Advanced track modelling for the simulation of the derailment of a Eurocity train in Lucerne in 2017

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Lucerne, March 21st 2017, 13:57: Derailment of EC158
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\begin{itemize}
  \item 7 people slightly injured
  \item Station closed for several days
  \item Immense damage at vehicle and infrastructure of 11 million CHF
\end{itemize}
Sequence of derailment

→ Train was running with 37 km/h
→ First wheelset of wagon 5 derailed on switch DKW63
→ Left wheel fell between switch rail and stock rail
→ Switch showed no severe damage and was not replaced after the accident
Hypothesis 1: Derailment caused by wheel climbing

- Derailment occurs when the relation of lateral force to vertical force exceeds a certain value.

- This can be influenced by:
  - wheel unloading (e.g. caused by twist or vehicle failure)
  - high lateral forces (e.g. caused by vehicle failure)
  - high friction between wheel flange and rail (dry weather conditions)

![Diagram of wheel flange forces at incipient derailment](EN 14363:2016 (E))
SIMPACK-Model of the vehicle

→ Rigid carbody
→ Detailed model of bogie including
  • tilting actuators
  • active lateral spring
Extension of standard track model

- Standard track is modelled as one body representing the both rails and the sleeper with one central spring for the stiffnesses
  - in vertical direction
  - in lateral direction
  - about longitudinal axis
Extension of standard track model

- Additional sleeper suspension spring
- Consideration of ground stiffness calculated from deflection measurements
- Evaluation of influence of twist resulting from stiffness differences right and left
Measured rail profiles

- Processing of 3D scan
- Using s-variable rail profiles
Hypothesis 1: Derailment caused by wheel climbing

- Several simulations were performed with different parameters:
  - Velocity
  - Friction between wheel and rail
  - Track twist due to deflection and geometry deviation
  - Track gauge variation
  - Rail and wheel profile variation
  - Vehicle failure (wheel load differences, high lateral forces)
  - Track layout

- Even the superposition of all negative influences did not lead to a derailment

- Unrealistic high values have to be chosen for the influencing parameters to enforce a derailment

- Hypothesis of wheel climbing was dismissed
Lucerne Station
Special switch layout

- Steepened double switch 1:9/1:7

- Radius starts in front of the switch rail (normally at the switch rail)
Special switch layout

- Switch layout influences the forces at the entrance of the switch

Standard switch:
lateral movement of wheelset due to curve entry
starts after the rail profile changes

Steepened switch:
laterally moved wheelset runs into the profile change (start of switch rail)
Movement of rails during train passage
Movement of rails during train passage
Hypothesis 2: Wheel ascends the switch rail

- Video of rail movement at the switch entrance shows large gap between switch rail and stock rail
- The switch rail can contact the wheel flange near the flange top
- Is it possible that this can lead to an ascending of the wheel on the switch rail?
Measurement of rail movement
Advanced modelling of track

- Separate bodies for the sleeper, stock rails and switch rails
- Suspension of rails (constant and distance dependent stiffnesses)
- Wheel/rail contact force elements to each rail body
- Stop between stock rail and switch rail
Evaluation of stiffnesses from Measurements

- Adjusting the stiffness values to the measured displacement
Lateral stiffness of switch rail

Analytical estimation of lateral stiffness depending on distance
Simulation with advanced track model

→ Wheelset is able to run over the gap
Measured wheel profiles

- Wheel profile of car 5 shows special shape at the tip of the wheel flange
Simulation with measured wheel profiles

→ Hypothesis of wheel ascending on switch rail was confirmed
Simulation with measured wheel profiles
Conclusion

➔ In November 2017 an ICE train derailed in Basel on a switch of the same type. The wheel profile of the derailed wheelset showed the same characteristic.

➔ All switches of this type were inspected and reinforced to prevent the risk of further derailments.

➔ Several tracks of Lucerne station were renewed in 2018. This planned renovation was used to change the layout and enable the use of standard double switches.

➔ In September 2019 the report of the Swiss Transportation Safety Investigation Board was published *). The analyses of other experts show similar conclusions.

➔ Though this advanced track modelling is not standard it could quite conveniently be modelled using standard SIMPACK Wheel/Rail elements. It does not cover all aspects of the track behaviour but was sufficient to find the cause of the accident.

Thank you for your attention.