

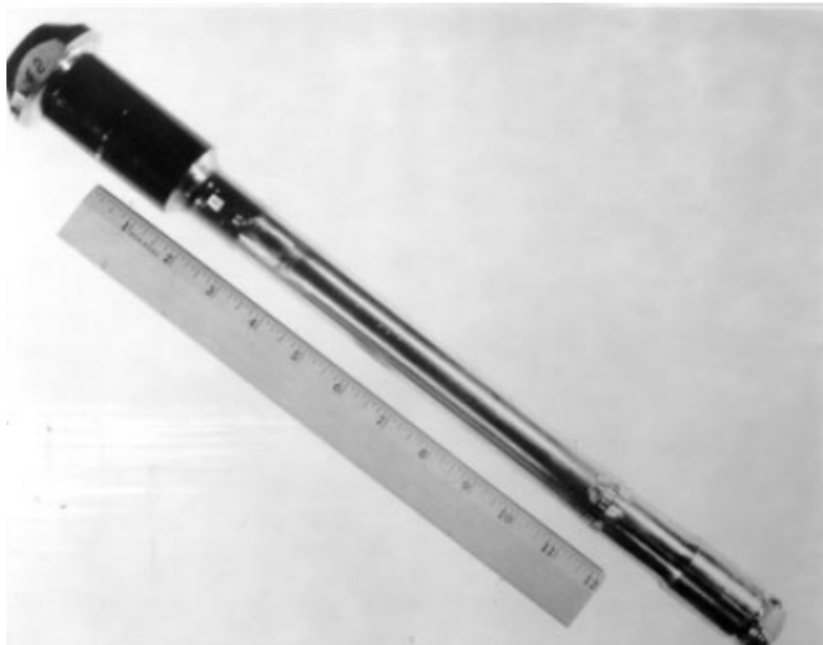
Investigation of Fatigue Failure of PH 13-8 Stainless Steel

Brighter Science

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The Problem

- Failure of PH 13-8 Mo stainless steel rods used for main rotor assembly



- Parts from three companies (one OEM) show different fatigue performance.
- ARL tasked to run metallurgical testing to find the reason

Fatigue Test Results from AATD

- A: OEM, B & C: Possible second sources

Component	No. of Cycles
A-1	108,460
A-2	157,274
B-1	94,335
B-2	131,460
C-1	46,735
C-2	54,637

- Tested at AATD in Ft. Eustis, VA
- No details given on the testing conditions
- No details given on which aircraft it is used

Where is the Tie Rod?



UH-60 & Tie Rods



<http://www4.army.mil/OCPA/uploads/large/2006/CSA-2006-06-29-094428.jpg>

Heat Treatments

H 1050

- Solution heat treat:
 - Heat to $927 \pm 14^{\circ}\text{C}$ for ≥ 1 Hr
 - Air cool
 - Run sample under cool water
- Age
 - Heat to $566 \pm 6^{\circ}\text{C}$ for 4 Hr ± 15 min
 - Air cool

H 1025

- Solution heat treat:
 - Heat to $927 \pm 14^{\circ}\text{C}$ for ≥ 1 Hr
 - Air cool
 - Run sample under cool water
- Age
 - **Heat to $556 \pm 6^{\circ}\text{C}$ for 4 Hr ± 15 min**
 - Air cool

Tests performed

- Hardness
 - all to spec. $A > B > C$
- Tensile
 - Specimens fabricated from rods
 - A and B to spec. and typical
 - C met min. but was lower than “typical”
 - A, B met spec. for H1025, but not C

Test Performed

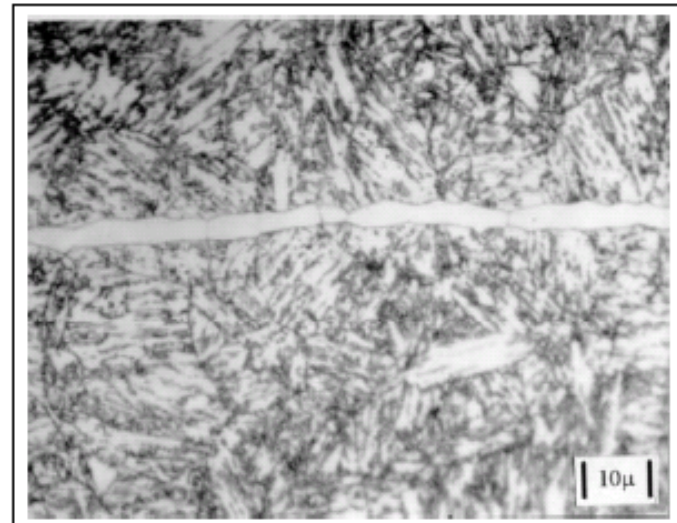
- Fatigue

Component	No. of Cycles
A-1	3 Mil. +
A-2	3 Mil. +
B-1	3 Mil. +
B-2	3 Mil. +
C-1	168,567
C-2	83,020

- Specimens cut from the failed rods to eliminate variability from machining
- Test parameters:
 - Stress: 1172 MPa
 - R-value: 0.1
 - Frequency: 25 Hz

Tests performed

- Metallography
 - Banding C>B>A, caused by larger ingot sizes
 - C: Delta ferrite within bands and free ferrite stringers, but within spec.
 - Grain sizes much smaller than spec.



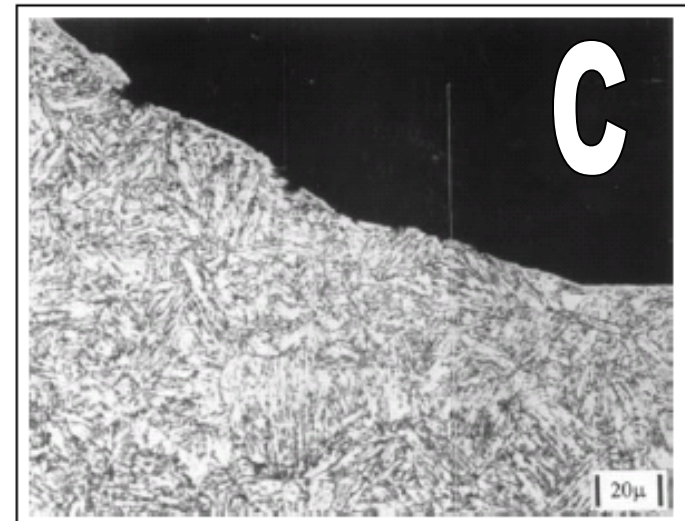
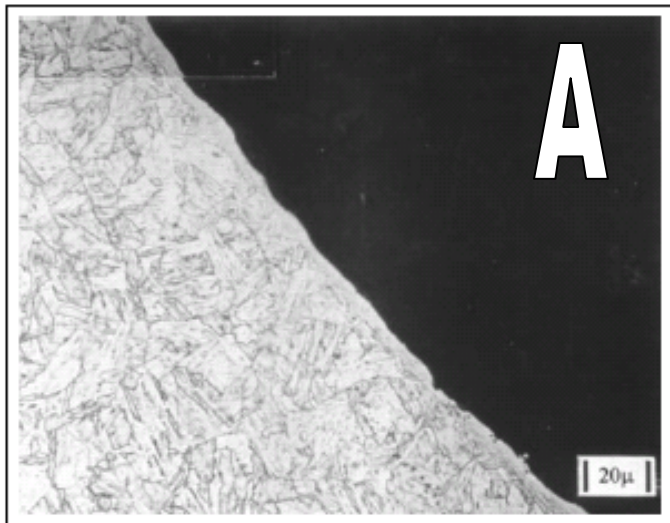
Chemical Analysis

- AMS 5629
- Plasma/Atomic emission microscopy was utilized.
- The Mg, Si, Cr, Ni, Mo contents differ in the rods.

=> Chemical elements do not reduce the fatigue life of the rods.

Tests performed

- Cold work layer
 - $A > C, B$
 - May explain differences in number of crack origins



Laboratory Heat Treatment

- Sections of “A” and “C” were re-heat treated and aged to the H1050 condition.
- Fatigue results of “C” were similar to “A”
 - “A” and “C” fail > 3 million cycles.
- Hardness testing:
 - The hardness of “A” **increased** about **0.5 HRC**, whereas the hardness of “C” **increased** about **2.7 HRC**.
- Tensile test:
 - The UTS of “A” **decreased** about **41.4 Mpa**, whereas the UTS of “C” **increased** about **103.4 Mpa**.

Results

- Heat treatment used by manufacturer C is insufficient
- Rolling recommended to form threads

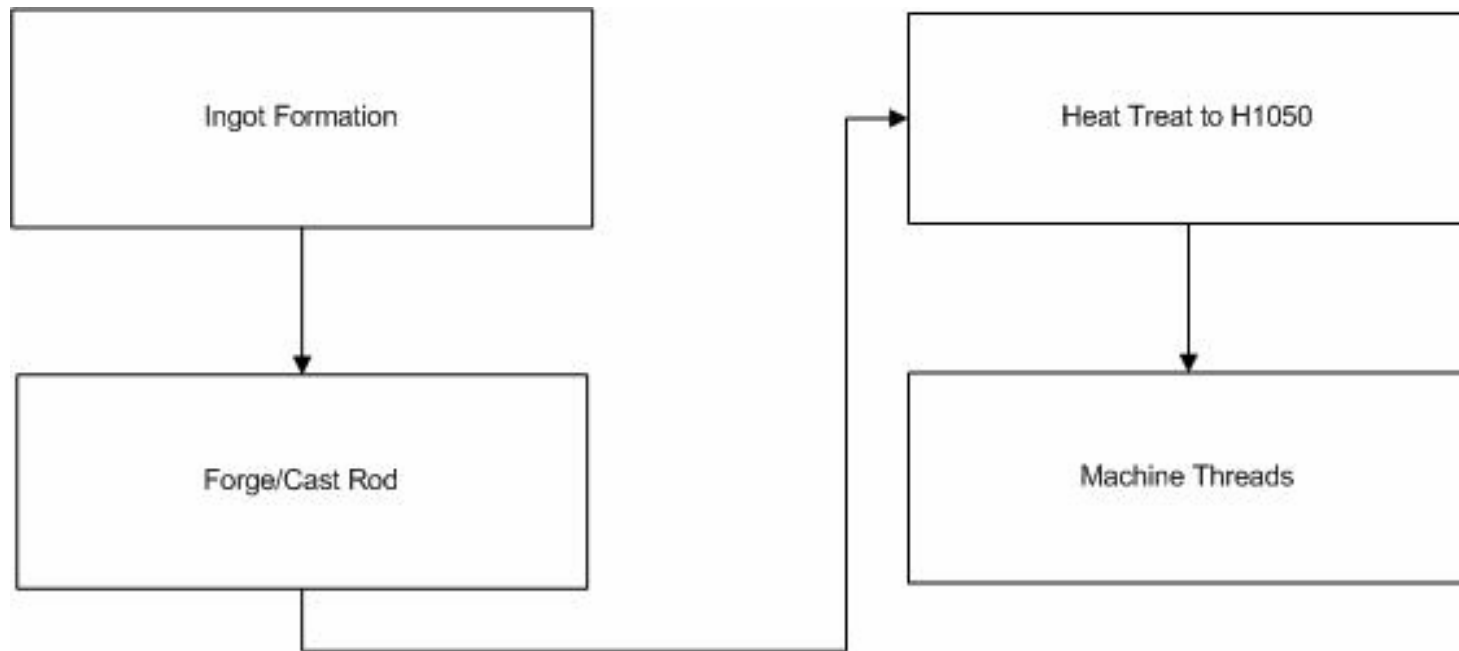
Deficiencies in Test Protocol

- Sample B was not tested
- Post heat treat analysis was not complete
- Processing was not traced back far enough
- Resonance frequency was not investigated

Incomplete Post Heat Treat Analysis

- Parts were mechanically tested (Fatigue, Tensile, Hardness)
- No microstructure analysis performed

Processing was not traced back far enough



Summary

- Three groups of helicopter spindle tie rods were fatigue tested, with one group having substantially lower fatigue life than the others
- The ARL found a fix for the problem, but did not locate the root cause
- We would carry out a more in depth investigation