Wayside Wheel / Rail Force Measurement and WILD Verification

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MxV Rail

Contents:

1. Background
2. Progress in wayside W/R force measurement
3. Benefits of full-continuous measurement
4. Verification of WILD
5. Conclusions

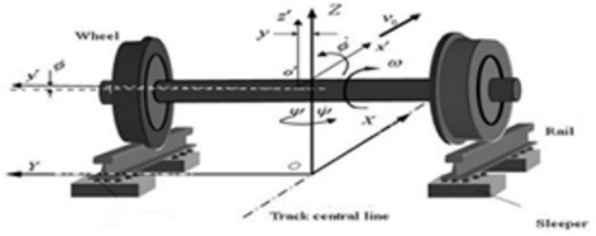
Background

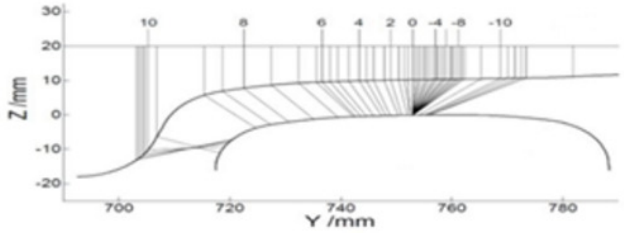
Wheel/Rail (W/R) Interaction

W/R is the key difference between railroad and other modes of transportation

Characteristics of a W/R pair:

- **Quasi-rigid rolling contact, low rolling resistance**
- **Wheelset with approximate conical tread, self-steering**





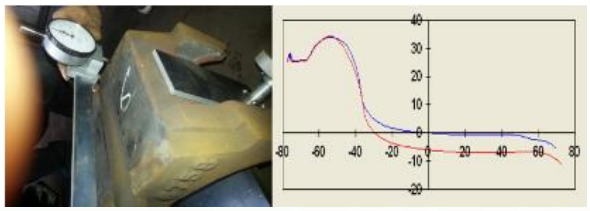
Actual Problems

Defects on rolling surface cause significant W/R impact

- **Can cause damage to vehicle & track**

Mismatches between W/R and/or between vehicle/track:

- **Excessive W/R wear**
- **Deterioration of vehicle performance**
- **Potential safety concern**



Significance of W/R Force Measurement

Identification of practical problems:

- **Fast and effective**
- **W/R problems ⟺ Change of W/R force**

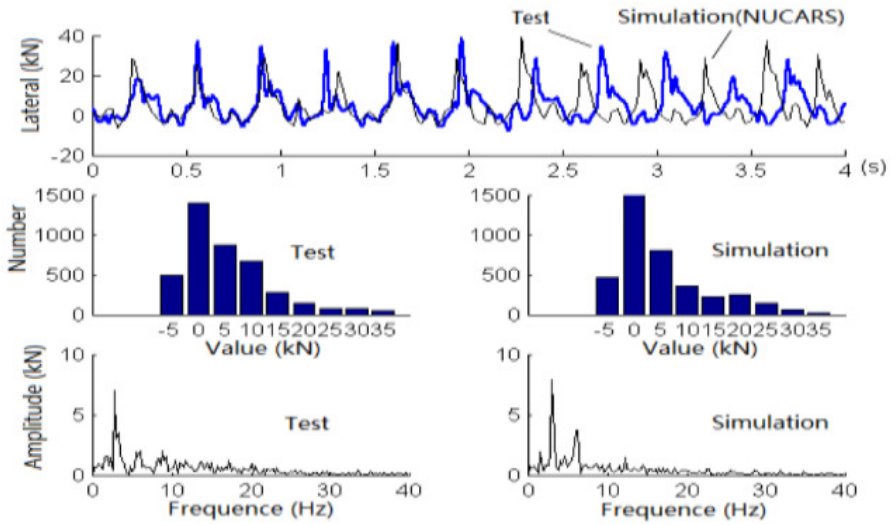
Research of W/R interaction:

- **Onboard – instrumented wheelset (IWS)**
- **Wayside – strain gaged rails, WILD, etc.**

Onboard Wheel Load Measurement

Continuous IWS has been widely used:

Advance the research and application of vehicle dynamics



IWS test and MxV Rail's NUCARS® simulation for truck hunting

(**NUCARS®** is a registered trademark of Transportation Technology Center, Inc.)

Wayside Wheel Load Measurement

From discontinuous to continuous:

1. **Field test, nearly 100% discontinuous**

Field test (discontinuous)

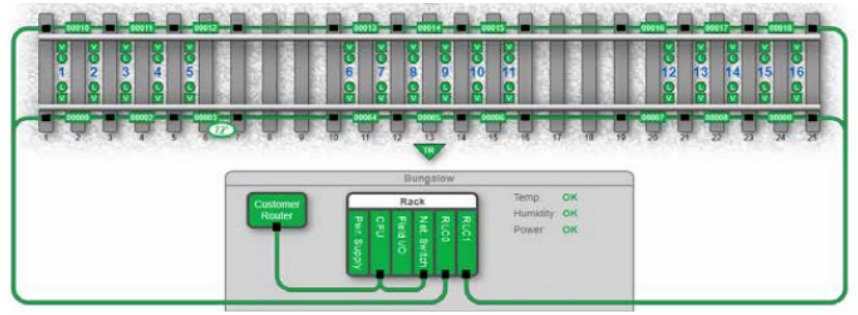
Test and validation center in Wegberg-Wildenrath
(Siemens, PCW, curve, continuous)

Wayside Wheel Load Measurement (cont.)

From discontinuous to continuous:

2. **The typical Wheel Impact Load Detector (WILD) discontinuous, success in North America**

Typical WILD Site on tangent track



Layout of typical WILD (16 cribs, LB Foster)

Direct or indirect measurement (AAR 1990s)

AAR conducted a comparison test in 1991 (AAR R-829, R-852)

1. **Evaluated the reliability and repeatability of WILD, load-based (direct), acceleration-based**
2. **Forty-eight test wheelsets with different levels of tread defects**
3. **Axle load 25–39 tons, speed 20–70 mph, more than 20 passes across site in each direction**

Results showed that the typical load-based WILD was much better than the acceleration-based WILD

Further Needs from Railroad Industry

- Enhance effectiveness of wheel monitoring
- Big data integration
- Enhance accuracy of Weigh In Motion (WIM)
- Unify onboard and wayside W/R force-based safety assessment

All need detailed, consistent and accurate W/R force information as input

Questions:

Is there any new/potential technology that meets our needs?

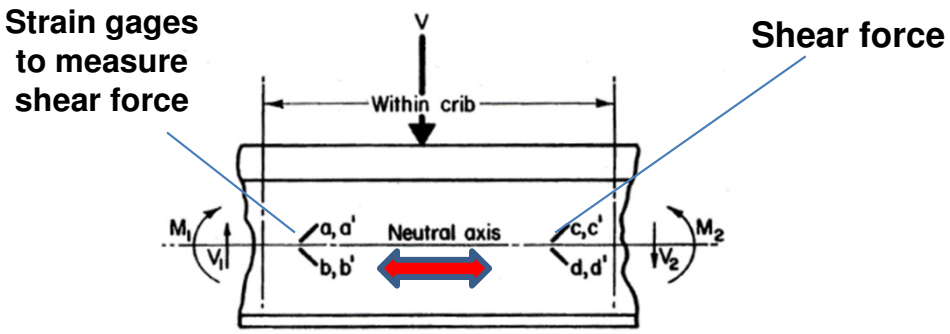
How to validate these technologies?

Progress in Wayside W/R Force Measurement

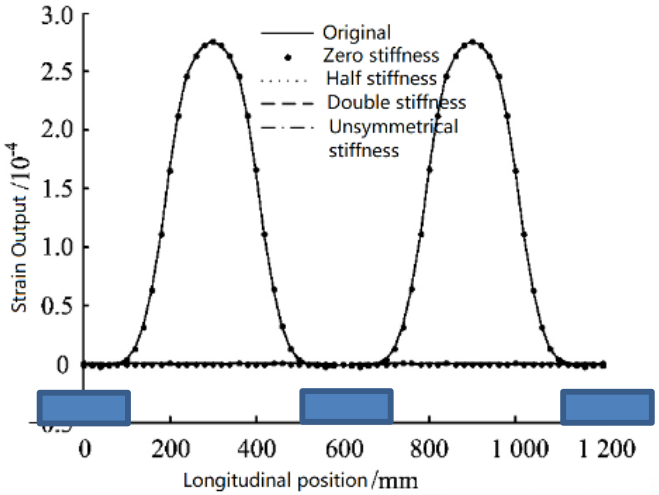
Discontinuous Measurement

Based on the rail strains or equivalent simple device

- **Shear force method(mid 1960s), bending method, compression method – simple and stable and short**



Shear Force Method
Effective zone (95%) < 100-200 mm

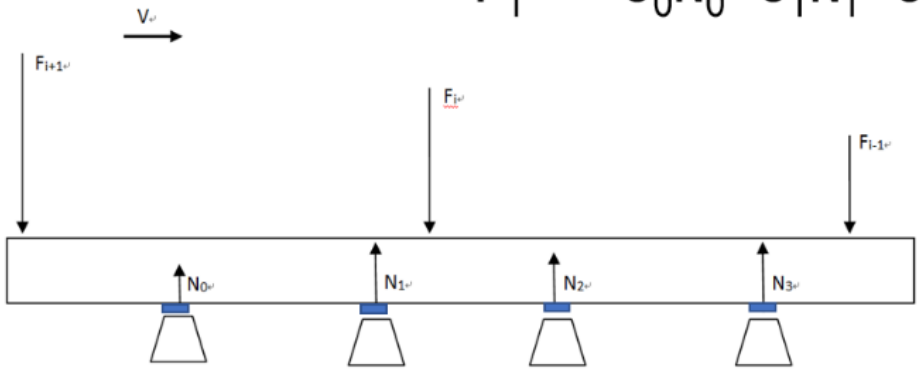


Early Continuous Measurement

Based on Load pad / instrumented tie plate

- **Long sensitive area, affected by adjacent wheel**

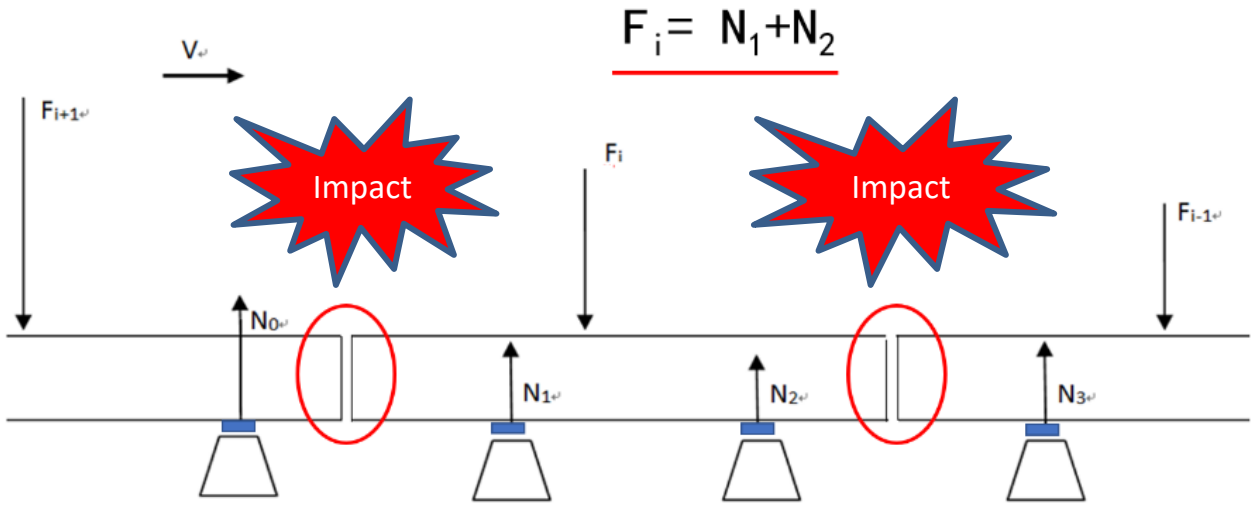
$$F_i \approx c_0N_0+c_1N_1+c_2N_2+c_3N_3$$



Source: IAVSD13-42.10-ID268 (2017)

Eliminate the Influence of Adjacent Wheel

Cut rail:

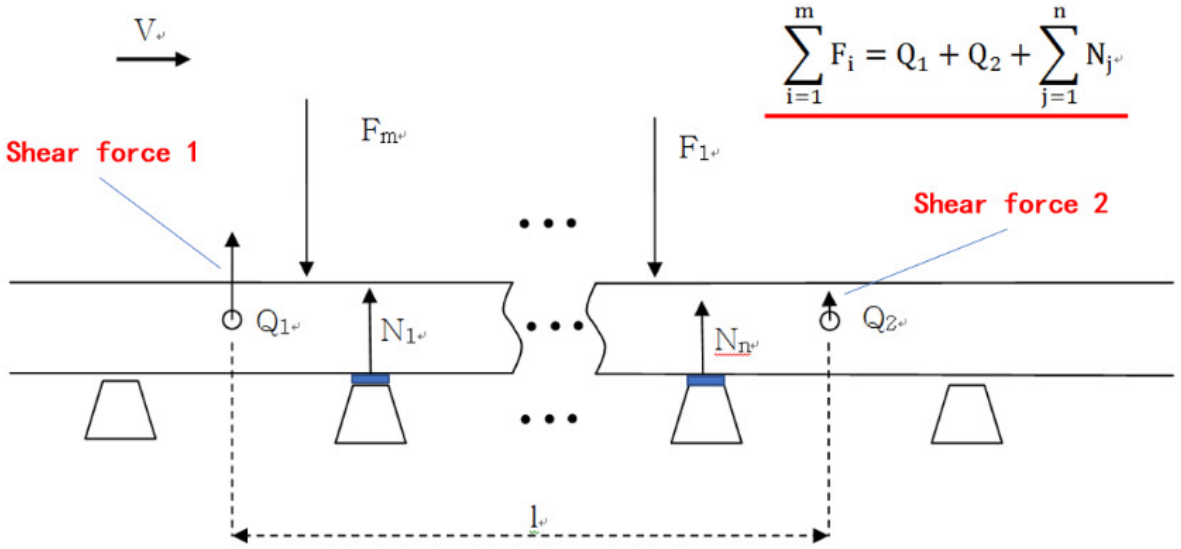


Typical application: Foundation tunnel type weighbridge / track scale

(Static and low-speed only)

Classic Discontinuous + Early Continuous

Cut rail in the sense of mechanics:



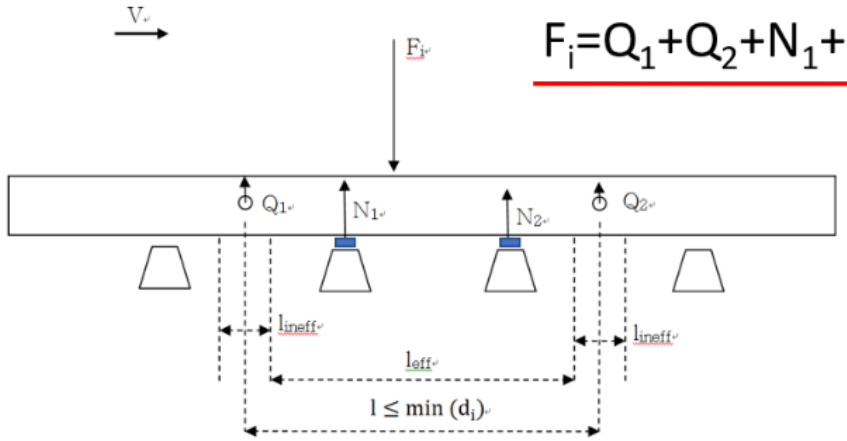
$$\sum_{i=1}^{m} F_i = Q_1 + Q_2 + \sum_{j=1}^{n} N_j$$

L> wheelbase &
L<wheel distance
between adjacent trucks

Typical application:
high-speed
foundationless track scale

"Shear force + Load pad" extends the effective zone without any W/R impact

W/R Force of Single Wheel



$$F_i = Q_1 + Q_2 + N_1 + N_2$$

*Additional restriction on the distance between shear sensors: less than the wheelbase

$$\max(l_k) \leq \min(d_i)$$

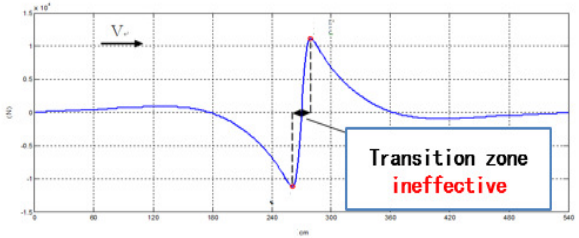
Effective measurement zone > 1000 mm, 2 or 3 tie spacing

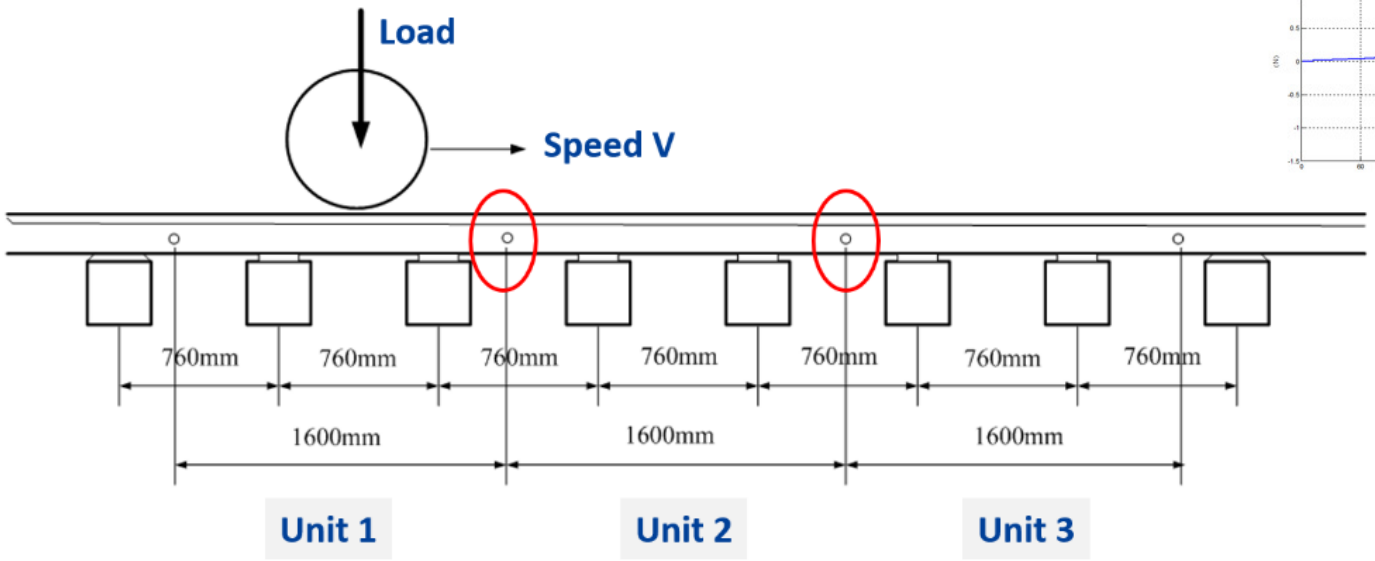
The basic idea/practice can date back to Mr. Harrison's work in late 1970s.

Successfully implemented in the 1990s.

Long Distance Measurement

The characteristics of mechanics cut





The prototype design of Train Performance Detection System (TPDS-CARS, on tangent track)

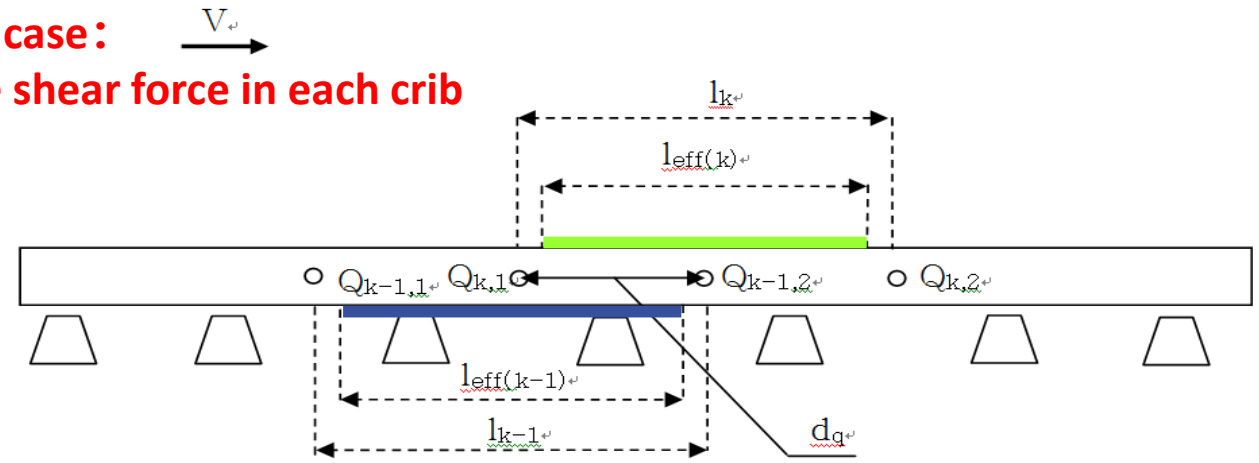
"Shear force + Load pad" is a **quasi-continuous** measurement

Full-continuous Measurement

“Overlap” method (early 2010s)

- **Add shear force sensor and make valid areas overlap**

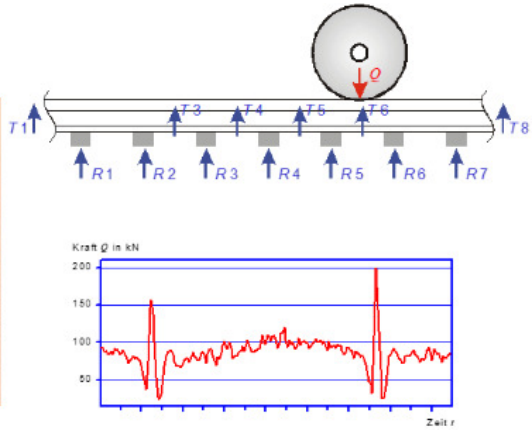
Extreme case：
Measure shear force in each crib



Cases of Full-continuous Measurement (Overlap)

- **Accurate**
- **Cost and reliability**

Schenck for Siemens PCW



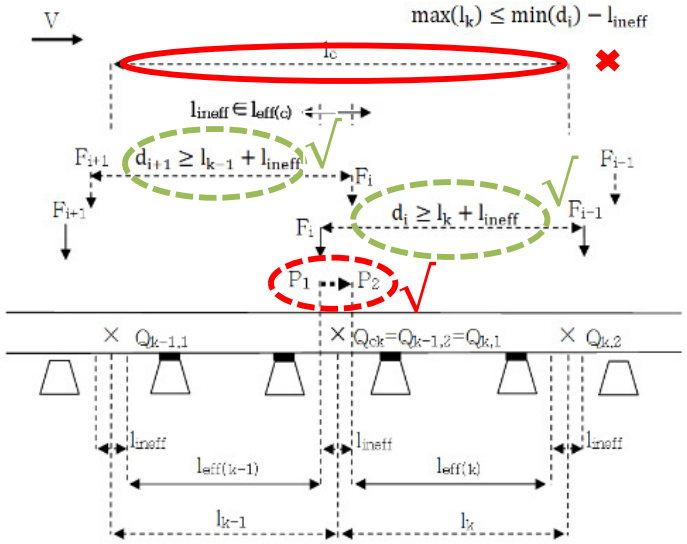
DafuR of DB

Innovative Method

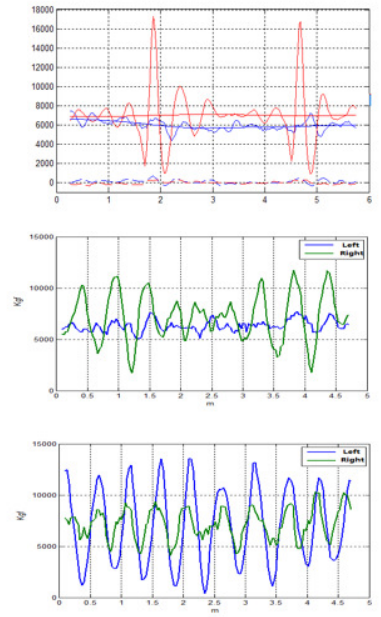
Achieve full-continuous result through algorithms

(early/mid 2010s)

- **No additional hardware cost**



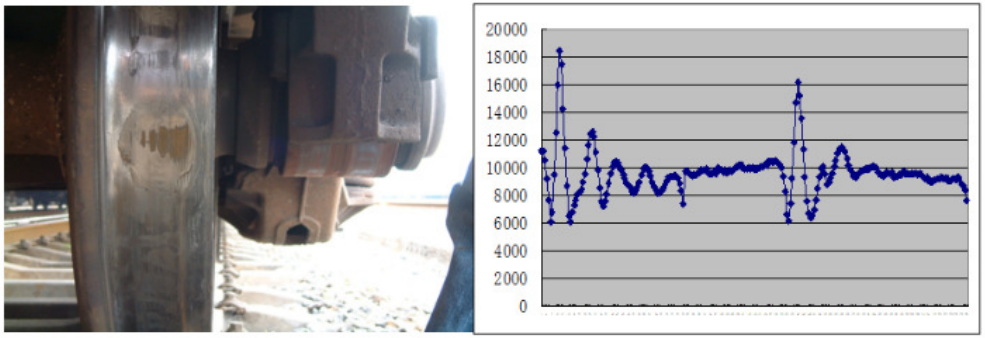
Composite Unit Method



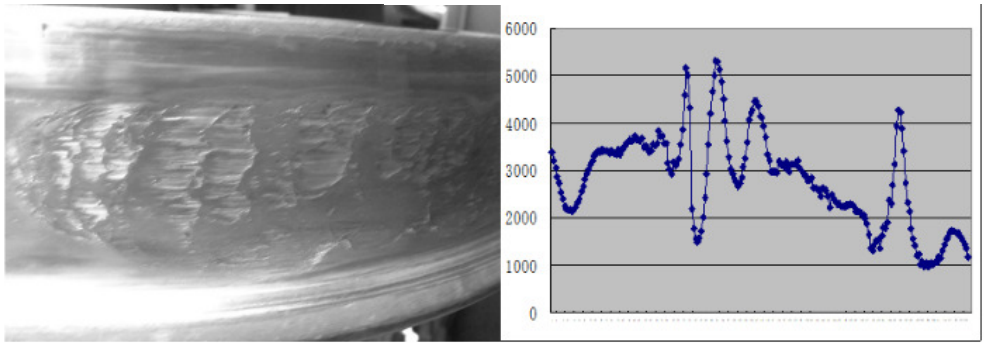
Force samples of passenger car

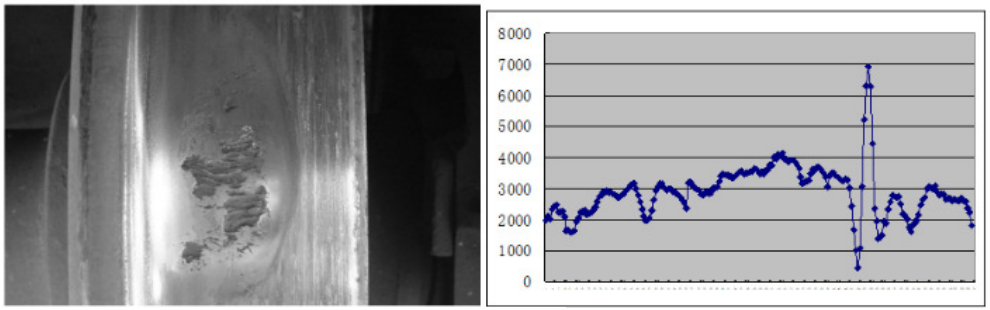
Detect Wheel Surface Defects

Slid flat

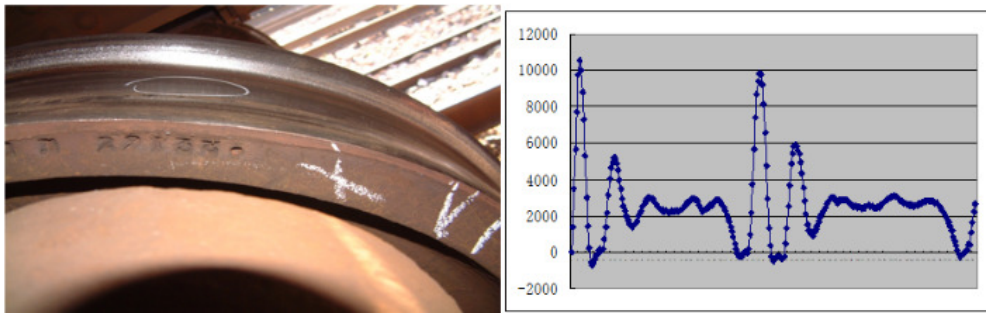


Buildup





Flat + shell

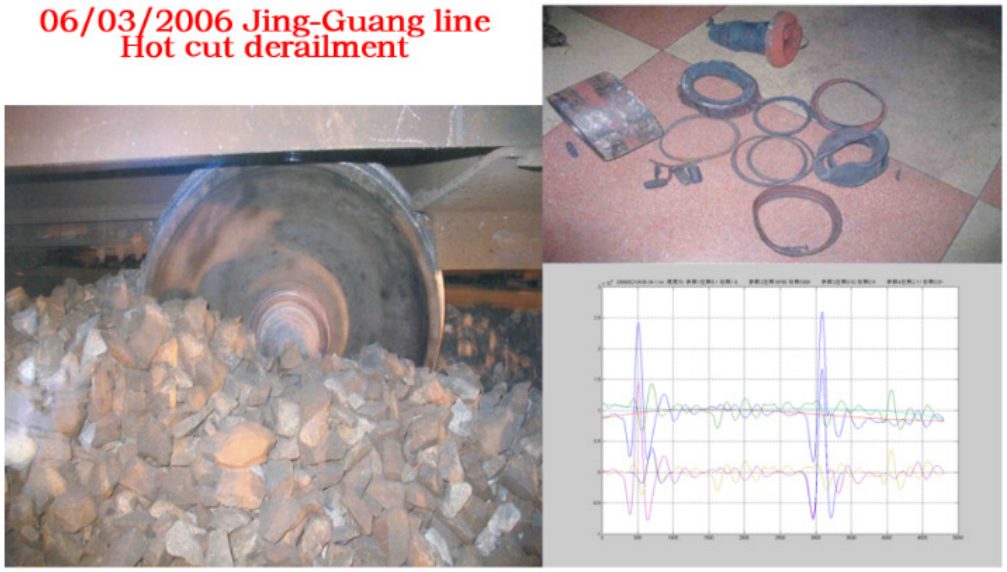


Indentation

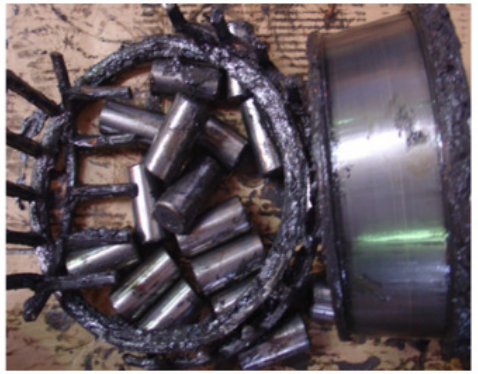
Avoiding Severe Accidents (CR, freight car)

Eight severe hot box accidents include four derailments between 01/15/2005 and 08/13/2006, all had tread defect and were detected by TPDS

06/03/2006 Jing-Guang line
Hot cut derailment



>25 T
(1.7 mm)

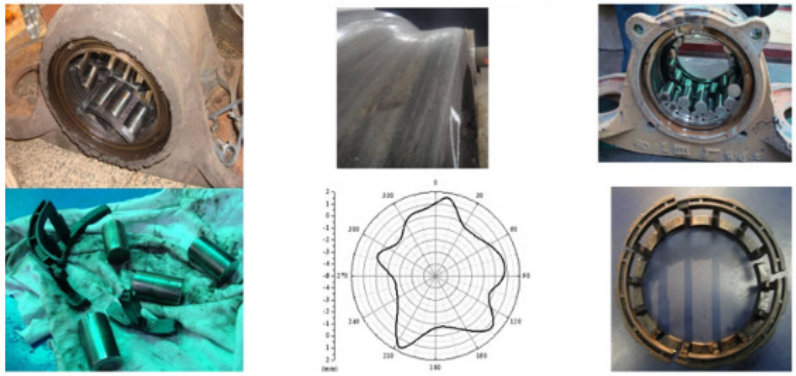


1. Replace steel cage with plastic cage

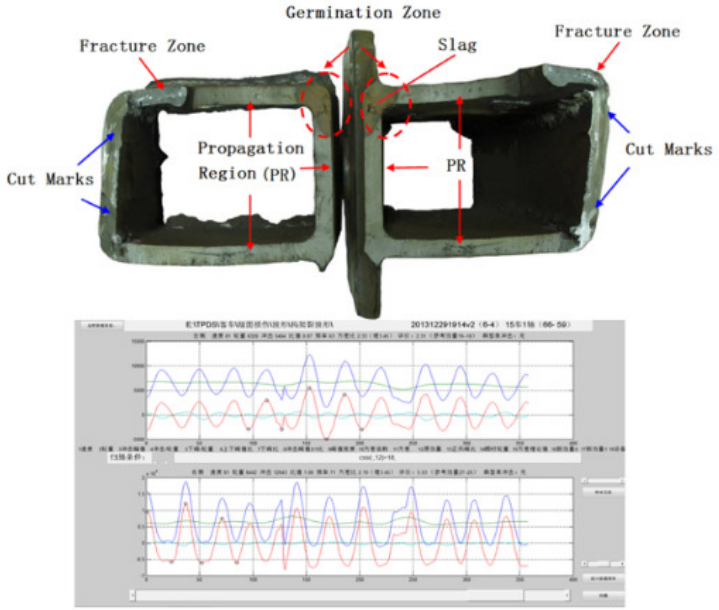
2. Start the application of TPDS' s HIW detection

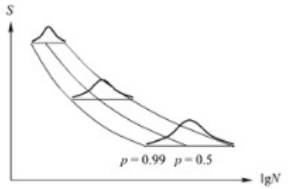
Avoiding severe accidents (CR, passenger car)

Nine bearing cages damaged between
12/22/2011 and 03/08/2012
all were polygonal wheel



12/30/2013 frame sill crack

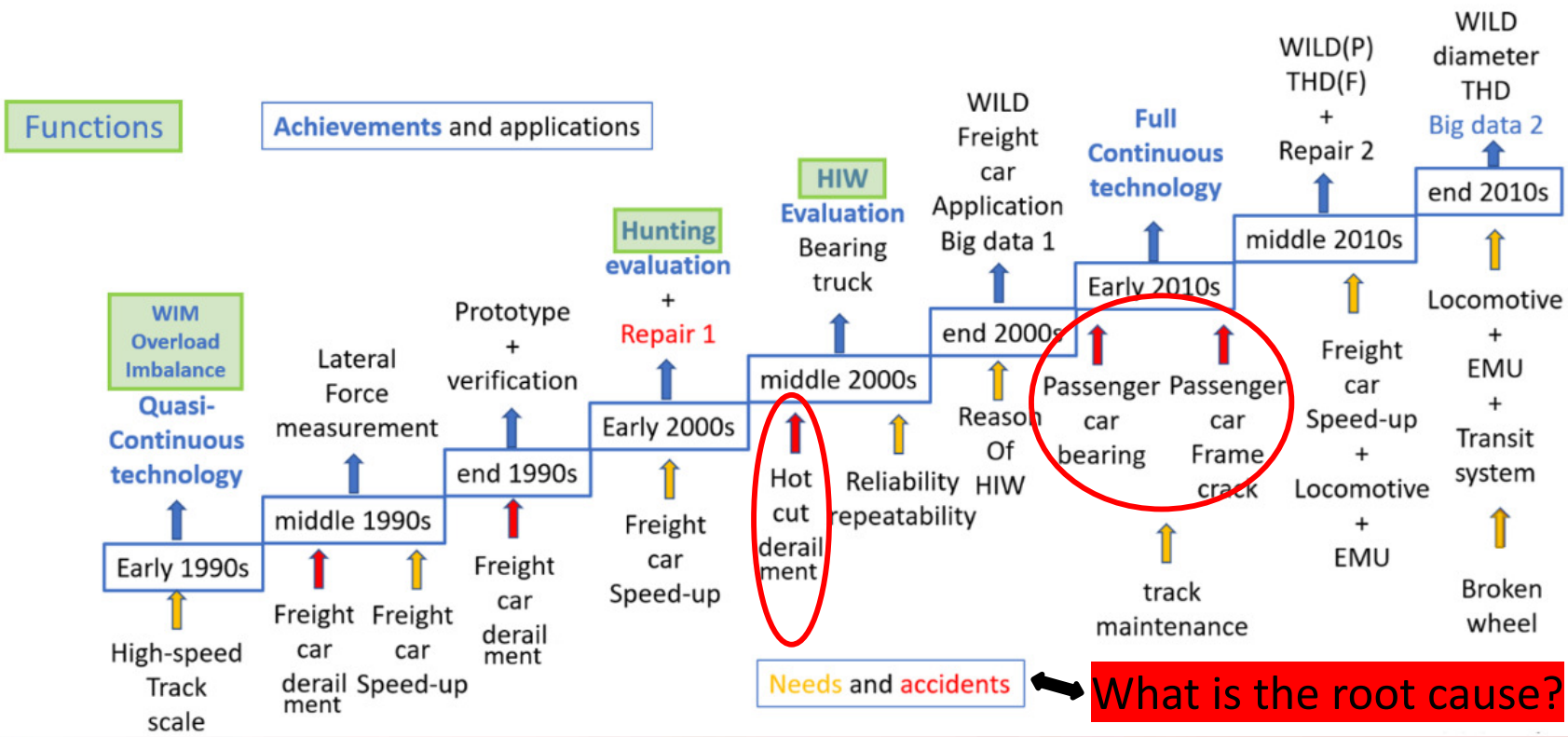




$\Sigma\ (n_s / N_s) = 1$

1. Install RFID tag on passenger car
2. Full-continuous measurement

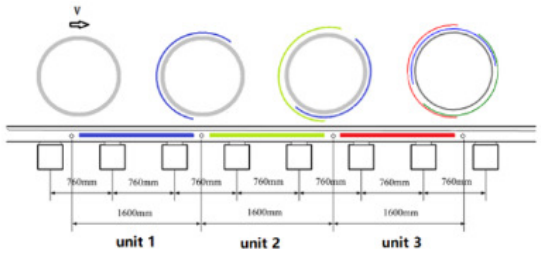
Needs and Accident-driven Research & Application (CR)



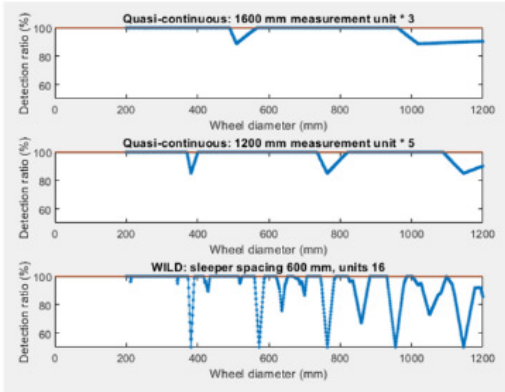
Benefits of Full Continuous Measurement

Cover Whole Wheel with Short Test Zone

- **Enhance the effectiveness of wheel/vehicle monitoring**
- **Provide more reliable and consistent data**
  - **Benefits information integration/big data application**



Coverage evaluation



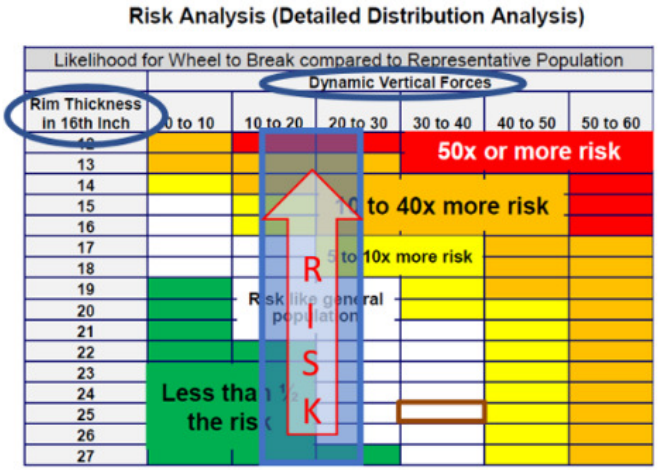
1600mm*3 units
(special tie spacing)
cover wheel
566mm-962mm 100%

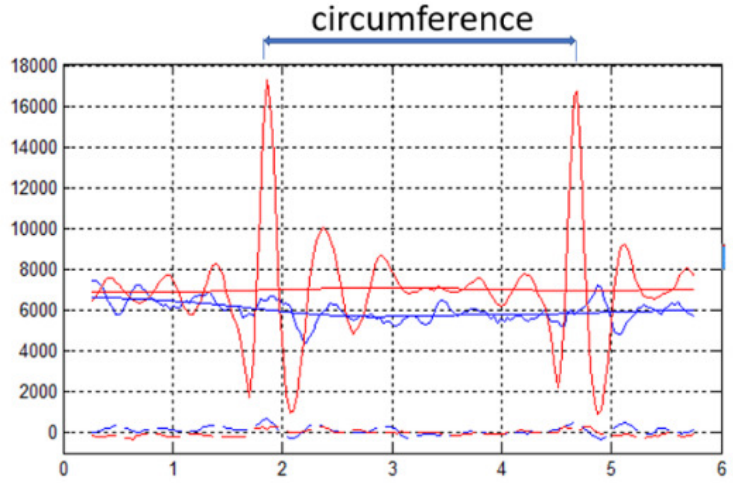
1200mm*5 units
(standard tie spacing)
cover wheel 401-735
820mm-1090mm 100%

Typical WILD
600(E300)mm*16 units
884mm-930mm 100%

Improve Risk Mitigation

- **Effectively detect critical parameters**
- **Mitigate the risk/loss from external causes, and possible strength decrease and damage accumulation**





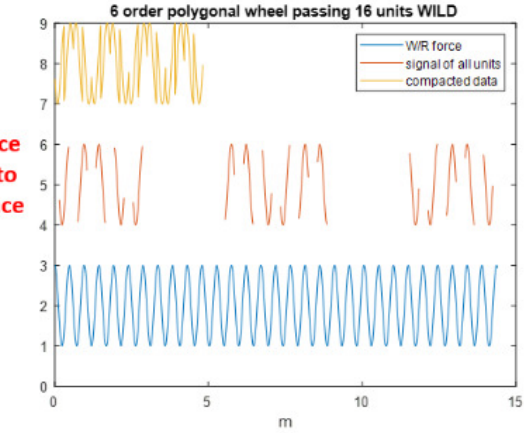
Source: MxV Rail (TD15-018)

Polygonal Wheel Monitoring

Reasonably assess the hazards of polygon wheels

- **Both amplitude and frequency of impact force are critical**

Time sequence is not equal to space sequence



Output of discontinuous measurement (Simulation)

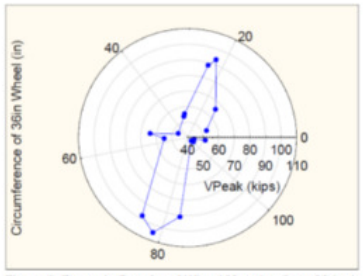
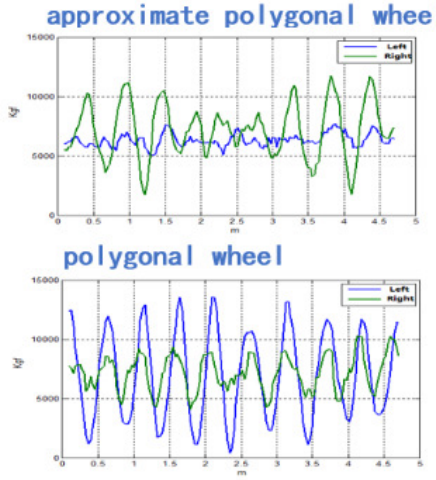


Figure 3. Example Results of Wheel Mapping for a 36-inch Wheel Possibly Showing the Wheel as Oval

WILD if know circumference

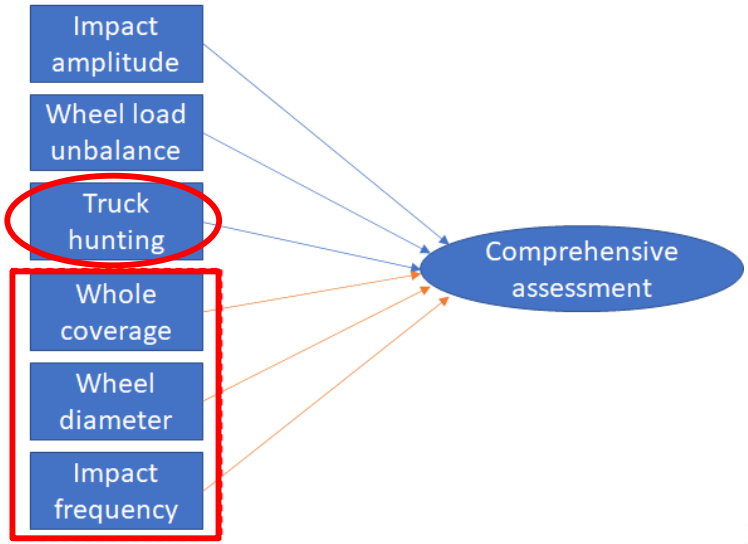
Source: MxV Rail (TD17-028)

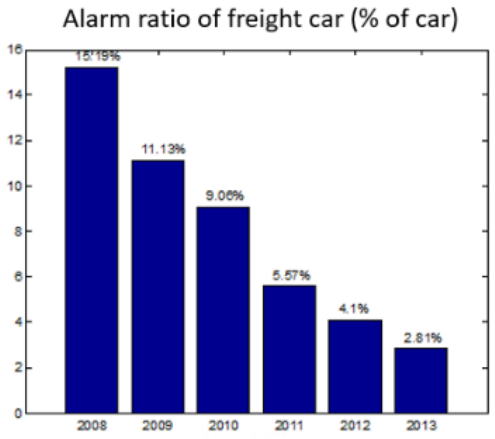


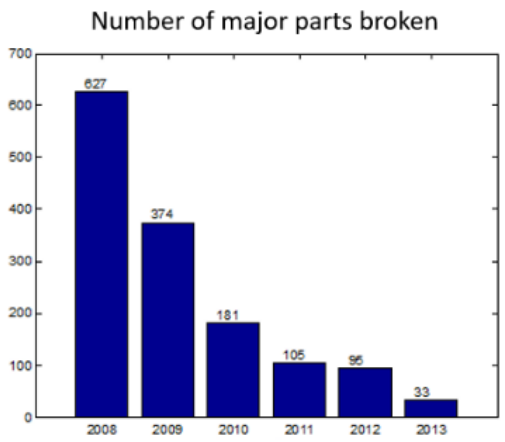
Output of continuous measurement
Time match space

Condition-based Repair (Vehicle)

- **Comprehensive condition-based repair**
- **Ensure safety while reducing cost**







Other Benefits

- Actual load environment (track)
- Safety evaluation
- Simulation
- Testing

Verification of New WILD

W/R force-based Validation

Industry desires validation of alternative WILD technologies

AAR S-6101: Detector Validation and Calibration Requirements

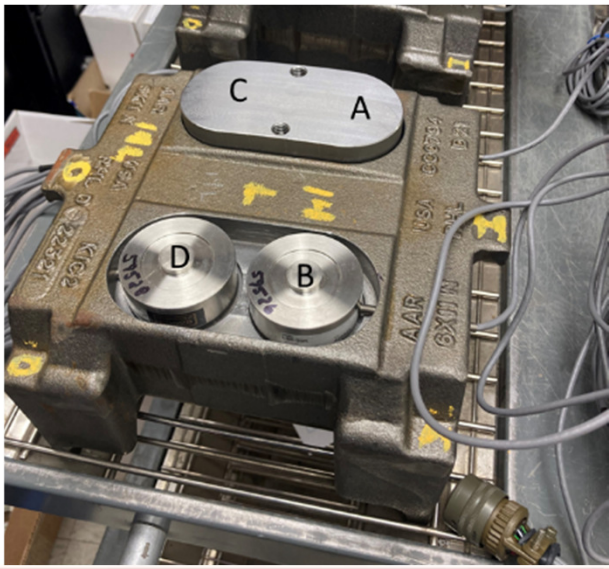
- **June 2021 update specified on-board measurement of wheel impact load using instrumented bearing adapters**

Assumption: Reaction at the bearing adapter equals force at the wheel/rail contact patch

- **Based on member prior experiences with car body dynamics testing**
- **Wheel impact load test results did not agree**

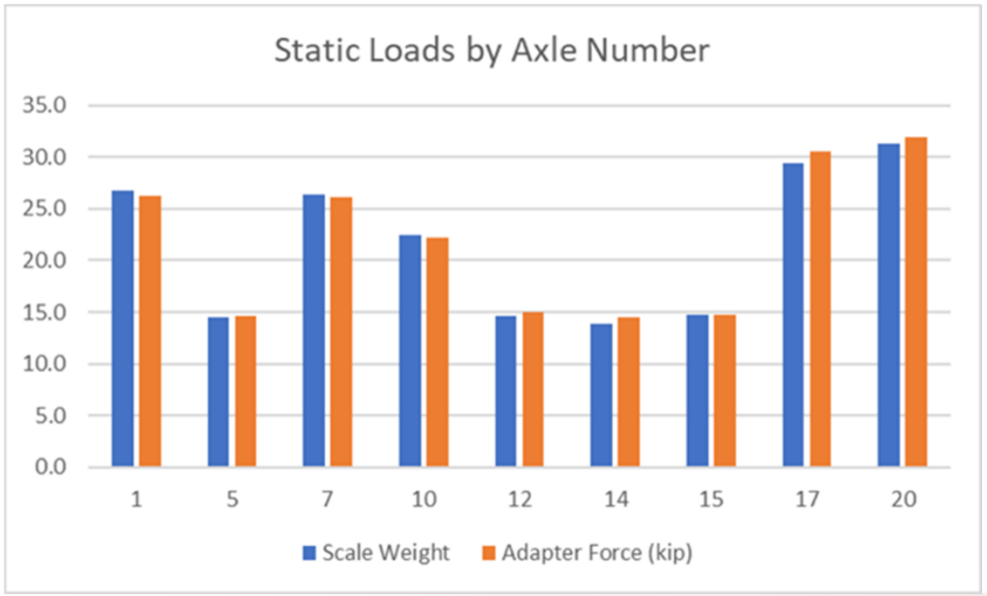
Practices

- Parallel load paths through four load cells:
  - Paired by groups with crown cap
  - Crown cap rides against side frame
- Sum of load cells represents wheel load
  - Adding half axle weight
- One instrumented adapter per HIW
- Mix of loaded and empty cars
- Range of HIW taken from service

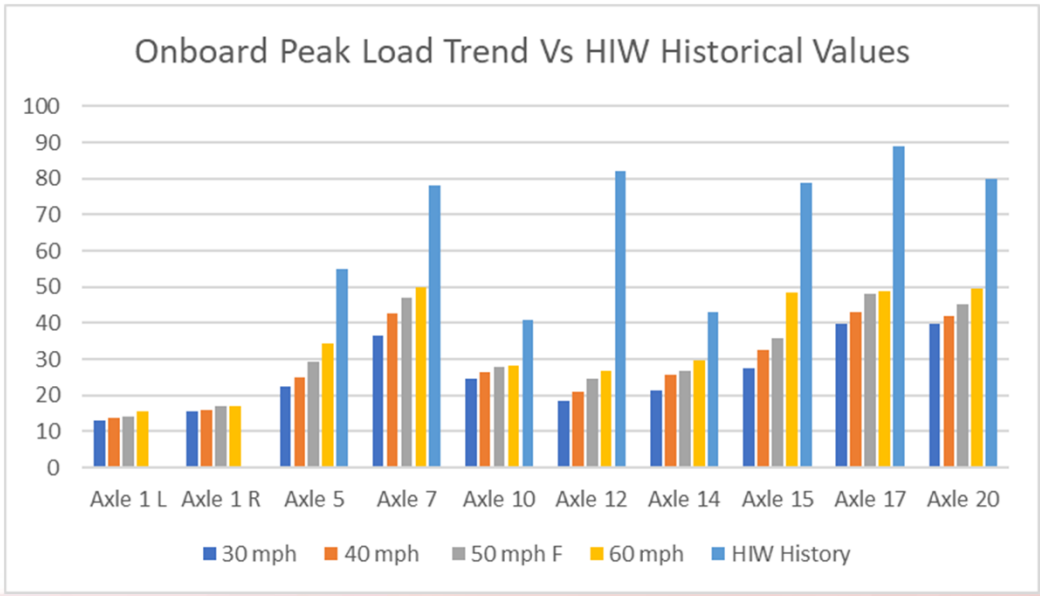


Test Result and Issues

Static weight matches scale weight within 5%

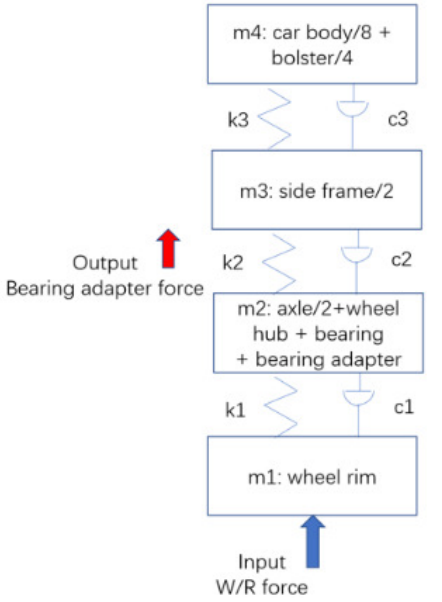


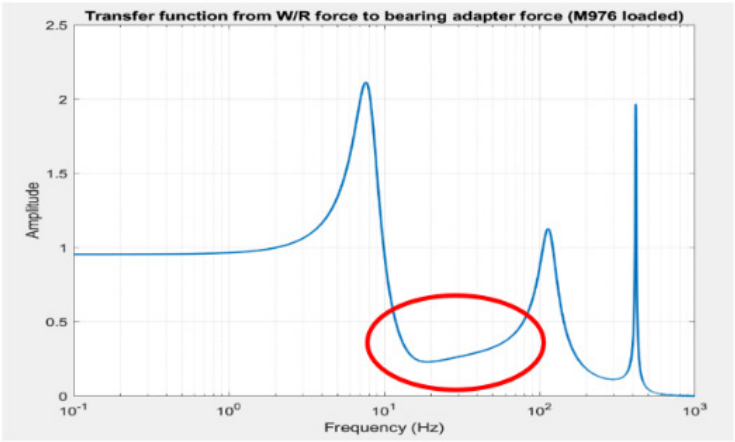
Dynamic readings are well below expected (blue bar)

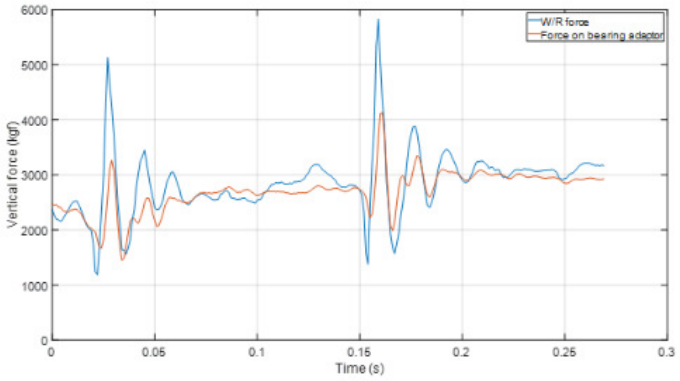


Reason

Four-degrees-of-freedom free boundary model

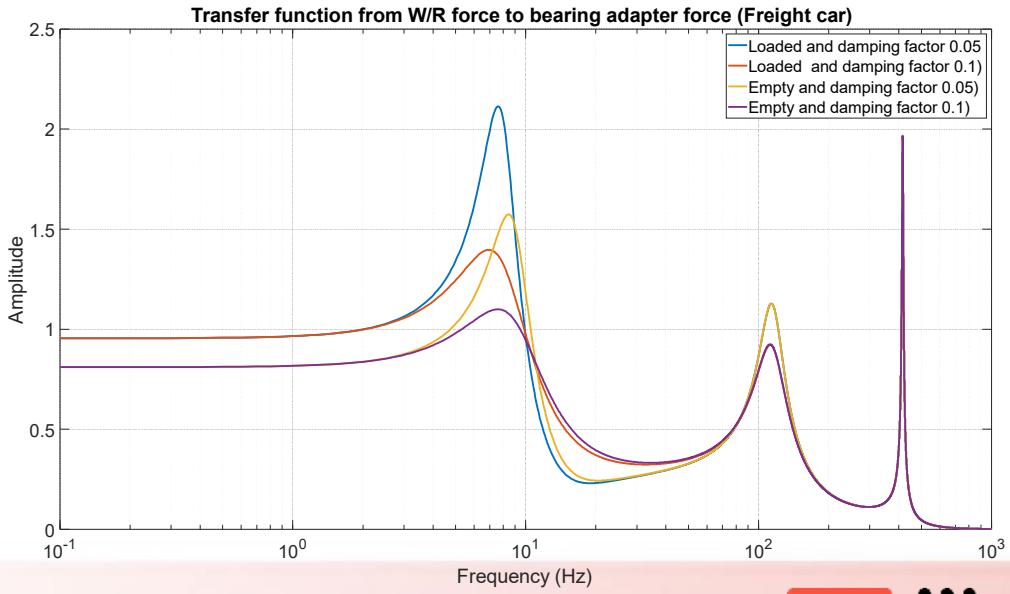






Challenges

- **Characteristics changed with vehicle parameters**
- **High frequency components**



Possible Alternatives:

- Performance-based evaluation
- Testing similar to that carried out in the 1990s
  - Establish repeatability and consistency, self-validating based on result, thresholds selected based on economics
- More goals
- Seek agreement from multiple measurement methods

Multiple Measurement Methods + Big Data Analysis

- **Big data-based verification**
- **Comparing an alternative system to outputs from multiple measurement methods**

Conclusions

Conclusions

- Wayside W/R force detection system is of great value to the railroad industry, both in terms of safety and cost reduction
- Full continuous W/R force measurement technology can provide additional information for maintenance and safety monitoring
- Big challenges remain in W/R force-based validation of new WILD
  - A comprehensive comparison testing with multiple purposes is necessary for both existing and new WILD
  - Big data-based analysis may be a reasonable approach

Thank You