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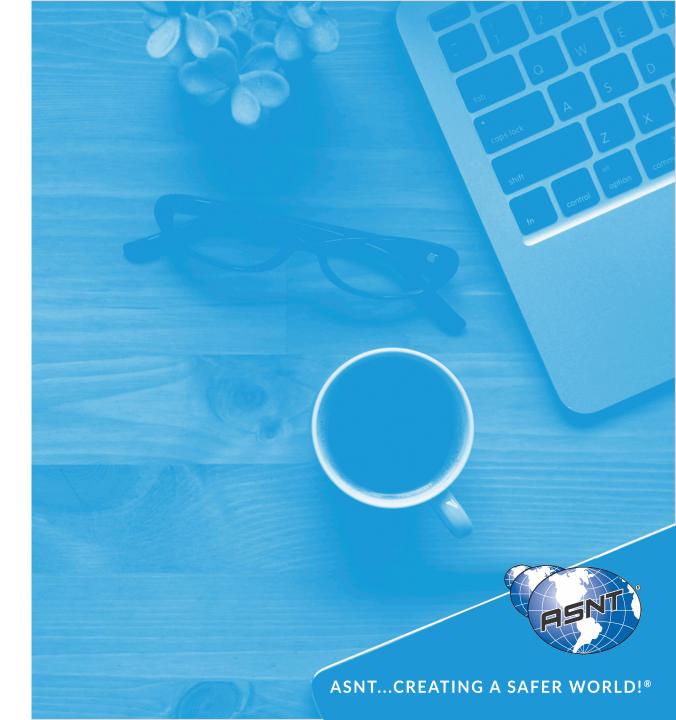
July 8, 2021

Host: Toni Bailey

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Railcar Wheels Subsurface Defect Monitoring Using Ultrasonics

Anish Poudel, PhD Principal Investigator – NDE

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Anish Poudel, Ph.D.

- Principal Investigator NDE, Transportation Technology Center, Inc.
- Ph.D., Mechanical Engineering, SIUC, Carbondale, IL
- ASNT leadership positions
 - Board of Directors
 - Chairman, Research Council
 - Past-Chairman, CO Section
 - Past- Program Chair, Research Symposium
 - Chair, AI/ML Committee Engineering Council
- Awards & Honors
 - IHHA Emerging Railway Professionals Award, 2019
 - ASNT Mentoring Award, 2018
 - ASNT Young NDT Professional Award, 2014
 - SIU Richard and Donna Falvo Outstanding Dissertation Award, 2015
 - SIU Alumni Association Outstanding Master's Thesis Award, 2011
- Representing USA/ASNT in Global Ambassadors on NDE 4.0
- 100+ peer-reviewed publications
- 1 Patent

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Presentation Outline

- TTCI/AAR Overview
- Introduction North American Railroads
- Background Broken Wheels
- Automated Cracked Wheel Detector System (ACWDS)
- Ultrasonic Testing (UT) Principle
- ACWDS Ultrasonic Output Results
- ACWDS Operation
- Facility for Accelerated Service Testing (FAST)
- ACWDS Recent Findings
- Conclusions
- Acknowledgements





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AAR/TTCI

- The Association of American Railroads (AAR) is an industry trade group representing primarily the major freight railroads of North America, Amtrak and some regional commuter railroads
 - Founded in 1934
 - Headquartered in Washington, D.C.
 - Major Areas of focus includes Policy making, Standard setting, Industry data, reports and publications, and Research and technology initiatives
- TTCI is a wholly owned subsidiary of the AAR
 - Operated by an on-site management team
 - Guided by an independent Board of Directors
 - Generally, the COO of each Class I railroad



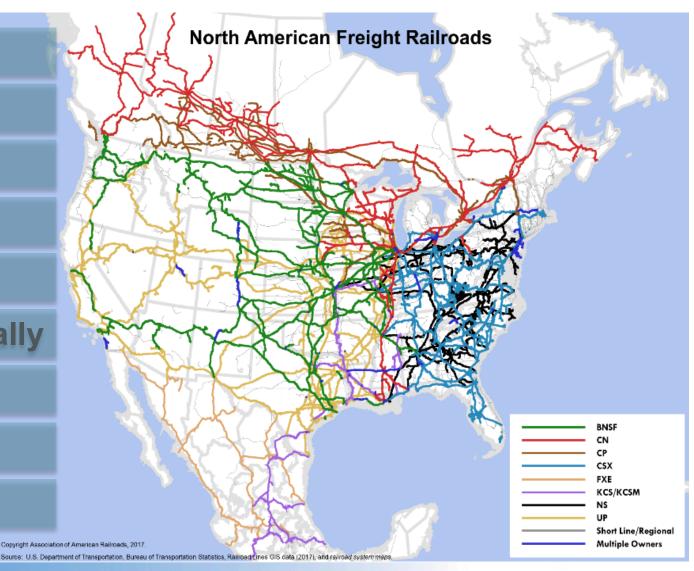


A Small Business Enterprise

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North American Freight Railroads

- 650 separate railroads; 7 Class I
- 1.6 million freight wagons
- 180,000 miles of track
- 167,000 employees
- 32.5-tonne axle loads allowed
- 1.47 billion tonnes of freight annually
- 32 million passengers annually
- 30,000 locomotives
- \$70 billion USD annual revenue

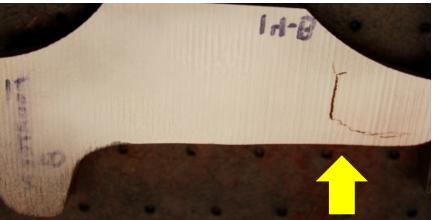




Why Wheel Inspection Research?

- Broken wheels are rare but important to find.
- A major precursor to wheel failure in Heavy Axle Load (HAL) service is attributed to subsurface fatigue cracks initiating and propagating from internal discontinuities such as voids, inclusions, and micro-cracks.
- These fatigue cracks typically initiate at the depth of the maximum shear stress (approximately 3 mm - 6 mm)
- Safely detecting internal defects on wheels before they become problematic, and without interrupting service, is the goal.

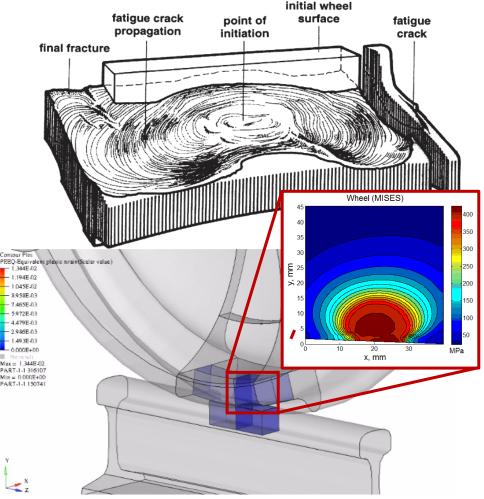




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Sub-surface Fatigue Crack Features

- Sketch of a fatigue crack which nucleated about 4 mm below the surface. Maximum depth of the crack below the wheel tread is about 14 mm
 - 1. No sign of inclusions or voids at the point of initiation
 - 2. Crack initiates at a depth of 3-10 mm below the wheel tread
 - 3. Crack propagates in an angle downward to a depth of about 20 mm
 - 4. Final fracture toward the surface



Wheel Rail Contact Stresses

Kiani, M. and Fry, G.T., 2017, "Fatigue analysis of railway wheel using a multiaxial strain-based critical-plane index," Fatigue Fract Eng Mater Struct., pp.1–13.



ACWDS

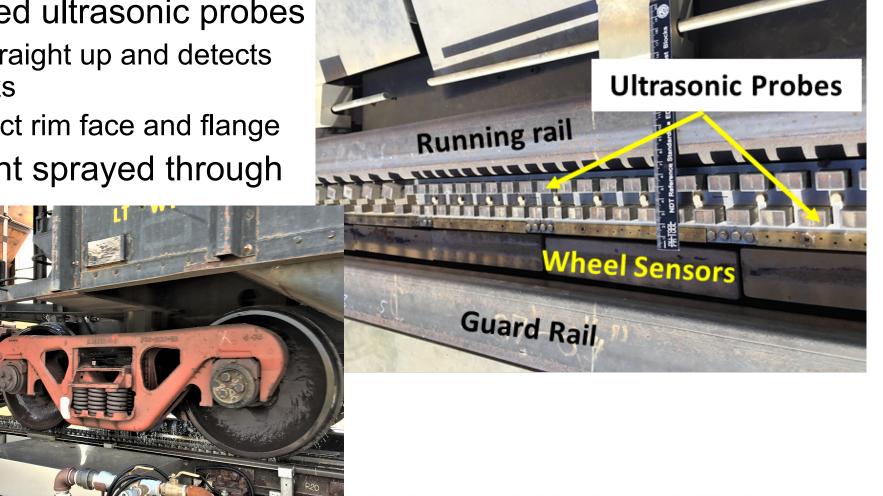
- Technology belongs to Nanjing Tycho company (China)
- Wayside NDE system for inspecting internal cracks on a moving train



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Ultrasonics Hardware Configuration

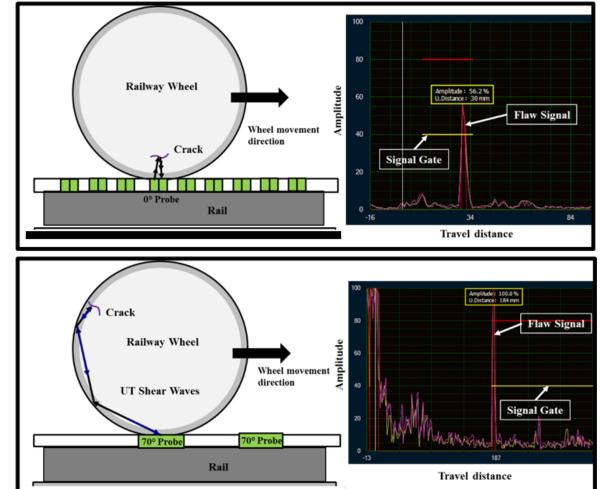
- Array of Spring-loaded ultrasonic probes
 - 0° UT probes look straight up and detects circumferential cracks
 - 70° UT probes inspect rim face and flange
- Water-based couplant sprayed through nozzles



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UT Principle

- 0° probes look straight up into the tread and look for the cracks running parallel to the tread surface (circumferential cracks)
- 70° probes inspect rim face and flange to detect cracks oriented in the radial direction
- These probes connect to a central computer, which runs the software program for analyzing wheel inspection ultrasonic signals.



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ACWDS Ultrasonics Results Output



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ACWDS Operation

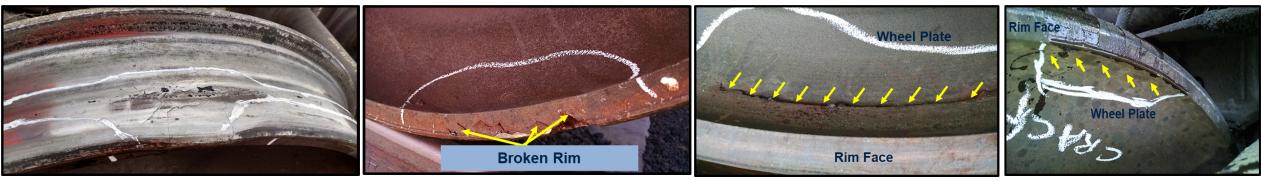
- System operation is automated
 - Self calibration
 - Internal self-check
 - Automated reporting
- Results available within 10 minutes
- Reporting is configurable
 - Defect alarm level (severity and confidence)
 - Reporting method (manual review, email alerts, sending alarms)

[©] Train wheel auto test system(20180717-SP)									-
Language Pump									
11:56:06 simu Online simu Off	Line FW_Ve	rsion	DtConf	ig			Single Wh	eel	Train
10-02 07:32:25.151] Got CY[37] Segudata axleNo:457	-	Cor	ning time:	2018-10-	02 07:18:45	i eft ti	me: 201	8-10-02	07:32:32
10-02 07:32:26.484] Got CY[41] Sequdata axleNo:456									
10-02 07:32:27.609] Got CY[41] Sequdata axleNo:457		Tra					ed: 13r	ninute46	second
10-02 07:32:32.214] Train left		IP	Sequ	Wheel	Detector	Line	Buffer	Lost	
10-02 07:32:32.267] [33] stop CY return=0:正常 10-02 07:32:32.321] [34] stop CY return=0:正常		13	54960	457	59	1	0	0	
10-02 07:32:32.321] [34] stop CY return=0:正常 10-02 07:32:32.375] [35] stop CY return=0:正常		14	54960	457	59	1	0	0	
10-02 07:32:32:429] [36] stop CY return=0:正常		<u> </u>				-	-	-	
L0-02 07:32:32:483] [37] stop CY return=0:正常		15	109920	457	119	1	0	0	
L0-02 07:32:32.536] [38] stop CY return=0:正常		16	109920	457	119	1	0	0	
10-02 07:32:32.590] [41] stop CY return=0:正常		17	109920	457	119	1	0	0	
10-02 07:32:35.610] [13] stop acquisition return=0:正常		18	109918	457	119	1	0	0	
10-02 07:32:35.611] [14] stop acquisition return=0:正常		21	54960	457	118	1	0	0	
10-02 07:32:35.612] [15] stop acquisition return=0:正常		21	54960	457	118	1	U	U	
10-02 07:32:35.613] [16] stop acquisition return=0:正常 10-02 07:32:35.614] [17] stop acquisition return=0:正常									
10-02 07:32:35.634] [17] stop acquisition return=0:正常									
10-02 07:32:35.642] [21] stop acquisition return=0:正常									
10-02 07:32:35.643] Idle									
10-02 07:32:35.934] 192.168.0.14 收到结束标志									
10-02 07:32:35.945] [14] finished all=0 / 54960 Lost:0.000%		_				- 1		_	
10-02 07:32:35.946] 192.168.0.13 收到结束标志		TYC							_
10-02 07:32:35.946] [13] finished all=0 / 54960 Lost:0.000%		UΤ	Device 2	46	8 10 12	- 2	ZH Device		
10-02 07:32:36.291] 192.168.0.15 收到结束标志 10-02 07:32:36.292] [15] finished all=0 / 109920 Lost:0.000%			1	35	7 9 11		进线速度:《		
10-02 07:32:36.292] [13] Hilshed all=0 7 109920 Cost:0.000%							平均速度:		
10-02 07:32:36.389] [17] finished all=0 / 109920 Lost:0.000%		TYC	ю				离线速度:《		
10-02 07:32:36.421] 192.168.0.16 收到结束标志		CY	2 Device	46	8 10 12		进入轮对:《 通过轮对:《		
10-02 07:32:36.422] [16] finished all=0 / 109920 Lost:0.000%			1	3 5	7 9 11				
10-02 07:32:36.423] 192.168.0.18 收到结束标志							环境温度:	+路	1/12
10-02 07:32:36.423] [18] finished all=0 / 109918 Lost:0.000%		E	部						水位
10-02 07:32:36.798] 192.168.0.21 收到结束标志		月	비비니			Ĩ	在线 正向 る	车 风扇	
L0-02 07:32:36.799] [21] finished all=0 / 54960 Lost:0.000%									
10-02 07:32:37.777][34] 仪器内部温度异常!		Test	date time	:					
L0-02 07:32:39.260] Write Sequ:D:\Tycho\data\2018\10\20181002_071845\Sequ.xml L0-02 07:32:39.303] every channel finished all=0 / 604558 Lost:0.000%			to	· [ReAnalyse		
18/10/2 7:18:45处理完成									
and the second sec									

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ACWDS Performance Testing

Defect Type	5 mph		10 mph			12 mph			15 mph			
	HITS	MISSES	Detection %	HITS	MISSES	Detection %	HITS	MISSES	Detection %	HITS	MISSES	Detection %
Broken Wheel # 1	15	0	100%	15	0	100%	15	0	100%	15	0	100%
Broken Wheel # 2	2	13	13%	1	14	7%	2	13	13%	1	14	7%
Broken Wheel # 3	15	0	100%	14	1	93%	13	2	87%	11	4	73%
Broken Wheel # 4	15	0	100%	15	0	100%	15	0	100%	15	0	100%
FALSE CALL		0			0			0	1		1	



Broken Wheel #1

Broken Wheel # 2

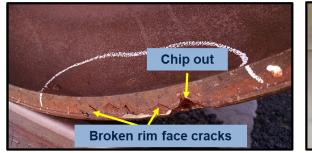
Broken Wheel #3

Broken Wheel #4

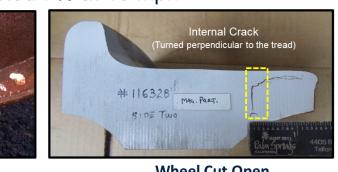
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ACWDS Detection Performance Verification

• Broken Wheel # 2: Detected 7% at 15 mph

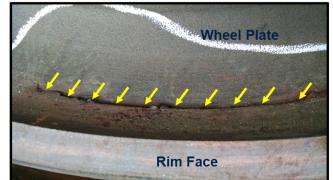


Broken Wheel # 2

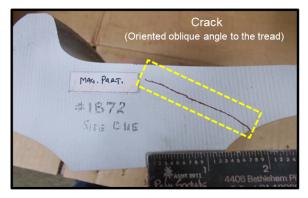


Wheel Cut Open

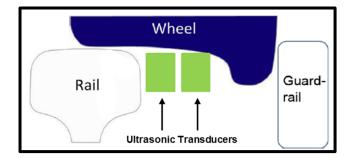
Broken Wheel # 3: Detected 73% at 15 mph



Broken Wheel # 3







Flaw shape, size, location, and orientation governs the UT detection!

• Broken Wheel # 4: Detected 100% at 15 mph



Broken Wheel # 4



Wheel Cut Open



ACWDS Outward Probes



 Outboard probes added later to finds sub-surface fatigue cracks outboard of tapeline



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ACWDS Demonstration



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TTCI FAST Operation

- High Tonnage Loop (HTL) 2.7 miles
- Mostly 315,000-pound cars (39-ton axle load)
- ≈50% of train operations in each direction
- Over balance speed in curves



FAST HAL Train – 2020 Broken Wheel Removals

Car position	Car No.	Wheel position alarmed	FAST mileage (miles)	Transducer alarmed	Hand UT verification results
71	33150	R3	201,751	0° outboard	3.2-inch x 1.5-inch x 0.5-inch
62	33395	R3	219,281	0° outboard 0° wide gage	3.25-inch x 2.75-inch
7	33166	L2	138,761	0° outboard	3.4-inch x 1.1-inch x 0.2-0.4-inch
17	33396	R1	194,466	0° outboard	1.0-inch x 1.2-inch x 0.25-inch
88	33317	L2	162,145	0° outboard	7.0-inch x 1.8-inch x 0.3-inch
58	33164	L3	156,027	0° outboard	5.25-inch x 1.5-inch x 0.2-0.7-inch
72	33290	L2	56,829	0° outboard	3.5-inch x 0.9-inch x 0.3-inch



13





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FAST Car 33164 Wheel L3

- Detected by 0° outboard probes
- Hand-UT Verification
 - 5.25-inch (L) x
 1.5-inch (W) x
 0.2-0.7-inch (D)



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FAST Car 33290 Wheel L2

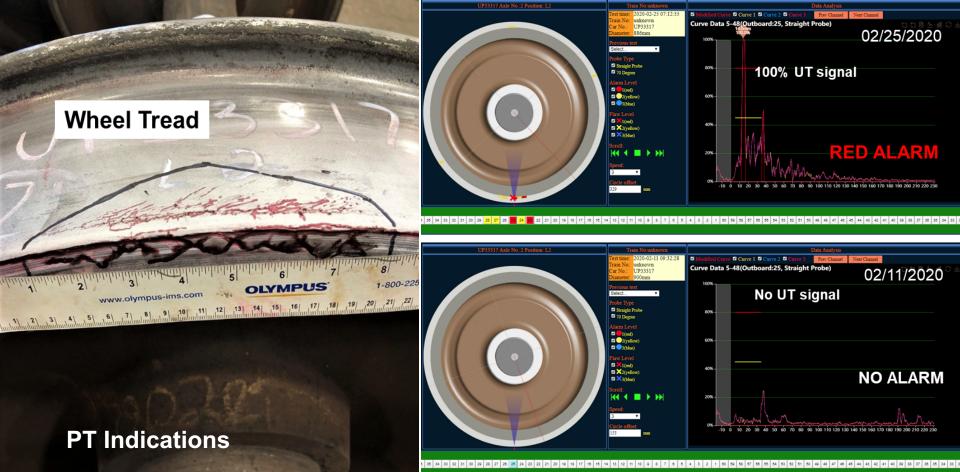
- Detected by 0° outboard probes
- Hand-UT Verification
 - 3.5-inch (L) x
 0.9-inch (W) x
 0.3-inch (D)



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FAST Car 33317 Wheel L2

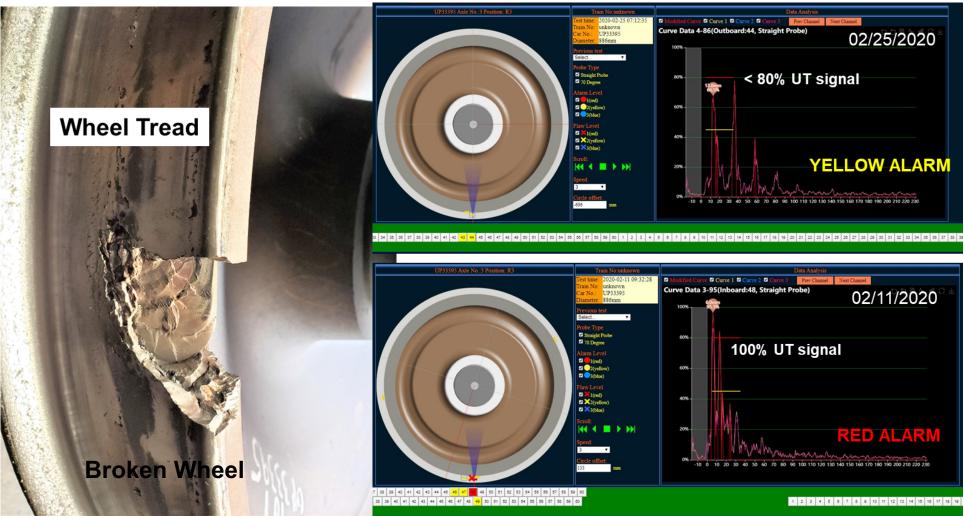
- Detected by 0° outboard probes
- Hand-UT Verification
 - 7.0-inch (L) x
 1.8-inch (W) x
 0.3-inch (D)



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FAST Car 33395 Wheel R3

- Detected by 0° inboard/ outboard probes
- Hand-UT
 Verification
 - 3.25-inch (L) x
 2.75-inch (W)



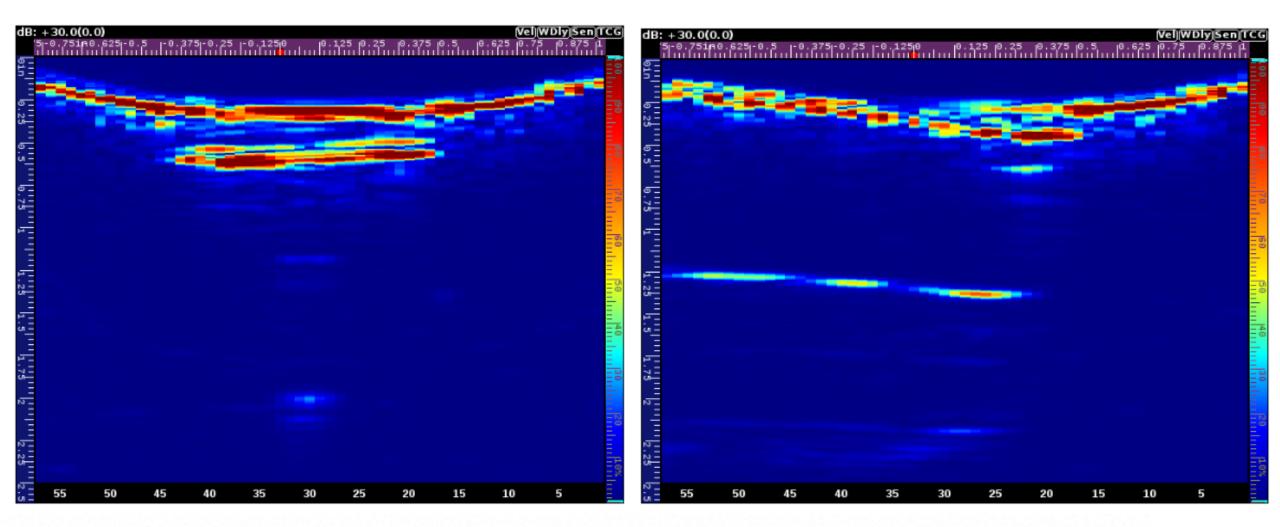
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Hand-held Phased Array UT Verification



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Hand-held Phased Array UT Verification



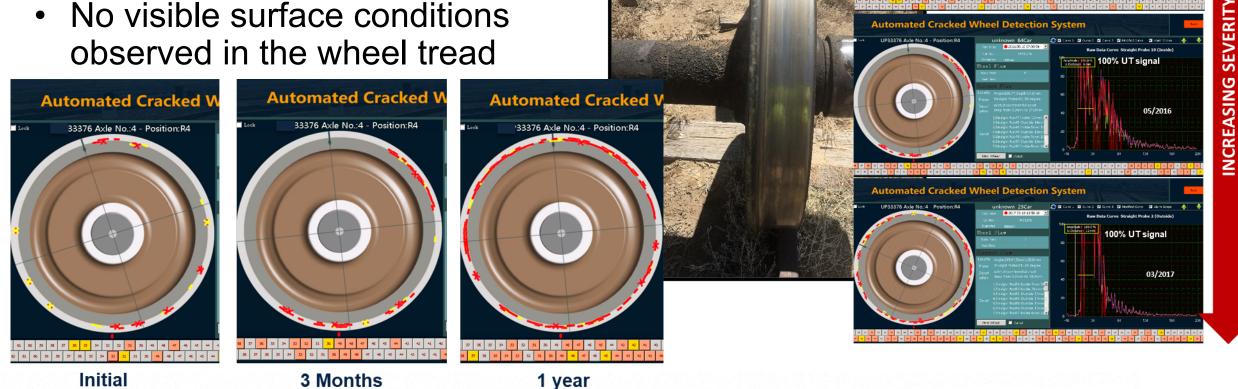
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Prior Year Removals & UT Verification

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FAST Car 33376 Wheel R4

- Total of 94,327 miles and 13.48 MGTM at FAST from 01/2013 to 03/2017
- No visible surface conditions observed in the wheel tread



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utomated Cracked Wheel Detection System

stomated Cracked Wheel Detection

100% UT signa

100% UT signal

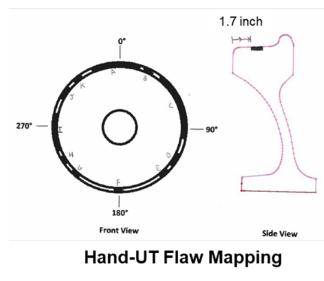
03/2016

UP33376 Axle No.:4 - Position:R4

FAST Car 33376 Wheel R4

- Hand UT NDE findings:
 - Sub-surface fatigue cracks
 - Length: entire circumference
 - Width: 1.4-inch to 1.5-inch
 - Depth: 0.24-inch to 0.36-inch
 - Location:1.7-inch from the rim face







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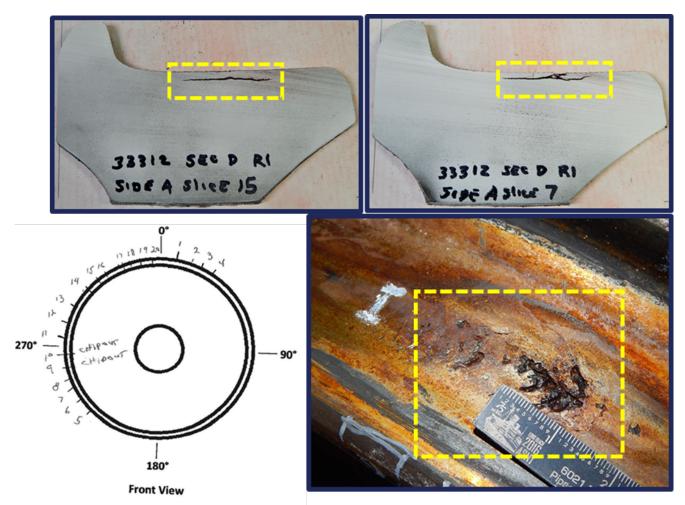
FAST Car 33312 Wheel R1

- Class C wheel manufactured in November 2004
- Total of 166,131 miles and 23.76 MGTM at FAST from 09/2009 to 05/2016
- RCF/spalling observed at two locations next to one another in the wheel tread
- Spall length and width was 1.2-inch (30 mm) by 0.8-inch (20 mm), respectively



FAST Car 33312 Wheel R1

- Hand-UT NDE findings:
 - Sub-surface fatigue cracks:
 - Length: 0.6-inch to 4.0-inch (15 mm to 102 mm)
 - Width: 0.3-inch to 1.0-inch (8 mm to 25 mm)
 - Depth: 0.19-inch to 0.25-inch (5 mm to 7 mm)
 - Location: 2.0-inch (51 mm) from the rim face (half of the entire circumference)



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Conclusions

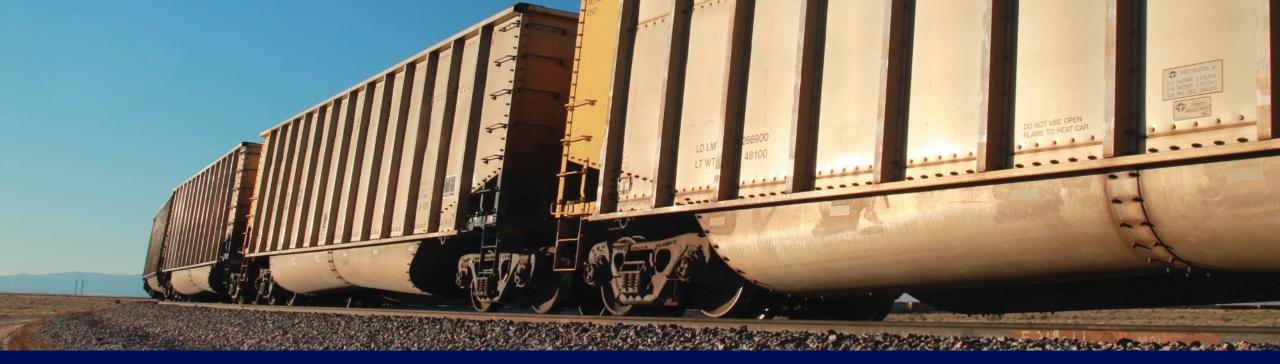
- Wayside testing of railway wheels for internal anomalies provides a means for identifying subsurface cracks.
- Automated detection and characterization of cracked wheels presents several advantages to the railroads and wheel manufacturers.
- Results from the testing on FAST train cars demonstrated the defect detection and trending studies for wheels with sub-surface fatigue cracking.
- The hand-held UT verifications were in agreement with the ACWDS findings.

Acknowledgements

- TTCI Team
- AAR SRI program
- AAR Members
- Nanjing Tycho







Thank you!

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