Numerical prediction of track settlement in railway turnouts

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Contents

• Objectives of CHARMEC TS15
• Introduction
• Numerical prediction of track settlement in S&C
  – Simulation of vehicle-track dynamics
  – Finite element simulation
  – Settlement calculation
• Outlook
Existing knowledge within Trafikverket shows that the main reason behind the high maintenance costs for switches (turnouts) is the need to repair and replace crossings and switch blades. These components are not sufficiently stable in level and alignment (track geometry) over time. Trafikverket states that bad track geometry increases the degradation rate leading to higher dynamic forces. They induce larger stresses and raise the risk of crack development.

Xin Li, 01/10/2012
Objectives of CHARMEC TS15

• Focus on Switches and Crossings (S&C)
  – Reduce
    • traffic disturbances
    • need for maintenance & life cycle costs
  – Increase understanding of track geometry degradation
  – Develop an iterative model for prediction of track settlement
  – Optimize S&C design
  – Cooperate with parallel research project at LTU
Introduction

• Definition of track irregularities

Introduction

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Introduction

• Load distribution
Introduction

- Definition of track substructure components
Introduction

• Settlement characterisation:
  – Two phases of settlement
    1. Short term settlement: fast settlement directly after tamping
    2. Long term settlement: slower linear settlement against time (or load)

\[ y = \gamma (1 - e^{-\alpha x}) + \beta x \]
\[ y = \gamma + \beta x \]

Introduction

• Settlement sources
  – Sleeper movement and ballast migration
  – Volume reduction due to particle rearrangement
  – Particle breakage
  – Abrasive wear
  – Subballast or subgrade penetration
  – Inelastic recovery during unloading

Introduction

• Differential track settlement
  – Track stiffness variation
    • Transition zone
    • Rail joint
    • Turnout
    • Voided sleeper
  • Heterogeneity in track components
    – Sleeper spacing, sleeper properties (length, width, material)
    – Discrete nature of ballast particle
    – Subgrade change
Iteration scheme

I Simulation of vehicle-track dynamics

Wheel-rail contact forces

Update degraded geometry

II Finite element simulation

Sleeper-ballast contact pressure

III Settlement calculation

Load cycles

Settlement

IV Summation of settlement
Simulation of vehicle-track dynamics

Train-turnout interaction is simulated in GENSYS

MBS-model
Freight train featuring Y25 bogies

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

Co-following track model(s)

Reference: Pålsson, B. CHARMEC

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Finite element simulation

Finite element simulation

Finite element simulation

Beam elements accounting for variation in rail cross-section

Discrete springs and dampers for elastic elements, ballast and subgrade

Modelling of track settlement

- **Empirical models**

  - $\varepsilon_i$ is permanent strain after first cycle
  - $C$ controls deformation rate
  - $\gamma$ gives the severity (size) of the settlement
  - $\alpha$ indicates how quickly the initial part of the settlement attenuates
  - $\beta$ determines the long-term settlement.

  US model:  
  **considers wheel load magnitude**

  JP model:  
  **capture initial short term settlement**

  *Settlement does not happen if the load magnitude is below a threshold value*

1. Crushed stones give a (much) lower value of $\beta$ than gravel.
2. $\beta$ is proportional to the square of the velocity of the repeated loading.
3. Soil contamination of the ballast may improve (if dry) or worsen (if wet) the settlement.
4. $\beta$ is proportional to sleeper pressure.
5. $\beta$ is proportional to ballast (vertical) acceleration.

The two last items are of particular interest in this study, as they are relatively easy to manipulate when building a new track or when renewing an old track. The sleeper pressure may be lowered by making the sleepers wider or by installing them closer together in the track. The sleeper pressure may also be changed by changing the pad stiffness and/or the rail bending stiffness and/or by using under-sleeper pad. The ballast acceleration is influenced by, for example, the speed of the train and the irregularities on the rail head and on the wheel tread.

Xin Li, 01/10/2012
Modelling of track settlement

- Constitutive models
  - Settlement envelop
  - Discrete Element Method

Outlook

• Document current literature survey
• Start dynamic simulation in GENSYS
• Implement empirical settlement model
• Perform iterative simulation scheme
• Compare the result from iterative scheme with data from literature and validate its functionality