On The Optimization of Switches

-An overview of the switch optimization work in CHARMEC project TS13

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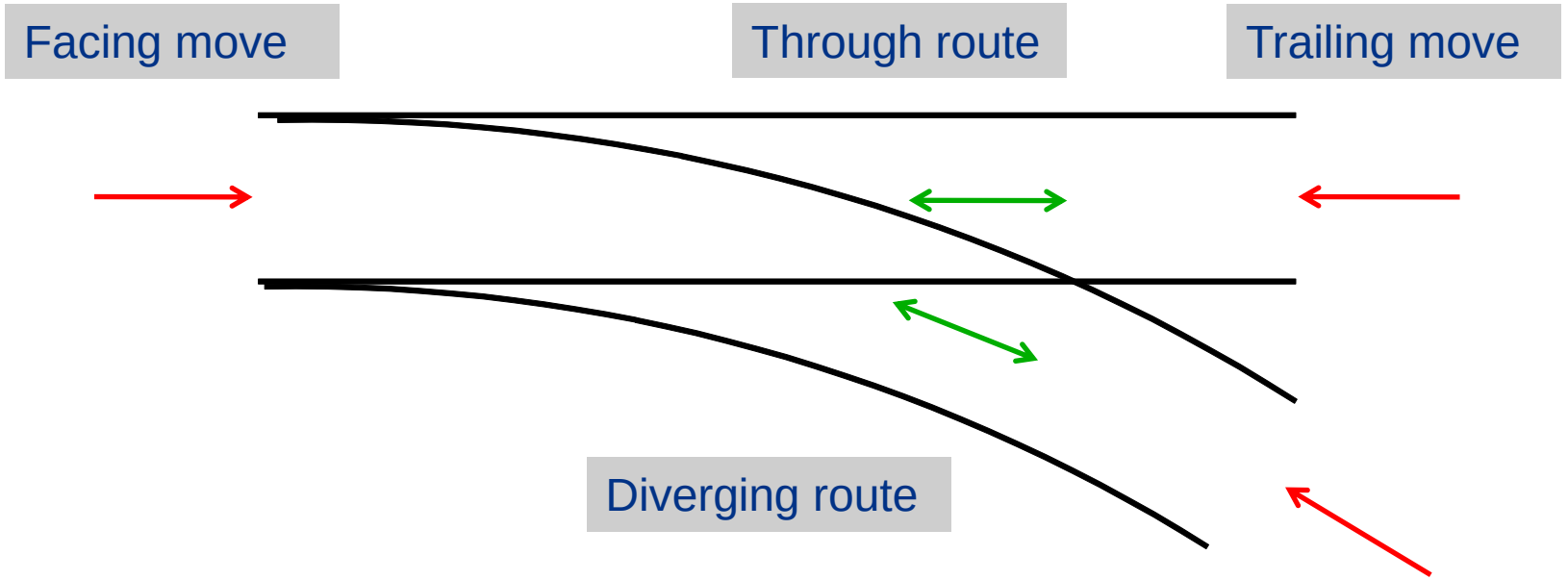
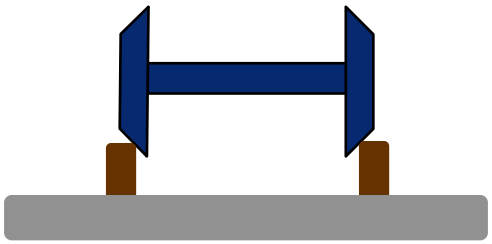
Support from Trafikverket, VAE GmbH & SL is greatfully acknowledged

Traffic in a Turnout

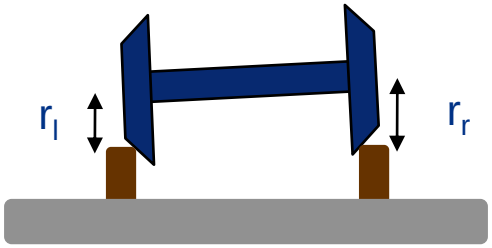


Rolling Radius Difference

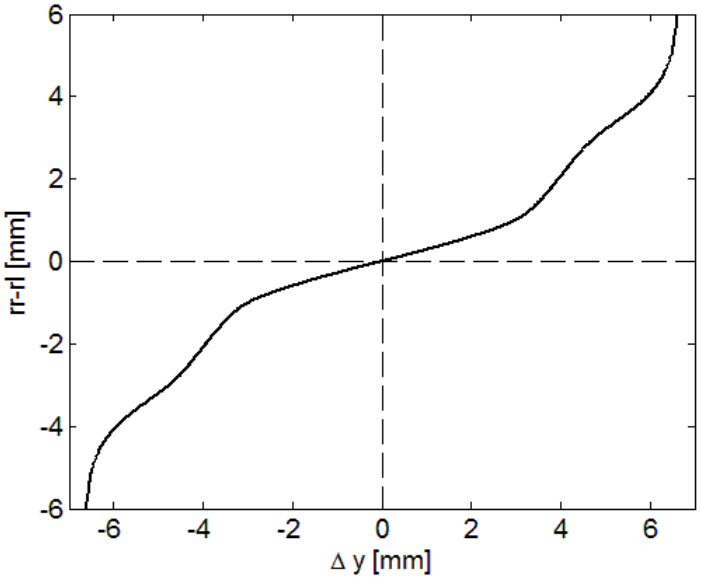
$\Delta y = 0$



$\Delta y > 0,\ r_r > r_l$

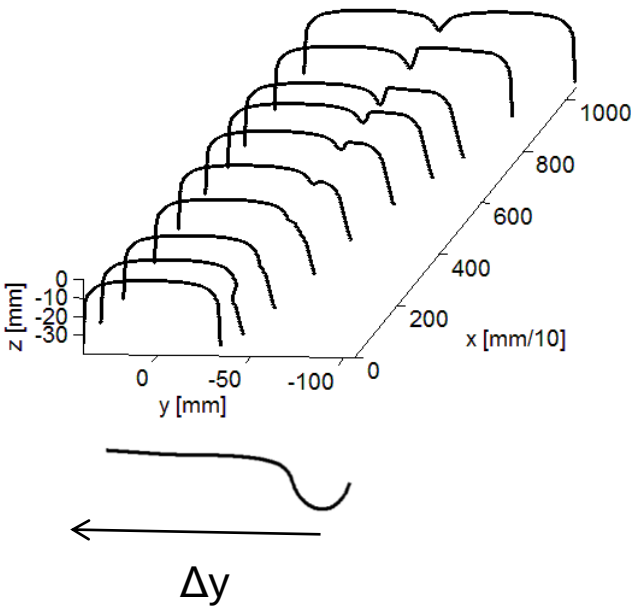


$\Delta y \longmapsto$

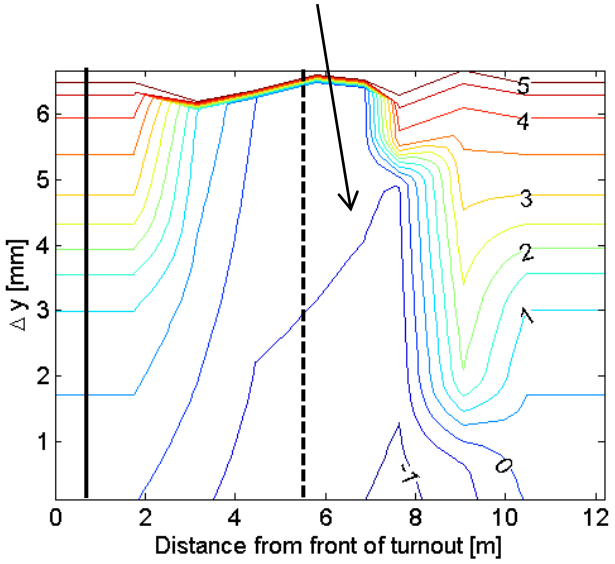


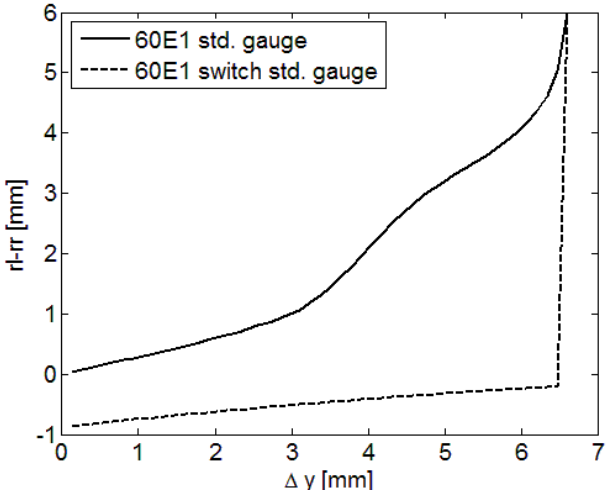
S1002 on 60E1 rails

Rolling Radius Difference in Switches

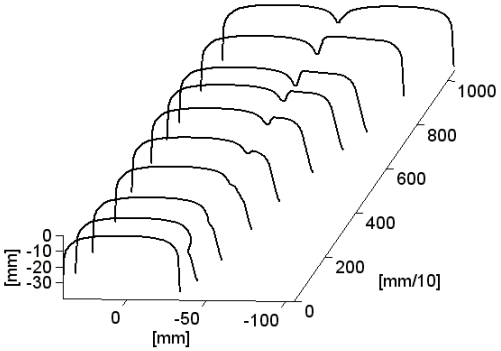


r-r difference iso lines [mm]

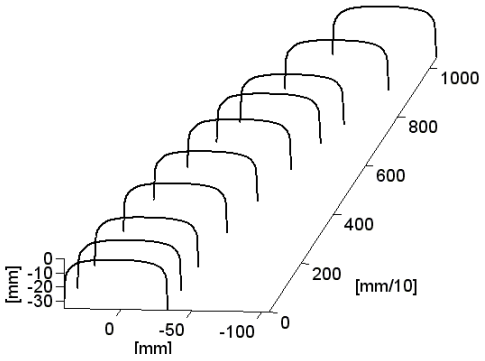




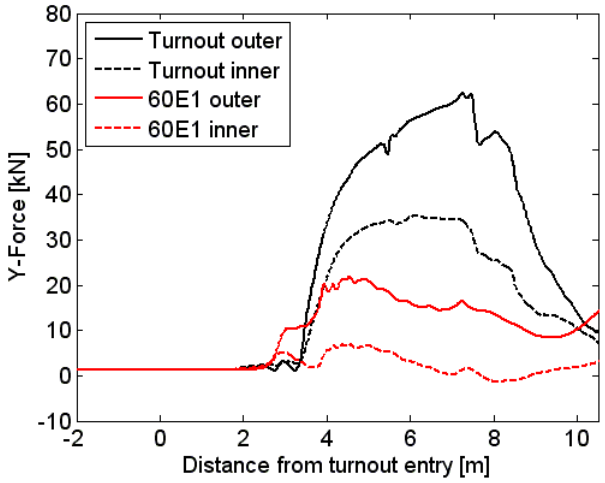
The switch rail profiles causes rolling radius deficiency

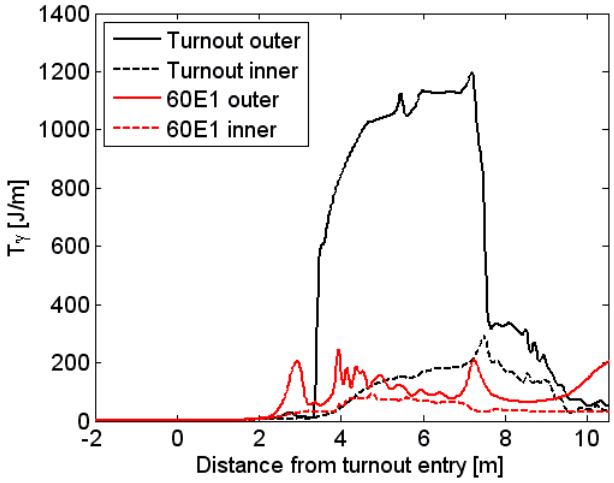


Turnout rail vs. Nominal rail



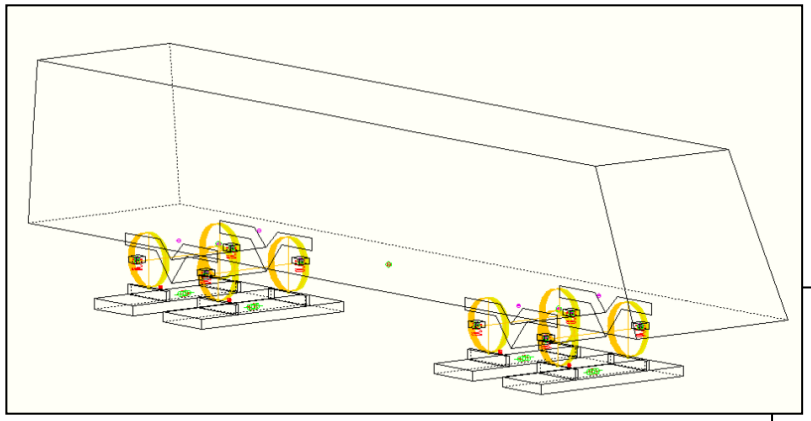
Results for facing move, diverging route and leading wheelset



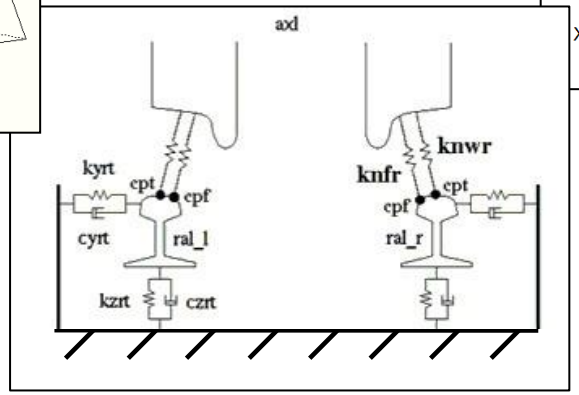


Simulation of Dynamics

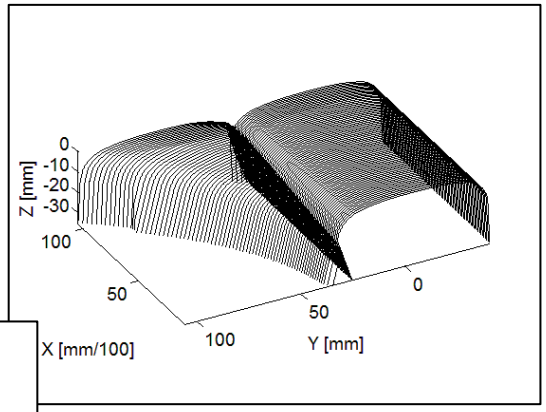
- Simulations of train-turnout interaction are performed in GENSYS



MBS-model
Freight vehicle featuring Y25 bogies



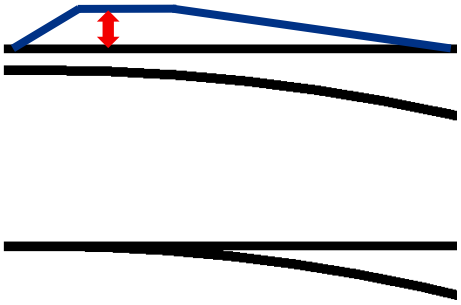
Co-following track model(s)



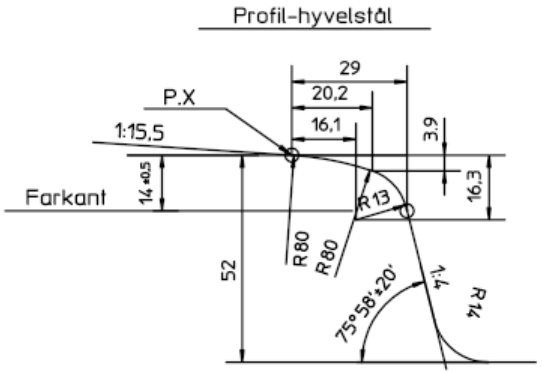
Discrete rail sections
60E1-760-1:15 turnout

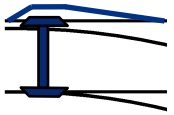
Mitigations for r-r Deficiency in Switches

KGO/Prescribed gauge widening



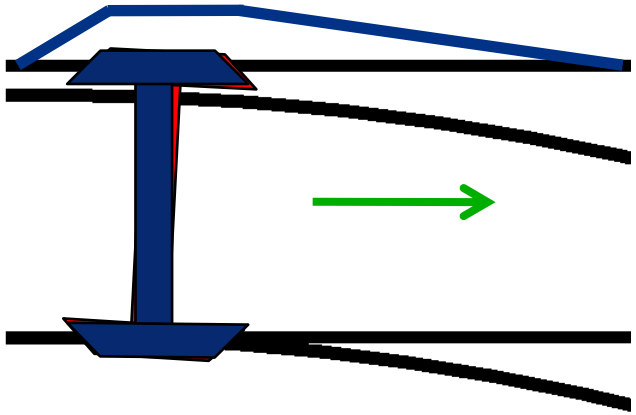
Switch rail profile geometry



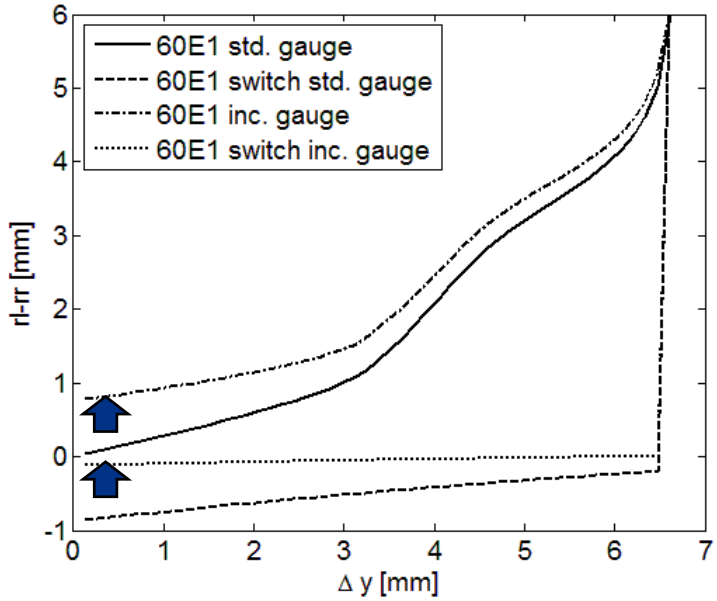


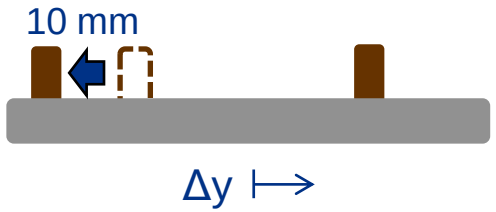
Mitigations for r-r Deficiency in Switches

KGO/Prescribed gauge widening



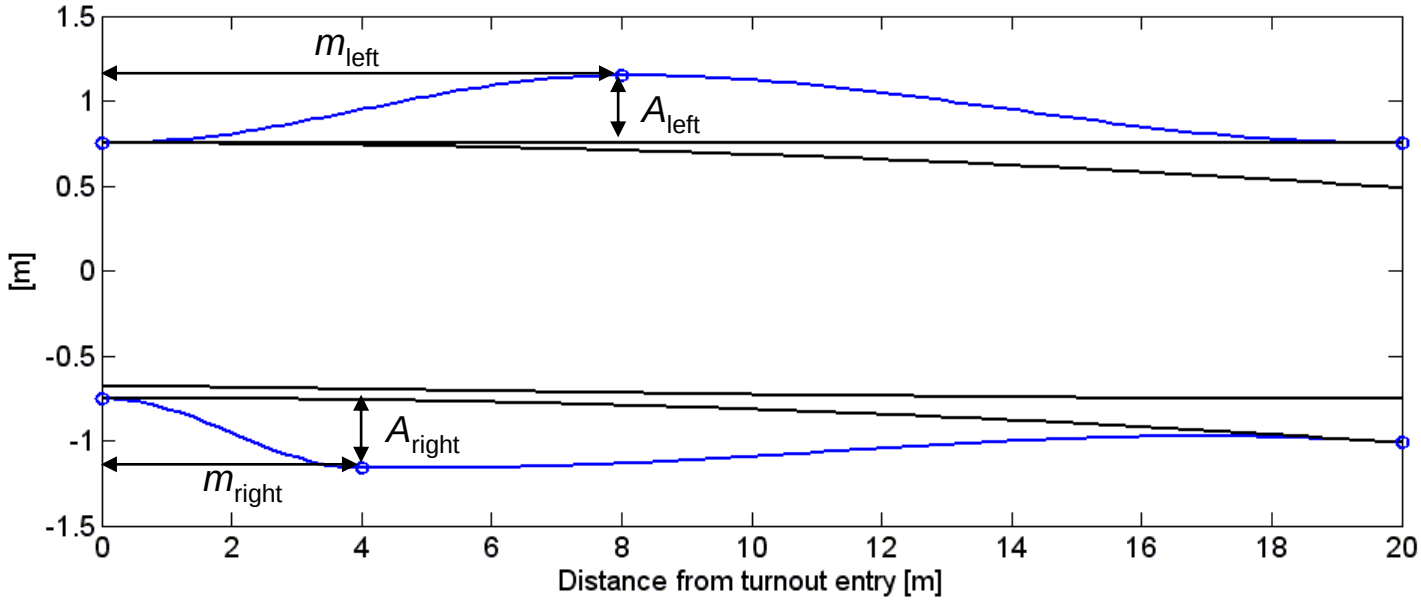
The idea





- Sufficient for the through route
- Helps in the diverging route

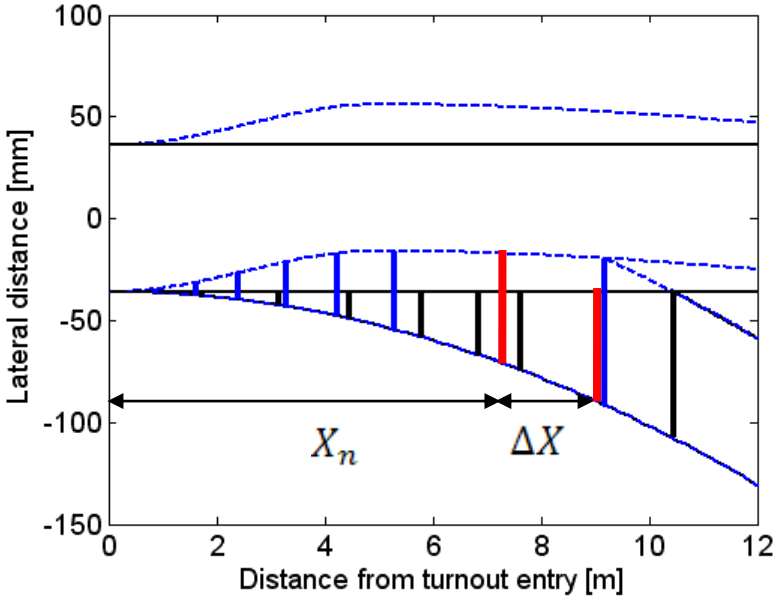
Design Variables

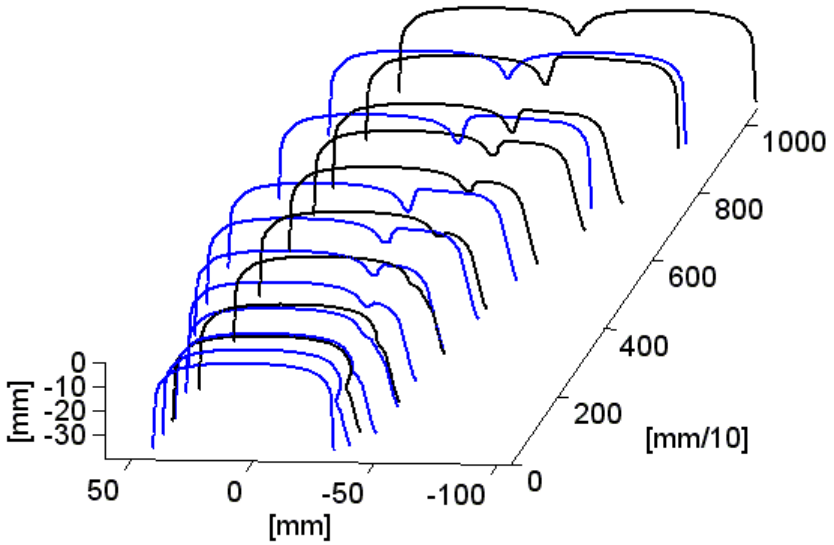


The gauge widening is parameterized by two variables on each side

$2.5 \leq m_i \leq 10$ [m] $\quad 0 \leq A_i \leq 20$ [mm]

Design Variables





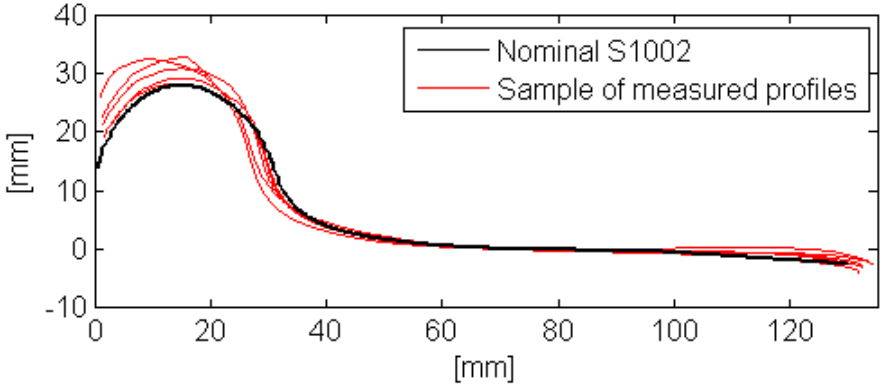
The switch rail becomes thicker when gauge widening is introduced

Objective(s)

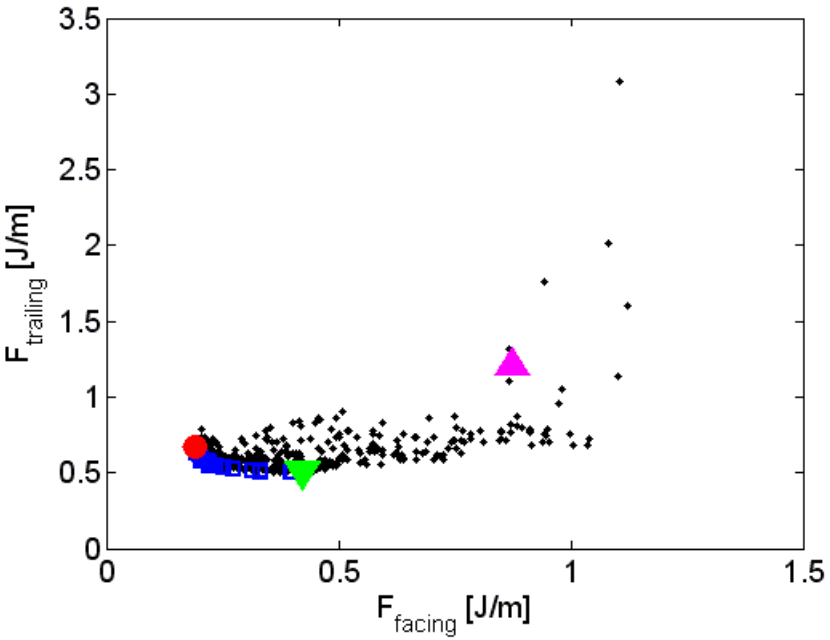
Minimize energy dissipation measure *F* in contact patches

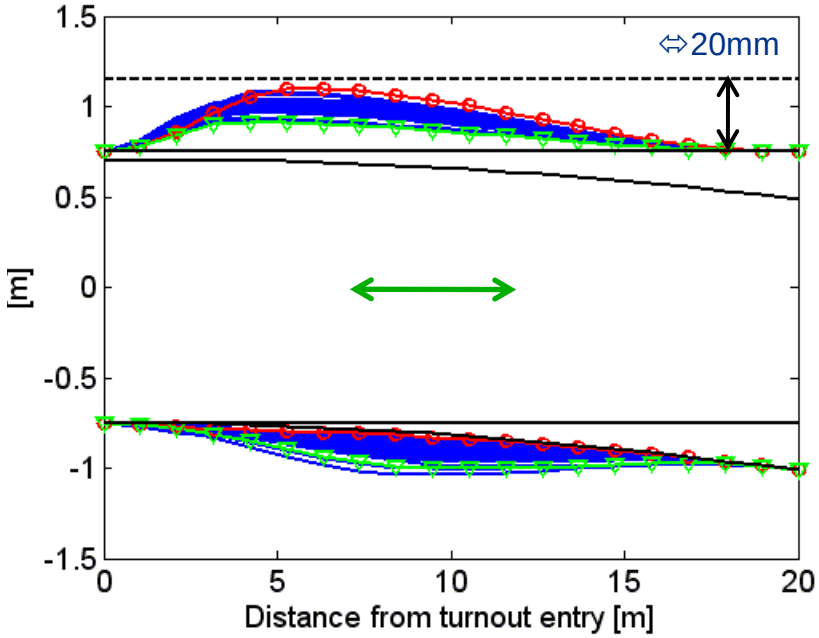
- Indicator of material removal
- Indicator of contact conditions
- Multi objective formulation
  - min(F_{divr},$F_{through}$)
  - min(F_{facing},$F_{trailing}$)

- The evaluation for each traffic direction is based on a sample of five runs with different sets of wheel profile and friction coefficient
- The samples are obtained using Latin Hypercube Sampling (a Monte Carlo method)



Results, Through Route

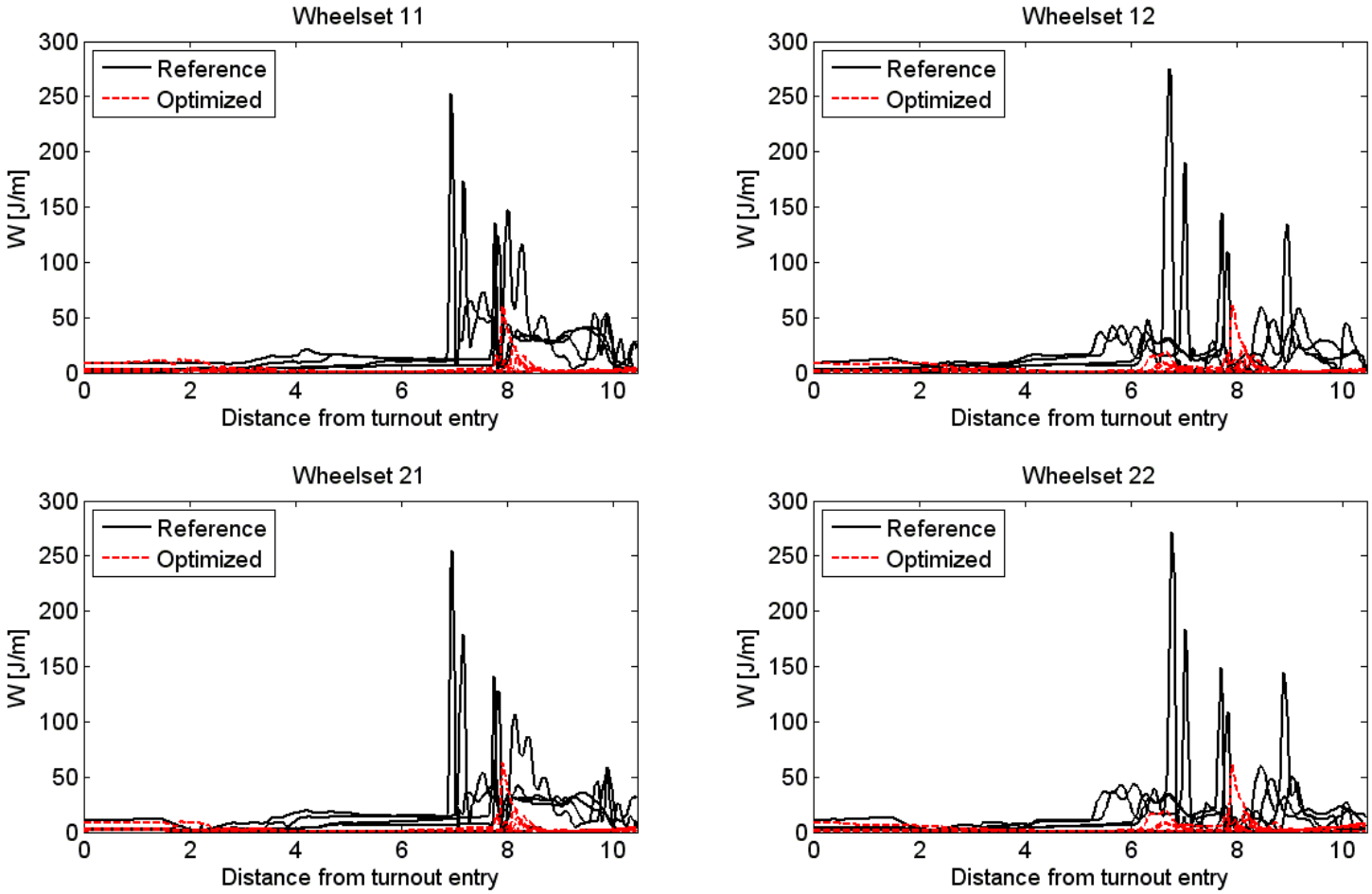




The Pareto front consists of non-dominated points where it is not possible to move to another point without worsening at least one of the objectives.

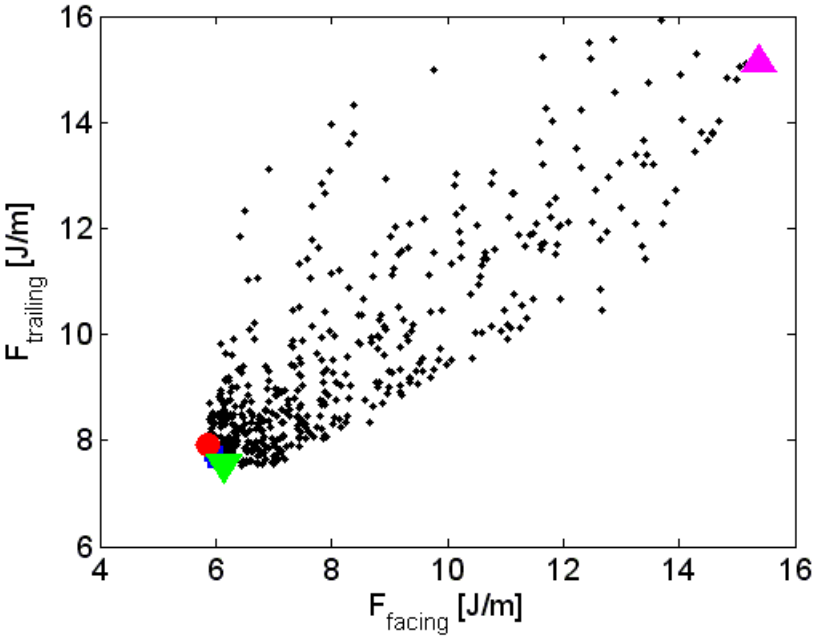
Genetic type algorithm *gamultiobj* in Matlab is used for the optimization.

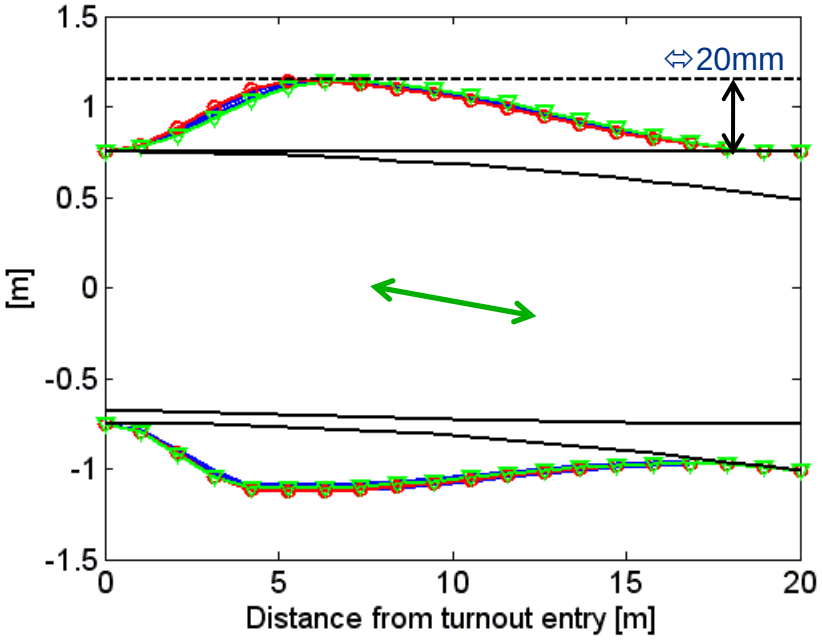
Optimum for Facing Move in Through Route



Results, Diverging Route

$$\min\left(F_{\text{facing}}, F_{\text{trailing}}\right)$$





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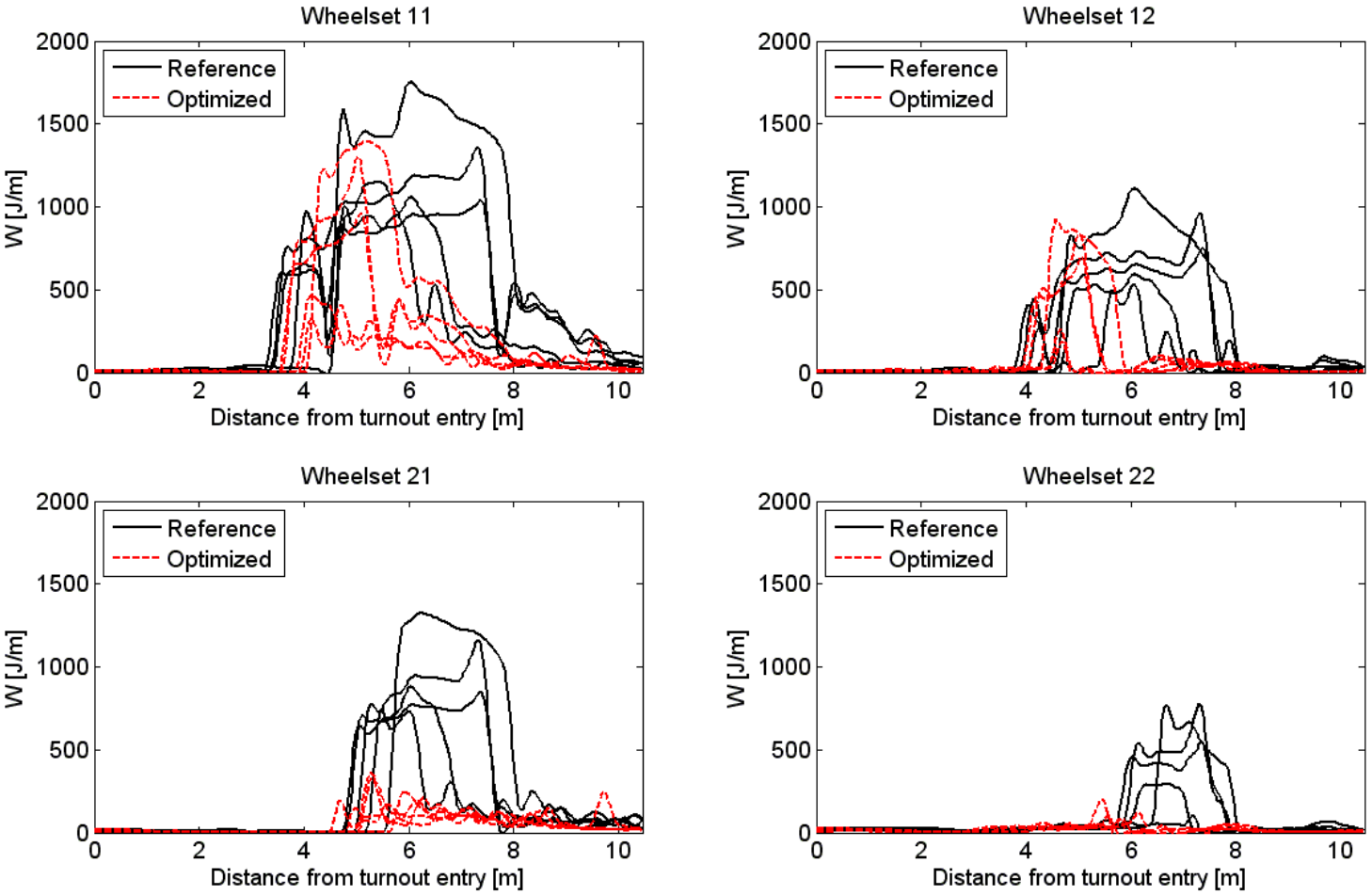
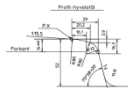
Optimum for Facing Move in Diverging Route

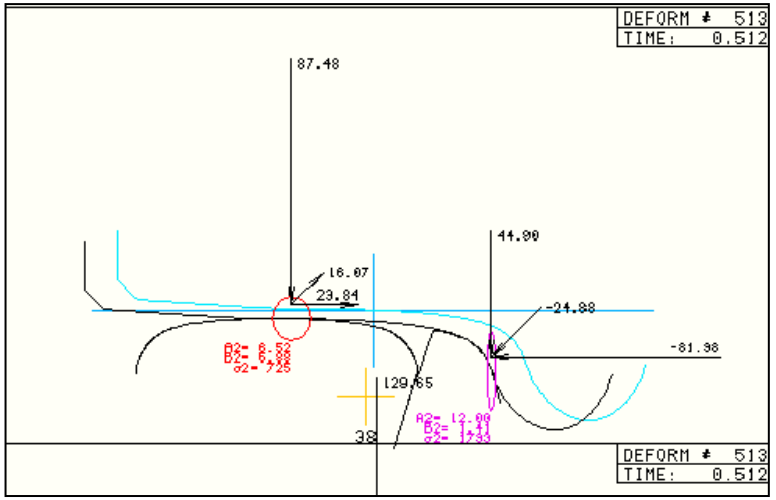




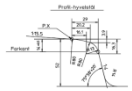
Mitigations For r-r Deficiency in Switches

Switch rail profile geometry

The height and shape of the switch rail will affect the location of the wheel transition from stock rail to switch rail

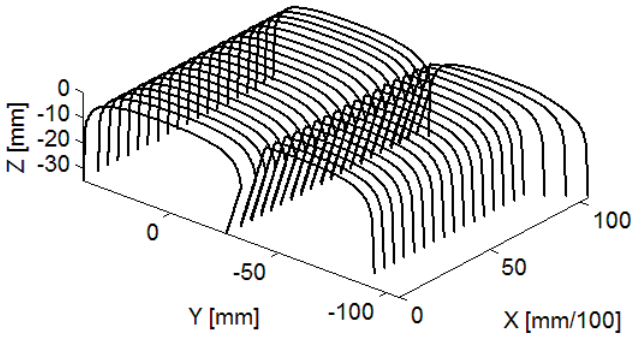


Helps in the diverging route, but the strength of the switch rail is a critical point

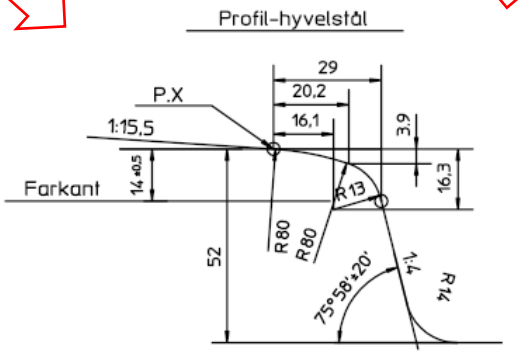


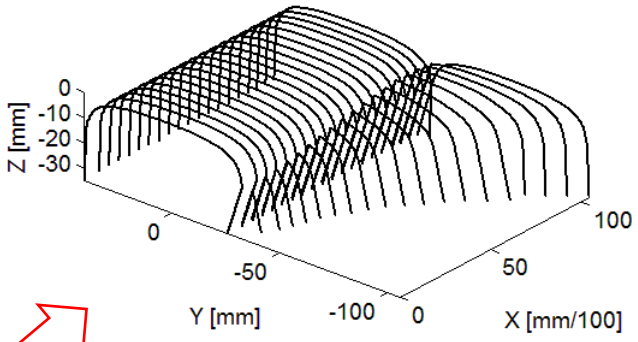
Switch Rail Base Design

Trafikverket 60E1-760-1:15 switch design is used as a starting point

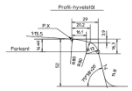


Rail Specimen

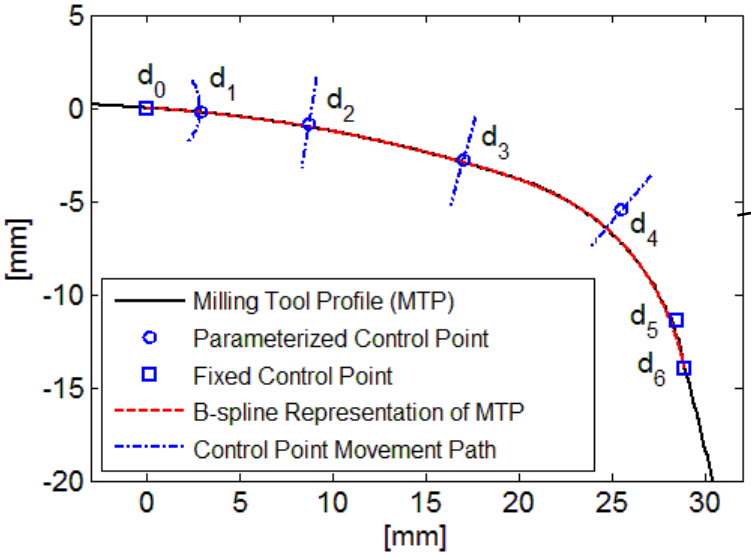


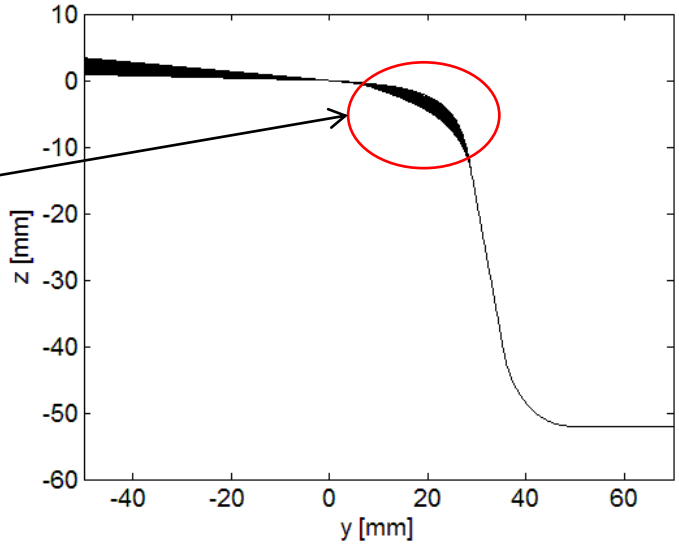


Milled Switch Rail



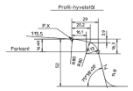
Milling Tool Parameterization



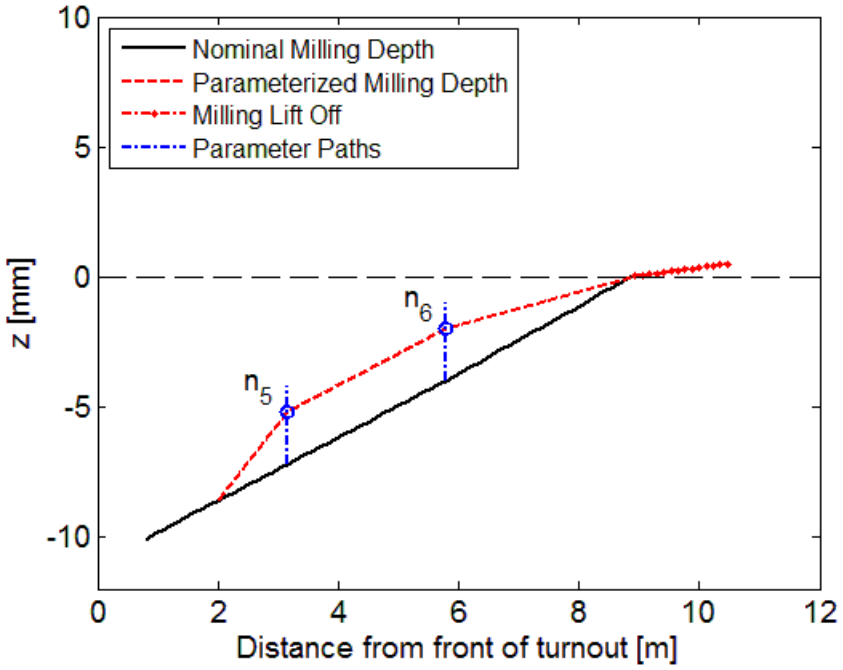


The profile is parameterized using B-splines and the shape is determined using control points

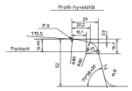
Profile variation range

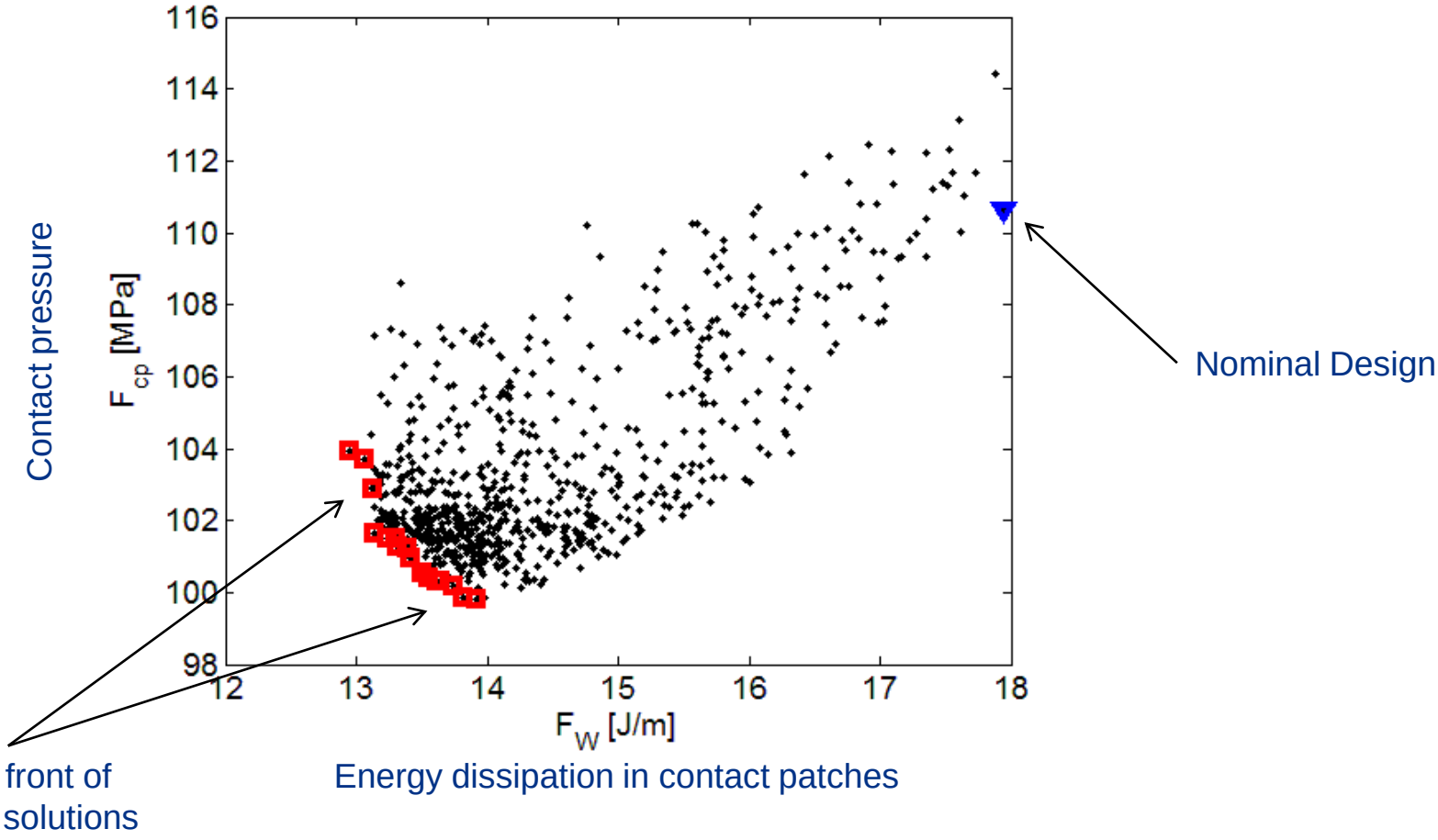


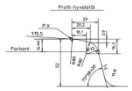
Vertical Milling Path Parameterization



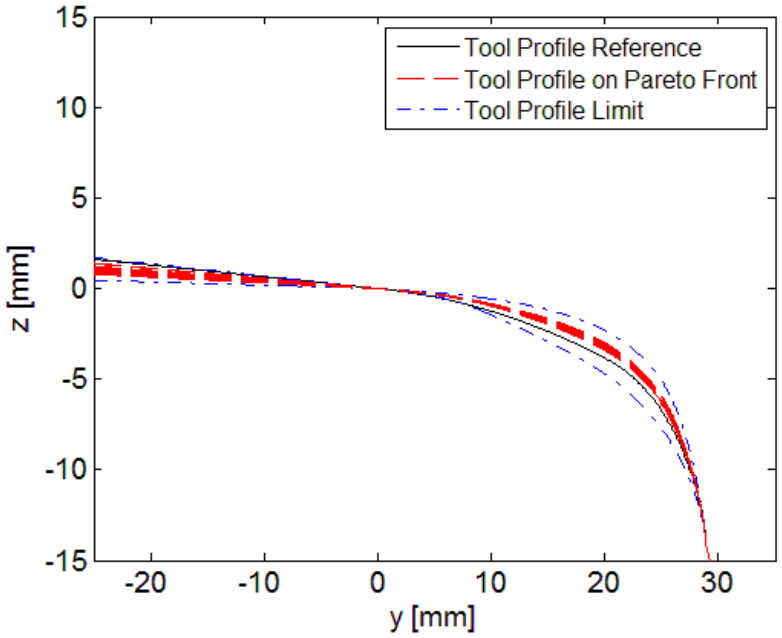
Results

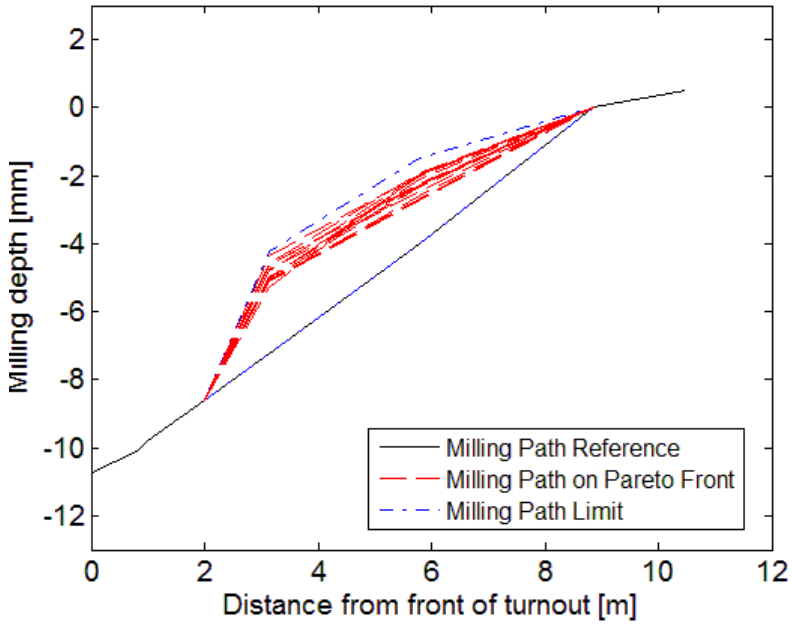



Contact pressure
F_{cp} [MPa]
116
114
112
110
108
106
104
102
100
98
12
13
14
15
16
17
18
F_W [J/m]
Nominal Design
Pareto front of efficient solutions
Energy dissipation in contact patches

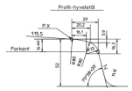


Pareto Front Configurations



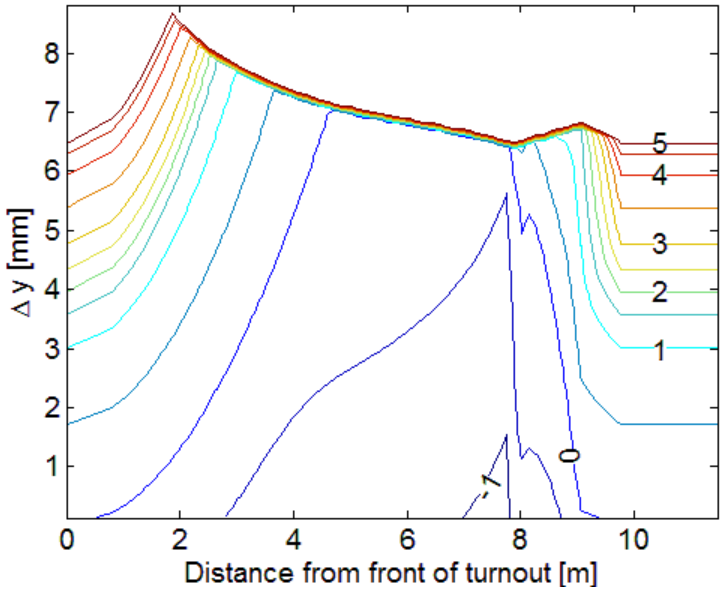


There is little variation in the Pareto variable sets

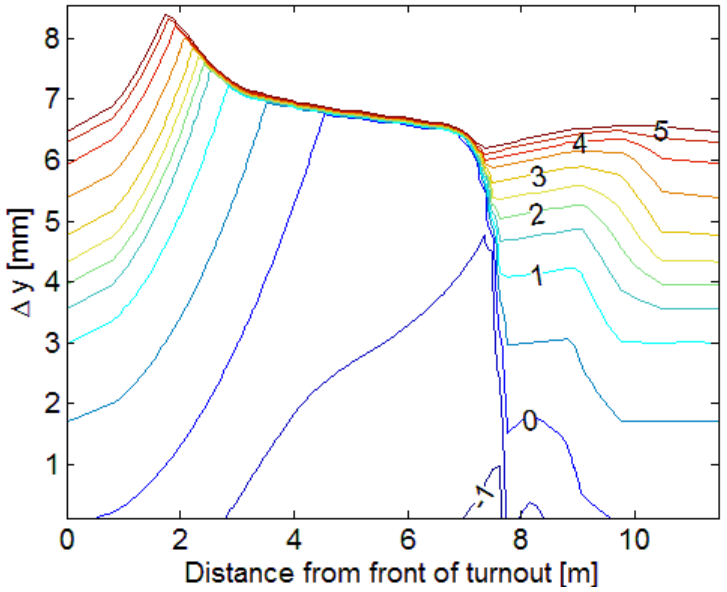


Rolling Radius Difference

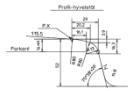
Nominal



Optimized

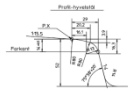


The optimzed solution is highly dependent on the switch rail thickness that can carry the full wheel load. It is here assumed to be 30 [mm].



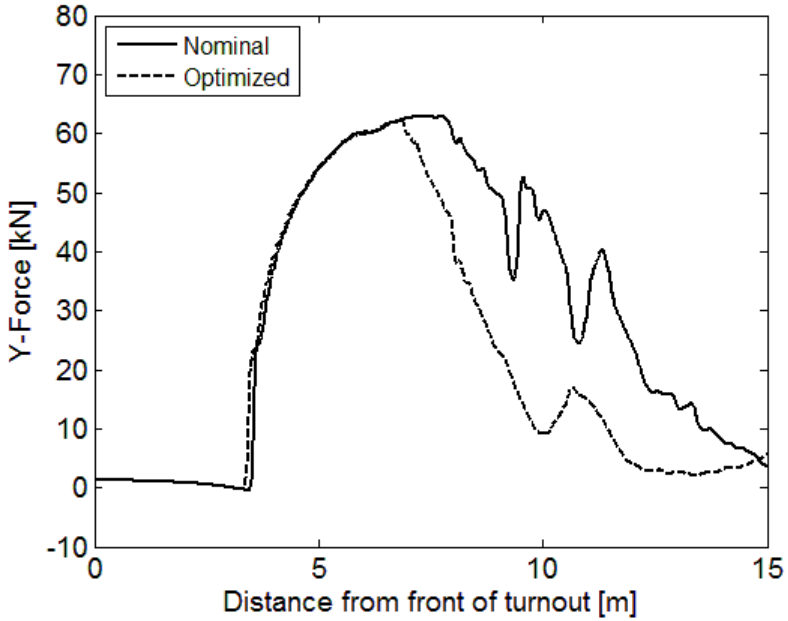
Transition Zone

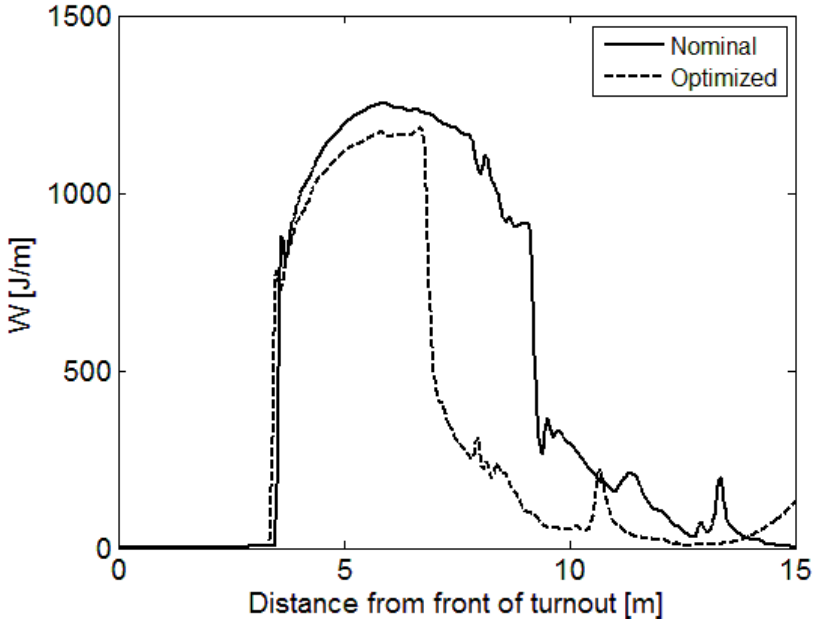
The transition zone will move towards the front of the turnout with the optimized geometry



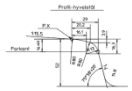
Performance Comparison

-Facing move, diverging route





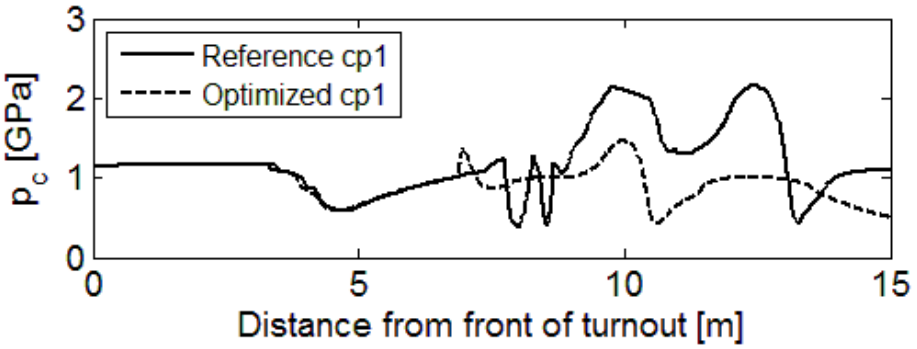
Significant improvement is found in the optimized configuration.
However, the magnitudes are still large where the switch rail is weakest.

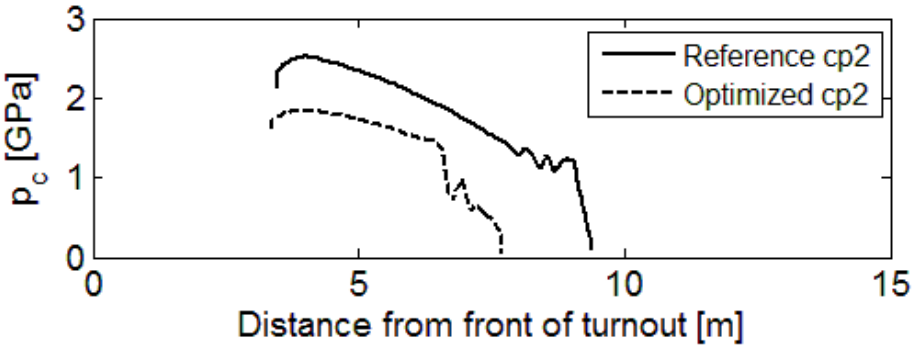


Performance Comparison

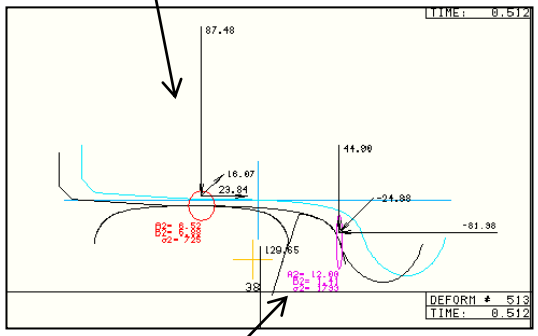
-Facing move

Contact pressure histories for both contact points





Tread Contact



Flange Contact

Discussion

- According to simulations, gauge widening can drastically reduce damage in the through route and reduce it in the diverging route
- Optimization of the switch rail profile can help reduce damage in the diverging route.
- The potential for profile optimization is highly dependent on the switch rail loading that can be tolerated
- A combination of the methodologies would probably provide the best result.

THE END