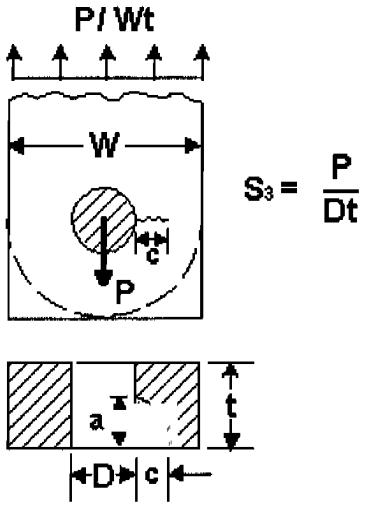
# AMS-02 Cryogenic Magnet Suspension Straps

## Fracture Analysis of Clevises

| Prepared By | Name/Date<br>Saike Wang<br>4/4/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Cryoclevis_ff |
|---|---|---|---|---|
| Checked By | 4/5/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section F-F. | | | |

# CC03




$$S_3 = \frac{P}{Dt}$$

Material: 6061-T651 (-452F)
NASA/FLAGRO Crack case type: CC03

Section Properties:

| | |
|---|---|
| Plate thickness | t = 0.63 in. |
| Plate width | w = 3.0 in. |
| Hole diameter | D = 0.75 in. |

Crack Properties:

a = 0.10 in.( dye penetrant inspection)
c = 0.10 in.
a/c = 1.0

Loads:

| | |
|---|---|
| Strap load (cryo) | f = 22099 lbs (ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 22099/2 = 11050 lbs |

| Prepared By | Name/Date<br>Saike Wang<br>4/4/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Cryoclevis_ff |
|---|---|---|---|---|
| Checked By | 4/4/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet strap Clevis (Cryo)<br>Section F-F | | | |

Stress:

Axial Stress

S3 = P/Dt

S3 = 11050/0.75*0.63 = 23.386 ksi

This C1W1 strap attaches to the clevis on the Race track end frame. (Ref drawing SCD0825, sheet 2 section C-C)
This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On - Orbit condition and Launch/Landing conditions. The Flagro analysis uses the truck, Air, On-Orbit and Launch/Landing case spectrums at cryo temp.
The material data used is from code M6AC13AB1 from the NASGRO library, except that the UTS and YS are changed as per the material property for the 6061-T651 material as per OIE205 Rev.d , page 24.

The truck, air, on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch/Landing spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis, and the standard dye penetrant crack size a = 0.10 in. and c = 0.10 in. is used. (Ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/28/02 TIME: 12:17:48
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**F-F lug With cold Launch and Landing for AMS-02 Magnet straps**
**(Ref. Drg. SCD0825, sht 2, Sect C-C)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.6300
Plate Width, W = 3.0000
Hole Diameter, D = 0.7500

FLAW SIZE (Standard NASA JSC NDE):
**Method of Inspection: Dye Penetrant**

a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: M6AC13AB1
Alloy Description : 6061-T651 ~2611
Alloy Cond/HT : Plt; L-T & T-L
~2621
Product Form : ~263
1
Environment : ~264
1
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl: No.: | UTS | YS | Kle | Klc | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **53.7** | **39.0** | 38.0 | 27.0 | 1.00 | 1.00 | 0.630 | 47.5 | |

| Matl: No.: | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.133D-06 | 2.248 | 0.50 | 1.00 | 3.50 | 1.50 | 0.10 | 0.70 | 1.50 | 0.30 |

**(Ref. OIE205 Rev.D, page 25 for UTS and YS for 6061-T6, 250 mm thick)**

F-F lug With cold Launch/Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks OF VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.23386 **(Ref. Cryoclevis_ff.doc, page 1)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.23386

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.23386

Stress Scaling Factors for Block Case: **4** **(GSFC-VCMAGNET)**

Scale Factor for Stress S3: 0.23386

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 4 | 1 |
| 5 - 8 | 2 |
| 9 - 12 | 3 |
| 13 - 24 | 4 |

Stresses: Tension, bending or pin

---

F-F lug With All of Cold
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks OF VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 36.70 | 5.60 | 36.70 | 5.60 |
| 2 | 1 | 2148.00 | 30.10 | 6.40 | 30.10 | 6.40 |
| 3 | 1 | 13668.00 | 25.50 | 6.90 | 25.50 | 6.90 |
| 4 | 1 | 38857.00 | 21.90 | 7.30 | 21.90 | 7.30 |
| 5 | 1 | 110517.00 | 19.50 | 7.50 | 19.50 | 7.50 |
| 6 | 1 | 150546.00 | 17.80 | 7.70 | 17.80 | 7.70 |
| 7 | 1 | 195456.00 | 16.50 | 7.90 | 16.50 | 7.90 |
| 8 | 1 | 1440631.00 | 15.90 | 7.90 | 15.90 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 2 | 1 | 594.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 3 | 1 | 695448.00 | 22.60 | 7.20 | 22.60 | 7.20 |
| 4 | 1 | 30.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 5 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 2 | 1 | 34.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 3 | 1 | 60.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 4 | 1 | 179.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 5 | 1 | 117.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 6 | 1 | 414.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 7 | 1 | 2404.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 8 | 1 | 9789.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 9 | 1 | 62675.00 | 13.40 | 8.50 | 13.40 | 8.50 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 2.00 | 96.10 | 3.90 | 96.10 | 3.90 |
| 2 | 1 | 4.00 | 88.10 | 4.30 | 88.10 | 4.30 |
| 3 | 1 | 8.00 | 80.00 | 4.80 | 80.00 | 4.80 |
| 4 | 1 | 15.00 | 72.00 | 5.20 | 72.00 | 5.20 |
| 5 | 1 | 49.00 | 64.00 | 5.60 | 64.00 | 5.60 |
| 6 | 1 | 81.00 | 55.90 | 6.00 | 55.90 | 6.00 |
| 7 | 1 | 178.00 | 47.90 | 6.40 | 47.90 | 6.40 |
| 8 | 1 | 641.00 | 39.90 | 6.80 | 39.90 | 6.80 |
| 9 | 1 | 3120.00 | 31.90 | 7.20 | 31.90 | 7.20 |
| 10 | 1 | 3405.00 | 23.80 | 7.60 | 23.80 | 7.60 |
| 11 | 1 | 5019.00 | 21.40 | 7.80 | 21.40 | 7.80 |
| 12 | 1 | 28853.00 | 19.80 | 7.80 | 19.80 | 7.80 |
| 13 | 1 | 91655.00 | 18.20 | 7.90 | 18.20 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

F-F lug With All of Cold
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks OF VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) t1 | S3 (ksi) t2 | S (ksi) t1 | S (ksi) t2 |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 8.58: | 1.31: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 : | 7.04: | 1.50: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 : | 5.96: | 1.61: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 : | 5.12: | 1.71: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 : | 4.56: | 1.75: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 : | 4.16: | 1.80: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 : | 3.86: | 1.85: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 : | 3.72: | 1.85: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

F-F lug With All of Cold
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks OF VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) t1 | S3 (ksi) t2 | S (ksi) t1 | S (ksi) t2 |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 : | 10.08: | 1.15: | 0.00: | 0.00: |
| 2: | 1: | 594.00 : | 10.08: | 1.15: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 : | 5.29: | 1.68: | 0.00: | 0.00: |
| 4: | 1: | 30.00 : | 10.08: | 1.15: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 : | 10.08: | 1.15: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

F-F lug With All of Cold
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks OF VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) t1 | S3 (ksi) t2 | S (ksi) t1 | S (ksi) t2 |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 : | 3.30: | 1.99: | 0.00: | 0.00: |
| 2: | 1: | 34.00 : | 3.25: | 1.99: | 0.00: | 0.00: |
| 3: | 1: | 60.00 : | 3.20: | 1.99: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4: | 1: | 179.00 : | 3.16: | 1.99: | 0.00: | 0.00: |
| 5: | 1: | 117.00 : | 3.30: | 1.99: | 0.00: | 0.00: |
| 6: | 1: | 414.00 : | 3.25: | 1.99: | 0.00: | 0.00: |
| 7: | 1: | 2404.00 : | 3.20: | 1.99: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 3.16: | 1.99: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 3.13: | 1.99: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

F-F lug With All of Cold
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE
---

Four Blocks OF VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 2.00 : | 22.47: | 0.91: | 0.00: | 0.00: |
| 2: | 1: | 4.00 : | 20.60: | 1.01: | 0.00: | 0.00: |
| 3: | 1: | 8.00 : | 18.71: | 1.12: | 0.00: | 0.00: |
| 4: | 1: | 15.00 : | 16.84: | 1.22: | 0.00: | 0.00: |
| 5: | 1: | 49.00 : | 14.97: | 1.31: | 0.00: | 0.00: |
| 6: | 1: | 81.00 : | 13.07: | 1.40: | 0.00: | 0.00: |
| 7: | 1: | 178.00 : | 11.20: | 1.50: | 0.00: | 0.00: |
| 8: | 1: | 641.00 : | 9.33: | 1.59: | 0.00: | 0.00: |
| 9: | 1: | 3120.00 : | 7.46: | 1.68: | 0.00: | 0.00: |
| 10: | 1: | 3405.00 : | 5.57: | 1.78: | 0.00: | 0.00: |
| 11: | 1: | 5019.00 : | 5.00: | 1.82: | 0.00: | 0.00: |
| 12: | 1: | 28853.00 : | 4.63: | 1.82: | 0.00: | 0.00: |
| 13: | 1: | 91655.00 : | 4.26: | 1.85: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

F-F lug With All of Cold
MODEL: CC03

ANALYSIS RESULTS:
---

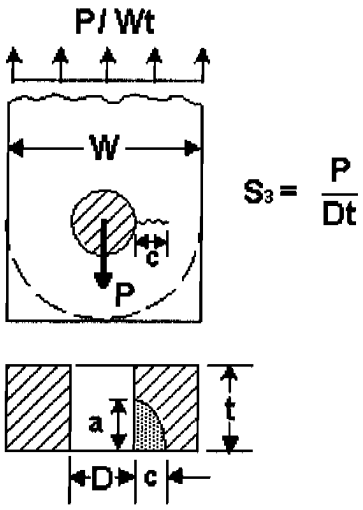
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10063 | 0.10000 | 4.499 | 3.336 |
| 1 | 2 | 3907160. | 0.10127 | 0.10000 | 4.501 | 3.348 |
| 1 | 3 | 5860740. | 0.10191 | 0.10000 | 4.503 | 3.360 |
| 1 | 4 | 7814320. | 0.10255 | 0.10000 | 4.505 | 3.372 |
| 1 | 5 | 8546056. | 0.13272 | 0.10814 | 5.459 | 4.386 |
| 1 | 6 | 9277792. | 0.16684 | 0.12239 | 5.655 | 4.658 |
| 1 | 7 | 10009528. | 0.20555 | 0.14070 | 5.865 | 4.859 |
| 1 | 8 | 10741264. | 0.24911 | 0.16216 | 6.062 | 5.011 |
| 1 | 9 | 10816970. | 0.24911 | 0.16216 | 1.983 | 1.639 |
| 1 | 10 | 10892676. | 0.24911 | 0.16216 | 1.983 | 1.639 |
| 1 | 11 | 10968382. | 0.24911 | 0.16216 | 1.983 | 1.639 |
| 1 | 12 | 11044088. | 0.24911 | 0.16216 | 1.983 | 1.639 |
| 1 | 13 | 11177118. | 0.25170 | 0.16298 | 13.517 | 11.174 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 14 | 11310148. | 0.25429 | 0.16381 | 13.530 | 11.204 |
| 1 | 15 | 11443178. | 0.25689 | 0.16464 | 13.543 | 11.234 |
| 1 | 16 | 11576208. | 0.25951 | 0.16548 | 13.556 | 11.263 |
| 1 | 17 | 11709238. | 0.26214 | 0.16633 | 13.569 | 11.292 |
| 1 | 18 | 11842268. | 0.26477 | 0.16719 | 13.582 | 11.321 |
| 1 | 19 | 11975298. | 0.26742 | 0.16806 | 13.595 | 11.349 |
| 1 | 20 | 12108328. | 0.27008 | 0.16893 | 13.609 | 11.377 |
| 1 | 21 | 12241358. | 0.27275 | 0.16982 | 13.622 | 11.405 |
| 1 | 22 | 12374388. | 0.27543 | 0.17071 | 13.635 | 11.432 |
| 1 | 23 | 12507418. | 0.27812 | 0.17161 | 13.648 | 11.459 |
| 1 | 24 | 12640448. | 0.28083 | 0.17251 | 13.662 | 11.486 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 91655.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.280826 , c = 0.172512 , a/c = 1.6279
Total Cycles = 12640448.

| Prepared By | Name/Date<br>Saike Wang<br>4/10/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Coldclevis_ff |
|---|---|---|---|---|
| Checked By | 4/10/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cold)<br>Section F-F. | | | |

# CC03




$$S_3 = \frac{P}{Dt}$$

Material: 6061-T651 (-452F)
NASA/FLAGRO Crack case type: CC03

Section Properties:

| | |
|---|---|
| Plate thickness | t = 0.63 in. |
| Plate width | w = 3.0 in. |
| Hole diameter | D = 0.75 in. |

Crack Properties:

a = 0.10 in.( dye penetrant inspection)
c = 0.10 in.
a/c = 1.0

Loads:

| | |
|---|---|
| Strap load (cryo) | f = 22099 lbs (ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 22099/2 = 11050 lbs |

| Prepared By | Name/Date<br>Saike Wang<br>4/4/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Coldclevis_ff |
|---|---|---|---|---|
| Checked By | 4/4/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet strap Clevis (Cold)<br>Section F-F | | | |

Stress:

Axial Stress $S3 = P/Dt$

$S3 = 11050/0.75*0.63 = 23.386$ ksi

This C1W1 strap attaches to the clevis on the Race track end frame. (Ref drawing SCD0825, sheet 2 section C-C)
This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On - Orbit condition and Launch conditions. The Flagro analysis uses the truck, Air, On-Orbit and Launch case spectrums at cryo temp.
The material data used is from code M6AC13AB1 from the NASGRO library, except that the UTS and YS are changed as per the material property for the 6061-T651 material as per OIE205 Rev.d , page 24.

The truck, air, on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis, and the standard dye penetrant crack size a = 0.10 in. and c = 0.10 in. is used. (Ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/28/02 TIME: 12:32:21
[computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**F-F lug with Cold launch AMS-02 Magnet straps**
**[Ref. Drg SCD0825, sht 2, sect C-C)**
Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.6300
Plate Width, W = 3.0000
Hole Diameter, D = 0.7500

FLAW SIZE (Standard NASA JSC NDE):
**Method of Inspection: Dye Penetrant**

a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: M6AC13AB1
Alloy Description : 6061-T651
~2611
Alloy Cond/HT : Plt; L-T & T-L ~2621
Product Form : ~2631

Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **53.7** | **39.0** | 38.0 | 27.0 | 1.00 | 1.00 | 0.630 | 47.5 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.133D-06 | 2.248 | 0.50 | 1.00 | 3.50 | 1.50 | 0.10 | 0.70 | 1.50 | 0.30 |

**[Ref. OIE205 Rev.D, page 25 for UTS and YS for 6061-T6, 250 mm thick)**
F-F lug With Cold Launch

MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks OF VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.23386 **(Ref. Coldclevis_ff.doc, page 2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.23386

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.23386

Stress Scaling Factors for Block Case: **4** **(LIFTOFF-ONLY)**

Scale Factor for Stress S3: 0.23386

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 4 | 1 |
| 5 - 8 | 2 |
| 9 - 12 | 3 |
| 13 - 24 | 4 |

Stresses: Tension, bending or pin

F-F lug With Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks OF VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 36.70 | 5.60 | 36.70 | 5.60 |
| 2 | 1 | 2148.00 | 30.10 | 6.40 | 30.10 | 6.40 |
| 3 | 1 | 13668.00 | 25.50 | 6.90 | 25.50 | 6.90 |
| 4 | 1 | 38857.00 | 21.90 | 7.30 | 21.90 | 7.30 |
| 5 | 1 | 110517.00 | 19.50 | 7.50 | 19.50 | 7.50 |
| 6 | 1 | 150546.00 | 17.80 | 7.70 | 17.80 | 7.70 |
| 7 | 1 | 195456.00 | 16.50 | 7.90 | 16.50 | 7.90 |
| 8 | 1 | 1440631.00 | 15.90 | 7.90 | 15.90 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses

(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 2 | 1 | 594.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 3 | 1 | 695448.00 | 22.60 | 7.20 | 22.60 | 7.20 |
| 4 | 1 | 30.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 5 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 2 | 1 | 34.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 3 | 1 | 60.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 4 | 1 | 179.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 5 | 1 | 117.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 6 | 1 | 414.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 7 | 1 | 2404.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 8 | 1 | 9789.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 9 | 1 | 62675.00 | 13.40 | 8.50 | 13.40 | 8.50 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 96.10 | 3.90 | 96.10 | 3.90 |
| 2 | 1 | 3.00 | 88.10 | 4.30 | 88.10 | 4.30 |
| 3 | 1 | 5.00 | 80.00 | 4.80 | 80.00 | 4.80 |
| 4 | 1 | 12.00 | 72.00 | 5.20 | 72.00 | 5.20 |
| 5 | 1 | 46.00 | 64.00 | 5.60 | 64.00 | 5.60 |
| 6 | 1 | 78.00 | 55.90 | 6.00 | 55.90 | 6.00 |
| 7 | 1 | 165.00 | 47.90 | 6.40 | 47.90 | 6.40 |
| 8 | 1 | 493.00 | 39.90 | 6.80 | 39.90 | 6.80 |
| 9 | 1 | 2229.00 | 31.90 | 7.20 | 31.90 | 7.20 |
| 10 | 1 | 2132.00 | 23.80 | 7.60 | 23.80 | 7.60 |
| 11 | 1 | 2920.00 | 21.40 | 7.80 | 21.40 | 7.80 |
| 12 | 1 | 22272.00 | 19.80 | 7.80 | 19.80 | 7.80 |
| 13 | 1 | 82954.00 | 18.20 | 7.90 | 18.20 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

F-F lug With Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks OF VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 8.58: | 1.31: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 | 7.04: | 1.50: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 | 5.96: | 1.61: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 | 5.12: | 1.71: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 | 4.56: | 1.75: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 | 4.16: | 1.80: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 | 3.86: | 1.85: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 | 3.72: | 1.85: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

F-F lug With Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks OF VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 10.08: | 1.15: | 0.00: | 0.00: |
| 2: | 1: | 594.00 | 10.08: | 1.15: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 | 5.29: | 1.68: | 0.00: | 0.00: |
| 4: | 1: | 30.00 | 10.08: | 1.15: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 | 10.08: | 1.15: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

F-F lug With Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks OF VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 3.30: | 1.99: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 3.25: | 1.99: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 3.20: | 1.99: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 3.16: | 1.99: | 0.00: | 0.00: |
| 5: | 1: | 117.00 | 3.30: | 1.99: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6: | 1: | 414.00 : | 3.25: | 1.99: | 0.00: | 0.00: |
| 7: | 1: | 2404.00 : | 3.20: | 1.99: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 3.16: | 1.99: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 3.13: | 1.99: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

F-F lug With Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks OF VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 22.47: | 0.91: | 0.00: | 0.00: |
| 2: | 1: | 3.00 : | 20.60: | 1.01: | 0.00: | 0.00: |
| 3: | 1: | 5.00 : | 18.71: | 1.12: | 0.00: | 0.00: |
| 4: | 1: | 12.00 : | 16.84: | 1.22: | 0.00: | 0.00: |
| 5: | 1: | 46.00 : | 14.97: | 1.31: | 0.00: | 0.00: |
| 6: | 1: | 78.00 : | 13.07: | 1.40: | 0.00: | 0.00: |
| 7: | 1: | 165.00 : | 11.20: | 1.50: | 0.00: | 0.00: |
| 8: | 1: | 493.00 : | 9.33: | 1.59: | 0.00: | 0.00: |
| 9: | 1: | 2229.00 : | 7.46: | 1.68: | 0.00: | 0.00: |
| 10: | 1: | 2132.00 : | 5.57: | 1.78: | 0.00: | 0.00: |
| 11: | 1: | 2920.00 : | 5.00: | 1.82: | 0.00: | 0.00: |
| 12: | 1: | 22272.00 : | 4.63: | 1.82: | 0.00: | 0.00: |
| 13: | 1: | 82954.00 : | 4.26: | 1.85: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

F-F lug With Cold Launch
MODEL: CC03

ANALYSIS RESULTS:

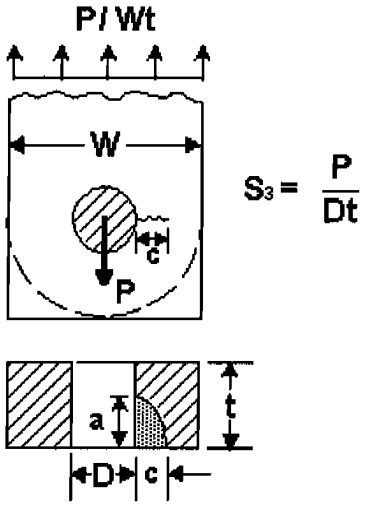
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10063 | 0.10000 | 4.499 | 3.336 |
| 1 | 2 | 3907160. | 0.10127 | 0.10000 | 4.501 | 3.348 |
| 1 | 3 | 5860740. | 0.10191 | 0.10000 | 4.503 | 3.360 |
| 1 | 4 | 7814320. | 0.10255 | 0.10000 | 4.505 | 3.372 |
| 1 | 5 | 8546056. | 0.13272 | 0.10814 | 5.459 | 4.386 |
| 1 | 6 | 9277792. | 0.16684 | 0.12239 | 5.655 | 4.658 |
| 1 | 7 | 10009528. | 0.20555 | 0.14070 | 5.865 | 4.859 |
| 1 | 8 | 10741264. | 0.24911 | 0.16216 | 6.062 | 5.011 |
| 1 | 9 | 10816970. | 0.24911 | 0.16216 | 1.983 | 1.639 |
| 1 | 10 | 10892676. | 0.24911 | 0.16216 | 1.983 | 1.639 |
| 1 | 11 | 10968382. | 0.24911 | 0.16216 | 1.983 | 1.639 |
| 1 | 12 | 11044088. | 0.24911 | 0.16216 | 1.983 | 1.639 |
| 1 | 13 | 11157398. | 0.25116 | 0.16285 | 13.517 | 11.174 |
| 1 | 14 | 11270708. | 0.25321 | 0.16355 | 13.528 | 11.196 |
| 1 | 15 | 11384018. | 0.25527 | 0.16425 | 13.539 | 11.219 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 16 | 11497328. | 0.25734 | 0.16496 | 13.551 | 11.241 |
| 1 | 17 | 11610638. | 0.25941 | 0.16567 | 13.562 | 11.263 |
| 1 | 18 | 11723948. | 0.26150 | 0.16639 | 13.574 | 11.285 |
| 1 | 19 | 11837258. | 0.26359 | 0.16711 | 13.585 | 11.307 |
| 1 | 20 | 11950568. | 0.26568 | 0.16784 | 13.596 | 11.328 |
| 1 | 21 | 12063878. | 0.26779 | 0.16857 | 13.608 | 11.349 |
| 1 | 22 | 12177188. | 0.26990 | 0.16931 | 13.619 | 11.370 |
| 1 | 23 | 12290498. | 0.27202 | 0.17005 | 13.631 | 11.391 |
| 1 | 24 | 12403808. | 0.27414 | 0.17080 | 13.642 | 11.412 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 82954.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.274142 , c = 0.170802 , a/c = 1.6050
Total Cycles = 12403808.

| Prepared By | Name/Date<br>Saike Wang<br>4/10/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name warmclevis_ff |
|---|---|---|---|---|
| Checked By | 4/10/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (warm)<br>Section F-F. | | | |

# CC03




$$S_3 = \frac{P}{Dt}$$

Material: 6061-T651 (75F)
NASA/FLAGRO Crack case type: CC03

Section Properties:
- Plate thickness: t = 0.63 in.
- Plate width: w = 3.0 in.
- Hole diameter: D = 0.75 in.

Crack Properties:

a = 0.2741 in. (Ref. FF-clevis-cold-launch,
c = 0.2741 in. page 6)
a/c = 1.0

Loads:
- Strap load (cryo): f = 19102 lbs (ref. Model 6-01 loads)
- Load per side on clevis: Paxial = 19102/2 = 9551 lbs

| Prepared By | Name/Date<br>Saike Wang<br>4/10/02 | LOCKHEED MARTIN | Page/Section<br>No. 2 | File Name<br>warmclevis_ff |
|---|---|---|---|---|
| Checked By | 4/10/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet strap Clevis (warm)<br>Section F-F | | | |

Stress:

Axial Stress $S3 = P/Dt$

$S3 = 9551/0.75*0.63 = 20.213$ ksi

This C1W1 strap attaches to the clevis on the Race track end frame. (Ref drawing SCD0825, sheet 2 section C-C)
This clevis is at room temperature (75F) for the landing condition. The Flagro analysis uses the landing case spectrum at room temp.
The material data used is from code M6AC13AB1 from the NASGRO library, except that the UTS and YS are changed as per the material property for the 6061-T651 material as per OIE205 Rev.d , page 24.

Landing spectrum is run for 3 missions with a scatter factor of 4. The final crack size from the cold launch condition a=0.2741 in. and a/c = 1.0 in. is used as the initial crack sizes for this model.

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/10/02 TIME: 09:57:59
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**FF Lug with warm landing for AMS-02 Magnet straps**
**(Ref. Drg. SCD0825, sht.2 sect c-c)**
Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.6300
Plate Width, W = 3.0000
Hole Diameter, D = 0.7500

FLAW SIZE: (User specified)

**a (init.) = 0.2741 (Ref. Final crack size from FF-pin-cold-launch,**
**c (init.) = 0.2741 page 6)**
**a/c (init.) = 1.000**

MATERIAL

MATL 1: Edited file data ~2211
~2221

Material Header Info.:

Material 1 Data ID: M6AC13AB1
Alloy Description : 6061-T651 ~2611

Alloy Cond/HT : Plt; L-T & T-L ~26
21
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **37.0** | **30.0** | 38.0 | 27.0 | 1.00 | 1.00 | 0.630 | 51.5 | |

Matl: Crack Growth Eqn Constants

| No. | C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.133D-06 | 2.248 | 0.50 | 1.00 | 3.50 | 1.50 | 0.10 | 0.70 | 1.50 | 0.30 |

**(Ref. OIE 205 Rev.D, page 25 for UTS and YS for 6061-T6, 250 mm. Thick)**

FF clevis warm landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

FF clevis warm landing

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(LAND-ONLY)**

Scale Factor for Stress S3: 0.20213 **(Ref. Warmclevis_ff.doc, page 2)**

Schedule info. was input manually

Total No. of Blocks in Schedule = 12

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 12 | 1 |

Stresses: Tension, bending or pin

FF clevis warm landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

FF clevis warm landing

SINGLE DISTINCT BLOCK

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 100.00 | 3.70 | 100.00 | 3.70 |
| 2 | 1 | 1.00 | 91.30 | 4.20 | 91.30 | 4.20 |
| 3 | 1 | 3.00 | 82.60 | 4.70 | 82.60 | 4.70 |
| 4 | 1 | 3.00 | 74.00 | 5.20 | 74.00 | 5.20 |
| 5 | 1 | 3.00 | 65.30 | 5.70 | 65.30 | 5.70 |
| 6 | 1 | 3.00 | 56.60 | 6.10 | 56.60 | 6.10 |
| 7 | 1 | 13.00 | 47.90 | 6.60 | 47.90 | 6.60 |
| 8 | 1 | 148.00 | 39.20 | 7.10 | 39.20 | 7.10 |
| 9 | 1 | 891.00 | 30.60 | 7.60 | 30.60 | 7.60 |
| 10 | 1 | 1273.00 | 21.90 | 8.10 | 21.90 | 8.10 |
| 11 | 1 | 2099.00 | 19.30 | 8.20 | 19.30 | 8.20 |
| 12 | 1 | 6581.00 | 17.50 | 8.30 | 17.50 | 8.30 |
| 13 | 1 | 8701.00 | 15.80 | 8.40 | 15.80 | 8.40 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

FF clevis warm landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

FF clevis warm landing

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 20.21 | 0.75 | 0.00 | 0.00 |
| 2 | 1 | 1.00 | 18.45 | 0.85 | 0.00 | 0.00 |
| 3 | 1 | 3.00 | 16.70 | 0.95 | 0.00 | 0.00 |
| 4 | 1 | 3.00 | 14.96 | 1.05 | 0.00 | 0.00 |
| 5 | 1 | 3.00 | 13.20 | 1.15 | 0.00 | 0.00 |
| 6 | 1 | 3.00 | 11.44 | 1.23 | 0.00 | 0.00 |
| 7 | 1 | 13.00 | 9.68 | 1.33 | 0.00 | 0.00 |
| 8 | 1 | 148.00 | 7.92 | 1.44 | 0.00 | 0.00 |
| 9 | 1 | 891.00 | 6.19 | 1.54 | 0.00 | 0.00 |
| 10 | 1 | 1273.00 | 4.43 | 1.64 | 0.00 | 0.00 |
| 11 | 1 | 2099.00 | 3.90 | 1.66 | 0.00 | 0.00 |
| 12 | 1 | 6581.00 | 3.54 | 1.68 | 0.00 | 0.00 |
| 13 | 1 | 8701.00 | 3.19 | 1.70 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

FF clevis warm landing
MODEL: CC03

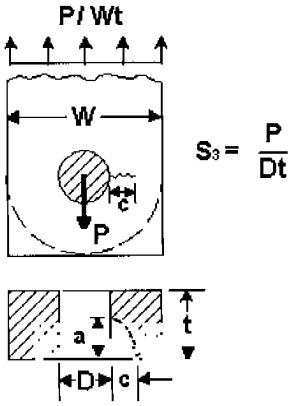
ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 19720. | 0.27447 | 0.27416 | 13.433 | 8.264 t |
| 1 | 2 | 39440. | 0.27480 | 0.27418 | 13.434 | 8.270 t |
| 1 | 3 | 59160. | 0.27514 | 0.27420 | 13.435 | 8.276 t |
| 1 | 4 | 78880. | 0.27547 | 0.27422 | 13.436 | 8.282 t |
| 1 | 5 | 98600. | 0.27580 | 0.27424 | 13.438 | 8.288 t |
| 1 | 6 | 118320. | 0.27614 | 0.27427 | 13.439 | 8.293 t |
| 1 | 7 | 138040. | 0.27647 | 0.27429 | 13.440 | 8.299 t |
| 1 | 8 | 157760. | 0.27680 | 0.27431 | 13.441 | 8.305 t |
| 1 | 9 | 177480. | 0.27714 | 0.27433 | 13.443 | 8.311 t |
| 1 | 10 | 197200. | 0.27747 | 0.27435 | 13.444 | 8.317 t |
| 1 | 11 | 216920. | 0.27781 | 0.27437 | 13.445 | 8.322 t |
| 1 | 12 | 236640. | 0.27814 | 0.27439 | 13.446 | 8.328 t |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 8701.00
of Load Step No. 13 Description: None
of Block No. 12
of Schedule No. 1
Crack Sizes: a = 0.278141 , c = 0.274394 , a/c = 1.0137
Total Cycles = 236640.00

| Prepared By | Name/Date<br>Saike Wang<br>4/15/02 | LOCKHEED MARTIN<br>Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Page/Section No. 1 | File Name Cryoclevis_gg |
|---|---|---|---|---|
| Checked By | 4/15/02 | | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section G-G | | | |

## CC03




| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.3930 in. (Ref. SCD0678, Sec. G-G) |
| Plate thickness | t = 0.197 in. (average thickness at Sec. G-G) |
| Plate width | w = 1.6380 in. |
| Hole diameter | D = 0.7500 in. |
| Crack Properties: | a = 0.10 in.<br>c = 0.10 in. |
| Loads: | |
| Strap load (cryo) | f = 22099 lbf (ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 22099/2 = 11050 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/15/02 | LOCKHEED MARTIN<br>Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Page/Section No. 2 | File Name Cryoclevis_gg |
|---|---|---|---|---|
| Checked By | 4/15/02 | | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section G-G | | | |

Tensile Stress

S3 = Paxial/D*T

S3 = 11050/0.75*0.393=37.489 ksi

This clevis is part of the Strap at Section G-G. (Ref. Drawing SCD0678, issue 07, Section G-G)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch/Landing conditions. The NASGRO analysis uses truck air, On-orbit and Launch/Landing case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch/Landing spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section G-G, and the standard dye penetrant crack sizes a= 0.10 in and c = 0.10 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/21/02 TIME: 13:25:39
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**G-G Lug With Cold Launch and Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678,issue 07, Section G-G)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1970
Plate Width, W = 1.6380
Hole Diameter, D = 0.7500

FLAW SIZE: **(User specified)**
**Method of Inspection: Dye Penetrant**
a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:
Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L ~2611

Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :

Data Reference :
Material Properties:

| :Matl: No.: | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| : 1 : | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.197 | 299.7 | |

| :Matl: No.: | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/ SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| : 1 : | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250 mm thick)**
G-G Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.37489 **(Ref. Cryoclevis_gg.doc, Page 2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.37489

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.37489

Stress Scaling Factors for Block Case: **4** **(GSFC-VCMAGNET)**

Scale Factor for Stress S3: 0.37489

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From | - | To | Block Case No. |
|---|---|---|---|
| 1 | - | 4 | 1 |
| 5 | - | 8 | 2 |
| 9 | - | 12 | 3 |
| 13 | - | 24 | 4 |

Stresses: Tension, bending or pin

G-G Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 36.70: | 5.60: | 36.70: | 5.60: |
| 2: | 1: | 2148.00 : | 30.10: | 6.40: | 30.10: | 6.40: |
| 3: | 1: | 13668.00 : | 25.50: | 6.90: | 25.50: | 6.90: |
| 4: | 1: | 38857.00 : | 21.90: | 7.30: | 21.90: | 7.30: |
| 5: | 1: | 110517.00 : | 19.50: | 7.50: | 19.50: | 7.50: |
| 6: | 1: | 150546.00 : | 17.80: | 7.70: | 17.80: | 7.70: |
| 7: | 1: | 195456.00 : | 16.50: | 7.90: | 16.50: | 7.90: |
| 8: | 1: | 1440631.00 : | 15.90: | 7.90: | 15.90: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 2 | 1 | 594.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 3 | 1 | 695448.00 | 22.60 | 7.20 | 22.60 | 7.20 |
| 4 | 1 | 30.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 5 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 2 | 1 | 34.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 3 | 1 | 60.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 4 | 1 | 179.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 5 | 1 | 117.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 6 | 1 | 414.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 7 | 1 | 2404.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 8 | 1 | 9789.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 9 | 1 | 62675.00 | 13.40 | 8.50 | 13.40 | 8.50 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 2.00 | 96.10 | 3.90 | 96.10 | 3.90 |
| 2 | 1 | 4.00 | 88.10 | 4.30 | 88.10 | 4.30 |
| 3 | 1 | 8.00 | 80.00 | 4.80 | 80.00 | 4.80 |
| 4 | 1 | 15.00 | 72.00 | 5.20 | 72.00 | 5.20 |
| 5 | 1 | 49.00 | 64.00 | 5.60 | 64.00 | 5.60 |
| 6 | 1 | 81.00 | 55.90 | 6.00 | 55.90 | 6.00 |
| 7 | 1 | 178.00 | 47.90 | 6.40 | 47.90 | 6.40 |
| 8 | 1 | 641.00 | 39.90 | 6.80 | 39.90 | 6.80 |
| 9 | 1 | 3120.00 | 31.90 | 7.20 | 31.90 | 7.20 |
| 10 | 1 | 3405.00 | 23.80 | 7.60 | 23.80 | 7.60 |
| 11 | 1 | 5019.00 | 21.40 | 7.80 | 21.40 | 7.80 |
| 12 | 1 | 28853.00 | 19.80 | 7.80 | 19.80 | 7.80 |
| 13 | 1 | 91655.00 | 18.20 | 7.90 | 18.20 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 13.76: | 2.10: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 | 11.28: | 2.40: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 | 9.56: | 2.59: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 | 8.21: | 2.74: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 | 7.31: | 2.81: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 | 6.67: | 2.89: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 | 6.19: | 2.96: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 | 5.96: | 2.96: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 16.16: | 1.84: | 0.00: | 0.00: |
| 2: | 1: | 594.00 | 16.16: | 1.84: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 | 8.47: | 2.70: | 0.00: | 0.00: |
| 4: | 1: | 30.00 | 16.16: | 1.84: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 | 16.16: | 1.84: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 5.29: | 3.19: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 5.21: | 3.19: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 5.14: | 3.19: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 5.06: | 3.19: | 0.00: | 0.00: |
| 5: | 1: | 117.00 | 5.29: | 3.19: | 0.00: | 0.00: |
| 6: | 1: | 414.00 | 5.21: | 3.19: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7: | 1: | 2404.00 : | 5.14: | 3.19: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 5.06: | 3.19: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 5.02: | 3.19: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 2.00 : | 36.03: | 1.46: | 0.00: | 0.00: |
| 2: | 1: | 4.00 : | 33.03: | 1.61: | 0.00: | 0.00: |
| 3: | 1: | 8.00 : | 29.99: | 1.80: | 0.00: | 0.00: |
| 4: | 1: | 15.00 : | 26.99: | 1.95: | 0.00: | 0.00: |
| 5: | 1: | 49.00 : | 23.99: | 2.10: | 0.00: | 0.00: |
| 6: | 1: | 81.00 : | 20.96: | 2.25: | 0.00: | 0.00: |
| 7: | 1: | 178.00 : | 17.96: | 2.40: | 0.00: | 0.00: |
| 8: | 1: | 641.00 : | 14.96: | 2.55: | 0.00: | 0.00: |
| 9: | 1: | 3120.00 : | 11.96: | 2.70: | 0.00: | 0.00: |
| 10: | 1: | 3405.00 : | 8.92: | 2.85: | 0.00: | 0.00: |
| 11: | 1: | 5019.00 : | 8.02: | 2.92: | 0.00: | 0.00: |
| 12: | 1: | 28853.00 : | 7.42: | 2.92: | 0.00: | 0.00: |
| 13: | 1: | 91655.00 : | 6.82: | 2.96: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Cold Launch and Landing
MODEL: CC03

ANALYSIS RESULTS:

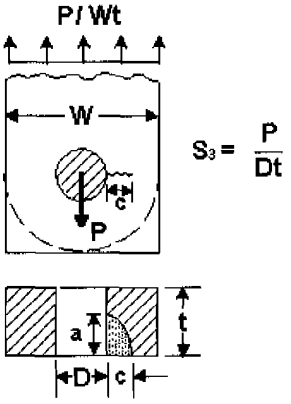
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10058 | 0.10011 | 13.274 | 10.673 |
| 1 | 2 | 3907160. | 0.10117 | 0.10022 | 13.289 | 10.713 |
| 1 | 3 | 5860740. | 0.10176 | 0.10033 | 13.305 | 10.753 |
| 1 | 4 | 7814320. | 0.10237 | 0.10044 | 13.320 | 10.793 |
| 1 | 5 | 8546056. | 0.11319 | 0.10576 | 16.158 | 13.436 |
| 1 | 6 | 9277792. | 0.12544 | 0.11237 | 16.807 | 14.304 |
| 1 | 7 | 10009528. | 0.13960 | 0.12068 | 17.560 | 15.253 |
| 1 | 8 | 10741264. | 0.16928 | 0.13267 | 18.879 | 17.503 |
| 1 | 9 | 10816970. | 0.16928 | 0.13267 | 6.167 | 5.717 |
| 1 | 10 | 10892676. | 0.16928 | 0.13267 | 6.167 | 5.717 |
| 1 | 11 | 10968382. | 0.16928 | 0.13267 | 6.167 | 5.717 |
| 1 | 12 | 11044088. | 0.16928 | 0.13267 | 6.167 | 5.717 |
| 1 | 13 | 11177118. | 0.17061 | 0.13367 | 42.038 | 38.966 |
| 1 | 14 | 11310148. | 0.17197 | 0.13469 | 42.242 | 39.188 |
| 1 | 15 | 11443178. | 0.17339 | 0.13574 | 42.452 | 39.415 |
| 1 | 16 | 11576208. | 0.17486 | 0.13681 | 42.668 | 39.657 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 17 | 11709238. | 0.17637 | 0.13791 | 42.890 | 39.908 |
| 1 | 18 | 11842268. | 0.17791 | 0.13904 | 43.120 | 40.168 |
| 1 | 19 | 11975298. | 0.17949 | 0.14020 | 43.355 | 40.437 |
| 1 | 20 | 12108328. | 0.18110 | 0.14138 | 43.598 | 40.715 |
| 1 | 21 | 12241358. | 0.18275 | 0.14260 | 43.849 | 41.003 |
| 1 | 22 | 12374388. | 0.18445 | 0.14385 | 44.107 | 41.300 |
| 1 | 23 | 12507418. | 0.18618 | 0.14514 | 44.374 | 41.608 |
| 1 | 24 | 12640448. | 0.18796 | 0.14647 | 44.649 | 41.927 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 91655.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.187956 , c = 0.146465 , a/c = 1.2833
Total Cycles = 12640448.

| Prepared By | Name/Date<br>Saike Wang<br>4/15/02 | LOCKHEED MARTIN<br>Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Page/Section No. 1 | File Name Coldclevis_gg |
|---|---|---|---|---|
| Checked By | 4/15/02 | | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section G-G | | | |

## CC03




| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.3930 in. (Ref. SCD0678, Sec. G-G) |
| Plate thickness | t = 0.197 in. (average thickness at Sec. G-G) |
| Plate width | w = 1.6380 in. |
| Hole diameter | D = 0.7500 in. |
| Crack Properties: | a = 0.10 in.<br>c = 0.10 in. |
| Loads: | |
| Strap load (cryo) | f = 22099 lbf (ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 22099/2 = 11050 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/15/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Coldclevis_gg |
|---|---|---|---|---|
| Checked By | 4/15/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section G-G | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 11050/0.75*0.393=37.489 ksi

This clevis is part of the Strap at Section G-G. (Ref. Drawing SCD0678, issue 07, Section G-G)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch conditions. The NASGRO analysis uses truck air, On-orbit and Launch case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section G-G, and the standard dye penetrant crack sizes a= 0.10 in and c = 0.10 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/22/02 TIME: 08:19:37
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**G-G Lug With Cold Launch for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section G-G)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1970
Plate Width, W = 1.6380
Hole Diameter, D = 0.7500

FLAW SIZE: **(User specified)**
**Method of Inspection: Dye Penetrant**
a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211 ~2221

Material Header Info.:

Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L ~2611
Alloy Cond/HT : Ann sht & plt ; -452F LHe ~2621
Product Form : ~2631

Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| :Matl: No.: | UTS | YS | K1e | Klc | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.197 | 299.7 | |

| :Matl: No.: | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev. D, Page 25 for UTS and YS of 316L, 250 mm thick)**
G-G Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.37489 **(Ref. Coldclevis_gg.doc, Page2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.37489

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.37489

Stress Scaling Factors for Block Case: **4** **(LIFTOFF-ONLY)**

Scale Factor for Stress S3: 0.37489

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 4 | 1 |
| 5 - 8 | 2 |
| 9 - 12 | 3 |
| 13 - 24 | 4 |

Stresses: Tension, bending or pin

---

G-G Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 36.70: | 5.60: | 36.70: | 5.60: |
| 2: | 1: | 2148.00 : | 30.10: | 6.40: | 30.10: | 6.40: |
| 3: | 1: | 13668.00 : | 25.50: | 6.90: | 25.50: | 6.90: |
| 4: | 1: | 38857.00 : | 21.90: | 7.30: | 21.90: | 7.30: |
| 5: | 1: | 110517.00 : | 19.50: | 7.50: | 19.50: | 7.50: |
| 6: | 1: | 150546.00 : | 17.80: | 7.70: | 17.80: | 7.70: |
| 7: | 1: | 195456.00 : | 16.50: | 7.90: | 16.50: | 7.90: |
| 8: | 1: | 1440631.00 : | 15.90: | 7.90: | 15.90: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 2 | 1 | 594.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 3 | 1 | 695448.00 | 22.60 | 7.20 | 22.60 | 7.20 |
| 4 | 1 | 30.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 5 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 2 | 1 | 34.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 3 | 1 | 60.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 4 | 1 | 179.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 5 | 1 | 117.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 6 | 1 | 414.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 7 | 1 | 2404.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 8 | 1 | 9789.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 9 | 1 | 62675.00 | 13.40 | 8.50 | 13.40 | 8.50 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 96.10 | 3.90 | 96.10 | 3.90 |
| 2 | 1 | 3.00 | 88.10 | 4.30 | 88.10 | 4.30 |
| 3 | 1 | 5.00 | 80.00 | 4.80 | 80.00 | 4.80 |
| 4 | 1 | 12.00 | 72.00 | 5.20 | 72.00 | 5.20 |
| 5 | 1 | 46.00 | 64.00 | 5.60 | 64.00 | 5.60 |
| 6 | 1 | 78.00 | 55.90 | 6.00 | 55.90 | 6.00 |
| 7 | 1 | 165.00 | 47.90 | 6.40 | 47.90 | 6.40 |
| 8 | 1 | 493.00 | 39.90 | 6.80 | 39.90 | 6.80 |
| 9 | 1 | 2229.00 | 31.90 | 7.20 | 31.90 | 7.20 |
| 10 | 1 | 2132.00 | 23.80 | 7.60 | 23.80 | 7.60 |
| 11 | 1 | 2920.00 | 21.40 | 7.80 | 21.40 | 7.80 |
| 12 | 1 | 22272.00 | 19.80 | 7.80 | 19.80 | 7.80 |
| 13 | 1 | 82954.00 | 18.20 | 7.90 | 18.20 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 13.76: | 2.10: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 | 11.28: | 2.40: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 | 9.56: | 2.59: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 | 8.21: | 2.74: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 | 7.31: | 2.81: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 | 6.67: | 2.89: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 | 6.19: | 2.96: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 | 5.96: | 2.96: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 16.16: | 1.84: | 0.00: | 0.00: |
| 2: | 1: | 594.00 | 16.16: | 1.84: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 | 8.47: | 2.70: | 0.00: | 0.00: |
| 4: | 1: | 30.00 | 16.16: | 1.84: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 | 16.16: | 1.84: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 5.29: | 3.19: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 5.21: | 3.19: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 5.14: | 3.19: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 5.06: | 3.19: | 0.00: | 0.00: |
| 5: | 1: | 117.00 | 5.29: | 3.19: | 0.00: | 0.00: |
| 6: | 1: | 414.00 | 5.21: | 3.19: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7: | 1: | 2404.00 : | 5.14: | 3.19: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 5.06: | 3.19: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 5.02: | 3.19: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 36.03: | 1.46: | 0.00: | 0.00: |
| 2: | 1: | 3.00 : | 33.03: | 1.61: | 0.00: | 0.00: |
| 3: | 1: | 5.00 : | 29.99: | 1.80: | 0.00: | 0.00: |
| 4: | 1: | 12.00 : | 26.99: | 1.95: | 0.00: | 0.00: |
| 5: | 1: | 46.00 : | 23.99: | 2.10: | 0.00: | 0.00: |
| 6: | 1: | 78.00 : | 20.96: | 2.25: | 0.00: | 0.00: |
| 7: | 1: | 165.00 : | 17.96: | 2.40: | 0.00: | 0.00: |
| 8: | 1: | 493.00 : | 14.96: | 2.55: | 0.00: | 0.00: |
| 9: | 1: | 2229.00 : | 11.96: | 2.70: | 0.00: | 0.00: |
| 10: | 1: | 2132.00 : | 8.92: | 2.85: | 0.00: | 0.00: |
| 11: | 1: | 2920.00 : | 8.02: | 2.92: | 0.00: | 0.00: |
| 12: | 1: | 22272.00 : | 7.42: | 2.92: | 0.00: | 0.00: |
| 13: | 1: | 82954.00 : | 6.82: | 2.96: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Only Cold Launch
MODEL: CC03

ANALYSIS RESULTS:

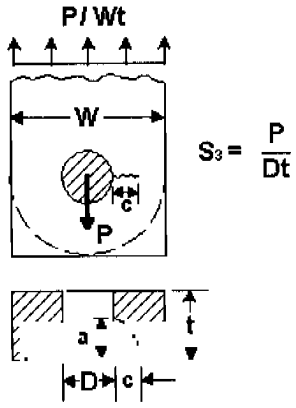
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10058 | 0.10011 | 13.274 | 10.673 |
| 1 | 2 | 3907160. | 0.10117 | 0.10022 | 13.289 | 10.713 |
| 1 | 3 | 5860740. | 0.10176 | 0.10033 | 13.305 | 10.753 |
| 1 | 4 | 7814320. | 0.10237 | 0.10044 | 13.320 | 10.793 |
| 1 | 5 | 8546056. | 0.11319 | 0.10576 | 16.158 | 13.436 |
| 1 | 6 | 9277792. | 0.12544 | 0.11237 | 16.807 | 14.304 |
| 1 | 7 | 10009528. | 0.13960 | 0.12068 | 17.560 | 15.253 |
| 1 | 8 | 10741264. | 0.16928 | 0.13267 | 18.879 | 17.503 |
| 1 | 9 | 10816970. | 0.16928 | 0.13267 | 6.167 | 5.717 |
| 1 | 10 | 10892676. | 0.16928 | 0.13267 | 6.167 | 5.717 |
| 1 | 11 | 10968382. | 0.16928 | 0.13267 | 6.167 | 5.717 |
| 1 | 12 | 11044088. | 0.16928 | 0.13267 | 6.167 | 5.717 |
| 1 | 13 | 11157398. | 0.17031 | 0.13345 | 42.035 | 38.963 |
| 1 | 14 | 11270708. | 0.17135 | 0.13423 | 42.193 | 39.134 |
| 1 | 15 | 11384018. | 0.17241 | 0.13504 | 42.354 | 39.308 |
| 1 | 16 | 11497328. | 0.17351 | 0.13586 | 42.518 | 39.486 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 17 | 11610638. | 0.17463 | 0.13669 | 42.686 | 39.673 |
| 1 | 18 | 11723948. | 0.17578 | 0.13753 | 42.858 | 39.865 |
| 1 | 19 | 11837258. | 0.17694 | 0.13840 | 43.034 | 40.061 |
| 1 | 20 | 11950568. | 0.17812 | 0.13928 | 43.214 | 40.263 |
| 1 | 21 | 12063878. | 0.17933 | 0.14018 | 43.397 | 40.470 |
| 1 | 22 | 12177188. | 0.18056 | 0.14109 | 43.585 | 40.682 |
| 1 | 23 | 12290498. | 0.18180 | 0.14202 | 43.777 | 40.900 |
| 1 | 24 | 12403808. | 0.18307 | 0.14298 | 43.974 | 41.123 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 82954.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.183073 , c = 0.142976 , a/c = 1.2804
Total Cycles = 12403808.

| Prepared By | Name/Date<br>Saike Wang<br>4/15/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Warmclevis_gg |
|---|---|---|---|---|
| Checked By | 4/15/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section G-G | | | |

## CC03




$S_3 = \frac{P}{Dt}$

| | | |
|---|---|---|
| Material: | AISI 316/316L (75F) | |
| NASA/FLAGRO Crack case type: | CC03 | |
| Section Properties: | | |
| Design Clevis Thickness | T=0.3930 in. | (Ref. SCD0678, Sec. G-G) |
| Plate thickness | t = 0.197 in. | (average thickness at Sec. G-G) |
| Plate width | w = 1.6380 in. | |
| Hole diameter | D = 0.7500 in. | |
| Crack Properties: | a = 0.1831 in. | (Ref. GG-clevis-cold-launch, P6) |
| | c = 0.1430 in. | |
| | a/c= 1.280 | |
| Loads: | | |
| Strap load (cryo) | f = 19102 lbf | (Ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 19102/2 = 9551 lbf | |

| Prepared By | Name/Date<br>Saike Wang<br>4/15/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Warmclevis_gg |
|---|---|---|---|---|
| Checked By | 4/15/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section G-G | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 9551/0.75*0.393=32.403 ksi

This clevis is part of the Strap at Section G-G. (Ref. Drawing SCD0678, issue 07, Section G-G)

This clevis is at room temperature (75F) for the Landing condition. The NASGRO analysis uses the landing case spectrum at room temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The landing spectrum is run for 3 missions with a scatter factor of 4. The final crack size from the cold launch condition a= 0.1831 in, c=0.1430 in, and a/c = 1.280 are used as the initial crack sizes for this model.

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/22/02 TIME: 10:12:10
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**G-G Lug With Warm Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section G-G)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1970
Plate Width, W = 1.6380
Hole Diameter, D = 0.7500

FLAW SIZE: **(User specified)**
**a (init.) = 0.1831** **(Ref. The final crack sizes from**
**c (init.) = 0.1430** **GG-clevis-cold-launch, Page 6)**
**a/c (init.) = 1.280**

MATERIAL

MATL 1: Edited file data ~2211
~2221

Material Header Info.:

Material 1 Data ID: F3KA13AB1
Alloy Description : AISI 316/316L ~261
1
Alloy Cond/HT : Ann sht & plt
~2621
Product Form : ~2631

Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **127.6** | **108.1** | 280.0 | 200.0 | 1.00 | 0.50 | 0.197 | 299.9 | |

| Matl No. | C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 3.50 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250mm thick)**
G-G Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: LAND_ONLY)**

Scale Factor for Stress S3: 0.32404 **(Ref. Warmclevis-gg.doc, Page 2)**

Schedule info. was input manually

Total No. of Blocks in Schedule = 12

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 12 | 1 |

Stresses: Tension, bending or pin

G-G Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

SINGLE DISTINCT BLOCK

| STEP | MATERIAL | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 100.00 | 3.70 | 100.00 | 3.70 |
| 2 | 1 | 1.00 | 91.30 | 4.20 | 91.30 | 4.20 |
| 3 | 1 | 3.00 | 82.60 | 4.70 | 82.60 | 4.70 |
| 4 | 1 | 3.00 | 74.00 | 5.20 | 74.00 | 5.20 |
| 5 | 1 | 3.00 | 65.30 | 5.70 | 65.30 | 5.70 |
| 6 | 1 | 3.00 | 56.60 | 6.10 | 56.60 | 6.10 |
| 7 | 1 | 13.00 | 47.90 | 6.60 | 47.90 | 6.60 |
| 8 | 1 | 148.00 | 39.20 | 7.10 | 39.20 | 7.10 |
| 9 | 1 | 891.00 | 30.60 | 7.60 | 30.60 | 7.60 |
| 10 | 1 | 1273.00 | 21.90 | 8.10 | 21.90 | 8.10 |
| 11 | 1 | 2099.00 | 19.30 | 8.20 | 19.30 | 8.20 |
| 12 | 1 | 6581.00 | 17.50 | 8.30 | 17.50 | 8.30 |
| 13 | 1 | 8701.00 | 15.80 | 8.40 | 15.80 | 8.40 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

One Block of Warm Landing

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 32.40 | 1.20 | 0.00 | 0.00 |
| 2 | 1 | 1.00 | 29.58 | 1.36 | 0.00 | 0.00 |
| 3 | 1 | 3.00 | 26.77 | 1.52 | 0.00 | 0.00 |
| 4 | 1 | 3.00 | 23.98 | 1.69 | 0.00 | 0.00 |
| 5 | 1 | 3.00 | 21.16 | 1.85 | 0.00 | 0.00 |
| 6 | 1 | 3.00 | 18.34 | 1.98 | 0.00 | 0.00 |
| 7 | 1 | 13.00 | 15.52 | 2.14 | 0.00 | 0.00 |
| 8 | 1 | 148.00 | 12.70 | 2.30 | 0.00 | 0.00 |
| 9 | 1 | 891.00 | 9.92 | 2.46 | 0.00 | 0.00 |
| 10 | 1 | 1273.00 | 7.10 | 2.62 | 0.00 | 0.00 |
| 11 | 1 | 2099.00 | 6.25 | 2.66 | 0.00 | 0.00 |
| 12 | 1 | 6581.00 | 5.67 | 2.69 | 0.00 | 0.00 |
| 13 | 1 | 8701.00 | 5.12 | 2.72 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

G-G Lug With Warm Landing
MODEL: CC03

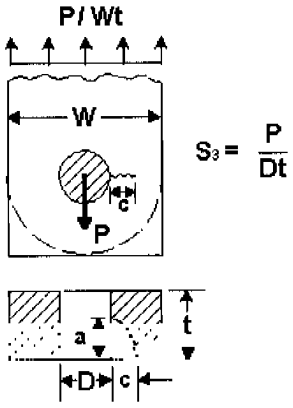
ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 19720. | 0.18340 | 0.14325 | 39.733 | 37.193 |
| 1 | 2 | 39440. | 0.18374 | 0.14351 | 39.783 | 37.248 |
| 1 | 3 | 59160. | 0.18408 | 0.14378 | 39.833 | 37.302 |
| 1 | 4 | 78880. | 0.18442 | 0.14405 | 39.883 | 37.358 |
| 1 | 5 | 98600. | 0.18476 | 0.14432 | 39.934 | 37.413 |
| 1 | 6 | 118320. | 0.18510 | 0.14460 | 39.985 | 37.469 |
| 1 | 7 | 138040. | 0.18545 | 0.14487 | 40.037 | 37.526 |
| 1 | 8 | 157760. | 0.18579 | 0.14515 | 40.089 | 37.583 |
| 1 | 9 | 177480. | 0.18614 | 0.14543 | 40.141 | 37.640 |
| 1 | 10 | 197200. | 0.18649 | 0.14571 | 40.194 | 37.698 |
| 1 | 11 | 216920. | 0.18684 | 0.14599 | 40.246 | 37.756 |
| 1 | 12 | 236640. | 0.18719 | 0.14627 | 40.299 | 37.814 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 8701.00
of Load Step No. 13 Description: None
of Block No. 12
of Schedule No. 1
Crack Sizes: a = 0.187188 , c = 0.146268 , a/c = 1.2798
Total Cycles = 236640.00

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Cryoclevis_hh |
|---|---|---|---|---|
| Checked By | 4/16/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section H-H | | | |

## CC03




| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.4016 in. (Ref. SCD0678, Sec. H-H) |
| Plate thickness | t = 0.201 in. (average thickness at Sec. H-H) |
| Plate width | w = 1.638 in. |
| Hole diameter | D = 0.7087 in. |
| Crack Properties: | a = 0.10 in.<br>c = 0.10 in. |
| Loads: | |
| Strap load (cryo) | f = 22099 lbf (Ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 22099/2 = 11050 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Cryoclevis_hh |
|---|---|---|---|---|
| Checked By | 4/16/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section H-H | | | |

Tensile Stress

S3 = Paxial/D*T

S3 = 11050/0.7087*0.4016=38.825 ksi

This clevis is part of the Strap at Section H-H. (Ref. Drawing SCD0678, issue 07, Section H-H)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch/Landing conditions. The NASGRO analysis uses truck air, On-orbit and Launch/Landing case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch/Landing spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section H-H, and the standard dye penetrant crack sizes a= 0.10 in and c = 0.10 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/21/02 TIME: 13:33:40
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**H-H Lug With Cold Launch and Landing for AMS02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section H-H)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.2010
Plate Width, W = 1.6380
Hole Diameter, D = 0.7087

FLAW SIZE: **(User specified)**
**Method of Inspection: Dye Penetrant**
a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L ~2611

Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.201 | 299.7 | |

| Matl No. | C | n | p | q | DKo | Cth+ | Cth- | Rc1 | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250 mm thick)**
H-H Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **[Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.38825 **(Ref. Cryoclevis_hh.doc, Page 2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.38825

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.38825

Stress Scaling Factors for Block Case: **4** **(GSFC-VCMAGNET)**

Scale Factor for Stress S3: 0.38825

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From | - | To | Block Case No. |
|---|---|---|---|
| 1 | - | 4 | 1 |
| 5 | - | 8 | 2 |
| 9 | - | 12 | 3 |
| 13 | - | 24 | 4 |

Stresses: Tension, bending or pin

H-H Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 36.70 | 5.60 | 36.70 | 5.60 |
| 2 | 1 | 2148.00 | 30.10 | 6.40 | 30.10 | 6.40 |
| 3 | 1 | 13668.00 | 25.50 | 6.90 | 25.50 | 6.90 |
| 4 | 1 | 38857.00 | 21.90 | 7.30 | 21.90 | 7.30 |
| 5 | 1 | 110517.00 | 19.50 | 7.50 | 19.50 | 7.50 |
| 6 | 1 | 150546.00 | 17.80 | 7.70 | 17.80 | 7.70 |
| 7 | 1 | 195456.00 | 16.50 | 7.90 | 16.50 | 7.90 |
| 8 | 1 | 1440631.00 | 15.90 | 7.90 | 15.90 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 2: | 1: | 594.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 3: | 1: | 695448.00 | 22.60: | 7.20: | 22.60: | 7.20: |
| 4: | 1: | 30.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 5: | 1: | 17832.00 | 43.10: | 4.90: | 43.10: | 4.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 14.10: | 8.50: | 14.10: | 8.50: |
| 2: | 1: | 34.00 | 13.90: | 8.50: | 13.90: | 8.50: |
| 3: | 1: | 60.00 | 13.70: | 8.50: | 13.70: | 8.50: |
| 4: | 1: | 179.00 | 13.50: | 8.50: | 13.50: | 8.50: |
| 5: | 1: | 117.00 | 14.10: | 8.50: | 14.10: | 8.50: |
| 6: | 1: | 414.00 | 13.90: | 8.50: | 13.90: | 8.50: |
| 7: | 1: | 2404.00 | 13.70: | 8.50: | 13.70: | 8.50: |
| 8: | 1: | 9789.00 | 13.50: | 8.50: | 13.50: | 8.50: |
| 9: | 1: | 62675.00 | 13.40: | 8.50: | 13.40: | 8.50: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 2.00 | 96.10: | 3.90: | 96.10: | 3.90: |
| 2: | 1: | 4.00 | 88.10: | 4.30: | 88.10: | 4.30: |
| 3: | 1: | 8.00 | 80.00: | 4.80: | 80.00: | 4.80: |
| 4: | 1: | 15.00 | 72.00: | 5.20: | 72.00: | 5.20: |
| 5: | 1: | 49.00 | 64.00: | 5.60: | 64.00: | 5.60: |
| 6: | 1: | 81.00 | 55.90: | 6.00: | 55.90: | 6.00: |
| 7: | 1: | 178.00 | 47.90: | 6.40: | 47.90: | 6.40: |
| 8: | 1: | 641.00 | 39.90: | 6.80: | 39.90: | 6.80: |
| 9: | 1: | 3120.00 | 31.90: | 7.20: | 31.90: | 7.20: |
| 10: | 1: | 3405.00 | 23.80: | 7.60: | 23.80: | 7.60: |
| 11: | 1: | 5019.00 | 21.40: | 7.80: | 21.40: | 7.80: |
| 12: | 1: | 28853.00 | 19.80: | 7.80: | 19.80: | 7.80: |
| 13: | 1: | 91655.00 | 18.20: | 7.90: | 18.20: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 14.25 | 2.17 | 0.00 | 0.00 |
| 2 | 1 | 2148.00 | 11.69 | 2.48 | 0.00 | 0.00 |
| 3 | 1 | 13668.00 | 9.90 | 2.68 | 0.00 | 0.00 |
| 4 | 1 | 38857.00 | 8.50 | 2.83 | 0.00 | 0.00 |
| 5 | 1 | 110517.00 | 7.57 | 2.91 | 0.00 | 0.00 |
| 6 | 1 | 150546.00 | 6.91 | 2.99 | 0.00 | 0.00 |
| 7 | 1 | 195456.00 | 6.41 | 3.07 | 0.00 | 0.00 |
| 8 | 1 | 1440631.00 | 6.17 | 3.07 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 16.73 | 1.90 | 0.00 | 0.00 |
| 2 | 1 | 594.00 | 16.73 | 1.90 | 0.00 | 0.00 |
| 3 | 1 | 695448.00 | 8.77 | 2.80 | 0.00 | 0.00 |
| 4 | 1 | 30.00 | 16.73 | 1.90 | 0.00 | 0.00 |
| 5 | 1 | 17832.00 | 16.73 | 1.90 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 5.47 | 3.30 | 0.00 | 0.00 |
| 2 | 1 | 34.00 | 5.40 | 3.30 | 0.00 | 0.00 |
| 3 | 1 | 60.00 | 5.32 | 3.30 | 0.00 | 0.00 |
| 4 | 1 | 179.00 | 5.24 | 3.30 | 0.00 | 0.00 |
| 5 | 1 | 117.00 | 5.47 | 3.30 | 0.00 | 0.00 |
| 6 | 1 | 414.00 | 5.40 | 3.30 | 0.00 | 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7: | 1: | 2404.00 : | 5.32: | 3.30: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 5.24: | 3.30: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 5.20: | 3.30: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 2.00 : | 37.31: | 1.51: | 0.00: | 0.00: |
| 2: | 1: | 4.00 : | 34.20: | 1.67: | 0.00: | 0.00: |
| 3: | 1: | 8.00 : | 31.06: | 1.86: | 0.00: | 0.00: |
| 4: | 1: | 15.00 : | 27.95: | 2.02: | 0.00: | 0.00: |
| 5: | 1: | 49.00 : | 24.85: | 2.17: | 0.00: | 0.00: |
| 6: | 1: | 81.00 : | 21.70: | 2.33: | 0.00: | 0.00: |
| 7: | 1: | 178.00 : | 18.60: | 2.48: | 0.00: | 0.00: |
| 8: | 1: | 641.00 : | 15.49: | 2.64: | 0.00: | 0.00: |
| 9: | 1: | 3120.00 : | 12.39: | 2.80: | 0.00: | 0.00: |
| 10: | 1: | 3405.00 : | 9.24: | 2.95: | 0.00: | 0.00: |
| 11: | 1: | 5019.00 : | 8.31: | 3.03: | 0.00: | 0.00: |
| 12: | 1: | 28853.00 : | 7.69: | 3.03: | 0.00: | 0.00: |
| 13: | 1: | 91655.00 : | 7.07: | 3.07: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Cold Launch and Landing
MODEL: CC03

ANALYSIS RESULTS:

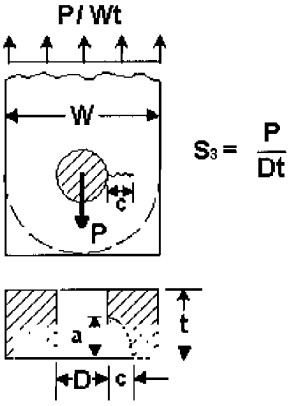
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10032 | 0.10008 | 12.639 | 9.995 |
| 1 | 2 | 3907160. | 0.10063 | 0.10016 | 12.647 | 10.014 |
| 1 | 3 | 5860740. | 0.10095 | 0.10024 | 12.656 | 10.033 |
| 1 | 4 | 7814320. | 0.10127 | 0.10032 | 12.664 | 10.052 |
| 1 | 5 | 8546056. | 0.11016 | 0.10426 | 15.236 | 12.381 |
| 1 | 6 | 9277792. | 0.11989 | 0.10899 | 15.643 | 12.977 |
| 1 | 7 | 10009528. | 0.13063 | 0.11464 | 16.110 | 13.617 |
| 1 | 8 | 10741264. | 0.14263 | 0.12144 | 16.652 | 14.323 |
| 1 | 9 | 10816970. | 0.14263 | 0.12144 | 5.450 | 4.689 |
| 1 | 10 | 10892676. | 0.14263 | 0.12144 | 5.450 | 4.689 |
| 1 | 11 | 10968382. | 0.14263 | 0.12144 | 5.450 | 4.689 |
| 1 | 12 | 11044088. | 0.14263 | 0.12144 | 5.450 | 4.689 |
| 1 | 13 | 11177118. | 0.14340 | 0.12188 | 37.148 | 31.960 |
| 1 | 14 | 11310148. | 0.14418 | 0.12233 | 37.227 | 32.064 |
| 1 | 15 | 11443178. | 0.14497 | 0.12278 | 37.308 | 32.169 |
| 1 | 16 | 11576208. | 0.14576 | 0.12324 | 37.389 | 32.275 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 17 | 11709238. | 0.14656 | 0.12370 | 37.471 | 32.381 |
| 1 | 18 | 11842268. | 0.14740 | 0.12417 | 37.555 | 32.489 |
| 1 | 19 | 11975298. | 0.14825 | 0.12465 | 37.640 | 32.603 |
| 1 | 20 | 12108328. | 0.14911 | 0.12513 | 37.726 | 32.718 |
| 1 | 21 | 12241358. | 0.14998 | 0.12562 | 37.814 | 32.836 |
| 1 | 22 | 12374388. | 0.15086 | 0.12612 | 37.903 | 32.955 |
| 1 | 23 | 12507418. | 0.15176 | 0.12662 | 37.993 | 33.076 |
| 1 | 24 | 12640448. | 0.15266 | 0.12713 | 38.085 | 33.198 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 91655.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.152659 , c = 0.127134 , a/c = 1.2008
Total Cycles = 12640448.

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Coldclevis_hh |
|---|---|---|---|---|
| Checked By | 4/16/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section H-H | | | |

## CC03




| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.4016 in. (Ref. SCD0678, Sec. H-H) |
| Plate thickness | t = 0.201 in. (average thickness at Sec. H-H) |
| Plate width | w = 1.6380 in. |
| Hole diameter | D = 0.7087 in. |
| Crack Properties: | a = 0.10 in.<br>c = 0.10 in. |
| Loads: | |
| Strap load (cryo) | f = 22099 lbf (ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 22099/2 = 11050 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Coldclevis_hh |
|---|---|---|---|---|
| Checked By | 4/16/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section H-H | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 11050/0.7087*0.4016=38.825 ksi

This clevis is part of the Strap at Section H-H. (Ref. Drawing SCD0678, issue 07, Section H-H)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch conditions. The NASGRO analysis uses truck air, On-orbit and Launch case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section H-H, and the standard dye penetrant crack sizes a= 0.10 in and c = 0.10 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/22/02 TIME: 08:32:54
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**H-H Lug With Only Cold Launch for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section H-H)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY
MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.2010
Plate Width, W = 1.6380
Hole Diameter, D = 0.7087

FLAW SIZE: **(User specified)**
**Method of Inspection: Dye Penetrant**
a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL
MATL 1: Edited file data ~2211
~2221

Material Header Info.:

Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L
~2611
Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl No. | UTS | YS | Kle | Klc | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.201 | 299.7 | |

| Matl No. | Crack Growth Eqn Constants | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250 mm thick)**
H-H Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: TRUCK3-VCMAGNET**

Scale Factor for Stress S3: 0.38825 **(Ref. Coldclevis_hh.doc, Page2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.38825

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.38825

Stress Scaling Factors for Block Case: **4** **(LIFTOFF-ONLY)**

Scale Factor for Stress S3: 0.38825

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From | - | To | Block Case No. |
|---|---|---|---|
| 1 | - | 4 | 1 |
| 5 | - | 8 | 2 |
| 9 | - | 12 | 3 |
| 13 | - | 24 | 4 |

Stresses: Tension, bending or pin

H-H Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 36.70 | 5.60 | 36.70 | 5.60 |
| 2 | 1 | 2148.00 | 30.10 | 6.40 | 30.10 | 6.40 |
| 3 | 1 | 13668.00 | 25.50 | 6.90 | 25.50 | 6.90 |
| 4 | 1 | 38857.00 | 21.90 | 7.30 | 21.90 | 7.30 |
| 5 | 1 | 110517.00 | 19.50 | 7.50 | 19.50 | 7.50 |
| 6 | 1 | 150546.00 | 17.80 | 7.70 | 17.80 | 7.70 |
| 7 | 1 | 195456.00 | 16.50 | 7.90 | 16.50 | 7.90 |
| 8 | 1 | 1440631.00 | 15.90 | 7.90 | 15.90 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 2: | 1: | 594.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 3: | 1: | 695448.00 : | 22.60: | 7.20: | 22.60: | 7.20: |
| 4: | 1: | 30.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 5: | 1: | 17832.00 : | 43.10: | 4.90: | 43.10: | 4.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 : | 14.10: | 8.50: | 14.10: | 8.50: |
| 2: | 1: | 34.00 : | 13.90: | 8.50: | 13.90: | 8.50: |
| 3: | 1: | 60.00 : | 13.70: | 8.50: | 13.70: | 8.50: |
| 4: | 1: | 179.00 : | 13.50: | 8.50: | 13.50: | 8.50: |
| 5: | 1: | 117.00 : | 14.10: | 8.50: | 14.10: | 8.50: |
| 6: | 1: | 414.00 : | 13.90: | 8.50: | 13.90: | 8.50: |
| 7: | 1: | 2404.00 : | 13.70: | 8.50: | 13.70: | 8.50: |
| 8: | 1: | 9789.00 : | 13.50: | 8.50: | 13.50: | 8.50: |
| 9: | 1: | 62675.00 : | 13.40: | 8.50: | 13.40: | 8.50: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 96.10: | 3.90: | 96.10: | 3.90: |
| 2: | 1: | 3.00 : | 88.10: | 4.30: | 88.10: | 4.30: |
| 3: | 1: | 5.00 : | 80.00: | 4.80: | 80.00: | 4.80: |
| 4: | 1: | 12.00 : | 72.00: | 5.20: | 72.00: | 5.20: |
| 5: | 1: | 46.00 : | 64.00: | 5.60: | 64.00: | 5.60: |
| 6: | 1: | 78.00 : | 55.90: | 6.00: | 55.90: | 6.00: |
| 7: | 1: | 165.00 : | 47.90: | 6.40: | 47.90: | 6.40: |
| 8: | 1: | 493.00 : | 39.90: | 6.80: | 39.90: | 6.80: |
| 9: | 1: | 2229.00 : | 31.90: | 7.20: | 31.90: | 7.20: |
| 10: | 1: | 2132.00 : | 23.80: | 7.60: | 23.80: | 7.60: |
| 11: | 1: | 2920.00 : | 21.40: | 7.80: | 21.40: | 7.80: |
| 12: | 1: | 22272.00 : | 19.80: | 7.80: | 19.80: | 7.80: |
| 13: | 1: | 82954.00 : | 18.20: | 7.90: | 18.20: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 14.25: | 2.17: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 : | 11.69: | 2.48: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 : | 9.90: | 2.68: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 : | 8.50: | 2.83: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 : | 7.57: | 2.91: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 : | 6.91: | 2.99: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 : | 6.41: | 3.07: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 : | 6.17: | 3.07: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 : | 16.73: | 1.90: | 0.00: | 0.00: |
| 2: | 1: | 594.00 : | 16.73: | 1.90: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 : | 8.77: | 2.80: | 0.00: | 0.00: |
| 4: | 1: | 30.00 : | 16.73: | 1.90: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 : | 16.73: | 1.90: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 : | 5.47: | 3.30: | 0.00: | 0.00: |
| 2: | 1: | 34.00 : | 5.40: | 3.30: | 0.00: | 0.00: |
| 3: | 1: | 60.00 : | 5.32: | 3.30: | 0.00: | 0.00: |
| 4: | 1: | 179.00 : | 5.24: | 3.30: | 0.00: | 0.00: |
| 5: | 1: | 117.00 : | 5.47: | 3.30: | 0.00: | 0.00: |
| 6: | 1: | 414.00 : | 5.40: | 3.30: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7: | 1: | 2404.00 : | 5.32: | 3.30: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 5.24: | 3.30: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 5.20: | 3.30: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 37.31: | 1.51: | 0.00: | 0.00: |
| 2: | 1: | 3.00 : | 34.20: | 1.67: | 0.00: | 0.00: |
| 3: | 1: | 5.00 : | 31.06: | 1.86: | 0.00: | 0.00: |
| 4: | 1: | 12.00 : | 27.95: | 2.02: | 0.00: | 0.00: |
| 5: | 1: | 46.00 : | 24.85: | 2.17: | 0.00: | 0.00: |
| 6: | 1: | 78.00 : | 21.70: | 2.33: | 0.00: | 0.00: |
| 7: | 1: | 165.00 : | 18.60: | 2.48: | 0.00: | 0.00: |
| 8: | 1: | 493.00 : | 15.49: | 2.64: | 0.00: | 0.00: |
| 9: | 1: | 2229.00 : | 12.39: | 2.80: | 0.00: | 0.00: |
| 10: | 1: | 2132.00 : | 9.24: | 2.95: | 0.00: | 0.00: |
| 11: | 1: | 2920.00 : | 8.31: | 3.03: | 0.00: | 0.00: |
| 12: | 1: | 22272.00 : | 7.69: | 3.03: | 0.00: | 0.00: |
| 13: | 1: | 82954.00 : | 7.07: | 3.07: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Only Cold Launch
MODEL: CC03

ANALYSIS RESULTS:

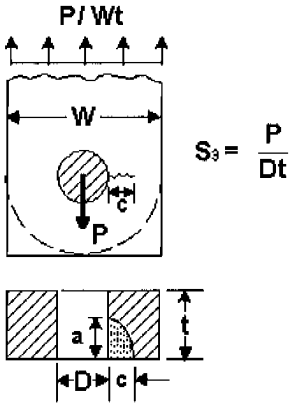
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10032 | 0.10008 | 12.639 | 9.995 |
| 1 | 2 | 3907160. | 0.10063 | 0.10016 | 12.648 | 10.014 |
| 1 | 3 | 5860740. | 0.10095 | 0.10024 | 12.656 | 10.033 |
| 1 | 4 | 7814320. | 0.10127 | 0.10032 | 12.664 | 10.052 |
| 1 | 5 | 8546056. | 0.11016 | 0.10426 | 15.236 | 12.381 |
| 1 | 6 | 9277792. | 0.11989 | 0.10899 | 15.644 | 12.977 |
| 1 | 7 | 10009528. | 0.13063 | 0.11465 | 16.110 | 13.617 |
| 1 | 8 | 10741264. | 0.14263 | 0.12144 | 16.652 | 14.323 |
| 1 | 9 | 10816970. | 0.14263 | 0.12144 | 5.450 | 4.689 |
| 1 | 10 | 10892676. | 0.14263 | 0.12144 | 5.450 | 4.689 |
| 1 | 11 | 10968382. | 0.14263 | 0.12144 | 5.450 | 4.689 |
| 1 | 12 | 11044088. | 0.14263 | 0.12144 | 5.450 | 4.689 |
| 1 | 13 | 11157398. | 0.14324 | 0.12179 | 37.146 | 31.958 |
| 1 | 14 | 11270708. | 0.14385 | 0.12214 | 37.209 | 32.040 |
| 1 | 15 | 11384018. | 0.14447 | 0.12250 | 37.273 | 32.123 |
| 1 | 16 | 11497328. | 0.14510 | 0.12286 | 37.337 | 32.206 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 17 | 11610638. | 0.14572 | 0.12322 | 37.402 | 32.290 |
| 1 | 18 | 11723948. | 0.14635 | 0.12359 | 37.467 | 32.374 |
| 1 | 19 | 11837258. | 0.14701 | 0.12396 | 37.533 | 32.459 |
| 1 | 20 | 11950568. | 0.14767 | 0.12434 | 37.600 | 32.547 |
| 1 | 21 | 12063878. | 0.14833 | 0.12472 | 37.668 | 32.637 |
| 1 | 22 | 12177188. | 0.14901 | 0.12510 | 37.736 | 32.727 |
| 1 | 23 | 12290498. | 0.14969 | 0.12549 | 37.805 | 32.819 |
| 1 | 24 | 12403808. | 0.15037 | 0.12588 | 37.876 | 32.912 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 82954.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.150373 , c = 0.125880 , a/c = 1.1946
Total Cycles = 12403808.

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Warmclevis_hh |
|---|---|---|---|---|
| Checked By | 4/16/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section H-H | | | |

## CC03




$S_3 = \frac{P}{Dt}$

Material: AISI 316/316L (75F)

NASA/FLAGRO Crack case type: CC03

Section Properties:

| | | |
|---|---|---|
| Design Clevis Thickness | T=0.4016 in. | (Ref. SCD0678, Sec. H-H) |
| Plate thickness | t = 0.201 in. | (average thickness at Sec. H-H) |
| Plate width | w = 1.638 in. | |
| Hole diameter | D = 0.7087 in. | |

Crack Properties:

a = 0.1504 in. (Ref. HH-clevis-cold-launch, P6)
c = 0.1259 in.
a/c= 1.1946

Loads:

| | |
|---|---|
| Strap load (cryo) | f = 19102 lbf (Ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 19102/2 = 9551 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Warmclevis_hh |
|---|---|---|---|---|
| Checked By | 4/16/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section H-H | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 9551/0.7087*0.4016=33.558 ksi

This clevis is part of the Strap at Section H-H. (Ref. Drawing SCD0678, issue 07, Section H-H)

This clevis is at room temperature (75F) for the Landing condition. The NASGRO analysis uses the landing case spectrum at room temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The landing spectrum is run for 3 missions with a scatter factor of 4. The final crack size from the cold launch condition a= 0.1504 in, c=0.1259 in, and a/c = 1.1946 are used as the initial crack sizes for this model.

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/22/02 TIME: 10:22:05
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**H-H Lug With Warm Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section H-H)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY
MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.2010
Plate Width, W = 1.6380
Hole Diameter, D = 0.7087

FLAW SIZE: **(User specified)**
**a (init.) = 0.1504** **(Ref. The final crack sizes from**
**c (init.) = 0.1259** **HH-clevis-cold-launch, Page 6)**
**a/c (init.) = 1.195**

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13AB1
Alloy Description : AISI 316/316L ~261
1
Alloy Cond/HT : Ann sht & plt
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **127.6** | **108.1** | 280.0 | 200.0 | 1.00 | 0.50 | 0.201 | 299.9 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 3.50 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250mm thick)**
H-H Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: 1 **(Name Block: LAND_ONLY)**

Scale Factor for Stress S3: 0.33558 **(Ref. Warmclevis-hh.doc, Page 2)**

Schedule info. was input manually

Total No. of Blocks in Schedule = 12

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 12 | 1 |

Stresses: Tension, bending or pin

H-H Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

SINGLE DISTINCT BLOCK

| STEP | MAT: NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|
| 1: | 1: 1.00 | 100.00: | 3.70: | 100.00: | 3.70: |
| 2: | 1: 1.00 | 91.30: | 4.20: | 91.30: | 4.20: |
| 3: | 1: 3.00 | 82.60: | 4.70: | 82.60: | 4.70: |
| 4: | 1: 3.00 | 74.00: | 5.20: | 74.00: | 5.20: |
| 5: | 1: 3.00 | 65.30: | 5.70: | 65.30: | 5.70: |
| 6: | 1: 3.00 | 56.60: | 6.10: | 56.60: | 6.10: |
| 7: | 1: 13.00 | 47.90: | 6.60: | 47.90: | 6.60: |
| 8: | 1: 148.00 | 39.20: | 7.10: | 39.20: | 7.10: |
| 9: | 1: 891.00 | 30.60: | 7.60: | 30.60: | 7.60: |
| 10: | 1: 1273.00 | 21.90: | 8.10: | 21.90: | 8.10: |
| 11: | 1: 2099.00 | 19.30: | 8.20: | 19.30: | 8.20: |
| 12: | 1: 6581.00 | 17.50: | 8.30: | 17.50: | 8.30: |
| 13: | 1: 8701.00 | 15.80: | 8.40: | 15.80: | 8.40: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

One Block of Warm Landing

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 33.56: | 1.24: | 0.00: | 0.00: |
| 2: | 1: | 1.00 : | 30.64: | 1.41: | 0.00: | 0.00: |
| 3: | 1: | 3.00 : | 27.72: | 1.58: | 0.00: | 0.00: |
| 4: | 1: | 3.00 : | 24.83: | 1.75: | 0.00: | 0.00: |
| 5: | 1: | 3.00 : | 21.91: | 1.91: | 0.00: | 0.00: |
| 6: | 1: | 3.00 : | 18.99: | 2.05: | 0.00: | 0.00: |
| 7: | 1: | 13.00 : | 16.07: | 2.21: | 0.00: | 0.00: |
| 8: | 1: | 148.00 : | 13.15: | 2.38: | 0.00: | 0.00: |
| 9: | 1: | 891.00 : | 10.27: | 2.55: | 0.00: | 0.00: |
| 10: | 1: | 1273.00 : | 7.35: | 2.72: | 0.00: | 0.00: |
| 11: | 1: | 2099.00 : | 6.48: | 2.75: | 0.00: | 0.00: |
| 12: | 1: | 6581.00 : | 5.87: | 2.79: | 0.00: | 0.00: |
| 13: | 1: | 8701.00 : | 5.30: | 2.82: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

H-H Lug With Warm Landing
MODEL: CC03

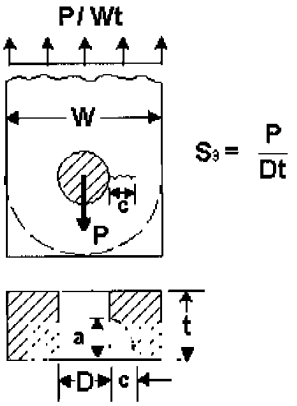
ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 19720. | 0.15057 | 0.12599 | 34.129 | 29.685 |
| 1 | 2 | 39440. | 0.15076 | 0.12610 | 34.148 | 29.710 |
| 1 | 3 | 59160. | 0.15096 | 0.12622 | 34.166 | 29.734 |
| 1 | 4 | 78880. | 0.15116 | 0.12633 | 34.185 | 29.758 |
| 1 | 5 | 98600. | 0.15135 | 0.12645 | 34.203 | 29.782 |
| 1 | 6 | 118320. | 0.15155 | 0.12656 | 34.222 | 29.806 |
| 1 | 7 | 138040. | 0.15175 | 0.12668 | 34.241 | 29.830 |
| 1 | 8 | 157760. | 0.15195 | 0.12680 | 34.260 | 29.855 |
| 1 | 9 | 177480. | 0.15215 | 0.12692 | 34.279 | 29.879 |
| 1 | 10 | 197200. | 0.15235 | 0.12703 | 34.298 | 29.904 |
| 1 | 11 | 216920. | 0.15255 | 0.12715 | 34.317 | 29.928 |
| 1 | 12 | 236640. | 0.15275 | 0.12727 | 34.336 | 29.953 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 8701.00
of Load Step No. 13 Description: None
of Block No. 12
of Schedule No. 1
Crack Sizes: a = 0.152750 , c = 0.127272 , a/c = 1.2002
Total Cycles = 236640.00

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Cryoclevis_jj |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section J-J | | | |

## CC03




$S_b = \frac{P}{Dt}$

| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.3504 in.(Ref. SCD0678, Sec. J-J) |
| Plate thickness | t = 0.1752 in.(average thickness at Sec. J-J) |
| Plate width | w = 1.449 in. |
| Hole diameter | D = 0.5512 in. |
| Crack Properties: | a = 0.10 in.<br>c = 0.10 in. |
| Loads: | |
| Strap load (cryo) | f = 8546 lbf (ref. John Ross Fax 1140 on 2/6/02) |
| Load per side on clevis | Paxial = 8546/2 = 4273 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Cryoclavis_jj |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section J-J | | | |

Tensile Stress

S3 = Paxial/D*T

S3 = 4273/0.5512*0.3504=22.124 ksi

This clevis is part of the Strap at Section J-J. (Ref. Drawing SCD0678, issue 07, Section J-J)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch/Landing conditions. The NASGRO analysis uses truck air, On-orbit and Launch/Landing case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch/Landing spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section J-J, and the standard dye penetrant crack sizes a= 0.10 in and c = 0.10 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/16/02 TIME: 15:40:05
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**J-J Lug With Cold Launch and Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section J-J)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1752
Plate Width, W = 1.4490
Hole Diameter, D = 0.5512

FLAW SIZE: (**User specified**)
**Method of Inspection: Dye Penetrant**
a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL
MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L ~2611

Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.175 | 299.8 | |

| Matl No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev. D, Page 25 for UTS and YS of 316L, 250 mm thick)**
J-J Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.22124 **(Ref. Cryoclevis_jj.doc, Page 2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.22124

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.22124

Stress Scaling Factors for Block Case: **4** **(GSFC-VCMAGNET)**

Scale Factor for Stress S3: 0.22124

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From | - | To | Block Case No. |
|---|---|---|---|
| 1 | - | 4 | 1 |
| 5 | - | 8 | 2 |
| 9 | - | 12 | 3 |
| 13 | - | 24 | 4 |

Stresses: Tension, bending or pin

---

J-J Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 36.70: | 5.60: | 36.70: | 5.60: |
| 2: | 1: | 2148.00 : | 30.10: | 6.40: | 30.10: | 6.40: |
| 3: | 1: | 13668.00 : | 25.50: | 6.90: | 25.50: | 6.90: |
| 4: | 1: | 38857.00 : | 21.90: | 7.30: | 21.90: | 7.30: |
| 5: | 1: | 110517.00 : | 19.50: | 7.50: | 19.50: | 7.50: |
| 6: | 1: | 150546.00 : | 17.80: | 7.70: | 17.80: | 7.70: |
| 7: | 1: | 195456.00 : | 16.50: | 7.90: | 16.50: | 7.90: |
| 8: | 1: | 1440631.00 : | 15.90: | 7.90: | 15.90: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses

(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 2 | 1 | 594.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 3 | 1 | 695448.00 | 22.60 | 7.20 | 22.60 | 7.20 |
| 4 | 1 | 30.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 5 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 2 | 1 | 34.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 3 | 1 | 60.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 4 | 1 | 179.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 5 | 1 | 117.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 6 | 1 | 414.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 7 | 1 | 2404.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 8 | 1 | 9789.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 9 | 1 | 62675.00 | 13.40 | 8.50 | 13.40 | 8.50 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 2.00 | 96.10 | 3.90 | 96.10 | 3.90 |
| 2 | 1 | 4.00 | 88.10 | 4.30 | 88.10 | 4.30 |
| 3 | 1 | 8.00 | 80.00 | 4.80 | 80.00 | 4.80 |
| 4 | 1 | 15.00 | 72.00 | 5.20 | 72.00 | 5.20 |
| 5 | 1 | 49.00 | 64.00 | 5.60 | 64.00 | 5.60 |
| 6 | 1 | 81.00 | 55.90 | 6.00 | 55.90 | 6.00 |
| 7 | 1 | 178.00 | 47.90 | 6.40 | 47.90 | 6.40 |
| 8 | 1 | 641.00 | 39.90 | 6.80 | 39.90 | 6.80 |
| 9 | 1 | 3120.00 | 31.90 | 7.20 | 31.90 | 7.20 |
| 10 | 1 | 3405.00 | 23.80 | 7.60 | 23.80 | 7.60 |
| 11 | 1 | 5019.00 | 21.40 | 7.80 | 21.40 | 7.80 |
| 12 | 1 | 28853.00 | 19.80 | 7.80 | 19.80 | 7.80 |
| 13 | 1 | 91655.00 | 18.20 | 7.90 | 18.20 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses

(Kmax less than Keac): NOT SET

J-J Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 8.12: | 1.24: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 | 6.66: | 1.42: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 | 5.64: | 1.53: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 | 4.85: | 1.62: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 | 4.31: | 1.66: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 | 3.94: | 1.70: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 | 3.65: | 1.75: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 | 3.52: | 1.75: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 9.54: | 1.08: | 0.00: | 0.00: |
| 2: | 1: | 594.00 | 9.54: | 1.08: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 | 5.00: | 1.59: | 0.00: | 0.00: |
| 4: | 1: | 30.00 | 9.54: | 1.08: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 | 9.54: | 1.08: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 3.12: | 1.88: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 3.08: | 1.88: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 3.03: | 1.88: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 2.99: | 1.88: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5: | 1: | 117.00 : | 3.12: | 1.88: | 0.00: | 0.00: |
| 6: | 1: | 414.00 : | 3.08: | 1.88: | 0.00: | 0.00: |
| 7: | 1: | 2404.00 : | 3.03: | 1.88: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 2.99: | 1.88: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 2.96: | 1.88: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S | M: | NUMBER | S3 | | S | |
|---|---|---|---|---|---|---|
| T | A: | OF | | | | |
| E | T: | FATIGUE | (ksi) | | (ksi) | |
| P | L: | CYCLES | (t1) | (t2) | (t1) | (t2) |
| 1: | 1: | 2.00 : | 21.26: | 0.86: | 0.00: | 0.00: |
| 2: | 1: | 4.00 : | 19.49: | 0.95: | 0.00: | 0.00: |
| 3: | 1: | 8.00 : | 17.70: | 1.06: | 0.00: | 0.00: |
| 4: | 1: | 15.00 : | 15.93: | 1.15: | 0.00: | 0.00: |
| 5: | 1: | 49.00 : | 14.16: | 1.24: | 0.00: | 0.00: |
| 6: | 1: | 81.00 : | 12.37: | 1.33: | 0.00: | 0.00: |
| 7: | 1: | 178.00 : | 10.60: | 1.42: | 0.00: | 0.00: |
| 8: | 1: | 641.00 : | 8.83: | 1.50: | 0.00: | 0.00: |
| 9: | 1: | 3120.00 : | 7.06: | 1.59: | 0.00: | 0.00: |
| 10: | 1: | 3405.00 : | 5.27: | 1.68: | 0.00: | 0.00: |
| 11: | 1: | 5019.00 : | 4.73: | 1.73: | 0.00: | 0.00: |
| 12: | 1: | 28853.00 : | 4.38: | 1.73: | 0.00: | 0.00: |
| 13: | 1: | 91655.00 : | 4.03: | 1.75: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Cold Launch and Landing
MODEL: CC03

ANALYSIS RESULTS:

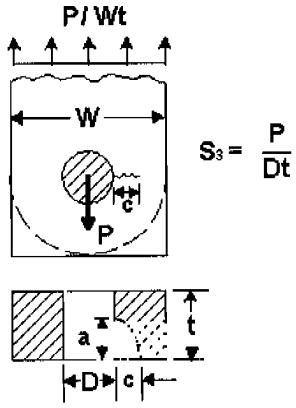
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10000 | 0.10000 | 6.075 | 4.622 |
| 1 | 2 | 3907160. | 0.10000 | 0.10000 | 6.075 | 4.622 |
| 1 | 3 | 5860740. | 0.10000 | 0.10000 | 6.075 | 4.622 |
| 1 | 4 | 7814320. | 0.10000 | 0.10000 | 6.075 | 4.622 |
| 1 | 5 | 8546056. | 0.10000 | 0.10000 | 7.135 | 5.428 |
| 1 | 6 | 9277792. | 0.10000 | 0.10000 | 7.135 | 5.428 |
| 1 | 7 | 10009528. | 0.10000 | 0.10000 | 7.135 | 5.428 |
| 1 | 8 | 10741264. | 0.10000 | 0.10000 | 7.135 | 5.428 |
| 1 | 9 | 10816970. | 0.10000 | 0.10000 | 2.334 | 1.776 |
| 1 | 10 | 10892676. | 0.10000 | 0.10000 | 2.334 | 1.776 |
| 1 | 11 | 10968382. | 0.10000 | 0.10000 | 2.334 | 1.776 |
| 1 | 12 | 11044088. | 0.10000 | 0.10000 | 2.334 | 1.776 |
| 1 | 13 | 11177118. | 0.10001 | 0.10000 | 15.909 | 12.102 |
| 1 | 14 | 11310148. | 0.10002 | 0.10000 | 15.909 | 12.103 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 15 | 11443178. | 0.10003 | 0.10000 | 15.909 | 12.103 |
| 1 | 16 | 11576208. | 0.10004 | 0.10001 | 15.909 | 12.104 |
| 1 | 17 | 11709238. | 0.10005 | 0.10001 | 15.910 | 12.105 |
| 1 | 18 | 11842268. | 0.10006 | 0.10001 | 15.910 | 12.106 |
| 1 | 19 | 11975298. | 0.10007 | 0.10001 | 15.910 | 12.106 |
| 1 | 20 | 12108328. | 0.10008 | 0.10001 | 15.910 | 12.107 |
| 1 | 21 | 12241358. | 0.10009 | 0.10001 | 15.910 | 12.108 |
| 1 | 22 | 12374388. | 0.10010 | 0.10001 | 15.911 | 12.109 |
| 1 | 23 | 12507418. | 0.10011 | 0.10001 | 15.911 | 12.109 |
| 1 | 24 | 12640448. | 0.10012 | 0.10002 | 15.911 | 12.110 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 91655.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.100120 , c = 0.100016 , a/c = 1.0010
Total Cycles = 12640448.

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN<br>Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Page/Section No. 1 | File Name Coldclevis_jj |
|---|---|---|---|---|
| Checked By | 4/17/02 | | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section J-J | | | |

## CC03




$S_3 = \frac{P}{Dt}$

| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.3504 in. (Ref. SCD0678, Sec. J-J) |
| Plate thickness | t = 0.1752 in. (average thickness at Sec. J-J) |
| Plate width | w = 1.449 in. |
| Hole diameter | D = 0.5512 in. |
| Crack Properties: | a = 0.10 in.<br>c = 0.10 in. |
| Loads: | |
| Strap load (cryo) | f = 8546 lbf (ref. John Ross Fax 1140 on 2/6/02) |
| Load per side on clevis | Paxial = 8546/2 = 4273 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/16/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Coldclevis_jj |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section J-J | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 4273/0.5512*0.3504=22.124 ksi

This clevis is part of the Strap at Section J-J. (Ref. Drawing SCD0678, issue 07, Section J-J)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch conditions. The NASGRO analysis uses truck air, On-orbit and Launch case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section J-J, and the standard dye penetrant crack sizes a= 0.10 in and c = 0.10 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/16/02 TIME: 15:59:09
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**J-J Lug With Cold Launch for AMS-02 Magnet Strap**
**[Ref. Drawing SCD0678, issue 07, Section J-J)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1752
Plate Width, W = 1.4490
Hole Diameter, D = 0.5512

FLAW SIZE: **(User specified)**
**Method of Inspection: Dye Penetrant**
a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL
MATL 1: Edited file data ~2211
~2221

Material Header Info.:
Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L
~2611
Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl: No. | UTS | YS | Kle | Klc | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.175 | 299.8 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev. D, Page 25 for UTS and YS of 316L, 250 mm thick)**
J-J Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.22124 **(Ref. Coldclevis_jj.doc, Page2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.22124

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.22124

Stress Scaling Factors for Block Case: **4** **(LIFTOFF-ONLY)**

Scale Factor for Stress S3: 0.22124

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 4 | 1 |
| 5 - 8 | 2 |
| 9 - 12 | 3 |
| 13 - 24 | 4 |

Stresses: Tension, bending or pin

---

J-J Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 36.70: | 5.60: | 36.70: | 5.60: |
| 2: | 1: | 2148.00 | 30.10: | 6.40: | 30.10: | 6.40: |
| 3: | 1: | 13668.00 | 25.50: | 6.90: | 25.50: | 6.90: |
| 4: | 1: | 38857.00 | 21.90: | 7.30: | 21.90: | 7.30: |
| 5: | 1: | 110517.00 | 19.50: | 7.50: | 19.50: | 7.50: |
| 6: | 1: | 150546.00 | 17.80: | 7.70: | 17.80: | 7.70: |
| 7: | 1: | 195456.00 | 16.50: | 7.90: | 16.50: | 7.90: |
| 8: | 1: | 1440631.00 | 15.90: | 7.90: | 15.90: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 2: | 1: | 594.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 3: | 1: | 695448.00 | 22.60: | 7.20: | 22.60: | 7.20: |
| 4: | 1: | 30.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 5: | 1: | 17832.00 | 43.10: | 4.90: | 43.10: | 4.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 14.10: | 8.50: | 14.10: | 8.50: |
| 2: | 1: | 34.00 | 13.90: | 8.50: | 13.90: | 8.50: |
| 3: | 1: | 60.00 | 13.70: | 8.50: | 13.70: | 8.50: |
| 4: | 1: | 179.00 | 13.50: | 8.50: | 13.50: | 8.50: |
| 5: | 1: | 117.00 | 14.10: | 8.50: | 14.10: | 8.50: |
| 6: | 1: | 414.00 | 13.90: | 8.50: | 13.90: | 8.50: |
| 7: | 1: | 2404.00 | 13.70: | 8.50: | 13.70: | 8.50: |
| 8: | 1: | 9789.00 | 13.50: | 8.50: | 13.50: | 8.50: |
| 9: | 1: | 62675.00 | 13.40: | 8.50: | 13.40: | 8.50: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 | 96.10: | 3.90: | 96.10: | 3.90: |
| 2: | 1: | 3.00 | 88.10: | 4.30: | 88.10: | 4.30: |
| 3: | 1: | 5.00 | 80.00: | 4.80: | 80.00: | 4.80: |
| 4: | 1: | 12.00 | 72.00: | 5.20: | 72.00: | 5.20: |
| 5: | 1: | 46.00 | 64.00: | 5.60: | 64.00: | 5.60: |
| 6: | 1: | 78.00 | 55.90: | 6.00: | 55.90: | 6.00: |
| 7: | 1: | 165.00 | 47.90: | 6.40: | 47.90: | 6.40: |
| 8: | 1: | 493.00 | 39.90: | 6.80: | 39.90: | 6.80: |
| 9: | 1: | 2229.00 | 31.90: | 7.20: | 31.90: | 7.20: |
| 10: | 1: | 2132.00 | 23.80: | 7.60: | 23.80: | 7.60: |
| 11: | 1: | 2920.00 | 21.40: | 7.80: | 21.40: | 7.80: |
| 12: | 1: | 22272.00 | 19.80: | 7.80: | 19.80: | 7.80: |
| 13: | 1: | 82954.00 | 18.20: | 7.90: | 18.20: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Only Cold Launch

MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 8.12 | 1.24 | 0.00 | 0.00 |
| 2 | 1 | 2148.00 | 6.66 | 1.42 | 0.00 | 0.00 |
| 3 | 1 | 13668.00 | 5.64 | 1.53 | 0.00 | 0.00 |
| 4 | 1 | 38857.00 | 4.84 | 1.61 | 0.00 | 0.00 |
| 5 | 1 | 110517.00 | 4.31 | 1.66 | 0.00 | 0.00 |
| 6 | 1 | 150546.00 | 3.94 | 1.70 | 0.00 | 0.00 |
| 7 | 1 | 195456.00 | 3.65 | 1.75 | 0.00 | 0.00 |
| 8 | 1 | 1440631.00 | 3.52 | 1.75 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 9.54 | 1.08 | 0.00 | 0.00 |
| 2 | 1 | 594.00 | 9.54 | 1.08 | 0.00 | 0.00 |
| 3 | 1 | 695448.00 | 5.00 | 1.59 | 0.00 | 0.00 |
| 4 | 1 | 30.00 | 9.54 | 1.08 | 0.00 | 0.00 |
| 5 | 1 | 17832.00 | 9.54 | 1.08 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 3.12 | 1.88 | 0.00 | 0.00 |
| 2 | 1 | 34.00 | 3.08 | 1.88 | 0.00 | 0.00 |
| 3 | 1 | 60.00 | 3.03 | 1.88 | 0.00 | 0.00 |
| 4 | 1 | 179.00 | 2.99 | 1.88 | 0.00 | 0.00 |
| 5 | 1 | 117.00 | 3.12 | 1.88 | 0.00 | 0.00 |
| 6 | 1 | 414.00 | 3.08 | 1.88 | 0.00 | 0.00 |
| 7 | 1 | 2404.00 | 3.03 | 1.88 | 0.00 | 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 8: | 1: | 9789.00 : | 2.99: | 1.88: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 2.96: | 1.88: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

J-J Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE
---

Four Blocks of VCMAGNET

| S | M: | NUMBER | S3 | | S | |
|---|---|---|---|---|---|---|
| T | A: | OF | | | | |
| E | T: | FATIGUE | (ksi) | | (ksi) | |
| P | L: | CYCLES | (t1) : | (t2) : | (t1) : | (t2) : |
| 1: | 1: | 1.00 : | 21.26: | 0.86: | 0.00: | 0.00: |
| 2: | 1: | 3.00 : | 19.49: | 0.95: | 0.00: | 0.00: |
| 3: | 1: | 5.00 : | 17.70: | 1.06: | 0.00: | 0.00: |
| 4: | 1: | 12.00 : | 15.93: | 1.15: | 0.00: | 0.00: |
| 5: | 1: | 46.00 : | 14.16: | 1.24: | 0.00: | 0.00: |
| 6: | 1: | 78.00 : | 12.37: | 1.33: | 0.00: | 0.00: |
| 7: | 1: | 165.00 : | 10.60: | 1.42: | 0.00: | 0.00: |
| 8: | 1: | 493.00 : | 8.83: | 1.50: | 0.00: | 0.00: |
| 9: | 1: | 2229.00 : | 7.06: | 1.59: | 0.00: | 0.00: |
| 10: | 1: | 2132.00 : | 5.27: | 1.68: | 0.00: | 0.00: |
| 11: | 1: | 2920.00 : | 4.73: | 1.73: | 0.00: | 0.00: |
| 12: | 1: | 22272.00 : | 4.38: | 1.73: | 0.00: | 0.00: |
| 13: | 1: | 82954.00 : | 4.03: | 1.75: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

J-J Lug With Only Cold Launch
MODEL: CC03

ANALYSIS RESULTS:
---

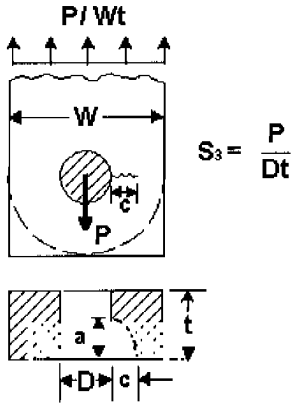
| Schdl | Block Step | Cycles | Final Flaw Size a | c | K max a-tip | c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10000 | 0.10000 | 6.075 | 4.621 |
| 1 | 2 | 3907160. | 0.10000 | 0.10000 | 6.075 | 4.621 |
| 1 | 3 | 5860740. | 0.10000 | 0.10000 | 6.075 | 4.621 |
| 1 | 4 | 7814320. | 0.10000 | 0.10000 | 6.075 | 4.621 |
| 1 | 5 | 8546056. | 0.10000 | 0.10000 | 7.135 | 5.427 |
| 1 | 6 | 9277792. | 0.10000 | 0.10000 | 7.135 | 5.427 |
| 1 | 7 | 10009528. | 0.10000 | 0.10000 | 7.135 | 5.427 |
| 1 | 8 | 10741264. | 0.10000 | 0.10000 | 7.135 | 5.427 |
| 1 | 9 | 10816970. | 0.10000 | 0.10000 | 2.334 | 1.776 |
| 1 | 10 | 10892676. | 0.10000 | 0.10000 | 2.334 | 1.776 |
| 1 | 11 | 10968382. | 0.10000 | 0.10000 | 2.334 | 1.776 |
| 1 | 12 | 11044088. | 0.10000 | 0.10000 | 2.334 | 1.776 |
| 1 | 13 | 11157398. | 0.10001 | 0.10000 | 15.908 | 12.101 |
| 1 | 14 | 11270708. | 0.10002 | 0.10000 | 15.908 | 12.102 |
| 1 | 15 | 11384018. | 0.10002 | 0.10000 | 15.908 | 12.103 |
| 1 | 16 | 11497328. | 0.10003 | 0.10000 | 15.909 | 12.103 |
| 1 | 17 | 11610638. | 0.10004 | 0.10000 | 15.909 | 12.104 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 18 | 11723948. | 0.10005 | 0.10001 | 15.909 | 12.105 |
| 1 | 19 | 11837258. | 0.10006 | 0.10001 | 15.909 | 12.105 |
| 1 | 20 | 11950568. | 0.10007 | 0.10001 | 15.909 | 12.106 |
| 1 | 21 | 12063878. | 0.10007 | 0.10001 | 15.909 | 12.107 |
| 1 | 22 | 12177188. | 0.10008 | 0.10001 | 15.910 | 12.107 |
| 1 | 23 | 12290498. | 0.10009 | 0.10001 | 15.910 | 12.108 |
| 1 | 24 | 12403808. | 0.10010 | 0.10001 | 15.910 | 12.108 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 82954.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.100100 , c = 0.100011 , a/c = 1.0009
Total Cycles = 12403808.

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Warmclevis_jj |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section J-J | | | |

## CC03




$S_3 = \frac{P}{Dt}$

Material: AISI 316/316L (75F)

NASA/FLAGRO Crack case type: CC03

Section Properties:

Design Clevis Thickness T=0.3504 in. (Ref. SCD0678, Sec. J-J)

Plate thickness t = 0.1752 in. (average thickness at Sec. J-J)

Plate width w = 1.449 in.

Hole diameter D = 0.5512 in.

Crack Properties: a = 0.1001 in. (Ref. JJ-clevis-cold-launch, P6)

c = 0.10001 in.

a/c= 1.001

Loads:

Strap load (cryo) f = 5894 lbf (Ref. John Ross Fax 1140, dated 2/6/02)

Load per side on clevis Paxial = 5894/2 = 2947 lbf

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Warmclevis_jj |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section J-J | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 2947/0.5512*0.3504=15.258 ksi

This clevis is part of the Strap at Section J-J. (Ref. Drawing SCD0678, issue 07, Section J-J)

This clevis is at room temperature (75F) for the Landing condition. The NASGRO analysis uses the landing case spectrum at room temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The landing spectrum is run for 3 missions with a scatter factor of 4. The final crack size from the cold launch condition a= 0.1001 in, c=0.1000 in, and a/c = 1.001 are used as the initial crack sizes for this model.

FATIGUE CRACK GROWTH ANALYSIS
---
DATE: 04/17/02 TIME: 09:16:03
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE
---
**J-J Lug With Warm Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section J-J)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY
---
MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1752
Plate Width, W = 1.4490
Hole Diameter, D = 0.5512

**FLAW SIZE: (User specified)**
**a (init.) = 0.1001 (Ref. The final crack sizes from**
**c (init.) = 0.1000 JJ-clevis-cold-launch, Page 6)**
**a/c (init.) = 1.001**

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13AB1
Alloy Description : AISI 316/316L
~2611
Alloy Cond/HT : Ann sht & plt
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **127.6** | **108.1** | 280.0 | 200.0 | 1.00 | 0.50 | 0.175 | 300.0 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 3.50 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250mm thick)**
J-J Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: LAND_ONLY)**

Scale Factor for Stress S3: 0.15258 **(Ref. Warmclevis-jj.doc, Page 2)**

Schedule info. was input manually

Total No. of Blocks in Schedule = 12

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 12 | 1 |

Stresses: Tension, bending or pin

J-J Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

SINGLE DISTINCT BLOCK

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 100.00 | 3.70 | 100.00 | 3.70 |
| 2 | 1 | 1.00 | 91.30 | 4.20 | 91.30 | 4.20 |
| 3 | 1 | 3.00 | 82.60 | 4.70 | 82.60 | 4.70 |
| 4 | 1 | 3.00 | 74.00 | 5.20 | 74.00 | 5.20 |
| 5 | 1 | 3.00 | 65.30 | 5.70 | 65.30 | 5.70 |
| 6 | 1 | 3.00 | 56.60 | 6.10 | 56.60 | 6.10 |
| 7 | 1 | 13.00 | 47.90 | 6.60 | 47.90 | 6.60 |
| 8 | 1 | 148.00 | 39.20 | 7.10 | 39.20 | 7.10 |
| 9 | 1 | 891.00 | 30.60 | 7.60 | 30.60 | 7.60 |
| 10 | 1 | 1273.00 | 21.90 | 8.10 | 21.90 | 8.10 |
| 11 | 1 | 2099.00 | 19.30 | 8.20 | 19.30 | 8.20 |
| 12 | 1 | 6581.00 | 17.50 | 8.30 | 17.50 | 8.30 |
| 13 | 1 | 8701.00 | 15.80 | 8.40 | 15.80 | 8.40 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

One Block of Warm Landing

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 15.26: | 0.56: | 0.00: | 0.00: |
| 2: | 1: | 1.00 : | 13.93: | 0.64: | 0.00: | 0.00: |
| 3: | 1: | 3.00 : | 12.60: | 0.72: | 0.00: | 0.00: |
| 4: | 1: | 3.00 : | 11.29: | 0.79: | 0.00: | 0.00: |
| 5: | 1: | 3.00 : | 9.96: | 0.87: | 0.00: | 0.00: |
| 6: | 1: | 3.00 : | 8.64: | 0.93: | 0.00: | 0.00: |
| 7: | 1: | 13.00 : | 7.31: | 1.01: | 0.00: | 0.00: |
| 8: | 1: | 148.00 : | 5.98: | 1.08: | 0.00: | 0.00: |
| 9: | 1: | 891.00 : | 4.67: | 1.16: | 0.00: | 0.00: |
| 10: | 1: | 1273.00 : | 3.34: | 1.24: | 0.00: | 0.00: |
| 11: | 1: | 2099.00 : | 2.94: | 1.25: | 0.00: | 0.00: |
| 12: | 1: | 6581.00 : | 2.67: | 1.27: | 0.00: | 0.00: |
| 13: | 1: | 8701.00 : | 2.41: | 1.28: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

J-J Lug With Warm Landing
MODEL: CC03

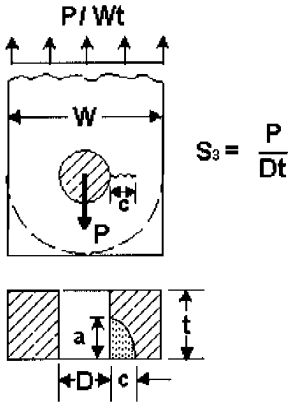
ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 19720. | 0.10010 | 0.10000 | 11.418 | 8.691 |
| 1 | 2 | 39440. | 0.10010 | 0.10000 | 11.418 | 8.691 |
| 1 | 3 | 59160. | 0.10010 | 0.10000 | 11.418 | 8.691 |
| 1 | 4 | 78880. | 0.10011 | 0.10000 | 11.418 | 8.691 |
| 1 | 5 | 98600. | 0.10011 | 0.10000 | 11.418 | 8.691 |
| 1 | 6 | 118320. | 0.10011 | 0.10000 | 11.418 | 8.691 |
| 1 | 7 | 138040. | 0.10011 | 0.10000 | 11.418 | 8.691 |
| 1 | 8 | 157760. | 0.10011 | 0.10000 | 11.418 | 8.691 |
| 1 | 9 | 177480. | 0.10011 | 0.10000 | 11.418 | 8.691 |
| 1 | 10 | 197200. | 0.10011 | 0.10000 | 11.418 | 8.691 |
| 1 | 11 | 216920. | 0.10011 | 0.10000 | 11.418 | 8.691 |
| 1 | 12 | 236640. | 0.10012 | 0.10000 | 11.418 | 8.691 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 8701.00
of Load Step No. 13 Description: None
of Block No. 12
of Schedule No. 1
Crack Sizes: a = 0.100115 , c = 0.100003 , a/c = 1.0011
Total Cycles = 236640.00

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Cryoclevis_kk |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section K-K | | | |

## CC03




$S_3 = \frac{P}{Dt}$

| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.2677 in. (Ref. SCD0678, Sec. K-K) |
| Plate thickness | t = 0.1339 in.(average thickness at Sec. K-K) |
| Plate width | w = 1.2992 in. |
| Hole diameter | D = 0.5512 in. |
| Crack Properties: | a = 0.10 in.<br>c = 0.10 in. |
| Loads: | |
| Strap load (cryo) | f = 8546 lbf (ref. John Ross Fax 1140 on 2/6/02) |
| Load per side on clevis | Paxial = 8546/2 = 4273 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Cryoclevis_kk |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | **AMS-02 Magnet Strap Clevis (Cryo)<br>Section K-K** | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 4273/0.5512*0.2677=28.958 ksi

This clevis is part of the Strap at Section K-K. (Ref. Drawing SCD0678, issue 07, Section K-K)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch/Landing conditions. The NASGRO analysis uses truck air, On-orbit and Launch/Landing case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch/Landing spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section K-K, and the standard dye penetrant crack sizes a= 0.10 in and c = 0.10 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/17/02 TIME: 13:05:03
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**K-K Lug With Cold Launch and Landing for AMS-02 Magnet Strap (Ref. Drawing SCD0678,issue 07, Section K-K)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY
MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1339
Plate Width, W = 1.2992
Hole Diameter, D = 0.5512

FLAW SIZE: **(User specified)**
**Method of Inspection: Dye Penetrant**
a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L ~261
1
Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl No. | UTS | YS | Kle | Klc | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.134 | 299.9 | |

| Matl No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250 mm thick)**
K-K Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.28958 **(Ref. Cryoclevis_kk.doc, Page 2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.28958

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.28958

Stress Scaling Factors for Block Case: **4** **(GSFC-VCMAGNET)**

Scale Factor for Stress S3: 0.28958

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 4 | 1 |
| 5 - 8 | 2 |
| 9 - 12 | 3 |
| 13 - 24 | 4 |

Stresses: Tension, bending or pin

K-K Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 36.70: | 5.60: | 36.70: | 5.60: |
| 2: | 1: | 2148.00 : | 30.10: | 6.40: | 30.10: | 6.40: |
| 3: | 1: | 13668.00 : | 25.50: | 6.90: | 25.50: | 6.90: |
| 4: | 1: | 38857.00 : | 21.90: | 7.30: | 21.90: | 7.30: |
| 5: | 1: | 110517.00 : | 19.50: | 7.50: | 19.50: | 7.50: |
| 6: | 1: | 150546.00 : | 17.80: | 7.70: | 17.80: | 7.70: |
| 7: | 1: | 195456.00 : | 16.50: | 7.90: | 16.50: | 7.90: |
| 8: | 1: | 1440631.00 : | 15.90: | 7.90: | 15.90: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 2 | 1 | 594.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 3 | 1 | 695448.00 | 22.60 | 7.20 | 22.60 | 7.20 |
| 4 | 1 | 30.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 5 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 2 | 1 | 34.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 3 | 1 | 60.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 4 | 1 | 179.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 5 | 1 | 117.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 6 | 1 | 414.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 7 | 1 | 2404.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 8 | 1 | 9789.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 9 | 1 | 62675.00 | 13.40 | 8.50 | 13.40 | 8.50 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 2.00 | 96.10 | 3.90 | 96.10 | 3.90 |
| 2 | 1 | 4.00 | 88.10 | 4.30 | 88.10 | 4.30 |
| 3 | 1 | 8.00 | 80.00 | 4.80 | 80.00 | 4.80 |
| 4 | 1 | 15.00 | 72.00 | 5.20 | 72.00 | 5.20 |
| 5 | 1 | 49.00 | 64.00 | 5.60 | 64.00 | 5.60 |
| 6 | 1 | 81.00 | 55.90 | 6.00 | 55.90 | 6.00 |
| 7 | 1 | 178.00 | 47.90 | 6.40 | 47.90 | 6.40 |
| 8 | 1 | 641.00 | 39.90 | 6.80 | 39.90 | 6.80 |
| 9 | 1 | 3120.00 | 31.90 | 7.20 | 31.90 | 7.20 |
| 10 | 1 | 3405.00 | 23.80 | 7.60 | 23.80 | 7.60 |
| 11 | 1 | 5019.00 | 21.40 | 7.80 | 21.40 | 7.80 |
| 12 | 1 | 28853.00 | 19.80 | 7.80 | 19.80 | 7.80 |
| 13 | 1 | 91655.00 | 18.20 | 7.90 | 18.20 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MIN/MAX | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 10.63 | 1.62 | 0.00 | 0.00 |
| 2 | 1 | 2148.00 | 8.72 | 1.85 | 0.00 | 0.00 |
| 3 | 1 | 13668.00 | 7.38 | 2.00 | 0.00 | 0.00 |
| 4 | 1 | 38857.00 | 6.34 | 2.11 | 0.00 | 0.00 |
| 5 | 1 | 110517.00 | 5.65 | 2.17 | 0.00 | 0.00 |
| 6 | 1 | 150546.00 | 5.15 | 2.23 | 0.00 | 0.00 |
| 7 | 1 | 195456.00 | 4.78 | 2.29 | 0.00 | 0.00 |
| 8 | 1 | 1440631.00 | 4.60 | 2.29 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MIN/MAX | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 12.48 | 1.42 | 0.00 | 0.00 |
| 2 | 1 | 594.00 | 12.48 | 1.42 | 0.00 | 0.00 |
| 3 | 1 | 695448.00 | 6.54 | 2.08 | 0.00 | 0.00 |
| 4 | 1 | 30.00 | 12.48 | 1.42 | 0.00 | 0.00 |
| 5 | 1 | 17832.00 | 12.48 | 1.42 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MIN/MAX | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 4.08 | 2.46 | 0.00 | 0.00 |
| 2 | 1 | 34.00 | 4.03 | 2.46 | 0.00 | 0.00 |
| 3 | 1 | 60.00 | 3.97 | 2.46 | 0.00 | 0.00 |
| 4 | 1 | 179.00 | 3.91 | 2.46 | 0.00 | 0.00 |
| 5 | 1 | 117.00 | 4.08 | 2.46 | 0.00 | 0.00 |
| 6 | 1 | 414.00 | 4.03 | 2.46 | 0.00 | 0.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7: | 1: | 2404.00 : | 3.97: | 2.46: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 3.91: | 2.46: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 3.88: | 2.46: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

K-K Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE
---
Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 2.00 : | 27.83: | 1.13: | 0.00: | 0.00: |
| 2: | 1: | 4.00 : | 25.51: | 1.25: | 0.00: | 0.00: |
| 3: | 1: | 8.00 : | 23.17: | 1.39: | 0.00: | 0.00: |
| 4: | 1: | 15.00 : | 20.85: | 1.51: | 0.00: | 0.00: |
| 5: | 1: | 49.00 : | 18.53: | 1.62: | 0.00: | 0.00: |
| 6: | 1: | 81.00 : | 16.19: | 1.74: | 0.00: | 0.00: |
| 7: | 1: | 178.00 : | 13.87: | 1.85: | 0.00: | 0.00: |
| 8: | 1: | 641.00 : | 11.55: | 1.97: | 0.00: | 0.00: |
| 9: | 1: | 3120.00 : | 9.24: | 2.08: | 0.00: | 0.00: |
| 10: | 1: | 3405.00 : | 6.89: | 2.20: | 0.00: | 0.00: |
| 11: | 1: | 5019.00 : | 6.20: | 2.26: | 0.00: | 0.00: |
| 12: | 1: | 28853.00 : | 5.73: | 2.26: | 0.00: | 0.00: |
| 13: | 1: | 91655.00 : | 5.27: | 2.29: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

K-K Lug With Cold Launch and Landing
MODEL: CC03

ANALYSIS RESULTS:
---

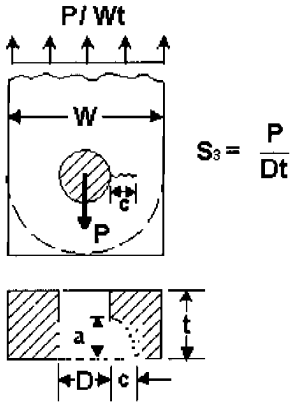
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10006 | 0.10000 | 9.613 | 7.827 |
| 1 | 2 | 3907160. | 0.10012 | 0.10000 | 9.614 | 7.831 |
| 1 | 3 | 5860740. | 0.10019 | 0.10000 | 9.614 | 7.834 |
| 1 | 4 | 7814320. | 0.10025 | 0.10000 | 9.615 | 7.838 |
| 1 | 5 | 8546056. | 0.10329 | 0.10107 | 11.373 | 9.383 |
| 1 | 6 | 9277792. | 0.10644 | 0.10233 | 11.472 | 9.583 |
| 1 | 7 | 10009528. | 0.10971 | 0.10378 | 11.582 | 9.790 |
| 1 | 8 | 10741264. | 0.11312 | 0.10542 | 11.724 | 10.043 |
| 1 | 9 | 10816970. | 0.11312 | 0.10542 | 3.832 | 3.280 |
| 1 | 10 | 10892676. | 0.11312 | 0.10542 | 3.832 | 3.280 |
| 1 | 11 | 10968382. | 0.11312 | 0.10542 | 3.832 | 3.280 |
| 1 | 12 | 11044088. | 0.11312 | 0.10542 | 3.832 | 3.280 |
| 1 | 13 | 11177118. | 0.11325 | 0.10549 | 26.119 | 22.354 |
| 1 | 14 | 11310148. | 0.11338 | 0.10556 | 26.130 | 22.373 |
| 1 | 15 | 11443178. | 0.11352 | 0.10562 | 26.141 | 22.392 |
| 1 | 16 | 11576208. | 0.11365 | 0.10569 | 26.153 | 22.411 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 17 | 11709238. | 0.11378 | 0.10576 | 26.164 | 22.430 |
| 1 | 18 | 11842268. | 0.11392 | 0.10583 | 26.175 | 22.450 |
| 1 | 19 | 11975298. | 0.11405 | 0.10591 | 26.187 | 22.469 |
| 1 | 20 | 12108328. | 0.11419 | 0.10598 | 26.198 | 22.488 |
| 1 | 21 | 12241358. | 0.11432 | 0.10605 | 26.210 | 22.507 |
| 1 | 22 | 12374388. | 0.11446 | 0.10612 | 26.221 | 22.527 |
| 1 | 23 | 12507418. | 0.11459 | 0.10619 | 26.233 | 22.546 |
| 1 | 24 | 12640448. | 0.11473 | 0.10626 | 26.244 | 22.565 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 91655.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.114727 , c = 0.106263 , a/c = 1.0797
Total Cycles = 12640448.

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Coldclevis_kk |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section K-K | | | |

## CC03




| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.2677 in. (Ref. SCD0678, Sec. K-K) |
| Plate thickness | t = 0.1339 in. (average thickness at Sec. K-K) |
| Plate width | w = 1.2992 in. |
| Hole diameter | D = 0.5512 in. |
| Crack Properties: | a = 0.10 in.<br>c = 0.10 in. |
| Loads: | |
| Strap load (cryo) | f = 8546 lbf (ref. John Ross Fax 1140 on 2/6/02) |
| Load per side on clevis | Paxial = 8546/2 = 4273 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Coldclevis_kk |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section K-K | | | |

Tensile Stress

S3 = Paxial/D*T

S3 = 4273/0.5512*0.2677=28.958 ksi

This clevis is part of the Strap at Section K-K. (Ref. Drawing SCD0678, issue 07, Section K-K)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch conditions. The NASGRO analysis uses truck air, On-orbit and Launch case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section K-K, and the standard dye penetrant crack sizes a= 0.10 in and c = 0.10 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS
---
DATE: 04/17/02 TIME: 13:10:47
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE
---
**K-K Lug With Cold Launch for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section K-K)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY
---
MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1339
Plate Width, W = 1.2992
Hole Diameter, D = 0.5512

FLAW SIZE: **(User specified)**
**Method of Inspection: Dye Penetrant**
a (init.) = 0.1000
c (init.) = 0.1000
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L
~2611
Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl: No. | UTS | YS | Kle | Klc | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.134 | 299.9 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev. D, Page 25 for UTS and YS of 316L, 250 mm thick)**
K-K Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---

Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.28958 **(Ref. Coldclevis_kk.doc, Page2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.28958

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.28958

Stress Scaling Factors for Block Case: **4** **(LIFTOFF-ONLY)**

Scale Factor for Stress S3: 0.28958

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From | - | To | Block Case No. |
|---|---|---|---|
| 1 | - | 4 | 1 |
| 5 | - | 8 | 2 |
| 9 | - | 12 | 3 |
| 13 | - | 24 | 4 |

Stresses: Tension, bending or pin

K-K Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---

Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 36.70 | 5.60 | 36.70 | 5.60 |
| 2 | 1 | 2148.00 | 30.10 | 6.40 | 30.10 | 6.40 |
| 3 | 1 | 13668.00 | 25.50 | 6.90 | 25.50 | 6.90 |
| 4 | 1 | 38857.00 | 21.90 | 7.30 | 21.90 | 7.30 |
| 5 | 1 | 110517.00 | 19.50 | 7.50 | 19.50 | 7.50 |
| 6 | 1 | 150546.00 | 17.80 | 7.70 | 17.80 | 7.70 |
| 7 | 1 | 195456.00 | 16.50 | 7.90 | 16.50 | 7.90 |
| 8 | 1 | 1440631.00 | 15.90 | 7.90 | 15.90 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 2 | 1 | 594.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 3 | 1 | 695448.00 | 22.60 | 7.20 | 22.60 | 7.20 |
| 4 | 1 | 30.00 | 43.10 | 4.90 | 43.10 | 4.90 |
| 5 | 1 | 17832.00 | 43.10 | 4.90 | 43.10 | 4.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 34.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 2 | 1 | 34.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 3 | 1 | 60.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 4 | 1 | 179.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 5 | 1 | 117.00 | 14.10 | 8.50 | 14.10 | 8.50 |
| 6 | 1 | 414.00 | 13.90 | 8.50 | 13.90 | 8.50 |
| 7 | 1 | 2404.00 | 13.70 | 8.50 | 13.70 | 8.50 |
| 8 | 1 | 9789.00 | 13.50 | 8.50 | 13.50 | 8.50 |
| 9 | 1 | 62675.00 | 13.40 | 8.50 | 13.40 | 8.50 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 96.10 | 3.90 | 96.10 | 3.90 |
| 2 | 1 | 3.00 | 88.10 | 4.30 | 88.10 | 4.30 |
| 3 | 1 | 5.00 | 80.00 | 4.80 | 80.00 | 4.80 |
| 4 | 1 | 12.00 | 72.00 | 5.20 | 72.00 | 5.20 |
| 5 | 1 | 46.00 | 64.00 | 5.60 | 64.00 | 5.60 |
| 6 | 1 | 78.00 | 55.90 | 6.00 | 55.90 | 6.00 |
| 7 | 1 | 165.00 | 47.90 | 6.40 | 47.90 | 6.40 |
| 8 | 1 | 493.00 | 39.90 | 6.80 | 39.90 | 6.80 |
| 9 | 1 | 2229.00 | 31.90 | 7.20 | 31.90 | 7.20 |
| 10 | 1 | 2132.00 | 23.80 | 7.60 | 23.80 | 7.60 |
| 11 | 1 | 2920.00 | 21.40 | 7.80 | 21.40 | 7.80 |
| 12 | 1 | 22272.00 | 19.80 | 7.80 | 19.80 | 7.80 |
| 13 | 1 | 82954.00 | 18.20 | 7.90 | 18.20 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 10.63: | 1.62: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 | 8.72: | 1.85: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 | 7.38: | 2.00: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 | 6.34: | 2.11: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 | 5.65: | 2.17: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 | 5.15: | 2.23: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 | 4.78: | 2.29: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 | 4.60: | 2.29: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 12.48: | 1.42: | 0.00: | 0.00: |
| 2: | 1: | 594.00 | 12.48: | 1.42: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 | 6.54: | 2.08: | 0.00: | 0.00: |
| 4: | 1: | 30.00 | 12.48: | 1.42: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 | 12.48: | 1.42: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 4.08: | 2.46: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 4.03: | 2.46: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 3.97: | 2.46: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 3.91: | 2.46: | 0.00: | 0.00: |
| 5: | 1: | 117.00 | 4.08: | 2.46: | 0.00: | 0.00: |
| 6: | 1: | 414.00 | 4.03: | 2.46: | 0.00: | 0.00: |

| | | | | | |
|---|---|---|---|---|---|
| 7: 1: | 2404.00 : | 3.97: | 2.46: | 0.00: | 0.00: |
| 8: 1: | 9789.00 : | 3.91: | 2.46: | 0.00: | 0.00: |
| 9: 1: | 62675.00 : | 3.88: | 2.46: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 27.83: | 1.13: | 0.00: | 0.00: |
| 2: | 1: | 3.00 : | 25.51: | 1.25: | 0.00: | 0.00: |
| 3: | 1: | 5.00 : | 23.17: | 1.39: | 0.00: | 0.00: |
| 4: | 1: | 12.00 : | 20.85: | 1.51: | 0.00: | 0.00: |
| 5: | 1: | 46.00 : | 18.53: | 1.62: | 0.00: | 0.00: |
| 6: | 1: | 78.00 : | 16.19: | 1.74: | 0.00: | 0.00: |
| 7: | 1: | 165.00 : | 13.87: | 1.85: | 0.00: | 0.00: |
| 8: | 1: | 493.00 : | 11.55: | 1.97: | 0.00: | 0.00: |
| 9: | 1: | 2229.00 : | 9.24: | 2.08: | 0.00: | 0.00: |
| 10: | 1: | 2132.00 : | 6.89: | 2.20: | 0.00: | 0.00: |
| 11: | 1: | 2920.00 : | 6.20: | 2.26: | 0.00: | 0.00: |
| 12: | 1: | 22272.00 : | 5.73: | 2.26: | 0.00: | 0.00: |
| 13: | 1: | 82954.00 : | 5.27: | 2.29: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Only Cold Launch
MODEL: CC03

ANALYSIS RESULTS:

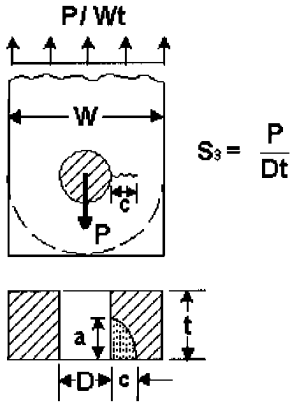
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.10006 | 0.10000 | 9.613 | 7.827 |
| 1 | 2 | 3907160. | 0.10012 | 0.10000 | 9.614 | 7.831 |
| 1 | 3 | 5860740. | 0.10019 | 0.10000 | 9.614 | 7.834 |
| 1 | 4 | 7814320. | 0.10025 | 0.10000 | 9.615 | 7.838 |
| 1 | 5 | 8546056. | 0.10329 | 0.10107 | 11.373 | 9.383 |
| 1 | 6 | 9277792. | 0.10644 | 0.10233 | 11.472 | 9.583 |
| 1 | 7 | 10009528. | 0.10971 | 0.10378 | 11.582 | 9.790 |
| 1 | 8 | 10741264. | 0.11312 | 0.10542 | 11.724 | 10.043 |
| 1 | 9 | 10816970. | 0.11312 | 0.10542 | 3.832 | 3.280 |
| 1 | 10 | 10892676. | 0.11312 | 0.10542 | 3.832 | 3.280 |
| 1 | 11 | 10968382. | 0.11312 | 0.10542 | 3.832 | 3.280 |
| 1 | 12 | 11044088. | 0.11312 | 0.10542 | 3.832 | 3.280 |
| 1 | 13 | 11157398. | 0.11323 | 0.10548 | 26.118 | 22.354 |
| 1 | 14 | 11270708. | 0.11334 | 0.10553 | 26.128 | 22.370 |
| 1 | 15 | 11384018. | 0.11345 | 0.10559 | 26.137 | 22.386 |
| 1 | 16 | 11497328. | 0.11357 | 0.10565 | 26.147 | 22.402 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 17 | 11610638. | 0.11368 | 0.10571 | 26.157 | 22.418 |
| 1 | 18 | 11723948. | 0.11379 | 0.10577 | 26.166 | 22.434 |
| 1 | 19 | 11837258. | 0.11390 | 0.10583 | 26.176 | 22.450 |
| 1 | 20 | 11950568. | 0.11402 | 0.10589 | 26.185 | 22.466 |
| 1 | 21 | 12063878. | 0.11413 | 0.10595 | 26.195 | 22.482 |
| 1 | 22 | 12177188. | 0.11424 | 0.10601 | 26.205 | 22.498 |
| 1 | 23 | 12290498. | 0.11436 | 0.10607 | 26.214 | 22.515 |
| 1 | 24 | 12403808. | 0.11447 | 0.10613 | 26.224 | 22.531 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 82954.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.114470 , c = 0.106130 , a/c = 1.0786
Total Cycles = 12403808.

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Warmclevis_kk |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section K-K | | | |

## CC03




$S_3 = \frac{P}{Dt}$

Material: AISI 316/316L (75F)

NASA/FLAGRO Crack case type: CC03

Section Properties:

| | | |
|---|---|---|
| Design Clevis Thickness | T=0.2677 in. | (Ref. SCD0678, Sec. K-K) |
| Plate thickness | t = 0.1339 in. | (average thickness at Sec. K-K) |
| Plate width | w = 1.2992 in. | |
| Hole diameter | D = 0.5512 in. | |

Crack Properties:

a = 0.1145 in. (Ref. KK-clevis-cold-launch, P6)
c = 0.1061 in.
a/c= 1.0786

Loads:

| | |
|---|---|
| Strap load (cryo) | f = 5894 lbf (Ref. John Ross Fax 1140, dated 2/6/02) |
| Load per side on clevis | Paxial = 5894/2 = 2947 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Warmclevis_kk |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section K-K | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 2947/0.5512*0.2677=19.972 ksi

This clevis is part of the Strap at Section K-K. (Ref. Drawing SCD0678, issue 07, Section K-K)

This clevis is at room temperature (75F) for the Landing condition. The NASGRO analysis uses the landing case spectrum at room temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The landing spectrum is run for 3 missions with a scatter factor of 4. The final crack size from the cold launch condition a= 0.1145 in, c=0.1061 in, and a/c = 1.0786 are used as the initial crack sizes for this model.

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/17/02 TIME: 13:16:58
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**K-K Lug With Warm Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section K-K)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1339
Plate Width, W = 1.2992
Hole Diameter, D = 0.5512

**FLAW SIZE: (User specified)**
**a (init.) = 0.1145** **(Ref. The final crack sizes from**
**c (init.) = 0.1061** **KK-clevis-cold-launch, Page 6)**
**a/c (init.) = 1.0786**

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13AB1
Alloy Description : AISI 316/316L ~261
1
Alloy Cond/HT : Ann sht & plt
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **127.6** | **108.1** | 280.0 | 200.0 | 1.00 | 0.50 | 0.134 | 300.0 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 3.50 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250mm thick)**
K-K Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: LAND_ONLY)**

Scale Factor for Stress S3: 0.19972 **(Ref. Warmclevis-kk.doc, Page 2)**

Schedule info. was input manually

Total No. of Blocks in Schedule = 12

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 12 | 1 |

Stresses: Tension, bending or pin

---

K-K Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

SINGLE DISTINCT BLOCK

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 100.00 | 3.70 | 100.00 | 3.70 |
| 2 | 1 | 1.00 | 91.30 | 4.20 | 91.30 | 4.20 |
| 3 | 1 | 3.00 | 82.60 | 4.70 | 82.60 | 4.70 |
| 4 | 1 | 3.00 | 74.00 | 5.20 | 74.00 | 5.20 |
| 5 | 1 | 3.00 | 65.30 | 5.70 | 65.30 | 5.70 |
| 6 | 1 | 3.00 | 56.60 | 6.10 | 56.60 | 6.10 |
| 7 | 1 | 13.00 | 47.90 | 6.60 | 47.90 | 6.60 |
| 8 | 1 | 148.00 | 39.20 | 7.10 | 39.20 | 7.10 |
| 9 | 1 | 891.00 | 30.60 | 7.60 | 30.60 | 7.60 |
| 10 | 1 | 1273.00 | 21.90 | 8.10 | 21.90 | 8.10 |
| 11 | 1 | 2099.00 | 19.30 | 8.20 | 19.30 | 8.20 |
| 12 | 1 | 6581.00 | 17.50 | 8.30 | 17.50 | 8.30 |
| 13 | 1 | 8701.00 | 15.80 | 8.40 | 15.80 | 8.40 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

One Block of Warm Landing

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 19.97 | 0.74 | 0.00 | 0.00 |
| 2 | 1 | 1.00 | 18.23 | 0.84 | 0.00 | 0.00 |
| 3 | 1 | 3.00 | 16.50 | 0.94 | 0.00 | 0.00 |
| 4 | 1 | 3.00 | 14.78 | 1.04 | 0.00 | 0.00 |
| 5 | 1 | 3.00 | 13.04 | 1.14 | 0.00 | 0.00 |
| 6 | 1 | 3.00 | 11.30 | 1.22 | 0.00 | 0.00 |
| 7 | 1 | 13.00 | 9.57 | 1.32 | 0.00 | 0.00 |
| 8 | 1 | 148.00 | 7.83 | 1.42 | 0.00 | 0.00 |
| 9 | 1 | 891.00 | 6.11 | 1.52 | 0.00 | 0.00 |
| 10 | 1 | 1273.00 | 4.37 | 1.62 | 0.00 | 0.00 |
| 11 | 1 | 2099.00 | 3.85 | 1.64 | 0.00 | 0.00 |
| 12 | 1 | 6581.00 | 3.50 | 1.66 | 0.00 | 0.00 |
| 13 | 1 | 8701.00 | 3.16 | 1.68 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

K-K Lug With Warm Landing
MODEL: CC03

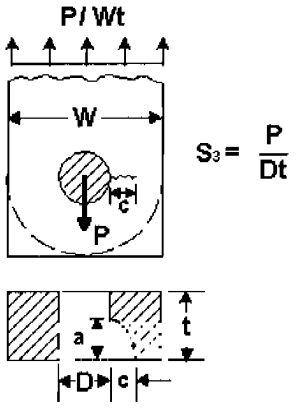
ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 19720. | 0.11452 | 0.10616 | 18.830 | 16.185 |
| 1 | 2 | 39440. | 0.11453 | 0.10617 | 18.831 | 16.186 |
| 1 | 3 | 59160. | 0.11455 | 0.10618 | 18.832 | 16.188 |
| 1 | 4 | 78880. | 0.11456 | 0.10619 | 18.833 | 16.189 |
| 1 | 5 | 98600. | 0.11458 | 0.10620 | 18.834 | 16.191 |
| 1 | 6 | 118320. | 0.11459 | 0.10621 | 18.835 | 16.192 |
| 1 | 7 | 138040. | 0.11461 | 0.10622 | 18.836 | 16.194 |
| 1 | 8 | 157760. | 0.11462 | 0.10623 | 18.837 | 16.195 |
| 1 | 9 | 177480. | 0.11464 | 0.10623 | 18.838 | 16.197 |
| 1 | 10 | 197200. | 0.11465 | 0.10624 | 18.839 | 16.199 |
| 1 | 11 | 216920. | 0.11467 | 0.10625 | 18.840 | 16.200 |
| 1 | 12 | 236640. | 0.11468 | 0.10626 | 18.841 | 16.202 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 8701.00
of Load Step No. 13 Description: None
of Block No. 12
of Schedule No. 1
Crack Sizes: a = 0.114682 , c = 0.106260 , a/c = 1.0793
Total Cycles = 236640.00

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Cryoclevis_II |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section L-L | | | |

## CC03




| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.3622 in. (Ref. SCD0678, Sec. L-L) |
| Plate thickness | t = 0.1811 in.(average thickness at Sec. L-L) |
| Plate width | w = 1.4960 in. |
| Hole diameter | D = 0.7087 in. |
| Crack Properties: | a = 0.050 in.<br>c = 0.050 in. |
| Loads: | |
| Strap load (cryo) | f = 22099 lbf (ref. Model 6-01, loads) |
| Load per side on clevis | Paxial = 22099/2 = 11049 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Cryoclevis_II |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section L-L | | | |

Tensile Stress

S3 = Paxial/D*T

S3 = 11049/0.7087*0.3622 = 43.047 ksi

This clevis is part of the Strap at Section L-L. (Ref. Drawing SCD0678, issue 07, Section L-L)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch/Landing conditions. The NASGRO analysis uses truck air, On-orbit and Launch/Landing case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch/Landing spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section L-L, and a special dye penetrant crack sizes a= 0.050 in and c = 0.050 in are used

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/21/02 TIME: 09:42:08
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**L-L Lug With Cold Launch and Landing for AMS-02 Magnet Straps**
**(Ref. Drg. SCD0678, issue 07, sect L-L)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1810
Plate Width, W = 1.4960
Hole Diameter, D = 0.7087

FLAW SIZE: (User specified)

a (init.) = 0.5000E-01 **(Special dye penetrant inspection)**
c (init.) = 0.5000E-01
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221

Material Header Info.:

Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L ~2611

Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.181 | 299.8 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/ |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**| Ref. OIE205, Rev D, page 25 for UTS and YS for 316L stainless steel)**

L-L Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **|TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.43047 **(Ref. Cryoclevis_LL.doc, page 2)**

Stress Scaling Factors for Block Case: **2** **|AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.43047

Stress Scaling Factors for Block Case: **3** **|ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.43047

Stress Scaling Factors for Block Case: **4** **|GSFC-VCMAGNET)**

Scale Factor for Stress S3: 0.43047

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From | - | To | Block Case No. |
|---|---|---|---|
| 1 | - | 4 | 1 |
| 5 | - | 8 | 2 |
| 9 | - | 12 | 3 |
| 13 | - | 24 | 4 |

Stresses: Tension, bending or pin

---

L-L Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 36.70: | 5.60: | 36.70: | 5.60: |
| 2: | 1: | 2148.00 | 30.10: | 6.40: | 30.10: | 6.40: |
| 3: | 1: | 13668.00 | 25.50: | 6.90: | 25.50: | 6.90: |
| 4: | 1: | 38857.00 | 21.90: | 7.30: | 21.90: | 7.30: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5: | 1: | 110517.00 | 19.50: | 7.50: | 19.50: | 7.50: |
| 6: | 1: | 150546.00 | 17.80: | 7.70: | 17.80: | 7.70: |
| 7: | 1: | 195456.00 | 16.50: | 7.90: | 16.50: | 7.90: |
| 8: | 1: | 1440631.00 | 15.90: | 7.90: | 15.90: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

BLOCK CASE NO. 2

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 2: | 1: | 594.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 3: | 1: | 695448.00 | 22.60: | 7.20: | 22.60: | 7.20: |
| 4: | 1: | 30.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 5: | 1: | 17832.00 | 43.10: | 4.90: | 43.10: | 4.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

BLOCK CASE NO. 3

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 14.10: | 8.50: | 14.10: | 8.50: |
| 2: | 1: | 34.00 | 13.90: | 8.50: | 13.90: | 8.50: |
| 3: | 1: | 60.00 | 13.70: | 8.50: | 13.70: | 8.50: |
| 4: | 1: | 179.00 | 13.50: | 8.50: | 13.50: | 8.50: |
| 5: | 1: | 117.00 | 14.10: | 8.50: | 14.10: | 8.50: |
| 6: | 1: | 414.00 | 13.90: | 8.50: | 13.90: | 8.50: |
| 7: | 1: | 2404.00 | 13.70: | 8.50: | 13.70: | 8.50: |
| 8: | 1: | 9789.00 | 13.50: | 8.50: | 13.50: | 8.50: |
| 9: | 1: | 62675.00 | 13.40: | 8.50: | 13.40: | 8.50: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

BLOCK CASE NO. 4

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 2.00 | 96.10: | 3.90: | 96.10: | 3.90: |
| 2: | 1: | 4.00 | 88.10: | 4.30: | 88.10: | 4.30: |
| 3: | 1: | 8.00 | 80.00: | 4.80: | 80.00: | 4.80: |
| 4: | 1: | 15.00 | 72.00: | 5.20: | 72.00: | 5.20: |
| 5: | 1: | 49.00 | 64.00: | 5.60: | 64.00: | 5.60: |
| 6: | 1: | 81.00 | 55.90: | 6.00: | 55.90: | 6.00: |
| 7: | 1: | 178.00 | 47.90: | 6.40: | 47.90: | 6.40: |
| 8: | 1: | 641.00 | 39.90: | 6.80: | 39.90: | 6.80: |
| 9: | 1: | 3120.00 | 31.90: | 7.20: | 31.90: | 7.20: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10: | 1: | 3405.00 : | 23.80: | 7.60: | 23.80: | 7.60: |
| 11: | 1: | 5019.00 : | 21.40: | 7.80: | 21.40: | 7.80: |
| 12: | 1: | 28853.00 : | 19.80: | 7.80: | 19.80: | 7.80: |
| 13: | 1: | 91655.00 : | 18.20: | 7.90: | 18.20: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

L-L Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE
---
four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 15.80: | 2.41: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 : | 12.96: | 2.76: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 : | 10.98: | 2.97: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 : | 9.43: | 3.14: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 : | 8.39: | 3.23: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 : | 7.66: | 3.31: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 : | 7.10: | 3.40: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 : | 6.84: | 3.40: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

L-L Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE
---
four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 : | 18.55: | 2.11: | 0.00: | 0.00: |
| 2: | 1: | 594.00 : | 18.55: | 2.11: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 : | 9.73: | 3.10: | 0.00: | 0.00: |
| 4: | 1: | 30.00 : | 18.55: | 2.11: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 : | 18.55: | 2.11: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET
-------

L-L Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE
---
four Blocks of VCMAGNET

| S T E | M: A: T: | NUMBER OF FATIGUE | S3 (ksi) | S (ksi) |
|---|---|---|---|---|

| P | L: | CYCLES | (t1) | (t2) | (t1) | (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 6.07: | 3.66: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 5.98: | 3.66: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 5.90: | 3.66: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 5.81: | 3.66: | 0.00: | 0.00: |
| 5: | 1: | 117.00 | 6.07: | 3.66: | 0.00: | 0.00: |
| 6: | 1: | 414.00 | 5.98: | 3.66: | 0.00: | 0.00: |
| 7: | 1: | 2404.00 | 5.90: | 3.66: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 | 5.81: | 3.66: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 | 5.77: | 3.66: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

four Blocks of VCMAGNET

| S | M: | NUMBER | S3 | | S | |
|---|---|---|---|---|---|---|
| T | A: | OF | | | | |
| E | T: | FATIGUE | (ksi) | | (ksi) | |
| P | L: | CYCLES | (t1) | (t2) | (t1) | (t2) |
| 1: | 1: | 2.00 | 41.37: | 1.68: | 0.00: | 0.00: |
| 2: | 1: | 4.00 | 37.92: | 1.85: | 0.00: | 0.00: |
| 3: | 1: | 8.00 | 34.44: | 2.07: | 0.00: | 0.00: |
| 4: | 1: | 15.00 | 30.99: | 2.24: | 0.00: | 0.00: |
| 5: | 1: | 49.00 | 27.55: | 2.41: | 0.00: | 0.00: |
| 6: | 1: | 81.00 | 24.06: | 2.58: | 0.00: | 0.00: |
| 7: | 1: | 178.00 | 20.62: | 2.76: | 0.00: | 0.00: |
| 8: | 1: | 641.00 | 17.18: | 2.93: | 0.00: | 0.00: |
| 9: | 1: | 3120.00 | 13.73: | 3.10: | 0.00: | 0.00: |
| 10: | 1: | 3405.00 | 10.25: | 3.27: | 0.00: | 0.00: |
| 11: | 1: | 5019.00 | 9.21: | 3.36: | 0.00: | 0.00: |
| 12: | 1: | 28853.00 | 8.52: | 3.36: | 0.00: | 0.00: |
| 13: | 1: | 91655.00 | 7.83: | 3.40: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Cold Launch and Landing
MODEL: CC03

ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | c | K max a-tip | c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.05019 | 0.05007 | 11.310 | 9.747 |
| 1 | 2 | 3907160. | 0.05038 | 0.05014 | 11.321 | 9.767 |
| 1 | 3 | 5860740. | 0.05057 | 0.05021 | 11.331 | 9.786 |
| 1 | 4 | 7814320. | 0.05076 | 0.05028 | 11.342 | 9.805 |
| 1 | 5 | 8546056. | 0.05690 | 0.05391 | 13.842 | 12.145 |
| 1 | 6 | 9277792. | 0.06400 | 0.05838 | 14.433 | 12.798 |
| 1 | 7 | 10009528. | 0.07236 | 0.06385 | 15.147 | 13.536 |
| 1 | 8 | 10741264. | 0.08235 | 0.07059 | 15.951 | 14.331 |

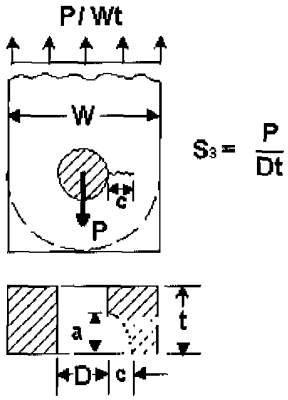
| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 9 | 10816970. | 0.08235 | 0.07059 | 5.223 | 4.693 |
| 1 | 10 | 10892676. | 0.08235 | 0.07059 | 5.223 | 4.693 |
| 1 | 11 | 10968382. | 0.08235 | 0.07059 | 5.223 | 4.693 |
| 1 | 12 | 11044088. | 0.08235 | 0.07059 | 5.223 | 4.693 |
| 1 | 13 | 11177118. | 0.08302 | 0.07103 | 35.601 | 31.988 |
| 1 | 14 | 11310148. | 0.08369 | 0.07148 | 35.721 | 32.108 |
| 1 | 15 | 11443178. | 0.08438 | 0.07194 | 35.842 | 32.228 |
| 1 | 16 | 11576208. | 0.08507 | 0.07240 | 35.965 | 32.351 |
| 1 | 17 | 11709238. | 0.08577 | 0.07287 | 36.089 | 32.474 |
| 1 | 18 | 11842268. | 0.08648 | 0.07335 | 36.215 | 32.599 |
| 1 | 19 | 11975298. | 0.08719 | 0.07384 | 36.343 | 32.725 |
| 1 | 20 | 12108328. | 0.08792 | 0.07433 | 36.472 | 32.853 |
| 1 | 21 | 12241358. | 0.08866 | 0.07483 | 36.603 | 32.982 |
| 1 | 22 | 12374388. | 0.08940 | 0.07534 | 36.735 | 33.112 |
| 1 | 23 | 12507418. | 0.09016 | 0.07585 | 36.870 | 33.244 |
| 1 | 24 | 12640448. | 0.09093 | 0.07638 | 37.006 | 33.378 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 91655.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.909273E-01 , c = 0.763778E-01 , a/c = 1.1905
Total Cycles = 12640448.

Execution time (hh:mm:ss): 00:00:00.0
Note: this is elapsed wall-clock time, not CPU time!

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Coldclevis_II |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section L-L | | | |

## CC03




$S_3 = \frac{P}{Dt}$

| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.3622 in. (Ref. SCD0678, Sec. L-L) |
| Plate thickness | t = 0.1811 in.(average thickness at Sec. L-L) |
| Plate width | w = 1.4960 in. |
| Hole diameter | D = 0.7087 in. |
| Crack Properties: | a = 0.050 in.<br>c = 0.050 in. |
| Loads: | |
| Strap load (cryo) | f = 22099 lbf (ref. Model 6-01, loads) |
| Load per side on clevis | Paxial = 22099/2 = 11049 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Coldclevis_II |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section L-L | | | |

Tensile Stress

S3 = Paxial/D*T

S3 = 11049/0.7087*0.3622 = 43.047 ksi

This clevis is part of the Strap at Section L-L. (Ref. Drawing SCD0678, issue 07, Section L-L)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch conditions. The NASGRO analysis uses truck air, On-orbit and Launch case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch/Landing spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section L-L, and a special dye penetrant crack sizes a= 0.050 in and c = 0.050 in are used

FATIGUE CRACK GROWTH ANALYSIS

DATE: 03/21/02 TIME: 10:13:07
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**L-L Lug With Only Cold Launch for AMS-02 Magnet straps**
**(Ref. Drg. SCD0678, issue 07, sect L-L)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1810
Plate Width, W = 1.4960
Hole Diameter, D = 0.7087

FLAW SIZE: (User specified)

a (init.) = 0.5000E-01 **(Special dye penetrant inspection)**
c (init.) = 0.5000E-01
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221

Material Header Info.:

Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L ~261
1
Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl: No.: | UTS : | YS : | K1e : | K1c : | Ak : | Bk : | Thk : | Kc : | Keac : |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.181 | 299.8 | |

| Matl No. | C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**( Ref. OIE205, Rev D, page 25 for UTS and YS for 316L stainless steel)**

L-L Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.43047 **(Ref. Coldclevis_LL,page 2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.43047

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.43047

Stress Scaling Factors for Block Case: **4** **(LIFTOFF-ONLY)**

Scale Factor for Stress S3: 0.43047

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From | - | To | Block Case No. |
|---|---|---|---|
| 1 | - | 4 | 1 |
| 5 | - | 8 | 2 |
| 9 | - | 12 | 3 |
| 13 | - | 24 | 4 |

Stresses: Tension, bending or pin

L-L Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 36.70: | 5.60: | 36.70: | 5.60: |
| 2: | 1: | 2148.00 : | 30.10: | 6.40: | 30.10: | 6.40: |
| 3: | 1: | 13668.00 : | 25.50: | 6.90: | 25.50: | 6.90: |
| 4: | 1: | 38857.00 : | 21.90: | 7.30: | 21.90: | 7.30: |
| 5: | 1: | 110517.00 : | 19.50: | 7.50: | 19.50: | 7.50: |
| 6: | 1: | 150546.00 : | 17.80: | 7.70: | 17.80: | 7.70: |
| 7: | 1: | 195456.00 : | 16.50: | 7.90: | 16.50: | 7.90: |
| 8: | 1: | 1440631.00 : | 15.90: | 7.90: | 15.90: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 2: | 1: | 594.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 3: | 1: | 695448.00 : | 22.60: | 7.20: | 22.60: | 7.20: |
| 4: | 1: | 30.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 5: | 1: | 17832.00 : | 43.10: | 4.90: | 43.10: | 4.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 : | 14.10: | 8.50: | 14.10: | 8.50: |
| 2: | 1: | 34.00 : | 13.90: | 8.50: | 13.90: | 8.50: |
| 3: | 1: | 60.00 : | 13.70: | 8.50: | 13.70: | 8.50: |
| 4: | 1: | 179.00 : | 13.50: | 8.50: | 13.50: | 8.50: |
| 5: | 1: | 117.00 : | 14.10: | 8.50: | 14.10: | 8.50: |
| 6: | 1: | 414.00 : | 13.90: | 8.50: | 13.90: | 8.50: |
| 7: | 1: | 2404.00 : | 13.70: | 8.50: | 13.70: | 8.50: |
| 8: | 1: | 9789.00 : | 13.50: | 8.50: | 13.50: | 8.50: |
| 9: | 1: | 62675.00 : | 13.40: | 8.50: | 13.40: | 8.50: |

Environmental Crack Growth Check for Sustained Stresses

(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 96.10 | 3.90 | 96.10 | 3.90 |
| 2 | 1 | 3.00 | 88.10 | 4.30 | 88.10 | 4.30 |
| 3 | 1 | 5.00 | 80.00 | 4.80 | 80.00 | 4.80 |
| 4 | 1 | 12.00 | 72.00 | 5.20 | 72.00 | 5.20 |
| 5 | 1 | 46.00 | 64.00 | 5.60 | 64.00 | 5.60 |
| 6 | 1 | 78.00 | 55.90 | 6.00 | 55.90 | 6.00 |
| 7 | 1 | 165.00 | 47.90 | 6.40 | 47.90 | 6.40 |
| 8 | 1 | 493.00 | 39.90 | 6.80 | 39.90 | 6.80 |
| 9 | 1 | 2229.00 | 31.90 | 7.20 | 31.90 | 7.20 |
| 10 | 1 | 2132.00 | 23.80 | 7.60 | 23.80 | 7.60 |
| 11 | 1 | 2920.00 | 21.40 | 7.80 | 21.40 | 7.80 |
| 12 | 1 | 22272.00 | 19.80 | 7.80 | 19.80 | 7.80 |
| 13 | 1 | 82954.00 | 18.20 | 7.90 | 18.20 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 15.80 | 2.41 | 0.00 | 0.00 |
| 2 | 1 | 2148.00 | 12.96 | 2.76 | 0.00 | 0.00 |
| 3 | 1 | 13668.00 | 10.98 | 2.97 | 0.00 | 0.00 |
| 4 | 1 | 38857.00 | 9.43 | 3.14 | 0.00 | 0.00 |
| 5 | 1 | 110517.00 | 8.39 | 3.23 | 0.00 | 0.00 |
| 6 | 1 | 150546.00 | 7.66 | 3.31 | 0.00 | 0.00 |
| 7 | 1 | 195456.00 | 7.10 | 3.40 | 0.00 | 0.00 |
| 8 | 1 | 1440631.00 | 6.84 | 3.40 | 0.00 | 0.00 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 18.55: | 2.11: | 0.00: | 0.00: |
| 2: | 1: | 594.00 | 18.55: | 2.11: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 | 9.73: | 3.10: | 0.00: | 0.00: |
| 4: | 1: | 30.00 | 18.55: | 2.11: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 | 18.55: | 2.11: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 6.07: | 3.66: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 5.98: | 3.66: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 5.90: | 3.66: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 5.81: | 3.66: | 0.00: | 0.00: |
| 5: | 1: | 117.00 | 6.07: | 3.66: | 0.00: | 0.00: |
| 6: | 1: | 414.00 | 5.98: | 3.66: | 0.00: | 0.00: |
| 7: | 1: | 2404.00 | 5.90: | 3.66: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 | 5.81: | 3.66: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 | 5.77: | 3.66: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 | 41.37: | 1.68: | 0.00: | 0.00: |
| 2: | 1: | 3.00 | 37.92: | 1.85: | 0.00: | 0.00: |
| 3: | 1: | 5.00 | 34.44: | 2.07: | 0.00: | 0.00: |
| 4: | 1: | 12.00 | 30.99: | 2.24: | 0.00: | 0.00: |
| 5: | 1: | 46.00 | 27.55: | 2.41: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6: | 1: | 78.00 : | 24.06: | 2.58: | 0.00: | 0.00: |
| 7: | 1: | 165.00 : | 20.62: | 2.76: | 0.00: | 0.00: |
| 8: | 1: | 493.00 : | 17.18: | 2.93: | 0.00: | 0.00: |
| 9: | 1: | 2229.00 : | 13.73: | 3.10: | 0.00: | 0.00: |
| 10: | 1: | 2132.00 : | 10.25: | 3.27: | 0.00: | 0.00: |
| 11: | 1: | 2920.00 : | 9.21: | 3.36: | 0.00: | 0.00: |
| 12: | 1: | 22272.00 : | 8.52: | 3.36: | 0.00: | 0.00: |
| 13: | 1: | 82954.00 : | 7.83: | 3.40: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Only Cold Launch
MODEL: CC03

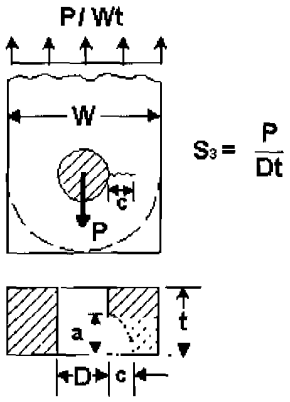
ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.05019 | 0.05007 | 11.310 | 9.747 |
| 1 | 2 | 3907160. | 0.05038 | 0.05014 | 11.321 | 9.767 |
| 1 | 3 | 5860740. | 0.05057 | 0.05021 | 11.331 | 9.786 |
| 1 | 4 | 7814320. | 0.05076 | 0.05028 | 11.342 | 9.805 |
| 1 | 5 | 8546056. | 0.05690 | 0.05391 | 13.842 | 12.145 |
| 1 | 6 | 9277792. | 0.06400 | 0.05838 | 14.433 | 12.798 |
| 1 | 7 | 10009528. | 0.07236 | 0.06385 | 15.147 | 13.536 |
| 1 | 8 | 10741264. | 0.08235 | 0.07059 | 15.951 | 14.331 |
| 1 | 9 | 10816970. | 0.08235 | 0.07059 | 5.223 | 4.693 |
| 1 | 10 | 10892676. | 0.08235 | 0.07059 | 5.223 | 4.693 |
| 1 | 11 | 10968382. | 0.08235 | 0.07059 | 5.223 | 4.693 |
| 1 | 12 | 11044088. | 0.08235 | 0.07059 | 5.223 | 4.693 |
| 1 | 13 | 11157398. | 0.08288 | 0.07094 | 35.599 | 31.986 |
| 1 | 14 | 11270708. | 0.08341 | 0.07130 | 35.693 | 32.080 |
| 1 | 15 | 11384018. | 0.08395 | 0.07166 | 35.789 | 32.175 |
| 1 | 16 | 11497328. | 0.08449 | 0.07202 | 35.886 | 32.271 |
| 1 | 17 | 11610638. | 0.08504 | 0.07239 | 35.984 | 32.368 |
| 1 | 18 | 11723948. | 0.08559 | 0.07276 | 36.082 | 32.466 |
| 1 | 19 | 11837258. | 0.08615 | 0.07314 | 36.182 | 32.564 |
| 1 | 20 | 11950568. | 0.08671 | 0.07352 | 36.283 | 32.664 |
| 1 | 21 | 12063878. | 0.08728 | 0.07391 | 36.384 | 32.764 |
| 1 | 22 | 12177188. | 0.08786 | 0.07430 | 36.487 | 32.865 |
| 1 | 23 | 12290498. | 0.08844 | 0.07469 | 36.591 | 32.967 |
| 1 | 24 | 12403808. | 0.08902 | 0.07509 | 36.696 | 33.070 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 82954.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.890243E-01 , c = 0.750931E-01 , a/c = 1.1855
Total Cycles = 12403808.

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Warmclevis_LL |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section L-L | | | |

## CC03




$S_3 = \frac{P}{Dt}$

Material: AISI 316/316L (75F)

NASA/FLAGRO Crack case type: CC03

Section Properties:

| | | |
|---|---|---|
| Design Clevis Thickness | T= 0.3622 in. | (Ref. SCD0678, Sec. L-L) |
| Plate thickness | t = 0.1810in. | (average thickness at Sec. L-L) |
| Plate width | w = 1.4960 in. | |
| Hole diameter | D = 0.7087 in. | |

Crack Properties:

a = 0.08902 in. (Ref. LL-clevis-cold-launch, P6)
c = 0.07509 in.
a/c= 1.1855

Loads:

| | |
|---|---|
| Strap load (cryo) | f = 19102 lbf (Ref. Model 6-01) |
| Load per side on clevis | Paxial = 19102/2 = 9551 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/17/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Warmclevis_LL |
|---|---|---|---|---|
| Checked By | 4/17/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section L-L | | | |

Tensile Stress

S3 = Paxial/D*T

S3 = 9551/0.7087*0.3622=37.209 ksi

This clevis is part of the Strap at Section L-L. (Ref. Drawing SCD0678, issue 07, Section L-L)

This clevis is at room temperature (75F) for the Landing condition. The NASGRO analysis uses the landing case spectrum at room temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The landing spectrum is run for 3 missions with a scatter factor of 4. The final crack size from the cold launch condition a= 0.08902 in, c=0.07509 in, and a/c = 1.1855 are used as the initial crack sizes for this model.

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/22/02 TIME: 15:13:11
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**L-L Lug With Warm Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section L-L)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1810
Plate Width, W = 1.4960
Hole Diameter, D = 0.7087

FLAW SIZE: **(User specified)**
**a (init.) = 0.8902E-01** **(Ref. The final crack sizes from**
**c (init.) = 0.7509E-01** **LL-clevis-cold-launch, Page 6)**
**a/c (init.) = 1.186**

MATERIAL
MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13AB1
Alloy Description : AISI 316/316L ~2611

Alloy Cond/HT : Ann sht & plt ~262
1
Product Form : ~2631

Environment : ~2641

Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **127.6** | **108.1** | 280.0 | 200.0 | 1.00 | 0.50 | 0.181 | 300.0 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 3.50 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250mm thick)**
L-L Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **|Name Block: LAND_ONLY)**

Scale Factor for Stress S3: 0.37209 **|Ref. Warmclevis-ll.doc, Page 2)**

Schedule info. was input manually

Total No. of Blocks in Schedule = 12

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 12 | 1 |

Stresses: Tension, bending or pin

L-L Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

SINGLE DISTINCT BLOCK

| STEP | MAT: NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|
| 1: | 1: 1.00 | 100.00: | 3.70: | 100.00: | 3.70: |
| 2: | 1: 1.00 | 91.30: | 4.20: | 91.30: | 4.20: |
| 3: | 1: 3.00 | 82.60: | 4.70: | 82.60: | 4.70: |
| 4: | 1: 3.00 | 74.00: | 5.20: | 74.00: | 5.20: |
| 5: | 1: 3.00 | 65.30: | 5.70: | 65.30: | 5.70: |
| 6: | 1: 3.00 | 56.60: | 6.10: | 56.60: | 6.10: |
| 7: | 1: 13.00 | 47.90: | 6.60: | 47.90: | 6.60: |
| 8: | 1: 148.00 | 39.20: | 7.10: | 39.20: | 7.10: |
| 9: | 1: 891.00 | 30.60: | 7.60: | 30.60: | 7.60: |
| 10: | 1: 1273.00 | 21.90: | 8.10: | 21.90: | 8.10: |
| 11: | 1: 2099.00 | 19.30: | 8.20: | 19.30: | 8.20: |
| 12: | 1: 6581.00 | 17.50: | 8.30: | 17.50: | 8.30: |
| 13: | 1: 8701.00 | 15.80: | 8.40: | 15.80: | 8.40: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

One Block of Warm Landing

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 37.21: | 1.38: | 0.00: | 0.00: |
| 2: | 1: | 1.00 : | 33.97: | 1.56: | 0.00: | 0.00: |
| 3: | 1: | 3.00 : | 30.73: | 1.75: | 0.00: | 0.00: |
| 4: | 1: | 3.00 : | 27.53: | 1.93: | 0.00: | 0.00: |
| 5: | 1: | 3.00 : | 24.30: | 2.12: | 0.00: | 0.00: |
| 6: | 1: | 3.00 : | 21.06: | 2.27: | 0.00: | 0.00: |
| 7: | 1: | 13.00 : | 17.82: | 2.46: | 0.00: | 0.00: |
| 8: | 1: | 148.00 : | 14.59: | 2.64: | 0.00: | 0.00: |
| 9: | 1: | 891.00 : | 11.39: | 2.83: | 0.00: | 0.00: |
| 10: | 1: | 1273.00 : | 8.15: | 3.01: | 0.00: | 0.00: |
| 11: | 1: | 2099.00 : | 7.18: | 3.05: | 0.00: | 0.00: |
| 12: | 1: | 6581.00 : | 6.51: | 3.09: | 0.00: | 0.00: |
| 13: | 1: | 8701.00 : | 5.88: | 3.13: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

L-L Lug With Warm Landing
MODEL: CC03

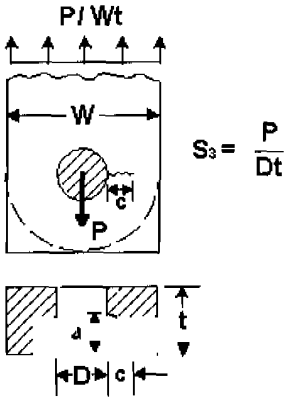
ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 19720. | 0.08920 | 0.07521 | 33.101 | 29.837 |
| 1 | 2 | 39440. | 0.08937 | 0.07533 | 33.129 | 29.865 |
| 1 | 3 | 59160. | 0.08955 | 0.07545 | 33.157 | 29.894 |
| 1 | 4 | 78880. | 0.08973 | 0.07556 | 33.186 | 29.922 |
| 1 | 5 | 98600. | 0.08991 | 0.07568 | 33.214 | 29.950 |
| 1 | 6 | 118320. | 0.09008 | 0.07580 | 33.243 | 29.979 |
| 1 | 7 | 138040. | 0.09026 | 0.07593 | 33.271 | 30.007 |
| 1 | 8 | 157760. | 0.09044 | 0.07605 | 33.300 | 30.036 |
| 1 | 9 | 177480. | 0.09062 | 0.07617 | 33.329 | 30.064 |
| 1 | 10 | 197200. | 0.09081 | 0.07629 | 33.358 | 30.093 |
| 1 | 11 | 216920. | 0.09099 | 0.07641 | 33.387 | 30.122 |
| 1 | 12 | 236640. | 0.09117 | 0.07654 | 33.416 | 30.151 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 8701.00
of Load Step No. 13 Description: None
of Block No. 12
of Schedule No. 1
Crack Sizes: a = 0.911690E-01 , c = 0.765366E-01 , a/c = 1.1912
Total Cycles = 236640.00

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name<br>Cryoclevis_mm |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section M-M | | | |

## CC03




$S_3 = \frac{P}{Dt}$

| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.3543 in. (Ref. SCD0678, Sec. M-M) |
| Plate thickness | t = 0.177 in. (average thickness at Sec. M-M) |
| Plate width | w = 1.591 in. |
| Hole diameter | D = 0.748 in. |
| Crack Properties: | a = 0.05 in.<br>c = 0.05 in. |
| Loads: | |
| Strap load (cryo) | f = 22099 lbf (ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 22099/2 = 11050 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Cryoclevis_mm |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section M-M | | | |

Tensile Stress

S3 = Paxial/D*T

S3 = 11050/0.748*0.3543 = 41.696 ksi

This clevis is part of the Strap at Section M-M. (Ref. Drawing SCD0678, issue 07, Section M-M)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch/Landing conditions. The NASGRO analysis uses truck air, On-orbit and Launch/Landing case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch/Landing spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section M-M, and the special dye penetrant crack sizes a = 0.05 in and c = 0.05 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/02/02 TIME: 08:24:29
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**M-M Lug With Cold Launch and Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678,issue 07, Section M-M)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1770
Plate Width, W = 1.5910
Hole Diameter, D = 0.7480

FLAW SIZE: **(User specified)**
**Method of Inspection: Special Dye Penetrant**
a (init.) = 0.5000E-01
c (init.) = 0.5000E-01
a/c (init.) = 1.000

MATERIAL

MATL 1: Edited file data ~2211
~2221

Material Header Info.:
Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L ~261
1
Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631
Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.177 | 299.8 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250 mm thick)**
M-M Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.41696 **(Ref. Cryoclevis_mm.doc, Page 2)**

Stress Scaling Factors for Block Case: **2** **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.41696

Stress Scaling Factors for Block Case: **3** **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.41696

Stress Scaling Factors for Block Case: **4** **(GSFC-VCMAGNET)**

Scale Factor for Stress S3: 0.41696

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From | - | To | Block Case No. |
|---|---|---|---|
| 1 | - | 4 | 1 |
| 5 | - | 8 | 2 |
| 9 | - | 12 | 3 |
| 13 | - | 24 | 4 |

Stresses: Tension, bending or pin

M-M Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE
---
Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 : | 36.70: | 5.60: | 36.70: | 5.60: |
| 2: | 1: | 2148.00 : | 30.10: | 6.40: | 30.10: | 6.40: |
| 3: | 1: | 13668.00 : | 25.50: | 6.90: | 25.50: | 6.90: |
| 4: | 1: | 38857.00 : | 21.90: | 7.30: | 21.90: | 7.30: |
| 5: | 1: | 110517.00 : | 19.50: | 7.50: | 19.50: | 7.50: |
| 6: | 1: | 150546.00 : | 17.80: | 7.70: | 17.80: | 7.70: |
| 7: | 1: | 195456.00 : | 16.50: | 7.90: | 16.50: | 7.90: |
| 8: | 1: | 1440631.00 : | 15.90: | 7.90: | 15.90: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 2: | 1: | 594.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 3: | 1: | 695448.00 | 22.60: | 7.20: | 22.60: | 7.20: |
| 4: | 1: | 30.00 | 43.10: | 4.90: | 43.10: | 4.90: |
| 5: | 1: | 17832.00 | 43.10: | 4.90: | 43.10: | 4.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 14.10: | 8.50: | 14.10: | 8.50: |
| 2: | 1: | 34.00 | 13.90: | 8.50: | 13.90: | 8.50: |
| 3: | 1: | 60.00 | 13.70: | 8.50: | 13.70: | 8.50: |
| 4: | 1: | 179.00 | 13.50: | 8.50: | 13.50: | 8.50: |
| 5: | 1: | 117.00 | 14.10: | 8.50: | 14.10: | 8.50: |
| 6: | 1: | 414.00 | 13.90: | 8.50: | 13.90: | 8.50: |
| 7: | 1: | 2404.00 | 13.70: | 8.50: | 13.70: | 8.50: |
| 8: | 1: | 9789.00 | 13.50: | 8.50: | 13.50: | 8.50: |
| 9: | 1: | 62675.00 | 13.40: | 8.50: | 13.40: | 8.50: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 2.00 | 96.10: | 3.90: | 96.10: | 3.90: |
| 2: | 1: | 4.00 | 88.10: | 4.30: | 88.10: | 4.30: |
| 3: | 1: | 8.00 | 80.00: | 4.80: | 80.00: | 4.80: |
| 4: | 1: | 15.00 | 72.00: | 5.20: | 72.00: | 5.20: |
| 5: | 1: | 49.00 | 64.00: | 5.60: | 64.00: | 5.60: |
| 6: | 1: | 81.00 | 55.90: | 6.00: | 55.90: | 6.00: |
| 7: | 1: | 178.00 | 47.90: | 6.40: | 47.90: | 6.40: |
| 8: | 1: | 641.00 | 39.90: | 6.80: | 39.90: | 6.80: |
| 9: | 1: | 3120.00 | 31.90: | 7.20: | 31.90: | 7.20: |
| 10: | 1: | 3405.00 | 23.80: | 7.60: | 23.80: | 7.60: |
| 11: | 1: | 5019.00 | 21.40: | 7.80: | 21.40: | 7.80: |
| 12: | 1: | 28853.00 | 19.80: | 7.80: | 19.80: | 7.80: |
| 13: | 1: | 91655.00 | 18.20: | 7.90: | 18.20: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 15.30: | 2.33: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 | 12.55: | 2.67: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 | 10.63: | 2.88: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 | 9.13: | 3.04: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 | 8.13: | 3.13: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 | 7.42: | 3.21: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 | 6.88: | 3.29: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 | 6.63: | 3.29: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 17.97: | 2.04: | 0.00: | 0.00: |
| 2: | 1: | 594.00 | 17.97: | 2.04: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 | 9.42: | 3.00: | 0.00: | 0.00: |
| 4: | 1: | 30.00 | 17.97: | 2.04: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 | 17.97: | 2.04: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 5.88: | 3.54: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 5.80: | 3.54: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 5.71: | 3.54: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 5.63: | 3.54: | 0.00: | 0.00: |
| 5: | 1: | 117.00 | 5.88: | 3.54: | 0.00: | 0.00: |
| 6: | 1: | 414.00 | 5.80: | 3.54: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7: | 1: | 2404.00 : | 5.71: | 3.54: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 5.63: | 3.54: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 5.59: | 3.54: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Cold Launch and Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 2.00 : | 40.07: | 1.63: | 0.00: | 0.00: |
| 2: | 1: | 4.00 : | 36.73: | 1.79: | 0.00: | 0.00: |
| 3: | 1: | 8.00 : | 33.36: | 2.00: | 0.00: | 0.00: |
| 4: | 1: | 15.00 : | 30.02: | 2.17: | 0.00: | 0.00: |
| 5: | 1: | 49.00 : | 26.69: | 2.33: | 0.00: | 0.00: |
| 6: | 1: | 81.00 : | 23.31: | 2.50: | 0.00: | 0.00: |
| 7: | 1: | 178.00 : | 19.97: | 2.67: | 0.00: | 0.00: |
| 8: | 1: | 641.00 : | 16.64: | 2.84: | 0.00: | 0.00: |
| 9: | 1: | 3120.00 : | 13.30: | 3.00: | 0.00: | 0.00: |
| 10: | 1: | 3405.00 : | 9.92: | 3.17: | 0.00: | 0.00: |
| 11: | 1: | 5019.00 : | 8.92: | 3.25: | 0.00: | 0.00: |
| 12: | 1: | 28853.00 : | 8.26: | 3.25: | 0.00: | 0.00: |
| 13: | 1: | 91655.00 : | 7.59: | 3.29: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Cold Launch and Landing
MODEL: CC03

ANALYSIS RESULTS:

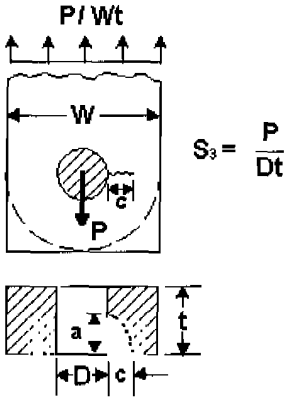
| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.05014 | 0.05006 | 10.952 | 9.531 |
| 1 | 2 | 3907160. | 0.05028 | 0.05012 | 10.961 | 9.544 |
| 1 | 3 | 5860740. | 0.05042 | 0.05018 | 10.969 | 9.558 |
| 1 | 4 | 7814320. | 0.05057 | 0.05024 | 10.978 | 9.572 |
| 1 | 5 | 8546056. | 0.05597 | 0.05351 | 13.356 | 11.800 |
| 1 | 6 | 9277792. | 0.06215 | 0.05745 | 13.871 | 12.373 |
| 1 | 7 | 10009528. | 0.06932 | 0.06221 | 14.460 | 12.991 |
| 1 | 8 | 10741264. | 0.07774 | 0.06797 | 15.173 | 13.708 |
| 1 | 9 | 10816970. | 0.07774 | 0.06797 | 4.963 | 4.484 |
| 1 | 10 | 10892676. | 0.07774 | 0.06797 | 4.963 | 4.484 |
| 1 | 11 | 10968382. | 0.07774 | 0.06797 | 4.963 | 4.484 |
| 1 | 12 | 11044088. | 0.07774 | 0.06797 | 4.963 | 4.484 |
| 1 | 13 | 11177118. | 0.07829 | 0.06834 | 33.830 | 30.563 |
| 1 | 14 | 11310148. | 0.07884 | 0.06872 | 33.928 | 30.665 |
| 1 | 15 | 11443178. | 0.07941 | 0.06910 | 34.029 | 30.767 |
| 1 | 16 | 11576208. | 0.07997 | 0.06948 | 34.130 | 30.870 |
| 1 | 17 | 11709238. | 0.08055 | 0.06987 | 34.232 | 30.974 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 18 | 11842268. | 0.08113 | 0.07027 | 34.336 | 31.079 |
| 1 | 19 | 11975298. | 0.08172 | 0.07067 | 34.440 | 31.185 |
| 1 | 20 | 12108328. | 0.08232 | 0.07108 | 34.546 | 31.292 |
| 1 | 21 | 12241358. | 0.08292 | 0.07149 | 34.654 | 31.399 |
| 1 | 22 | 12374388. | 0.08353 | 0.07191 | 34.762 | 31.508 |
| 1 | 23 | 12507418. | 0.08414 | 0.07233 | 34.872 | 31.618 |
| 1 | 24 | 12640448. | 0.08477 | 0.07276 | 34.983 | 31.729 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 91655.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.847666E-01 , c = 0.727612E-01 , a/c = 1.1650
Total Cycles = 12640448.

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Coldclevis_mm |
|---|---|---|---|---|
| Checked By | 4/23/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section M-M | | | |

## CC03




$$S_3 = \frac{P}{Dt}$$

| | |
|---|---|
| Material: | AISI 316/316L (-452F) |
| NASA/FLAGRO Crack case type: | CC03 |
| Section Properties: | |
| Design Clevis Thickness | T=0.3543 in. (Ref. SCD0678, Sec. M-M) |
| Plate thickness | t = 0.177 in. (average thickness at Sec. M-M) |
| Plate width | w = 1.591 in. |
| Hole diameter | D = 0.748 in. |
| Crack Properties: | a = 0.05 in.<br>c = 0.05 in. |
| Loads: | |
| Strap load (cryo) | f = 22099 lbf (ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 22099/2 = 11050 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Coldclevis_mm |
|---|---|---|---|---|
| Checked By | 4/23/02 | Science, Engineering, Analysis, & Test<br>*Mechanical Systems Analysis Department.* | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Cryo)<br>Section M-M | | | |

Tensile Stress

S3 = Paxial/D*T
S3 = 11050/0.748*0.3543=41.696 ksi

This clevis is part of the Strap at Section M-M. (Ref. Drawing SCD0678, issue 07, Section M-M)

This clevis is at cryogenic temperature (-452F) for Truck transportation, Air transportation, On-Orbit, and Launch conditions. The NASGRO analysis uses truck air, On-orbit and Launch case spectrums at cryo temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The truck, air and on orbit spectrums are run for 1 mission with a scatter factor of 4 and the Launch spectrum is run for 3 missions with a scatter factor of 4. Dye penetrant inspection is used to inspect the clevis at Section M-M, and the special dye penetrant crack sizes a= 0.05 in and c = 0.05 in are used (ref. JSC22267A, table 2).

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/02/02 TIME: 09:32:10
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**M-M Lug With Cold Launch for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section M-M)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1770
Plate Width, W = 1.5910
Hole Diameter, D = 0.7480

FLAW SIZE: **(User specified)**
**Method of Inspection: Special Dye Penetrant**
a (init.) = 0.5000E-01
c (init.) = 0.5000E-01
a/c (init.) = 1.000

MATERIAL
MATL 1: Edited file data ~2211
~2221

Material Header Info.:
Material 1 Data ID: F3KA13LA2
Alloy Description : AISI 316/316L
~2611
Alloy Cond/HT : Ann sht & plt ; -452F LHe
~2621
Product Form : ~2631

Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :

Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **203.1** | **162.5** | 280.0 | 200.0 | 1.00 | 0.50 | 0.177 | 299.8 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 8.00 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev. D, Page 25 for UTS and YS of 316L, 250 mm thick)**
M-M Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: 1 **(Name Block: TRUCK3-VCMAGNET)**

Scale Factor for Stress S3: 0.41695 **(Ref. Coldclevis_mm.doc, Page2)**

Stress Scaling Factors for Block Case: 2 **(AIR3-VCMAGNET)**

Scale Factor for Stress S3: 0.41695

Stress Scaling Factors for Block Case: 3 **(ONORBIT2-VCMAGNET)**

Scale Factor for Stress S3: 0.41695

Stress Scaling Factors for Block Case: 4 **(LIFTOFF-ONLY)**

Scale Factor for Stress S3: 0.41695

Schedule info. was input manually

Total No. of Blocks in Schedule = 24

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 4 | 1 |
| 5 - 8 | 2 |
| 9 - 12 | 3 |
| 13 - 24 | 4 |

Stresses: Tension, bending or pin

---

M-M Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

Four Blocks of VCMAGNET

BLOCK CASE NO. 1

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1757.00 | 36.70 | 5.60 | 36.70 | 5.60 |
| 2 | 1 | 2148.00 | 30.10 | 6.40 | 30.10 | 6.40 |
| 3 | 1 | 13668.00 | 25.50 | 6.90 | 25.50 | 6.90 |
| 4 | 1 | 38857.00 | 21.90 | 7.30 | 21.90 | 7.30 |
| 5 | 1 | 110517.00 | 19.50 | 7.50 | 19.50 | 7.50 |
| 6 | 1 | 150546.00 | 17.80 | 7.70 | 17.80 | 7.70 |
| 7 | 1 | 195456.00 | 16.50 | 7.90 | 16.50 | 7.90 |
| 8 | 1 | 1440631.00 | 15.90 | 7.90 | 15.90 | 7.90 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 2

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 2: | 1: | 594.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 3: | 1: | 695448.00 : | 22.60: | 7.20: | 22.60: | 7.20: |
| 4: | 1: | 30.00 : | 43.10: | 4.90: | 43.10: | 4.90: |
| 5: | 1: | 17832.00 : | 43.10: | 4.90: | 43.10: | 4.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 3

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 : | 14.10: | 8.50: | 14.10: | 8.50: |
| 2: | 1: | 34.00 : | 13.90: | 8.50: | 13.90: | 8.50: |
| 3: | 1: | 60.00 : | 13.70: | 8.50: | 13.70: | 8.50: |
| 4: | 1: | 179.00 : | 13.50: | 8.50: | 13.50: | 8.50: |
| 5: | 1: | 117.00 : | 14.10: | 8.50: | 14.10: | 8.50: |
| 6: | 1: | 414.00 : | 13.90: | 8.50: | 13.90: | 8.50: |
| 7: | 1: | 2404.00 : | 13.70: | 8.50: | 13.70: | 8.50: |
| 8: | 1: | 9789.00 : | 13.50: | 8.50: | 13.50: | 8.50: |
| 9: | 1: | 62675.00 : | 13.40: | 8.50: | 13.40: | 8.50: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

BLOCK CASE NO. 4

| STEP | MAT | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1.00 : | 96.10: | 3.90: | 96.10: | 3.90: |
| 2: | 1: | 3.00 : | 88.10: | 4.30: | 88.10: | 4.30: |
| 3: | 1: | 5.00 : | 80.00: | 4.80: | 80.00: | 4.80: |
| 4: | 1: | 12.00 : | 72.00: | 5.20: | 72.00: | 5.20: |
| 5: | 1: | 46.00 : | 64.00: | 5.60: | 64.00: | 5.60: |
| 6: | 1: | 78.00 : | 55.90: | 6.00: | 55.90: | 6.00: |
| 7: | 1: | 165.00 : | 47.90: | 6.40: | 47.90: | 6.40: |
| 8: | 1: | 493.00 : | 39.90: | 6.80: | 39.90: | 6.80: |
| 9: | 1: | 2229.00 : | 31.90: | 7.20: | 31.90: | 7.20: |
| 10: | 1: | 2132.00 : | 23.80: | 7.60: | 23.80: | 7.60: |
| 11: | 1: | 2920.00 : | 21.40: | 7.80: | 21.40: | 7.80: |
| 12: | 1: | 22272.00 : | 19.80: | 7.80: | 19.80: | 7.80: |
| 13: | 1: | 82954.00 : | 18.20: | 7.90: | 18.20: | 7.90: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 1757.00 | 15.30: | 2.33: | 0.00: | 0.00: |
| 2: | 1: | 2148.00 | 12.55: | 2.67: | 0.00: | 0.00: |
| 3: | 1: | 13668.00 | 10.63: | 2.88: | 0.00: | 0.00: |
| 4: | 1: | 38857.00 | 9.13: | 3.04: | 0.00: | 0.00: |
| 5: | 1: | 110517.00 | 8.13: | 3.13: | 0.00: | 0.00: |
| 6: | 1: | 150546.00 | 7.42: | 3.21: | 0.00: | 0.00: |
| 7: | 1: | 195456.00 | 6.88: | 3.29: | 0.00: | 0.00: |
| 8: | 1: | 1440631.00 | 6.63: | 3.29: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 17832.00 | 17.97: | 2.04: | 0.00: | 0.00: |
| 2: | 1: | 594.00 | 17.97: | 2.04: | 0.00: | 0.00: |
| 3: | 1: | 695448.00 | 9.42: | 3.00: | 0.00: | 0.00: |
| 4: | 1: | 30.00 | 17.97: | 2.04: | 0.00: | 0.00: |
| 5: | 1: | 17832.00 | 17.97: | 2.04: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1: | 1: | 34.00 | 5.88: | 3.54: | 0.00: | 0.00: |
| 2: | 1: | 34.00 | 5.80: | 3.54: | 0.00: | 0.00: |
| 3: | 1: | 60.00 | 5.71: | 3.54: | 0.00: | 0.00: |
| 4: | 1: | 179.00 | 5.63: | 3.54: | 0.00: | 0.00: |
| 5: | 1: | 117.00 | 5.88: | 3.54: | 0.00: | 0.00: |
| 6: | 1: | 414.00 | 5.80: | 3.54: | 0.00: | 0.00: |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7: | 1: | 2404.00 : | 5.71: | 3.54: | 0.00: | 0.00: |
| 8: | 1: | 9789.00 : | 5.63: | 3.54: | 0.00: | 0.00: |
| 9: | 1: | 62675.00 : | 5.59: | 3.54: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Only Cold Launch
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

Four Blocks of VCMAGNET

| S | M: | NUMBER | S3 | | S | |
|---|---|---|---|---|---|---|
| T | A: | OF | | | | |
| E | T: | FATIGUE | (ksi) | | (ksi) | |
| P | L: | CYCLES | (t1) : | (t2) | (t1) : | (t2) |
| 1: | 1: | 1.00 : | 40.07: | 1.63: | 0.00: | 0.00: |
| 2: | 1: | 3.00 : | 36.73: | 1.79: | 0.00: | 0.00: |
| 3: | 1: | 5.00 : | 33.36: | 2.00: | 0.00: | 0.00: |
| 4: | 1: | 12.00 : | 30.02: | 2.17: | 0.00: | 0.00: |
| 5: | 1: | 46.00 : | 26.68: | 2.33: | 0.00: | 0.00: |
| 6: | 1: | 78.00 : | 23.31: | 2.50: | 0.00: | 0.00: |
| 7: | 1: | 165.00 : | 19.97: | 2.67: | 0.00: | 0.00: |
| 8: | 1: | 493.00 : | 16.64: | 2.84: | 0.00: | 0.00: |
| 9: | 1: | 2229.00 : | 13.30: | 3.00: | 0.00: | 0.00: |
| 10: | 1: | 2132.00 : | 9.92: | 3.17: | 0.00: | 0.00: |
| 11: | 1: | 2920.00 : | 8.92: | 3.25: | 0.00: | 0.00: |
| 12: | 1: | 22272.00 : | 8.26: | 3.25: | 0.00: | 0.00: |
| 13: | 1: | 82954.00 : | 7.59: | 3.29: | 0.00: | 0.00: |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Only Cold Launch
MODEL: CC03

ANALYSIS RESULTS:

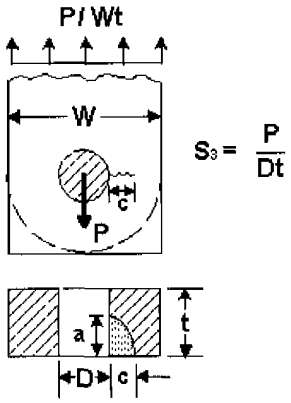
| Schdl | Block Step | Cycles | Final Flaw Size a | c | K max a-tip | c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 1953580. | 0.05014 | 0.05006 | 10.952 | 9.531 |
| 1 | 2 | 3907160. | 0.05028 | 0.05012 | 10.960 | 9.544 |
| 1 | 3 | 5860740. | 0.05042 | 0.05018 | 10.969 | 9.558 |
| 1 | 4 | 7814320. | 0.05057 | 0.05024 | 10.977 | 9.572 |
| 1 | 5 | 8546056. | 0.05597 | 0.05351 | 13.356 | 11.800 |
| 1 | 6 | 9277792. | 0.06215 | 0.05745 | 13.871 | 12.373 |
| 1 | 7 | 10009528. | 0.06932 | 0.06221 | 14.460 | 12.991 |
| 1 | 8 | 10741264. | 0.07774 | 0.06797 | 15.172 | 13.708 |
| 1 | 9 | 10816970. | 0.07774 | 0.06797 | 4.963 | 4.484 |
| 1 | 10 | 10892676. | 0.07774 | 0.06797 | 4.963 | 4.484 |
| 1 | 11 | 10968382. | 0.07774 | 0.06797 | 4.963 | 4.484 |
| 1 | 12 | 11044088. | 0.07774 | 0.06797 | 4.963 | 4.484 |
| 1 | 13 | 11157398. | 0.07817 | 0.06827 | 33.827 | 30.561 |
| 1 | 14 | 11270708. | 0.07861 | 0.06856 | 33.905 | 30.641 |
| 1 | 15 | 11384018. | 0.07905 | 0.06886 | 33.985 | 30.722 |
| 1 | 16 | 11497328. | 0.07950 | 0.06917 | 34.065 | 30.803 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 17 | 11610638. | 0.07995 | 0.06947 | 34.145 | 30.885 |
| 1 | 18 | 11723948. | 0.08041 | 0.06978 | 34.227 | 30.967 |
| 1 | 19 | 11837258. | 0.08086 | 0.07010 | 34.309 | 31.050 |
| 1 | 20 | 11950568. | 0.08133 | 0.07041 | 34.392 | 31.133 |
| 1 | 21 | 12063878. | 0.08179 | 0.07073 | 34.475 | 31.217 |
| 1 | 22 | 12177188. | 0.08227 | 0.07105 | 34.559 | 31.302 |
| 1 | 23 | 12290498. | 0.08274 | 0.07138 | 34.645 | 31.387 |
| 1 | 24 | 12403808. | 0.08322 | 0.07171 | 34.731 | 31.473 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 82954.00
of Load Step No. 13 Description: None
of Block No. 24
of Schedule No. 1
Crack Sizes: a = 0.832220E-01 , c = 0.717118E-01 , a/c = 1.1605
Total Cycles = 12403808.

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 1 | File Name Warmclevis_mm |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section M-M | | | |

## CC03




$S_3 = \frac{P}{Dt}$

Material: AISI 316/316L (75F)

NASA/FLAGRO Crack case type: CC03

Section Properties:

| | | |
|---|---|---|
| Design Clevis Thickness | T=0.3543 in. | (Ref. SCD0678, Sec. M-M) |
| Plate thickness | t = 0.177 in. | (average thickness at Sec. M-M) |
| Plate width | w = 1.591 in. | |
| Hole diameter | D = 0.748 in. | |

Crack Properties:

a = 0.08322 in. (Ref. MM-clevis-cold-launch, P6)
c = 0.07171 in.
a/c= 1.1605

Loads:

| | |
|---|---|
| Strap load (warm) | f = 19102 lbf (Ref. Model 6-01 loads) |
| Load per side on clevis | Paxial = 19102/2 = 9551 lbf |

| Prepared By | Name/Date<br>Saike Wang<br>4/22/02 | LOCKHEED MARTIN | Page/Section No. 2 | File Name Warmclevis_mm |
|---|---|---|---|---|
| Checked By | 4/22/02 | Science, Engineering, Analysis, & Test<br>Mechanical Systems Analysis Department. | Drawing No. | SCD0678 |
| Title | AMS-02 Magnet Strap Clevis (Warm)<br>Section M-M | | | |

Tensile Stress

$S3 = Paxial/D*T$

$S3 = 9551/0.748*0.3543 = 36.039$ ksi

This clevis is part of the Strap at Section M-M. (Ref. Drawing SCD0678, issue 07, Section M-M)

This clevis is at room temperature (75F) for the Landing condition. The NASGRO analysis uses the landing case spectrum at room temperature. The material data used is from code AISI 316/316L of the NASGRO library, except that the UTS and YS are changed as per the material property for the 316L S.S. as per OIE205 Rev.D, Page 25.

The landing spectrum is run for 3 missions with a scatter factor of 4. The final crack size from the cold launch condition a= 0.08322 in, c=0.07171 in, and a/c = 1.1605 are used as the initial crack sizes for this model.

FATIGUE CRACK GROWTH ANALYSIS

DATE: 04/02/02 TIME: 10:56:07
(computed: NASGRO Version 3.0.4, Jan 2000.)
U.S. customary units [inches, ksi, ksi sqrt(in)]

PROBLEM TITLE

**M-M Lug With Warm Landing for AMS-02 Magnet Strap**
**(Ref. Drawing SCD0678, issue 07, Section M-M)**

Crack Growth Model: Non Interaction
Equation/Table : NASGRO Equation

GEOMETRY

MODEL: CC03-Corner crack from hole in lug (2D).

Plate Thickness, t = 0.1770
Plate Width, W = 1.5910
Hole Diameter, D = 0.7480

FLAW SIZE: **(User specified)**
**a (init.) = 0.0832** **(Ref. The final crack sizes from**
**c (init.) = 0.0717** **MM-clevis-cold-launch, Page 6)**
**a/c (init.) = 1.161**

MATERIAL

MATL 1: Edited file data ~2211
~2221
Material Header Info.:

Material 1 Data ID: F3KA13AB1
Alloy Description : AISI 316/316L ~261
1
Alloy Cond/HT : Ann sht & plt
~2621
Product Form : ~2631

Environment : ~2641
Specimen Type :
Specimen Orientation :
Specimen Thickness :
Specimen Width :
Specimen Test Frequency :
Data Reference :
Material Properties:

| Matl: No. | UTS | YS | K1e | K1c | Ak | Bk | Thk | Kc | Keac |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **127.6** | **108.1** | 280.0 | 200.0 | 1.00 | 0.50 | 0.177 | 300.0 | |

| Matl: No. | Crack Growth Eqn Constants C | n | p | q | DKo | Cth+ | Cth- | Rcl | Alpha | Smax/SIGo |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.220D-09 | 3.200 | 0.25 | 0.25 | 3.50 | 1.50 | 0.10 | 0.70 | 2.50 | 0.30 |

**(Ref. OIE205 Rev.D, Page 25 for UTS and YS of 316L, 250mm thick)**
M-M Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

[Note: Stress = Input Value * Scale Factor]

Stress Scaling Factors for Block Case: **1** **(Name Block: LAND_ONLY)**

Scale Factor for Stress S3: 0.36039 **(Ref. Warmclevis-mm.doc, Page 2)**

Schedule info. was input manually

Total No. of Blocks in Schedule = 12

Block Number and Case Correspondences

| Block Number From - To | Block Case No. |
|---|---|
| 1 - 12 | 1 |

Stresses: Tension, bending or pin

M-M Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK INPUT TABLE

One Block of Warm Landing

SINGLE DISTINCT BLOCK

| STEP | MAT'L | NUMBER OF FATIGUE CYCLES | S3 (t1) | S3 (t2) | S (t1) | S (t2) |
|---|---|---|---|---|---|---|
| 1 | 1 | 1.00 | 100.00 | 3.70 | 100.00 | 3.70 |
| 2 | 1 | 1.00 | 91.30 | 4.20 | 91.30 | 4.20 |
| 3 | 1 | 3.00 | 82.60 | 4.70 | 82.60 | 4.70 |
| 4 | 1 | 3.00 | 74.00 | 5.20 | 74.00 | 5.20 |
| 5 | 1 | 3.00 | 65.30 | 5.70 | 65.30 | 5.70 |
| 6 | 1 | 3.00 | 56.60 | 6.10 | 56.60 | 6.10 |
| 7 | 1 | 13.00 | 47.90 | 6.60 | 47.90 | 6.60 |
| 8 | 1 | 148.00 | 39.20 | 7.10 | 39.20 | 7.10 |
| 9 | 1 | 891.00 | 30.60 | 7.60 | 30.60 | 7.60 |
| 10 | 1 | 1273.00 | 21.90 | 8.10 | 21.90 | 8.10 |
| 11 | 1 | 2099.00 | 19.30 | 8.20 | 19.30 | 8.20 |
| 12 | 1 | 6581.00 | 17.50 | 8.30 | 17.50 | 8.30 |
| 13 | 1 | 8701.00 | 15.80 | 8.40 | 15.80 | 8.40 |

Environmental Crack Growth Check for Sustained Stresses
(Kmax less than Keac): NOT SET

M-M Lug With Warm Landing
MODEL: CC03

FATIGUE SCHEDULE BLOCK STRESS TABLE

One Block of Warm Landing

| S T E P | M: A: T: L: | NUMBER OF FATIGUE CYCLES | S3 (ksi) (t1) | S3 (ksi) (t2) | S (ksi) (t1) | S (ksi) (t2) |
|---|---|---|---|---|---|---|
| 1 | 1: | 1.00 | 36.04: | 1.33: | 0.00: | 0.00: |
| 2 | 1: | 1.00 | 32.90: | 1.51: | 0.00: | 0.00: |
| 3 | 1: | 3.00 | 29.77: | 1.69: | 0.00: | 0.00: |
| 4 | 1: | 3.00 | 26.67: | 1.87: | 0.00: | 0.00: |
| 5 | 1: | 3.00 | 23.53: | 2.05: | 0.00: | 0.00: |
| 6 | 1: | 3.00 | 20.40: | 2.20: | 0.00: | 0.00: |
| 7 | 1: | 13.00 | 17.26: | 2.38: | 0.00: | 0.00: |
| 8 | 1: | 148.00 | 14.13: | 2.56: | 0.00: | 0.00: |
| 9 | 1: | 891.00 | 11.03: | 2.74: | 0.00: | 0.00: |
| 10 | 1: | 1273.00 | 7.89: | 2.92: | 0.00: | 0.00: |
| 11 | 1: | 2099.00 | 6.96: | 2.96: | 0.00: | 0.00: |
| 12 | 1: | 6581.00 | 6.31: | 2.99: | 0.00: | 0.00: |
| 13 | 1: | 8701.00 | 5.69: | 3.03: | 0.00: | 0.00: |

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ANALYSIS RESULTS:

| Schdl | Block Step | Cycles | Final Flaw Size a | Final Flaw Size c | K max a-tip | K max c-tip |
|---|---|---|---|---|---|---|
| 1 | 1 | 19720. | 0.08336 | 0.07180 | 31.315 | 28.385 |
| 1 | 2 | 39440. | 0.08351 | 0.07190 | 31.337 | 28.409 |
| 1 | 3 | 59160. | 0.08365 | 0.07199 | 31.360 | 28.433 |
| 1 | 4 | 78880. | 0.08380 | 0.07208 | 31.382 | 28.456 |
| 1 | 5 | 98600. | 0.08394 | 0.07218 | 31.404 | 28.480 |
| 1 | 6 | 118320. | 0.08409 | 0.07227 | 31.427 | 28.504 |
| 1 | 7 | 138040. | 0.08423 | 0.07237 | 31.449 | 28.528 |
| 1 | 8 | 157760. | 0.08438 | 0.07246 | 31.472 | 28.552 |
| 1 | 9 | 177480. | 0.08452 | 0.07256 | 31.495 | 28.576 |
| 1 | 10 | 197200. | 0.08467 | 0.07265 | 31.517 | 28.600 |
| 1 | 11 | 216920. | 0.08482 | 0.07275 | 31.540 | 28.624 |
| 1 | 12 | 236640. | 0.08497 | 0.07285 | 31.563 | 28.648 |

**FINAL RESULTS:**
**Critical Crack Size has NOT been reached.**
at Cycle No. 8701.00
of Load Step No. 13 Description: None
of Block No. 12
of Schedule No. 1
Crack Sizes: a = 0.849651E-01 , c = 0.728462E-01 , a/c = 1.1664
Total Cycles = 236640.00