Evaluation of Barkhausen Noise During Overhaul

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Outline

- Barkhausen Noise Effect
- In-house Demo
  - Results = Capability
- BNI Facilities Visit
- Data Collection study
  - Remaining questions – False calls, sensitivity, learning curve
- LG incident = Pin heat damaged, confirmed with BN at Delta and Boeing;
- Phased Implementation

Motivation

- Overhaul = Preventing needless chrome strip
  - Avoids 7-10 day turn-time per part

- On-wing = Preventing needless early gear removals
  - B737NG NLG Axle
  - B777/767/757 Pivot bores

- Specified in numerous manuals
  - B737NG Service Letter 2014
  - B777/767/757 Pivot Bore ADs
  - Fleet NDT Manuals

THE BARKHAUSEN EFFECT

- A micromagnetic phenomena observed in ferromagnetic materials
- In the presence of a changing magnetic field the net sample magnetization changes
- Domains parallel to the applied field grow at the expense of others
- As domains grow/shrink domain walls move through the sample and are pinned by obstacles – dislocations, inclusions, precipitates, etc.
- These obstacles act as wall pinning sites, requiring more energy to pass
- When the requisite energy (H) is reached, the domain wall "snaps" past the pinning site
- This magnetization changes in discontinuous "jumps", aka Barkhausen "jumps"

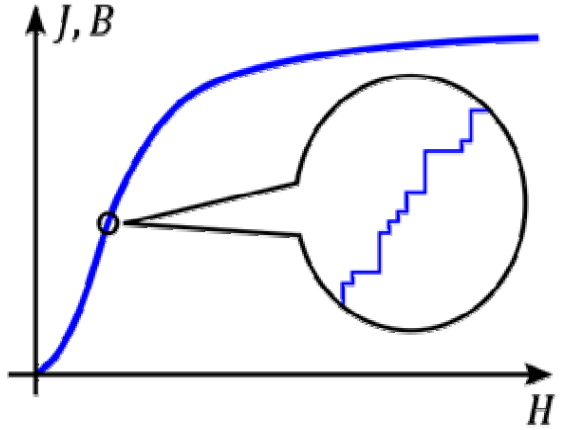


Figure 1[a] – Magnetization (J) or Magnetic Flux Density (B) with respect to applied field strength (H)

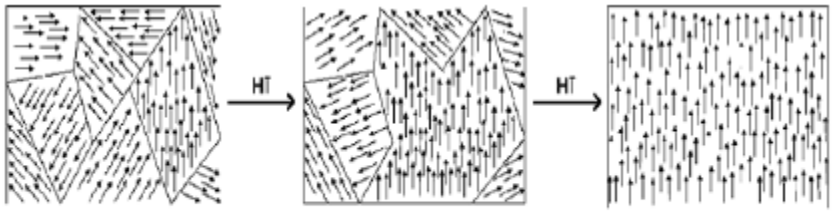


Figure 2[a] – Resizing and reorienting of domains as a result of applied field H

DESCRIPTION OF BARKHAUSEN NOISE

DELTA TechOps

- Stresstech Oy, based in Finland (U.S. representative is American Stress Technologies in Cheswick, PA).

- All the major landing gear manufacturers (Messier-Dowty, Goodrich/UTAS) as well as Boeing and Airbus use this inspection method, primarily for manufacturing quality control, but also during some overhaul operations.

- Barkhausen Noise inspection is an acoustically or inductively measured signal that comes from ferromagnetic materials when it is magnetized.
  - –Domain movements produce “Barkhausen noise”

- BN measures the changes of the residual stress, hardness and microstructure, when magnetic field is applied.

- Developed for grinding burn detection, however, any manufacturing process that can change microstructure and/or stress is a good application.
  - – Hard turning, heat treating, shot peening, grinding, carburizing treatments.

- Industry specifications: BAC 5653, SAE ARP4462, MIL spec

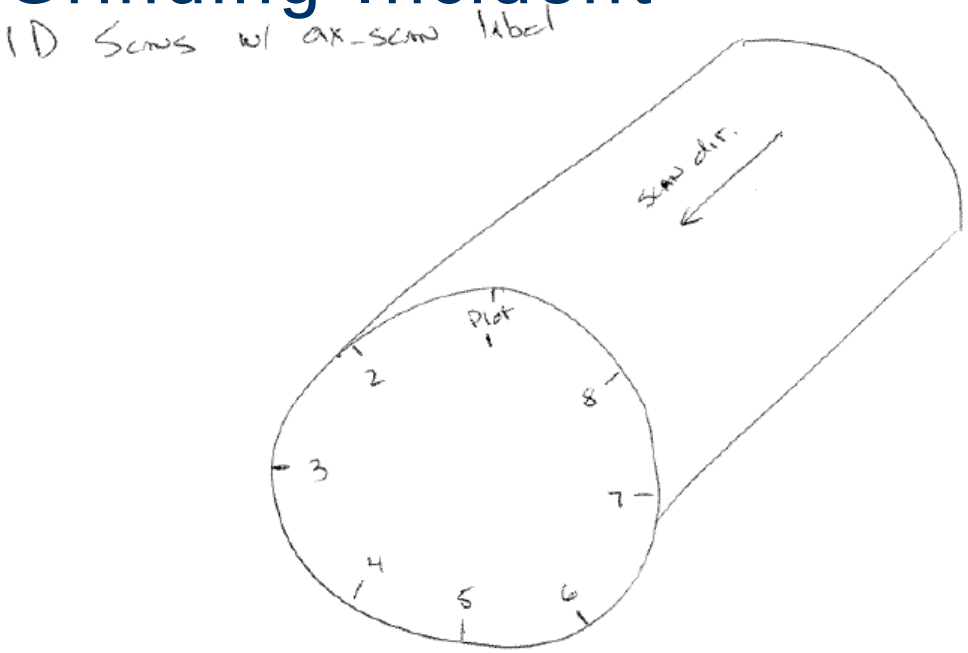
BN can detect burns through chrome plating

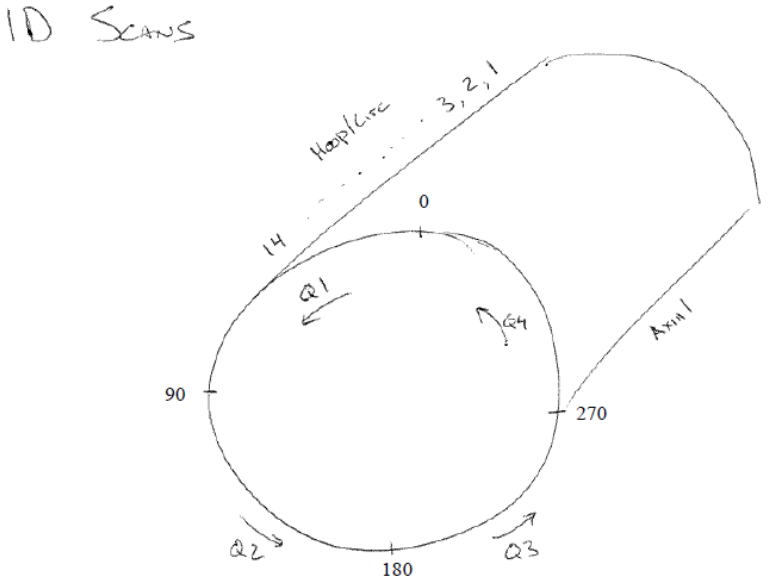
CAPABILITY DEMO – Overspeed Grinding Incident

- New machine installed, software error => overspeed in certain condition
- AST visit to demo and conduct study
- Two 'suspect' gear cylinders, 1 completed 'overhauled' gear, and Engineering specimens used
- BN inspection indications (through 0.008" thick chrome)
- Later, cylinder found 'overtemp' by Nital Etch, and cracking discovered with MPI in areas that BN inspection had identified as 'suspect'.
- Proves the 'capability' of Barkhausen Noise inspection to detect grinding burns through chrome(0.008").

Successfully showed 'capability' to detect burns through chrome

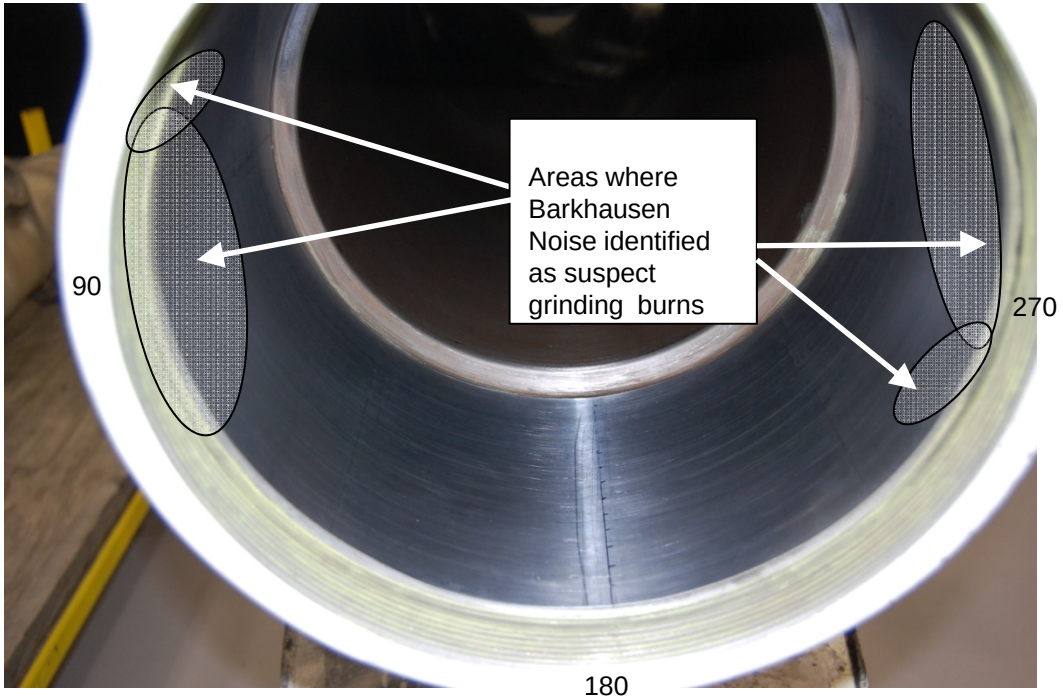
CAPABILITY DEMO – Overspeed Grinding Incident

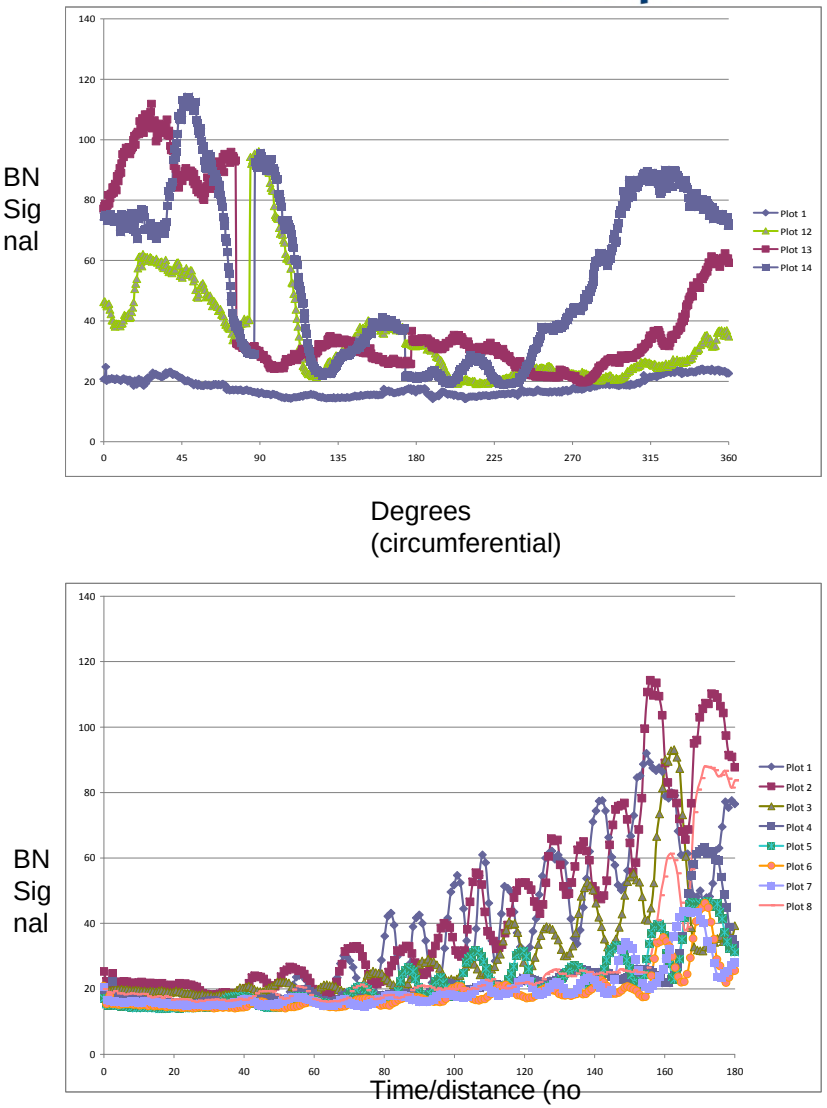




Axial and Circumferential 'segment' scans were acquired

CAPABILITY DEMO

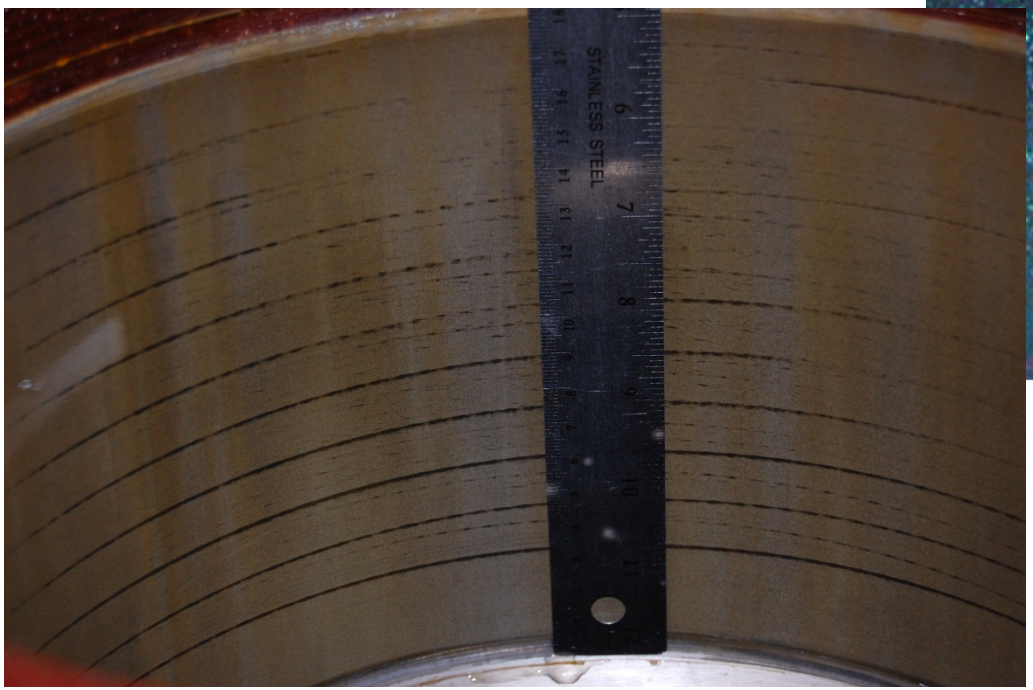


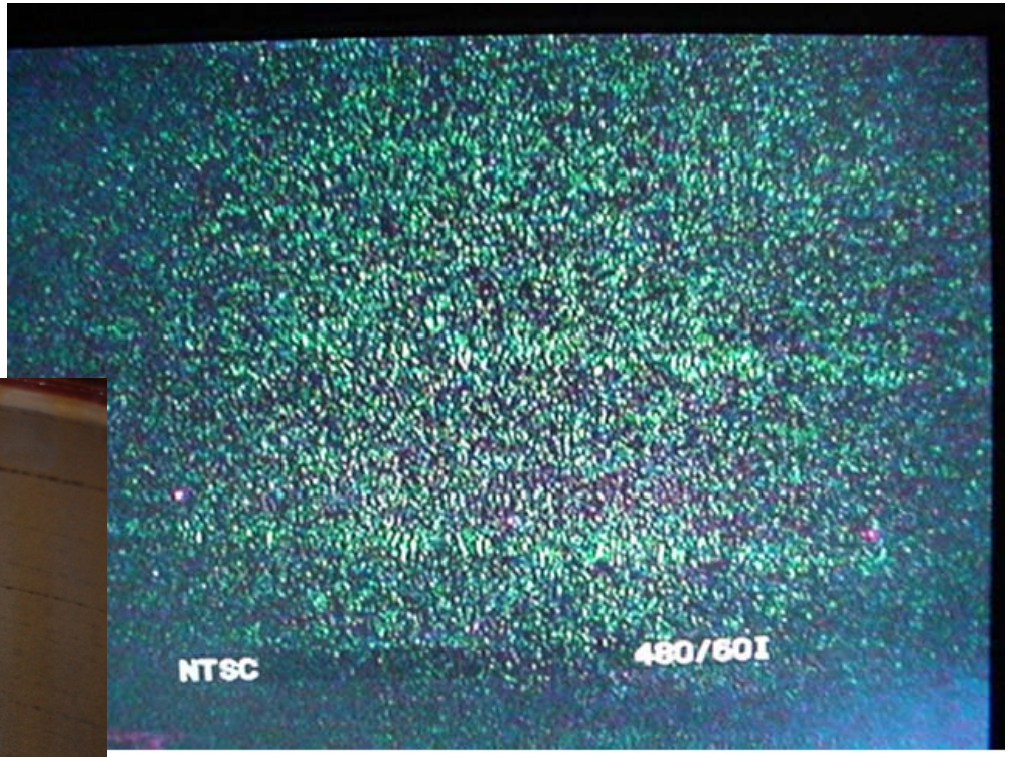


BNI indications in both axial and circumferential scans

CAPABILITY DEMO

Nital etch indications match BN indications





MPI indications of cracking in affected area

Nital Etch and MPI confirmed the BNI indications as grinding damage

BNI FACILITIES VISIT

- Visited facility to examine BNI implementation
- Manufacturing = automated BN process.
  - New part production = applied to all axle ODs, with automated setup on lathe.
  - Not applied to ID surfaces, as those are plated to size and honed to finish.
- Only performed hand-scanning BN on overhauls (mostly military, C-17; Commercial AC use only if requested by customer).
  - Applied on all chrome plated surfaces following initial Stress Relief Bake.
  - A second test is accomplished if the part is ground following chrome plate.
- Process for investigating indications = strip, nital etch.
- Frequency of indications = 1-3% rate, reflecting in-service stresses, heat damage, or 'other'.
- False calls are approximately 50% of the 'reject' calls.
  - 'Undocumented' Nickel-filled repairs.
  - Inconsistent grit blast; Inconsistent shot peen.
  - Inconsistent chrome thicknesses.
  - Edge effect of chrome (finish grind poor run-out).
  - Nicks and gouges on substrate.

Many questions answered during visit – others created

BNI FACILITIES VISIT

- At ‘overhaul’ facility, parts ‘wheeled’ over to the inspection area, similar to MPI (i.e., not on the lathe/grinder machine).
- In-house ‘process standard’ provided, follows BAC 5653/SRP 4462.
- Good records must be kept and parts mapped for reference; Can map on plastic overlay.
- Machinists, trained and certified as ‘Level IIs’ are trained to perform this task. Level III involvement if questions on interpretation.
  - Approx 4 weeks of training (self-study & OJT, no classroom).
  -
- Approximately one year learning curve in both facilities to “understand what information the tool was providing”.
- Approx 30-45 minutes per inspection per axle.
- Probe life = From three (3) to six (6) years.
- Annual PMET = AST (BN vendor) visits both sites annually, and recertifies the equipment.

Recurring theme: If handled correctly, BN is excellent

FEAR OF THE UNKNOWN !

- BNI is very sensitive = too sensitive? Will we be able to process anything? False calls 50% of rejects?
- Sensitive to chrome thickness = just like MPI limitation?
- Learning curve?
- Ensure complete coverage – fixturing? Dedicated lathe? Axial & Circumferential or just one? OD/ID?
- Reference Std, Procedure?
  - SAE ARP, BAC acceptable?
  - Boeing assistance
- Recommended a Data Collection Study
  - AST Assistance in leasing equipment

Lots of scary reasons to hesitate

BN Data Collection & Volume Study

DELTA TechOps

Procedure:

1. Ref Std made for 4340M using scrapped pin
2. Internal Delta Technique Sheet made.

DELTA	Non Destructive Testing Technique Sheet	ET 126-32 Date: 04-24-2012 J. Bohler rev 2, 5-15-2012

Barkhausen Noise Testing of Chrome Plated Steel Parts

MFG PN: Various

REFERENCE: BAC 5653
ARP 4462.
Delta EA 10-499962-14

PURPOSE
To provide instructions for proper instrument set up and inspection of parts for grinding burns through chrome using the Barkhausen Noise Testing method. This technique sheet is for manual scanning only.

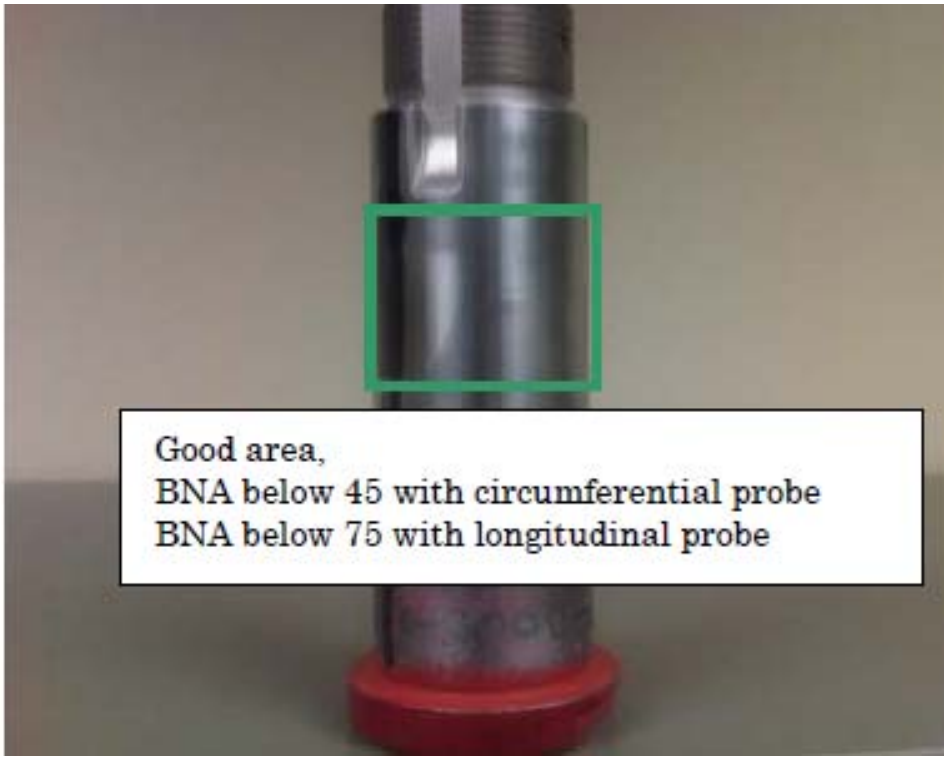
NOTE: Only individuals who have successfully completed the Barkhausen Noise course TNDTBKHSNN and have it listed in their LMS transcript are permitted to perform Barkhausen Noise inspections at Delta Air Lines.

EQUIPMENT

A. Rollscan 300 CPU
B. High Output Axial OD Sensor, See figure 2.
C. High Output Circumferential OD Sensors. See figure 2.
D. Reference Pin 161N4001-2 BNR
E. Tape, PTFE, Teflon, or other high wear resistance tape with a thickness of 0.003 ± 0.001

Decided to 'collect data' for ~9 months to answer questions

BN Data Collection & Volume Study



Reference standard made from scrapped pin

BN Data Collection & Volume Study

- 269 parts with BN data collected over 58 unique PNs:
  - 154 were processed without Nital etch
  - 113 with Nital etch
    - 59 parts with BN indications and were stripped/nital etched
    - **54 parts had no BN indications, but were stripped / nital etched anyway**
- Shop order sequence (Visual/Dim, BN vs BN then Vis/Dim)
  - For every instance of visual defects (chrome flaking, corrosion, wear), there were strong Barkhausen Noise signals. Thus, the 59/113 parts with BN signals did have some type of visual defect, which would require chrome strip and nital etch.

Chrome wear provides visual & BNI indication

Data collection provided valuable info, learning

BN Data Collection & Volume Study

- 54/113 parts with no BN signals would have had acceptable visual and dimensional inspections (Verified with Shop order).
  - It is these 54 parts which could be ‘saved’ by performing BN (i.e., by doing BN would allow for chrome to remain, thereby skipping plating removal, nital etch, replating, etc), which is an estimated 7-10 days of turn time per part.

Conclusion: By implementing the Barkhausen Noise inspection technique, many parts per year would avoid 7-10 days of unnecessary procedures and turn time.

Many concerns alleviated; Implementation recommended

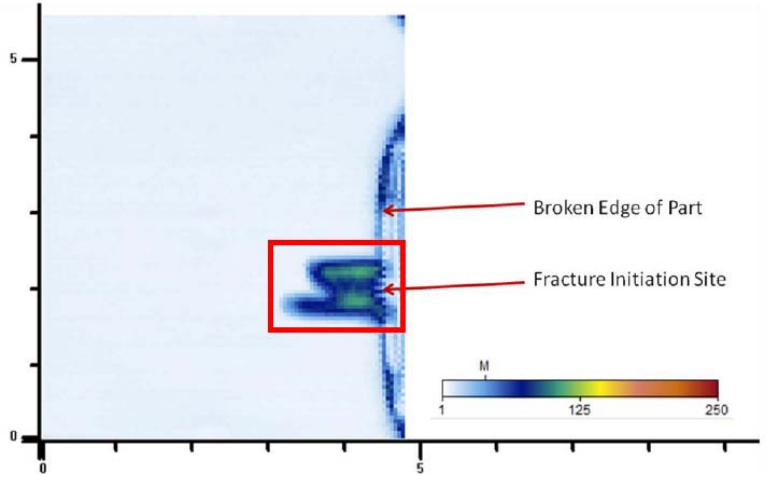
Failure Investigation

767 Lower Torsion Link Pin Failure:

1. Broken half inspected by DL – strong BN indication
2. Boeing – confirmed BN indication
3. "…showed evidence of base metal grinding burns under the Chrome plate at the site of fracture origin."

- Other Boeing examples of heat damage
  - Grinding during overhaul and
  - In-service damage (poor lubrication)

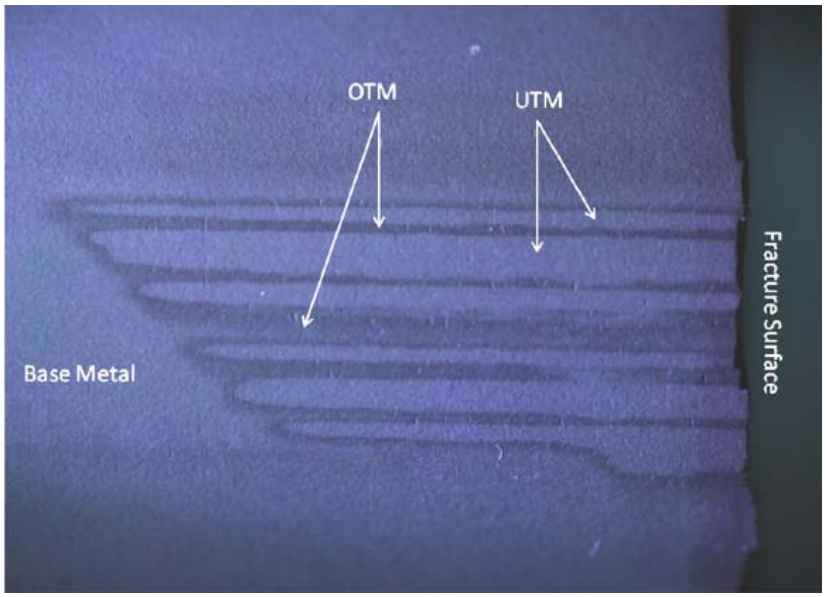
- Delta has had 4 broken axles due to heat damage



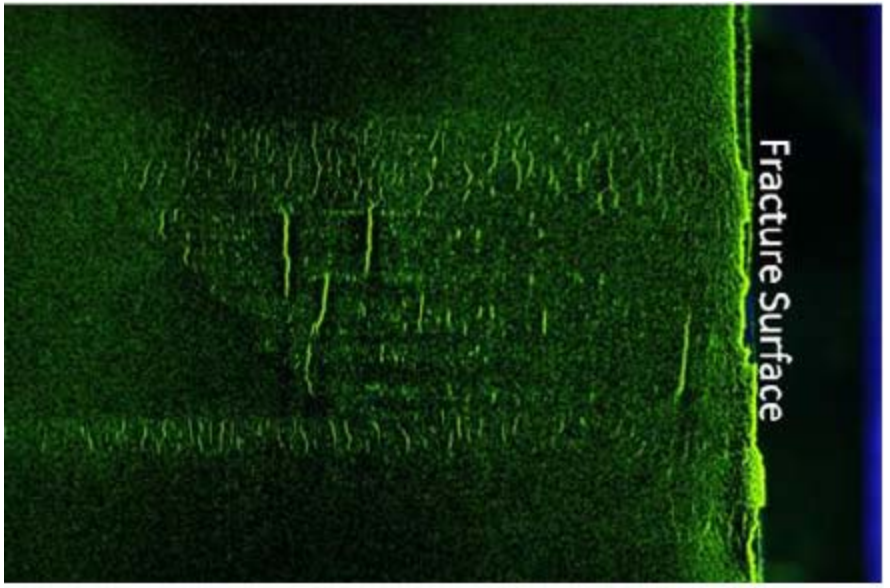
History of issues, which could be solved with BN

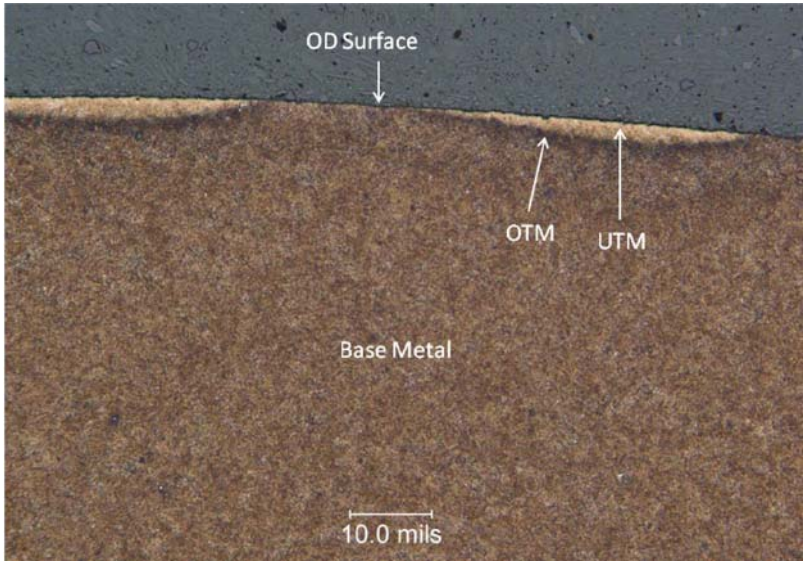
Failure Investigation

Nital etch



MPI





Depth of 4 mils

Phased Implementation

- Implemented in Shop prior to overhaul
- 11 PN selected in initial round
- Follow the money – avoid needless strip (vs high-risk parts)
    - Data mining to determine which parts
- Training program established: course, OJT
- Ramp-up slightly in 2016
- Shifting to high-risk parts?
- On-wing applications being explored
- Post final-grind BNI being discussed
- Business cases by PN

Summary

- Capability demonstrated by in-house demo
- BNI Facility visit provided lots of info, but also generated more questions, fears
- Data Collection study to alleviate fears: false calls, too sensitive, complete coverage
- Boeing NDT Manual, ref stds created
- Failure Investigation validated
- Phased Implementation during overhaul