Project no. TIP5-CT-2006-031415

INNOTRACK

Integrated Project (IP)

Thematic Priority 6: Sustainable Development, Global Change and Ecosystems

D3.1.3 - Draft specification of the S&C demonstrators

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Revision Final

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

Abbreviation / acronym	Description
LCC	Life Cycle Cost
S&C	Switches and Crossings
NR	Network Rail (UK)
GT	Gross Ton

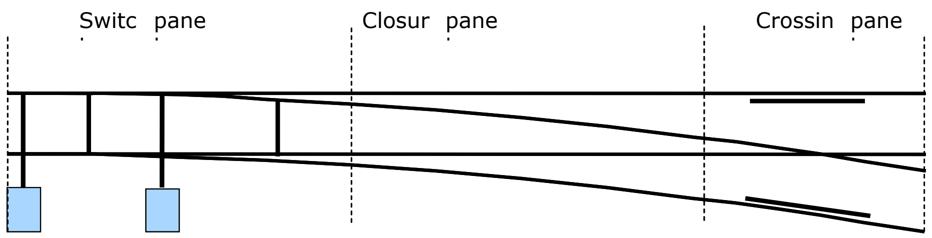

Figure 1 - Sections of S&C

1. Introduction

This document contains the proceeding and the draft demonstrator specifications for the WP 3.1 track related improvements.

In the following chapters the overall proceeding and the simulation steps are described. This is followed by a description of preliminary works: identifying the main cost factors as a motivation for optimizing frogs and switch blades via simulation. In the end the demonstrators are presented.

It should be pointed out that this approach is a premiere: to develop optimized track related components of a switch with scientific methods and simulation tools in a European wide collaboration of suppliers, infrastructures and Universities instead of a time consuming 'learning by doing'.

2. Work task and responsibilities

Participants: BV, Chalmers, VAE, VCSA, DB, MMU

N°, title and delivery date:

D3.1.3 Draft specification of the S&C demonstrator (M26). Responsible: Wolfgang Grönlund, DB

Description: Detailed functional specification of the S&C demonstrator that will be implemented during the demonstration phase of the project. The specification should refer to the previous deliverables. The specification should be developed in such a way so that it can be used to evaluate the effectiveness of the final demonstrator.

3. Aims & proceeding

In the ongoing work of the INNOTRACK project WP 3.1 aims at optimizing the track related components of switches. Figure 1 shows the overall proceeding for optimization of S&C.

After identifying the major cost factors:

↓

Optimization via simulation:
frogs (geometry and stiffness) and
switch rails (horizontal and vertical stiffness, gauge)

↓

Optimized results to be realized as demonstrators

↓

Validating the benefit via LCC

Figure 2 - Overview of the overall proceeding for optimization of track related components of S&C

This deliverable is focussed on the realization of demonstrators as a result of optimization via numerical simulation. The advantage of simulation is the possibility of obtaining the parametric influence in a short time period and to carry out the configuration with best results as demonstrators. The simulation proceeding is based on a „work-planning“ document.

The proceeding to reach this aim has been (the work is still ongoing):

Step 1:	Comparison of simulation programs (BV, MMU, DB, VCSA)
Step 2:	Optimization via simulation of <u>frogs</u> (geometry and stiffness) Optimization via simulation of <u>switch rails</u> (hor. & vert. stiffness, gauge)
Step 3a:	Constructing & producing of frogs and adapted components for switch rails (i.e. fastenings)
Step 3b:	Start of demonstrators/test sites

Figure 3 - Proceeding of simulation and S & C demonstrator

4. Preparation and preliminary work

This chapter gives a short overview over the preliminary works which have been done to work out the fundamentals and to verify the components which are of most importance for optimization. This is followed by the description of the simulations.

4.1 Identifying the main cost factors of S&C

The figures below show the main results of the merged deliverables D3.1.1 (Definition of key parameters) and D3.1.2 (Report on cost drivers for goal-directed innovation).

Results from DB

The analysis of the selected high speed line from DB (with UIC 60 S&C, mixed traffic with about 17.5 MGT/year (average) and 458 chosen S&C from which 276 S&C had caused maintenance activities) has identified the following key parameters (without costs for inspection, service and test measures):

- **renewal of switch rails** (half set) with about 35%,
- **large elements** (these are not separated between frogs or switch rails etc.) with 17% and
- **frog renewal** with about 13%.

All together this is an amount of 65% of the costs per S&C while the other activities like welding, maintenance (e.g. minimal repair), tamping etc. sum up to “only” 35% on the selected line.

Results from BV

The analysis of the maintenance costs of the selected line 119 with mixed traffic (about 25% passenger and 75% freight traffic) with assumed 18 MGT/year has identified the following key parameters:

- The main cost factors (without inspection/service/test) are Short-range planned actions after inspections with **30%.** This is mainly **adjustment, build up welding and minimal repairs**. This are actions after inspection but are seen by Banverket as immediate corrective maintenance.
- Long-range planned actions after inspection with **26%.** This includes **replacement of frogs, switch rails and check rails**. This is part of the condition based maintenance.
- Costs for **inspections & predetermined maintenance** with **17%**.

The costs for these measures sum up to 73% while the amount for the other activities inspection, grinding and tamping are of 27%.

Beside that the difference between the costs for DB and BV are to be investigated the results of this analysis show that the main cost factors of S&C are renewal of frogs and switch rails. This is the validated motivation for optimizing of these components.

4.2 Proceeding of simulation and results (examples)

This chapter shows details of the simulation proceeding as shown in figure 3 including examples of simulation results.

Step 1: Comparision of simulation programs (BV, MMU, DB, VCSA)

Before starting the INNOTRACK project each participant has used it's own simulation programs. Therefore in the starting phase of INNOTRACK the first step has been to compare these programs to make sure that the results are comparable.

Therefore simulation and calculations based on a UIC 60 switch with a radius of 760 m has been carried out and compared to measurement results from a switch at Härad made by BV. The numerical simulations were carried out by:

- Deutsche Bahn AG: Simpack with flexible track
- VCSA: BCCM
- MMU: Simpack
- Chalmers University: Gensys and DIFF3D

The results of this comparison have been:

- Vehicle dynamics tools produce similar results for lateral force and vertical wheel-rail forces which also compared well with field measurements
- Tools are adequate for switch optimisation tasks

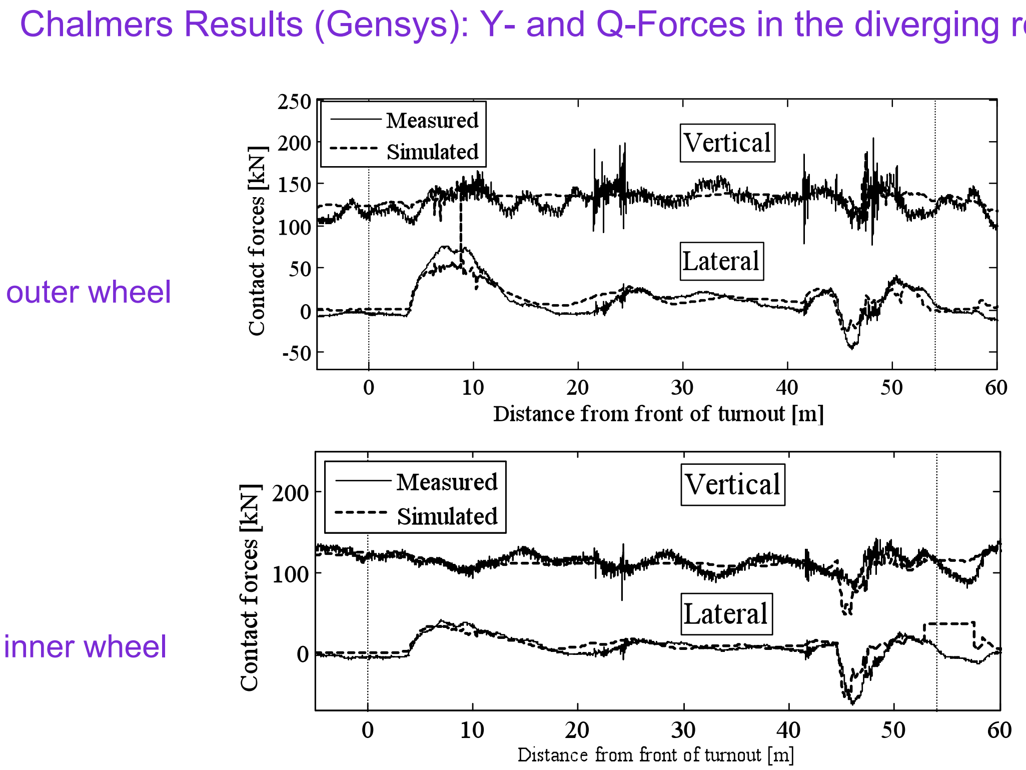

Figure 4 - Example: comparison of measured and simulated forces done by Chalmers

As one example for well matching results figure 4 shows the comparison of measured and simulated forces.

Step 2: Optimization via simulation of frogs (geometry and stiffness) and switch rails (hor. & vert. stiffness, gauge)

After comparison of the simulation programs the work has been continued by simulating variations in geometry and stiffness based on the planning of simulation work as described in "int-sp31-work_planning_D5".

The following figures give an impression of the results of optimizing.

Frogs: variation of stiffness

Simulation Results – facing direction

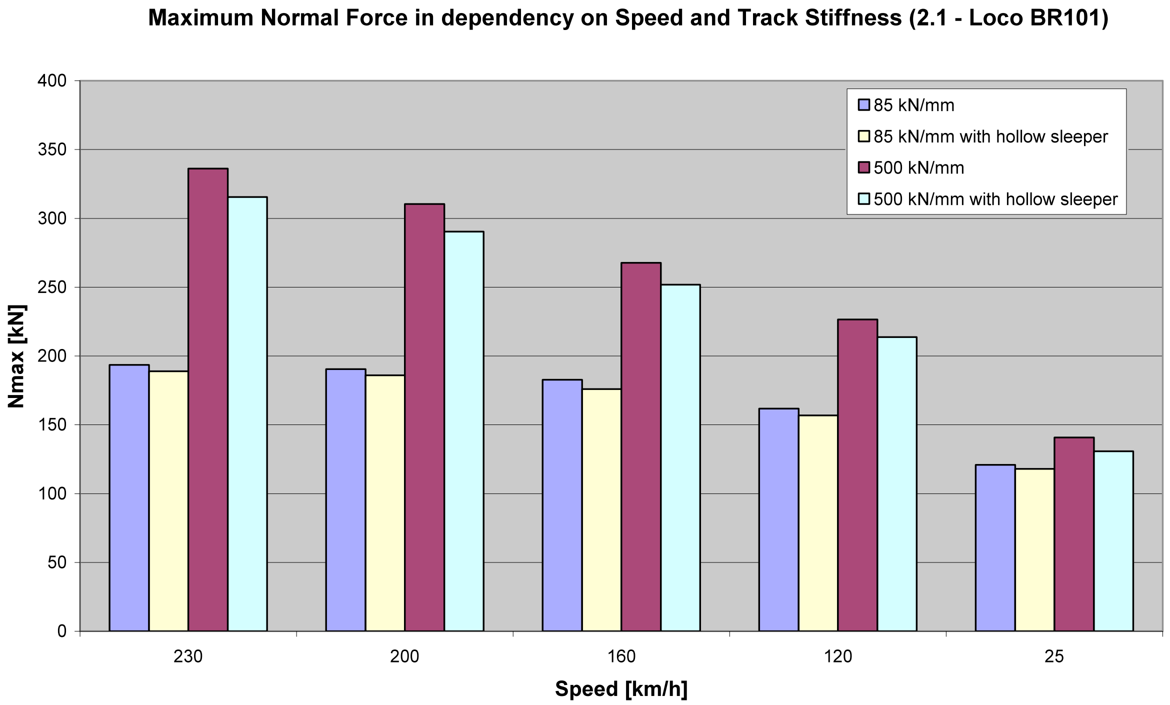

Figure 5 - Example of optimization via simulation: Frogs with varying stiffness and speed, done by DB

Figure 5 shows the maximum normal forces in dependency on speed and track stiffness with a Loco passing the frog in facing move. It shows that a decrease of the track stiffness reduces the normal forces significantly. The relative reduction of the forces (this means displacement between forces resulting from high stiffness to those resulting from low stiffness) increases with increasing speed.

Simulation Results – facing direction

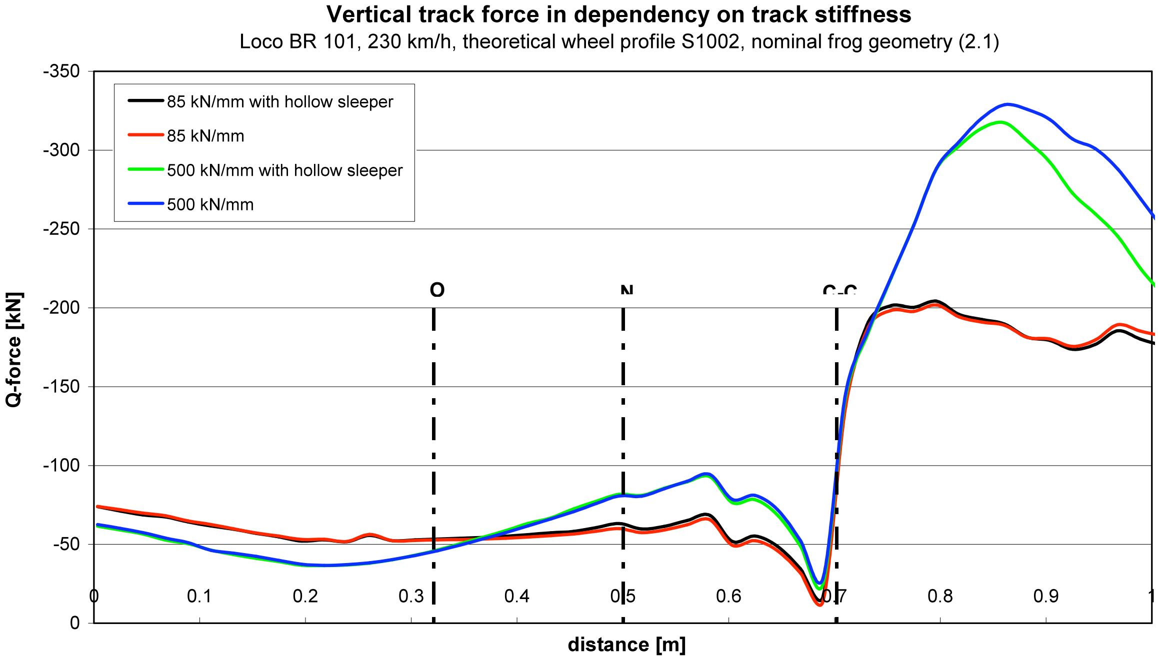

Figure 6 - Example of optimization via simulation: Frogs with varying stiffness and speed, run of the forces

In addition to the maximum forces in Figure 5 the figure above shows the evolution of vertical wheel forces while the wheel passes the frog in facing move. The force magnitude when the wheel impacts the frog is significantly reduced by the elastic rail pads.

Frogs: variation of geometry

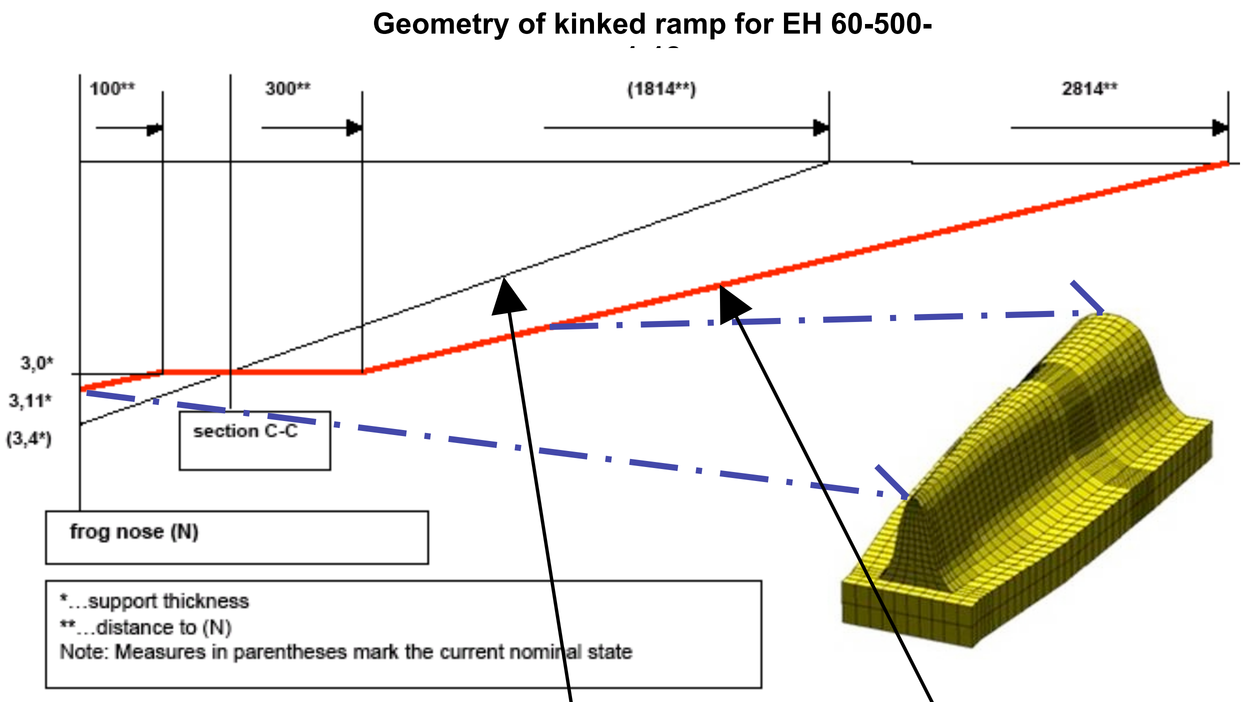

Figure 7 - Example of variations of geometries:

Normal frog geometry (black line) and kinked ramp (red line)

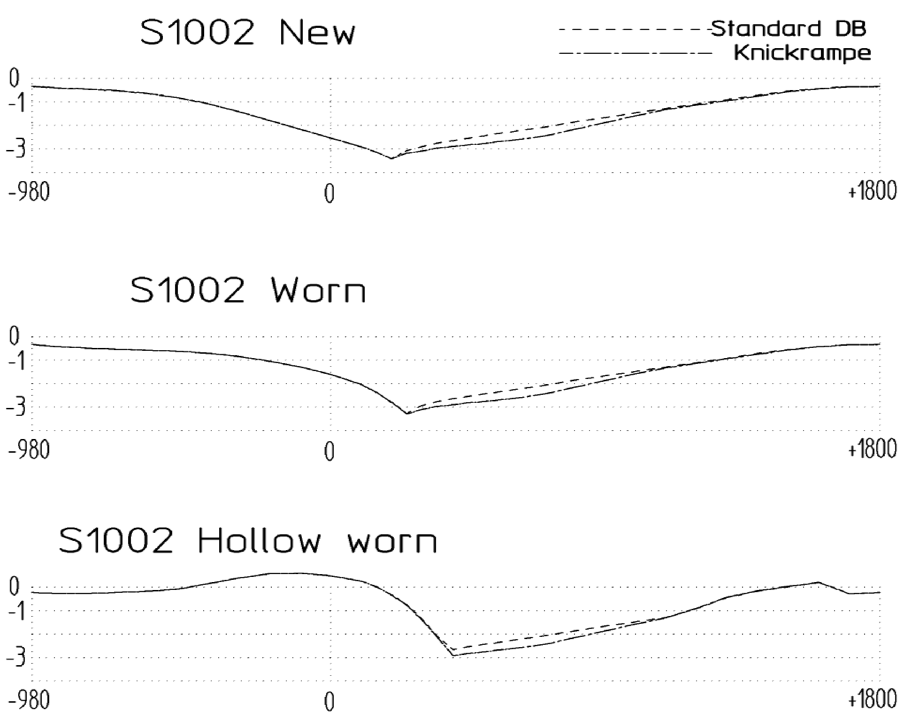

Figure 8 - BCCM (VCSA) Simulation: vertical bouncing for 3 wheels

The BCCM software developed by VCSA uses as input the cross sections from the crossing design and the different possible wheel profiles. The wheel/crossing contact is calculated for all sections (in our example from a longitudinal coordinate –980 mm to +1800 mm from the crossing nose).

The vertical bouncing is calculated for all lateral wheel positions from –10 mm to +10 mm from the centred wheel position with an increment of 0.5 mm (as example see in Figure 8 the bouncing curves for a swaying = 0 mm (= centred wheel position)).

With the 3D bouncing iso curves as shown in Figure 9, we obtain a global overview of the crossing over-running effects.

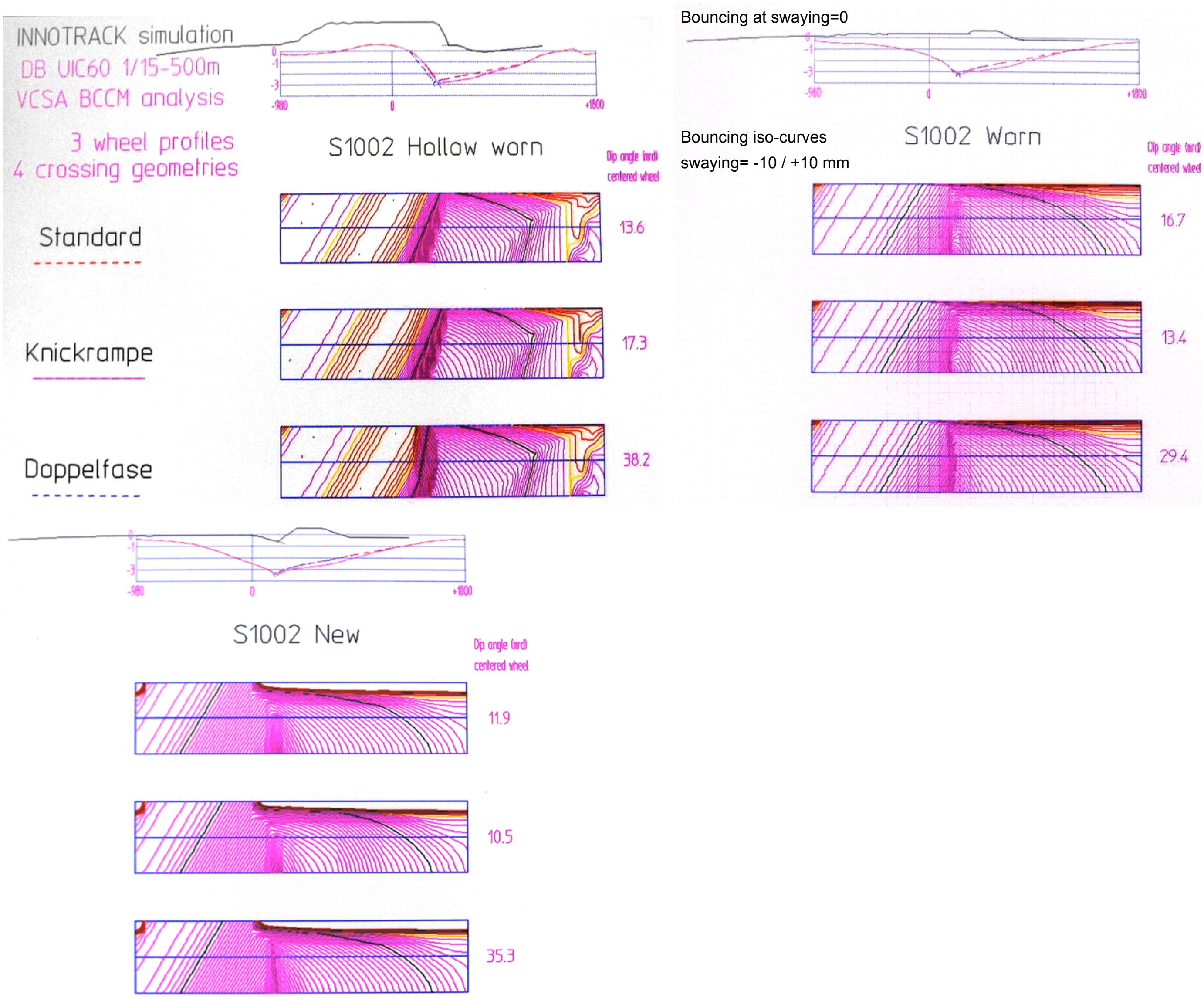

Figure 9 - Example of optimization via simulation: BCCM software from VCSA – dip angle comparison

Simulation Results – facing direction

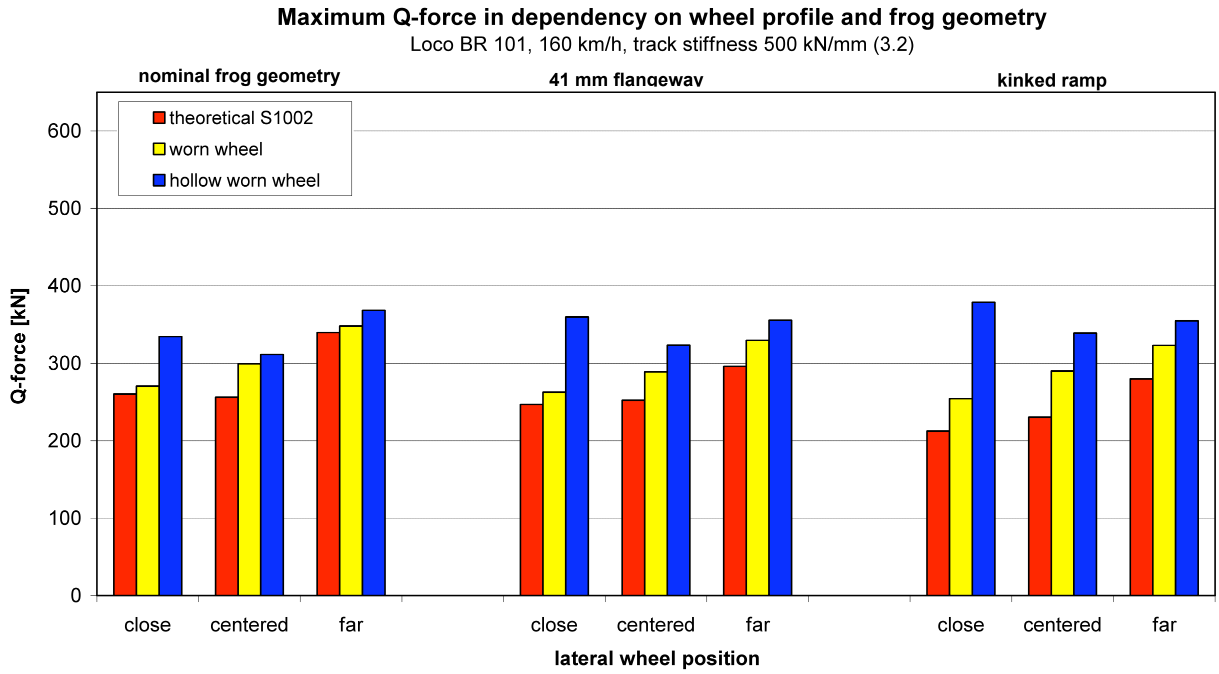

Figure 10 - Example of optimization via simulation: Frogs with varying geometry (nominal frog geometry and "kinked ramp")

Figure 10 shows the influence of different frog geometries on the maximum Q-forces depending on the lateral position of the wheel (close / centred / far from the frog) and on the condition of the wheel (new / worn / hollow worn) while the wheel passes the frog in facing move.

Compared to the force reduction reachable by a "soft" track stiffness the reduction by advanced frog geometries is so far less impressive.

Switch blade: gauge variation

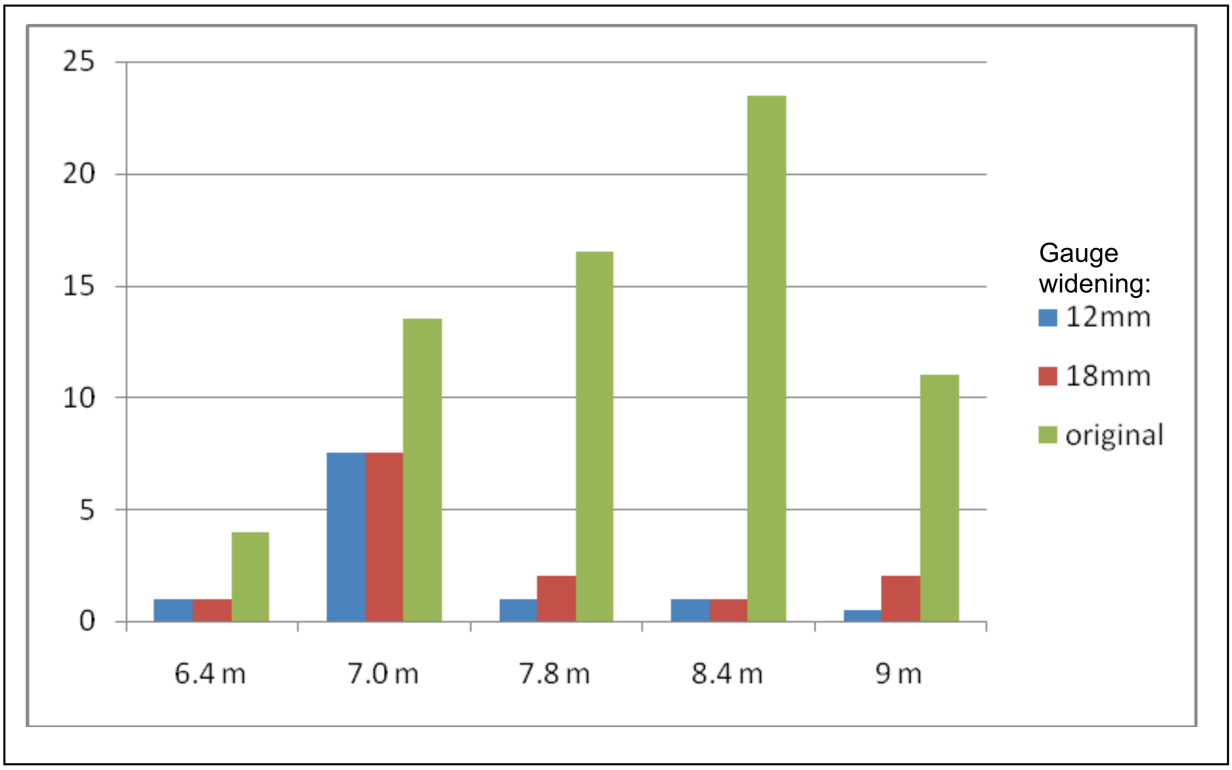

Figure 11 - Example of optimization via simulation: Switch rails with gauge variation done by MMU

A total of 54 simulation cases have been run, for a freight vehicle with Y25 bogie in laden conditions, running at 100 km/h. 18 different measured wheel profiles have been used for the two dynamic gauge widening cases and the original design (without gauge widening).

The simulation results as shown in Figure 11 are evaluated in terms of Wear damage, based on the $T\gamma$ output from the simulations. Five specific locations on the track (switch panel) have been selected, all between L=6.4 m and L=9 m measured from stock rail point, where the values of traction coefficients and contact stresses were higher on the preliminary simulations.

The accumulated wear on each section is represented by calculating the average and median $T\gamma$ of all the simulations for the freight vehicle case.

The results show that the new optimised designs reduce $T\gamma$ at all sections, and in particular at the ones where the original design showed the highest $T\gamma$ values. Both the 12 mm design and the 18 mm design perform similarly. A very significant reduction of wear in all locations along the switch is obtained. Also, more consistency in the $T\gamma$ results are obtained for different wheel profiles.

The simulation proceeding is scheduled until end of 2008 (see final results in D3.1.4, "Summary of results from simulations and optimisation of switches") followed by:

Step 3: Constructing & producing of frogs and adapted components for switch rails (i.e. fastenings)

Start of demonstrators / test sites

The demonstrators are described in chapter 5.

5. Demonstrators

This chapter describes details and time schedule of the INNOTRACK SP 3.1 demonstrators.

The choice of demonstrator test sites is a compromise between S&C with representative European ordinary duty conditions and the possibility for installation which have been available due to already planned renewals of S&C. This is the reason for a partly late start of some demonstrators.

The demonstrators are scheduled as follows:

Frog demonstrators (crossing panel)			
Test site	**Location**	**Demonstrator**	**starting**
DB	Haste	2 frogs with optimized geometry "kinked ramp" 1 frog with optimized geometry "MaKüDe"	in April 09 in April 09
	Worms	6 frogs with optimized vertical stiffness	end of 08
BV	Eslöv	2 frogs with optimized (lower) vertical stiffness	Sept 2009

Table 1 - Schedule of frog demonstrators

Description and constraints of test sites:

Haste (near Hannover):

- v_{max} = 160 km/h
- mixed traffic with 70.000 GT/ per day
- max. axle load: 22.5 tonnes
- 10 frogs under same traffic and substructure conditions incl. reference frog
- UIC60-500 1:12
- CrBainit frogs

Remark: This test site has been arranged several years ago for the special purpose of testing frogs. Therefore only the crossing panels are mounted in the track.

Figure 12 - DB test site Haste

Worms:

- v_{max} = 100 km/h
- mixed traffic with 40.000 GT/ per day
- max. axle load: 22.5 tonnes
- KR54 – 1:4,444 (crossing)
- Track stiffness (optimized): 85 kN/MM

Eslöv:

- dense traffic area with 15 MGT/ per year
- max. axle load: 25 tonnes

- UIC60-760-1:15, S&C number 413 (South bound traffic) and 454 (north bound traffic)
- explosion hardened cast Mn-steel

Switch rail demonstrators (switch panel)			
Test site	**Location**	**Demonstrator**	**starting**
DB	Frankfurt, Wirtheim	2 switches with test of horizontal stiffness	about end of 08
BV	Eslöv	3 switches with test of vertical stiffness (incl. gauge widening in the switch panel)	in Oct 2009
NR	Glasgow – Edinburgh (in discussion)	varying gauge or alignment and stiffness	in discussion

Table 2 - Schedule of switch rail demonstrators

Description and constraints of test sites:

Frankfurt:

- v_{max} = 80 km/h
- mixed traffic, 70.000 GT/ per day
- max. axle load: 22.5 tonnes
- W204, IBW54-760 1:14 (inside curved turnout)

Wirtheim:

- v_{max} = 60 / 130 km/h
- mixed traffic, >30.000 GT/ per day
- max. axle load: 22.5 tonnes
- W601, IBW60-1200 1:18,5 (inside curved turnout)

Eslöv:

- see above
- head hardened rail 350 HT
- inclined rail 1:30

Glasgow – Edinburgh (in discussion):

- It is discussed to carry out these demonstrators within the NR "intelligent infrastructure" project.

Eslöv: Installation of prefabricated S&C

If possible the assembly of the S&C shall be done at a factory and the switch transported to the station on special wagons. After the installation a prescribed procedure should be followed with tamping and grinding according to the instruction of the manufacturer.

Measuring on site

All demonstrators will be evaluated by different tests. So far the following measurements have been taken into account:

- Force measurement by instrumented wheel sets
- Force measurement by strain gauges on the rail
- Vibration/acceleration-measurements to study the deflection of the rail
- Stiffness measurement by vehicle
- Measurements of geometry behaviour / changes
- Stiffness measurement by hammer impact

First results

First results from all demonstrators described in this chapter can be expected about one year after start. Experiences have shown that validated results can normally be expected 1.5 years after start.

The results from the demonstrators will be validated via LCC to show the benefit of these innovative measures.

Participation in demonstrator activities

Demonstrators SP 3.1

<table>
<tr><th></th><th></th><th colspan="4">Participation</th></tr>
<tr><th></th><th>SP</th><th>DB</th><th>BV</th><th>Vossloh *</th><th>VAE *</th></tr>
<tr><td>Switch blades: horizontal track stiffness incl. Installation</td><td>3.1.6 / 3.1.7</td><td>x</td><td>x</td><td>x</td><td rowspan="2">x</td></tr>
<tr><td>Crossings incl. Installation</td><td>3.1.6 / 3.1.7</td><td>x</td><td>x</td><td></td></tr>
<tr><td>measurements of optimized frogs</td><td>3.1.7</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>measurements of optimized switch rails</td><td>3.1.7</td><td>x</td><td>x</td><td></td><td></td></tr>
</table>

* : participation at BV demonstrators

Simulation done by: DB, VCSA, MMU, Chalmers

6. Conclusions

In the INNOTRACK WP3.1, the creation of optimized track related components for S&C is based on a very clear analytic proceeding supported by scientific methods and simulation tools in a European wide collaboration of suppliers, infrastructures and Universities:

Identifying the major cost factors
as a motivation for optimizing frogs and switch rails

⇩

Optimization via simulation

⇩

Demonstrators: frogs and switch rails with optimized geometry and elasticity

⇩

Validated results to be expected 1.5 years after start

⇩

Validation via LCC

The railway history is characterized by gradual improvements based on time consuming and expensive 'learning by doing'.

With the proceeding in WP3.1 a relatively short time period a significant step in the improvement of track related components of S&C can be expected with increased life time and decreased life cycle costs.