The Driving Force of your Heavy Haul Operation

October 2015

Onboard Health & Performance Monitoring
Agenda

Onboard Health & Performance Monitoring

- IONX remote monitoring platform
- Onboard weighing system
- Hand brake monitoring system
- End of car systems:
  - Impact detection
  - Cushion unit health
- Bearing condition monitoring:
  - Temperature based
  - Vibration based
- Bogie performance monitoring
- Wheel fault detection
IONX Remote Monitoring System: Overview

T5X/T6X/T7X CMU

Wireless Sensor Nodes

Strain

Temperature

Vibration

Force

Proximity
Onboard Weighing System: Overview

Goal:
- Design a 1% accurate onboard weighing system

Key Requirements:
- Standalone system per car – no wires
- Bluetooth interface for local monitoring
- Integrate into Amsted Rail truck system (“smart” component)

Approach:
- Integrate transducers into truck system and calibrate
Onboard Weighing System: System Overview

A-End OWS Truck

Raw Transducer Readings → Wireless Sensor Nodes → Transmit Readings

Convert raw data to A- and B- truck payload

Bluetooth or cellular connection

Net Payload displayed on tablet/PC

B-End OWS Truck

Raw Transducer Readings → Wireless Sensor Nodes → Transmit Readings

Bluetooth or cellular connection

Net Payload displayed on tablet/PC

Amsted Rail
Onboard Weighing System: Performance

Lab Results:
- Accuracy better than 0.5% during calibration cycles in load frame

Field Results:
- Payload readings compared to track scale readings
- Average accuracy of 3.1%
- Six (6) tank cars in service for 853 days to date

Next Steps:
- Second generation hardware deployed in tank car field trial (September 2015)

Over 90 loading and unloading events captured during 853 days of field trial
Hand Brake Sensor: Overview

Goal:
- Develop a hand brake force monitoring system

Key Requirements:
- Compatibility with existing hand brake systems/chain
- Accurate and reliable operation from -40 to 85 degrees Celsius

Approach:
- Strain-based custom transducer design
- Provide chain tension readings/alerts
Hand Brake Sensor: Performance

Specifications:

- Accuracy better than 1.0% from -40 to 85 degrees Celsius
- Survived 4,500 cycles (application and full release)
- Breaking strength of 39,000 Lbf
- Capable of batch calibration
Hand Brake Sensor: Application

Chain force > Threshold

Alert sent to CMU

Alert transmitted up intra-train network

Alert sent via Cellular

To in cab display
Goal:
- Estimate struck coupler force during coupling events

Approach:
- Indirect - correlate peak car body acceleration and peak impact force
- Direct - instrument coupling system (force measuring coupler)

Progress:
- Accuracy better than ± 150 kips achieved using IONX T-series device with built-in accelerometer
- Accuracy better than ± 100 kips achieved with instrumented coupler concept
Field Data Analysis:

- Heat map identifies locations of overspeed impacts

- Of 1,933 cars monitored, 14 have seen input forces of 1 million pounds or more

- 1 million pounds is equivalent to 13 g’s on an empty car
End of Car Systems: Cushion Unit Health Monitoring

Goal:
- Estimate cushion unit ‘health’ using carbody acceleration data

Progress:
- T4S placed on car to monitor cushion unit health
- Known condition of draft system based on inspection:
  - A-end: minor wear
  - B-end: wear and minor leakage
- Calculated statistics from acceleration data indicate damage
Bearing Condition Monitoring: Overview

Goal:

- Detect and diagnose bearing defects using onboard sensors

Approach:

- Temperature-based on roller bearing adapter
- Vibration-based on roller bearing adapter
  - “Features” extracted from time domain vibration data
  - Pattern recognition & machine learning used to classify bearing
Goal:
- Measure bogie performance and condition using onboard sensors

Concept Studies:
- Body mounted sensors:
  - Measures roll, pitch, yaw, and bounce
- Truck mounted sensors:
  - Measures single truck response
  - Can detect worn wheels, worn wedges, or side bearings

TTCI Testing:
- Acceleration data collected during hunting acceptance tests with different levels of wheel wear
Bogie Performance & Condition Monitoring: Overview

Algorithm & Results:
- ‘Features’ extracted from raw vibration waveforms
  - Time domain
  - Frequency domain
- Features ranked according to mutual information (MI)
- Classifier trained using training set
- Classifier utilized with ‘fresh’ data
  - Accuracy of 90% demonstrated

**Test speeds [mph] for each wheel profile**

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<th>BNSF</th>
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* Red color indicates speeds at which hunting occurred.
Wheel Fault Detection: Overview

Goals:
- Detect & diagnose wheel defects using onboard sensors

Approach:
- Vibration-based on roller bearing adapter

Progress:
- Field data with high kip wheels used for analysis
- ‘Features’ extracted from acceleration signal
- Machine learning used to “classify” data
- Accuracy of 70% achieved with single feature and up to 100% with multiple features