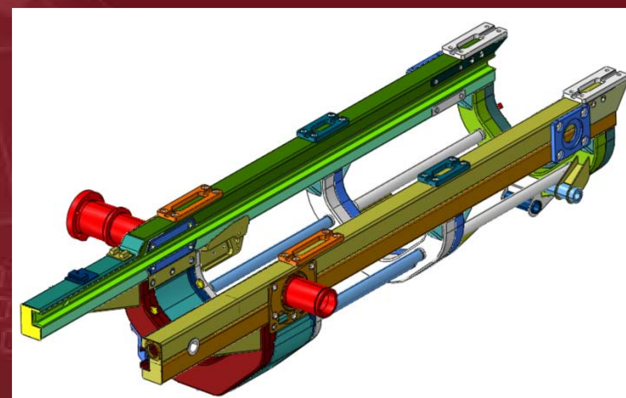


TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Analysis of Fatigue Life Estimate for the M119 Cradle Assembly with a Gouge Cut Defect

Caitlin Weaver, Robert K. Terhune, Brian Peterson

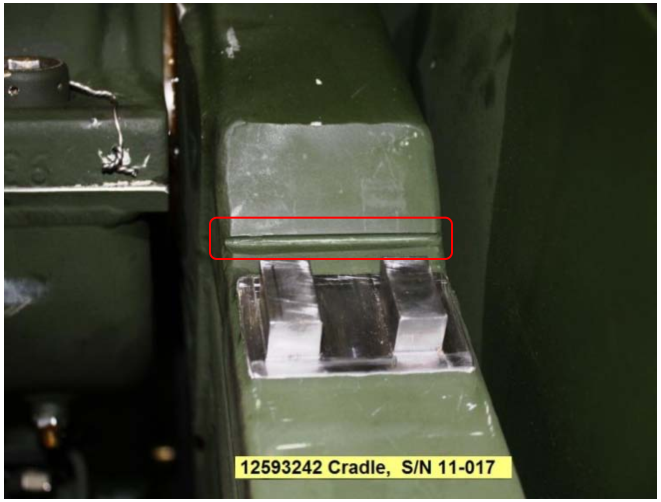
AMSRD-AAR-MEF-E, Building 94, 2nd floor
Fuze and Precision Armaments Directorate
AETC, U.S. Army ARDEC, Picatinny Arsenal, NJ 07806-5000
phone: 973-724-6349, fax: 973-724-2417, caitlin.m.weaver@us.army.mil

2012 NDIA Joint Armaments Conference, Seattle, WA
May 14-17, 2012

Outline

- I. Background
- II. Method - Abaqus
  - Geometry, Part Instances, BC, Materials, and Loads
  - Pre-cracked Models
  - Applied Loads
- III. Method - Fe-Safe
  - Material Property and Load Data
  - Analysis Summary
- IV. Method – NASGRO
  - Geometry, Material Property and Normalized Stress Data
  - Loads
  - Schedule Cycle
- V. Results
  - XFEM
  - Maximum Stress and Plastic Strain
  - Fe-Safe
  - NASGRO
- VI. Conclusions/Further Work
- VII. Questions

I. Background



- During the manufacturing process in 2011, 46 M119A2 systems were manufactured with a tooling groove defect in the 12593242 Cradle.
- The worst case tooling groove was 0.071-in deep and 2.300-in long, spanning the full length of the channel.

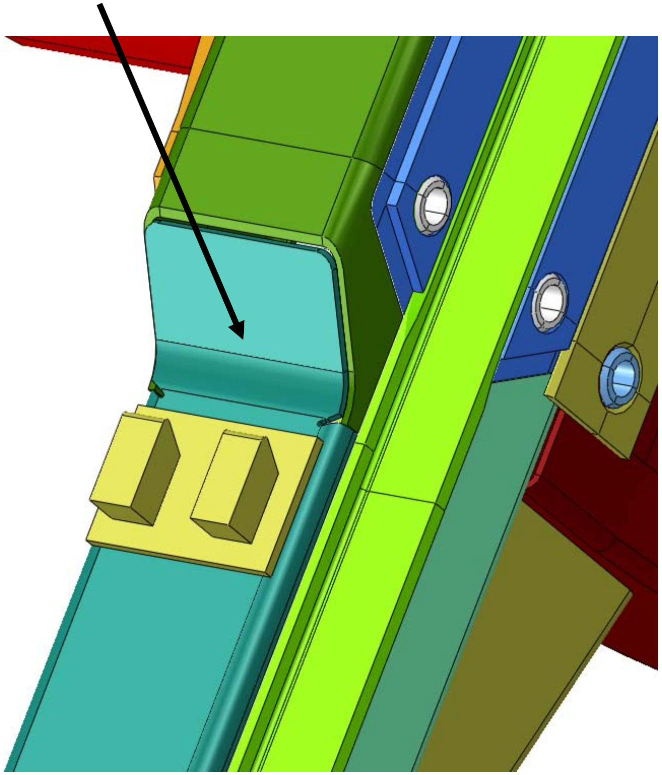
- **<u>Goals:</u>**
  - Run a fatigue and critical crack analysis on the modeled portion of the plate that has the tooling defect (gouge).
  - Determine if cradle will survive for 1100 cycles (per reliability requirement MIL-DTL-32191).
  - Determine if further analysis is needed.

- **<u>Scope:</u>**
  - The primary concern of the analysis effort is to analyze M119 cradle components specifically the firing mechanism plate of the cradle channel.
  - The model is loaded by pressure data calculated from strain gauge data that was recorded during live fire testing.

I. Background (cont.)

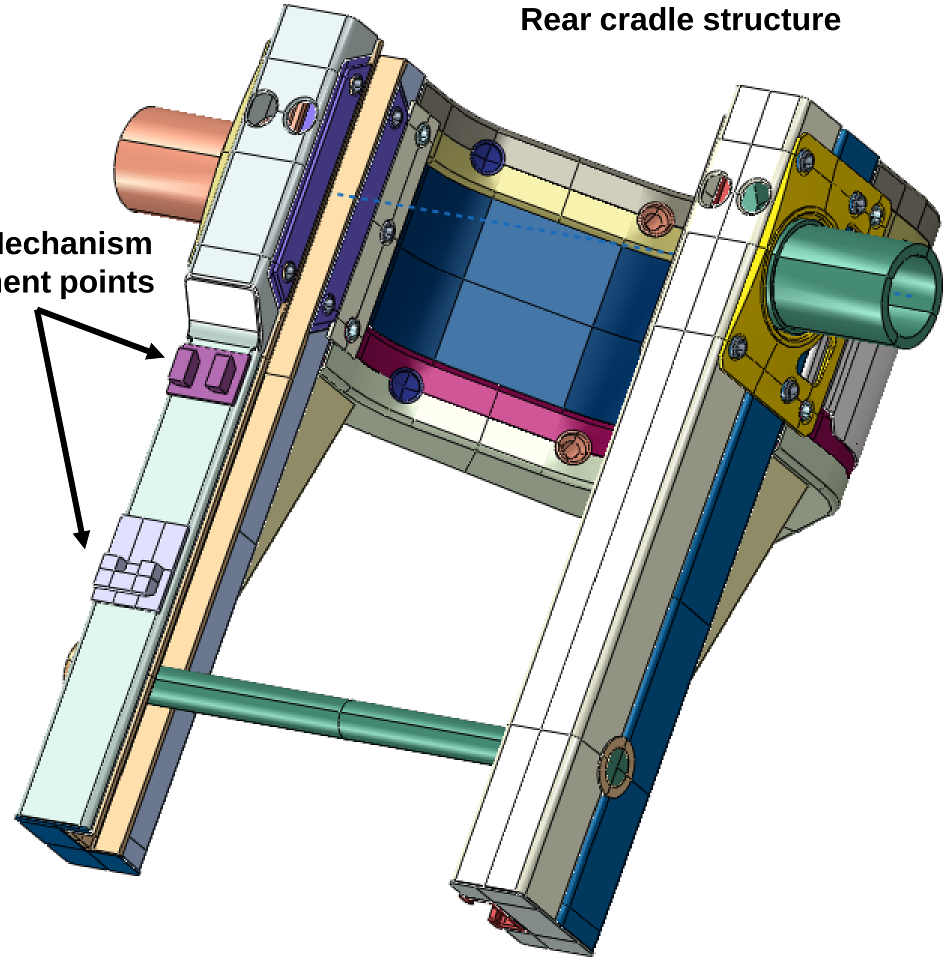
***Note: Cradle critical components labeled, individual parts not specified below

Firing Mechanism Plate (gouge flaw)



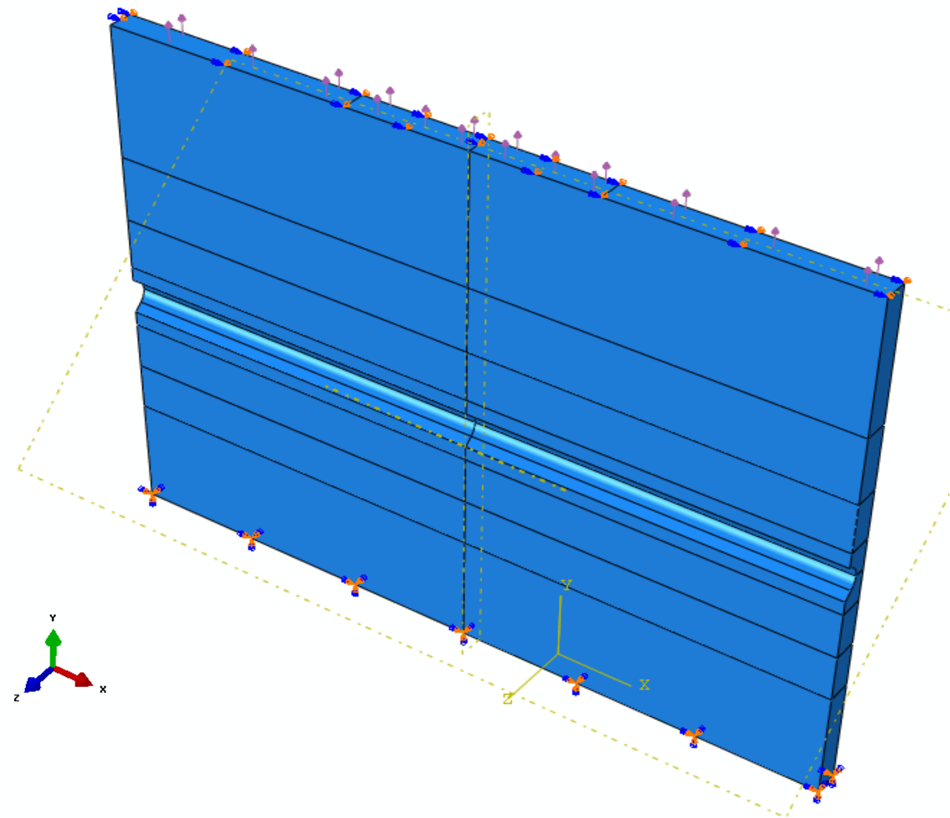
Rear cradle structure

Firing Mechanism attachment points



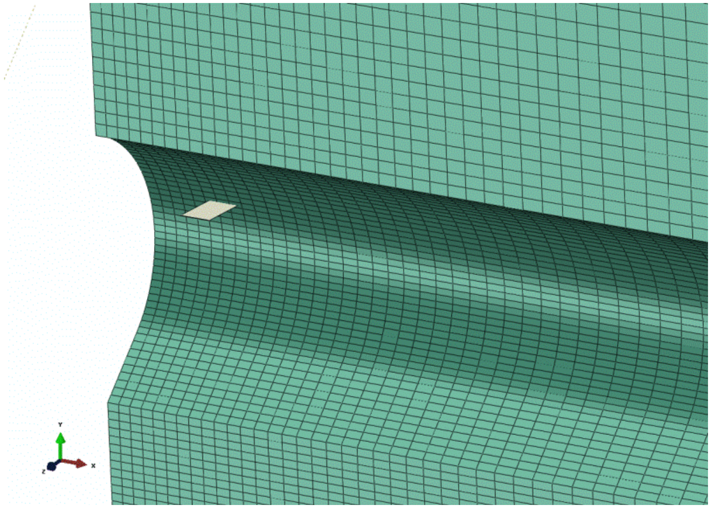
II.a. Method - Abaqus: Geometry, Part instances, BC, Materials and Loads

- Analysis was performed using Abaqus 6.11
  - Analyses types: Dynamic implicit (XFEM) and explicit, non-linear materials, non-linear geometry
  - All models were meshed with 8-node hexahedral elements (C3D8R).
- To simulate the fixed position of the channel on the cradle:
  - the bottom face of the plate in the x-z plane was constrained in all directions and rotations using an Encastre boundary condition.
  - the top face in the x-z plane was constrained directionally and rotationally in the z-direction.
- Load:
  - the top face in the x-z plane was partitioned evenly into three equal parts.
  - the pressure load from the recorded test data was applied to the corresponding left, middle and right part of the top face of the x-z plane.
- Material used: 95-15 Stainless Steel.
  - Material property data was obtained from in house testing.



II.b. Method – Abaqus: Pre-Cracked Simulations

- To insert a crack into the model:
  - Create a planar shell with dimensions needed for desired crack size (Part Module).
  - Translate the crack instance to desired location, making sure that it doesn't correspond to an element edge.



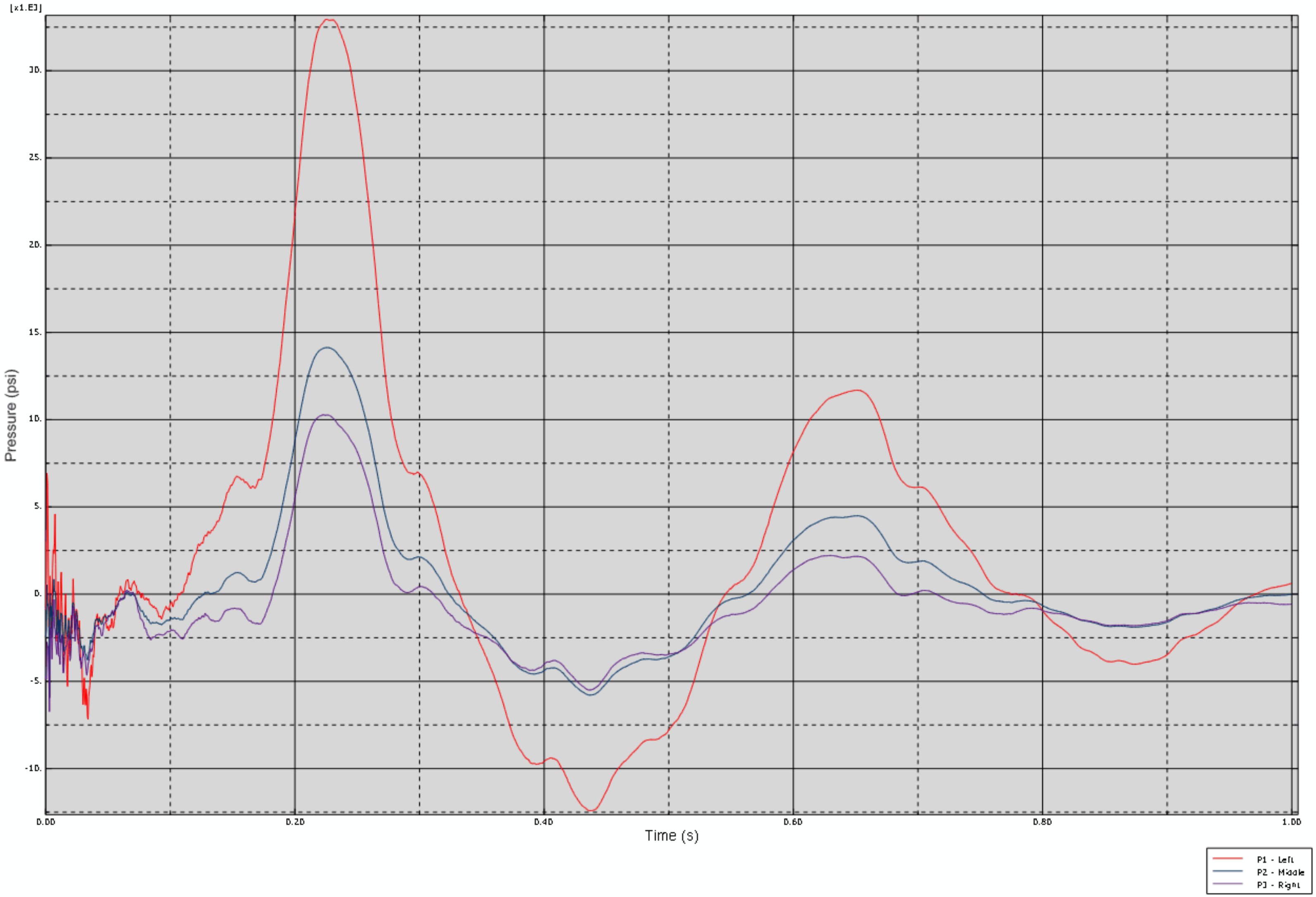
Example of a Crack in Finite Element Mesh

- Two pre-cracked models were used for XFEM simulation:
  - Case (1): a crack 0.015 x 0.011 inch horizontally along the gouge cut.
  - Case (2): a crack 0.015 x 0.011 inch vertically along the gouge cut.

- These pre-cracked models were done based off the results of a florescent penetrant test performed at YPG on 11 June 2011 that showed the presence of a 0.015 inch crack in the tooling defect area.

II.c. Method - Abaqus: Load Data

Applied Pressure Data



III.a. Method – Fe-Safe: Material Property and Load Data

- Analysis was performed using Fe-Safe version 6.2
  - Analysis type: imported dynamic explicit Abaqus analysis
- Material Used: SAE 4140
  - Ultimate tensile strength: 156,060 psi (very similar to 95-15 SS)
- Load Settings:
  - Step 1 at time = 0.2s, peak stress = 154,719, load scale: 0, 1; repeats = 5 (to simulate the reverbating from gun launch)

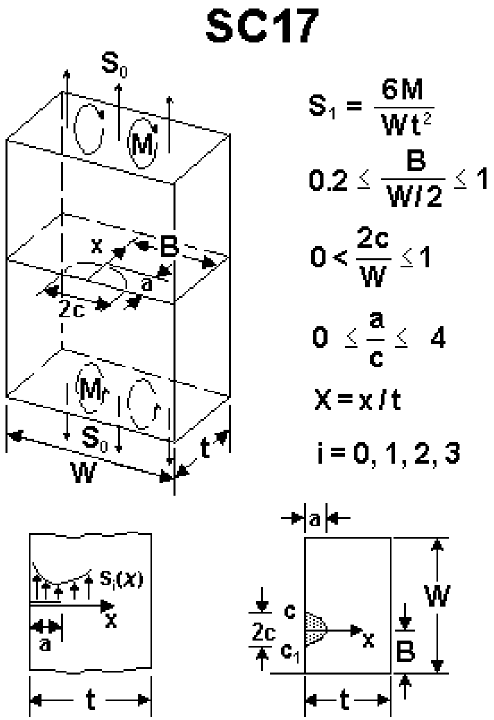
III.b. Method – Fe-Safe: Analysis Summary

FEA Fatigue Analysis Summary

Algorithm	BrownMiller:-Morrow
Material	SAE-4140-system.dbase
Surface	75 um < Ra-default.kt
Kt	2.45
UTS	156.055 ksi
Subgroup	Surface
Knock-Down	Off
Model File (s)	C:\Abqwork\M119_fs_cmw_13feb12_2fesafe.odb
FEA Units	S=psi
Loading	Loading is equivalent to 1 Repeats
	Load Definition File : current.ldf
	Elastic FEA
Scale factor	1
Overflow Life value	0
Infinite Life value	Material CAEL
Temperature analysis	Enabled if temperatures present
Histories	None
Log	None
List of Items	None
Histories for Items	None
Log for Items	None
Output contours to	C:\Users\caitlin.m.weaver\Documents\fe-safe.version.6.2\projects\project_01\jobs\job_01\fe-results\M119_fs_cmw_13feb
Contour variables	LOGLife-Repeats, SMAX/Yield, SMAX/UTS
...Intermediate	C:\Users\caitlin.m.weaver\Documents\fe-safe.version.6.2\projects\project_01\jobs\job_01\fe-results\fesafe.fer
Influence coeffs.	Disabled
Gauges.	Disabled
Solvers	Embedded Solver

Continue Cancel

IV.a. Method – NASGRO: Geometry, Material Property, and Normalized Stress Data

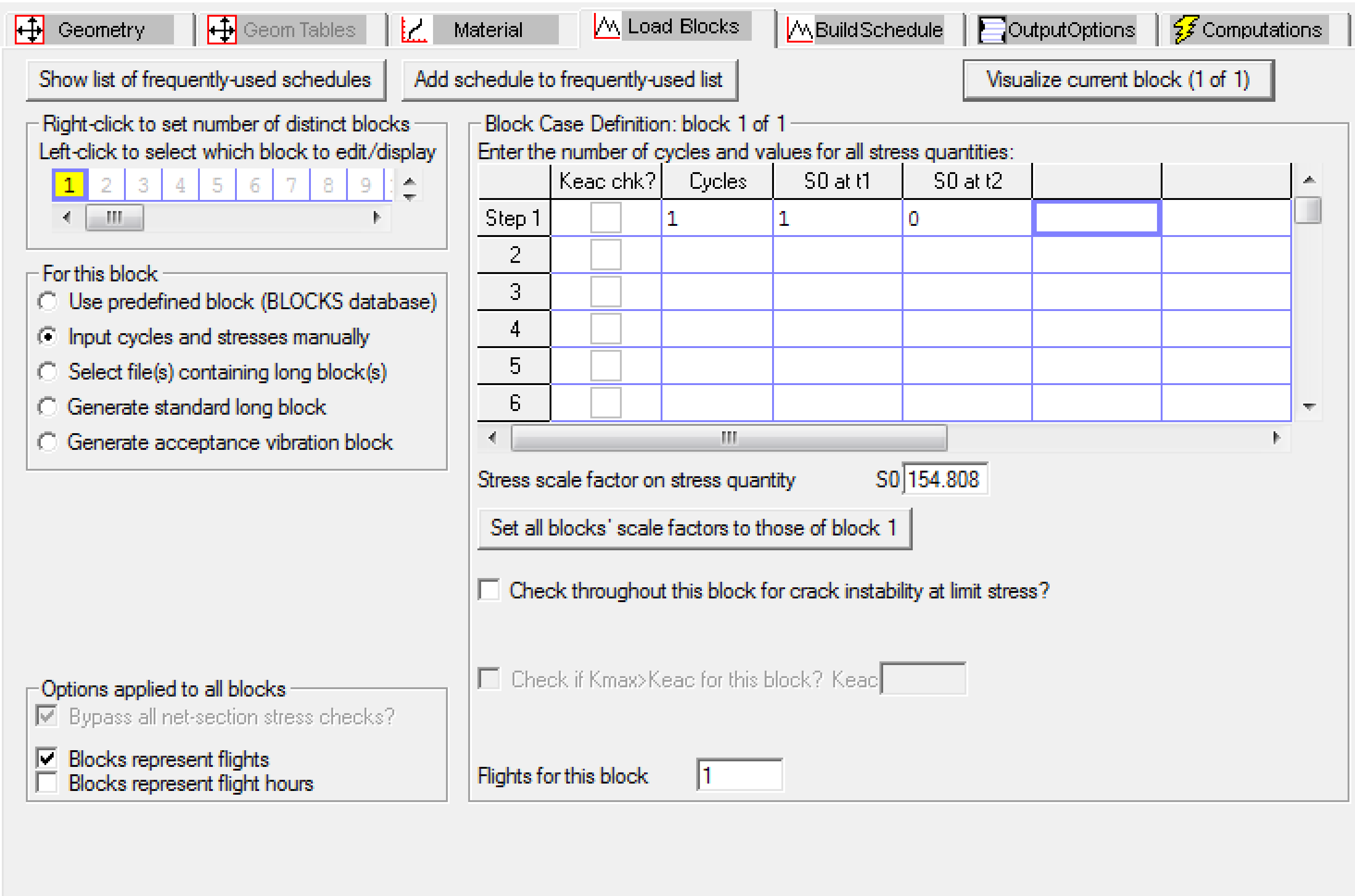


- Analysis was performed using NASGRO version 5.0
- Model used was surface crack plate specimen (SC17) with the same dimensions as the plate measured in Abaqus
  - Model was chosen after consultation with J. Cardinal (staff engineer at SwRI)
- Materials: 95-15 Stainless Steel (from in-house testing) and 15-5PH H1025 Stainless Steel (defined in NASGRO)

Thickness, t	0.08
Width, W	2.35
Crack ctr offset, B	1.175
Initial flaw size, a	0.0375291
Initial a/c	0.375291

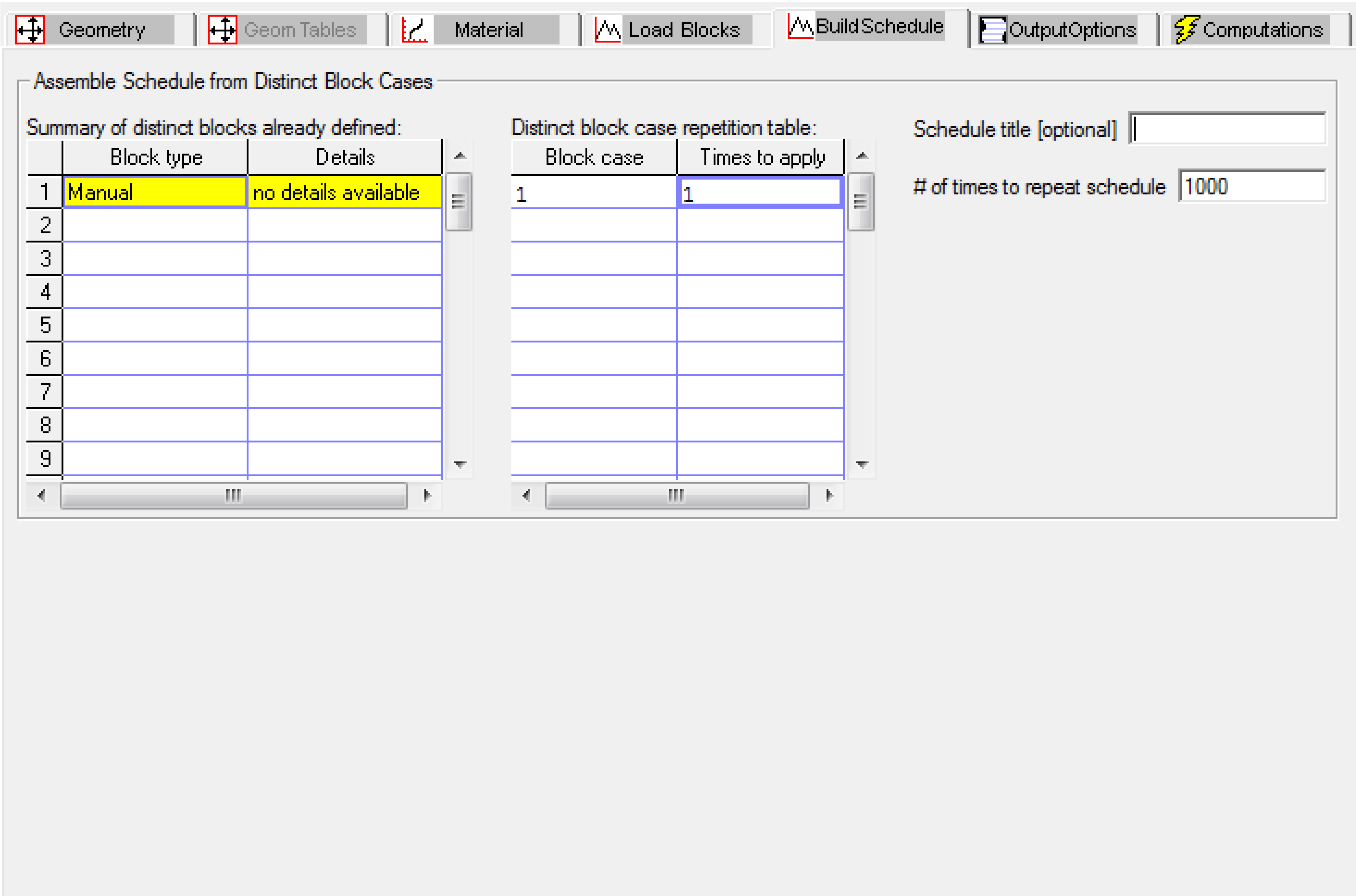
Normalized X	Normalized S0	Stress from Abaqus ODB
0	1	154808
0.1	0.989083252	153118
0.2	0.967068885	149710
0.3	0.823122836	127426
0.4	0.577328045	89375
0.5	0.380914423	58968.6
0.6	0.221089349	34226.4
0.7	0.105762622	16372.9
0.8	0.142635394	22081.1
0.9	0.322923234	49991.1
1	0.427379722	66161.8

IV.b. Method – NASGRO: Loads



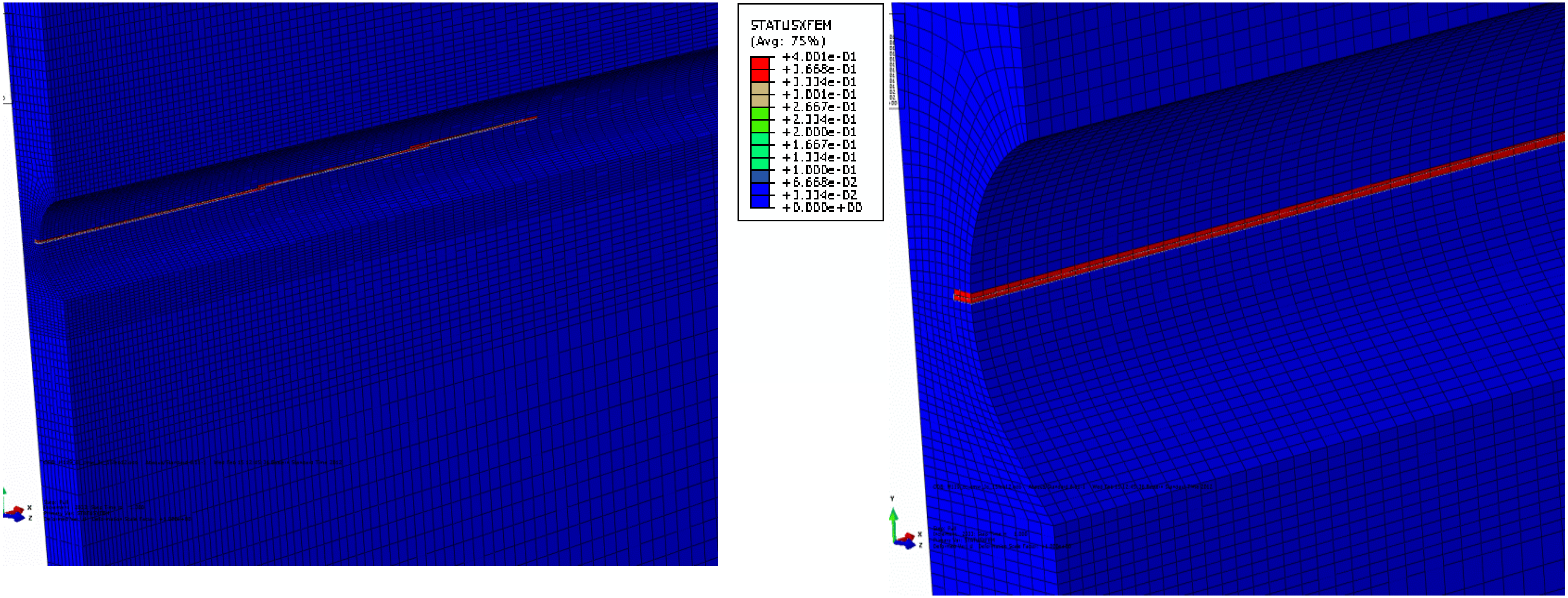
- Screen shot of load blocks used for analysis; S0 = 154,808 psi corresponds to the value from the Abaqus analysis; load corresponds to 1 cycle.

IV.c. Method – NASGRO: Cycle Schedule



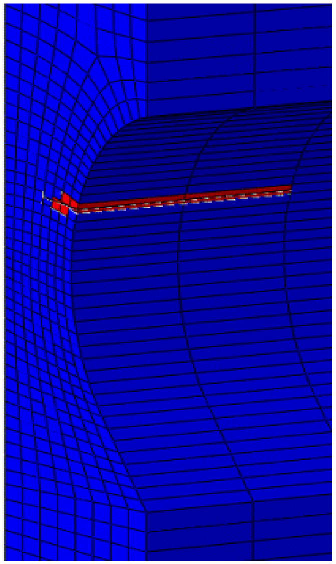
- Screen shot of build schedule; each load block is applied 1 time for 1000 cycles.

V.a. Results - XFEM

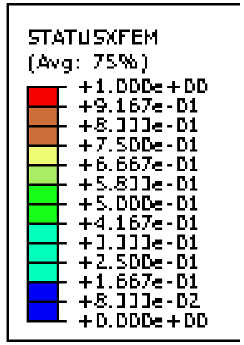


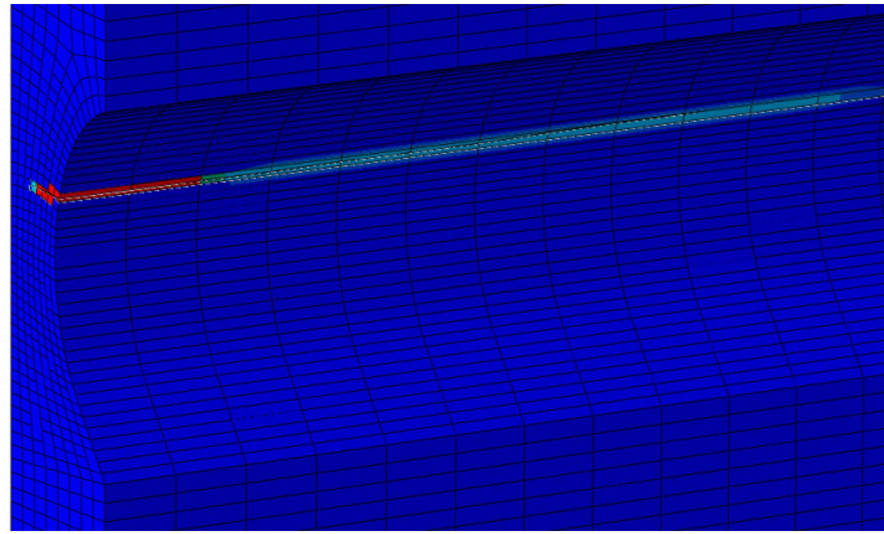
- The crack grows along the x-direction and varies between one and three elements through the thickness of the y-z plane.
- Value of 0.4 shows partial or surface cracking, not a complete through crack.

V.b. Results – XFEM pre-crack (X-axis)



Crack at t=0s

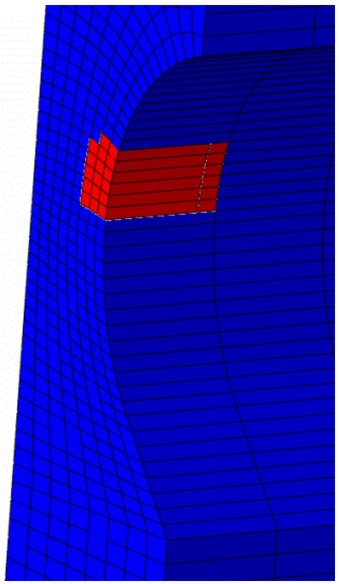




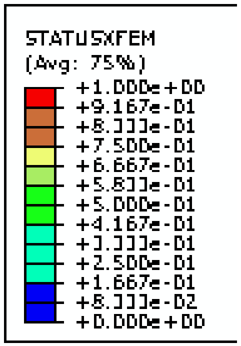
Crack at t=1s

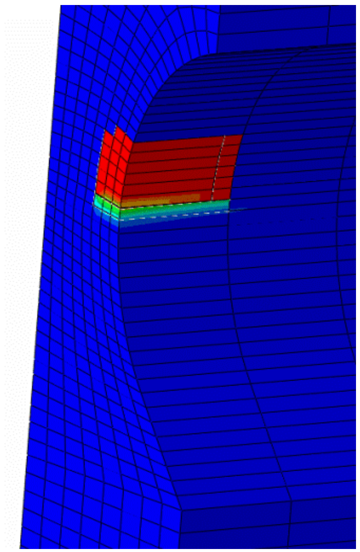
- The crack grows along the x- and z- direction.
- Crack propagation is similar to the crack initiation case.
- Crack is partial or surface cracking, not a complete through crack (based on the color values).

V.c. Results – XFEM pre-crack (Y-axis)



Crack at t=0s

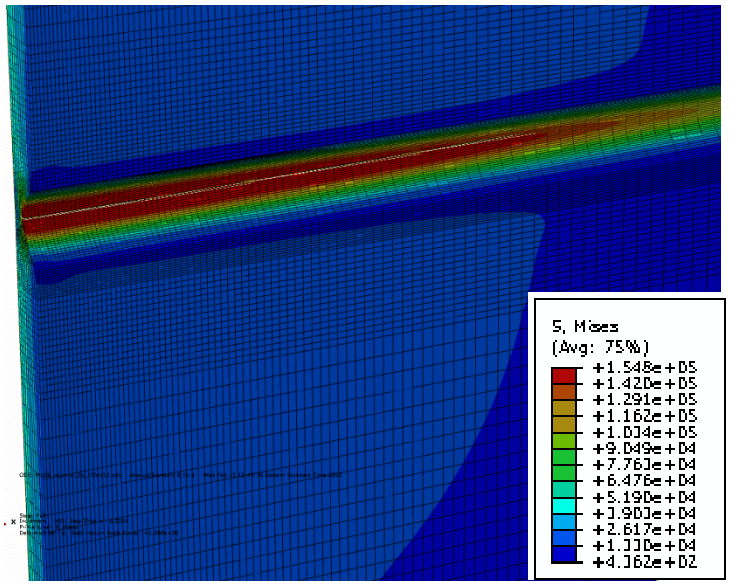


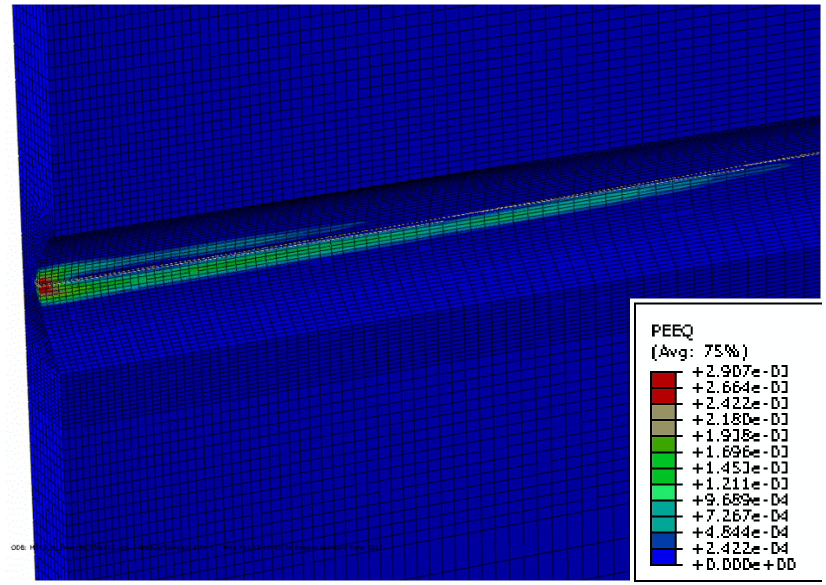


Crack at t=1s

- The crack grows along the x- and z- direction; no crack growth in the y-direction.
- Crack propagation is not similar to the crack initiation case.
- Crack is partial or surface cracking, not a complete through crack (based on the color values).

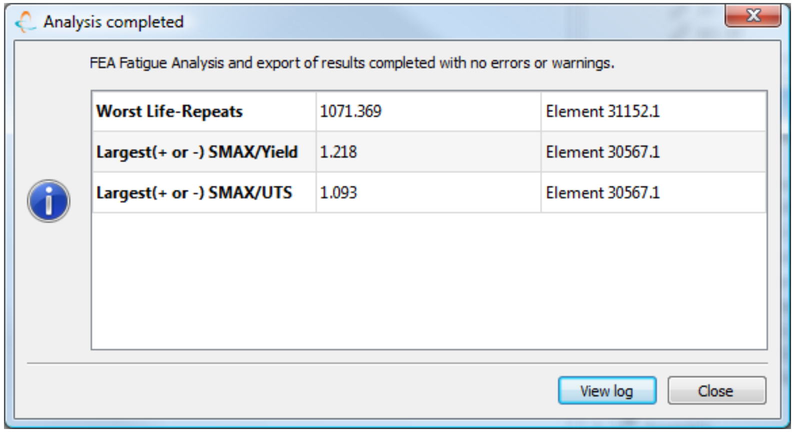
V.d. Results – Maximum Stress and Plastic Strain

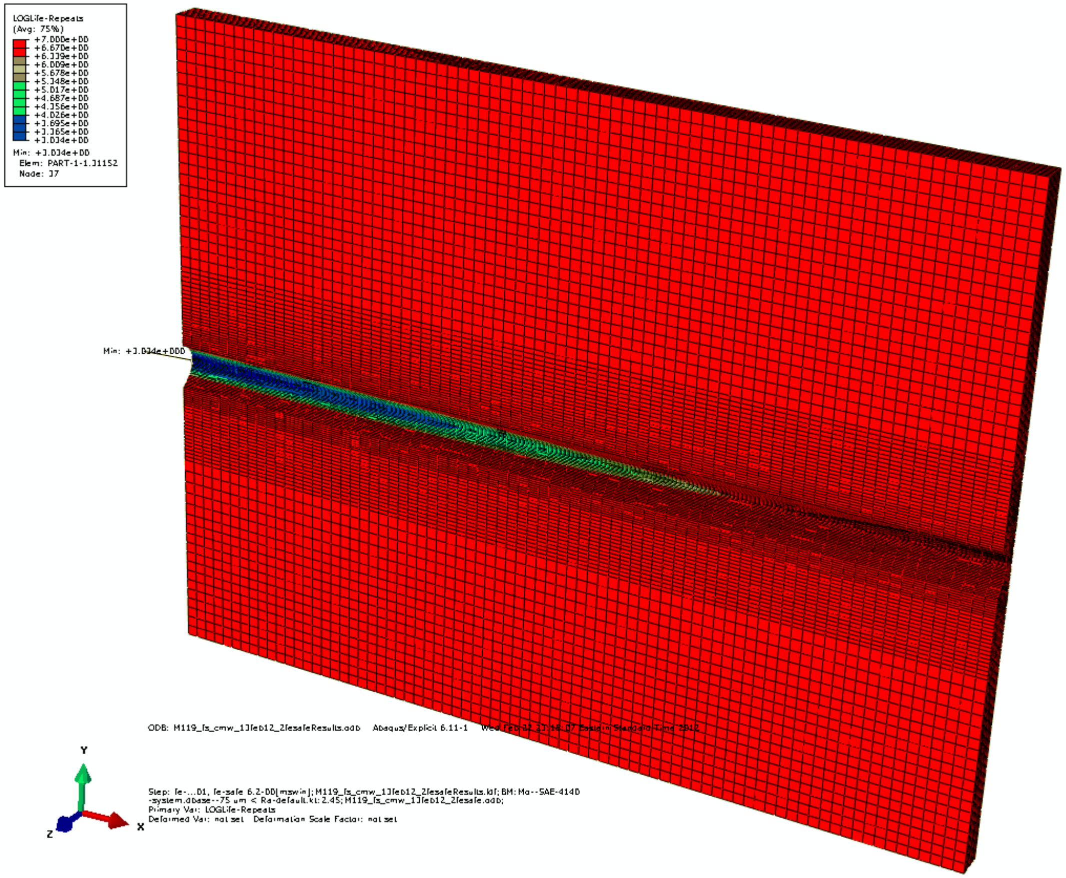




- Crack initiation occurs at a Von Mises stress of 144,562 psi, which is slightly lower than the yield stress of the material
  - As the crack continues to propagate yield stress is reached
- Plastic strain was not exceeded

V.e. Results – fe-safe

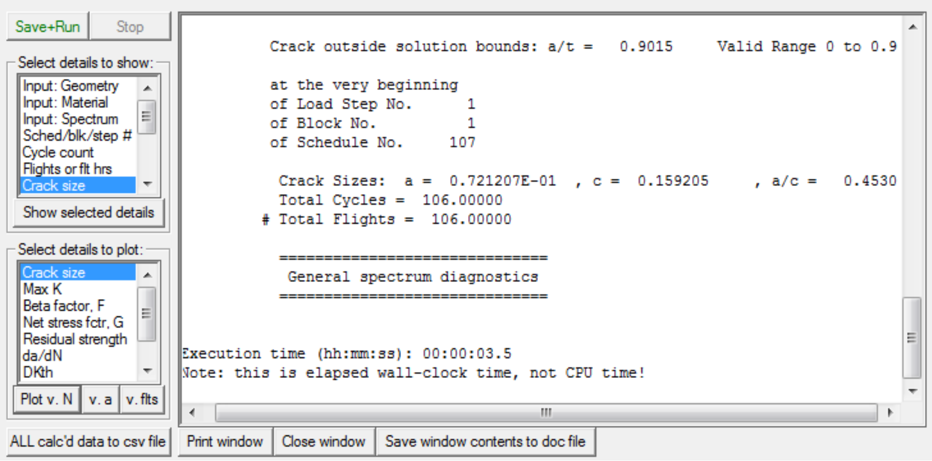


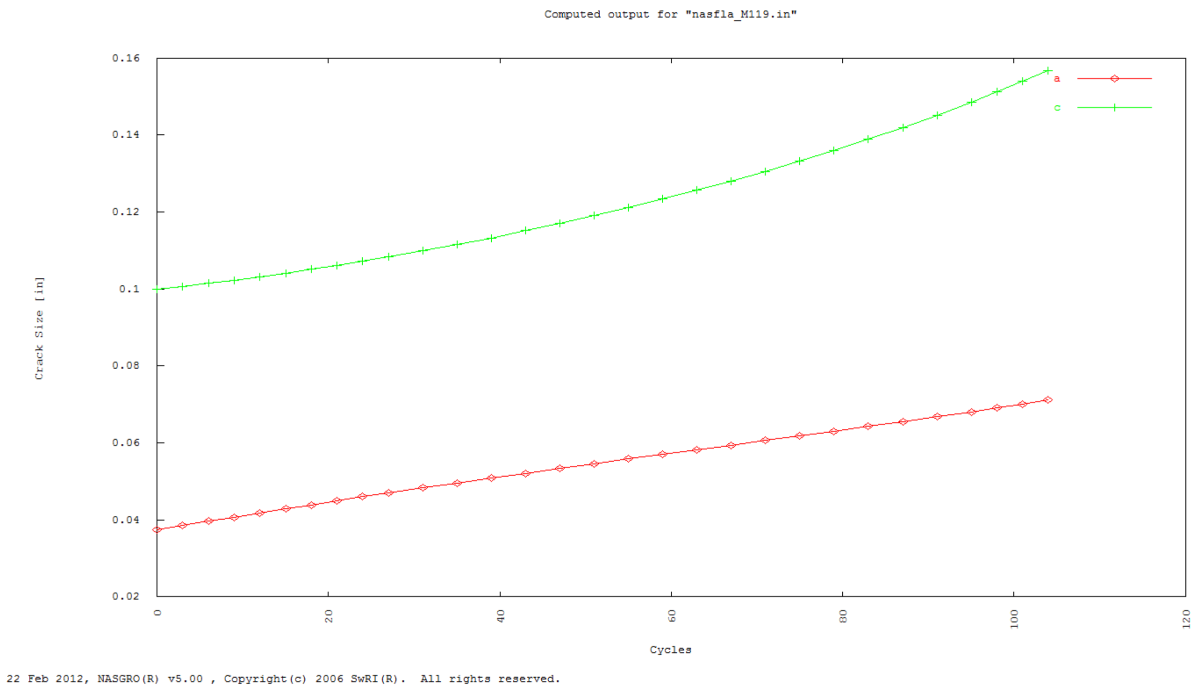


- Analysis shows a life cycle of 1071

V.f. Results - NASGRO

- Results show that crack becomes unstable after 106 cycles
  - Crack grows to 0.072-in before failure, which is almost the thickness of the part.
    - Part thickness is 0.080-in





Distribution Statement A: Approved for Public Release; distribution unlimited

VI. Conclusions

Conclusions:

- Results from all three methods show that the plate specimen fails the reliability requirement of 1100 mean rounds.
- The plate specimen was not able to prove that the channels with the tooling defects would survive the required amount of firings/cycles.

Path Forward (suggested):

- Since the plate specimen was not able to prove survivability, a more accurate FEA model needs to be analyzed in Abaqus and fe-safe to determine of the firing mechanism plate/channel would survive in the cradle assembly.

Questions

Distribution Statement A: Approved for Public Release; distribution unlimited