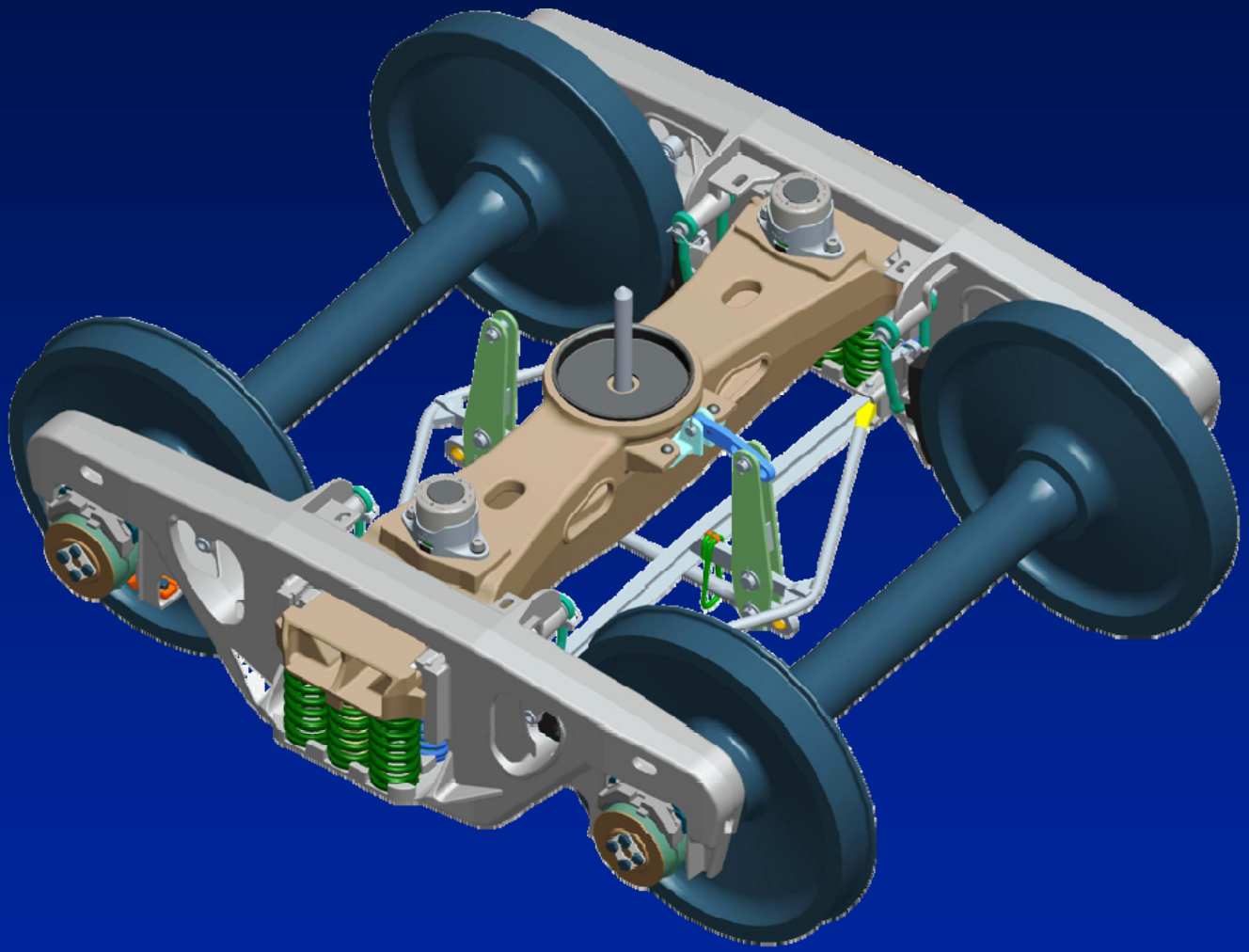
Brent M. Wilson

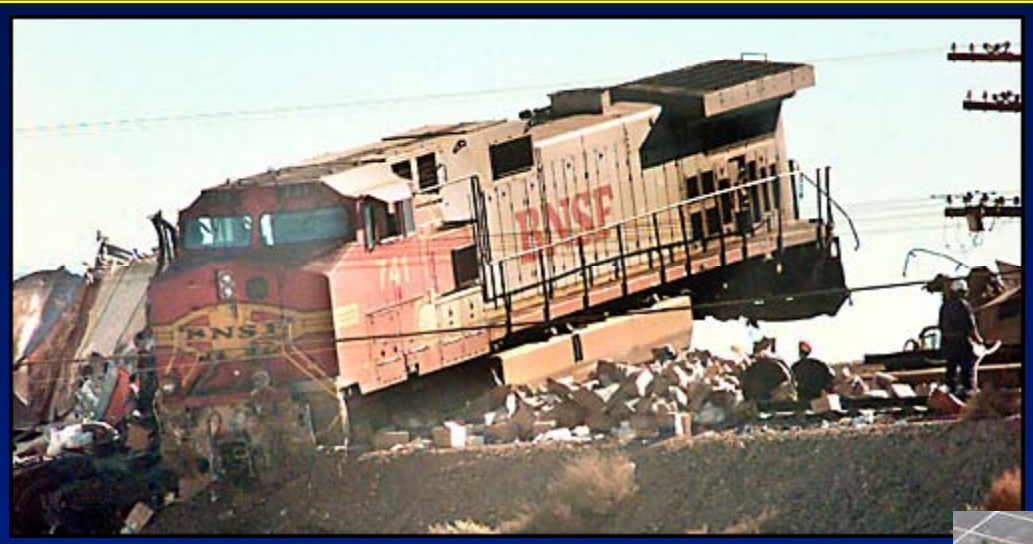
Amsted Rail

February 12, 2010

What does Amsted Rail do??



CLASS AND SIZE	CAR CAPACITY (TONS)	CONE BORE (in)	CUP O.D. (in)
B (4 1/4 X 8)	30	4.0000	6.5000
C (5 X 9)	40	4.6875	7.6875
D (5 1/2 X 10)	50	5.1870	8.1875
E (6 X 11)	70	5.6870	8.6875
L (6 X 8)	70	5.6870	8.6564
F (6 1/2 X 12)	100	6.1870	9.9375
K (6 1/2 X 9)	100	6.1870	9.8375
G (7 X 12)	125	6.9996	10.8750
M (7 X 9)	125	6.4995	10.3750
EE	Passenger Car	5.4995 5.9995	10.8780
GG	Locomotive	6.4995 6.8745	11.8780



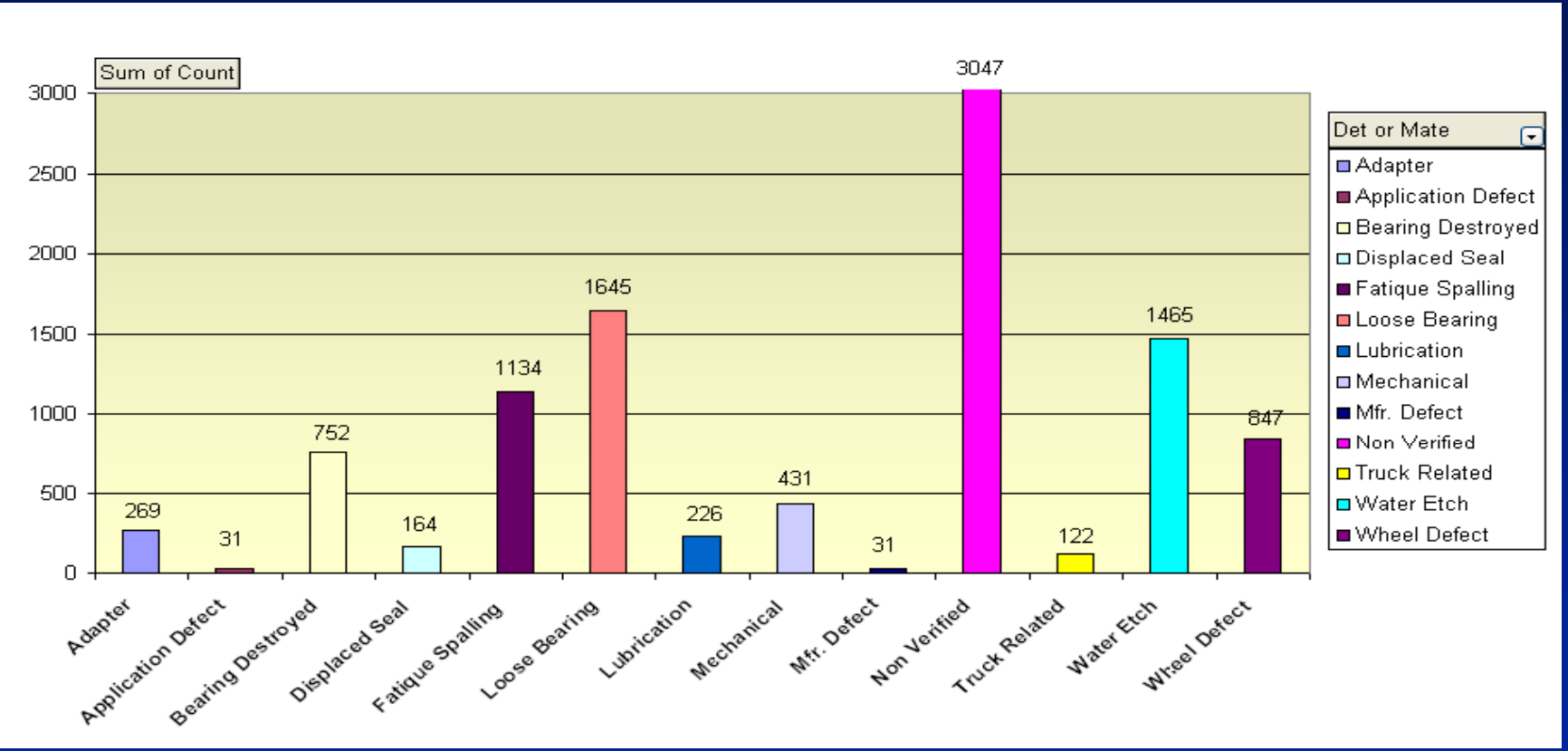
AmstedRail

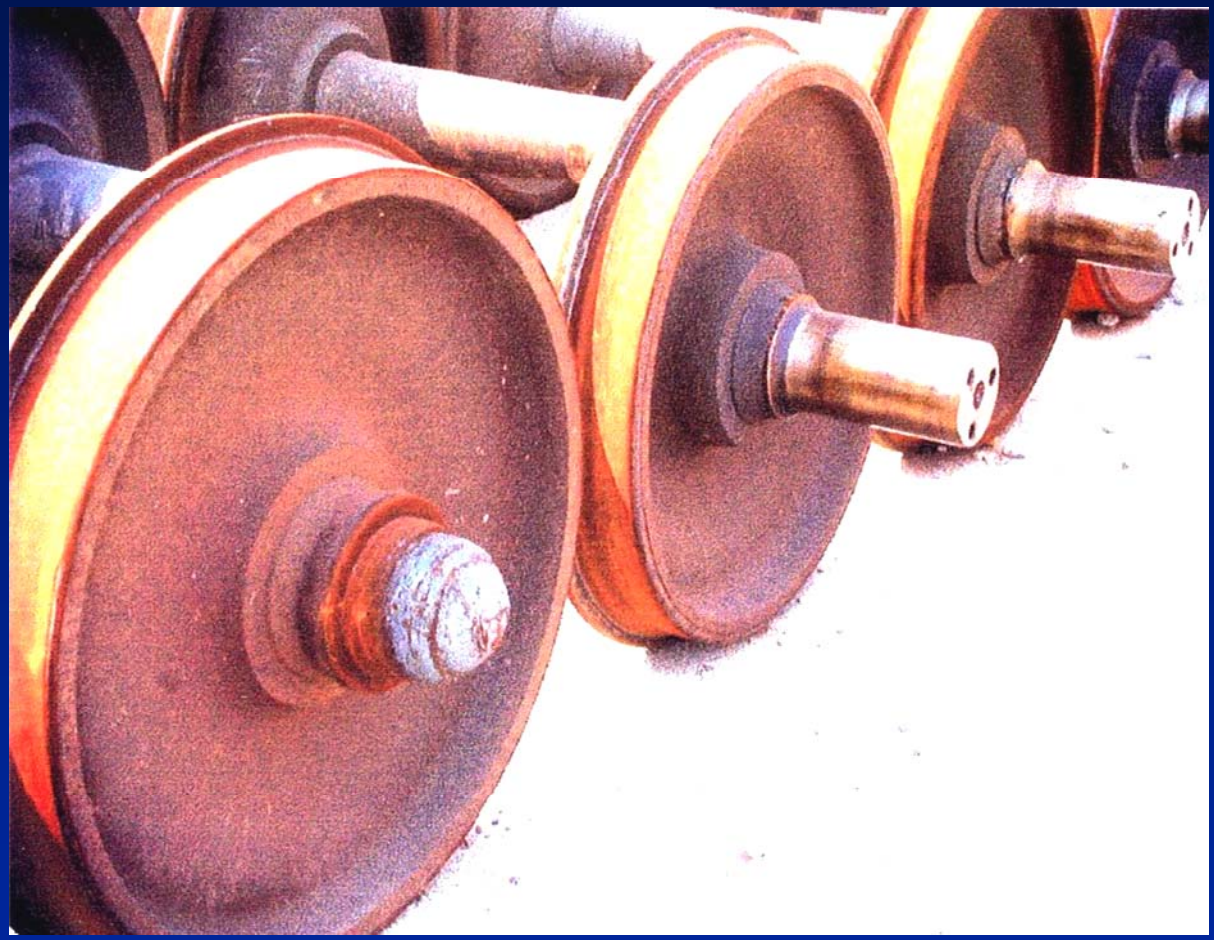
- A primary reason for bearings to be pulled is due to overheating
  - Bearing overheating is detected by a hot box scanner
  - Hot Box Trigger is @

    T > 190°F above ambient

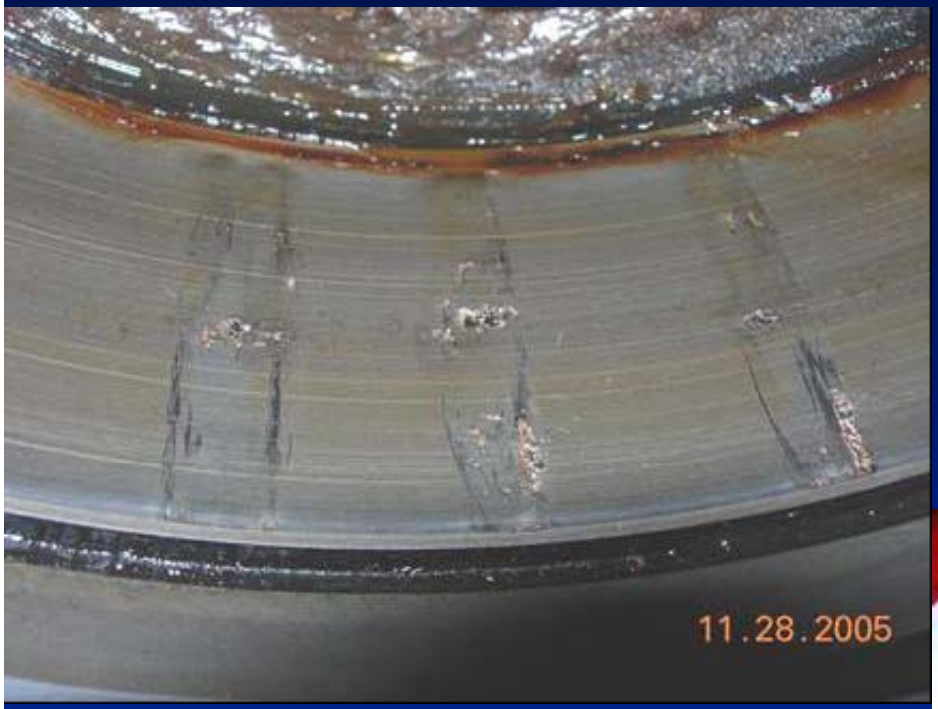
AmstedRail

WMC 50 removals





AmstedRail



AmstedRail

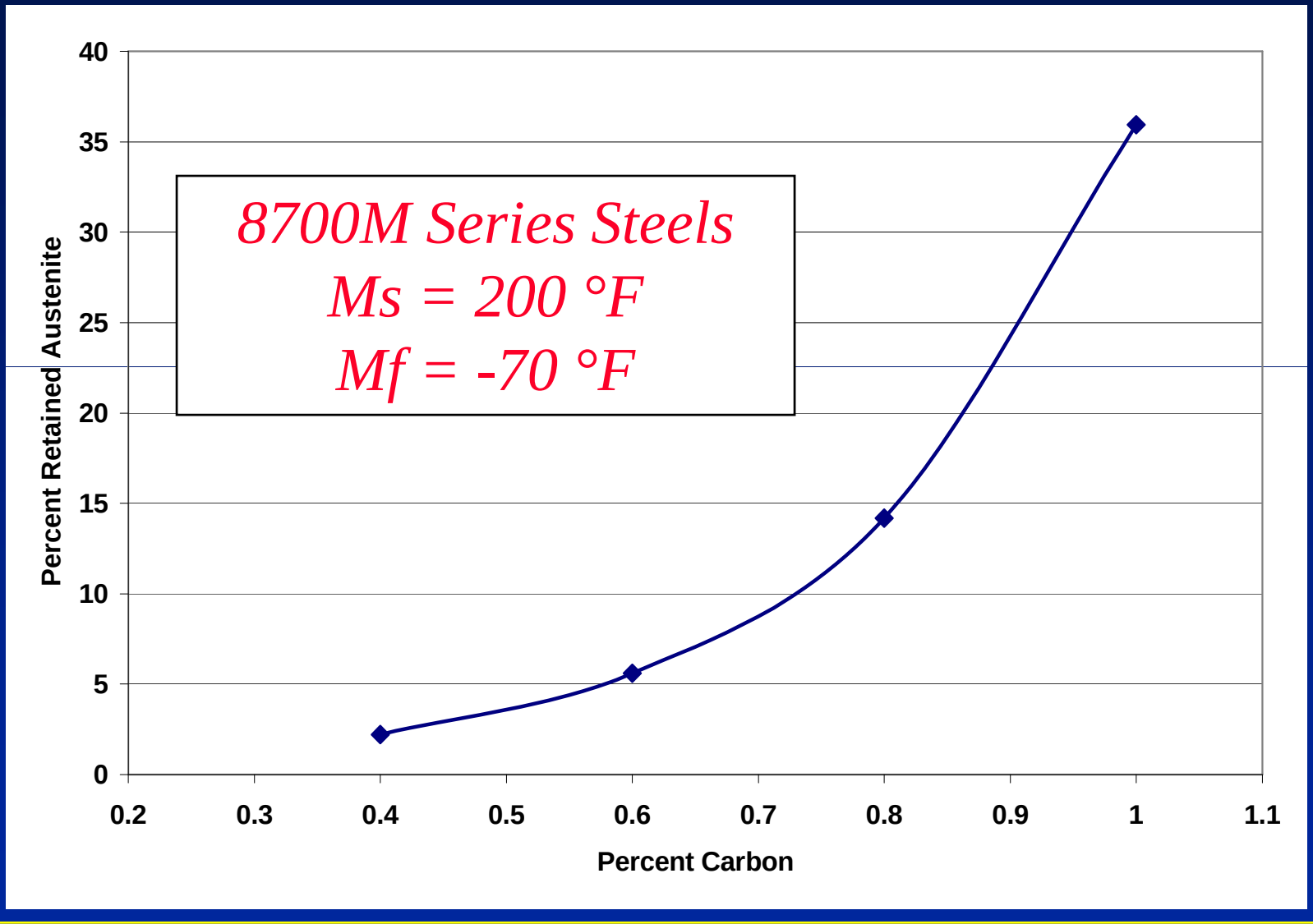
a) Wheel flat b) Shell / Spall

c) Shattered rim d) Built-up-tread

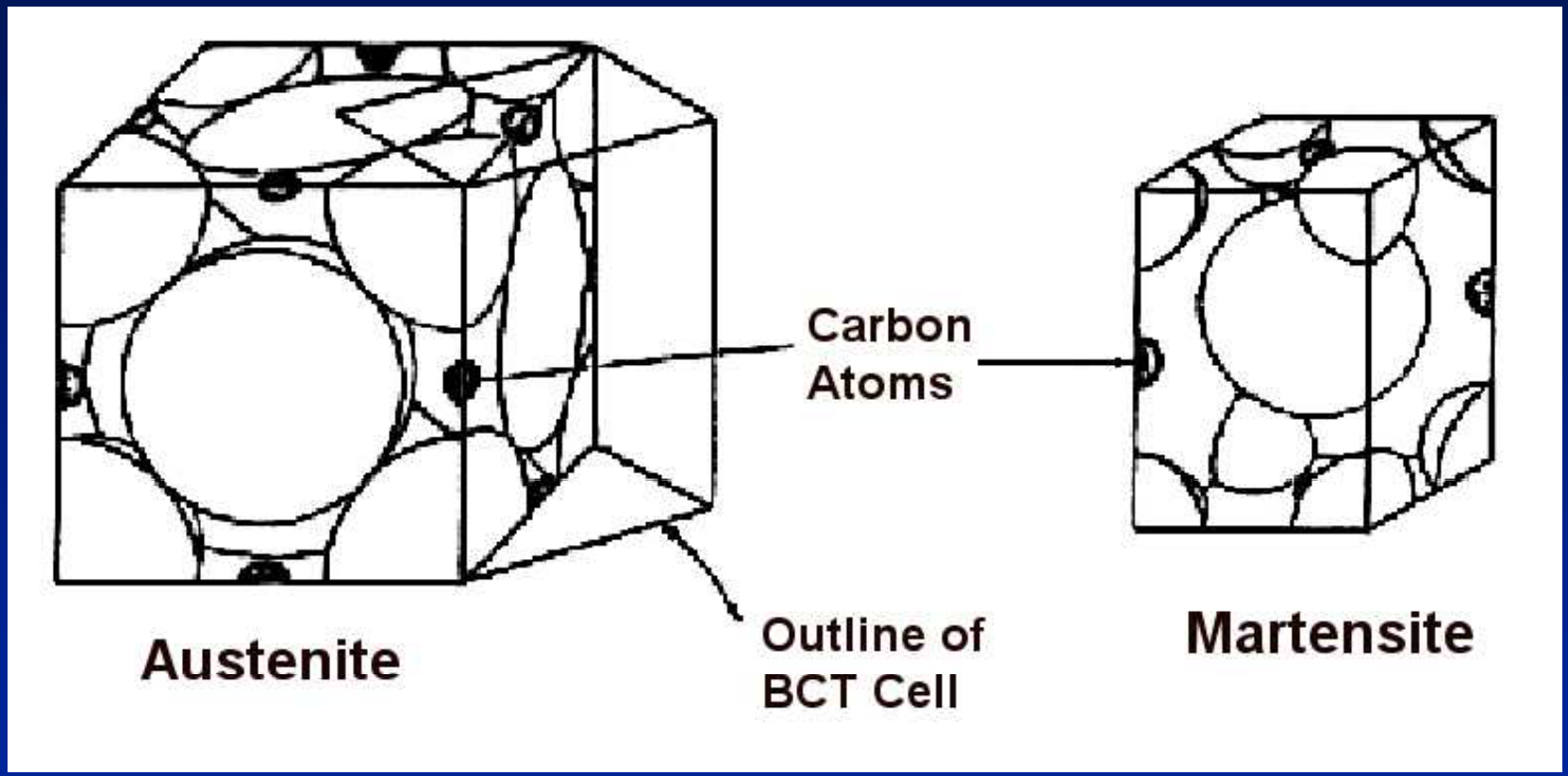
AmstedRail

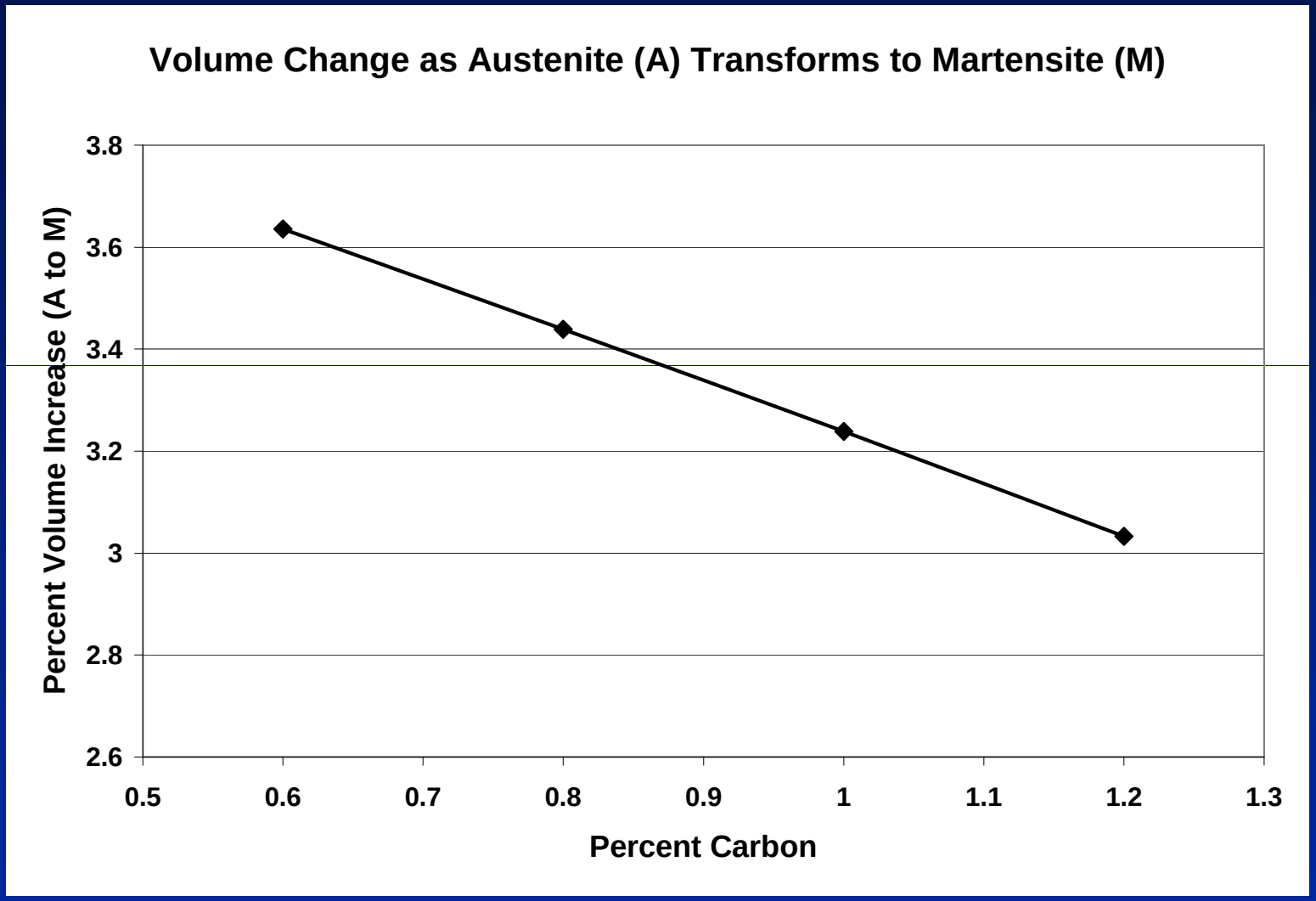
1. Control of Retained Austenite
   a) Transformation of retained austenite causes a 3-4% volume change at the surface of the bearing race.
   b) Transformation leads to cone bore growth, and can cause an “axle burn-off failure”
2. Microscopic Cleanliness
   a) Subsurface discontinuities act as stress risers and are the primary sites of fatigue initiation.
   b) Subsurface fatigue initiation leads to “spalling” type failures which generate heat and can cause derailments.
3. Wheel / Rail Interactions
   a) Impact damage from “wheel flats” can lead to structural damage.
   b) Early detection and energy absorbent structures are necessary.

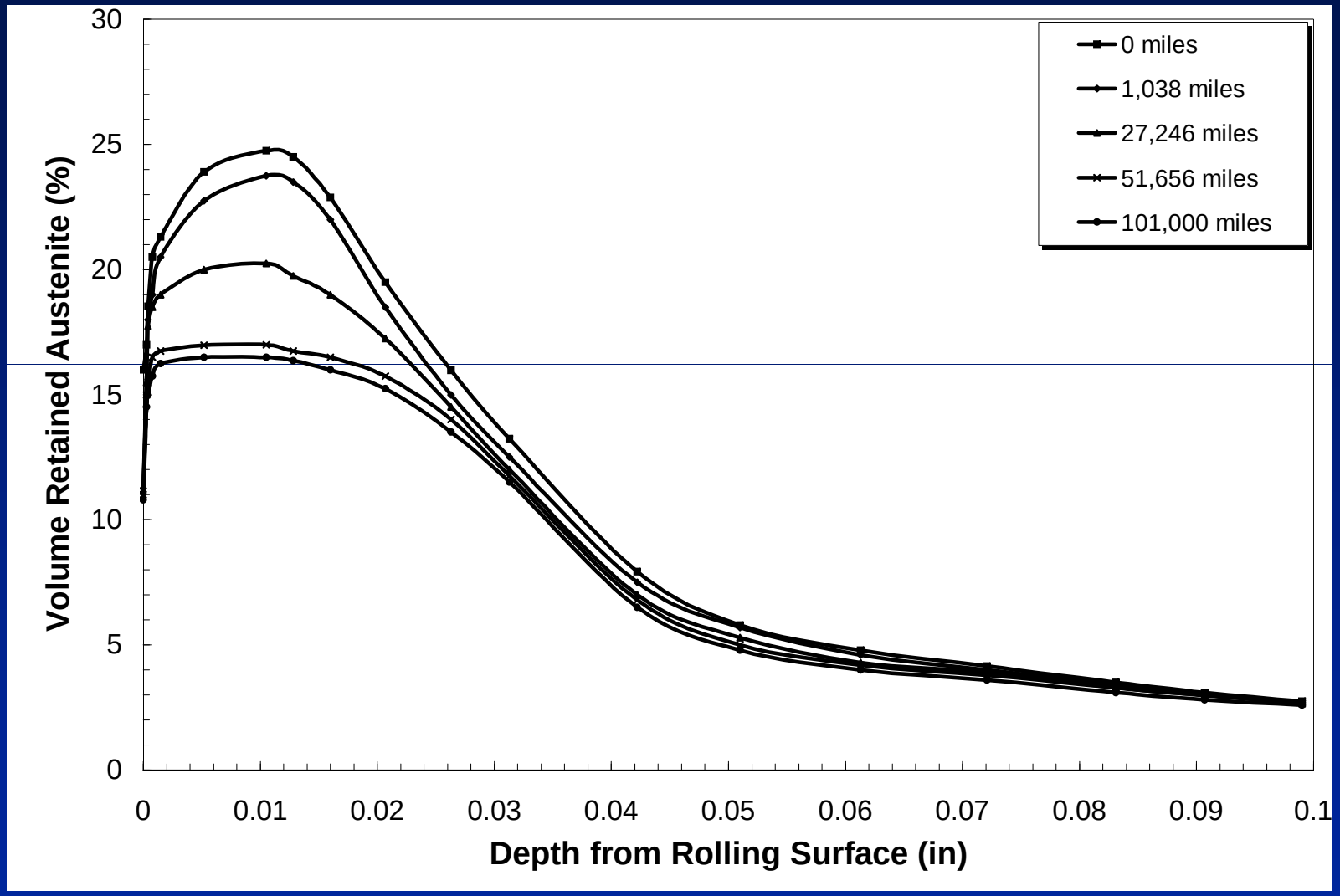
Retained Austenite and Residual Stress


8700M Series Steels
Ms = 200 °F
Mf = -70 °F
Percent Retained Austenite
40
35
30
25
20
15
10
5
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
Percent Carbon

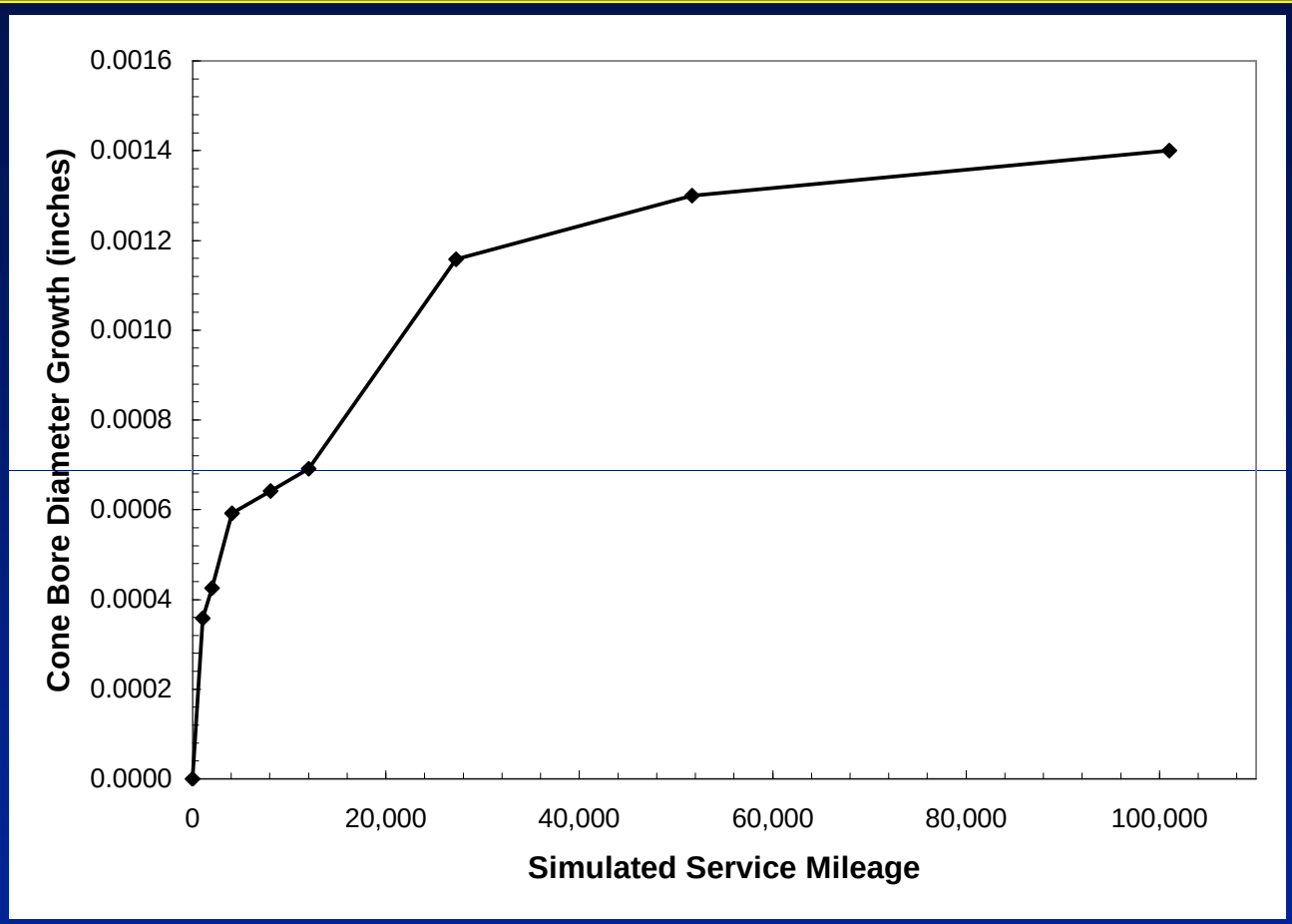
AmstedRail


Carbon
Atoms
Austenite
Outline of
BCT Cell
Martensite


Volume Change as Austenite (A) Transforms to Martensite (M)
Percent Volume Increase (A to M)
3.8
3.6
3.4
3.2
3
2.8
2.6
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
Percent Carbon


Volume Retained Austenite (%)
30
25
20
15
10
5
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Depth from Rolling Surface (in)
0 miles
1,038 miles
27,246 miles
51,656 miles
101,000 miles

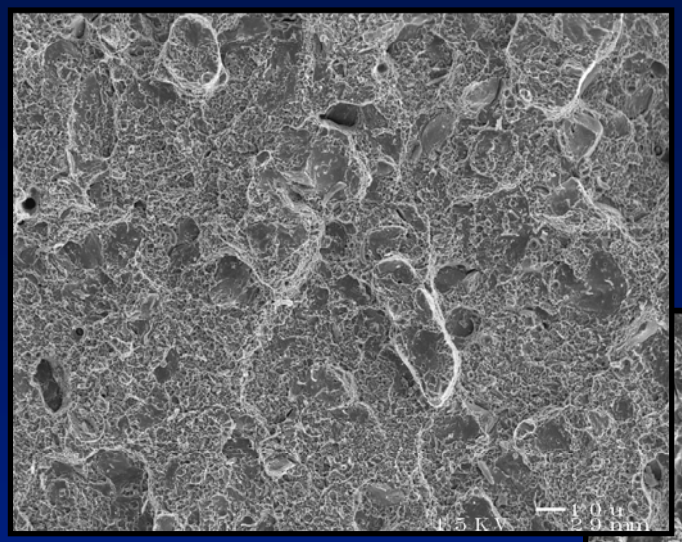
AmstedRail



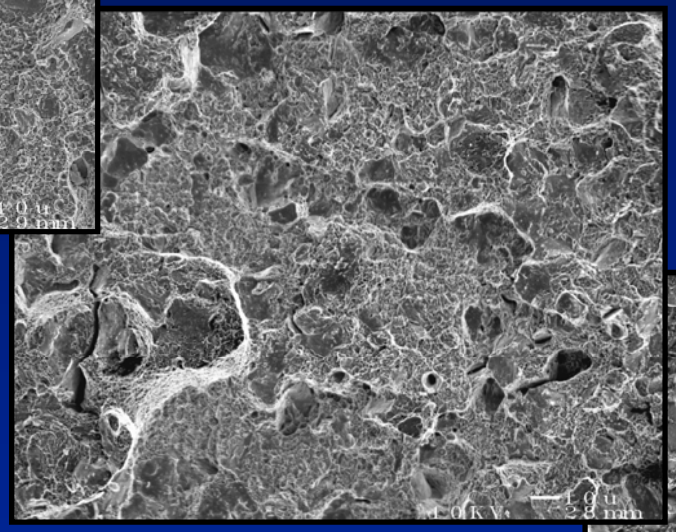
During service the cone will grow on the order of 0.001 to 0.002 inches.

AmstedRail

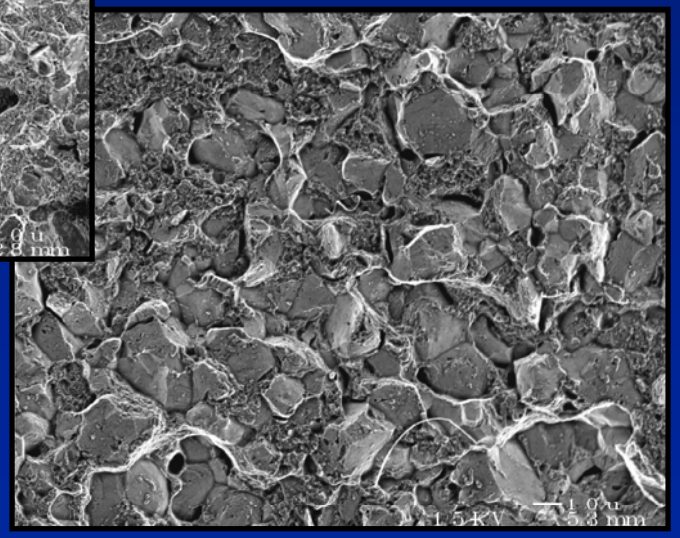
Samples fractured at 200 °C
Viewed at 500x



18% RA
37 in-lbs

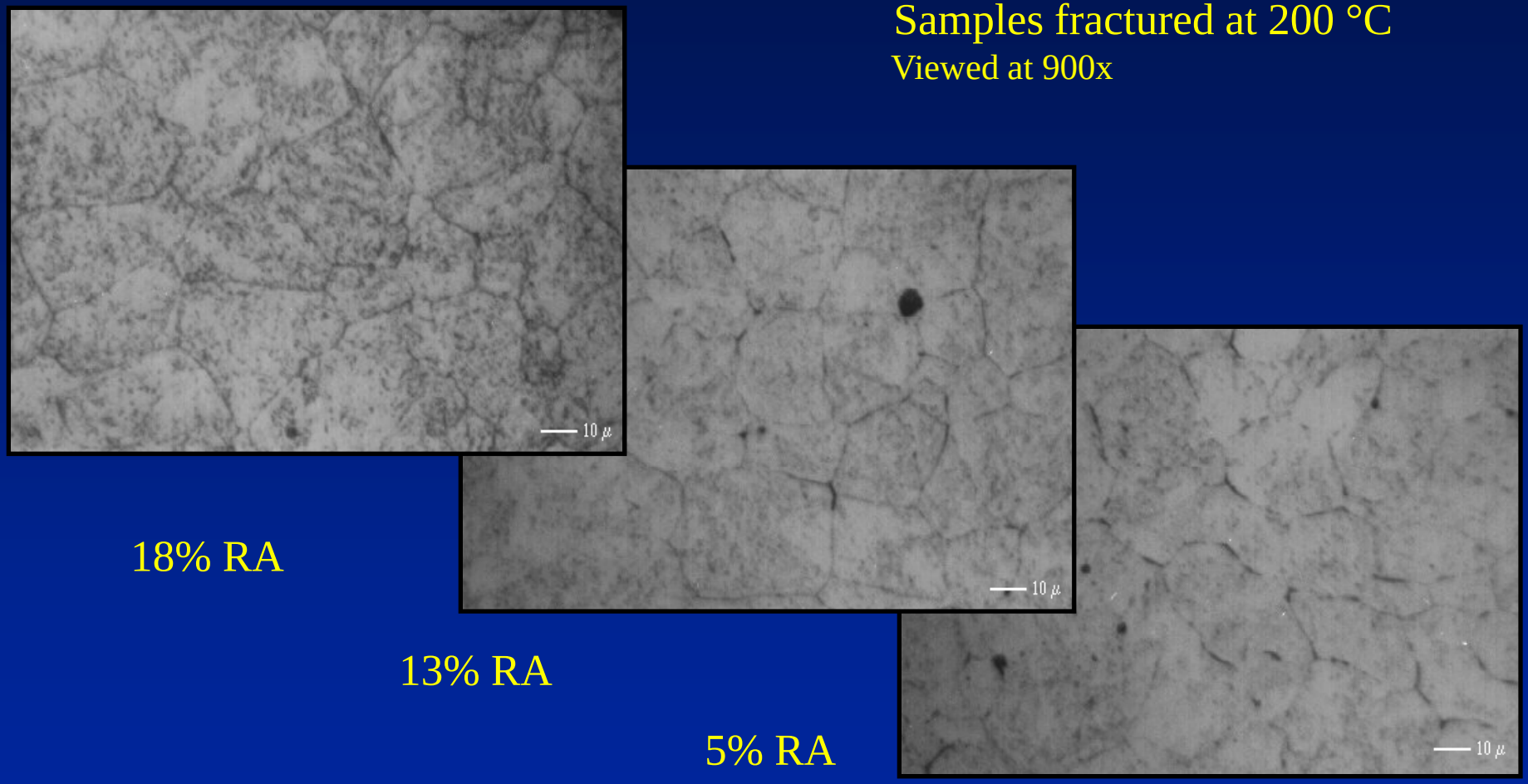


13% RA
15.5 in-lbs



5% RA
16 in-lbs

Samples fractured at 200 °C
Viewed at 900x



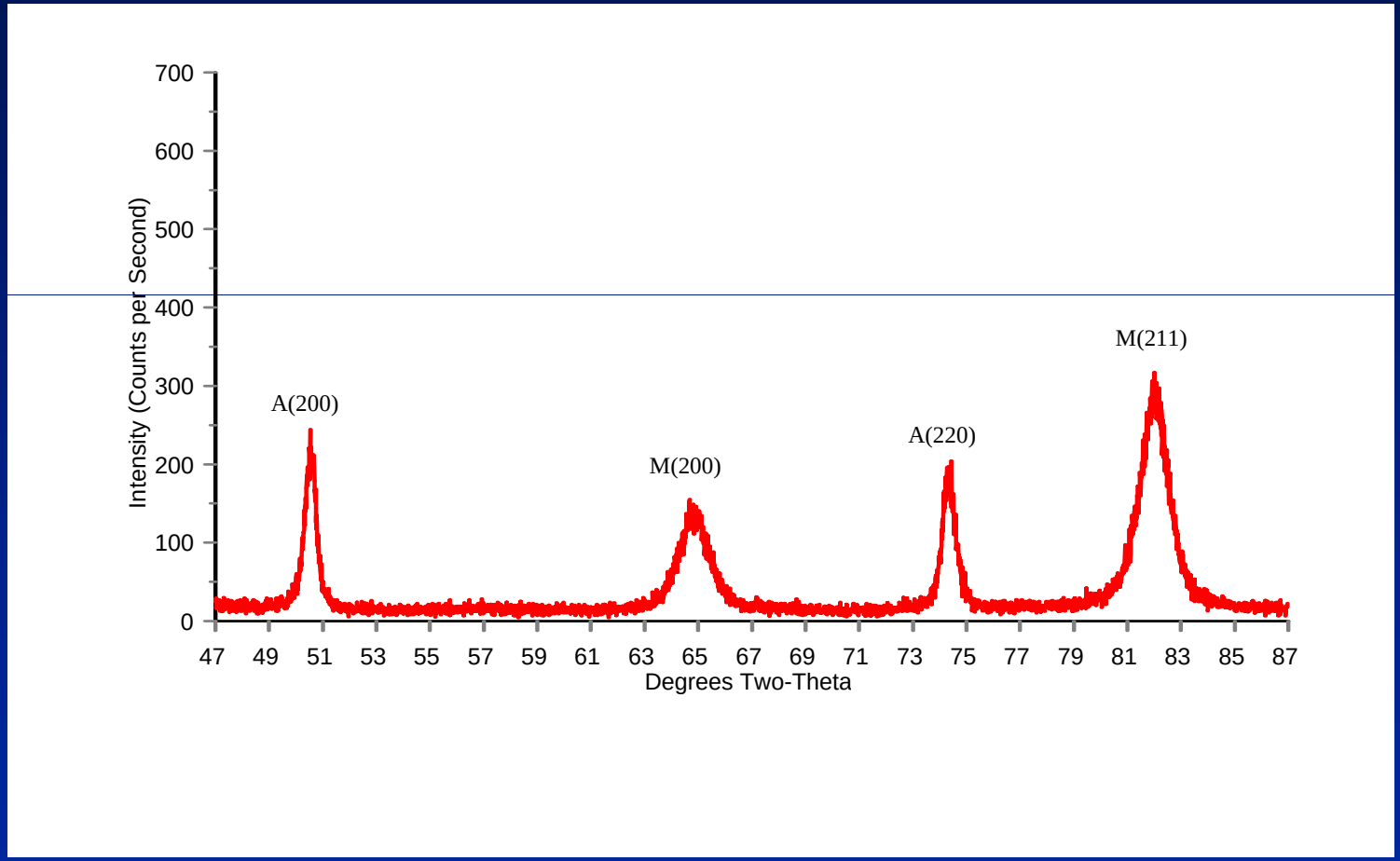
18% RA

13% RA

5% RA

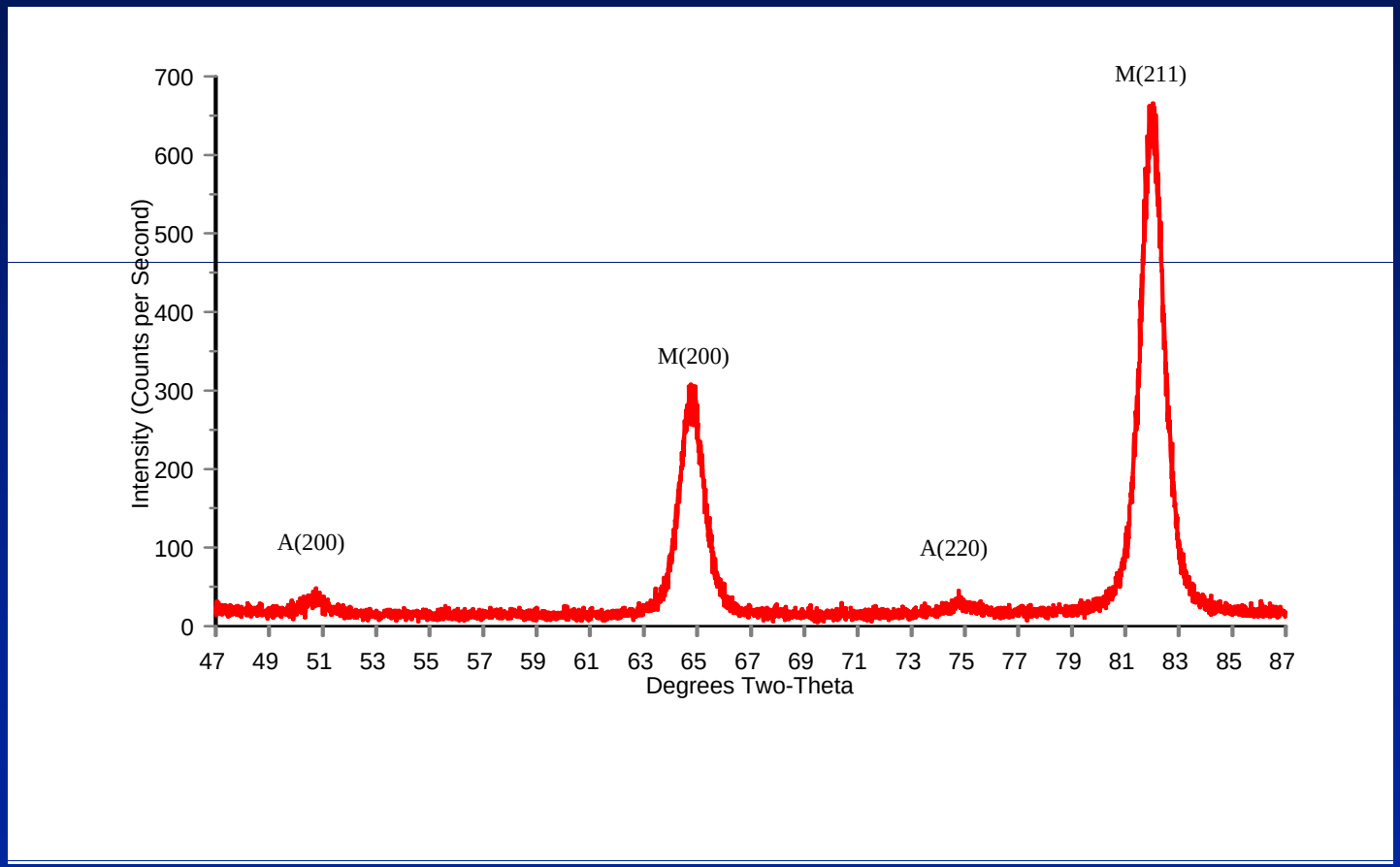
AmstedRail

25% Retained Austenite



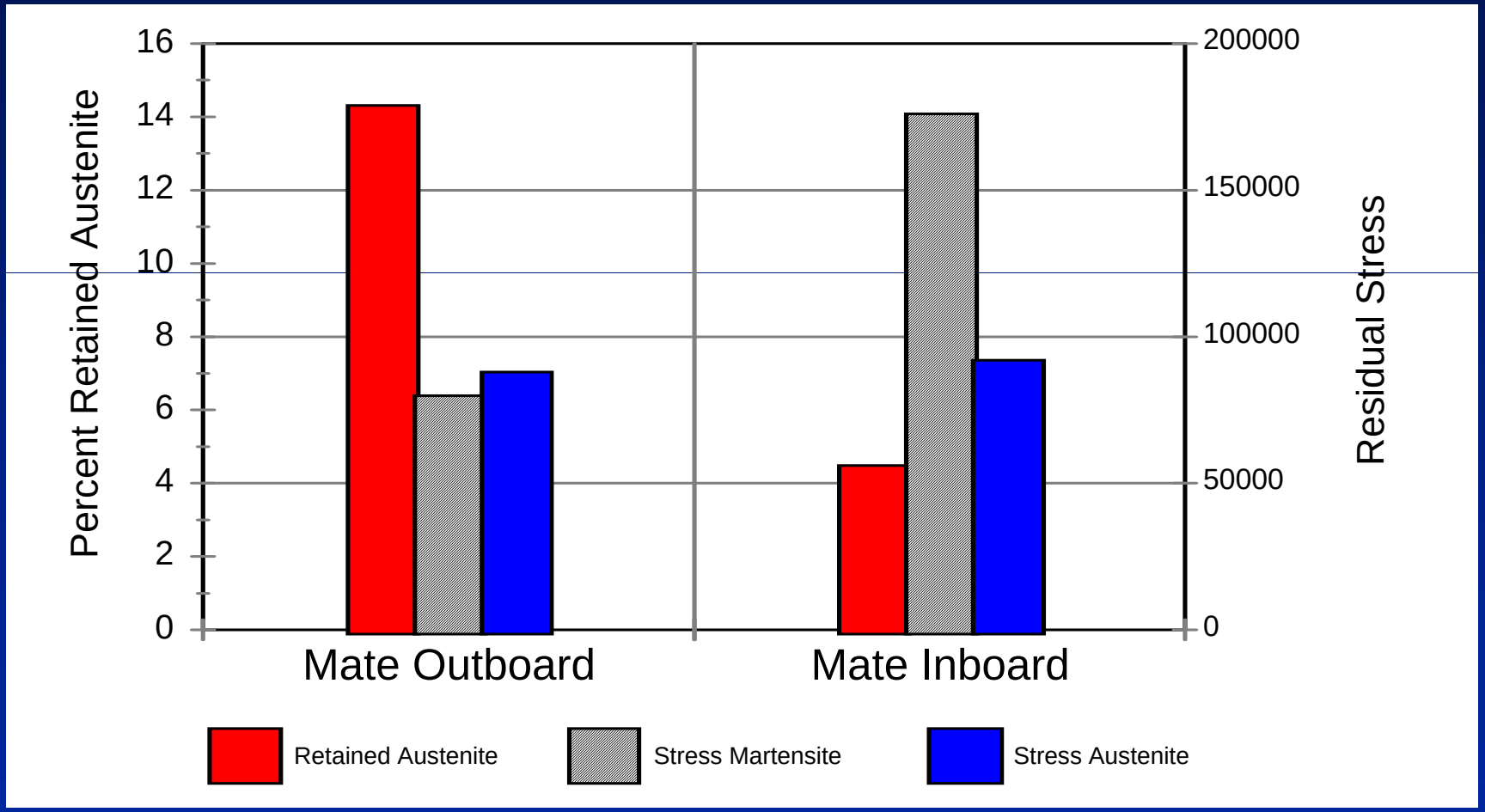
AmstedRail

3% Retained Austenite



AmstedRail

Residual stress and retained austenite reflect the service history



Service Load Factor (SLF) :

Absolute residual stress (martensite) / %RA

Normalized to new cones (42.5/22.5 = 1.88)

	Serviced Load Factor
New Product 0 lbs 0 miles	1.00
Typical Bench Test 34,500 lbs 250,000 miles	2.38
Typical Field Test 34,500 lbs 300,000 - 600,000	2.56
Failure Criterion 140ksi / 10% RA	7.50
Severe Overload	15.10

1 million miles

	Serviced Load Factor
1 million mile 66 OB *	6.56
1 million mile 66 IB	3.23
1 million mile 67 OB	3.40
1 million mile 67 IB	5.93
Failure Criterion 140ksi / 10% RA	7.50

1.2 million miles

	Serviced Load Factor
1 million mile 66 OB	10.67
1 million mile 66 IB	3.45
Failure Criterion 140ksi / 10% RA	7.50

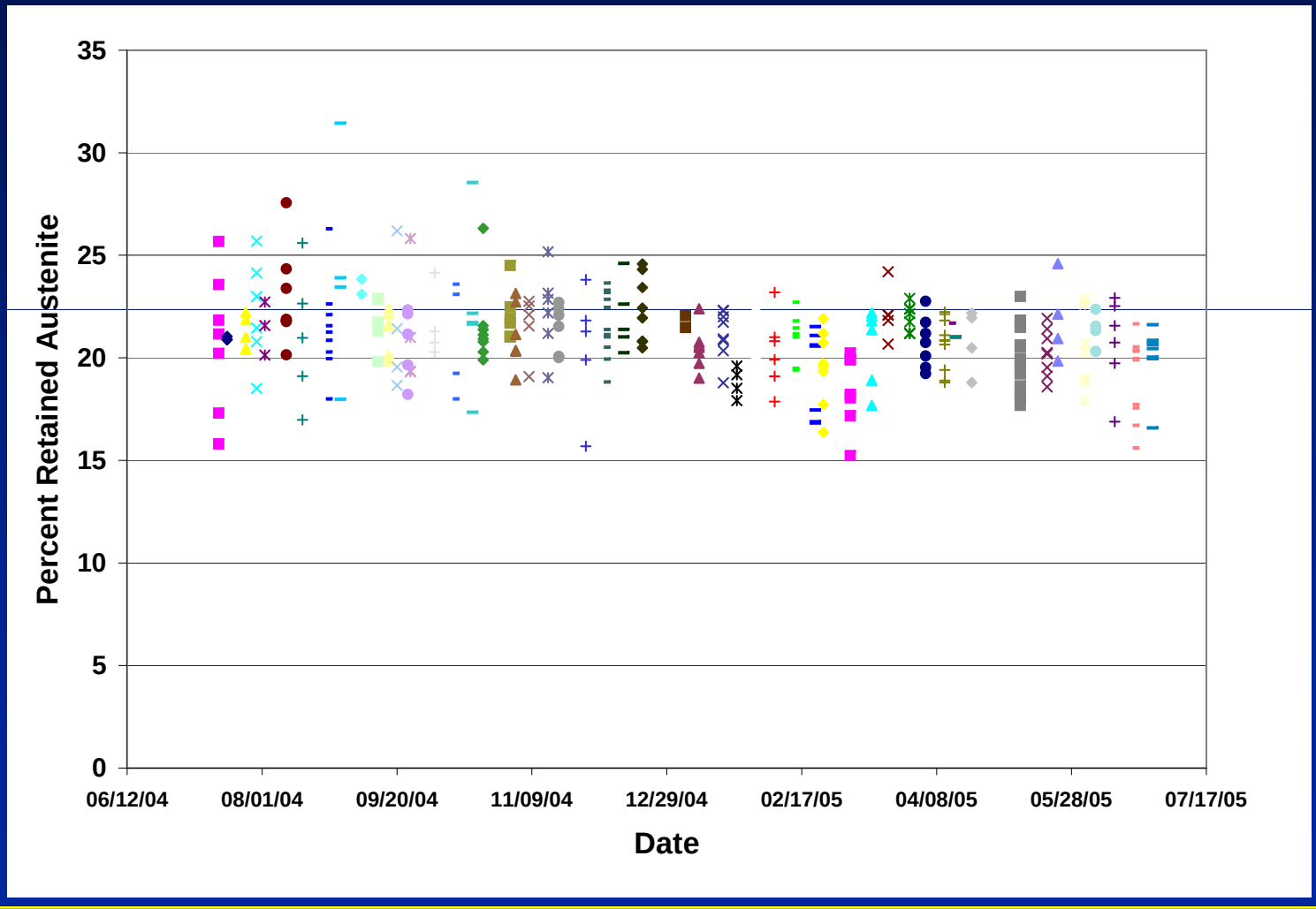
* One measurement = 7.89

AmstedRail

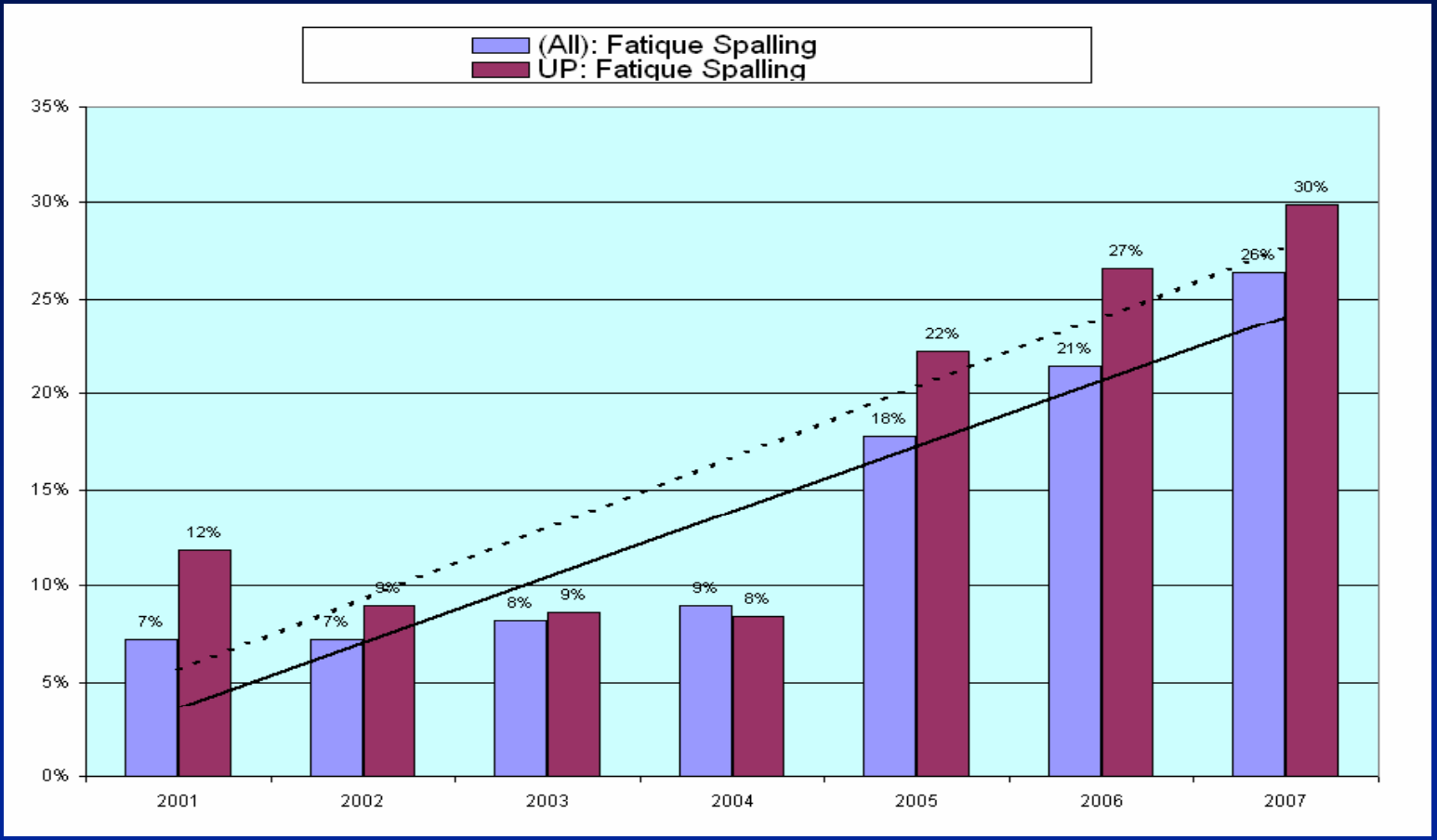
1 million

1.2 million

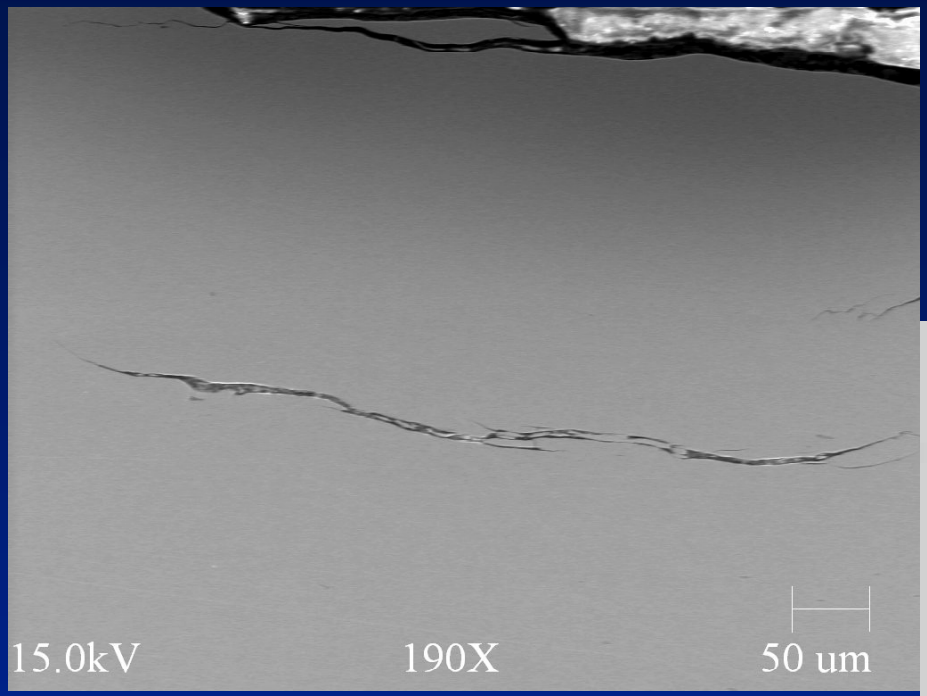
Retained Austenite of bearing cones, July 2004 – June 2005

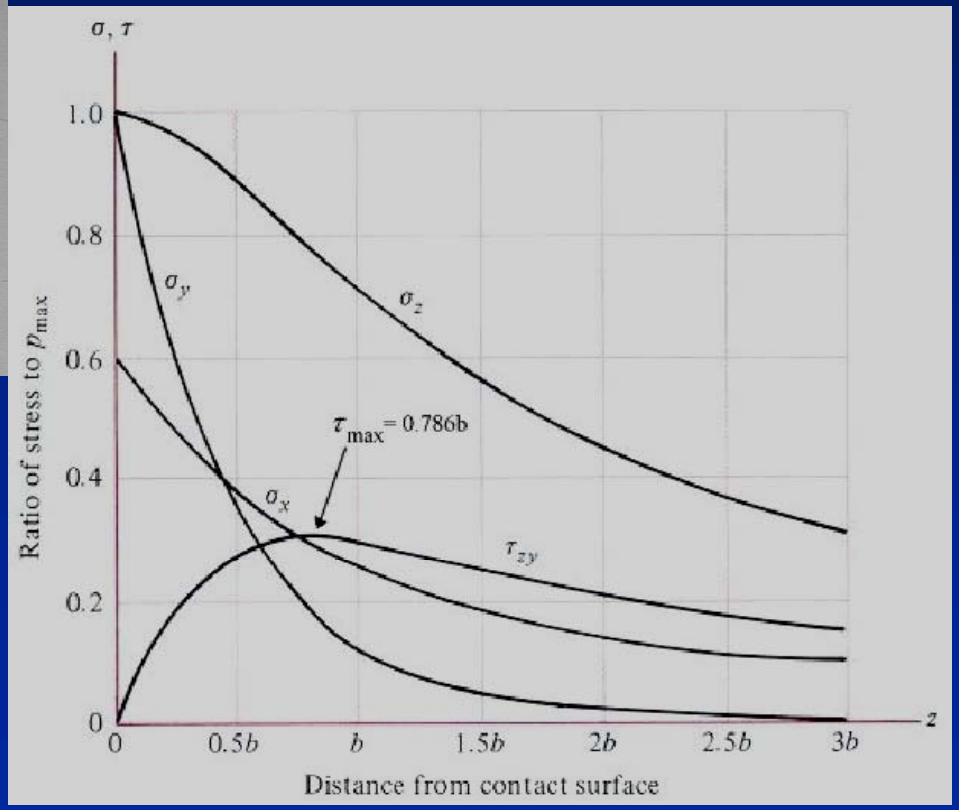


Steel Cleanliness and Ultrasonic Testing


(All): Fatique Spalling
UP: Fatique Spalling
35%
30%
25%
20%
15%
10%
5%
0%
2001
2002
2003
2004
2005
2006
2007
7%
12%
7%
9%
8%
9%
9%
8%
18%
22%
21%
27%
26%
30%

AmstedRail

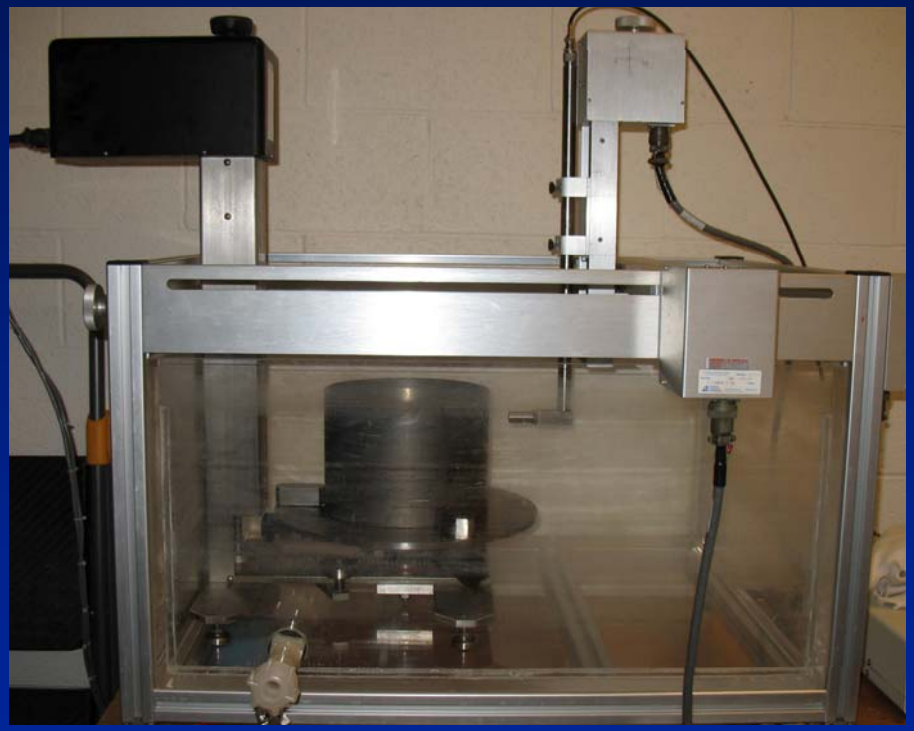

15.0kV
190X
50 um

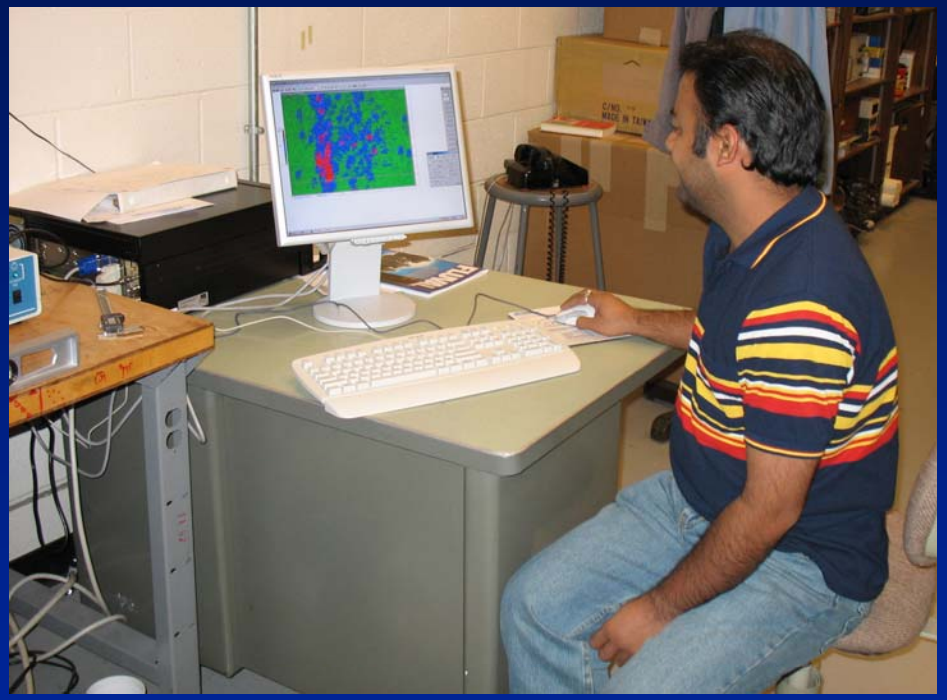

σ, τ
1.0
0.8
0.6
0.4
0.2
0
Ratio of stress to p_{max}
σ_y
σ_z
$\tau_{max} = 0.786b$
σ_x
τ_{zy}
0
0.5b
b
1.5b
2b
2.5b
3b
z
Distance from contact surface

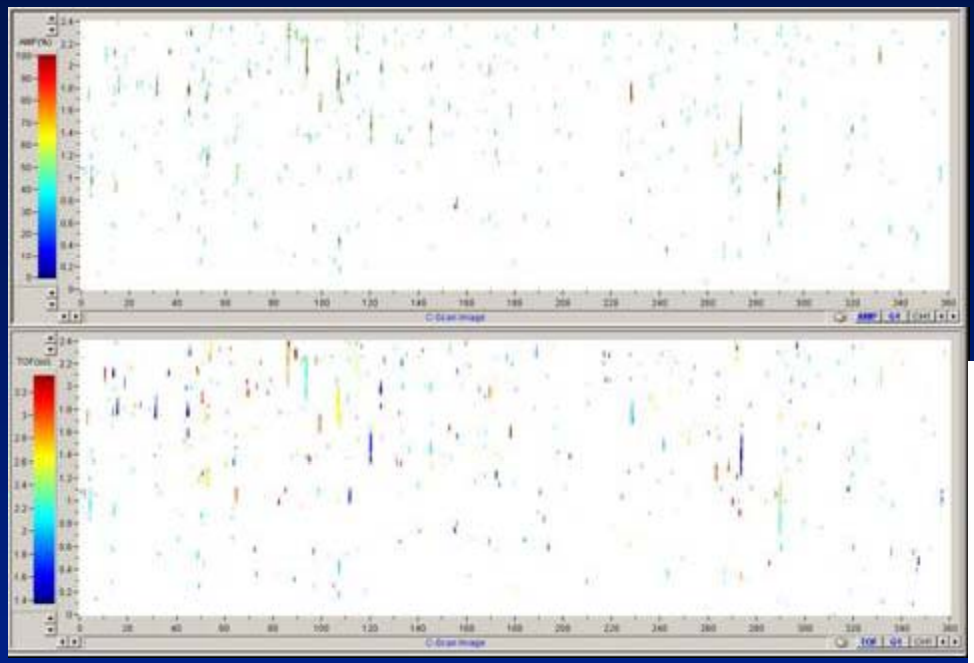
Objectives

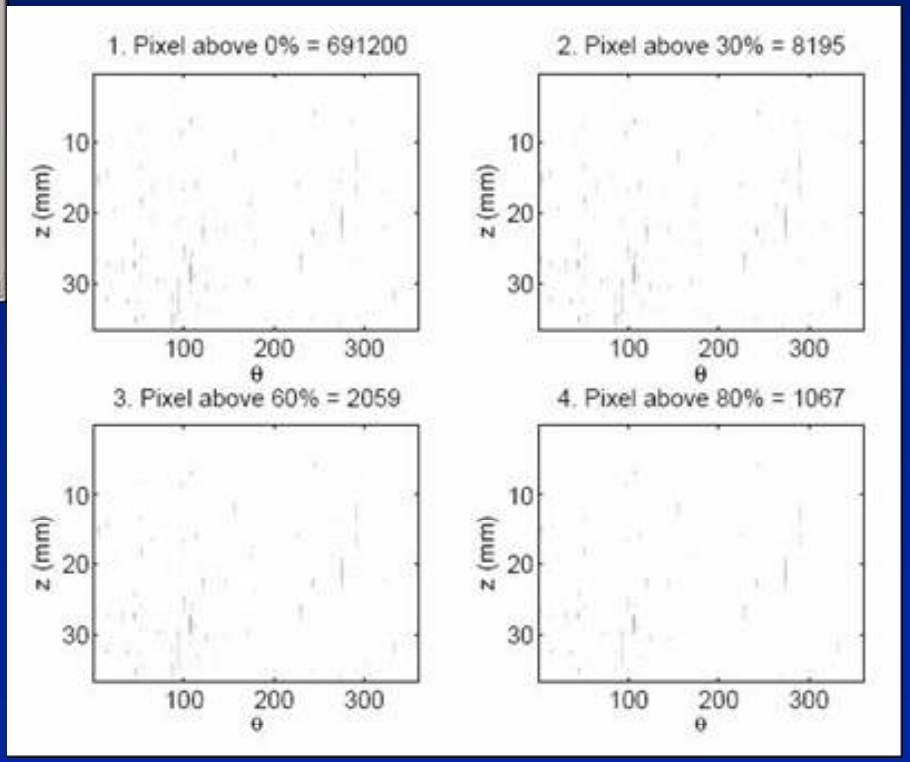
- Phase 1 – Develop an automatic inclusion detection system for the purpose of quality inspections. System is able to scan a cup/cone and rank the cleanliness based on total number of indications per inspected volume.
- Phase 2 – Goal is to qualify premium components for certain heavy haul markets.
- Phase 3 – Ultrasonic testing integrated into the manufacturing process.

Ultrasonic Scanning System



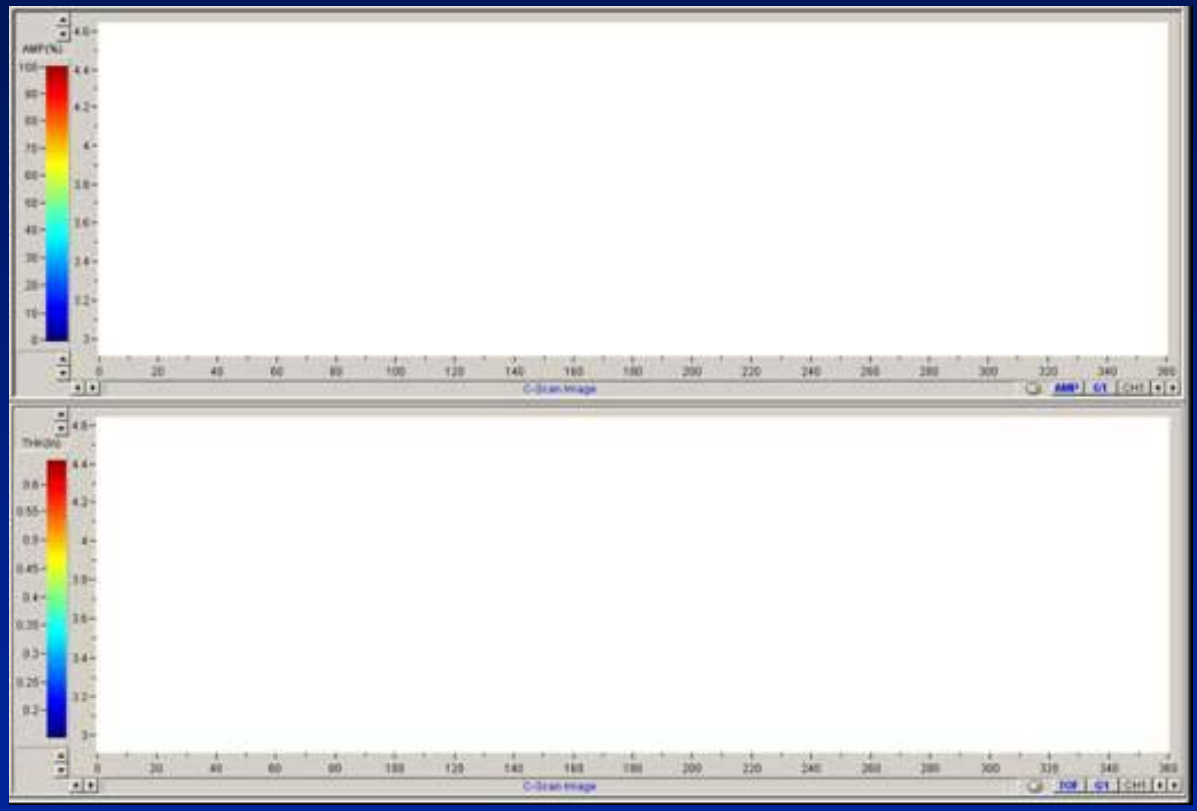




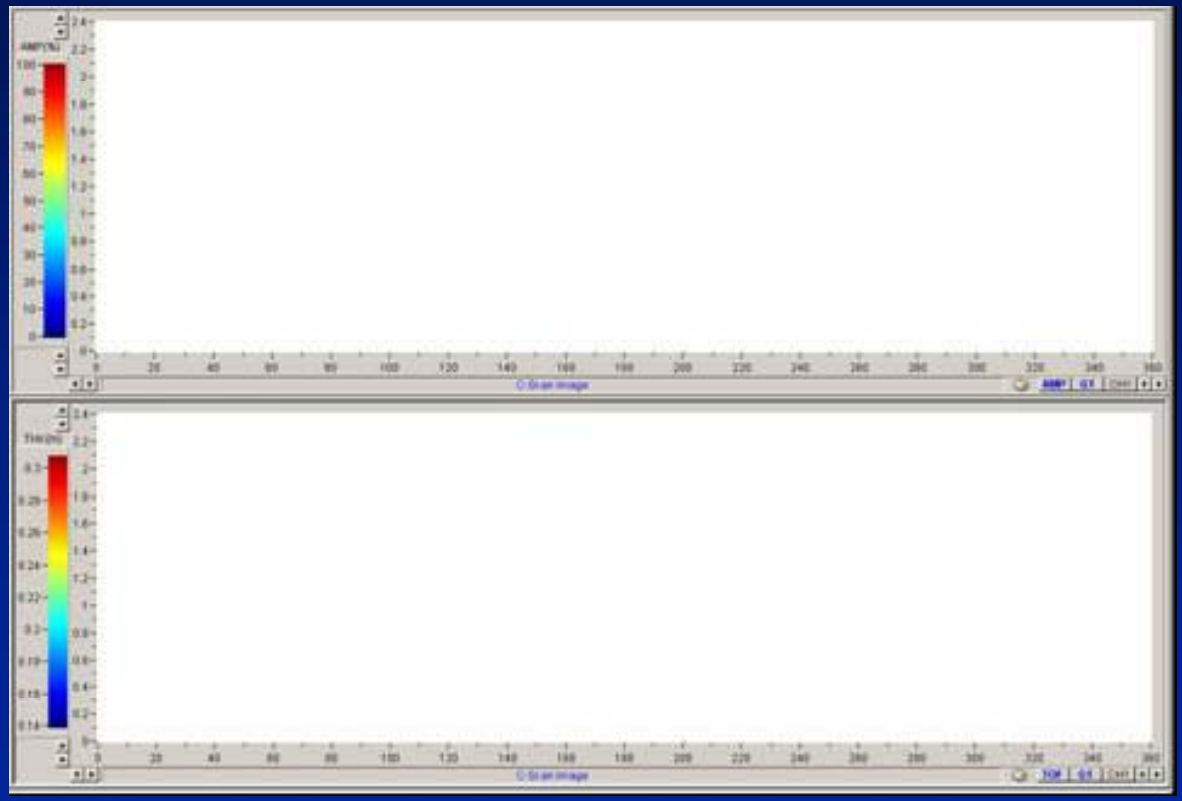

1. Pixel above 0% = 691200
2. Pixel above 30% = 8195
3. Pixel above 60% = 2059
4. Pixel above 80% = 1067
z (mm)
θ
10
20
30
100
200
300

AmstedRail

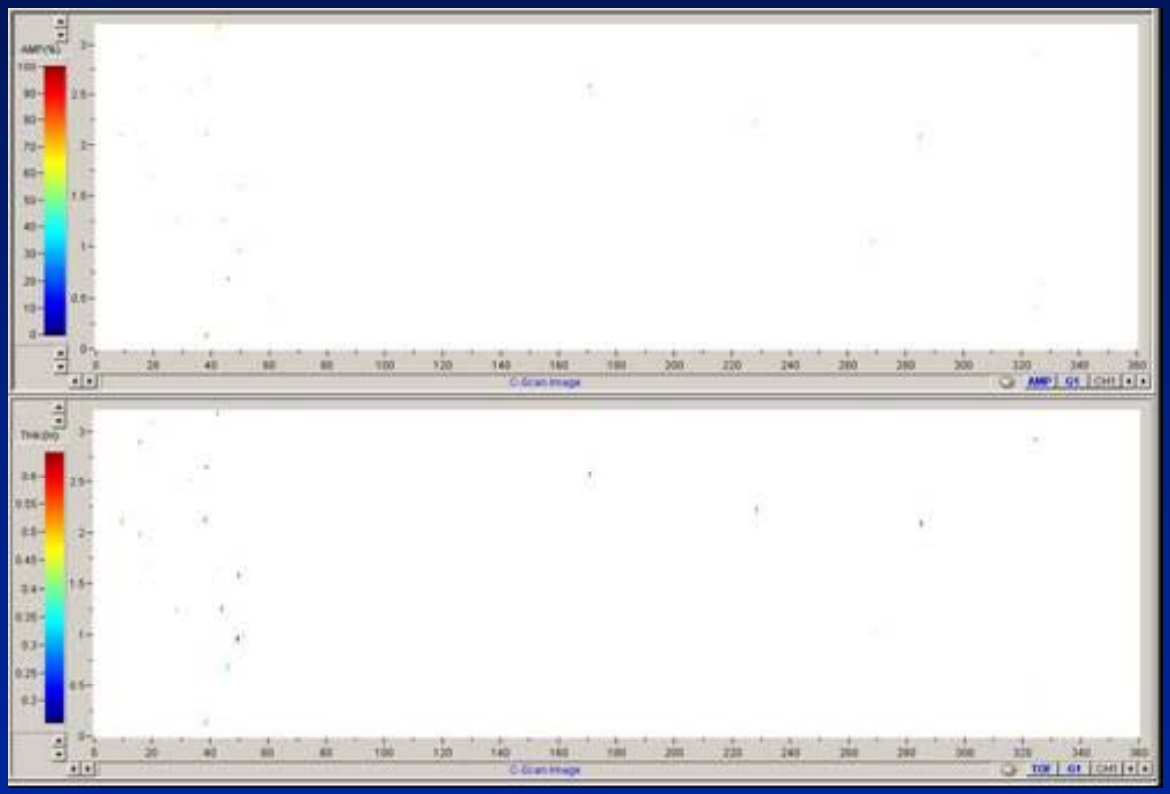
C-scan (top) and TOF (bottom) for Chinese Steel



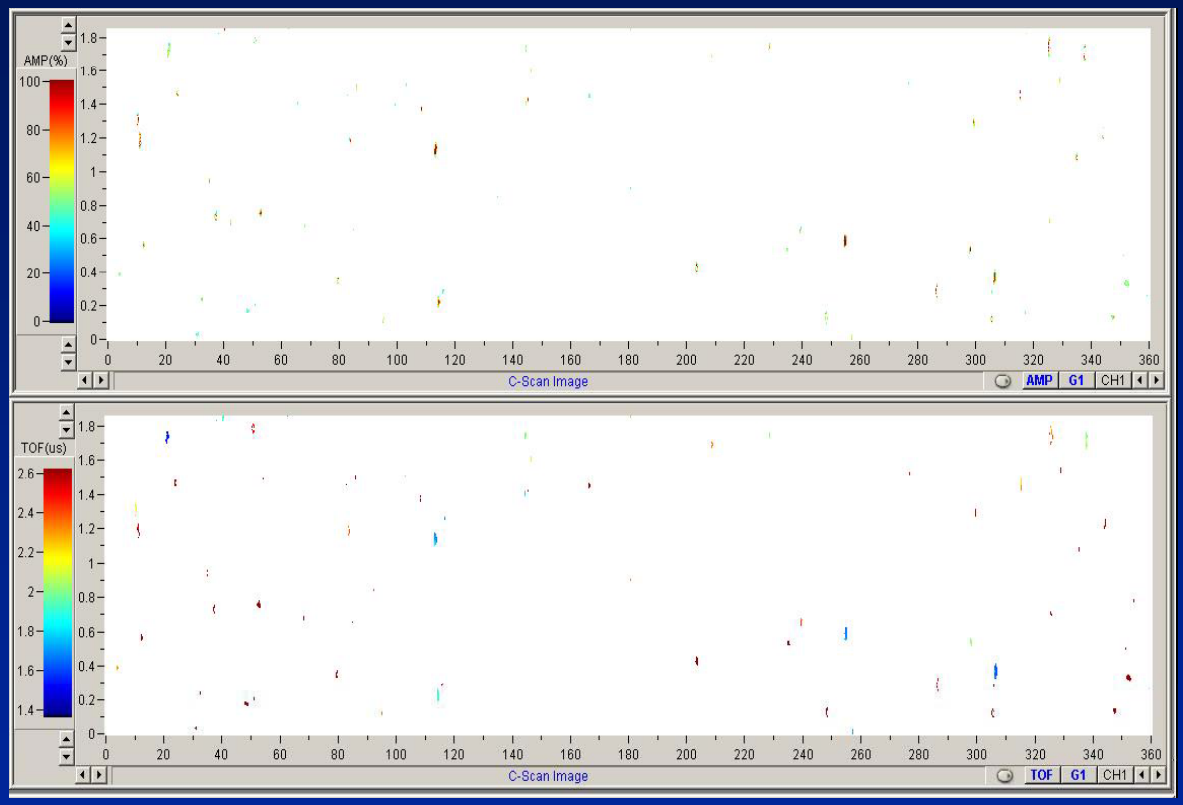
C-scan (top) and TOF (bottom) for North European steel



C-scan (top) and TOF (bottom) for USA steel

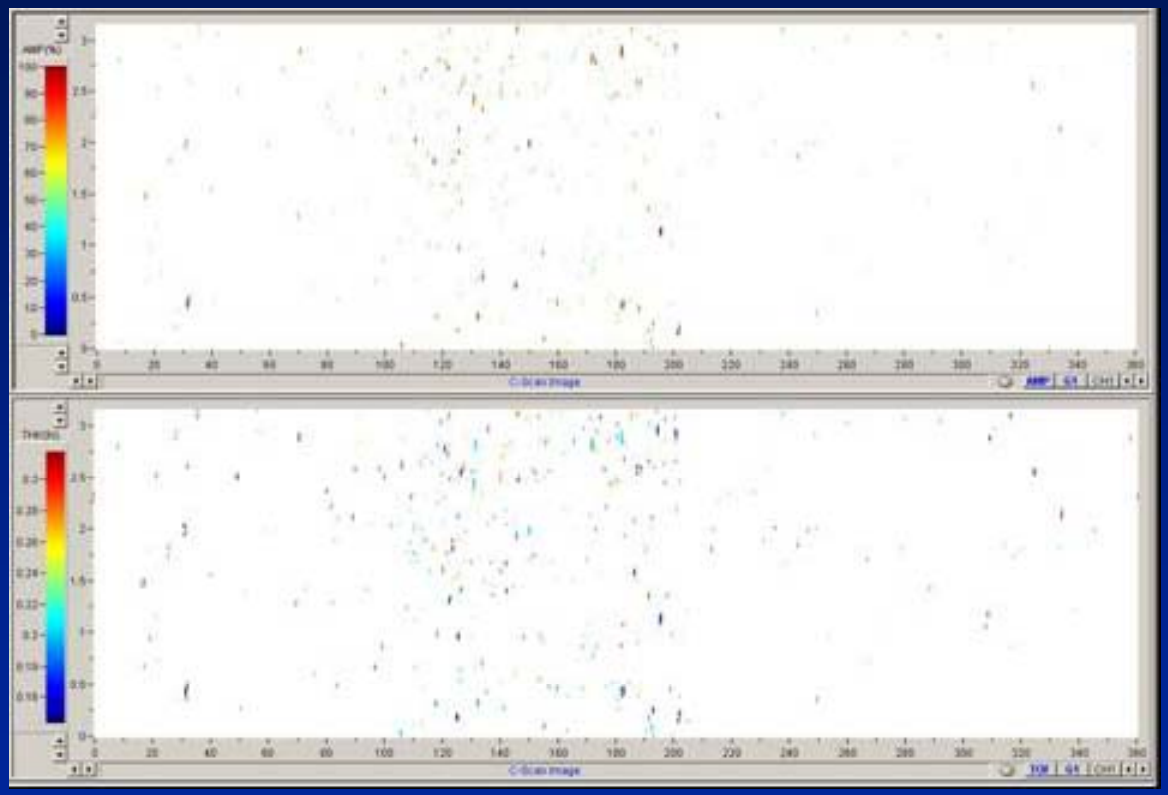


C-scan (top) and TOF (bottom) for South European steel



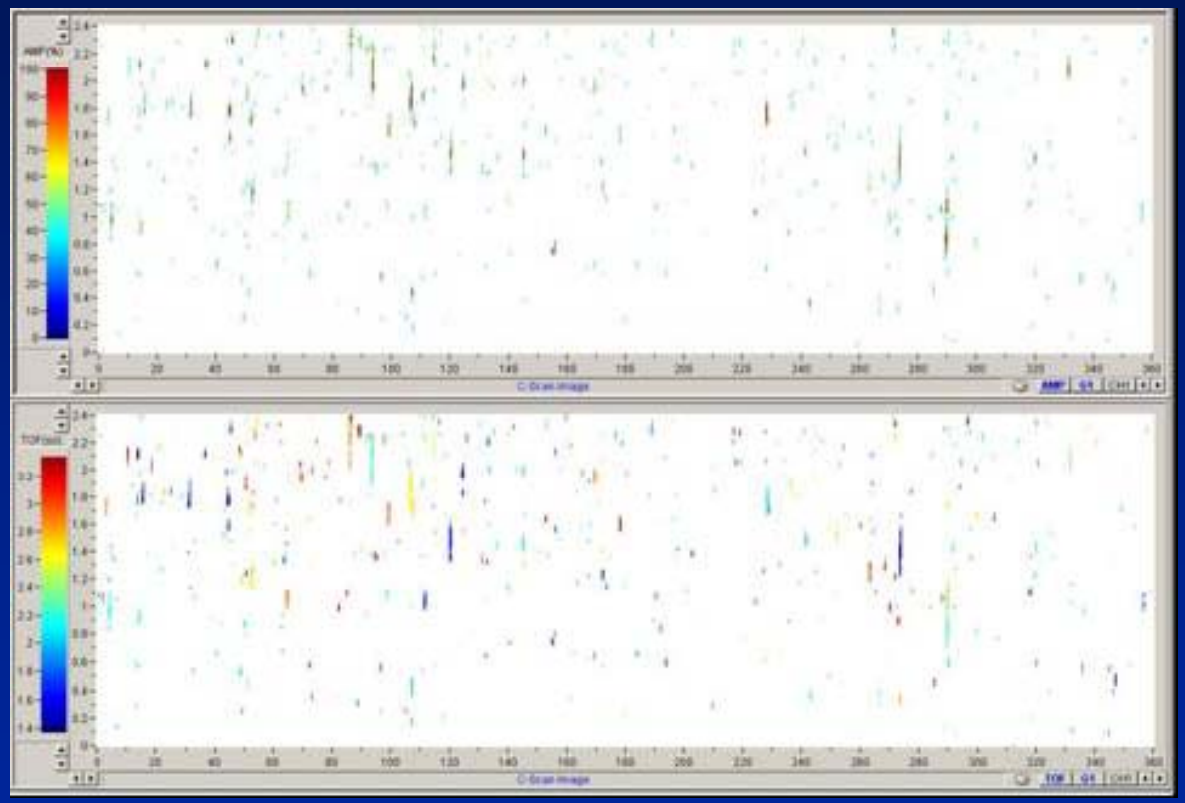
Amsted Rail

C-scan (top) and TOF (bottom) for Russian steel



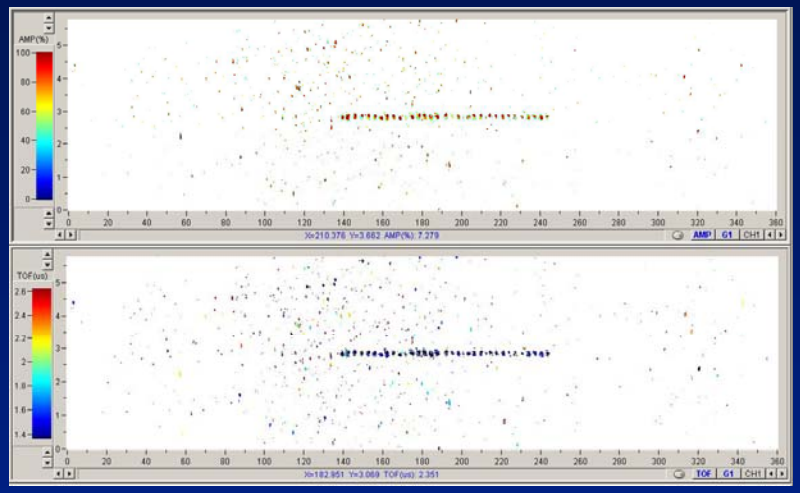
AmstedRail

C-scan (top) and TOF (bottom) for Indian steel

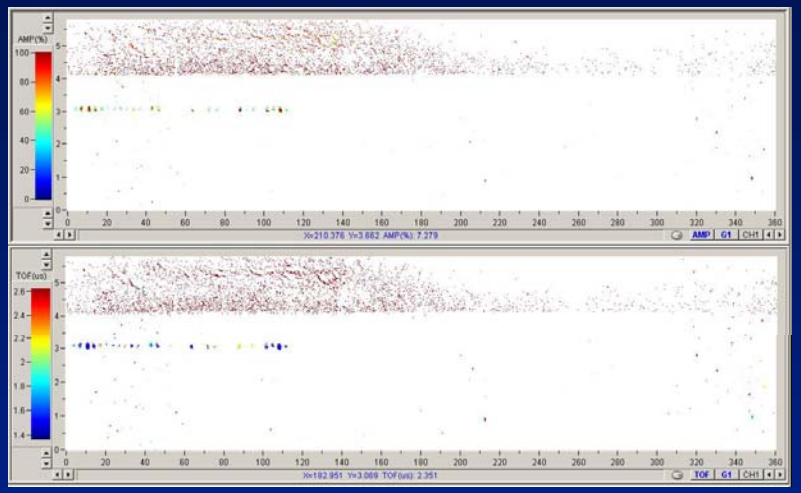


AmstedRail

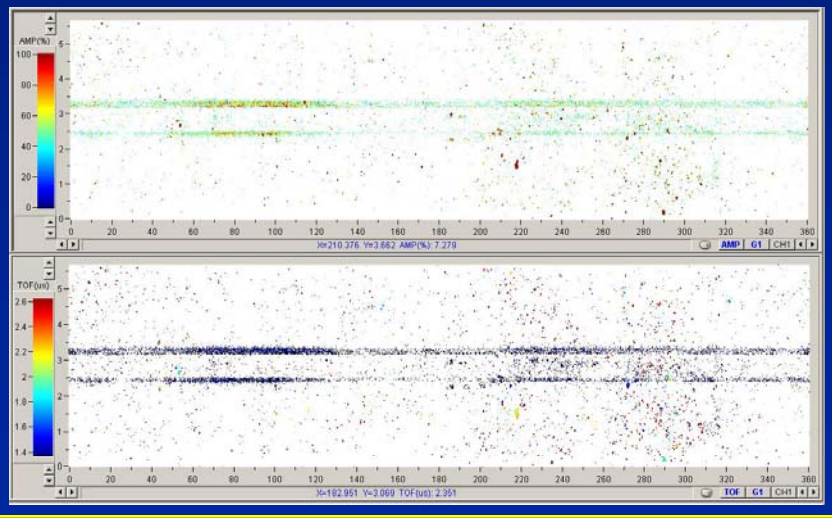
C-scan (top) and TOF (bottom) for ABD setouts



Sept 98



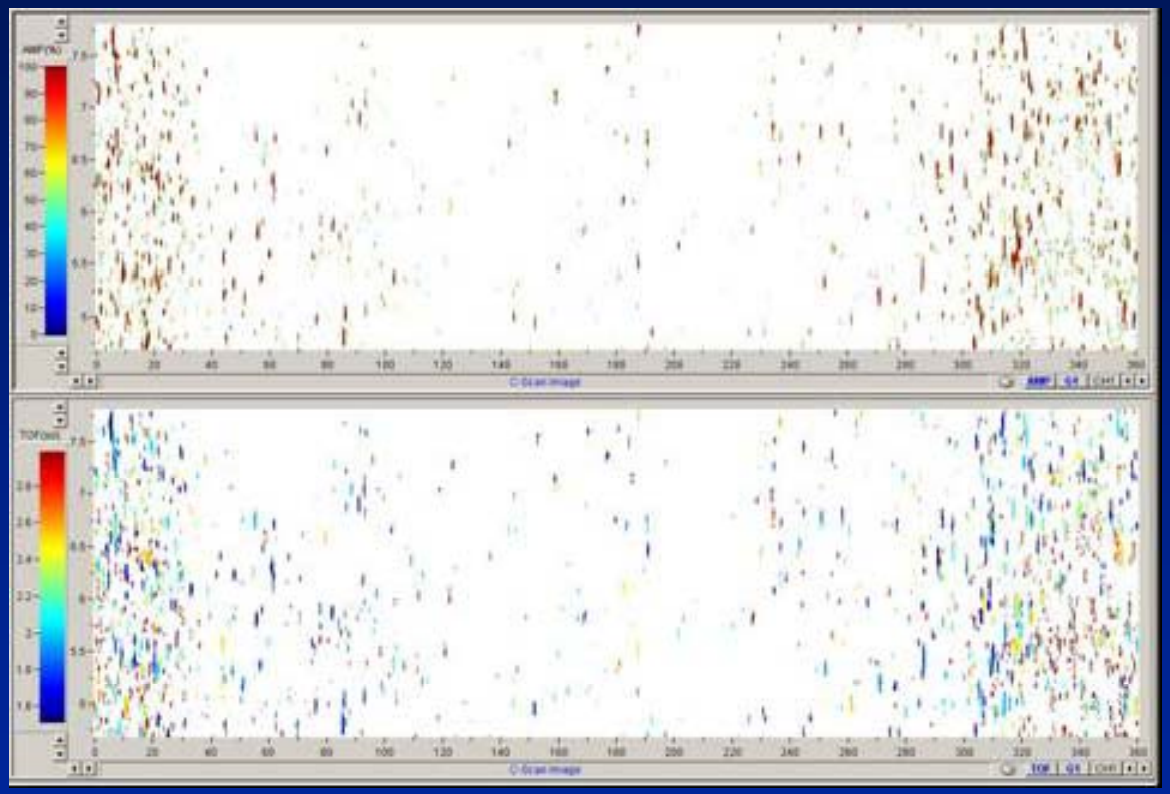
Aug 02



Mar 99

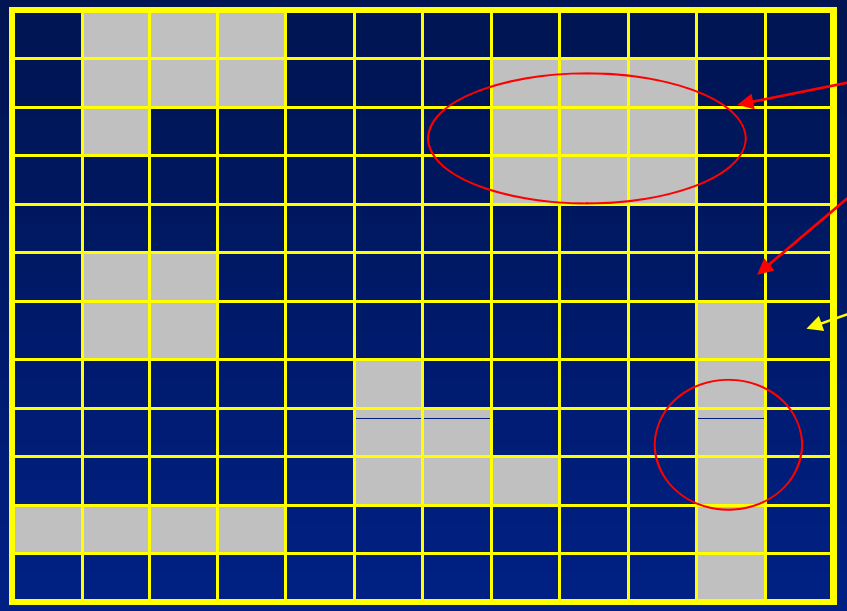
AmstedRail

C-scan (top) and TOF (bottom) for Korean steel



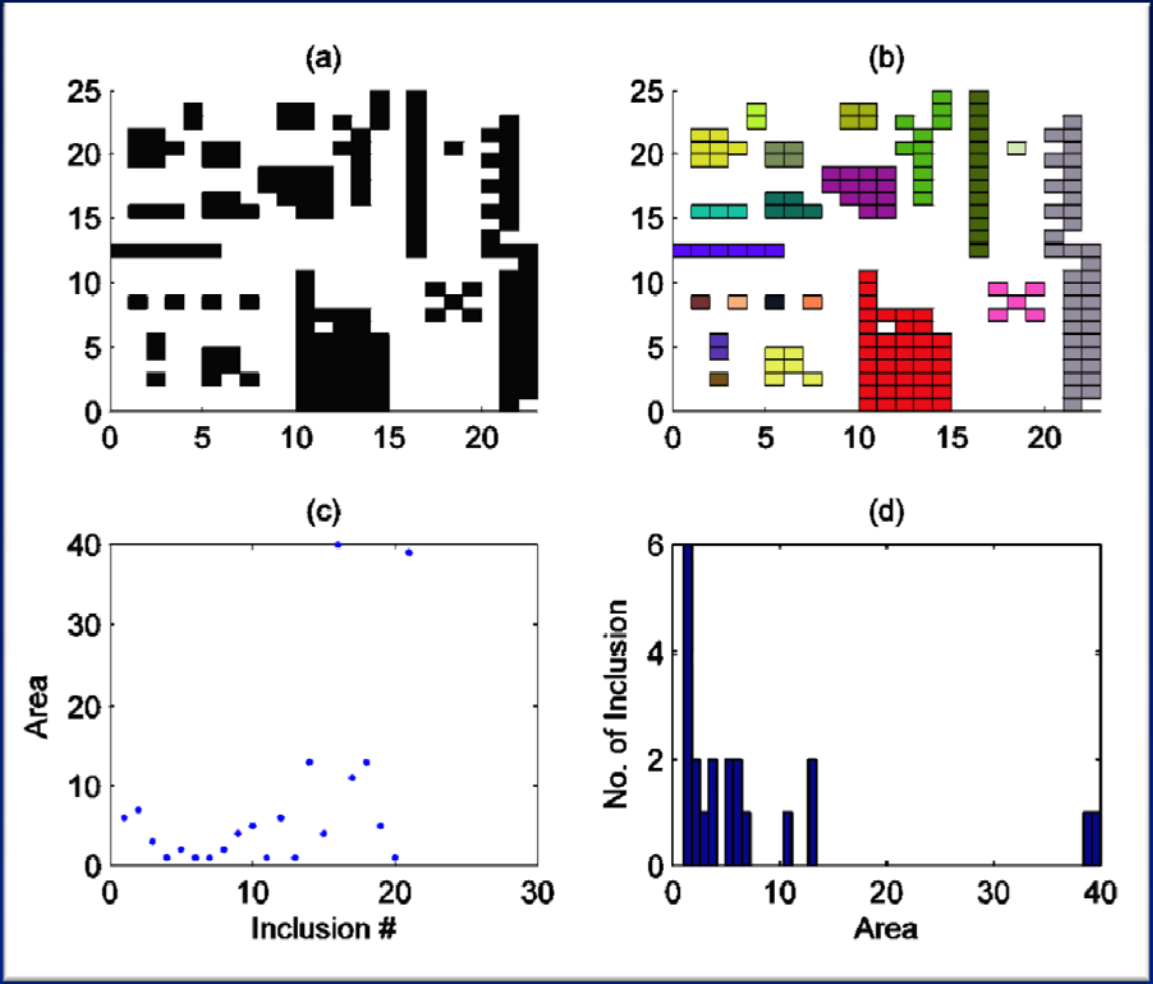
AmstedRail

Advanced Analysis



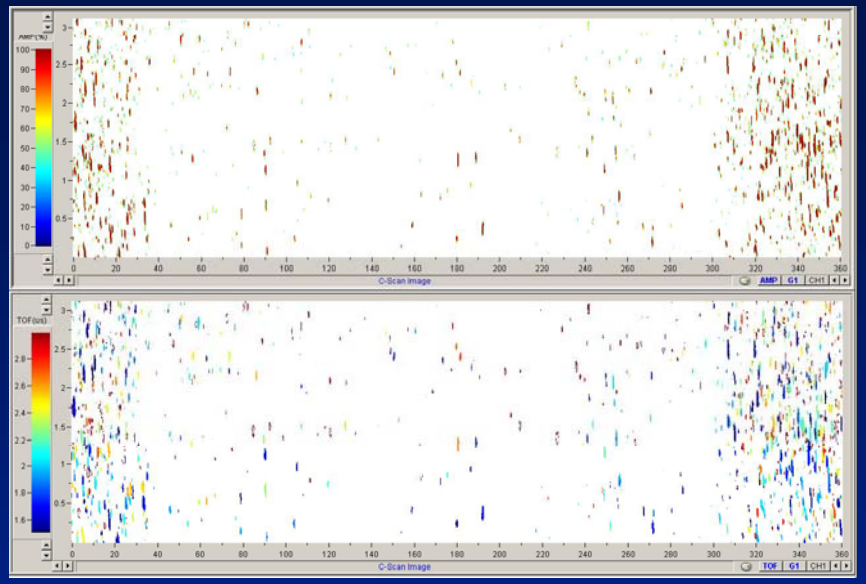
In this example there are 6 inclusions

- Any C-Scan image consists of pixels in a matrix format
- The pixels in grey indicate inclusions
- We need to form cluster of pixels which belongs to the same inclusion
- For every pixel, we look at its 8 neighboring pixels to decide which inclusion any particular grey pixel belongs to



- Fig. (a) - C-Scan
- Fig (b) - Post processing data from Fig. (a). Here each inclusion is denoted by individual color
- Fig (c) is the area of each inclusion
- Fig. (d) is the histogram of inclusion area distribution

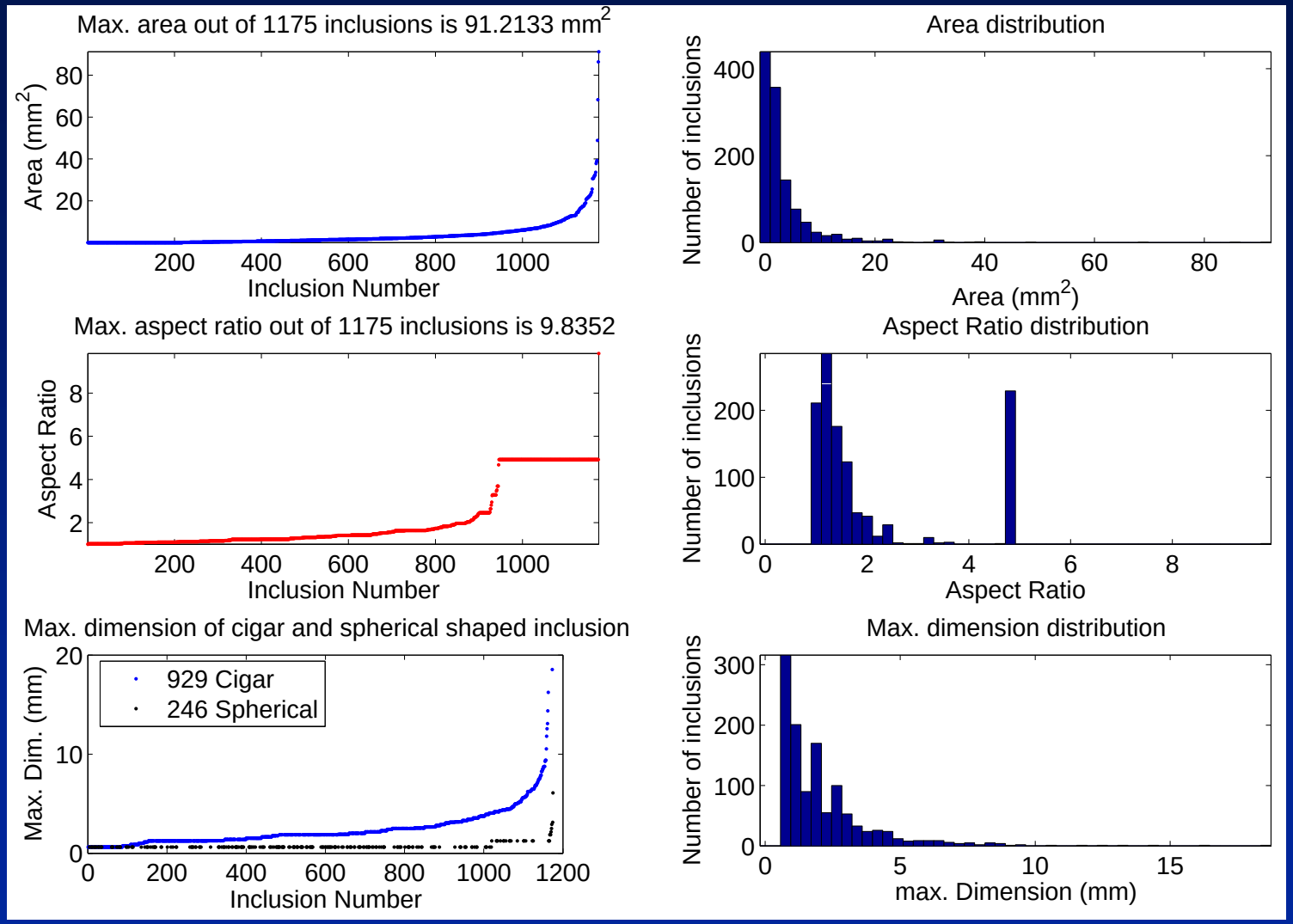
Korean vs. USA

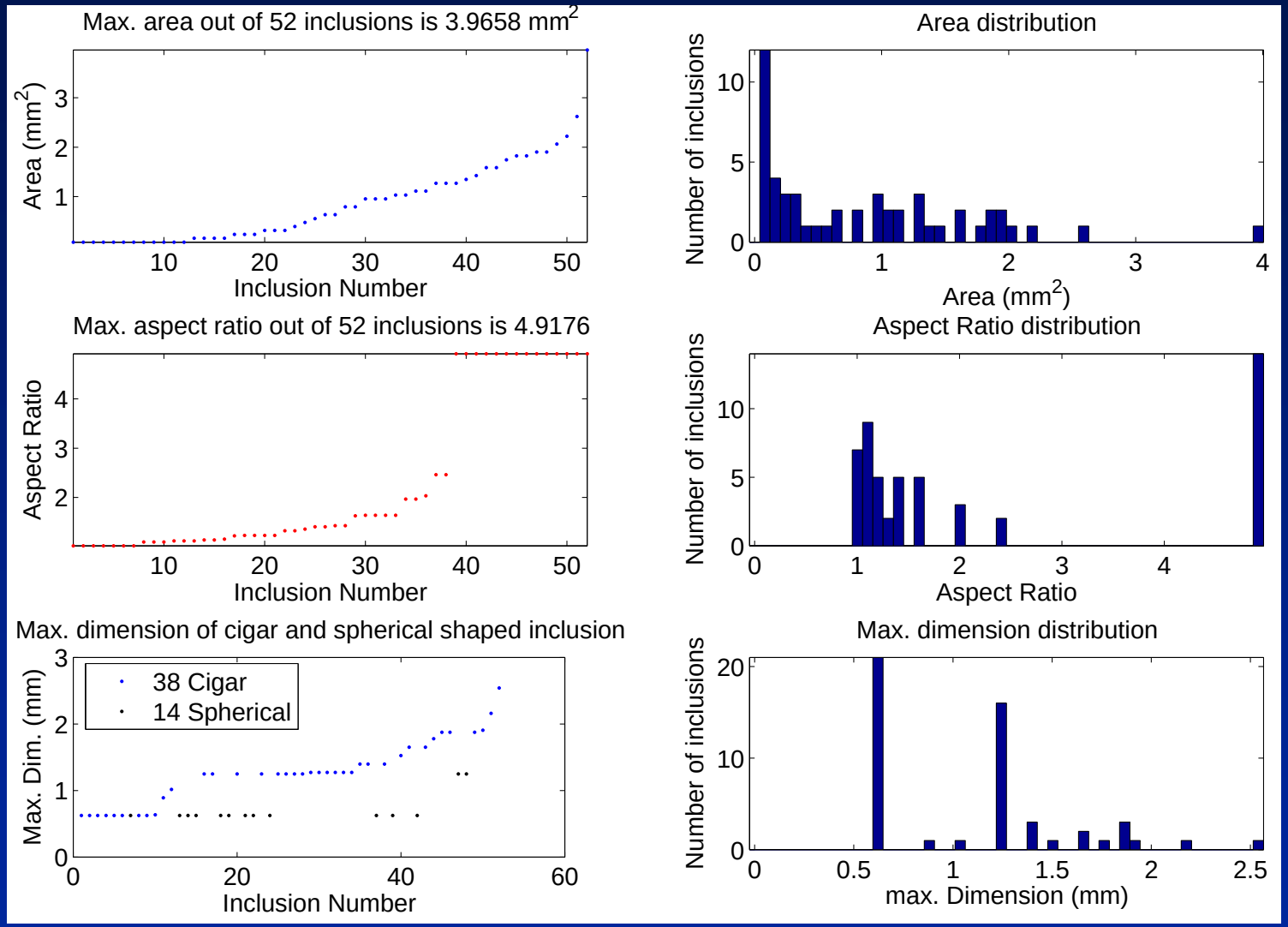


Total Scan Area = 7.1 x 10^4 mm^2,
Total Inclusion Area = 4,047 mm^2

Total Scan Area = 7.1 x 10^4 mm^2,
Total Inclusion Area = 44.5 mm^2

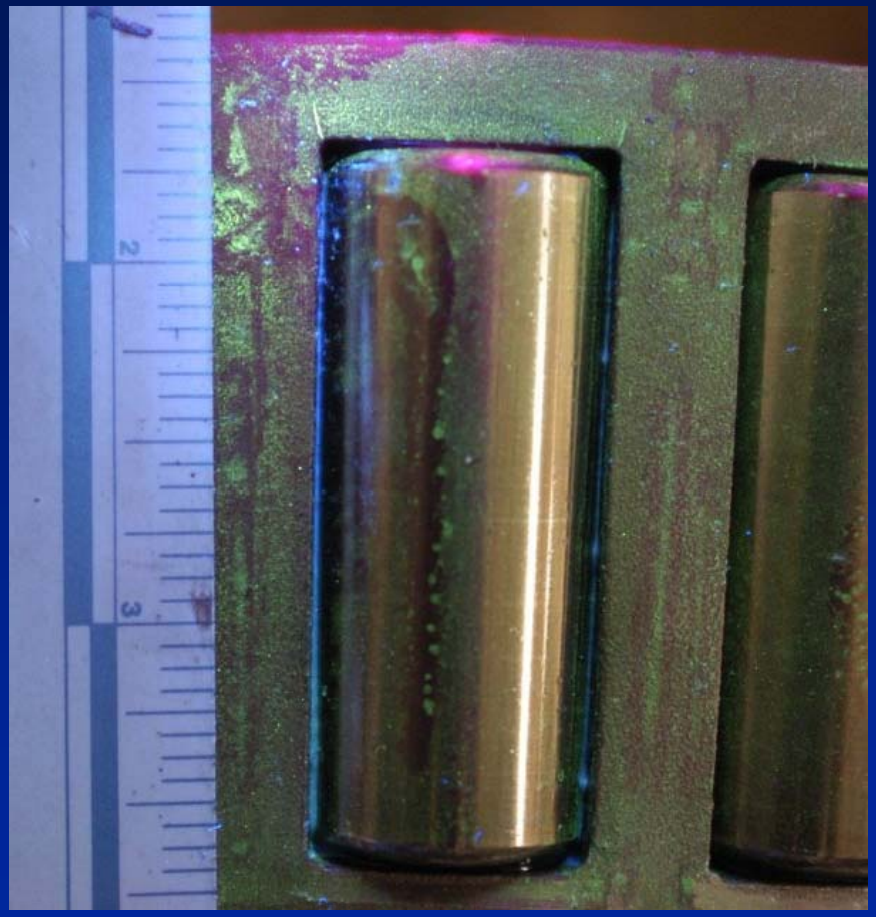
AmstedRail


Max. area out of 1175 inclusions is 91.2133 mm2
Area (mm2)
Inclusion Number
Area distribution
Number of inclusions
Area (mm2)
Max. aspect ratio out of 1175 inclusions is 9.8352
Aspect Ratio
Inclusion Number
Aspect Ratio distribution
Number of inclusions
Aspect Ratio
Max. dimension of cigar and spherical shaped inclusion
929 Cigar
246 Spherical
Max. Dim. (mm)
Inclusion Number
Max. dimension distribution
Number of inclusions
max. Dimension (mm)

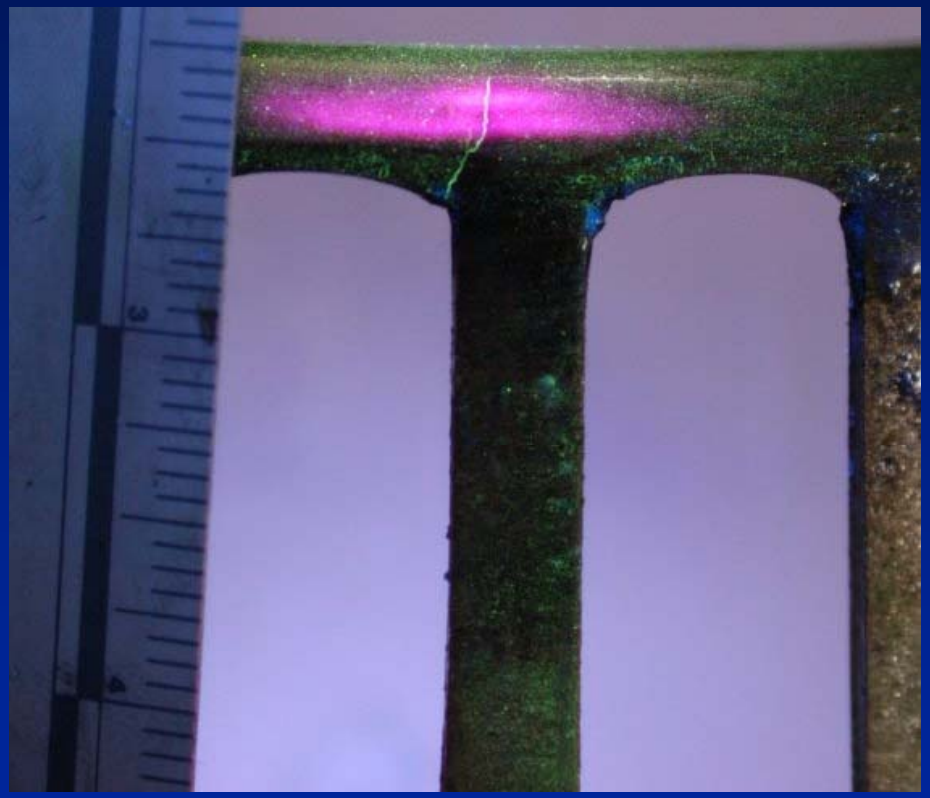

Max. area out of 52 inclusions is 3.9658 mm2
Area (mm2)
Inclusion Number
Area distribution
Number of inclusions
Area (mm2)
Max. aspect ratio out of 52 inclusions is 4.9176
Aspect Ratio
Inclusion Number
Aspect Ratio distribution
Number of inclusions
Aspect Ratio
Max. dimension of cigar and spherical shaped inclusion
38 Cigar
14 Spherical
Max. Dim. (mm)
Inclusion Number
Max. dimension distribution
Number of inclusions
max. Dimension (mm)

The Effects of Impacting Wheels

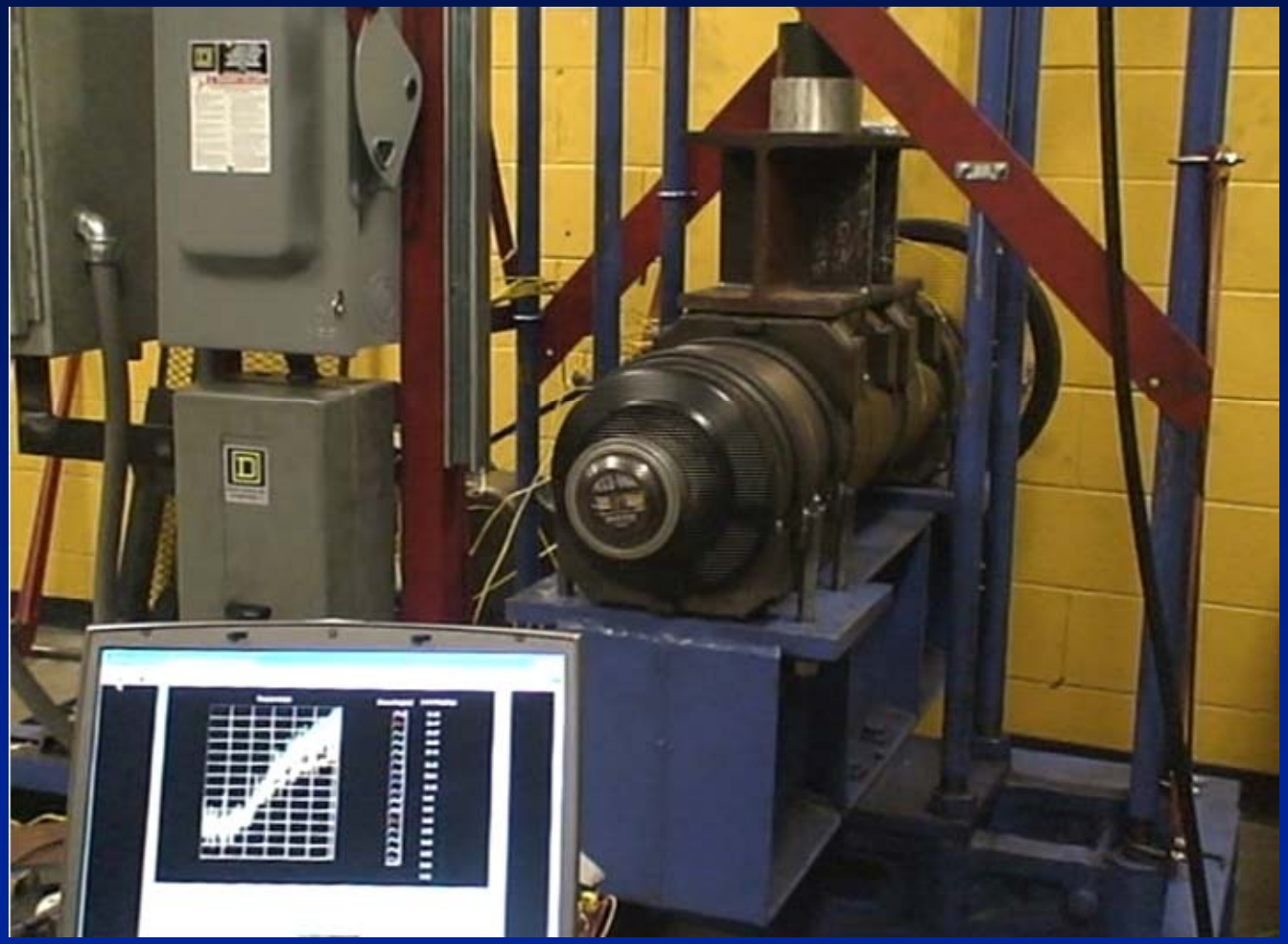
CO317H OB



X61H OB

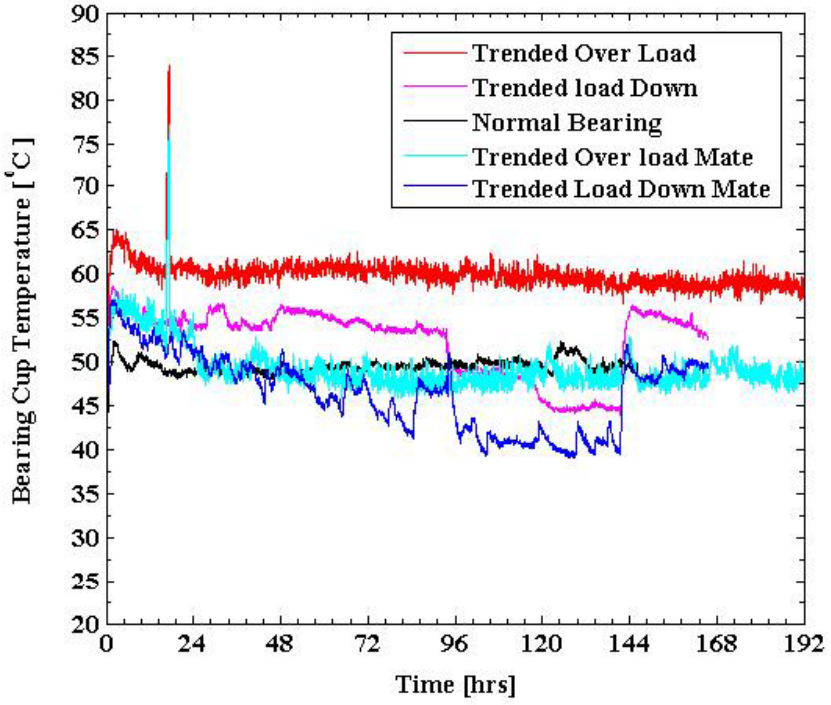


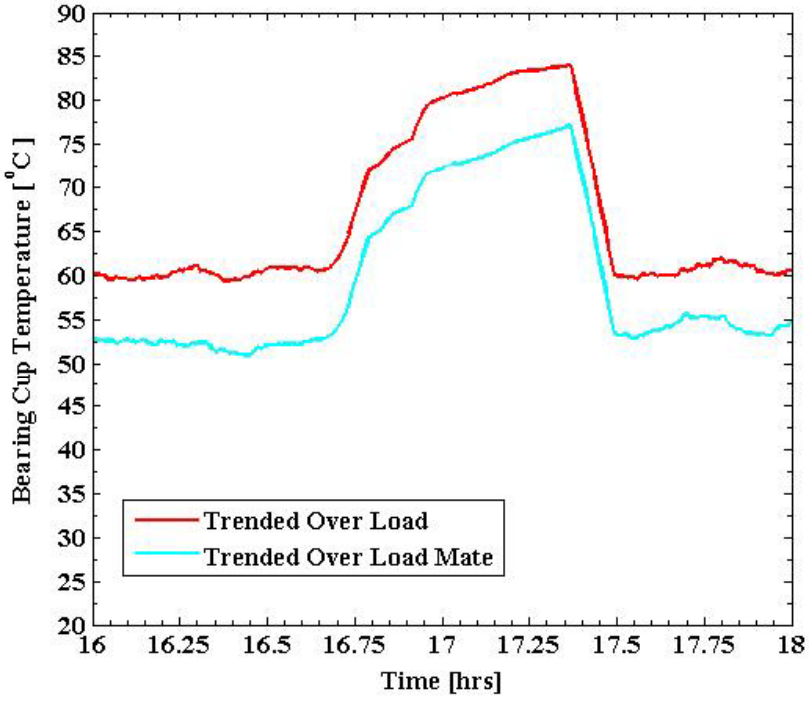
AmstedRail



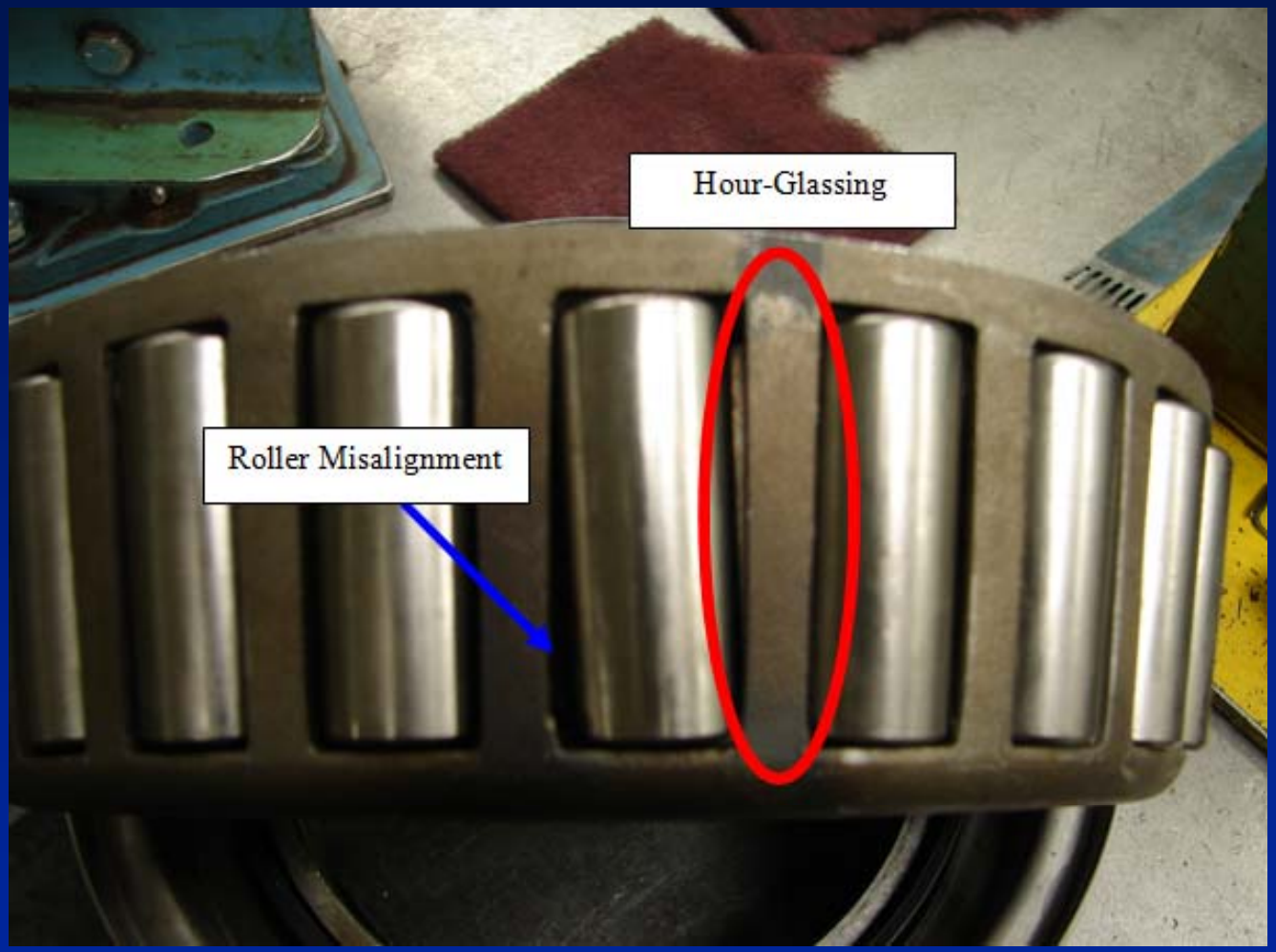
AmstedRail

Dynamic Testing Results



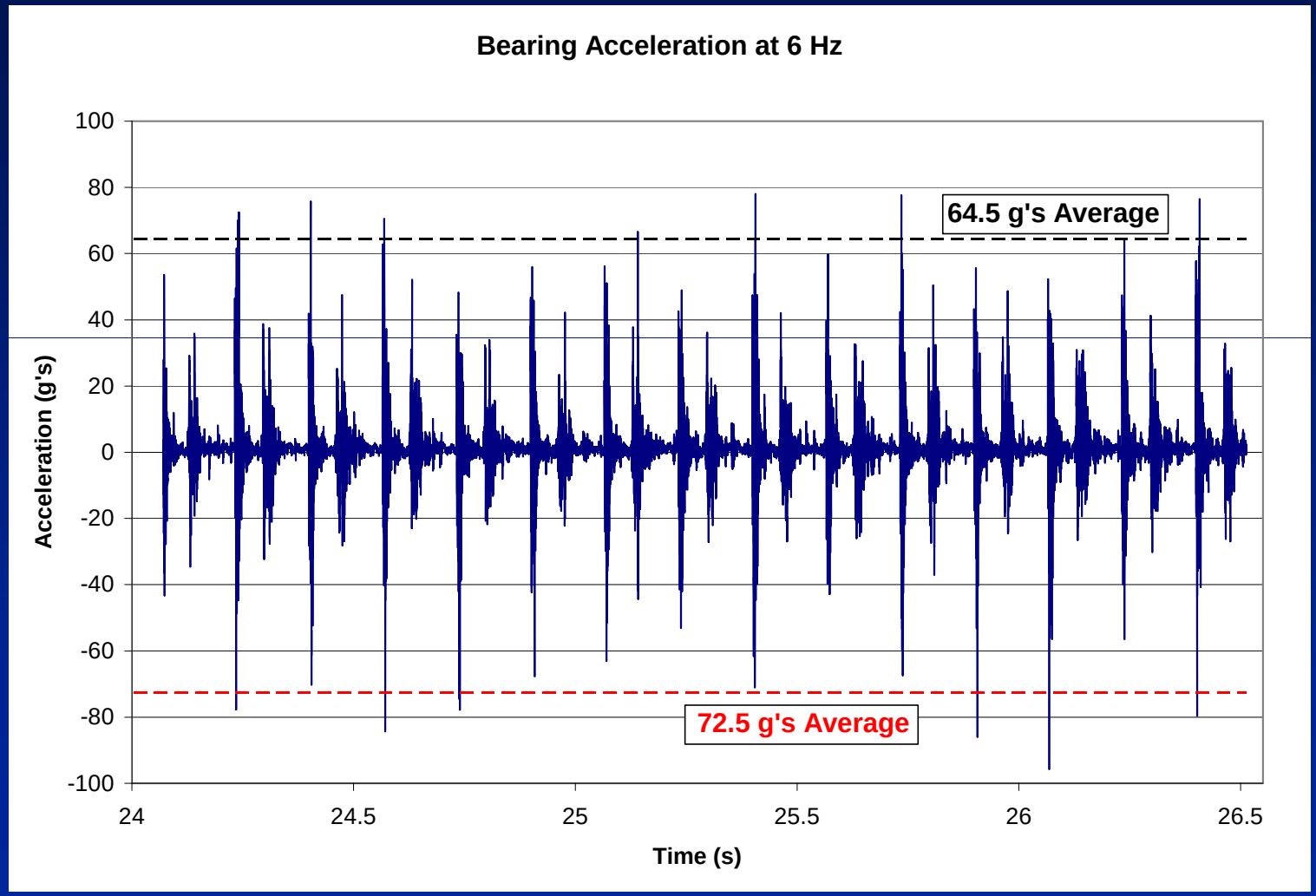


AmstedRail

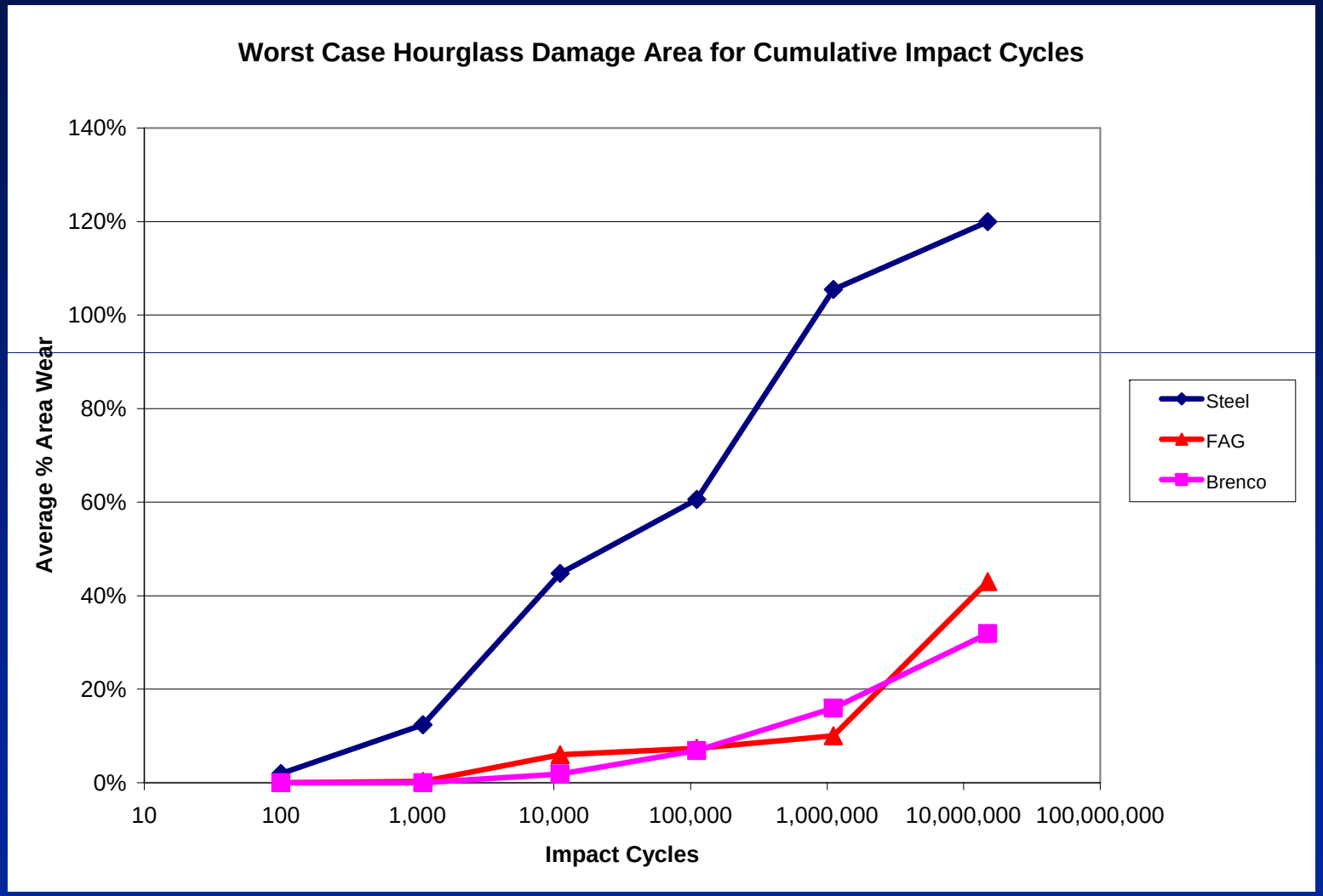


AmstedRail

AmstedRail

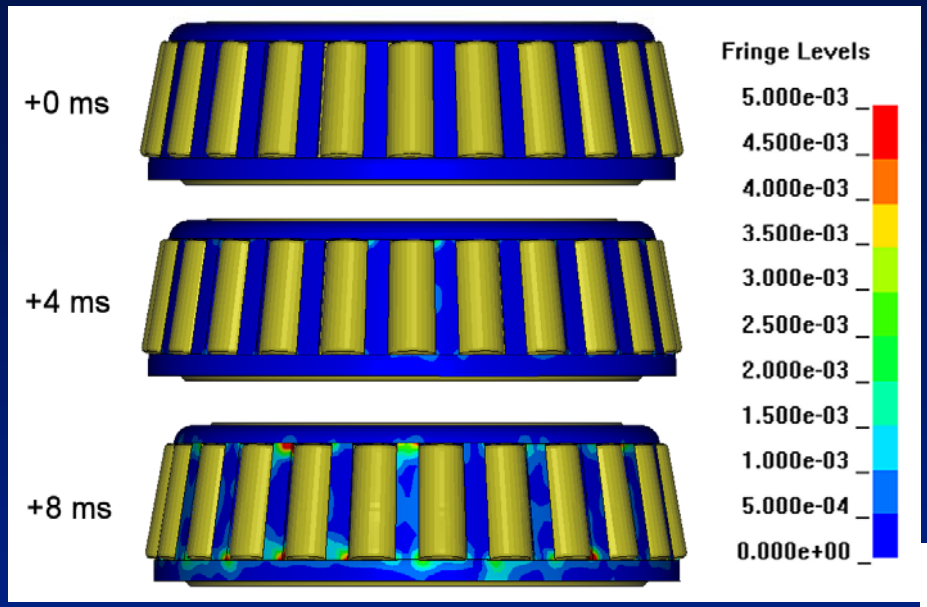

Bearing Acceleration at 6 Hz
100
80
60
40
20
0
-20
-40
-60
-80
-100
Acceleration (g's)
64.5 g's Average
72.5 g's Average
24
24.5
25
25.5
26
26.5
Time (s)

AmstedRail


Worst Case Hourglass Damage Area for Cumulative Impact Cycles
Average % Area Wear
140%
120%
100%
80%
60%
40%
20%
0%
10
100
1,000
10,000
100,000
1,000,000
10,000,000
100,000,000
Impact Cycles
Steel
FAG
Brenco

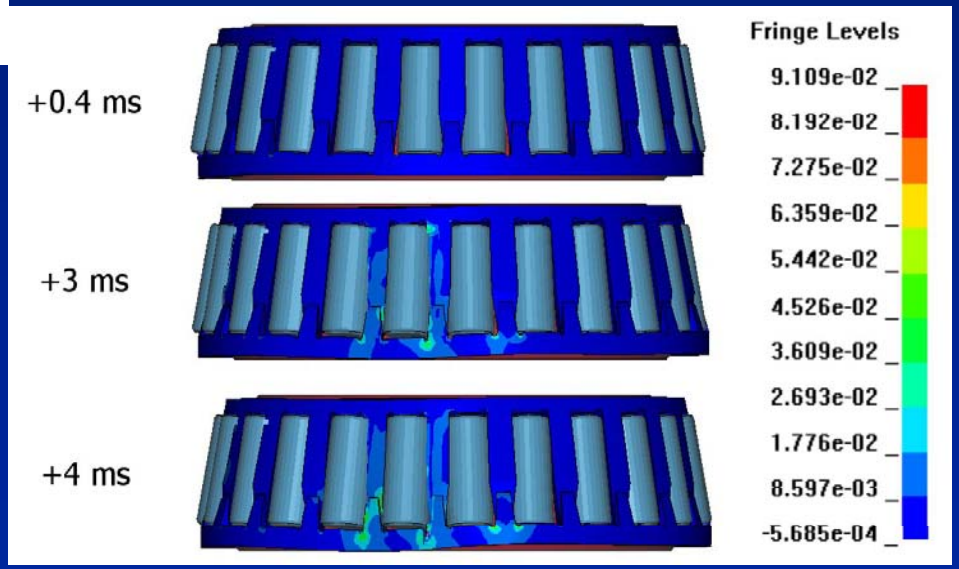
AmstedRail

Bearing Impact Rotational (plastic strain)



Steel Cage

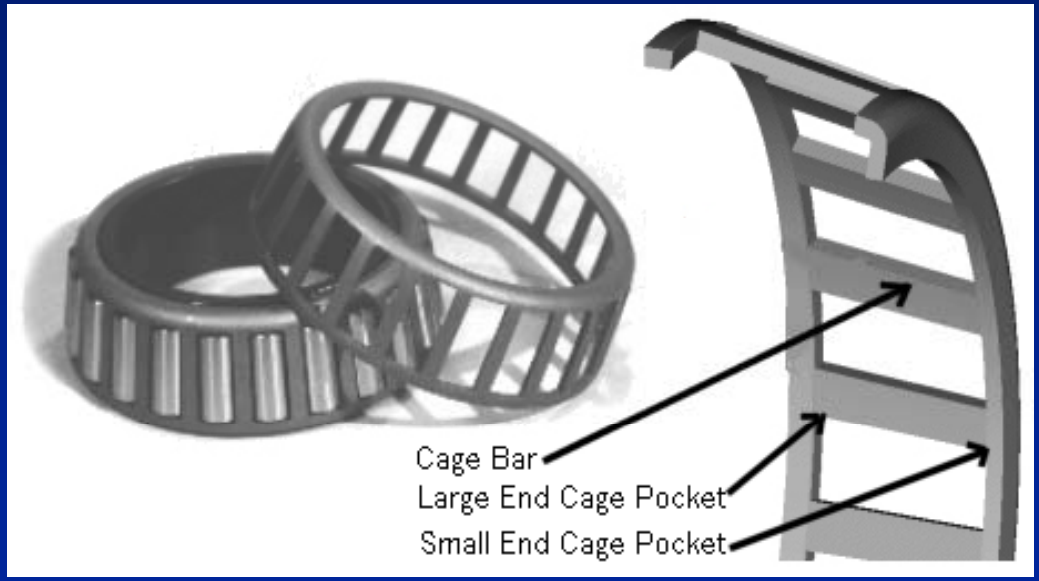
Polyamide Cage



AmstedRail

Bearing Trending

- Laboratory bearing testing has determined that the root cause of trending is due to roller misalignment caused by vibration
- Excessive tolerances and deformation of the cage can allow misalignment to occur … multiple solutions under test:
- A collaborative field test with the UP validated the laboratory findings and future studies are underway.



AmstedRail

Brent M. Wilson

Amsted Rail

February 12, 2010