Vision Based Wheel Condition Monitoring

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Condition Based Maintenance
Benefits for the Industry

- High Availability of Rolling Stock
- Optimum use of personnel for Maintenance
- Preventative Maintenance
- Need Based Maintenance vs Time based Maintenance
- Minimizing Timely and Unscheduled Maintenance to Prevent Adverse Impact on Operation
- Monitoring Leading Indicators
- General Fleet Weakness and Failure Point Detection
- Cost Savings
- Reduce Risk to Personnel / Increased Safety
Industry Expectations from TCM systems
Reduced Cost with Higher Reliability, Freight vs Passenger

Operations Consideration
• Painless Operation
• Reliability
• Availability
• Verifiability
• High Enough Accuracy
• High Data Quality
• Actionable Information

Business Considerations
• Inspection of Rolling Stock Using Technology
• Predict and Prevent Failures
• Move Hard Decision Away from the Maintenance Crew
• Minimize Depot Maintenance Visits
• Use Labor to Repair
• Drive Planning and the Supply Chain through CM
• Prevent Disasters
Main Wayside Detector Types
From 40’s to 2101’s and Future

Wayside Detectors have been deployed since early 1950’s with first talkers at 60’s

- GEN 1: Hotbox/Hot Wheel (1950’s with IR Detectors)
- GEN 2: WILD and Acoustic Bearing Detectors (1980’s)
- GEN 3: Wheel Profile Measurement (Early 2000’s)
- GEN 4: Brake Shoe and simpler Image Based Systems (2000’s)
- GEN 5: Vision Based Inspection Systems (2010’s)
- Next Generation: Full Vision Inspection along with Multispectral/Thermal/3D aligned with other non-contact sensing technologies

There has been some attempts to bring Ultrasonic, EMAT, X-Ray, Thermal, Radar, Lidar and other NDT techniques to mainline wayside detection systems.
Characteristics of Vision Based Systems
Cameras to Improve Inspector Eyes

- **Versatility**: Cameras see a Whole Lot
- **Fast**: Sophisticated Inspections at Speed
- **Easy Verification**: Verification is Usually Very Easy with Access to Images
- **Data Presentation**: Intuitive with Combination of Data and Images
- **Processing Categories**: Measurements vs. Inspections (Detection)
- **System Categories**: Component Specific to Area Specific Imaging
- **Capabilities**: Complex and Accurate Measurements/Inspections
Characteristics of Vision Based Systems

Complexities of Vision Based Systems

- **High Computational Complexity**: Demand for High Computational Power
- **Development Time**: Sophisticated Vision Algorithms Takes Time to Mature
- **Large Data Volume**: GBytes of Data per Train
- **Power**: Some Systems are Power Hungry
- **Availability**: Keeping Systems Fully Operational 24/7
- **Ambient Light is the Main Enemy**: Only a Well Designed System Can do the Job
- **Not as Easy as it may Look!**
A Typical US Vision Detector Site

Usually Multiple Sensors are Installed in One Location
In this site systems that are installed listed from left to right: Coupler Inspection System, Undercarriage Inspection System, Wheel Profile Measurement, Brake Shoe Measurement, and Truck Inspection Systems
A Typical Western Australian Site

Usually Multiple Tracks are Equipped with Detectors
This is a double track site with several systems installed on each track.
A Typical Passenger Train Inspection Site

A Typical Successful Example

- Wheel Profile and Brake Pad Units Installed
- Painless Operation for 5 years
- Very Reliable
- More than 99.9% Availability
- Yearly Verification
- Accuracy to the Level of 0.2mm
- High Quality Data
- Replaced Manual Measurement for Daily Maintenance
- Operates on Different Types of Rolling Stock

Helsinki, Finland Passenger Train Operation
Different Vision System Types (1)

Laser Based Systems

- Wheel Profile Measurement
- Total Wheel Inspection
- Brake Pad/Shoe Measurement
Different Vision System Types (2)

Pure Image Based Systems

Brake Shoe Measurement

Bogie (Truck) Inspection

Undercarriage Inspection
Different Vision System Types (3)
Laser/3D/Image/Thermal Imaging Based Systems

- Pantograph Inspection
- Total Train Inspection
- Brake Disk Measurement
Typical Images from Different Systems
Real Images from Real Systems
Complete Optical Wheel Inspection
Full Wheel Inspection Station
Static and Dynamic Wheel Measurements

**STATIC**
- Wheel Profile
- Wheel Diameter
- Wheel Equivalent Conicity
- Wheel Surface Defect
- Wheel Plate Inspection
- Broken Wheel Sections
- Externally Visible Cracks
- Internal Defects and Cracks

**DYNAMIC**
- Wheel Hunting
- Angle of Attack
- Back to Back
- Wheel Surface Temperature
Wheel Profile Measurement

WheelView

**Standard Measurements**
- Flange Height
- Flange Thickness
- Flange Slope
- Tread Hollow
- Rim Thickness
- Back-to-Back
- Tread Rollover
- False flange
- Tracking Position
- Wheel Diameter (Option with WV-F/I/D)

**Typical Accuracy**
- Flange Height, Thickness, Hollow:
  - General accuracy: ±0.5mm
  - Low speed depot: ±0.3mm
- B2B: ±1.0mm
- Rim Thickness: ±1.0mm
- Diameter: ±2.5mm
Wheel Profile Measurement
Raw Images from WVF
Measure Wheel Profile
Full End to End Profile
### Wheel Profile Measurement

#### Flange Thickness Measurement

<table>
<thead>
<tr>
<th>Measure</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Flange Thickness Meas.</td>
<td>0.13</td>
</tr>
<tr>
<td>Flange Height Meas.</td>
<td>1.03</td>
</tr>
<tr>
<td>Flange Height Diff.</td>
<td>0.04</td>
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<tr>
<td>Flange Length Meas.</td>
<td>0.04</td>
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<tr>
<td>Flange Width Meas.</td>
<td>0.04</td>
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<tr>
<td>Flange Width Diff.</td>
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<tr>
<td>Flange Depth Meas.</td>
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<td>Flange Depth Diff.</td>
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<td>Flange Circumference Meas.</td>
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<tr>
<td>Flange Circumference Diff.</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Flange Thickness trend showing:

- **Flange Thickness** trend showing a consistent value with slight variations.
- **Flange Height** and **Flange Width** also show similar trends.

**Graph**:

[Graph showing flange thickness measurement trends]

**Image**:

[Image of measurement software interface showing data tables and graphs]
From *Wheel Profile and Impact* to *Wheel Condition*

- Wheel profiles are measured at one or few points on the wheel.
- In wheel profile measurement systems, inherent assumption is that wheel wear is uniform.
- Impact measurement systems have an inherent assumption that the contact patch is on the defective part of the wheel and impact measurement can detect it.
- Even so, many condemnable wheel defects may not have significant wheel impact.
- Impact measurement requires a minimum speed of travel.
- Many catastrophic wheel failures do usually either start with small surface defects or demonstrate themselves as an anomaly on the wheel surface.
- **Optical Wheel Surface Inspection** has turned out to be a viable solution that can fill in the gaps.
Wheel Surface Scanning Operation
A Wheel Inspection Station

TreadView and WheelView
This site was developed to evaluate the performance of a fully automated wheel condition monitoring system. This site sees up to 60 trains a day.
Wheel Inspection in a Freight Track

TreadView
BNSF Installation of TreadView
Full Surface Condition Monitoring
Static Wheel Measurements

- **Wheel Surface Defects**
  - Shelling
  - Spalling
  - Dents
  - Flats
  - Fatigue Cracks
  - Out of Round
  - Built-up tread

- Grooves
- Broken and Separated Sections
- Externally Visible Cracks
- Shattered Rim
- Wear Variation along the wheel surface
- Significant Spread Rim
- Vertical Split Rim
Sample Wheel Defects
Detectable with TreadView

- Dent
- Built-up
- Shattered
- Shelled
- Spalled
- Skid Flat
More Defective Wheels
Built-up and Broken Rim

Built-Up Tread
Broken Rim
A Full Vision Based Wheel Inspection Station

**TreadView and WheelView**

With this station, the task of Wheel Inspection is completely eliminated from the shop floor. Wear, Tread, and Plate condition monitoring are all performed automatically.

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Full Wheel Inspection System
TreadView

Standard Measurements
• Shelled/Spalling/RCF Wheel
• Flat Wheel (Skid, Localized Collapse, Polygonazation)
• Built-up Tread
• Wheel Profile Variation
• Wheel OOR
• Missing/Broken/Shocked Flange/Tread
• Tread Groove
• Angle of Attack and Wheel Hunting

Typical Accuracy
• Out of Round : ±0.25mm
• Wheel Surface Defects:
  – Lateral : ±0.1mm
  – Longitudinal: ± 1mm
  – Depth: ±0.2mm
• Longitudinal for low speed depot: ±0.3mm
Perfect Wheel
Hollow Wheel
Measured Across the Whole Wheel
Flat Wheel
Size and Depth are Measured
A Sample 3D Map of a Defective Wheel

Shelling
TreadView Surface Defect
A Detected Shell Example
3D Wheel Surface Data
A Shell is detected on the wheel surface
Another Wheel Surface Defect
Shelled/Spalled/Built-up Tread Wheel Detection
Wheel Surface Imaging
Visual Inspection
Visual Inspection of Wheel Flats

Automatic Detection and Size Evaluation
Out of Round Measurement

Graph from Manual measurements:
- 35 mm length
- 139 mm length
- 80 mm length
- 68 mm length

Graph from TRDV:
- 0.46 mm depth
- 0.50 mm depth
Broken Wheel and its Detection Model
Wheel Surface Representation
Color Depth Display

![Diagram of wheel surface representation with color depth display, showing flange wall and tread wall with numerical scale for mm and degrees.](image)
Cracked/Broken Wheel Plate

Use Wheel Plate Images
Conclusion
Wayside Detectors and Vision Based Condition Monitoring Systems,

- Role of Wayside Condition Monitoring Systems in the Railroad Industry has become pronounced in the last two decades.
- Vision Based Inspection Systems is now playing a significant role in this sector.
- Wheel Inspection technology has reached to a mature state where a full inspection of the wheel is possible at full track speed.
- Vision Based CM systems are irreversibly changing railroad maintenance operations worldwide.
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Thank You / Questions

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