

# 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



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# 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**



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# 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.



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# 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



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# 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!



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# 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



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# 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.



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# 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



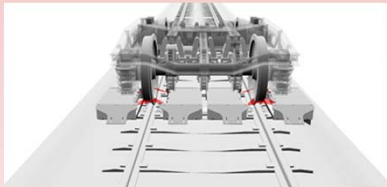
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# Different Vision System Types (1)

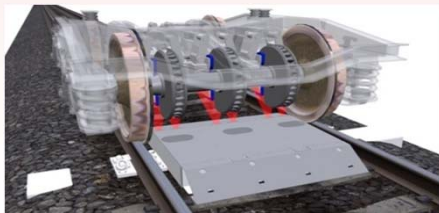
Laser Based Systems



Wheel Profile Measurement



Total Wheel Inspection



Brake Pad/Shoe Measurement



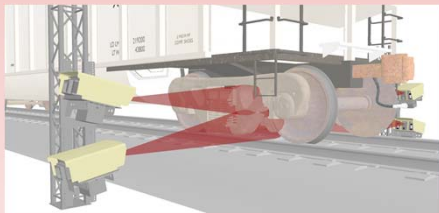
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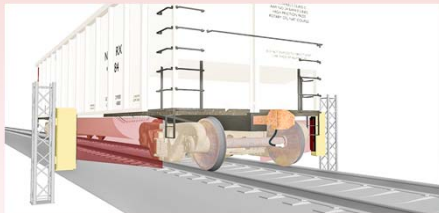
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# Different Vision System Types (2)

Pure Image Based Systems



Brake Shoe Measurement



Bogie (Truck) Inspection



Undercarriage Inspection



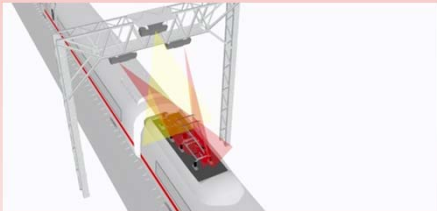
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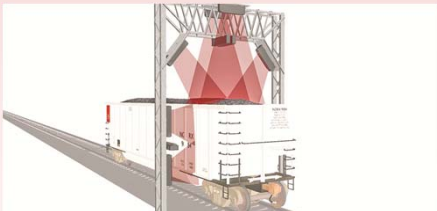
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# Different Vision System Types (3)

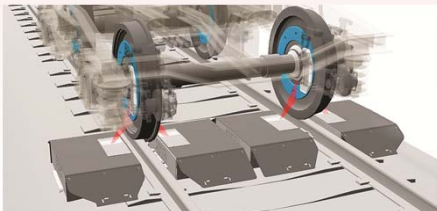
Laser/3D/Image/Thermal Imaging Based Systems



Pantograph Inspection



Total Train Inspection

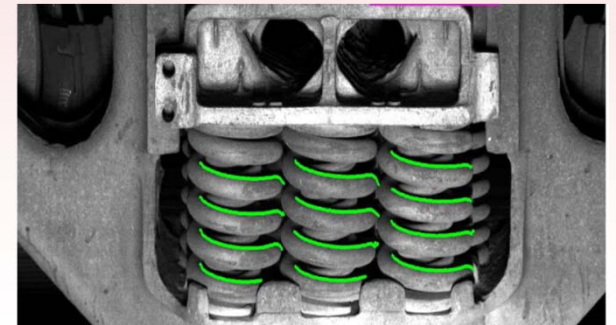
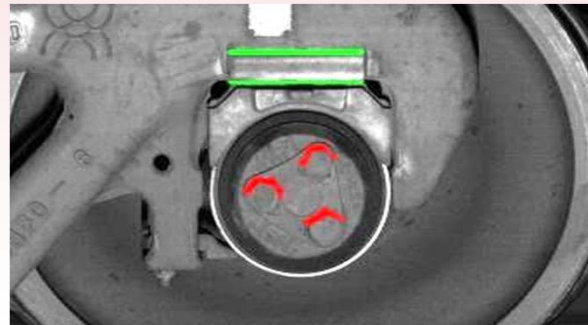
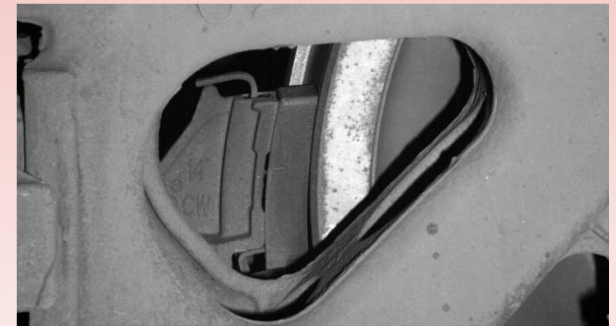
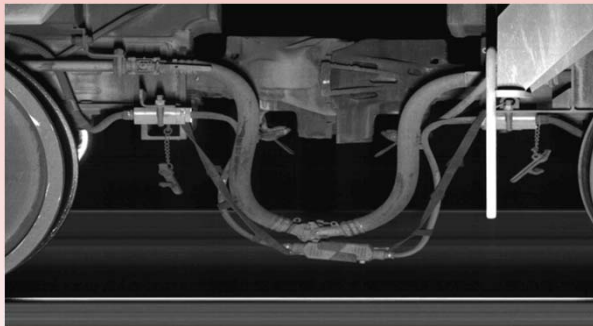


Brake Disk Measurement



# Typical Images from Different Systems

Real Images from Real Systems

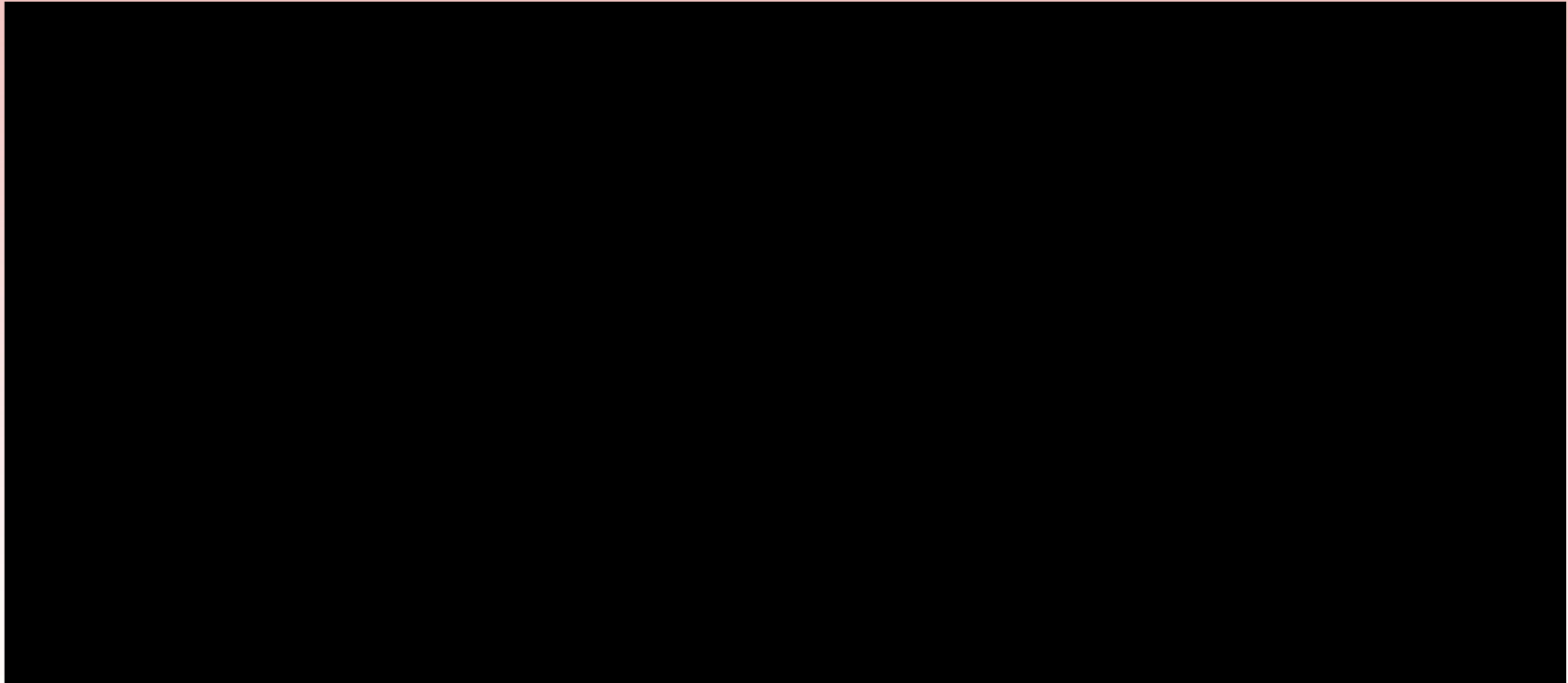


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US/Australia /Europe Sites



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# 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



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# 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:  $\pm 0.5\text{mm}$
  - Low speed depot:  $\pm 0.3\text{mm}$
- B2B:  $\pm 1.0\text{mm}$
- Rim Thickness:  $\pm 1.0\text{mm}$
- Diameter:  $\pm 2.5\text{mm}$



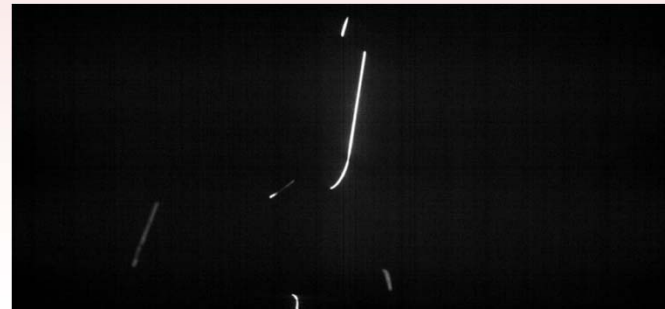
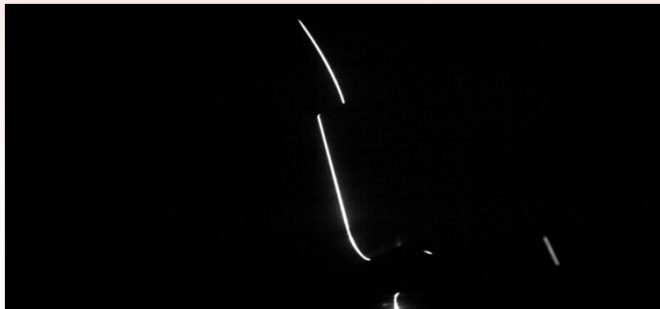
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# Wheel Profile Measurement

Raw Images from WVF



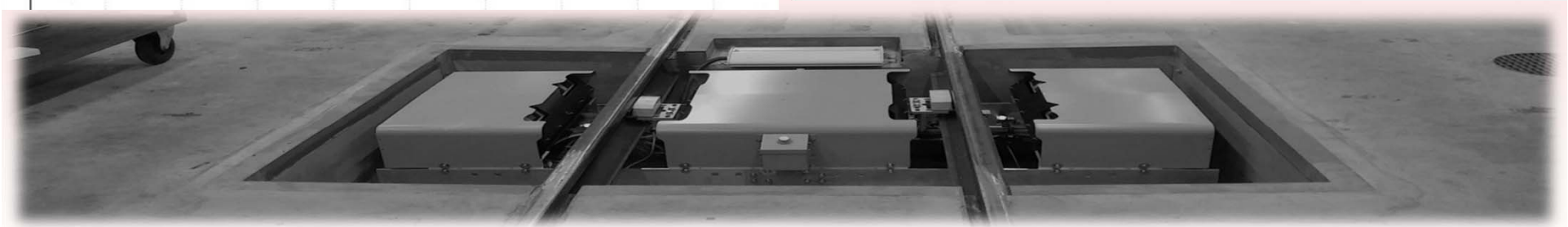
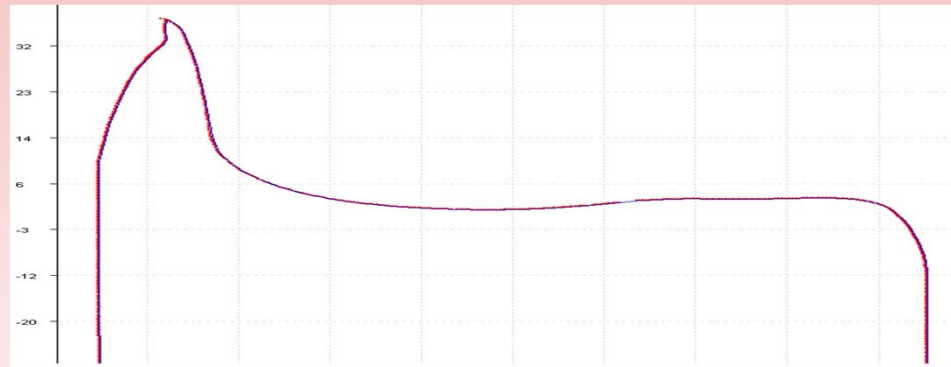
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# Measure Wheel Profile

Full End to End Profile



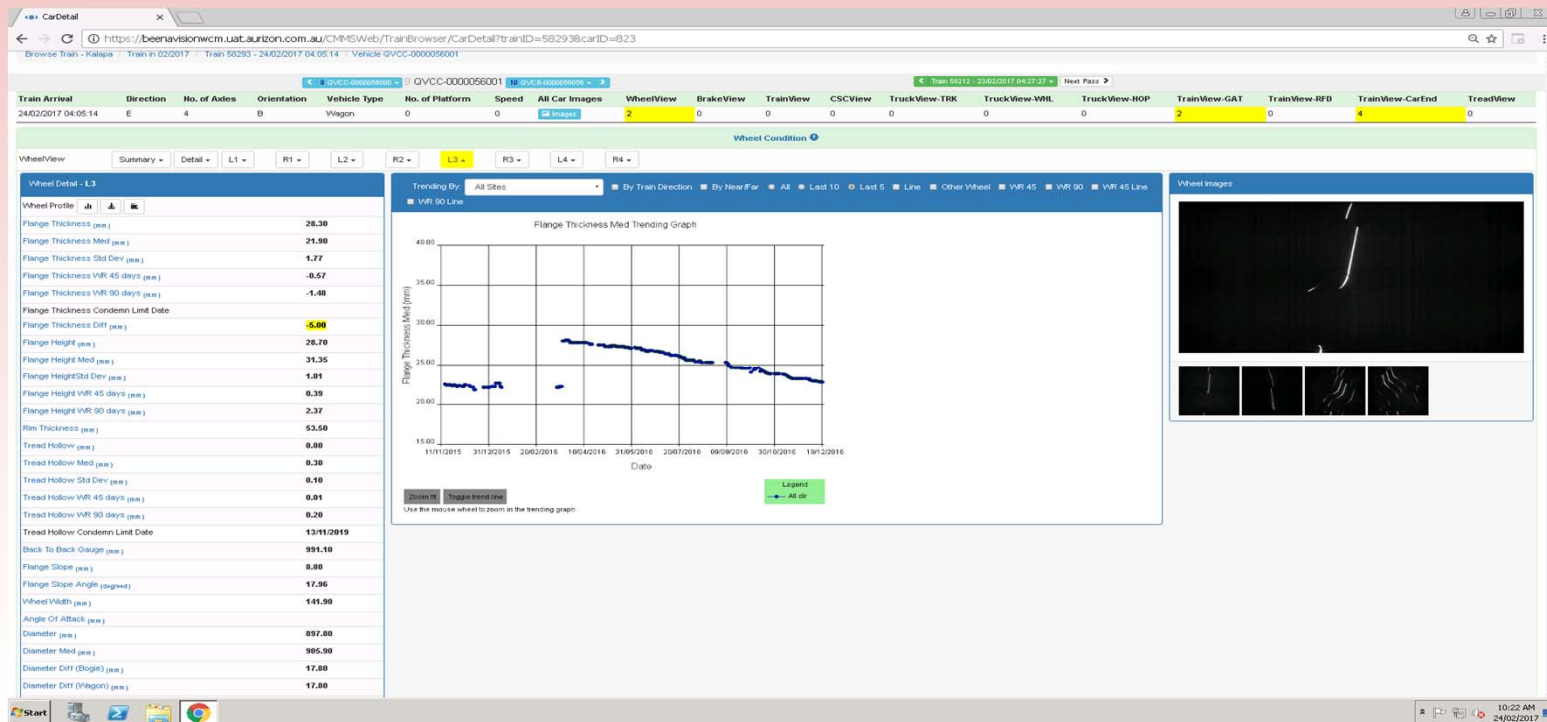
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# Wheel Profile Measurement

## Flange Thickness Measurement



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# 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.

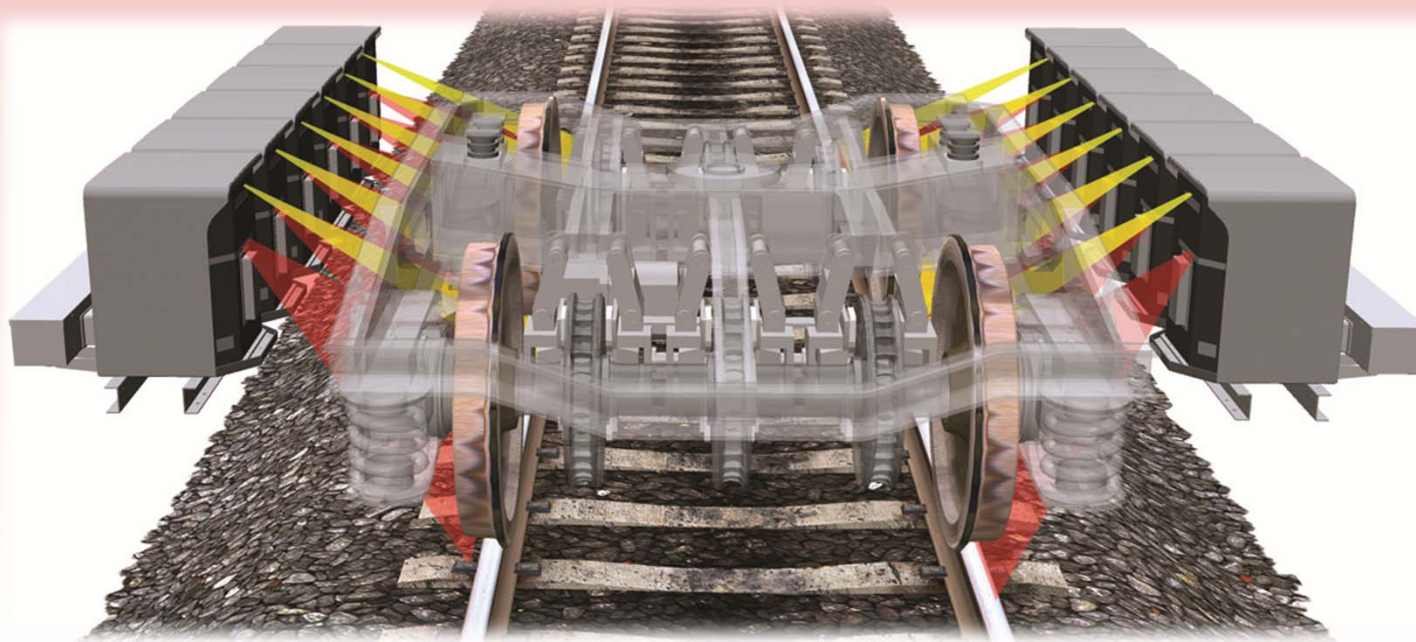


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# Wheel Surface Scanning Operation



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# 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.



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# Wheel Inspection in a Freight Track

TreadView





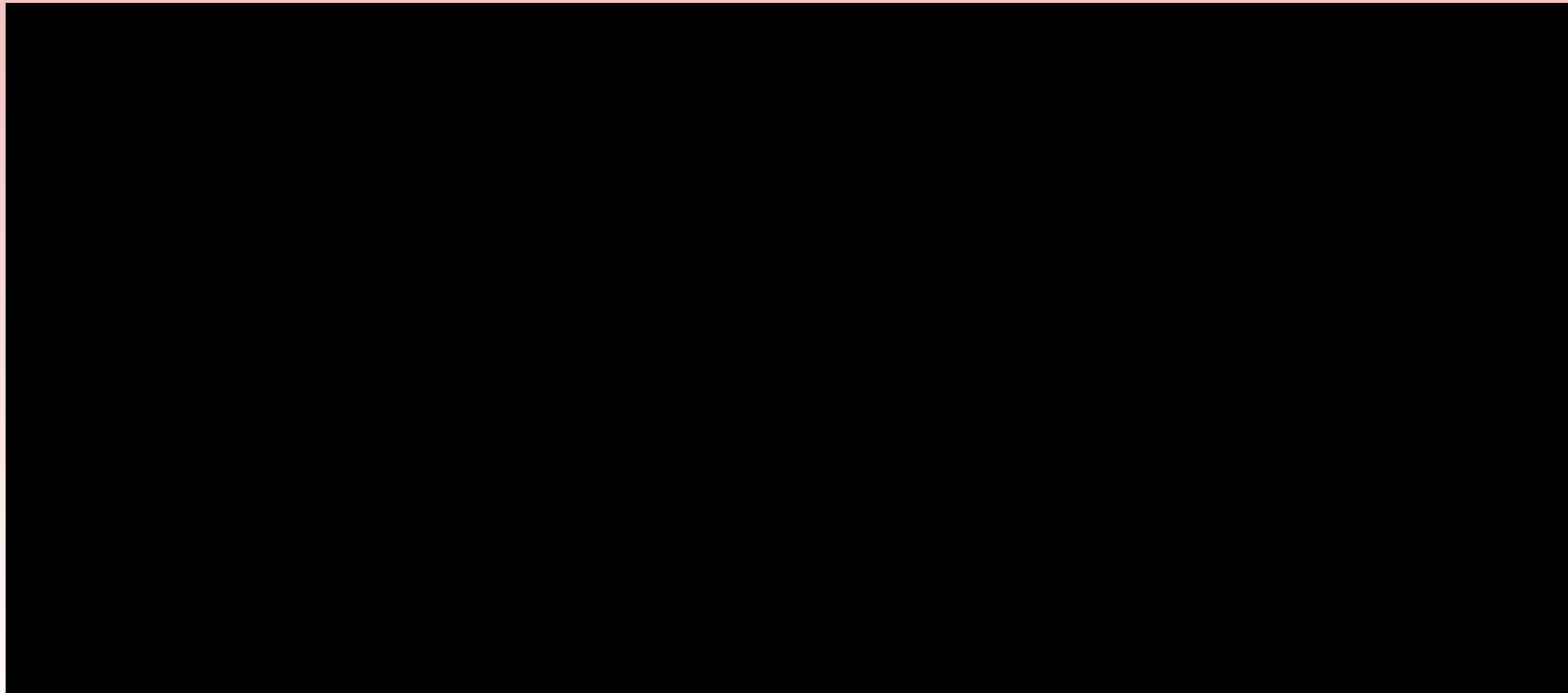
# BNSF Installation of TreadView



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# 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



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# Sample Wheel Defects

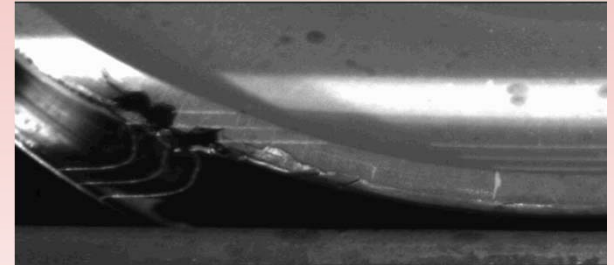
Detectable with TreadView



Dent



Built-up



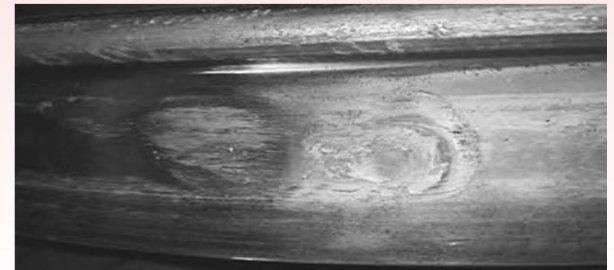
Shattered



Shelled



Spalled



Skid Flat



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# More Defective Wheels

Built-up and Broken Rim



**Built-Up Tread**



**Broken Rim**



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# 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, Polygonization)
- 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 :  $\pm 0.25\text{mm}$
- Wheel Surface Defects:
  - Lateral :  $\pm 0.1\text{mm}$
  - Longitudinal:  $\pm 1\text{mm}$
  - Depth:  $\pm 0.2\text{mm}$
- Longitudinal for low speed depot:  $\pm 0.3\text{mm}$

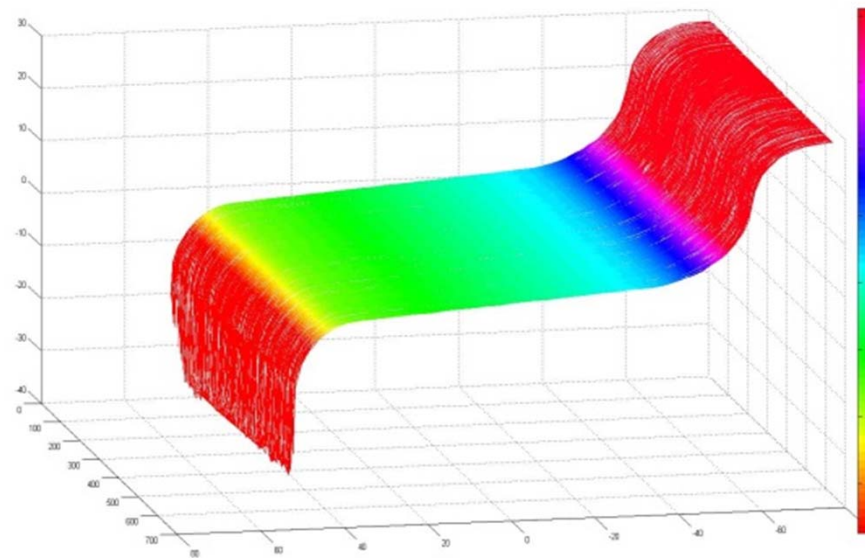


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# Perfect Wheel



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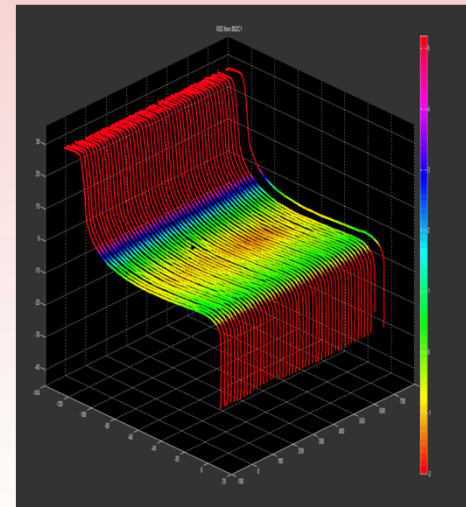
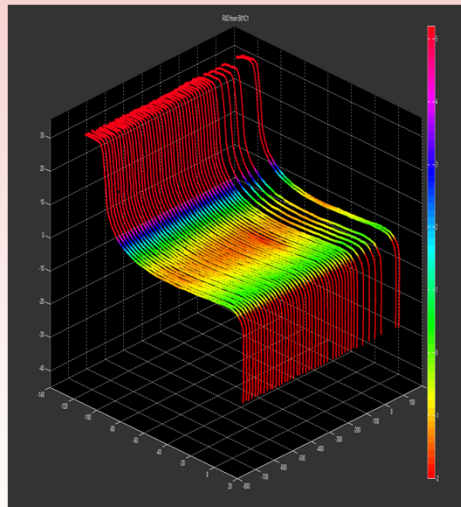
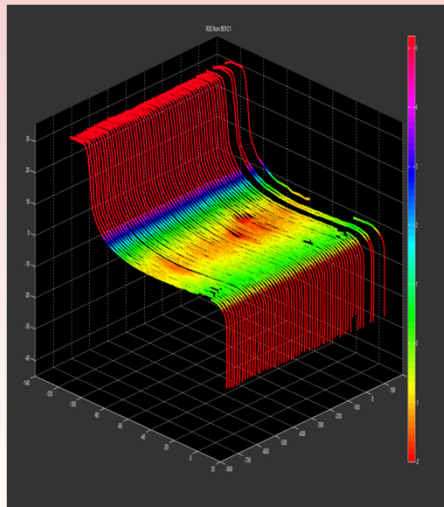
  
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# Hollow Wheel

Measured Across the Whole Wheel



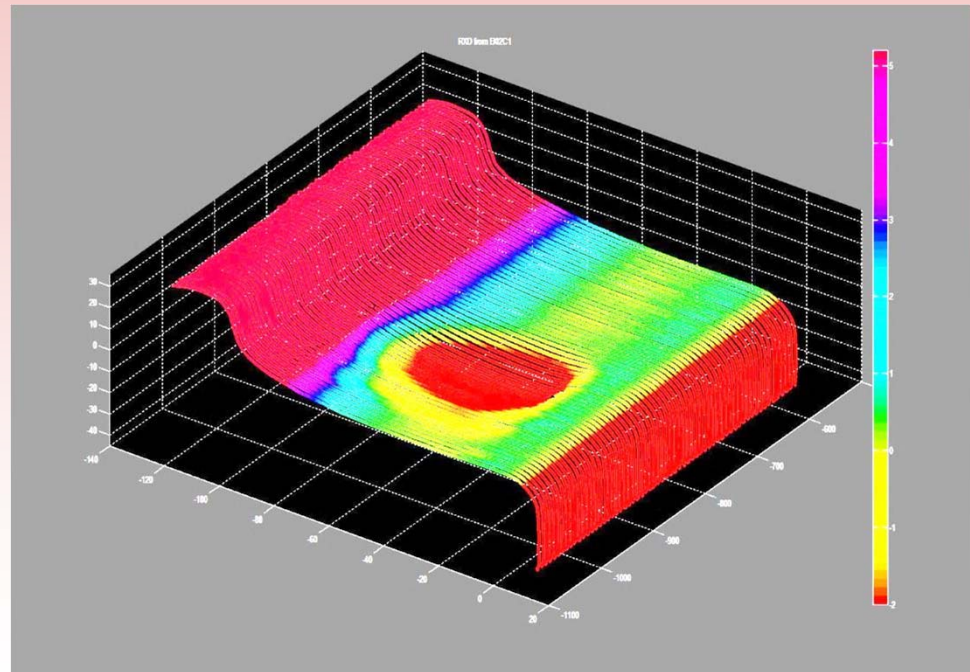
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# Flat Wheel

Size and Depth are Measured



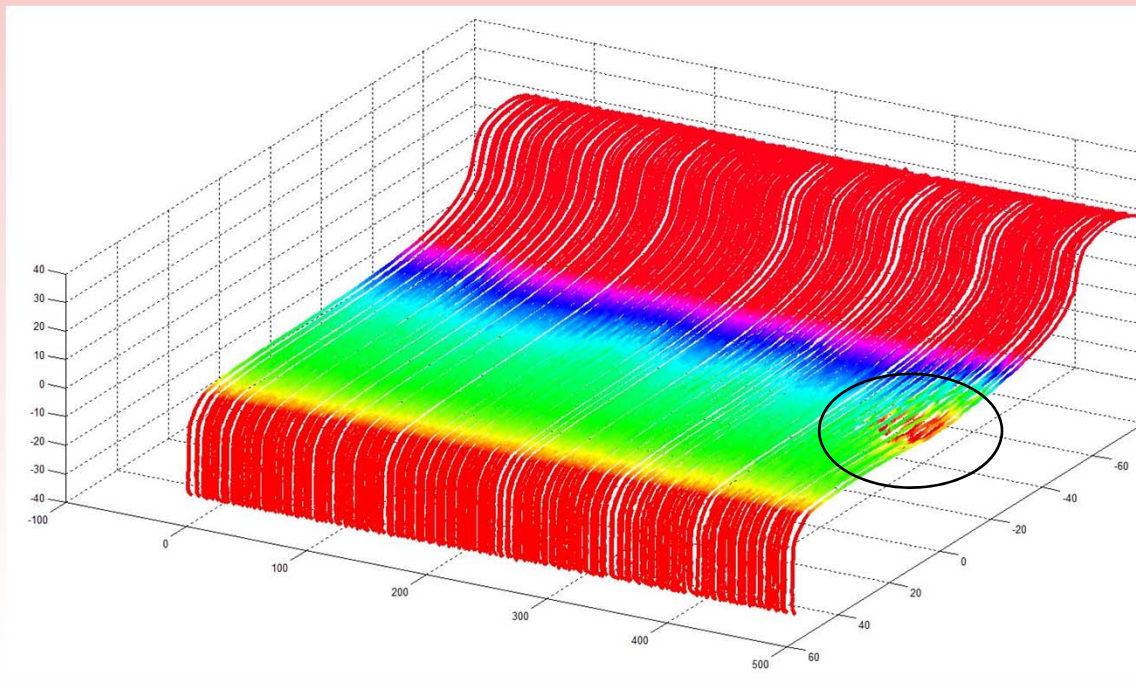
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# A Sample 3D Map of a Defective Wheel

Shelling



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# TreadView Surface Defect

A Detected Shell Example



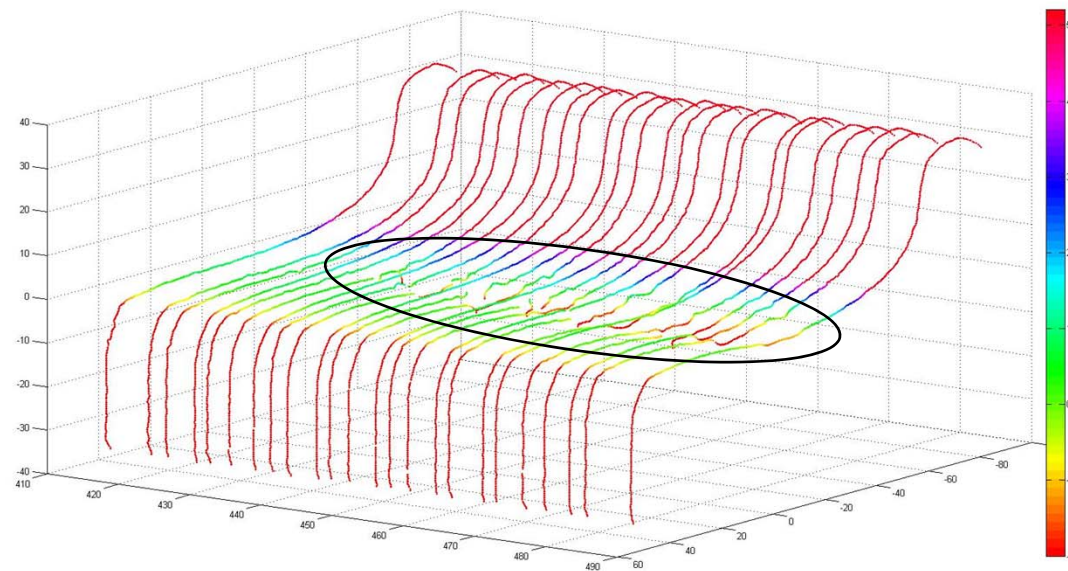
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# 3D Wheel Surface Data

A Shell is detected on the wheel surface



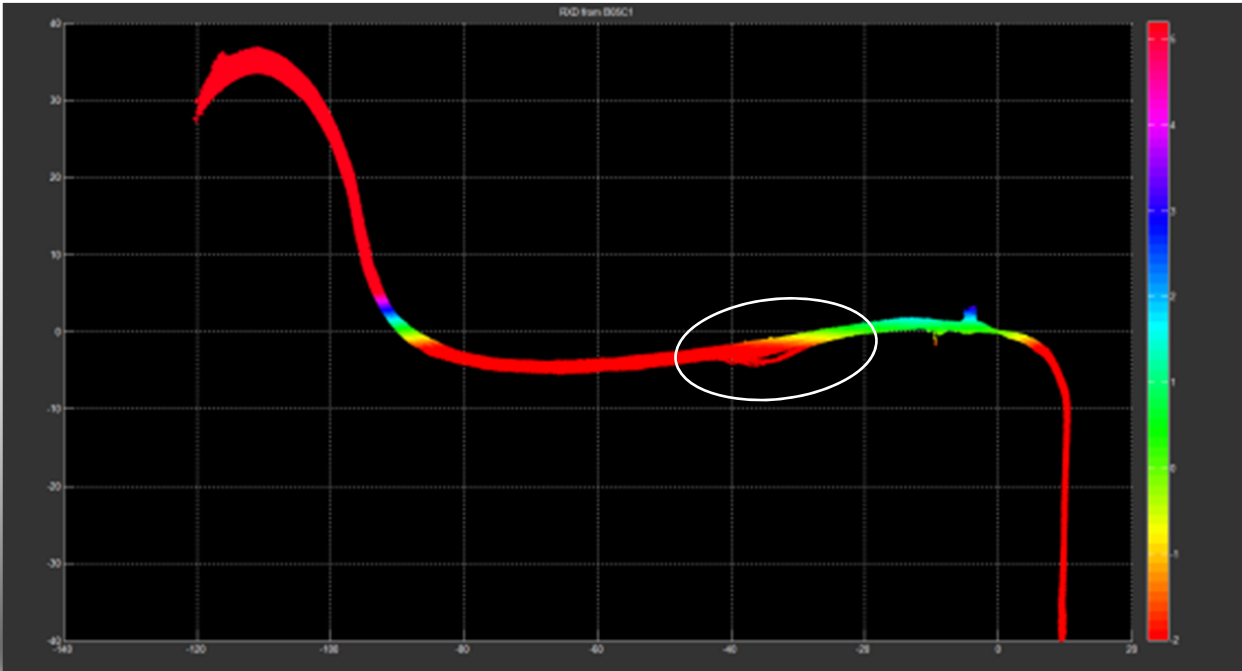
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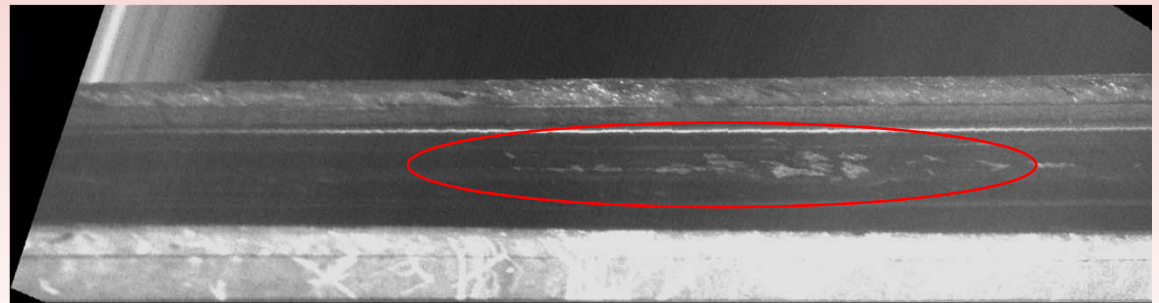
# Another Wheel Surface Defect

Shelled/Spalled/Built-up Tread Wheel Detection



# Wheel Surface Imaging

Visual Inspection



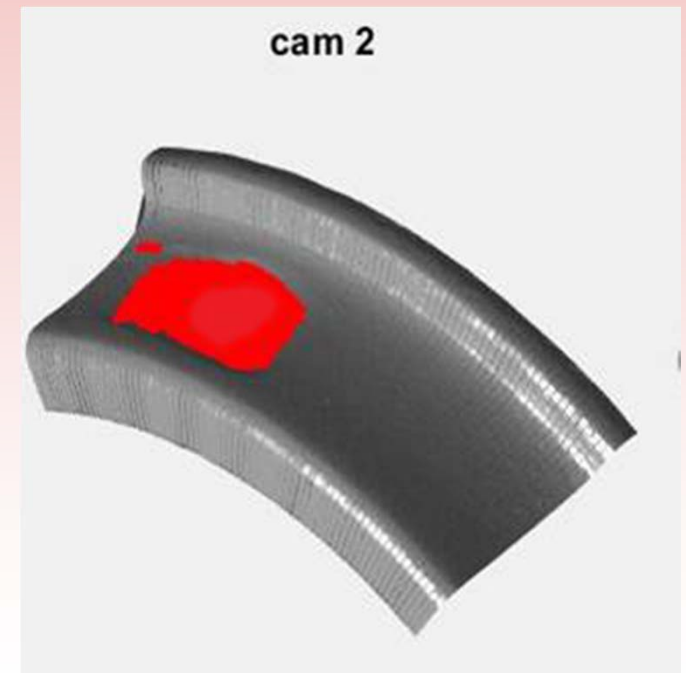
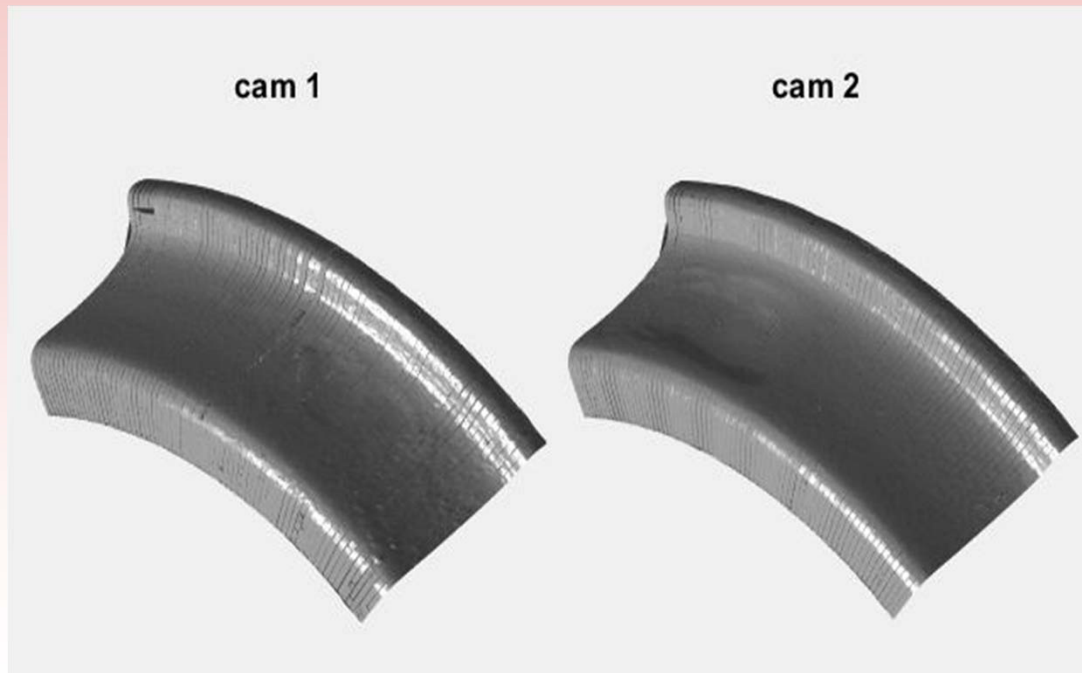
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# Visual Inspection of Wheel Flats

Automatic Detection and Size Evaluation



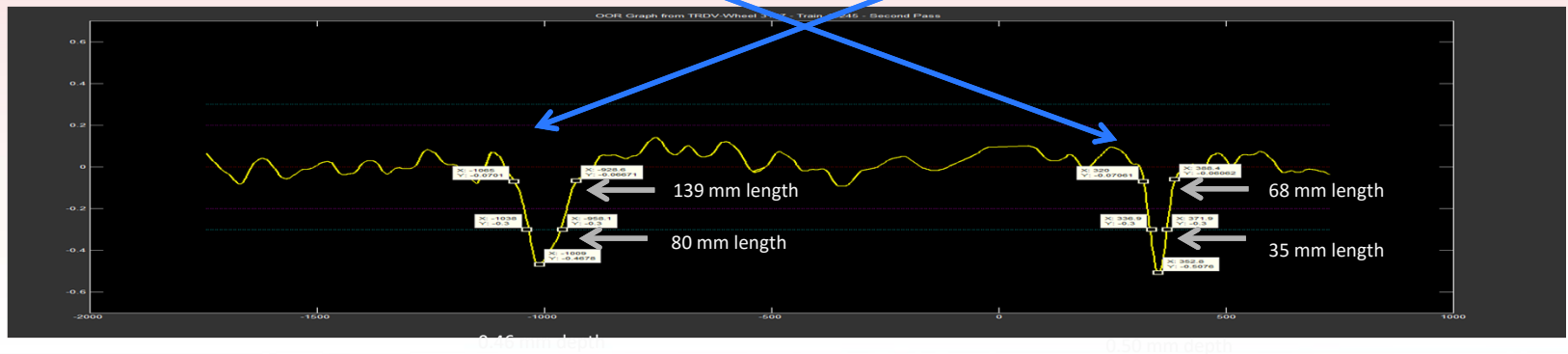
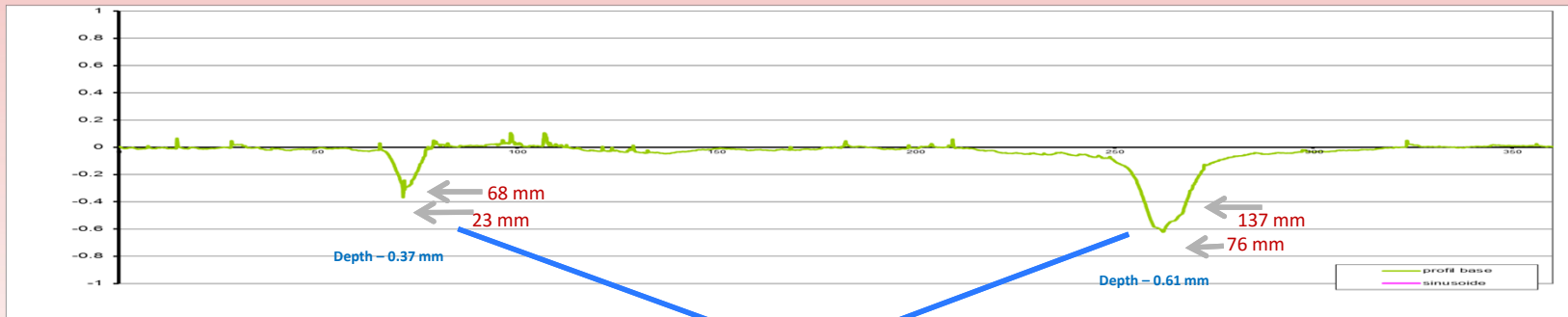
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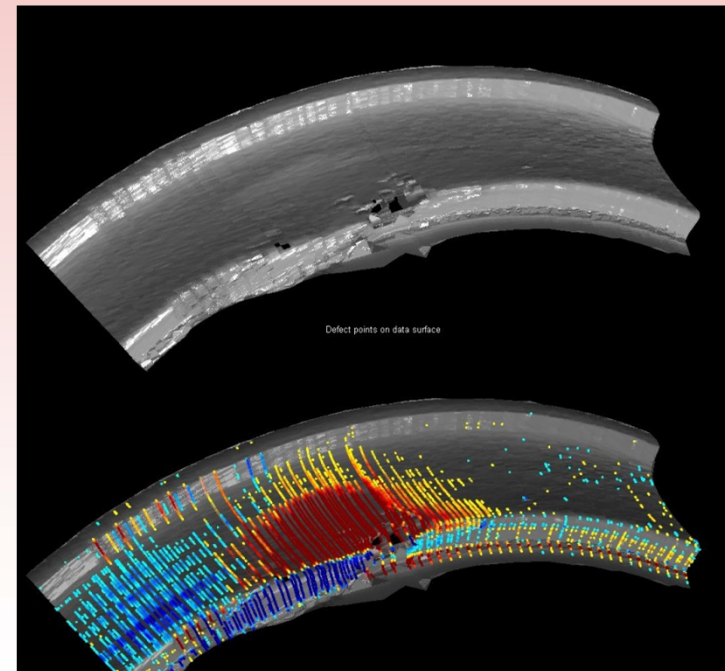


# Out of Round Measurement



# Broken Wheel and its Detection Model

Rendering



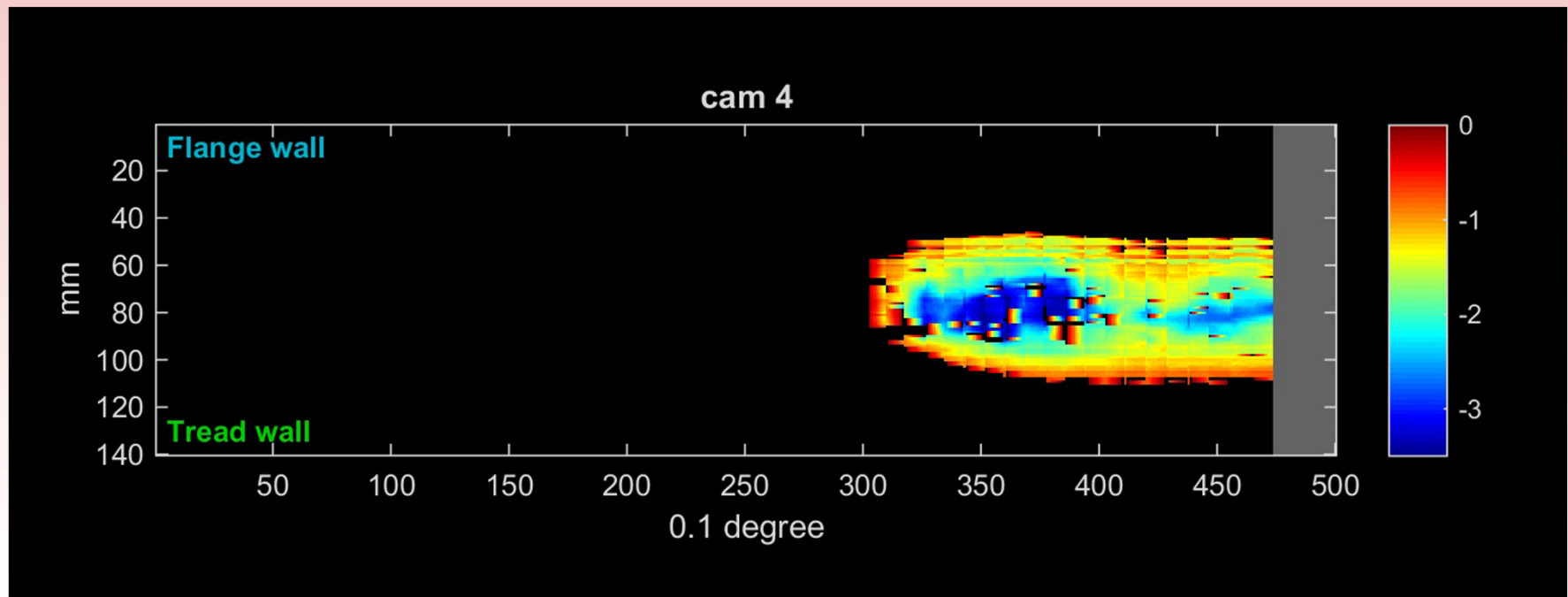
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# Wheel Surface Representation

Color Depth Display



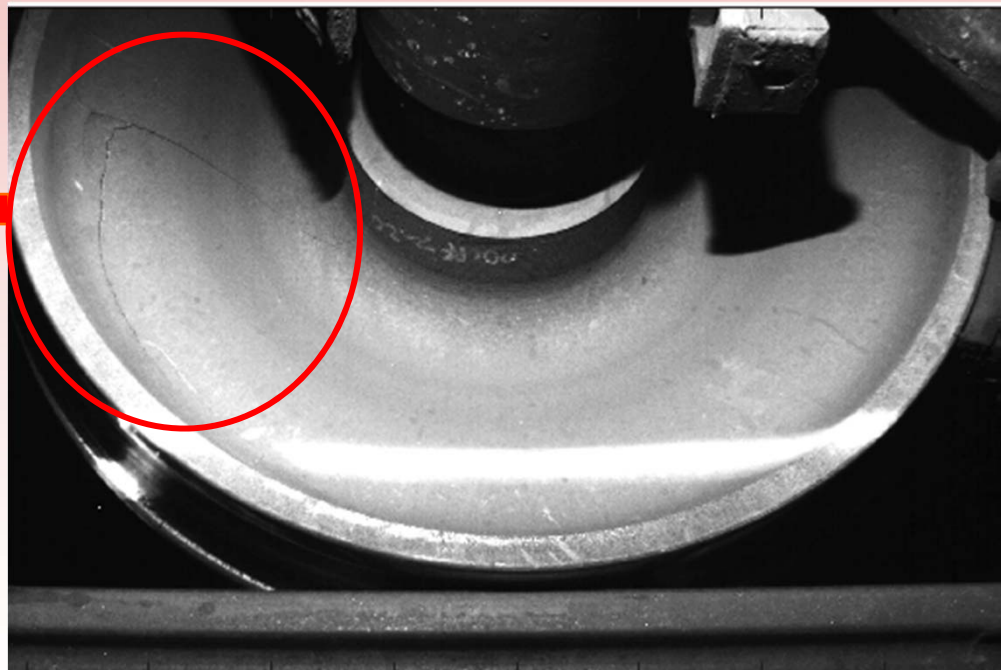
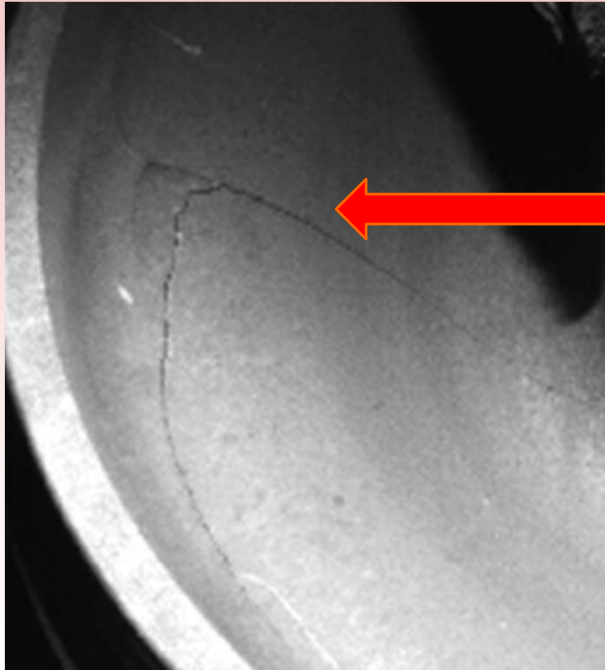
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# Cracked/Broken Wheel Plate

Use Wheel Plate Images



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# 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.**
- Acknowledgements: BNSF Railway



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## Thank You / Questions

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