Track Maintenance for High Speed Rail

Railroad Infrastructure Diagnosis and Prognosis

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Track Maintenance for High Speed Rail – Perspective

- Currently, by international standards, there is no HSR in North America
- There is a large body of experience in higher speed rail
  - Amtrak NEC, speeds up to 150 MPH
  - Porter, IN to Detroit, MI, speeds up to 110 MPH
  - Poughkeepsie, NY to Hoffmans, NY, speeds up to 110 MPH
  - Joliet, IL to East St. Louis, IL, speeds up to 110 MPH
- Even though North America is not quite there yet, the lessons from around the world are clear
  - Technology is transferable
  - Will require North American railway engineers to think differently
- Focus here is on true high speed (300 KPH or higher)
What is a Good Approach to High Speed Track Maintenance?

- Starts with good construction standards focused on
  - High quality track structure, **UNIFORMLY** supported
  - Track quality is also married to systems

- Performance based safety and maintenance standards
  - Safety is job one, ride comfort is job two
  - Track and vehicle perform dynamically as a system

- Inspection and maintenance based on data
  - Requires automated inspection backed by data analysis
  - Maintenance plans based on proactive repair
  - Dedicated maintenance windows

- Good work methods
A Look at Performance Based Standards

- What about FRA 213 Subpart G?
  - FRA standards are prescriptive, based on high probability of derailment
  - Can’t afford to operate HSR at rejection limits
    - Speed restrictions kill schedules and service reliability
    - Does not give repair crews time to properly plan and execute work
    - Ride quality probably impacted before rejection limits reached
  - Multiple small defects (within limits) can cause problems
    - Combination defects
    - Small defects that lead to harmonic behavior of vehicles, discomfort

- Vehicles may not tolerate some deviations in lower track classes governed by 213 Subparts A thru F
A Look at Performance Based Standards

- Where do we start?
  - With a known vehicle
    - Suspension type, characteristics must be a known, also car body parameters
    - Existing vehicle should have a dynamics “model” already developed
  - If the vehicle is entirely new, a dynamics model must be developed
    - Can estimate parameters initially
    - Must verify with prototype when built and tested

- Once rolling stock models are available, they can be tested
  - On existing track based on data from geometry cars and other sources
  - Deviations can be identified that excite the vehicle
    - FRA has limits on wheel/rail interactive forces (L/V, NAL, etc.)
    - Those passing FRA but violating ride comfort criteria
A Look at Performance Based Standards

- At the end of the day, good riding comfort will be obtained when:
  - Geometry deviations are identified that excite the vehicle
    - Single deviations
    - Multiple deviations of the same type
    - Combination deviations
  - Wheel/Rail interaction is controlled
    - Poor contact geometry can trigger hunting or high interactive forces
    - Efficient conformity between wheel and rail can be:
      - Modeled
      - Tested with prototype
- When the vehicle/track forces are under control, the track maintenance work load will be minimized
A Look at Performance Based Standards

- The standards particular to an HSR system should include limits based on:
  - Action required by regulator (FRA)
  - Action required by internal standards, especially where ride quality is compromised
  - Getting out and doing planned renewals/repairs economically before the first two bullets kick in
Inspection and Maintenance Based on Data

- Be prepared for big data
  - Multiple inspection systems tied together generate huge amounts of data
  - Trending based on advanced statistical tools requires large amounts of data...
    - Bayesian methods
    - Neural networks
    - Be able to handle small probability occurrences

- With autonomous sensors, can inspect real time in revenue service
- Inspection trains perform many types of inspection at revenue speed
- Those functions inspecting at speeds slower than revenue must fit into scheduled maintenance windows
Inspection and Maintenance Based on Data

- Inspection frequency should be based on what the data shows:
  - Degradation rates, statistically derived
    - Based on probability envelopes, not simple mean trend lines
    - Typically data exhibits saw-toothed tendencies
  - Minimum intervals that guard against small probability events
- Communications systems go hand in hand with real time inspection
- Inspection can be accomplished by identifying exceptions to normal
  - VTI accelerometer reading that does not match normal results
  - Helps cover unanticipated failure modes
Inspection and Maintenance Based on Data

- Technology supporting inspection is good and will only get better.
- Work still needed to make systems cross talk (software protocol).
- Examples:
  - Drones with cameras for external roadbed integrity.
  - GPS antennae for location.
  - LIDAR for location and shape (i.e. ballast section).
  - GRMS for lateral track strength.
  - Line scan cameras for tie and fastener integrity.
  - Accelerometers for measuring Vehicle Track Interaction (VTI).
  - GPR for internal roadbed integrity, ballast condition.
  - Non-stop testing for internal rail flaws.
  - Rail surface analyzers.
Maintenance Plans Based on Proactive Repairs

- Fix it before it breaks
  - Less disruption, less service impact
  - Less costly to do planned repairs than running around fixing broken things
  - Trend degradation from big data streams, combine with probability models

- When something does fail in-service, chase the root cause to ground
  - Check against degradation trend models
    - Outlier?
    - Model need updating?
  - Was there a clue of impending failure from a secondary inspection source?

- Requires analyses of many possible failure modes
Renewal versus repair
- In a complex asset (i.e. turnout) consider workload likely in the future and how many outages/mobilizations would be required to repair components one at a time rather than replace the whole turnout
  - Outages may impact customers
  - Mobilizations impact labor costs
- Renewals are preferred when repairs might jeopardize ride quality
  - Sometimes repair quality in the field is difficult to obtain
  - If possible, repair materials should be specifically designed to fit in a worn situation
Maintenance Plans Based on Proactive Repairs

- **Focus Areas**
  - Safety/Reliability
  - Ride Comfort
  - Forecasting asset replacement

- **Examples**
  - Integrity of track structure
  - Geometry
  - Rail surface and profile
  - Track support
    - Subgrade
    - Ballast condition
All track, particularly when ballasted, must be referenced

- Referenced means a system that enables staff to know where each foot (meter) is in space (x,y,z) with a high level of accuracy
  - For design
  - Where it is currently
- Tampers capable of working with references can put track back on design
- With only internal chords as reference, the tamper will only be able to smooth with the following long-term impacts:
  - Curves points will drift, possibly with mismatched superelevation
  - Curves will drift from uniform to variable radii
  - Tangents will develop multiple bearings

Referencing track is becoming less expensive as technology improves
Good Work Methods - Examples

- Measure track quality before work
- Measure track quality after work as well
- Notice in the example that there are still significant errors at the 10th percentile level after work
- Why?
- Study and fix process!
Good Work Methods - Examples

- “After” measurement for surfacing shows almost no improvement
- How can that be?
- Problems with US equipment, methods?

![Graph showing cumulative distribution and average error for RProf124 Error + XL Error (inches) for Track 2. Data taken nine months apart.]
Good Work Methods - Examples

- Turns out to be a problem worldwide as this data from Europe shows
- Track returns to its former shape quickly after surfacing
- Why?

Courtesy Steven Chrismer, PhD
Good Work Methods - Examples

- Track raises less than 20mm are not durable
- Track has to be “over lifted” to achieve desired results
- Making surface corrections without over lifting results in short return tamping cycles
- Short tamping cycles destroys ballast...
- Ballast renewal is disruptive and expensive

Track Settlement (mm)

Initial Track Lift (mm)

Courtesy Steven Chrismer, PhD
Summary – Keys to Good High Speed Track

- Good construction standards
- Performance based safety and maintenance standards
- Data driven inspection and maintenance
- Good work methods

THANKS FOR YOUR ATTENTION!