK) per party during Stage 2

Party	Cash		In-kind		Total	
	Budget	Paid	Budget	Performed	Budget	Paid/Perf
NUTEK	16 400	16 400	0	0	16 400	16 400
Chalmers	2 250	2 250	16 500	16 500	18 750	18 750
Abetong	2 550	2 550	900	984	3 450	3 534
Adtranz	3 000	3 000	2 400	2 813	5 400	5 813
Banverket	5 960	5 960	2 100	2 174	8 060	8 134
Cardo	1 500	1 500	900	691	2 400	2 191
Duroc	900	900	600	605	1 500	1 505
Inexa	501	501	750	264	1 251	765
SJ	1 500	1 500	900	953	2 400	2 453
TOTAL	34 561	34 561	25 050	24 984	59 611	59 545

After CHARMEC's quarterly invoicing, the following has also been paid in,

kSEK 8 x 1362.5 + 4 x 1375 from NUTEK

The total amounts are to be found in Table 1.

In-kind contributions

The in-kind contributions made by the Industrial Interests Group and Banverket correspond well to the agreement for Stage 2, see Table 1. The work performed is presented briefly in the section "Projects and Results" above. Major contributions have been in the form of three in-field test campaigns performed in co-operation with Banverket, SJ and Adtranz Wheelset.

In-kind contributions have been returned on a form from CHARMEC which the industrial partner concerned has filled in and signed. NUTEK's guidelines of 1995-11-07 were followed. On the form were shown salary costs (number of hours and cost per hour) and other costs (use of machines, materials and computers, and travel expenses, services purchased etc). All costs relate to the CHARMEC projects as specified in the present report.

Report per programme area

The accounts for each individual project have been allocated funds according to budgets decided by the CHARMEC Board. A compilation by programme area is given in Table 2, where in-kind contributions are also shown. In the same table is included CHARMEC's contribution to the EU projects. The special studies were: a literature survey on non-roundness of railway wheels for project TS5 (kSEK 150), a pre-study on sonar pulses for braking control for project SD2 (kSEK 395), a pre-study on computer control of braking systems for project SD3 (kSEK 100), work on making the DIFF computer program user friendly (kSEK 200), and a literature survey on butt-welding of rails for project MU8 (kSEK 100). CHARMEC has also contributed kSEK 1000 to the noise rig in project VB3, mainly for the computerized data collection and control system.

Funds used and work performed during Stage 2

Of the total cash budget of kSEK 34561 in Table 1, the amount kSEK 32050 has been transferred during Stage 2 from the CHARMEC account to the CHARMEC projects, of which a total of kSEK 30180 had been used as at 30 June 2000, see Table 2. The remaining kSEK 2511, together with a revenue of kSEK 307 in interest during Stage 2, will be added to the budget of Stage 3. Funds not used during Stage 2 in a project will be kept there for later use.

The members of the Industrial Interests Group, by and large, have performed the in-kind contributions agreed in the contract for Stage 2 of CHARMEC, see again Table 2.

Table 2. Budgeted and used cash and in-kind contributions (kSEK) during Stage 2, with Industrial Interests Group (including Banverket) and Chalmers shown separately, for each programme area and for management and administration. CHARMEC's programme areas for Stage 2 are TS = Interaction of train and track, VB = Vibrations and noise, MU = Materials and maintenance, SD = Systems for monitoring and operation, and EU = Parallel EU projects

Programme area	Cash		In-kind industry		In-kind Chalmers		Total	
	Budget	Used	Budget	Used	Budget	Used	Budget	Used
TS	5 300	4 884	2 000	1 347	2 625	2 625	9 925	8 856
VB	4 790	4 372	2 100	3 090	2 650	2 650	9 540	10 112
MU	11 315	10 848	3 150	3 305	6 050	6 050	20 515	20 203
SD	1 700	1 118	1 300	742	925	925	3 925	2 785
EU	3 000	3 000	0	0	2 100	2 100	5 100	5 100
Special studies	945	945	0	0	0	0	945	945
Noise rig (VB3)	1 000	1 000	0	0	0	0	1 000	1 000
Management	4 000	4 013	0	0	2 150	2 150	6 150	6 163
TOTAL	32 050	30 180	8 550	8 484	16 500	16 500	57 100	55 164

The status reported below is of December 2000. Also the new partner Adtranz Sweden of Stage 3 has been included.

Abetong Teknik

Manufacturer of prefabricated and pretensioned concrete structural components with 500 employees including sister companies in Sweden. Belongs to the Heidelberger Zement Group (formerly Scancem Group and Euroc Group). Abetong designs and manufactures, in Växjö (Vislanda), prestressed concrete railway sleepers for main lines and turnouts. Modern tools for the design of sleepers are of great interest to Abetong. Ballast properties and turnout behaviour are other areas of particular interest to the company as is the proportion of noise emitted by the sleepers. The main buyer of sleepers in Sweden is Banverket. Abetong also has partly owned and licensed sleeper plants at about 20 locations all over the world.

Adtranz Sweden

or, in full, DaimlerChrysler Rail Systems (Sweden) AB. Train manufacturer with 1600 employees, with headquarters in Västerås and with main activities in Västerås and Kalmar. Worldwide, Adtranz has 22000 employees in 60 countries. This company, which is fully-owned by DaimlerChrysler, is now being sold to Canada-based Bombardier. Adtranz Sweden develops and manufactures intercity, regional and metro trains. Examples of products are X2 (also known as X2000), Regina and C20, the latter for Stockholm Transport (SL).

Adtranz Wheelset

or, in full, DaimlerChrysler Rail Systems (Wheelset) AB. Railway wheelset manufacturer in Surahammar with 100 employees, which was a fully-owned subsidiary of Adtranz Sweden. Areas of interest for Adtranz Wheelset are the design, manufacturing, mounting, running, braking and maintenance of wheelsets. New materials for wheelsets and noise emission from wheels are of particular interest. The main buyers of the wheelsets are SJ and Adtranz Sweden, but some export of products and services also occurs. In November 2000, Adtranz Wheelset was sold to the Italian Lucchini Group and the name was changed to Lucchini Sweden. The Group headquarters are located in Brescia in Lombardy.

Banverket

with the acronym BV. The Swedish National Rail Administration (infrastructure authority) with a total of 8000 employees. CHARMEC's partner is the headquarters in Borlänge with 300 employees including the Tomteboda laboratories. CHARMEC also co-operate with some regional offices. Areas of interest are the design, construction and maintenance of track structures. Of particular interest are the wear and corrugation of the railhead (calling for grinding) and the overall degradation of the track structure. It is especially important to understand and predict the influence on the track of proposed higher speeds and increased axleloads. Of primary importance to Banverket is also research concerning vibrations, noise and safety.

Examples of surface damage on wheel tread and rail head as observed in revenue traffic. CHARMEC's research in this area aims at (i) understanding and explaining the mechanisms behind the damage and (ii) finding and formulating scientifically based rules for the prediction of the frequency of occurrence of damage and for the design against excessive damage. A basis for proper operational and maintenance procedures (turning and grinding) is also of great interest

Cardo Rail

with its trademark SAB WABCO. One of the largest suppliers in the world of railway brake systems with headquarters in Malmö and with production units in Sweden, Germany, France, Italy, Great Britain and several other countries. The total number of employees is 2500, of whom 130 are located in Sweden. The main area of interest in the co-operation with CHARMEC is brake systems. New overall concepts are being developed for signal transfer along the train and the components for tread-braking of freight trains are being investigated. In particular, the interaction of brake block and wheel tread is of interest. New and better materials for these blocks are sought for. The Cardo group comprises Cardo Door, Cardo Pump and Cardo Rail and has 9000 employees.

Duroc

A company with a large proportion of the Swedish railway wheelset maintenance market where it performs traditional reprofiling of wheels etc. However, the company's development work focusses on laser treatment techniques for the running surfaces of wheels and rails. Different metallic, ceramic and composite materials are deposited in thin layers on these surfaces to modify their friction coefficients and to decrease their wear. The number of employees in the company is 200. Areas of interest in the co-operation with CHARMEC are general issues regarding the wheel/rail contact and, in particular, the surface properties, binding conditions and life spans of laser-treated wheel treads and railheads.

Inexa Profil

The only rail producer in the Nordic region. In parallel to rails, the company also rolls shipbuilding profiles and round and square bars for the engineering industry. The number of employees in the Inexa Group is about 1000 including a recently bought mill in Slovenia now named Inexa Store. Inexa Profil handles its own metallurgical processing and delivers rails of different steel grades and sizes. One big customer outside Sweden is Deutsche Bahn. Areas of interest in the co-operation with CHARMEC are the initiation and propagation of surface and subsurface cracks in the rails and the corrugation and wear of the railhead. Also butt-welding of rails and the influence of residual stresses from manufacturing and straightening are research subjects. The development of new and better materials and thermal treatments is also of great interest.

SJ

The acronym SJ stands for the Swedish State Railways. Main rolling stock operator with a total of 12000 employees. CHARMEC's partner during Stage 2 has been the SJ Teknik (previously the SJ Machine Division) headquarters in Stockholm with 140 employees including the Hagalund laboratories. We also co-operate with some regional offices and workshops. Areas of interest in the co-operation with CHARMEC are the design, mounting, running, braking and maintenance of railway wheelsets, especially lifetime estimations and reprofiling practice for the wheels. Of particular interest are the mechanisms behind so-called wheel flats on the treads as caused by unintentional braking and sliding of the wheels. Also research about wheel/rail contact, safety technology, noise problems, new materials and improved brake systems is in great demand at SJ. As at 1 January 2001, SJ has been broken up into minor independent parts in the form of six state-owned companies. EuroMaint AB and Green Cargo AB participate in CHARMEC. Within EuroMaint, TrainTech Engineering Sweden is the company that co-operates with CHARMEC during Stage 3.

PARTNERS IN EU PROJECTS

Our 43 partners in CHARMEC's seven EU projects during Stages 1 and 2 are listed. Some of them may lately have changed their names and affiliations.

Adtranz Sweden	Swedish section of the multinational company Adtranz which designs and manufactures railway transportation systems and components
Banverket	The Swedish National Rail Administration (infrastructure authority)
BR Research	Research and development division of British Rail located in Derby (now owned by AEA Technology plc)
BS	British Steel plc is a multinational steel producer with research facilities at several locations (now in the Corus Group plc after a merger with Koninklijke Hoogovens NV in the Netherlands)
CAF	Construcciones y Auxiliar de Ferrocariles SA is a Spanish company designing and manufacturing trains
CEIT	Centro de Estudios e Investigaciones Técnicas de Gipuzkoa is a Spanish non-profit research organisation
Cronau	Heinrich Cronau GmbH is a German company in Homburg specializing in construction and maintenance of railway tracks
DB	Deutsche Bahn AG. The German Railways
Duroc	Duroc AB is a Swedish company in Umeå and Luleå doing surface treatment by use of laser technology. Its three divisions are Duroc Tooling, Duroc Applications and Duroc Rail
ERRI	European Rail Research Institute (in 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 plc, with Railway Division in Stockport, England, is a company developing and manufacturing railway frictional materials
FIAT	Il Centro Ricerche FIAT (CRF) is an Italian research organisation in Turin dealing with ground vehicles
FS	Ferrovie dello Stato SpA with headquarters in Rome. The Italian Railways represented by a department in Florence
Inexa Profil	Inexa Profil AB is a Swedish company in Luleå with a rolling mill for rails
INSA	Institut National des Sciences Appliquées de Lyon. Engineering university and research institute in Lyon, France
ISVR	The Institute of Sound and Vibration Research at the University of Southampton, England
Jenbacher	Jenbacher-Transportsysteme AG is a small Austrian company manufacturing components for railway vehicles
Kassel University	The Institute of Geotechnics at Universität Gesamthochschule Kassel in Germany
KTH	The Royal Institute of Technology in Stockholm, Sweden
LBF	Fraunhofer-Institut für Betriebsfestigkeit LBF is a German establishment in Darmstadt performing experimental and numerical analyses of mechanical components

Lucchini CRS	Lucchini Centro Ricerca e Sviluppo is a research organisation within the Italian Lucchini Group, which produces steel and manufactures rails and wheelsets
MDI	Mechanical Dynamics Italy in Udine is a subsidiary of Mechanical Dynamics Inc in USA developing, using and promoting the ADAMS software
Metravib	Metravib RDS in Ecully is a French private contract research organisation specialized in vibroacoustics
NS	Nederlandse Spoorwegen NV. The Dutch Railways represented by two departments in Utrecht
NSTO	NS Technisch Onderzoek is the research organisation within NS (now owned by AEA Technology Rail of UK and trading under the name AEA Technology Rail BV)
Otto Fuchs	Otto Fuchs Metallwerke in Meinerzhagen is a German industry which forges and extrudes nonferrous alloys
Otto-von-Guericke-Universität	Machine Design Department of Magdeburg University in Germany
Pandrol	Multinational company developing and manufacturing rail fastening systems and components
Politecnico di Milano	Mechanical Engineering Department of Milan University of Technology in Italy
Politecnico di Torino	Aeronautical and Space Engineering Department of Turin University of Technology in Italy
RATP	Régie Autonome des Transports Parisiens. Metro operator and track manager in Paris, France
SBB	Schweizerische BundesBahnen, Bern. The Swiss Railways represented by the department Zugförderung und Werkstätten
SLM	Schweizerische Lokomotiv- und Maschinenfabrik AG in Winterthur. SLM involves Sulzer-Innotec (research organisation of Sulzer Corporation)
Sogerail	French manufacturer of rails in d'Hayange (now owned by British Steel)
SNCF	Société Nationale des Chemins de Fer Français. The French Railways
Talbot	Waggonfabrik Talbot Aachen in Germany. Rolling stock producer (freight wagons, passenger coaches and bogies)
TNO	Contract research organisation in Delft, the Netherlands
TSO	Travaux du Sud-Ouest is a French company with headquarters in Chelles specializing in construction and maintenance of railway tracks
TU Berlin	Department of Luft- und Raumfahrt at Technische Universität Berlin in Germany (doing research in railway mechanics)
University of Sheffield	Department of Mechanical Engineering at the University of Sheffield
Valdunes	Wheelset manufacturer in Valenciennes and Dunkerque, France (now owned by Freedom Forge Corporation in USA)
Vibratec	Industrial RTD company in Lyon and Ecully, France

Some of the events and achievements during Stage 2, which have not been accounted for elsewhere, will be presented.

Study visits

Three of the twelve board meetings during CHARMEC's Stage 2 were combined with study visits: 8-9 September 1997, the tunnel element factory in Copenhagen, the railway link under the Great Belt and DSB's sleeper factory (an Abetong licensee) in Fredericia, Denmark, were visited; 1 June 1999, wheel manufacturing was demonstrated and the noise rig was inaugurated at Adtranz Wheelset at Surahammar; 7–9 June 2000, the Board visited the rolling mill for rails in Luleå and participated in Inexa Profil's International Rail Seminar at Storforsen.

External consultants

It has only been partly possible to include CHARMEC's EU projects in the regular programme of doctoral studies and research for doctoral candidates. Senior researchers have often been required to contribute at short notice. Chalmers/CHARMEC have consequently temporarily engaged the following, among others, as external consultants during Stage 2: Hans Bjarnehed, Lennart Mähler and Jan Henrik Sällström (all PhDs), Tore Vernersson (Lic Tech), and Anders Johansson and Markus Wallentin (both MScs), see also the photo with text on page 42. Docent Jens Nielsen has worked with supervision and research for CHARMEC on almost a full-time basis. An agreement has been reached with Linköping Institute of Technology on Tore Dahlberg's continued involvement in the EU project EUROBALT II.

Other co-workers

Bengt Åkesson, Professor Emeritus of Solid Mechanics, has assisted the Director of the Centre during Stage 2 on a 50% part-time basis. Dr Elena Kabo of St Petersburg State University and the holder of a scholarship at Chalmers Solid Mechanics has worked for CHARMEC since June 1999. Cédric Pouligny from Lyon and Jeanette Lavery from Belfast have been working on their master's theses within CHARMEC.

All persons working within CHARMEC, including external consultants, signed a paper guaranteeing that they fully understood the conditions agreed on in the Competence Centre's main agreement for Stage 2.

Stays abroad

Johan Jonsson of CHARMEC spent 3 August 1998 – 29 January 1999 at the Department of Civil Engineering at the University of Tokyo. Jonas Ringsberg spent 1–29 November 1998 at the Department of Mechanical Engineering at the University of Sheffield. Lars Jacobsson spent 28 February – 18 May 2000 at the Department of Civil, Environmental, and Architectural Engineering at the University of Colorado at Boulder. Anders Ekberg did research at Spoornet Engineering in Pretoria 7 January – 16 March 1999.

KTH, SP and NUTEK

CHARMEC's earlier declaration of intent and agreement on co-ordination and co-operation with KTH Railway Technology and the Swedish National Testing and Research Institute (SP), respectively, have run on during Stage 2. After Evert Andersson's resignation from the Board, both he and Mats Berg of KTH Railway Technology have been regularly invited to the Competence Centre's morning seminars.

NUTEK's liaison person with CHARMEC during Stage 2 was first William Ingberg and then Carl Naumburg. The university liaison person was Roger Johansson.

The Director of CHARMEC together with some Chalmers researchers and representatives of the Industrial Interests Group participated in each of NUTEK's Competence Centre Days on 29 October 1997 in Gothenburg, 20 October 1998 in Lund and 27 October 1999 in Linköping.

Olof Nilsson, Lennart Nordhall, Stefan Westberg, Lars Sjöstedt and Hugo von Bahr at the Board meeting in Luleå on 7 June 2000

Evaluations

In December 1997, at the initiative of NUTEK, Öhrlings, Coopers & Lybrand carried out an audit of CHARMEC (and two other competence centres) as regards the organisation and routines of the Centre. A written report was sent to NUTEK. An international evaluation of CHARMEC's scientific and industrial achievements was carried out in March 2000. A high rating was given, see the Executive Summary on page 6.

Seminars and fairs

CHARMEC arranged a seminar in railway mechanics at the Arken Conference Centre in Gothenburg on 12–13 March 1998. It was attended by 98 participants, of whom more than half were from industry. Four persons were from Denmark and four from Norway. Six outline papers were read and 42 special papers. Corresponding seminars were later arranged by railway researchers in Luleå on 24–25 March 1999 and in Trondheim on 22–23 March 2000. CHARMEC's researchers presented their work on all three occasions. The same goes for Svenska Mekanikdagar (Swedish Mechanics Days) in Stockholm on 7–9 June 1999.

CHARMEC researchers have contributed to several European seminars in railway mechanics besides their projects running at the time. For instance, Jens Nielsen and Clas Andersson took part in a seminar on non-round wheels in Berlin on 13 November 1997 at IFV (Interdisziplinärer ForschungsVerband) Bahntechnik. Further, several CHARMEC researchers contributed to the Duroc Event in Luleå on 25–26 March 1999 and the Inexa International Rail Seminar on 8–9 June at Storforsen.

CHARMEC participated in the Nordic Rail fairs at Elmia in Jönköping on 30 September – 2 October 1997 and 5–7 October 1999. We shared a stand with KTH Railway Technology, the Swedish Transport and Communications Research Board (KFB) and the Swedish National Road and Transport Research Institute (VTI).

Heavy haul

Banverket, MTAB and SJ Cargo Group formed the Nordic Heavy Haul Association (NHH) in April 1999 and CHARMEC has joined NHH as a supporting member. NHH has been accepted as a full member of the International Heavy Haul Association (IHHA).

Wanming Zhai

is a professor of the Train & Track Research Institute at Southwest Jiaotong University in Chengdu (China). He was a guest at CHARMEC on 7–9 September 1998 and gave an overview lecture. A number of meetings with smaller groups were also held, especially with those CHARMEC researchers working with track dynamics.

Joe Kalousek

of the National Research Council (NRC) in Vancouver (Canada) was a guest at CHARMEC on 5–6 October 1998. He is the leader of an internationally well-known tribology group. Dr Kalousek met several groups of CHARMEC researchers. He also gave a lecture in conjunction with the regular CHARMEC seminars on the morning of 6 October. Dr Kalousek is the "father" of the international conference series "Contact Mechanics and Wear of Rail/Wheel Systems". These conferences have been held in Vancouver 1982, Kingston (Ontario) 1986, Cambridge (England) 1990, Vancouver 1994, Budapest 1996 (this was an intermediate mini-conference) and Tokyo 2000.

Roger Lundén has been a member of the Scientific Committee for the International Conference on Contact Mechanics and Wear of Rail/Wheel Systems since 1999. The next conference of the series will be arranged by CHARMEC in Gothenburg 2003.

Information exchange

A meeting to exchange information between DB, SJ, Banverket, Adtranz and Chalmers/CHARMEC was held on 1–2 February 2000 in Stockholm and Tillberga. Roger Lundén participated from CHARMEC and contributed with three papers. A similar meeting was held in Minden on 25–26 May 1999 (the meeting after that was held in Minden and Nürnberg on 25–26 September 2000).

In May 1999, CHARMEC gave their written opinion about Banverket's R&D programme in the railway area for the period 1999–2005.

Petersburg State Transport University

The President and Vice President of Petersburg State Transport University, Professor Valery I Kovalev and Dr Yelena A Afanasieva, visited Gothenburg and Chalmers/CHARMEC on 2 February 2000. Study visits were made to the SJ maintenance workshop at Sävenäs and to Volvo Trucks, where a guided tour of the production facilities was arranged. Roger Lundén presented information on CHARMEC's activities at Chalmers. A dinner with the President of Chalmers as the host rounded off the day and possible future co-operation was discussed.

The initiative for the visit had been taken by Bernt Andersson of SwedeRail (previously head of the SJ Machine Division). The Swedish Trade Council was represented by Per-Olof Lansing.

Chalmers and Sheffield

On 6 April 2000, the day before Anders Ekberg's doctoral disputation, a joint Chalmers/Sheffield seminar entitled "Rolling Contact Fatigue and Wear with Railway Applications" was arranged at Chalmers. The Sheffield researchers Dr Robert Dwyer-Joyce and Professor Mike Brown contributed together with the Chalmers/CHARMEC researchers. In the evening, CHARMEC arranged an "Industry Dinner" attended by 27 researchers and industrialists.

Swedish-Russian seminar

Roger Lundén and Bengt Åkesson took part in a Swedish-Russian railway seminar at the Transport University in St Petersburg on 16–17 May 2000. From the Russian side, there were ca 120 persons from the country's 17 railway regions and also persons from Belorussia, the Ukraine and Kazakstan. From Moscow came, among others, the head of the All-Russian Railway Research Institute, A L Licitsin, and a deputy Minister of Transport from the Russian government. Slightly more than 20 persons participated from Adtranz, Banverket, SJ, SRS, SwedeRail, SWETRAK, TGOJ, Tyréns and others. The chairman for the seminar days was the President of the Transport University, Professor Valery I Kovalev, assisted by Einar Smitterberg from SwedeRail and Per Olof Lansing from SWERIG (as mentioned above, Professor Kovalev had visited us at Chalmers on 2 February 2000, together with his Vice President for International Relations, Dr Yelena Afanasieva).

The seminar had been initiated from the Swedish side by SwedeRail, the Swedish Trade Council and SWERIG (*SWE*dish *R*ail *I*ndustry *G*roup) with support from SIDA (Swedish International Development Agency). CHARMEC contributed in St Petersburg with a paper by Roger Lundén (together with SwedeRail's Bernt Andersson) on the upgrading of Malmbanan (the Iron Ore Line). In the exhibition hall, we handed out CHARMEC's Intermediate Report from September 1999 and off-prints of three articles in Railway Gazette International and the IMechE Journal of Rail and Rapid Transit on Malmbanan and high axleloads.

Daniel Stone

of the Association of American Railroads/Transportation Technology Center (AAR/TTC) in Pueblo, Colorado, visited CHARMEC on 18 May 2000. He is well known in railway research circles, especially as far as wheels and wheelsets are concerned, and he is, among other things, the "father" of the series of International Wheelset Congresses. Anders Ekberg organised the visit and presentations were given by several CHARMEC researchers, mainly about wheel materials and defects. Co-operation between CHARMEC and TTC was discussed.

Scancem and Inexa Profil

On 26 May 1998, Bengt Åkesson gave a talk at Scancem in Malmö to Abetong Teknik's international licensees. He also contributed to Inexa Profil's Rail Seminar (Schienenseminar) in Berlin on 6 May 1999. Among those present were representatives of Deutsche Bahn and four welding stations in Germany. Bengt Åkesson also held a seminar in railway mechanics at KTH Solid Mechanics on 25 May 1999 and gave a lecture to Scancem in Gothenburg on 26 May 1999.

Informal meetings

Apart from the events registered above, a large number of seminars and formal and informal meetings have been held during Stage 2 with our partners in the Industrial Interests Group and specially invited experts from home and abroad to discuss the current and planned projects at the Competence Centre. In the EU projects, there has been particularly intensive co-operation with NS (Nederlandse Spoorwegen) and the University of Sheffield. Researchers, industrialists and administrators from European railways have visited CHARMEC in groups from, among other countries, Finland, France, Poland and Germany.

European standardisation

During CHARMEC's Stage 2, Roger Lundén has continued to be an active member of the CEN/TC256/SC2/WG11 which is the working group for European standardisation of railway wheels and railway axles.

Swedtrain Prize

Mattias Olsson and Joakim Mattsson of Chalmers received on 15 May 2000 Swedtrain's prize for the best thesis on railway technology. The title of their work is "Rolling Contact Fatigue in Rail Heads – Three-Dimensional FE Simulations of Stresses and Strains". Lennart Josefson and Jonas Ringsberg of CHARMEC were their supervisors.

The popular booklet "Tågen på spåren – om järnvägens mekanik" (The Trains on the Track – on the Mechanics of Railways, 27 pp, in Swedish) by Bengt Åkesson is based on his William Chalmers Lecture of 5 November 1996, and was then printed in an edition of 1600 (now expired). A new edition (2000 copies) was printed in September 1999.

CHARMEC STAGE 3

An agreement on CHARMEC's Stage 3 (1 July 2000 – 30 June 2003) was made at NUTEK's office in Stockholm on 22 June 2000. In addition to the previous seven members during Stage 2, the new member Adtranz Sweden then joined the Industrial Interests Group. A separate agreement has been drawn up for Banverket's participation. The programme areas during Stage 3 are the same as during Stage 2, see TS, VB, MU, SD and EU on page 10. About 8 new licentiate's degrees and 10 new doctor's degrees in railway mechanics are foreseen during Stage 3.

The funding of CHARMEC's Stage 3 is shown in the table below. The payment from Brussels of the projects EU6 and EU7 is not included in the table. As of 1 January 2001, the new national research agency VINNOVA has taken over NUTEK's responsibility for CHARMEC.

Jan-Eric Sundgren, President of Chalmers University of Technology, has appointed the following to be members of the Board of CHARMEC during Stage 3:

Björn Paulsson (chairman)	Banverket Headquarters
Stefan Westberg	Abetong Teknik
Lennart Nordhall	Adtranz Wheelset (now Lucchini Sweden)
Henrik Tengstrand	Adtranz Sweden
Mats Svensson	Cardo Rail
Mats Önner	Duroc
Olof Nilsson	Inexa Profil
Hugo von Bahr	SJ (now TrainTech Engineering Sweden)
Hans Andersson	SP
Stefan Östlund	KTH Railway Group

	Cash	In-kind	Total
NUTEK/VINNOVA	18 000	–	18 000 (31%)
Industrial Interests Group	13 140	6 600	19 740 (34%)
Chalmers	2 250	18 150	20 400 (35%)
Banverket	6 835	1 500	8 335
From Stage 2	2 818	–	2 818
Total	43 043	26 250	69 293 KSEK

VINNOVA
VERKET FÖR INNOVATIONSSYSTEM

VINNOVA, the Swedish Agency for Innovation Systems, became operational on 1 January 2001. Among VINNOVA's main roles are to finance research, development and demonstration activities that meet the needs of business and the public sector, and to foster co-operation between universities, industrial research institutes and business.

CONCLUDING REMARKS

As evident from the international evaluation in March 2000 (see the Executive Summary on page 6), Stage 2 of the NUTEK Competence Centre in Railway Mechanics has been successful. The co-operation between the University and the Industry has been further developed and the national and international network has been widened. The worldwide presentation of research results has been intense and the conferring of licentiate's and doctor's degrees at Chalmers has been according to plan. In my opinion, CHARMEC has firmly established itself, nationally and internationally, as a knowledgeable partner for dialogue, as an important information hub and as a competent network builder. I look forward to the continuation of the Centre's Stage 3 with confidence.

Gothenburg in February 2001

ROGER LUNDÉN

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