Swedish (railway) research is largely carried out at universities.

The research sets out from strategic areas identified by Banverket in the mid 90-s.

The research is carried out in centra to maximize efficiency, create synergies and facilitate implementation.

In all research centres industrial partners are active and supporting participants.

Knowledge transfer between the centra is assured by joint projects, participation in reference groups etc.
Chalmers University of Technology
founded in 1829 by the will of
William Chalmers

In 1937 Chalmers becomes a
governmental university with the
authority to award doctoral degrees

Turnover of 2.8 billion SEK of which
roughly 75% is research.

1088 Msc and 121 PhD in 2010

CHARMEC
founded in 1995 as a National
Centre of Excellence.

Railway research going back to 1985.

Details in triennial report and on
webpage www.chalmers.se/charmec
FIELD OF EXPERTISE

National centre of excellence in railway mechanics

Mainly phenomena with their origin in the wheel–rail interface

Mainly components from the bogie and downwards

Focus on interaction of phenomena by combining our expertises
The board consists of members from all partners and approves all research projects.

Industrial relevance and implementation is ensured through project reference groups.

All partners can have members in any reference group.

Scientific excellence is ensured through international publication, examinations etc.
Programme areas

• **TS** – Interaction of train and track
  – Prediction and measurement of dynamic forces
    • In particular vertical dynamics
  – Related wear and rolling contact fatigue phenomena
    • Corrugation
    • Out-of-round wheels
  – Identification of dynamic forces
  – Dynamics of track switches
  – Sleeper response and design

• **VB** – Vibrations and noise
  – Structural and ground vibrations
  – Noise generation and mitigation
  – Structure borne noise and vibrations
Programme areas

• MU – Materials and maintenance
  – Development, tests and numerical modeling of materials
    • Rail and wheel steels
    • Ballast
    • Reinforced concrete
  – Material transformations and treatment
  – Prediction and mitigation of material deterioration
    • Rolling contact fatigue
    • Plastic deformation
  – Influencing factors
    • Thermal effects
    • Contact conditions
  – Maintenance planning and optimization
Programme areas

• SD – Systems for monitoring and operation
  – Brake systems
  – Suspension systems

• EU – Parallel EU projects
  – EuroSABOT – Tread braking
  – Silent Freight – Noise
  – Silent Track – Noise
  – ICON – Rolling contact fatigue
  – EuroBALT II – Ballast and subsoil
  – HIPERWHEEL – Wheel development
  – INFRASTAR – Cladding of rails
  – ERS – Noise
  – EURNEX – Network of Excellence
  – INNOTRACK – Innovative track solutions
  – Q CITY – Noise
Programme areas

• SP – Special projects
  Shorter term projects with specific goals
  • Bilateral agreements
  • Development projects
    – Rails
    – Sleepers
    – Brake systems
    – Wheels
    – Track stiffness
  • Measurement campaigns
    – Track forces
    – Switches and crossings
  • Pilot studies
    – Sun kinks
    – Insulated joints
    – Ground vibrations
CHARMEC covers the scope from targeted research to implementation. This is obtained by

- funding from different sources with different focus
- efficient communication between researchers to bridge interfaces
- functional interfaces to infrastructure managers and industry

Example:
Optimization of crossings involves methods/models of dynamic interaction, material mechanics and fatigue & fracture analysis that started as targeted research within CHARMEC some 10–15 years ago
Interaction of train and track

TS1 Calculation models of track structures
Prof Thomas Abrahamsson
Doc Jens Nielsen
Mr Johan Oscarsson

TS2 Railhead corrugation formation
Prof Tore Dahlberg
Ms Annika Igeland (now Annika Lundberg)

TS3 Sleeper and railpad dynamics
Prof Tore Dahlberg
Ms Åsa Fenander (now Åsa Stilström)

TS4 Lateral track dynamics
Prof Thomas Abrahamsson
Doc Jens Nielsen
Mr Claes Andersson

TS5 Out-of-round wheels – causes and consequences
Doc Jens Nielsen
Prof Roger Lundén
Mr Anders Johansson

TS6 Identification of dynamic forces in trains
Prof Thomas Abrahamsson
Dr Peter Möller
Mr Lars Nordström

TS7 Dynamics of track switches
Prof Jens Nielsen
Prof Tore Dahlberg
Mr Elias Kassa

TS8 Integrated track dynamics
Prof Jens Nielsen

TS9 Track dynamics and sleepers
Prof Thomas Abrahamsson
Prof Jens Nielsen
Ms Johanna Lilja

TS10 Track response when using Under Sleeper Pads (USP)
Dr Rikard Bolmavik
Prof Jens Nielsen
Dr Johan Johansson

TS11 Rail corrugation growth on curves
Prof Jens Nielsen
Dr Anders Frid
Mr Peter Torstensson

TS12 Identification of wheel/rail contact forces
Doc Fredrik Larson
Dr Håkan Johansson
Prof Kenneth Runesson
Dr Peter Möller
Prof Jens Nielsen
Mr Hamed Ronasi

TS13 Optimization of track switches
Prof Jens Nielsen
Prof Thomas Abrahamsson
Mr Björn Pålsson

Upper name(s):
Project leader(s) and supervisor(s)
Lower name(s):
Doctoral candidate(s) or other coworker(s)

Doc stands for Docent

Notes:
1. Licentiate (teknologie licentiat)
2. PhD (teknologie doktor)
3. This project has been finished
4. Now at Linköping Institute of Technology
Example – out-of-round wheels

- Full-scale measurement (accounting for high frequency loading) of impact of various wheel flats

- Numerical simulations calibrated and validated

- Employed to evaluate allowable impact wheel flats
| VB1 | Structural vibrations from railway traffic<sup>3</sup>  
|     | Prof Sven Ohlsson /  
|     | Prof Thomas Abrahamsson  
|     | Mr Johan Jonsson<sup>2</sup> |
| VB2 | Noise from tread braked railway vehicles<sup>3</sup>  
|     | Prof Roger Lundén / Dr Peter Møller  
|     | Mr Tore Vernersson<sup>2</sup>/Mr Martin Petersson<sup>1</sup> |
| VB3 | Test rig for railway noise<sup>3</sup>  
|     | Prof Roger Lundén  
|     | Mr Tore Vernersson |
| VB4 | Vibrations and external noise from train and track<sup>3</sup>  
|     | Prof Roger Lundén / Dr Anders Frid /  
|     | Doc Jens Nielsen  
|     | Mr Carl Fredrik Hartung<sup>1</sup> |
| VB5 | Wave propagation under high-speed trains<sup>3</sup>  
|     | Prof Nils-Erik Wiberg  
|     | Mr Torbjörn Ekevid<sup>2</sup> |
| VB6 | Interaction of train, soil and buildings<sup>3</sup>  
|     | Dr Johan Jonsson |
| VB7 | Vibration transmission in railway vehicles<sup>3</sup>  
|     | Prof Thomas Abrahamsson /  
|     | Prof Thomas McKelvey  
|     | Mr Per Sjövall<sup>2</sup> |
| VB7 | Ground vibrations from railways<sup>3</sup>  
|     | Prof Anders Boström /  
|     | Prof Thomas Abrahamsson  
|     | Mr Anders Karlström<sup>2</sup> |
| VB8 | Dynamics of railway systems<sup>3</sup>  
|     | Prof Nils-Erik Wiberg / Dr Torbjörn Ekevid  
|     | Mr Häkan Lane<sup>2</sup> |
| VB9 | External noise generation from trains  
|     | Prof Wolfgang Kropp  
|     | Ms Astrid Pieringer<sup>1</sup> |

**Upper name(s):**  
Project leader(s) and supervisor(s)  

**Lower name(s):**  
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Example – ground vibrations

- Efficient evaluation of ground vibrations at subsonic and supersonic speeds
- The model can account for layered soils and e.g. ditches (included on the top side of the track)

Ground vibrations during a train passage that induces supersonic wave propagation in the soil
CHARMPEC RESEARCH 1995 – 2012

Materials and maintenance
Programme area 3

**Upper name(s):**
Project leader(s) and supervisor(s)

**Lower name(s):**
Doctoral candidate(s) or other coworker(s)

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**MU1**
**Mechanical properties of ballast**
Prof Kenneth Runesson
Mr Lars Jacobsson

**MU2**
**New materials in wheels and rails**
Prof Birger Karlsson
Mr Johan Ahlström

**MU3**
**Martensite formation and damage around railway wheel flats**
Prof Roger Lundén
Mr Johan Jergés

**MU4**
**Prediction of lifetime of railway wheels**
Prof Roger Lundén
Mr Anders Ekberg

**MU5**
**Mechanical properties of concrete sleepers**
Prof Kent Gythiof
Mr Rikard Gustavsson (now Rikard Bolmsvik)

**MU6**
**Rolling contact fatigue of rails**
Prof Lennart Josefsson
Mr Jonas Ringsberg

**MU7**
**Laser treatment of wheels and rails**
Prof Birger Karlsson
Mr Simon Niederhauser

**MU8**
**Butt-welding of rails**
Prof Lennart Josefsson / Doc Jonas Ringsberg
Mr Anders Skytebol

**MU9**
**Rolling contact fatigue of railway wheels**
Doc Anders Ekberg / Dr Elena Kabo
Prof Roger Lundén

**MU10**
**Crack propagation in railway wheels**
Prof Hans Andersson / Dr Elena Kabo / Doc Anders Ekberg
Ms Eka Lunsler

**MU11**
**Early crack growth in rails**
Prof Lennart Josefsson / Doc Jonas Ringsberg / Prof Kenneth Runesson
Mr Anders Bergkvist

**MU12**
**Contact and crack mechanics for rails**
Prof Peter Hansbo
Mr Per Heinitz

**MU13**
**Wheel and rail materials at low temperatures**
Dr Johan Ahlström / Prof Birger Karlsson

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3. This project has been finished
Materials and maintenance (cont’d)

Programme area 3

MU14
Damage in track switches
Doc Magnus Ekh / Prof Kenneth Runesson
Mr Göran Johansson

MU15
Microstructural development during laser coating
Prof Birger Karlsson / Dr Johan Ahlström

MU16
Alternative materials for wheels and rails
Dr Johan Ahlström / Prof Birger Karlsson
Mr Niklas Köppen

MU17
Elastoplastic crack propagation in rails
Dr Fredrik Larsson / Prof Kenneth Runesson / Prof Lennart Josefson
Mr Johan Tillberg

MU18
Wheels and rails at high speeds and axle loads
Doc Anders Ekberg / Prof Lennart Josefson / Prof Kenneth Runesson / Prof Jacques de Maré
Mr Johan Sandström

MU19
Material anisotropy and RCF of rails and switches
Doc Magnus Ekh / Prof Kenneth Runesson / Doc Anders Ekberg
Ms Nasim Larijani

MU20
Wear impact on RCF of rails
Doc Magnus Ekh / Doc Fredrik Larsson / Doc Anders Ekberg
Mr Jim Brouzoulis

MU21
Thermal impact on RCF of wheels
Doc Anders Ekberg / Doc Elena Kabo / Doc Magnus Ekh / Dr Tore Vernersson
Ms Sara Caprioli

MU22
Improved criterion for surface initiated RCF
Doc Anders Ekberg
Doc Elena Kabo / Prof Roger Lundén

MU23
Material behaviour at rapid thermal processes
Prof Birger Karlsson / Dr Johan Ahlström
Mr Kirte Cveikovski

MU24
High-strength steels for railway rails
Prof Birger Karlsson / Dr Johan Ahlström
Mr Martin Schilke

MU25
Thermodynamically coupled contact between wheel and rail
Doc Anders Ekberg / Doc Fredrik Larsson / Prof Kenneth Runesson
Mr Andreas Dragani

Notes:
1. Licentiate (teknologie licentiat)
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3. This project has been finished
6. Rolling Contact Fatigue

Doc stands for Docent
Example – material defects in wheels

• Statistical evaluation of the risk of subsurface initiated rolling contact fatigue failures in railway wheels given a material defect distribution and an operational scenario

Failure probability after a rolled distance of 278 000 km

Failure probability as function of operational distance
### Systems for monitoring and operation

**Programme area 4**

| SD1 | Braking of freight trains – a systems approach[^3]  
|----|-----------------------------------------------------------------|
| Prof Göran Gerbert  
| Mr Daniel Thuresson[^2] |

| SD2 | Sonar pulses for braking control[^3]  
<table>
<thead>
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<tbody>
<tr>
<td>Prof Bengt Schmidibauer / Mr Hans Sandholt</td>
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</tbody>
</table>

| SD3 | Computer control of braking systems of freight trains[^3]  
|----|-----------------------------------------------------------------|
| Mr Håkan Edler / Prof Jan Torin  
| Mr Roger Johansson[^2] |

| SD4 | Control of block braking[^3]  
|----|-----------------------------------------------------------------|
| Prof Roger Lundén  
| Mr Tore Vernersson[^2] |

| SD5 | Active and semi-active systems in railway vehicles[^3]  
|----|-----------------------------------------------------------------|
| Prof Jonas Sjöberg  
| Prof Thomas Abrahamsson  
| Ms Jessica Fagerlund[^1] |

| SD6 | Adaptronics for bogies and other railway components  
|----|-----------------------------------------------------------------|
| Prof Viktor Berbyuk / Doc Mikael Enelund  
| Mr Albin Johnsson |

| SD7 | Thermal capacity of tread braked railway wheels  
|----|-----------------------------------------------------------------|
| Prof Roger Lundén / Dr Tore Vernersson  
| Mr Shahab Teimourimanesh |

| SD8 | Wear of disk brakes and block brakes  
<table>
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<tbody>
<tr>
<td>Dr Tore Vernersson / Prof Roger Lundén</td>
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**Upper name(s):**

Project leader(s) and supervisor(s)

**Lower name(s):**

Doctoral candidate(s) or other coworker(s)

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[^3]: Doc stands for Docent
Example – analysis of tread braking

- Numerical simulations calibrated and validated towards measurements

Heat and rail chill for different brake blocks

81-94% to wheel with no rail chill

59-71% to wheel with rail chill

23 to 29% of braking heat goes to rail
### Parallel EU projects

#### Programme area 5

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<th>Project</th>
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<tr>
<td>EU1</td>
<td>EuroSABOT&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Prof Roger Lundén&lt;br&gt;Mr Tore Vernersson / Mr Martin Petersson</td>
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<tr>
<td>EU2</td>
<td>Silent Freight&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Dr Jens Nielsen&lt;br&gt;Mr Martin Petersson / Mr Markus Wallentin</td>
<td></td>
</tr>
<tr>
<td>EU3</td>
<td>Silent Track&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Dr Jens Nielsen&lt;br&gt;Mr Clas Andersson</td>
<td></td>
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<tr>
<td>EU4</td>
<td>ICON&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Prof Lennart Josefson&lt;br&gt;Mr Jonas Ringsberg</td>
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<tr>
<td>EU5</td>
<td>EuroBALT II&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Prof Tore Dahlberg&lt;br&gt;Mr Johan Oscarsson</td>
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<tr>
<td>EU6</td>
<td>HIPERWHEEL&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Prof Roger Lundén&lt;br&gt;Doc Jens Nielsen / Dr Anders Ekberg</td>
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<tr>
<td>EU7</td>
<td>INFRASTAR&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Prof Lennart Josefson / Prof Roger Lundén&lt;br&gt;Doc Jens Nielsen / Dr Jonas Ringsberg / Prof Birger Karlsson</td>
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<tr>
<td>EU8</td>
<td>ERS&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Prof Roger Lundén&lt;br&gt;Mr Martin Helgen / Doc Jan Henrik Sällström / Mr Tore Vernersson</td>
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<tr>
<td>EU9</td>
<td>EURNEX</td>
<td>Prof Roger Lundén&lt;br&gt;Doc Anders Ekberg</td>
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<tr>
<td>EU10</td>
<td>INNOTRACK</td>
<td>Prof Roger Lundén with some 20 co-workers</td>
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<tr>
<td>EU11</td>
<td>QCITY</td>
<td>Prof Jens Nielsen</td>
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**Doc stands for Docent**

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4. Now at Linköping Institute of Technology
Example – S&C deterioration

- Numerical simulations of contact loads and subsequent deterioration (wear, plasticity, RCF)

Simulation of dynamics

3D elasto-plastic contact simulations

Summation and smoothing of total profile change

a) Plasticity calculation

b) Wear calculation
### Parallel Special Projects

#### Programme Area 6

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<td>SP3</td>
<td>Track force measurements on X2</td>
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<td>SP4</td>
<td>VAE AG (bilateral agreement)</td>
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<td>SP5</td>
<td>voestalpine Schienen GmbH (bilateral agreement)</td>
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<td>SP6</td>
<td>Development of a quiet rail</td>
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<td>SP7</td>
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<td>SP8</td>
<td>Design of insulated joints</td>
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<td>SP9</td>
<td>Sleeper design for 30 tonne axle load</td>
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<td>Noise reduction measures and EU project QCITY</td>
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<td>Vertical contact forces of high-speed trains</td>
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<td>New sleeper specifications</td>
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<td>SP13</td>
<td>Alarm limits for wheel damage</td>
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<td>SP14</td>
<td>Particle emissions and noise from railways</td>
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<td>SP15</td>
<td>Computer program for design of block brakes</td>
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<td>SP16</td>
<td>Identification of dynamic properties in track of timber sleepers and concrete replacement sleepers</td>
</tr>
<tr>
<td>SP17</td>
<td>Switch sleeper specifications</td>
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<tr>
<td>SP18</td>
<td>Ground vibrations from railway traffic – a pre-study on the influence of vehicle parameters</td>
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Example – high frequency contact forces

- To identify rail irregularities, derive operational load spectra, calibrate numerical simulations etc.

Measured vertical forces, Power spectral density of these and rail irregularities measured by CAT. Horizontal scale in km.