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Evaluation of
Chalmers Centre for Railway Mechanics, CHARMEC
at
Chalmers University of Technology, Gothenburg

1. Preface, Methodology, and Acknowledgement

This document reports on the Third International Evaluation of CHARMEC with respect to its technical and scientific achievements, its international status, its defined benefits to industry and its future strategies.

The process of evaluation started with documentation received on the activities of CHARMEC a few weeks prior to the two-day visit to the Chalmers University of Technology. Having read the supplied documents, two of us, the scientific experts Dr Robert Fröhling, Spoornet, Railway Engineering, Pretoria, South Africa and Professor Dudley Roach, Central Queensland University, Rockhampton, Australia, were briefed by CHARMEC's management team, members of the Board, technical staff, representatives from their industry partners and senior staff of the Chalmers University of Technology during the period 25–26 March 2003. This gave the scientific experts an excellent opportunity to discuss and scrutinize the technical and scientific outputs of the Centre and their implementation in industry. Three of us, the generalists or so-called "Competence Centre Experts" Professor John Baras, Professor Per Stenius and Professor Cesar Dopazo, were briefed during the second day.

We would like to thank the CHARMEC Director Professor Roger Lundén, the Board Chairman Björn Paulsson, the representatives of the Chalmers management and everyone who contributed to provide evidence for the evaluation process. The presentations and interviews were open and frank with direct to-the-point answers to the panel´s questions. Our thanks also go to VINNOVA for our invitation and particularly to Carl Naumburg and Staffan Hjorth for their support during the process.

2. Technical and Scientific Outcomes

Excellent scientific achievement is evident within the six Programme Areas of CHARMEC, which have received attention during Stage 3. During this period, 9 projects were completed and 23 new projects started. Presently there are 34 projects active within the five Programme Areas. The sixth Programme Area, called "Parallel Special Projects", was a new area added during Stage 3. This project area is specifically aimed at producing bilateral agreements with organizations to focus on capturing the benefits to industry that are accruing from the research outcomes. Seven projects/agreements with industry partners are being developed to fully exploit the CHARMEC technology.

Major Technical Achievements

Each of the current projects has a technical outcome that will benefit the railway industry. Some specific technological achievements that are particularly important and can be readily implemented are discussed below.

The Lateral Track Dynamics Project TS4 has revealed the previously unrecognized influence of cyclic lateral behaviour at the wheel/rail contact patch on the development of rail corrugations. The problem was analyzed with a new three-dimensional computer model capable of calculating lateral dynamics as well as vertical dynamics at the contact patch. An efficient method for reducing the computing time while maintaining accuracy of the results has been developed in that programme.

Project TS5 on out-of-round wheels has demonstrated the importance of understanding the growth rate of out-of-roundness as well as the in-track measurement of wheel/rail contact forces. Early results had demonstrated the practical limits to the size of wheel flats that would exceed the Swedish wheel damage criterion for wheel replacement. If the early indications in Project TS6 (Identification of Dynamic Forces in Trains) continue and the researchers are successful in solving the "inverse problem", a new and commercially attractive method for measuring contact forces will have a major impact on the railway industry worldwide.

Project VB3 has developed a new Railway Noise Test Rig that can measure the noise caused by the various components in running trains.

Project VB5 has developed numerical solutions for soil wave propagation under high speed trains where the train speed exceeds the shear wave speed in Sweden's soft clays. The effect of these ground waves on battered embankments is still unknown at this stage. The models developed here can be used to gain a better understanding of this phenomenon. Application of the model has shown that reinforcing the track by a thin concrete slab in the substrate beneath the track is ineffective in damping the passage of the waves through the clay layer.

Project MU5 has delivered a concrete sleeper model verified by both laboratory and field tests that can accurately predict the effectiveness of different sleeper design strategies. The outcomes will allow the industry to produce better performing railway sleepers.

Project MU7 on laser treatment of wheels and rails has shown that the small temperature changes that occur during the coating process dramatically influence the resulting hardness of the components. New ways of achieving fine control of these process temperatures will result in significant improvements in product performance.

The inadequacy of linear modeling of crack growth in rails has been demonstrated in Project MU11. Nonlinear models of crack growth have been developed that will be used by track owners to plan rail grinding programmes.

Project SD3 (Computer Control of Braking Systems) has shown that a safety critical system such as electrically controlled train braking can be manufactured from low-cost off-the-shelf industrial components if proper attention is given to system redundancy.

Major Scientific Achievements and Productivity

Scientific production and communication has been enhanced through the establishment of project reference groups in May 2001. These groups have created a forum for informal presentations and discussions of results and planning for future activities.

Some specific scientific achievements are:

- The development of DIFF3D for the analysis and prediction of rail corrugations.
- Optimized solution techniques for soil wave propagation predictions under high speed trains.
- Fundamental research work conducted on contact fatigue and crack propagation to eventually be able to guide decisions with respect to wheel and rail maintenance intervals.

Since the Second International Evaluation of CHARMEC in March 2000, the research has resulted in 44 scientific journal papers, 43 conference papers, 23 other reports, 7 Doctoral dissertations, 7 Licentiate's theses and 7 MSc. thesis of high quality and scientific relevance. Furthermore, a docent degree has been awarded to Jens Nielsen.

Education and Training

Through its professors, senior researchers, Doctoral and Masters candidates and the embedded company staff that are actively involved in its research programmes, CHARMEC provides a highly trained resource for the education and training needs of Sweden and Europe. All of the university based staff and postgraduate candidates have a teaching function at undergraduate and postgraduate levels. The members of the university staff at CHARMEC are capable of providing high-level courses across the broad topic of Railway Mechanics.

Furthermore, a postgraduate course in Contact Mechanics was held at Chalmers in 2002. Courses in Train/Track Dynamics are run each year as part of the Nordic Railtrack Technical Engineering Programme. CHARMEC staff and students contribute to a range of in-house seminars and workshops organized by their industry partners to effect technology transfer to the railway industry. A less structured but no less important aspect of CHARMEC is the informal contribution to education and training of the Swedish railway industry.

Conclusions and Recommendations

CHARMEC has established an internationally recognized multidisciplinary Centre of Excellence in railway mechanics with a critical mass of senior research competence. Based on good project management and engineering expertise, excellent results are achieved on vital projects within the railway industry. CHARMEC has been recognized

by its industry partners for its international contact network by which they obtain access to the global railway business.

As new demands require railways to exceed the limit of existing materials, continuous research by CHARMEC is required to ensure sustainable rail transport solutions for Sweden. There is general consensus that CHARMEC is beneficial for the railway industry.

3. Industrial Benefits. Impact on Industrial Partners.

Industrial Interaction and Involvement in Centre Activities

CHARMEC has established extensive, meaningful and productive industrial involvement. Ample evidence was given with respect to the active interaction between academic researchers and industry personnel from industry partners within CHARMEC, and industry at large. There is a shared vision and research plan and goals between the industry partners and university researchers. The overall mission and objectives were clearly described by the Centre Director and the Chairman of the Board.

There are now nine active industry partners contributing substantial cash investments in the CHARMEC research programme. The addition of non-Swedish companies has given CHARMEC a more international character and is helpful towards its pursuit of projects and funding within the EU. The Board is functioning very well, there is good cooperation with the Centre Director and there is strong support from Chalmers. These views and impressions were shared by all industry representatives present during the international evaluation.

An excellent initiative taken by CHARMEC, in response to recommendations from the Stage 2 international review to stimulate regular interaction, is the creation of the so-called project reference groups. These groups serve as direction setting and working groups for each project as well as information dissemination groups for all industry partners within CHARMEC.

During the session with the Industrial Partners, many examples were given of industry-initiated projects. Some specific examples are: (a) the project on vibration transmission into railway vehicles to improve passenger comfort initiated by Bombardier Transportation, and (b) the project on computer control of braking systems to lower manufacturing costs and improve reliability initiated by SAB WABCO.

Industry appreciates and benefits greatly from the focused top quality technical expertise now existing within CHARMEC. The associated network of contacts between providers, operators and end users has created additional benefits and opportunities to all companies. Another activity, made possible by CHARMEC, is the joint pursuit of participation in large EU projects by partner companies as well as Chalmers.

There is sufficient evidence that CHARMEC has an integrated approach to research through interaction with local and international experts. Consultancy companies are also used to help with work load peaks and shorter projects or research work.

Although no patents have been produced the Centre has in place agreements and policies defining how patent worthy IP will be handled and exploited.

Implementation of Results: Technology Transfer, Commercialization, Success Stories

In addition to the technical achievements discussed in Section 2, CHARMEC continues to identify, through workshops and brain storming sessions with its industry partners new projects that address particularly urgent and important technological problems for the railway industry. The Project Reference Groups also ensure that the research stays focused and produces a solution that can be implemented by industry.

Technology transfer to industry partners takes place within CHARMEC extensively and under various forms. Banverket stated that utilization of research results and knowledge acquired through their participation in CHARMEC, has helped them to reduce costs in existing lines and increase axle loads, to reduce noise and vibrations, and to design more durable tracks and track switches. The advances made possible by application of these results amount to hundreds of MSEK savings and other financial benefits.

Duroc Rail is an SME, which has benefited greatly from participation in CHARMEC. They are using knowledge and research results from CHARMEC in their development of two-material wheels and rails and mobile cladding of rails. They have received scientific validation of their designs and proposals from CHARMEC scientists, deeper knowledge and understanding of cladding, substrate failures, crack formation, as well as tools to select good or bad layer material.

Abetong Teknik also obtained better knowledge and understanding of the entire track structure and new design tools for concrete sleeper development. The contact network enabled by CHARMEC has allowed them to enter into professional discussions with end users regarding their products. They have designed a specific project to educate their employees in the technological area covered by CHARMEC and have hired a PhD graduate from the Centre. They stated that CHARMEC has enhanced the design and production technologies for concrete sleepers, and has assisted them in presentations to their licensees.

TrainTech has received extensive knowledge input, new customers through the network of contacts, opportunities to participate in industry projects on new wheelset designs and measurement equipment designs. Bombardier Transportation and SAB WABCO have received high quality and useful knowledge and expertise.

A good example of successful technology transfer has been the work on switches and turnouts. Turnouts are particularly susceptible to damage because of their inherent discontinuities. As track damage at turnouts is a significant problem, Banverket raised the topic with CHARMEC and a number of workshops were held with interested companies. Meanwhile CHARMEC completed a thorough study of current best practice. A project reference group was establish with representatives from Abetong Teknik, Banverket, Linköping University, Luleå University of Technology, SL, VAE (Austria), Voestalpine (Austria) and CHARMEC. Two cooperative projects were identified that integrated the train dynamics in the software programme DIFF3D and the new work on damage

mechanisms in track switches. CHARMEC is an active partner in a consortium that is proposing an Integrated Project with considerable research into track switches and turnouts to be funded from the Sixth Framework Programme of the European Union. The outcomes from this EU project will be eagerly implemented by the partners in the consortium.

Another example is the incorporation of software for the Fatigue Index Evaluator for Rolling Contact Environments (FIERCE) into practice software packages used by industry, through the EU consortium project HIPERWHEEL. The industrial partners will use the software. Another example is the transfer of models and parametric settings for laser treatment of wheels and rails to the industry partners Duroc and Lucchini.

Conclusions and Recommendations

From the feedback from CHARMEC's industrial partners, it is clear that they have a great appreciation of the work done by CHARMEC. All aspects of industry collaboration are working well within CHARMEC, including technology transfer and commercialization to products. This is best evidenced by the fact that industry partners are signing up to continue for the 4th stage and are strongly supporting continuation of CHARMEC after the end of stage 4.

The Board and the Centre should hold a planning retreat to examine carefully new emerging technologies and opportunities for programme support and expansion, especially within EU for the future of CHARMEC. The Board should also examine carefully the establishment of policies and means for exploitation of all IP generated and the possibility of revenue stream creation for CHARMEC through licensing of IP. In this context taking advantage of various instruments and strategies being implemented by Chalmers should be carefully examined.

4. Present Standing of the Centre

International Ranking and Attractiveness

The progress and level of CHARMEC projects is followed by reference groups with members from the supporting industries and scientists associated with CHARMEC. However, CHARMEC has not established an International Scientific Advisory Board, and considers the input in terms of acceptance in leading scientific journals, invitations to conferences etc. as giving sufficient indications of the scientific level of the research. Several such invitations, assignments as international expert advisors, responsibility for the arrangement of international conferences and the participation of large international companies in the Centre indicate that it is well established and that its research is at an international level.

The Centre as a National Asset

During its seven years of existence the CHARMEC has developed so that new graduate students now can join established research groups with guidance from both senior and

junior scientists. Thus, the size of the groups in each of the main research topics now is satisfactory and exceeds the minimum requirements for the maintenance of level and continuity in research.

CHARMEC has defined its core competences in the field of railway mechanics very clearly in terms of five programme areas (Interaction of Train and Track, Vibrations and Noise, Materials and Maintenance, Systems for Monitoring and Operation, Parallel EU projects and Parallell Special Projects (including bilateral agreements with industries). Within these areas, the Centre is undoubtedly an important asset for Swedish industries and also an attractive partner internationally.

Role and Impact of the Centre as a Part of the University

The Dean of the School of Mechanical Engineering and the Vice President of Chalmers both stated that Vehicular Engineering is one of the core areas of competence of the School of Mechanical Engineering. Railway mechanics is an important part of this core.

As the other Competence Centres at Chalmers, CHARMEC reports directly to the Vice President, thus promoting and simplifying the possibilities for interdisciplinary cooperation. As recommended in the previous review this cooperation has been broadened during the last three years, in that the Department of Signals and Systems has joined CHARMEC. The Centre endeavours to strengthen its position within Chalmers by promoting the establishment of sustainable transport engineering as an area of core competence within Chalmers and strengthening teaching in railway engineering. In view of the strong and positive response to CHARMEC from industry this appears to be a development that can be recommended.

The main contribution of CHARMEC to education is teaching and supervision of graduate students (licentiates and PhDs). The Centre has developed a graduate course in Contact Mechanics and it also contributes to undergraduate education by participating in courses and supervising M.Sc. theses.

Conclusions and Recommendations

CHARMEC has provided the Swedish railway industry with an excellent research and educational base.

The Centre should continue to promote strengthening of education in railway mechanics at the Chalmers School of Mechanical Engineering

5. Future Prospects and Strategies

Technological-Scientific Prospects of Research Area. Focus of Future Research.

CHARMEC has reached over the critical mass and has established itself as an attractor for new PhD students and senior investigators. Academic indicators of excellence have also been met both in qualitative and quantitative terms. The continued strong support of

the participating industries is a sign of a lively scientific and technical dynamics. Being invited to join industrial/university consortia for participation at the EU Sixth Framework Programme, attracting new industrial partners, cooperating with EU companies and being consulted by Deutsche Bahn on the 1998 high speed train Eschede accident are significant and worth mentioning distinctions.

Offering new highly qualified PhD students a five years salaried employment is an excellent incentive and an evidence of CHARMEC rational recruiting policy.

The existing applied research lines will actively continue, providing support to participating industries, and naturally evolving towards the use of newly developed state-of-the-art experimental and numerical tools. In particular, the materials group is faced with many promising opportunities and challenges.

Interests and Priorities of Centre Partners

As already stated, CHARMEC will certainly expand existing expertise in the established areas (train/track interaction, vibrations and noise, materials and maintenance, and monitoring and operation systems). The low profitability of Swedish rail operators might hamper the growth of CHARMEC with its present structure. More participation of EU industrial partners at the Centre should be secured in the near future based on its unique expertise in a few narrowly focused topics.

Strategies for Stage 4 and beyond

After establishing itself as a Centre of Excellence during the past 7 years and undergoing a consolidation process during Stage 3, emphasizing industrial participation at the EU scale, the big challenge faced by CHARMEC for Stage 4 is to secure the continuation of VINNOVA funding. Should this support continue during an additional period, the Centre should really think about increasing the number of patents and, if possible, obtain revenues from a joint industry/university exploitation of successful research products.

Should the VINNOVA funding cease from June 2005 on, the prospects for CHARMEC activity would have to be carefully analyzed. Participation in EU-funded projects should definitely be increased, as well as short- and mid-term bilateral arrangements with the present partners and with new ones. Separating some mature activities from the present RTD lines and integrating them into newly created consulting firms or spin-off companies should be rigorously investigated and not excluded a priori.

Conclusions and Recommendations

The role of Chalmers University in the future of CHARMEC is crucial, possibly through the creation of senior research positions and a chair Professorship in railway mechanics. The establishment of a core area of RTD in “Sustainable Transport Engineering” as a part of the School of Mechanical Engineering would be a strategically correct positioning, that surely would help, among other things, to secure the future of CHARMEC.

6. General Conclusions and Recommendations

During the last three years, CHARMEC has enhanced its status in the Swedish railway industry. They have established themselves as a critical link between their industrial partners and the international railway industry. Comments from the industrial partners clearly indicated that contact with the railway industry through their partnership with CHARMEC is very important to their sustainability.

From the evidence provided, it is clear that CHARMEC's strengths are its sustainability and international recognition, its multi-disciplinary approach, its high standard of tutoring and its industrial angle to research projects.

The following comment given by Lucchini gives an appropriate summary of CHARMEC's status in industry: "CHARMEC´s contribution to our research work gives us very high confidence in the market we are in, as the research results obtained from them are always of high quality and have never been questioned."

In view of the general success of CHARMEC we have the following recommendations:

- VINNOVA should either try to secure the funding of CHARMEC beyond June 2005 or help to guarantee a smooth transition towards the Centre independence.

- Establishing CHARMEC as a leading Research and Development Group at the EU scale for most Sixth and Seventh Framework Programmes should become a main concern. Lobbying activities within the EU would be important.

- CHARMEC should spend time and effort in finding its future niche within the EU DG-TREN, exploring ways to fits its expertise within the Strategic Rail Research Agenda 2002 (SRRA-2002).

Gothenburg, March 26, 2003

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