What’s New at TTCI?

Lisa A. Stabler
President
Agenda

♦ TTCI Overview

♦ Research Update
  ● Phased Array
  ● Automated Cracked Wheel Detector
  ● Fiber Optics
  ● Drones
TTCI Overview
TTCI – Transportation Technology Center, Inc.

- Opened in 1971 as the High Speed Ground Test Center
- Wholly owned subsidiary of the Association of American Railroads
- Located in Pueblo, Colorado
- Operates the Transportation Technology Center on behalf of the Federal Railroad Administration
- Focus on research, development, testing and training for the rail industry
- 300+ Employees
- 52 square mile facility with 48 miles of track
- Full-size laboratories capable of testing rail cars

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Full-size laboratories capable of testing rail cars
Engineered Facilities for Dynamic Testing

High Tonnage Loop (HTL)
- 2.7-mile loop, three 5° curves, one 6° curve
- Main use – HAL studies
- Test bed for various premium track components
- 25 MGT/month in controlled environment

Wheel/Rail Mechanism Track (WRM)
- 7.5°, 10°, and 12° curving performance tests
- Dynamic curving tests
- Lubrication studies

Transit Test Track (TTT)
- 9.1-mile loop
- 80 mph max speed
- DC electrified third rail
  - Up to 1150 volts
  - Up to 12,000 amps

Railroad Test Track (RTT)
- 13.5-mile loop
- 1°-15’ curve and four 50’ curves
- Maximum speed 165 mph
- 12.5-, 25-, and 50-kV overhead catenary

Precision Test Track (PTT)
Multi-use track for railcar testing
- Pitch and bounce
- Twist and roll
- Yaw and sway
- Car impact
- Miscellaneous studies
Full-Scale Laboratory Testing

- Vibration Test Unit
- Simuloader
- Squeeze Fixture
- Impact Wall
Revenue Service-Like Test Facilities

♦ Revenue service like environment
♦ Controlled conditions
♦ Known defects left in track or rolling stock
♦ Current facilities
  ● Precision Test Track
  ● Bridge Test Bed
  ● High Speed Adjustable Perturbation Slab
  ● Rail Defect Test Facility
  ● Positive Train Control
  ● Open Inspection of Track Components
  ● Security and Emergency Response Training Center
Training - Security and Emergency Response Training Center (SERTC)

♦ In operation at TTC since 1985

♦ Hazmat response for Surface Transportation
  ● Focus on Rail and Highway

♦ Approximately 60,000 students trained
  ● Railroad
  ● Chemical and petroleum
  ● Local, State, Federal and Tribal First Responders

♦ “Graduate level” program

♦ Emphasis on preparedness and response

♦ See [www.sertc.org](http://www.sertc.org) for more information
Phased Array
Why Improved Rail Defect Detection

♦ Problem Definition
  ● Increased defect occurrence on older rails
  ● Defects masked by surface defects/rolling contact fatigue
  ● Limitations of current inspection technologies
    ▲ Up to 10 percent of rail defects are missed

♦ Required
  ● Reduce undetected rail flaws
  ● Increase detection efficiency
    ▲ Reduce false positives
    ▲ Improve inspection rate
Background

- Conventional rail inspection does not catch all internal defects
- Conventional ultrasonic inspection uses fixed probe directions that scan only part of the rail head cross section
- Profile wear misdirects beams
- Defects must be confirmed by hand inspection

Conventional Rail Inspection

- 70° coverage
- Side looker coverage
- 0° coverage
TTCI Phased Array Configuration

♦ Full Matrix Phased Array
♦ Optimized Probe Layout
  ● Optimal railhead coverage
  ● 20-mph vehicle inspection speed
  ● Rail wear compensation algorithm
♦ Two Modes
  ● 20-mph scan for flaws
  ● High resolution mode
  ▲ On-board flaw validation

*TTCI patent pending
# Phased Array Performance Compared to Conventional Ultrasonic Detection

Single Pass on Rail Defect Test Facility – 5 mph

<table>
<thead>
<tr>
<th>Flaw Type</th>
<th>Total</th>
<th>Phased Array</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>26</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Web</td>
<td>11</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Weld</td>
<td>4</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Vertical Split Head</td>
<td>2</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Bolt Hole Crack</td>
<td>1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Transverse Fissure</td>
<td>3</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>TD Under Shell</td>
<td>6</td>
<td>83</td>
<td>0</td>
</tr>
</tbody>
</table>
Automated Cracked Wheel Detection
Maximize Safety by Significantly Reducing Wheel-Related Derailments

Challenges

- Internal Fatigue Defects/RCF
- Reliable Real-time Detection Systems

Solutions: Facilitate development, testing, and evaluation of cracked wheel and cracked axle detectors capable of inspecting moving trains
Tycho Automated Cracked Wheel Detection System (ACWDS)

- Wayside NDE system for inspecting wheel tread for surface damages and internal cracks on a moving train.
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TYCHO ACWD System

♦ Background and Review
  ● Currently used in China
    ▲ Locomotive wheel inspection
    ▲ 5 mph
  ● U.S. implementation goal
    ▲ All freight cars
    ▲ 20 mph
  ● Installation started at TTC in 2013
  ● Preliminary results after initial development (late 2014)

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>5 mph</th>
<th>7 mph</th>
<th>10 mph</th>
<th>12 mph</th>
</tr>
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<tbody>
<tr>
<td>Hits</td>
<td>16</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Misses</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>False Calls</td>
<td>19</td>
<td>16</td>
<td>14</td>
<td>12</td>
</tr>
</tbody>
</table>
Tycho ACWD Detection Performance Summary

<table>
<thead>
<tr>
<th>Defect Type</th>
<th>5 MPH</th>
<th>10 MPH</th>
<th>12 MPH</th>
<th>15 MPH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HITS</td>
<td>MISSES</td>
<td>Detection %</td>
<td>HITS</td>
</tr>
<tr>
<td>Shattered Rim Crack (SRC) Wheel # 1</td>
<td>15</td>
<td>0</td>
<td>100%</td>
<td>15</td>
</tr>
<tr>
<td>Shattered Rim Crack (SRC) Wheel # 2</td>
<td>2</td>
<td>13</td>
<td>13%</td>
<td>1</td>
</tr>
<tr>
<td>Vertical Split Rim (VSR) Wheel #1</td>
<td>15</td>
<td>0</td>
<td>100%</td>
<td>14</td>
</tr>
<tr>
<td>Vertical Split Rim (VSR) Wheel #2</td>
<td>15</td>
<td>0</td>
<td>100%</td>
<td>15</td>
</tr>
<tr>
<td>FALSE CALL</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

♦ One false detection event was noted during the 60 confidence test runs. This alarm was related to a missed flange sensor triggering event.
Tycho Machine Vision System

♦ Wheel Tread Inspection System Added ahead of UT Inspection
  • Technical supplement to UT inspection
  • Assesses wheel tread condition for UT probe coupling

Wheel Diameter Measurement System

Wheel Tread Inspection System
Tycho Machine Vision Result

- Work is currently in progress for creating automated compensation routines to identify wheel surface conditions (wheels with tread damages)
- More testing will occur 4Q16.
Fiber Optics
The system consists of two major parts:
- standard fiber positioned (e.g., buried) near the object to be analyzed
- the analyzer connected to one end of the fiber

The fiber acts as a distributed acoustic sensor along its entire path. Backscattered light provides a measurement every 1 meter along the fiber. A single 20 km fiber optic cable acts as 20,000 individual sensors.

Each meter of fiber acts as an individual sensor allowing for monitoring of time and position as well as allowing for the determination of event characteristics.
Fiber Installation on HTL

Bridges with various sensor configurations

Detection Equipment Bungalow
Flat Wheel Testing

Distance

Time

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Example of Fiber Optic Signature from a Rail Break

Rail Break

Rail Break Repaired
Fiber Optic Distributed Acoustic System
Industry Research

♦ Current focus is on derailment prevention in real time
  ● Wheel defect related
  ● Rail break related
  ● Future – Thermal Track misalignment

♦ TTCI Support of Industry Research
  ● Three Fiber Optic Test Beds at TTC
  ● Continuing test efforts yielding published algorithms
    ▲ WP-174 Flat Wheel Detection
    ▲ WP-176 Flat Wheel Characterization
    ▲ WP-177 Axle Detection
    ▲ WP-175 Rail Break Detection
  ● Actively working with Class Is and FRA
    ▲ FRA Evaluation of Fiber Optic Broken Rail Detection Systems
    ▲ FRA Vitality and Track Circuit Requirement Study
    ▲ AAR Fiber Optic Acoustic Detection TAG
Drones
Drone Operations at TTCI

8/29/2016 -- new FAA Small UAS Rule (Part 107)

- OK to operate any small UAV – Pilot responsible to determine it is safe to operate.
- Pilot certificate no longer required.
  ▲ New Remote Pilot Airman Certificate
  ▲ Must pass FAA Aeronautical Knowledge exam – no actual flight skill test
  ▲ Pilot may allow others to operate the drone provide he is in a position to take control
- External load operation allowed
- Within visual line of sight of pilot (potential for waiver)
- No night flight (potential for waiver)
- Minimum 3 mile visibility (potential for waiver)
- No flights over non participating people (potential for waiver)
- Max altitude 400 feet
FRA Funding

* Goal – set up TTC as a test site where customers can test UAV technologies

* New Small UAS Rule has resulted in a change of approach
  - Special Certificate of Authority no longer required
  - FRA has retained UAV consultant to assist in developing an operations manual that includes training procedures, personnel, and risk analysis procedures
  - We received draft Operations Manual in mid August
    ▲ Reviewing / revising to make sure that it fits TTCI
AAR / SRI Developments

♦ No funding proposed for 2017
♦ Proposed UAV committee for regulatory issues
♦ Recent poll of Bridge TAG and UAV Tag established in 2015
♦ Railroad 1
  ● Working with FAA to develop protocols for beyond visual line of sight
  ● Using UAVs for supplemental bridge inspections and have inspected many major
    bridges that are difficult to access with traditional methods.
♦ Railroad 2
  ● Testing program underway for bridge inspection
  ● Preliminary inspection of culverts to determine if manned inspection is needed or not.
♦ Railroad 3
  ● Watching industry developments
♦ Railroad 4
  ● Doing some work on bridges
  ● Most drone use is by their real estate group at this time.
♦ Railroad 5
  ● Inspected 35 to 40 major bridges that have challenging access.
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Questions: x1771

Drones at TTCI
AAR / SRI Developments

♦ Potential applications
  ● Security / Surveillance
  ● Track buckle inspection
  ● Broken rail detection
  ● Initial overview of derailments
  ● Initial overview of large scale disruptions such as floods and earthquakes
  ● Inspection for track integrity ahead of key trains in dark territory
  ● Geotechnical inspection on slopes with difficult access
  ● Bridge inspection
  ● Trending of track and structures deterioration (detect changes over time)
SERTC -- Develop Procedures for Chemical Sensor Panel Deployment & Interpretation

- Investigate live chemical releases at incidents
- Methods for sensor pack data interpretation
  - Real-time downwind plume modeling
  - Multiple sensors (Flammability, Toxic, & Radiological)
- Develop procedures / training programs for UASs at derailment sites
  - Training for RR, Emergency Responders, etc
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Derailment Investigation
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Track Work

♦ Gauge-widen track
  ● 61.66 inch gauge as opposed to standard gauge of 56.5 inch.

♦ Wheels ride on edge of rim
  ● Exposes tread for UT probes

♦ Guardrails keep wheels centered

Schematic of gage widened track section

Ultrasonic probe layout
**Wheel Flaw Details**

*SRC Wheel # 1:* detected 100% at 15 mph

---

**Wheel Defect Type**

<table>
<thead>
<tr>
<th>Wheel Defect Type</th>
<th>Handheld UT Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SRC Wheel 1</strong></td>
<td><strong>Indications</strong></td>
</tr>
<tr>
<td></td>
<td>• Metal flow in shattered rim area (6&quot; long x 2.9&quot; wide)</td>
</tr>
<tr>
<td></td>
<td>• Multiple sub-surface delaminations all around tread surface</td>
</tr>
<tr>
<td></td>
<td><strong>Length</strong> [inch] **</td>
</tr>
<tr>
<td></td>
<td><strong>SRC</strong></td>
</tr>
<tr>
<td></td>
<td>4.40 2.90 0.23~ 0.63</td>
</tr>
<tr>
<td></td>
<td><strong>Sub-surface delaminations</strong></td>
</tr>
<tr>
<td></td>
<td>0.60 ~ 1.60 0.22 ~ 0.26</td>
</tr>
</tbody>
</table>

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**Wheel Flaw Details**

♦ **SRC Wheel # 2: detected 7% at 15 mph**

![Wheel Flaw Image]

- **Chip out**
- **Shattered rim face cracks**

---

<table>
<thead>
<tr>
<th>Wheel Defect Type</th>
<th>Handheld UT Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SRC Wheel 2</strong></td>
<td>• Visible crack and chipout in rim face</td>
</tr>
<tr>
<td></td>
<td>• 3 Sub-surface delaminations</td>
</tr>
<tr>
<td></td>
<td>• Visible shelling and RCF</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Chip out**
  - Length: 1.00 inch
  - Width: 1.00 inch
  - Depth: 1.00 inch

- **SRC**
  - Length: 8.00 inch
  - Width: 2.00 inch
  - Depth: 0.75 inch

- **Sub-surface delaminations**
  - Length: 0.50 to 3.20 inch
  - Width: 0.25 to 1.00 inch
  - Depth: 0.20 to 0.15 inch
Wheel Flaw Details

* VSR Wheel # 1: detected 73% at 15 mph

<table>
<thead>
<tr>
<th>Wheel Defect Type</th>
<th>Handheld UT Measurement</th>
</tr>
</thead>
</table>
| VSR Wheel 1       | • VSR crack in the field side fillet between rim and plate  
                    • Some RCF in tread | 9.00          | 2.00         | 1.00         |
Wheel Flaw Details

♦ VSR Wheel # 2: detected 100% at 15 mph

Wheel Flaw Details

<table>
<thead>
<tr>
<th>Wheel Defect Type</th>
<th>Handheld UT Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>VSR Wheel 2</td>
<td>• VSR crack in the field side fillet between rim and plate</td>
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