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EVALUATION, MODIFICATION AND DAMAGE TOLERANCE OF AN IN-SERVICE AIRCRAFT CRITICAL AREA

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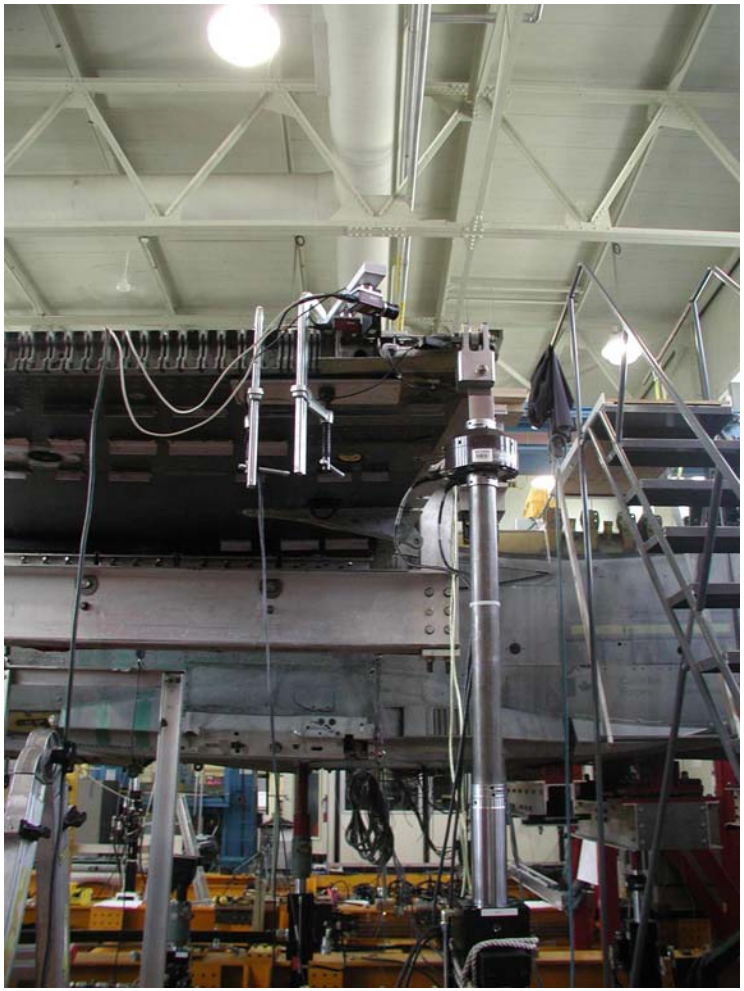
Presentation Overview

- Introduction
- FT312 Test Objectives
- Methodology
- Test Operation
- Residual Strength Test
- Conclusions



In the beginning…

- In the early 1980s, the CF bought a new fighter – the McDonnell Douglas F/A-18, or CF-188 as it was called in Canada.
- A twin engine, single or dual seat, multi-role aircraft designed for the USN, the F/A-18 was also bought by Australia, Switzerland, Spain and Switzerland.

Definition…IFOSTP

- IFOSTP – International Follow-On Structural Test Programme
  A joint venture between the air forces of Canada and Australia, with the support of their various national institutions and contractors. The IFOSTP came out of informal discussions at TTCP meetings.

- In Canada – National Research Council Institute for Aerospace Research and L-3 Communications MAS/Bombardier.

- In Australia – Defence Science and Technology Organisation Aeronautical and Maritime Research Laboratory.

Reasons for IFOSTP

- USN requirements were for a safe-life design, CF lifing policy required a different approach. This lead to different interpretations of certification test results.
- USN usage spectrum (design and service) much less severe than CF.
- Fatigue usage rates in early CF flying projected a very early fleet retirement.

The IFOSTP Tests

- In Australia:
  - **FT46** – real-time quasi-dynamic test of the rear fuselage and empennage.
- In Canada:
  - **FT55** – at L3 Com / BA, Mirabel. Fatigue test of centre fuselage.
  - **FT245** – at IAR, Ottawa. Fatigue test of inner and outer wing boxes.

IFOSTP Wing …. Certification

- FT245, was the primary means of wing structural certification.
- Three repeated load lives of simulated flight hours (SFH) provided proof that the wing could safely fly for the design-life flying objective using CF missions.
- NRC developed method to characterize the dynamic content of the wing loads spectrum.
- Test spectrum was for an average aircraft in a severe squadron based on MSDRS data statistics 1989-1990.

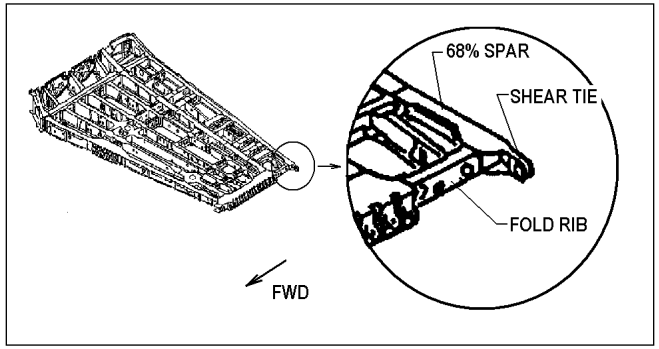
Wing Spectrum …

- Spectrum designated IARPO3a and included dynamic loads caused by trailing edge and wing tip buffet.

- Wing test - dynamic loads at the control surface attachments on the trailing edges were severely truncated to complete the fatigue testing within the client desired time frame.

- Consequently some areas of the wing susceptible to dynamic loads may have been under tested.

In service damage …



- Cracks were found in the wing-fold aft-spar shear-ties of in-service aircraft.

- FT245 fatigue test spectrum was not severe enough?

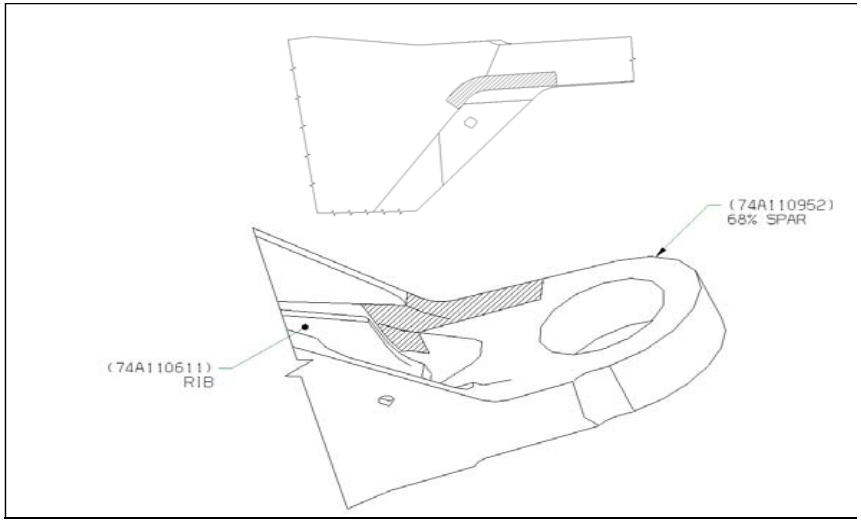
  or Surface preparation for strain gauges may have removed acid etched surface damage - typically present on all aluminium on this aircraft.

- Acid etch damage - a by product of the cleaning process applied just prior to corrosion prevention ion vapour deposition at manufacture.

Repairs Proposed … Test

- To repair the cracks in the fleet wing shear-ties, various blends were proposed.

- Due to the severity of the problem, NRC Canada - tasked for a local fatigue test on the aft-spar shear-tie on an inner wing.



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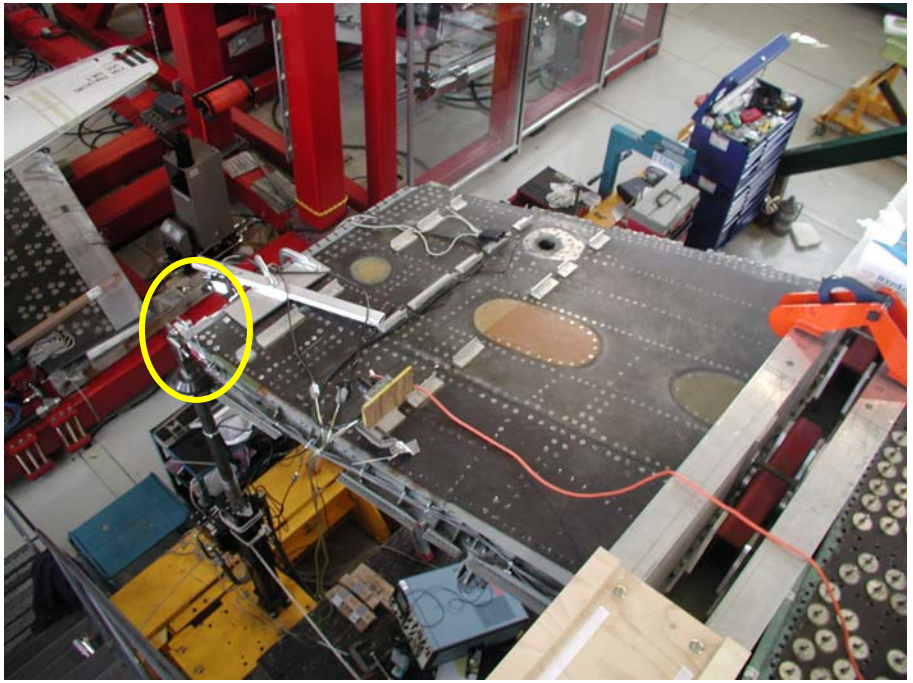
Fatigue Test … Repair and Continue

- Locally test the wing-fold aft-spar shear-tie.
- Generate cracking similar to that found in-service.
- In-service repair via structural modification proposed for area.
- Determine the post-modification life under representative spectrum for five repeated load lifetimes (RLLs).
- Generate test crack growth data - management & provision of fleet modifications.

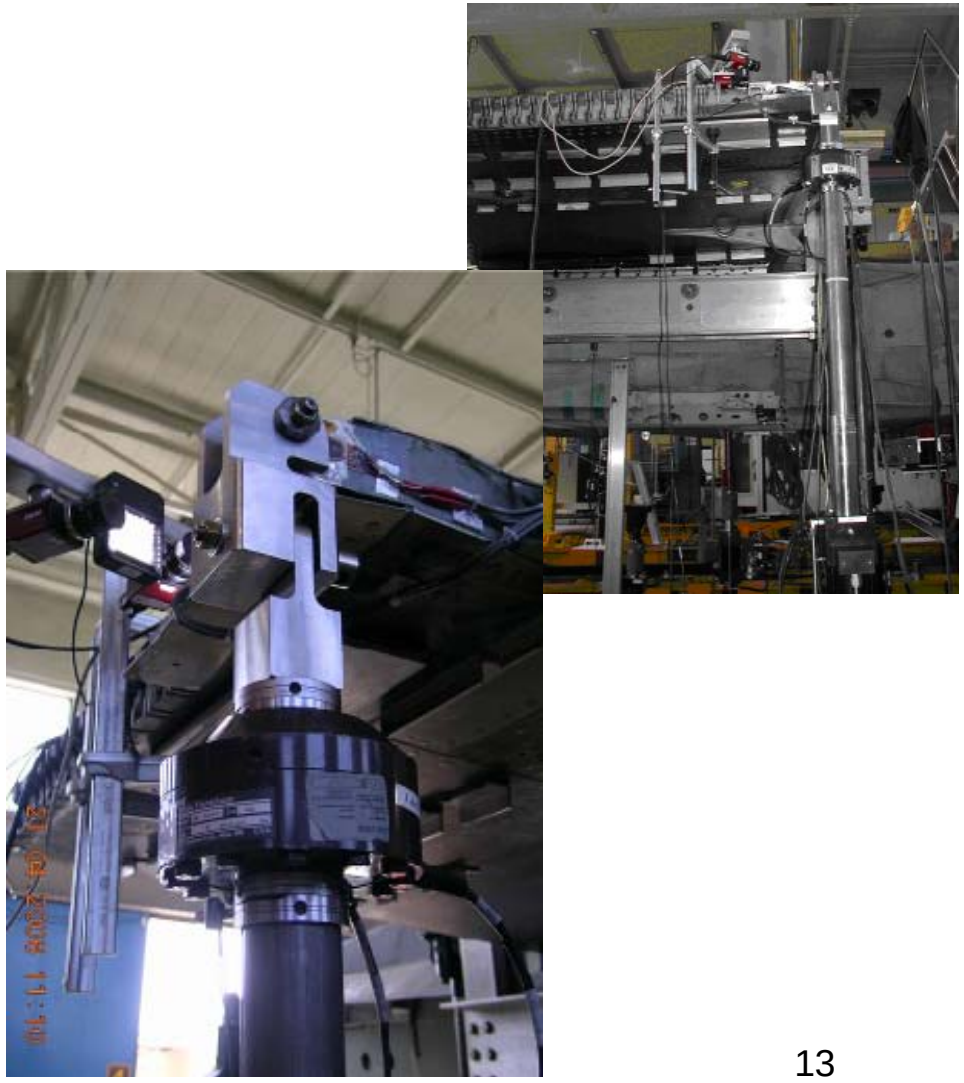
Specimen

- Port Wing of FT245 was used as the test specimen.
- Serial A12-0312 was retired, 60% of one RLLs of usage.
- Wing fold shear-tie area not loaded during FT245 testing.



Test Rig Configuration

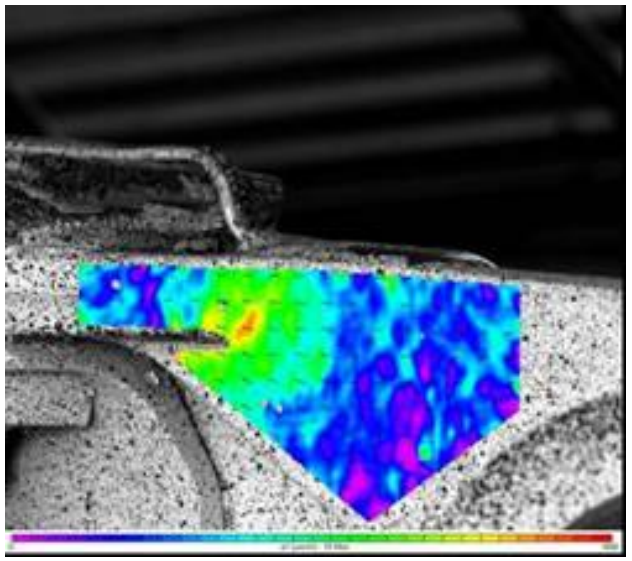
- Double lug arrangement.
- Single actuator / load cell.
- Three different offsets considered in the spectrum development.



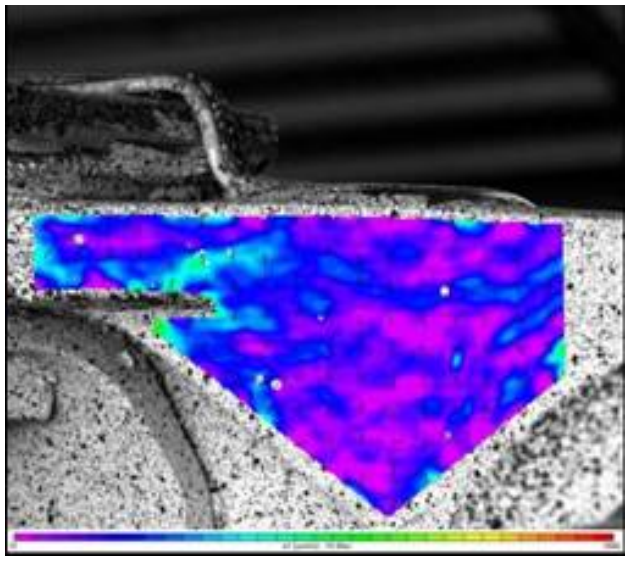
Strain Survey…. Configuration

- Pre-test strain survey used to obtain desired strain distribution.
- Strains measured using digital image correlation and eight strain gauges.
- A 7.62 mm (0.3 inch) lug aft offset was selected for the fatigue test.

47% DLL Down

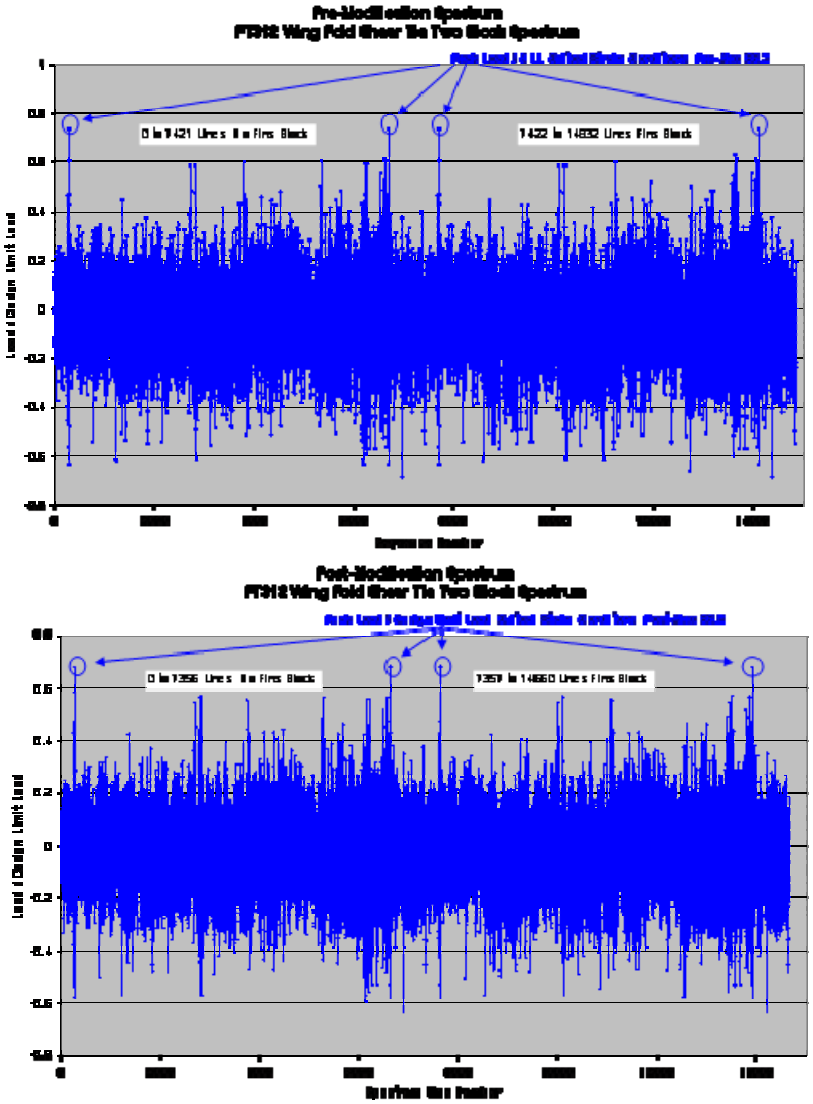


47% DLL Up Load



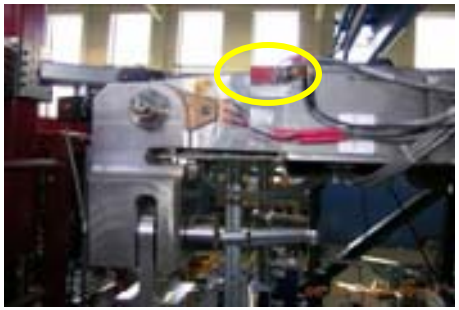
Spectrum

- Alternate fins off/fins on blocks, 7421 and 7411 lines respectively.
- After repair the spectrum adjusted to meet the intended blend stress.
- Required peak load post mod to be reduced by ~ 8%.



Instrumentation

- Eight strain gauges installed.
- Ultrasonic sensor located on the shear-tie, opposite the critical radius, to monitor flaw size.
- Digital image correlation.

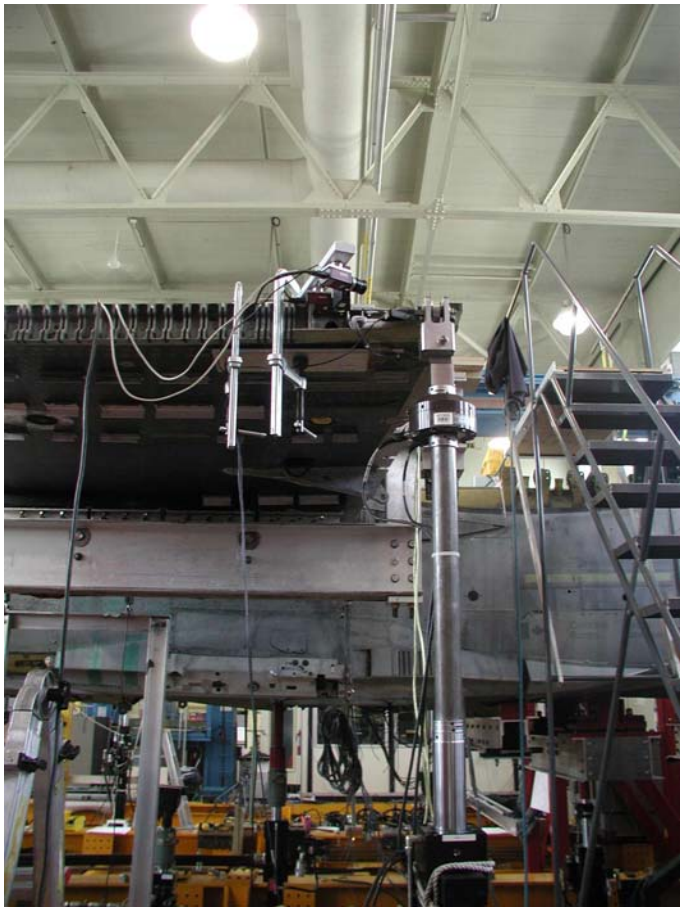


Ultrasonic Sensor

Reflectoscope

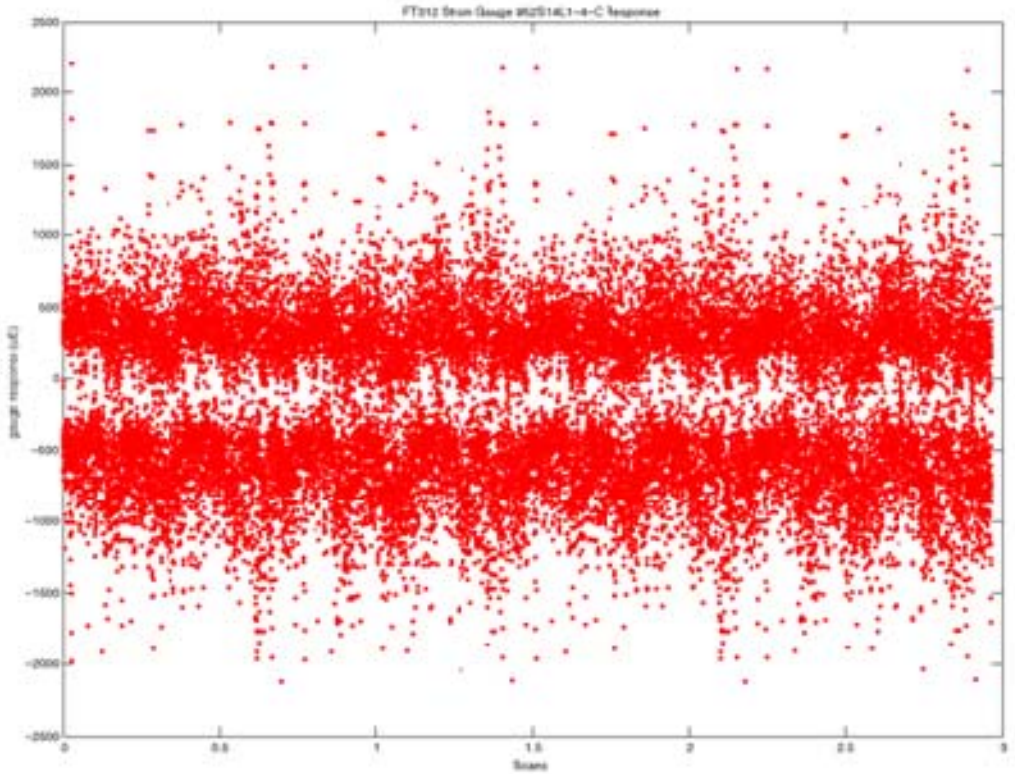
Regular operation…

- Daily monitoring.
- Rig inspections.
- Examined digital image correlation data.
- Trend monitoring.
- Error monitoring.



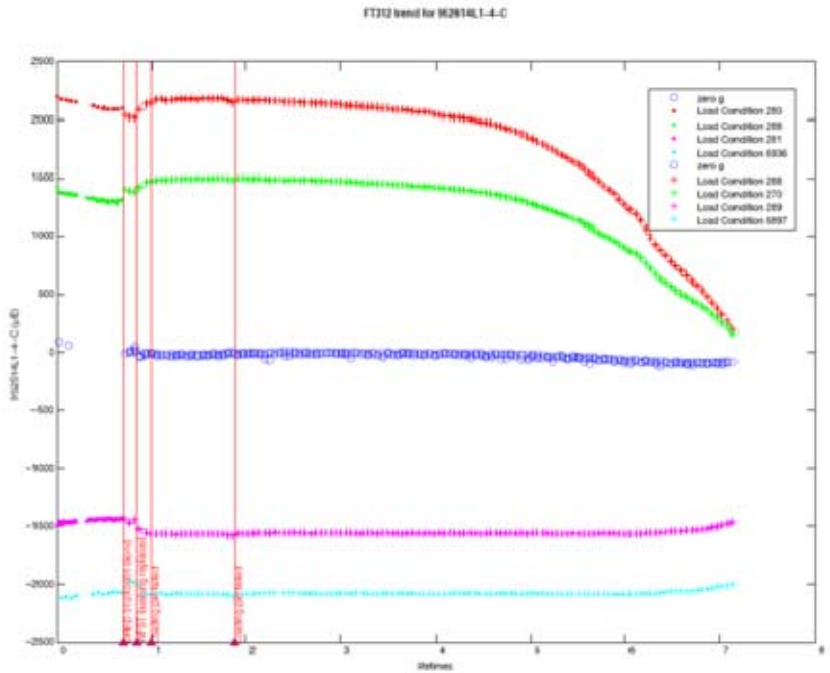
Strain Sequences...

- Full Sequences - load & strain were recorded - blocks 1, 2, 3, 4.
- After the spectrum changed blocks 15 and 16.



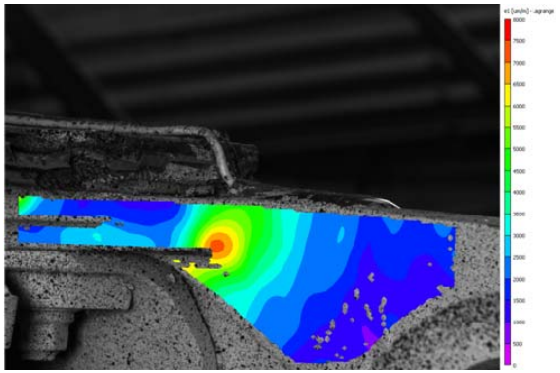
Trend Monitoring...

- All blocks - a limited number of end levels were recorded to enable trend monitoring.
- 73%, 47%, -47% and -69% of design limit load (DLL) during the pre-modification spectrum.
- 68%, 47%, -47% and -63% DLL during the post-modification blocks



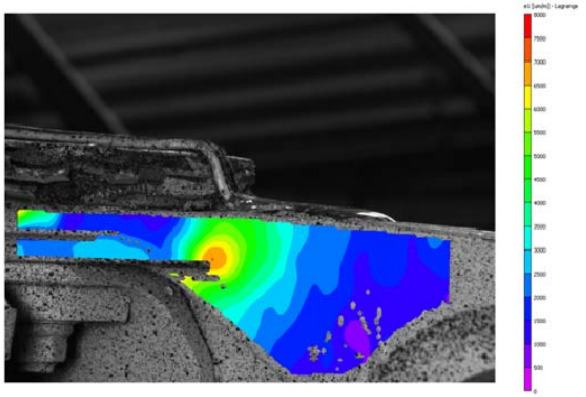
Digital Image Monitoring...

- All blocks – each peak down load was recorded to enable trend monitoring of surface strains.



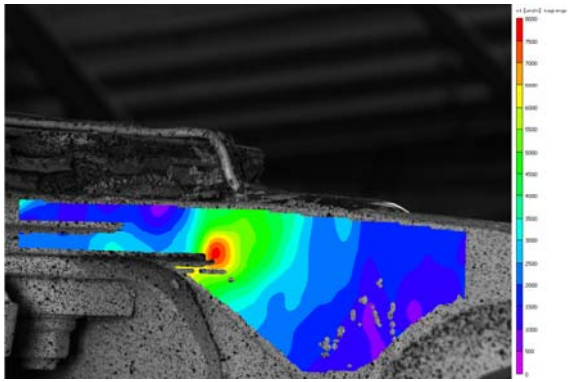
Test Start .6 RLL

Little Change

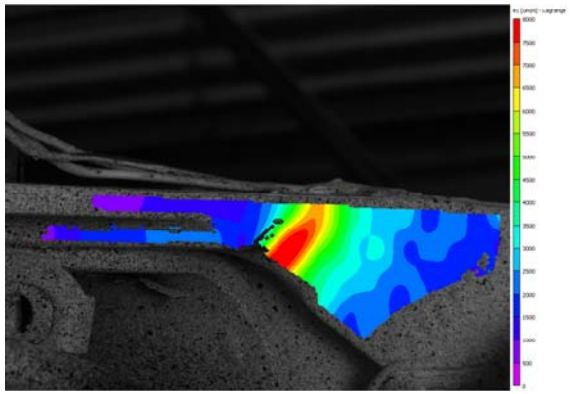


1 RLL

6-9% Increase

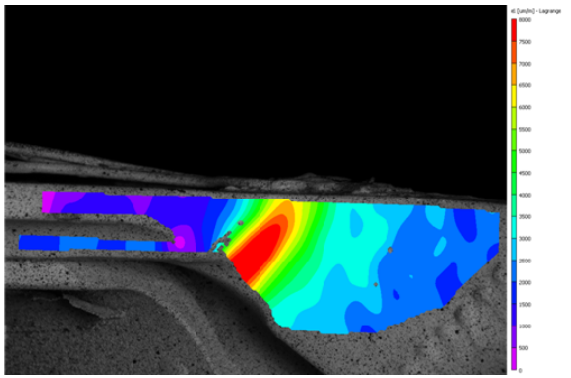


1.26 RLL



Post Mod 1.33 RLL

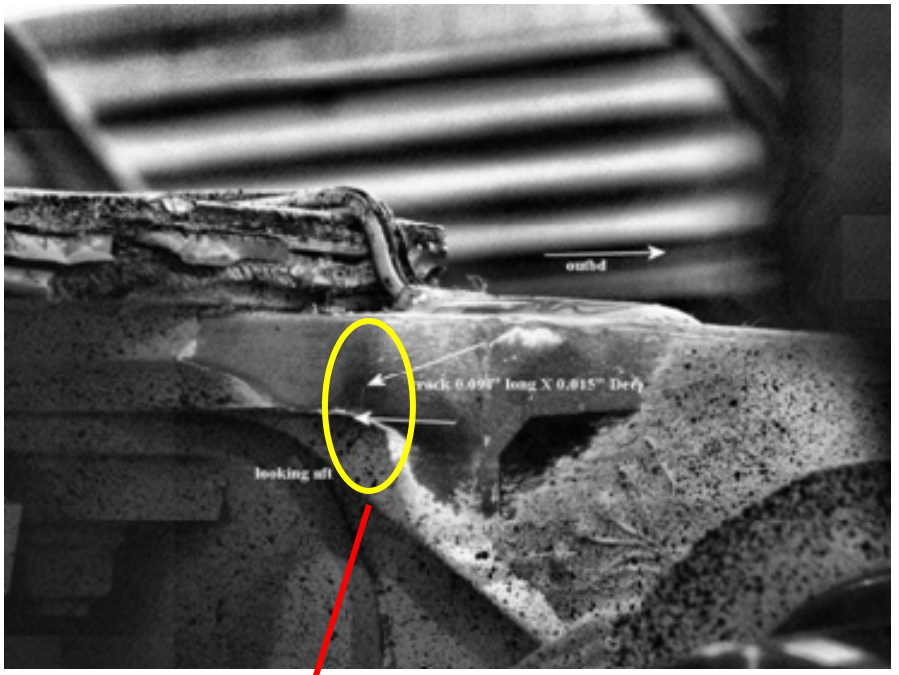
Increase

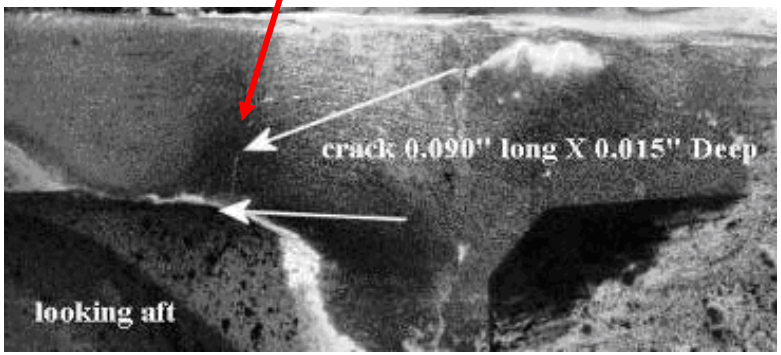


Post Mod 2 RLL

Inspection...

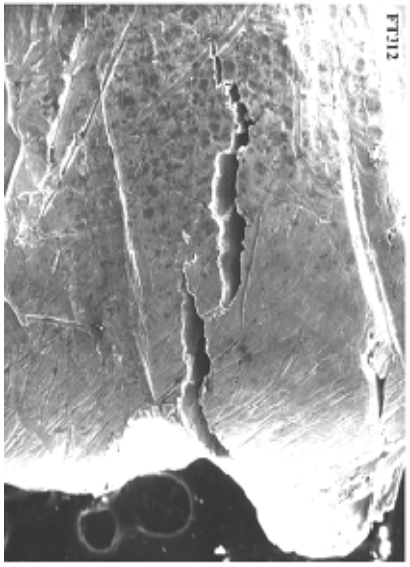
- No planned inspections.
- Automated ultrasonic inspections continuously.
- Surface strain measurements.
- Ultrasonics set to 0.13-0.25 mm first triggered at 1 RLL to stop testing.
- 49 Ultrasonic stops from 1 - 1.3 RLL.
- Test stopped LPI inspection 1.32 RLL.

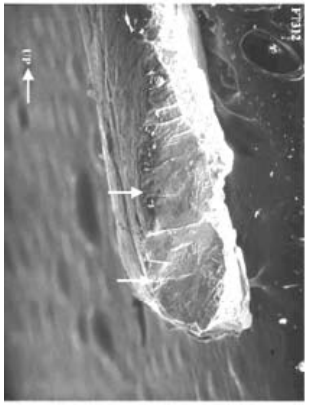




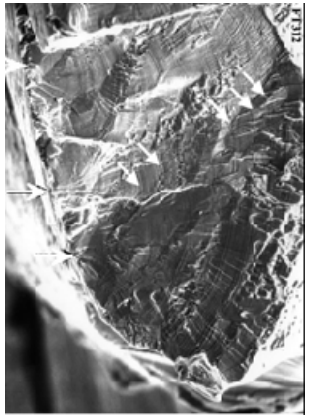
Crack Excision... Quantitative Fractography

- Crack excised.

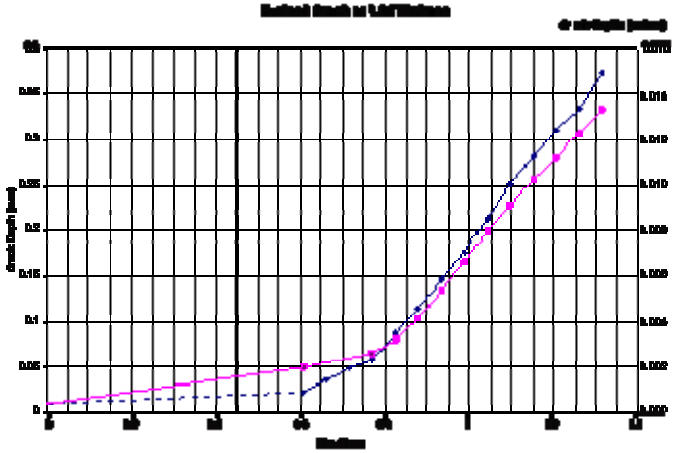




- Quantitative Fractography.

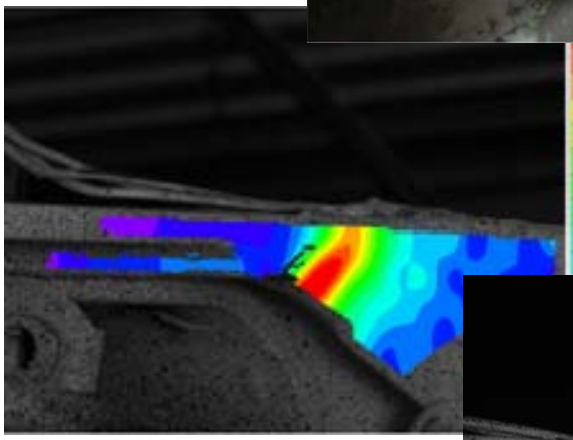


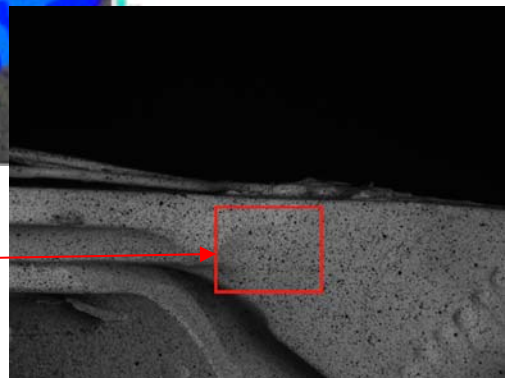
- Crack Growth.



QF carried out by QETE – Dr. Roth

Repair... Blend

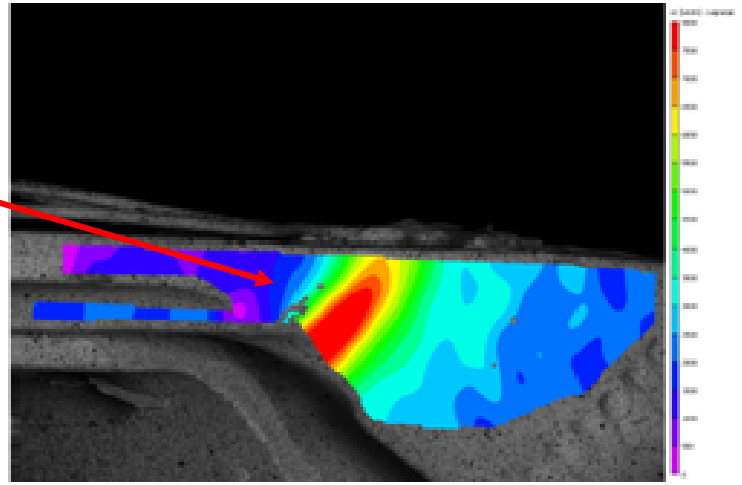




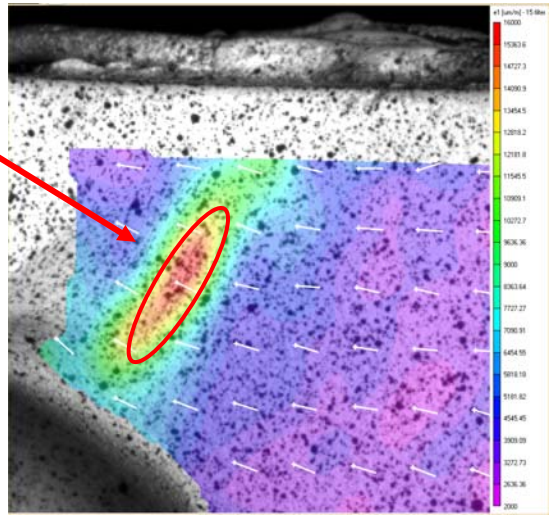
- At 1.32 RLL the a hand blend and polish of the cracked area.
- Area was repainted for surface strain measurements.
- High strains measured.
- Image correlation also used to extract blended geometry for FEM.
- Resulted in spectrum modification of peak loads.

Continued... Testing

- By 2.0 RLL strains were increased in the critical area.

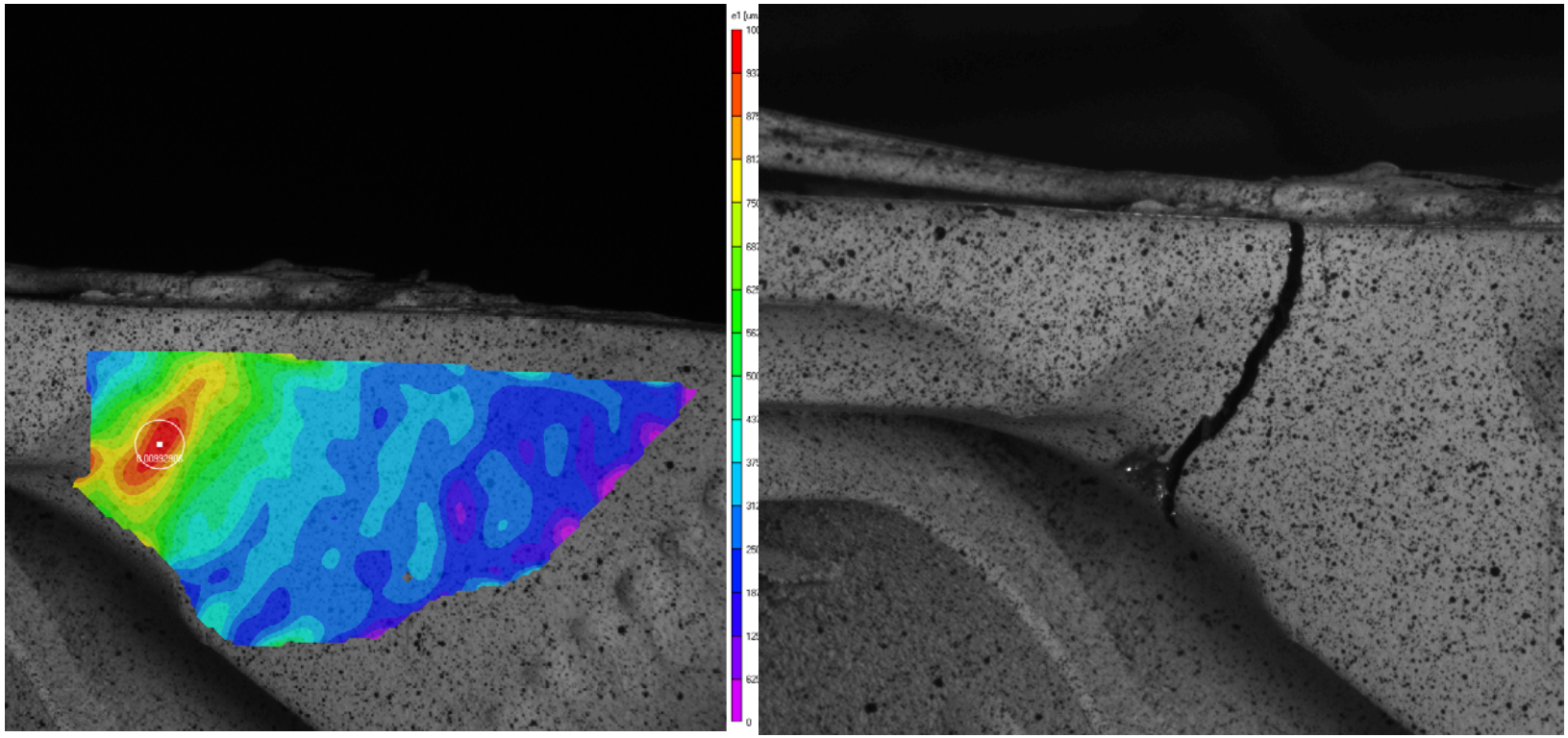


- Visible cracking found at 2.3 RLL.



Long stable… Crack growth

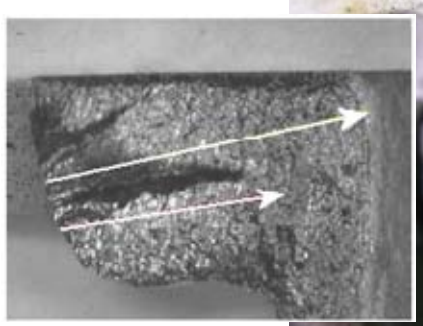
- Triggered digital image correlation - monitored growth 24/7.
- Fatigue testing required minimum 5 RLLs post-modification.

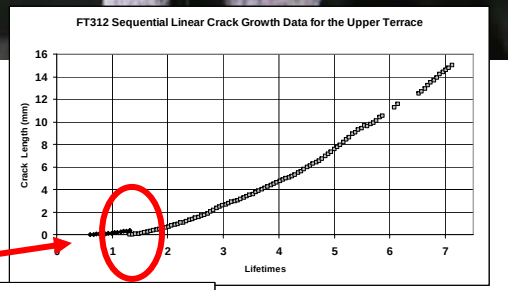


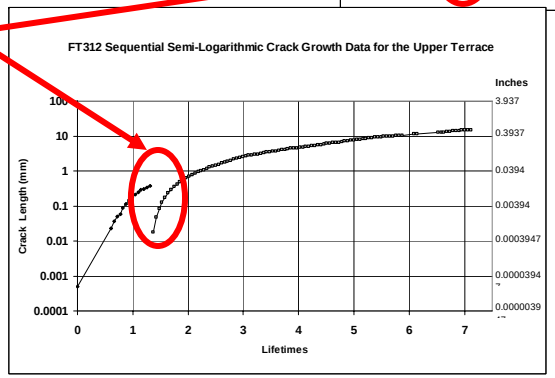
First Principle strains

Residual Strength... Testing

- At 7.75 RLLs a residual strength test to failure was carried out.
- Failure surface used for quantitative fractography.
- QF confirm long stable cracking.
- Mod delayed the cracking of fitting by only 43% of one RLL.







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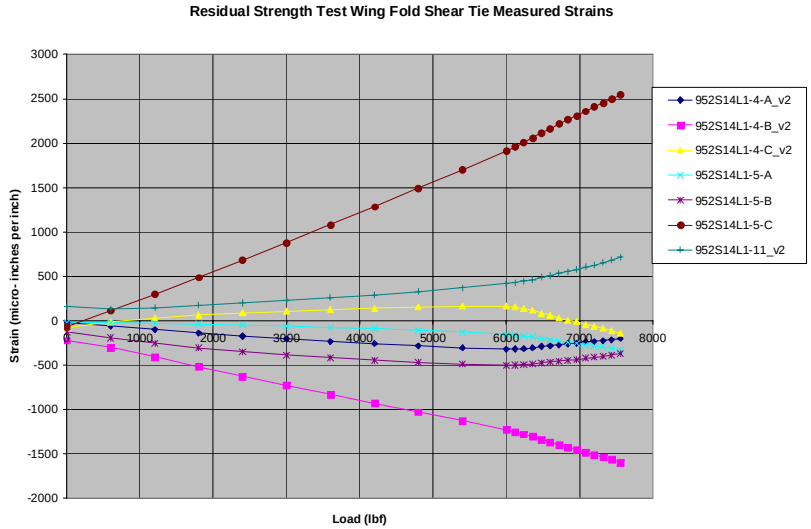
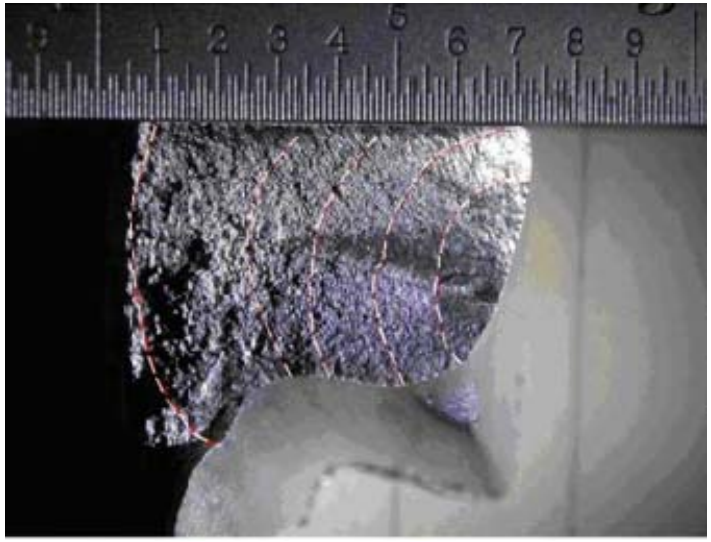
Residual Strength... Testing

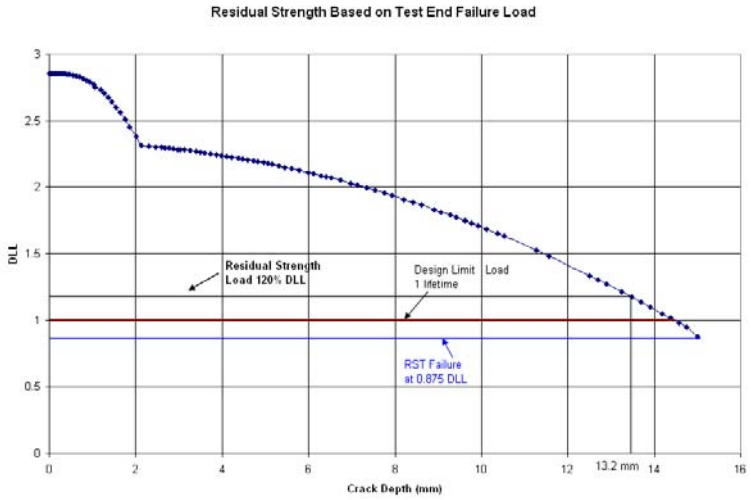
- The residual strength test applied loads in 10 % increments to the spectrum peak.
- Loads were then applied in 2% increments to failure.
- Failure occurred at 87.5% DLL and 128% of the peak spectrum.
- Strains measured by gauges did not exceed 3000 microstrain.



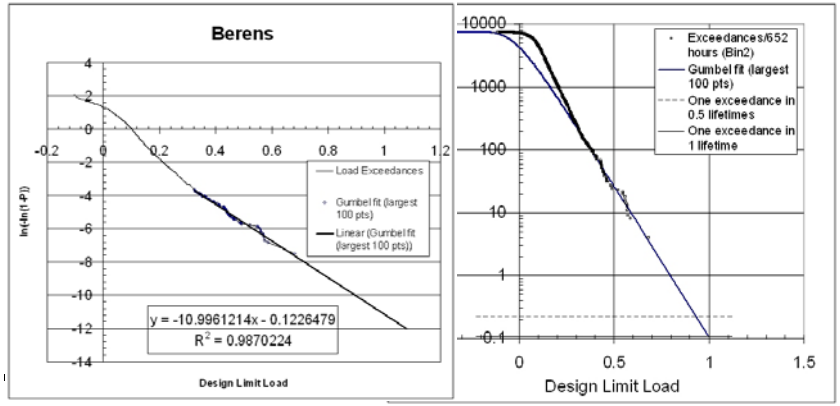
Tested to 87.5 %DLL….
120 % DLL req'd …

- Post RST found semi-circular fatigue cracking.
- Failure stress was estimated and RST curve was generated.





- DLL defined, Gumble extrapolation of test spectra- Berens Methodology



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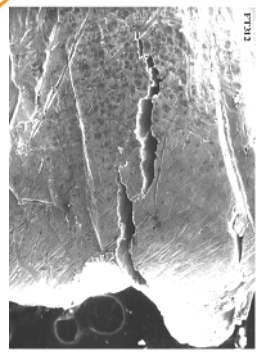
Conclusions



- Testing generated in-service typical cracking in 1.32 RLL.
- Crack was excised & QF generated crack growth data.
- Lug was hand blended by R&O.
- Post mod cracking to the same 0.5 mm occurred in ~ 0.4 RLL.
- Testing continued for 6.4 RLL with stable crack growth.
- RST carried out.
- Critical crack size - 13 mm. at 120% DLL.
- If a safety by inspection damage tolerance methodology is applied vs durability safe life approach, the WF Shear Tie inspection recommended @ ½ RLL post-modification, with subsequent inspections @ ½ RLL.

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