

Cryogenic Proof Load Testing of the Aircraft Arresting Gear Stinger



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Acknowledgements

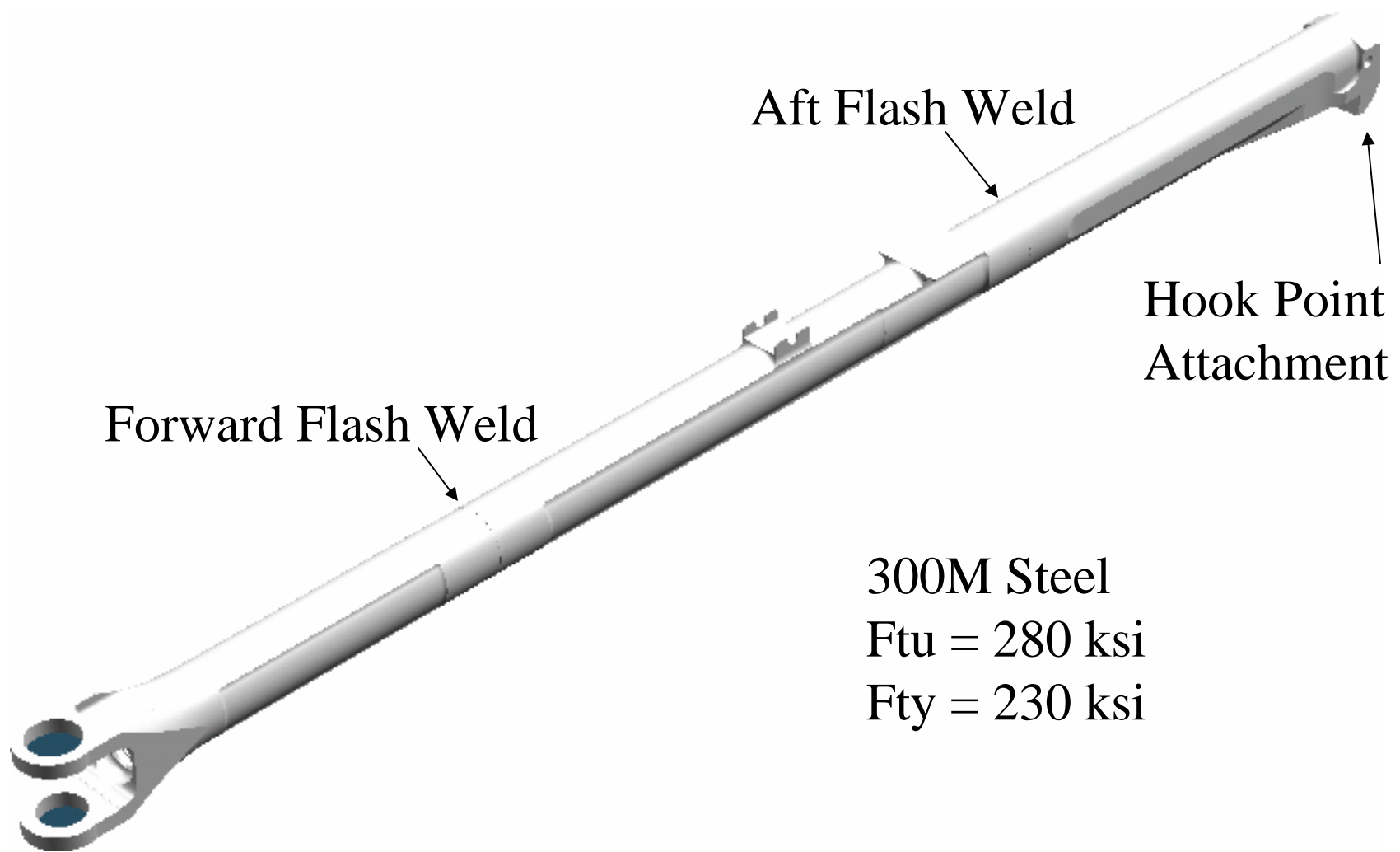
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F-14 Stinger Overview

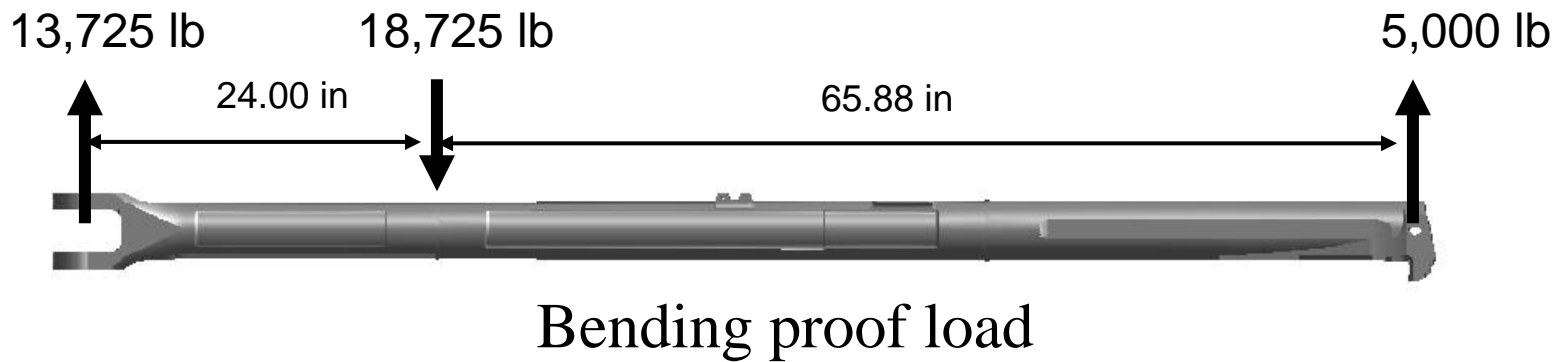


Background Information

- The purpose of a proof load is to apply a test load to a critical item that (if successful) will insure that the critical item is safe for operational use, for a given period.
- Original proof test for carrier arresting developed to screen for manufacturing defects has been adopted as post rework / overhaul QC check.
- A F-14 Stinger Assembly failed during an attempted carrier landing.
- The Stinger failed on the second carrier arrestment (trap) following Depot rework, overhaul and room temperature proof load.
- The total number of traps for this Stinger was 313.
- It became clear that the existing proof load could not insure the integrity of the existing stinger inventory

F-14 Arresting Gear Stinger

Room Temperature Proof Loads



F-14 Arresting Gear Stinger Proof Load Analysis

- $K_{1C} = 55$ ksi Ref NASGRO database
 - Stress at bottom of forward weld during proof load,
 $f_{\text{bot}} = 158$ ksi
 - Critical crack size for room temperature proof load,
 $a_{\text{cr}} = 0.067$ in.
 - Remaining unfactored life with initial flaw of $a = 0.067$ in.
is 29 arrestments* (spectrum of average arrestments)
 - *Ref AFGROW 4.0007.12.11
 - Since the room temperature proof load magnitude is limited by yielding of stinger, in order to screen out smaller flaws it was proposed to lower the K_{1C} by cryogenically cooling the stinger.

F-14 Arresting Gear Stinger Proof Load Analysis

- NASA Technical Paper 1288 on 300M Steel Properties shows room temperature K_{Ic} is reduced to near one third at the temperature of liquid nitrogen.
- $K_{Ic} = 22 \text{ ksi sqrt-in. at } -310 \text{ degrees F}$
- This reduction allows about a six fold reduction in critical flaw size

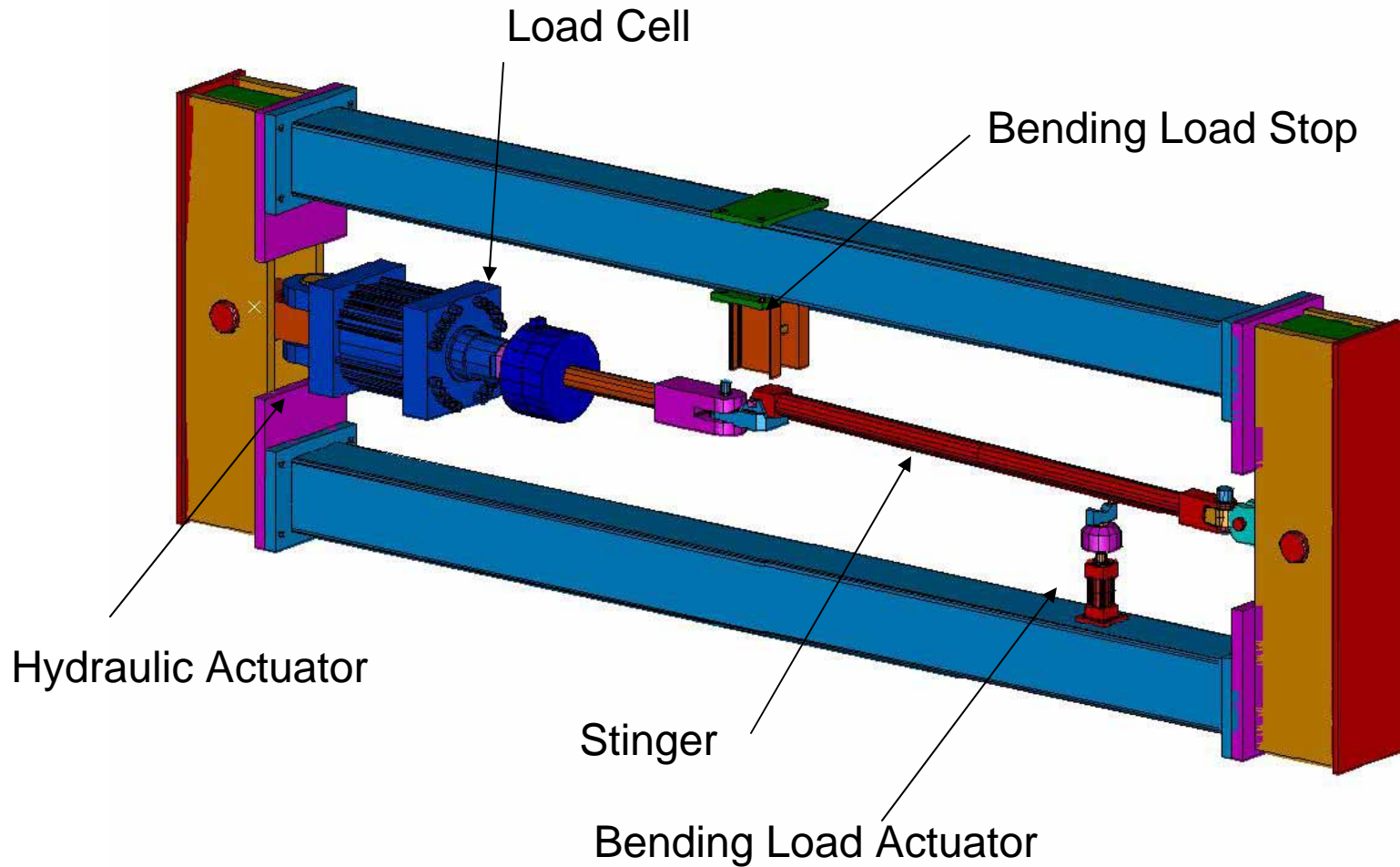
F-14 Arresting Gear Stinger Proof Load Analysis

- $K_{1C} = 22$ ksi at -310°F (ref NASA Tech Paper 1288)
 - Stress at tube bottom during proof load, $f_{\text{bot}} = 143$ ksi
 - Critical crack size for cryogenic proof load,
 $a_{\text{cr}} = 0.015$ in.
 - Remaining unfactored life with initial flaw of $a = 0.015$ in. is 795 arrestments*, (spectrum of average arrestments)
 - *Ref AFGROW 4.0007.12.11
 - By cryogenically cooling the stinger to -310°F any stinger that survives the proof load is assured of having a crack growth life substantially greater than the overhaul/proof load interval.

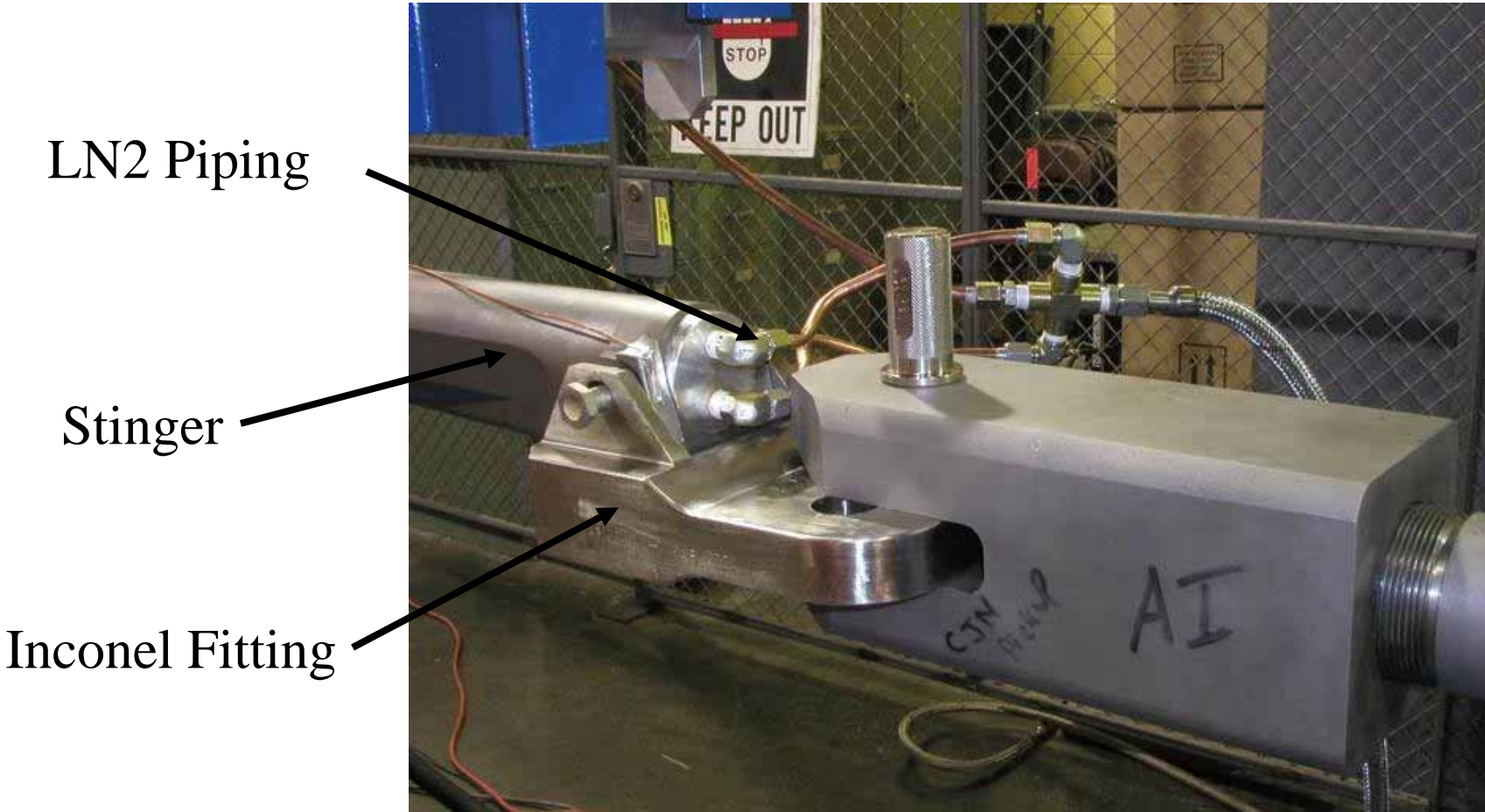
F-14 Stinger Cryogenic Proof Load Fixture

- In order to cool the stingers to -310°F the liquid nitrogen (LN2) is introduced directly into the inside of the stinger tube using a “piccolo tube” to distribute the flow along the length of the tube.
- Stingers are instrumented with thermocouples to verify temperature distribution but no active temperature control is utilized. LN2 boils at -310°F.
- This method provides an efficient method of cryogenically cooling items for proof testing without utilizing large environmental chambers.
- Inconel 718 load introduction fittings utilized since this material maintains it's toughness at cryogenic temperatures.

F-14 Stinger Cryogenic Proof Load Fixture



F-14 Stinger Proof Load Test Fixture



Cryogenic Proof Test Concerns

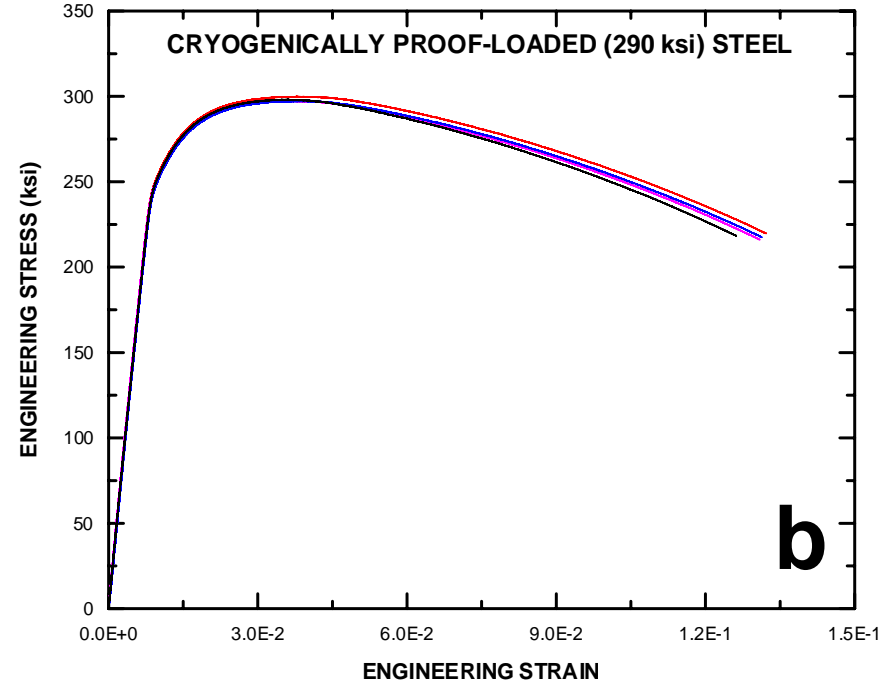
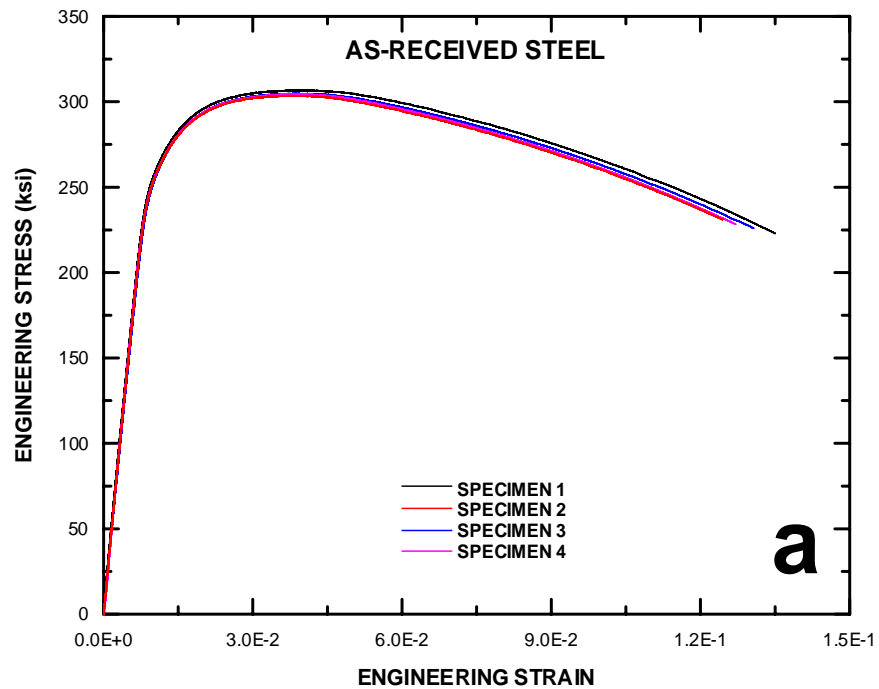
The effect of straining 300M steel at cryogenic temperatures was a concern as it alters the alloys heat treatment properties, retained austenite. Concerns were raised about thermal expansion differences within the material matrix during the cooling. A coupon test program was performed by the materials lab at NAVAIR Pax River and NADEP Jacksonville to investigate the effect of this process on the room temperature properties of 300M.

For this test newly manufactured 300M steel was heated treated to the procurement spec. A portion of the material was then cooled to -310°F and stressed to 290ksi. Material tests were then performed on coupons cut from the as heat treated specimens and the cryogenically proof loaded specimens.

No significant differences were observed.



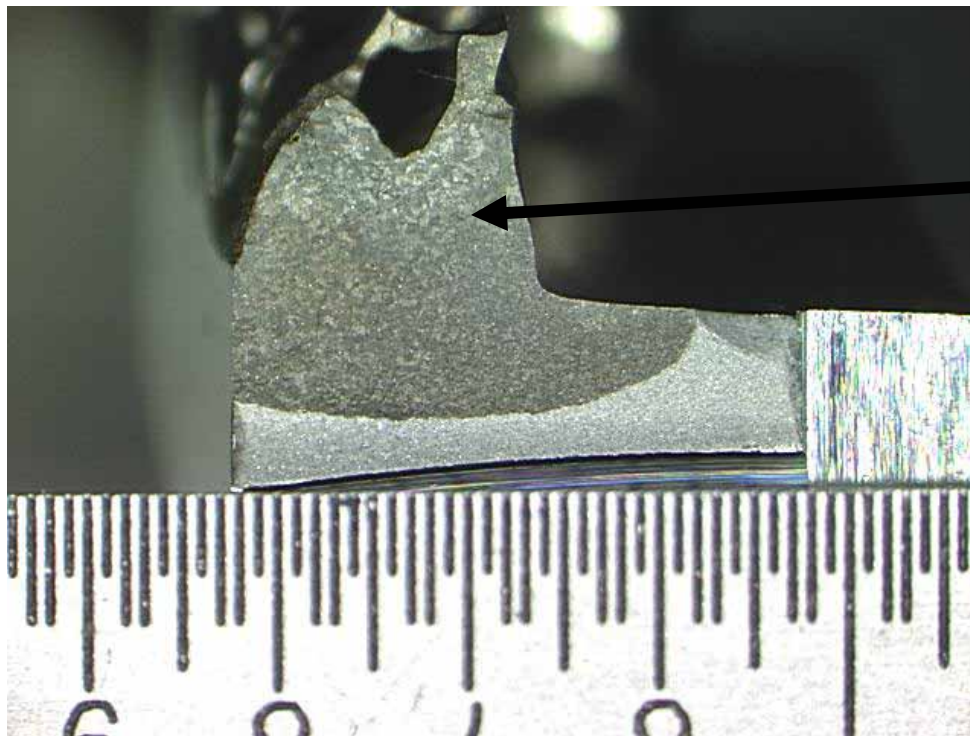
Effects of Stressing 300M at Cryogenic Temperatures on Room Temperature Properties



Cryogenic Proof Test Lessons Learned

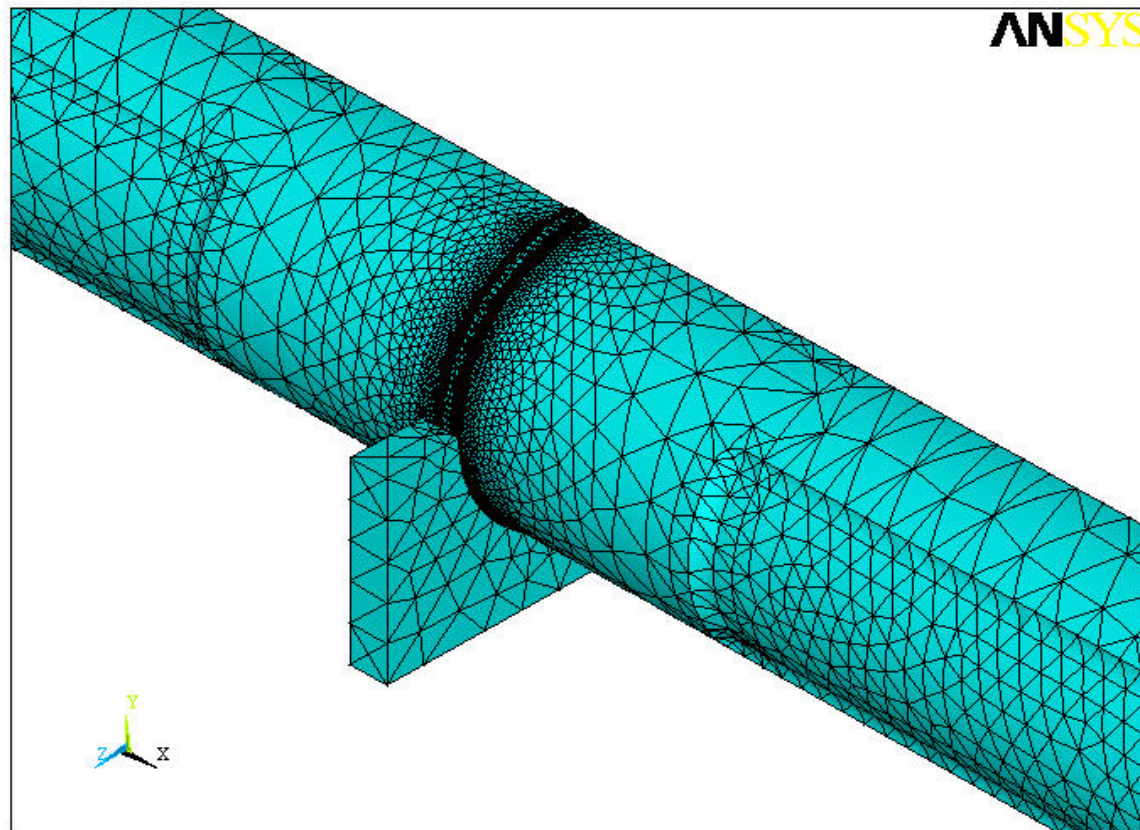
- Five stingers were cryogenically proof loaded and then destructively examined for evidence of cracking.
 - Several fore-aft cracks were found in forward flash weld, due to hoop bending during bending proof load.
 - Cracking attributed to one-sided “U” shaped bracket that allowed stinger to ovalize during the bending load application.
 - Redesign to a four point bending and clamping arrangement eliminated cracking.

F-14 Stinger Longitudinal Crack Induced by Three Point Bending Proof Load

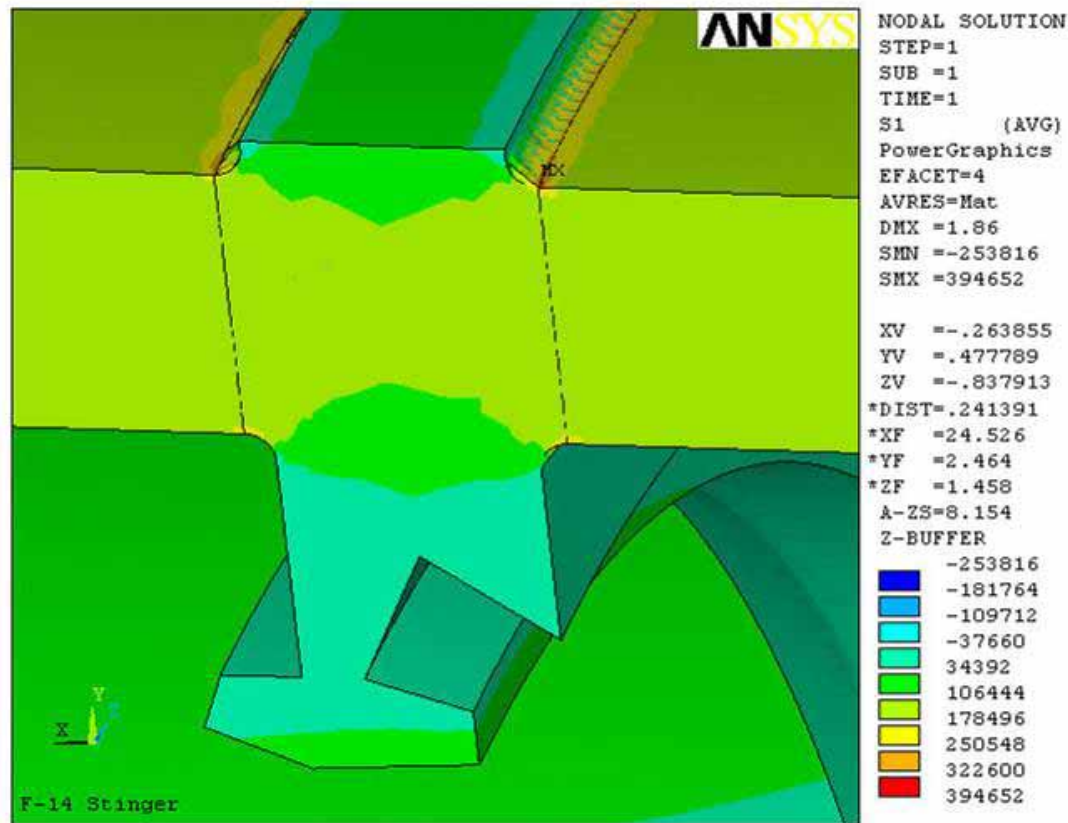


Weld Flash on
ID of stinger

F-14 Stinger Bend Test Three Point Bending FEM

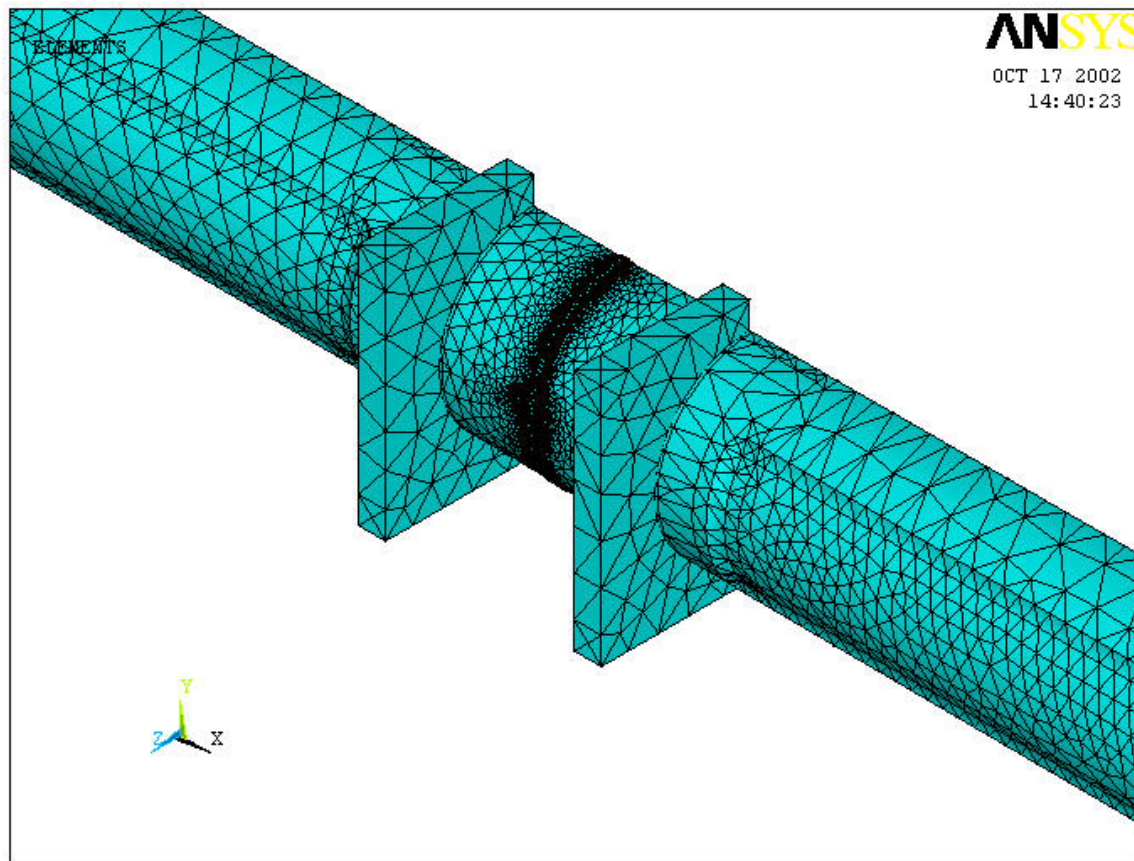


F-14 Stinger Bend Test Three Point Bending

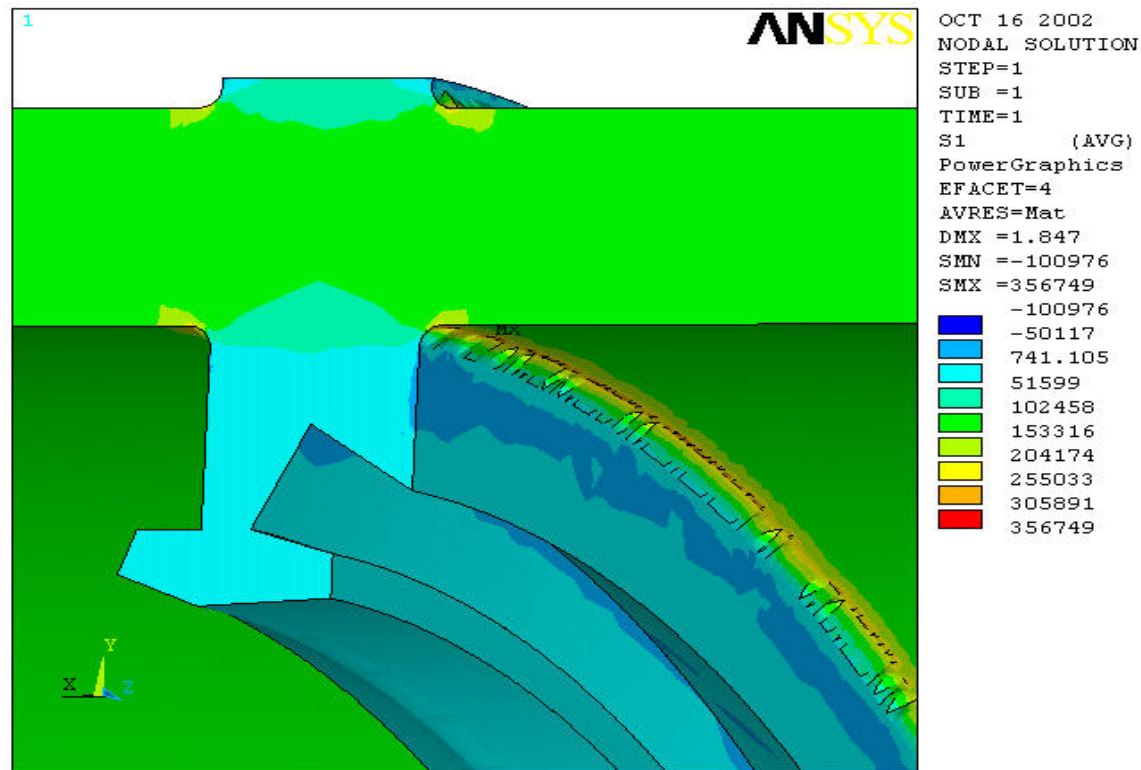


F-14 Stinger Bend Test

Four Point Bending, Clamps



F-14 Stinger Bend Test Four Point Bending



Failed Stinger During Cryogenic Proof Load



Failed Stinger During Cryogenic Proof Load



10 of 136 used stingers have failed during cryogenic proof test.
None of the 50 new production stingers tested to date have failed.

Cryogenic Proof Test Conclusions

- Cryogenically cooling F-14 Stingers for proof load testing allows stingers with much smaller flaws to be found and removed from service as compared to a room temperature proof load.
- Directly cooling the stingers with LN2 is an efficient method to cool test items without using environmental chambers.
- Coupons tests and destructive inspections of first article test items is an important process for this type of testing