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

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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.

Goals:
- 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.

Scope:
- 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

- 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.

• 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

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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 reverberating from gun launch)
### III.b. Method – Fe-Safe: Analysis Summary

#### FEA Fatigue Analysis Summary

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**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)

<table>
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<th>Normalized X</th>
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<th>Stress from Abaqus ODB</th>
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<tr>
<td>0</td>
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<td>1</td>
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| 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      |
Screen shot of load blocks used for analysis; $S_0 = 154,808$ psi corresponds to the value from the Abaqus analysis; load corresponds to 1 cycle.
• 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)

- 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)

- 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).
• 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
• Analysis shows a life cycle of 1071
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.

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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.