# Istanbul Technical University

## Graduate School of Science Engineering and Technology



MKC517E
Special Topics in Solid Mechanics

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# Homework 1

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**a**

Center crack having initial length of 0.5 mm in a finite width plate (TC01 crack scenario, Figure 1) with 100 mm width and 2 mm thickness is considered using the load spectrum for the space transportation system (STS) given in Nasgro manual on p.61 (Table 1). Assuming that loads are in the fundamental frequency range of 50 to 100 Hz (multiplication factor of 2 for both tensile and bending stresses) and 1000 load blocks in the schedule, cycle at which panel fails is to be determined. Material is 2024-T3 (Nasgro data).

Table 1: Launch and Landing Spectrum for STS Payloads.

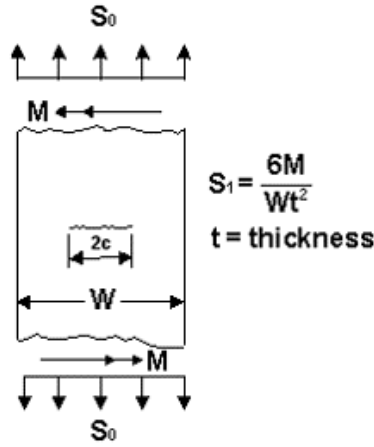| Load Step | Cycles/flight | | | Cyclic Stress (% limit value) | |
|---|---|---|---|---|---|
| Number | Launch | Landing | Total | Minimum | Maximum |
| 1 | 1 | 1 | 2 | -100 | 100 |
| 2 | 3 | 1 | 4 | -90 | 90 |
| 3 | 5 | 3 | 8 | -80 | 80 |
| 4 | 12 | 3 | 15 | -70 | 70 |
| 5 | 46 | 3 | 49 | -60 | 60 |
| 6 | 78 | 3 | 81 | -50 | 50 |
| 7 | 165 | 13 | 178 | -40 | 40 |
| 8 | 493 | 148 | 641 | -30 | 30 |
| 9 | 2229 | 891 | 3120 | -20 | 20 |
| 10 | 2132 | 1273 | 3405 | -10 | 10 |
| 11 | 2920 | 2099 | 5019 | -7 | 7 |
| 12 | 22272 | 6581 | 28853 | -5 | 5 |
| 13 | 82954 | 8701 | 91655 | -3 | 3 |



Figure 1: Finite width plate with a through crack at the center of plate (TC01).

No retardation (Non-interaction) crack growth model is selected for the growth model. Forman crack growth rate equation is used for growth-rate calculation.

Total number of cycles without failure is calculated as **5,720,290**, corresponding to 44th block, with final crack size of **1.25641 mm**. Plot of the crack growth is given in Figure 2.

**b**

Using same material and geometric properties in Section a, critical crack size is going to be calculated using $K_{IE} = K_c = 1598.43\,\text{MPa}\sqrt{\text{mm}}$, $S0 = 100\,\text{MPa}$ and $S1 = 0$. Yield stress is taken as $\sigma_y = 365.4223\,\text{MPa}$, initial crack length is chosen 1 mm. Critical crack size is calculated as $c = 35.5847\,\text{mm}$.
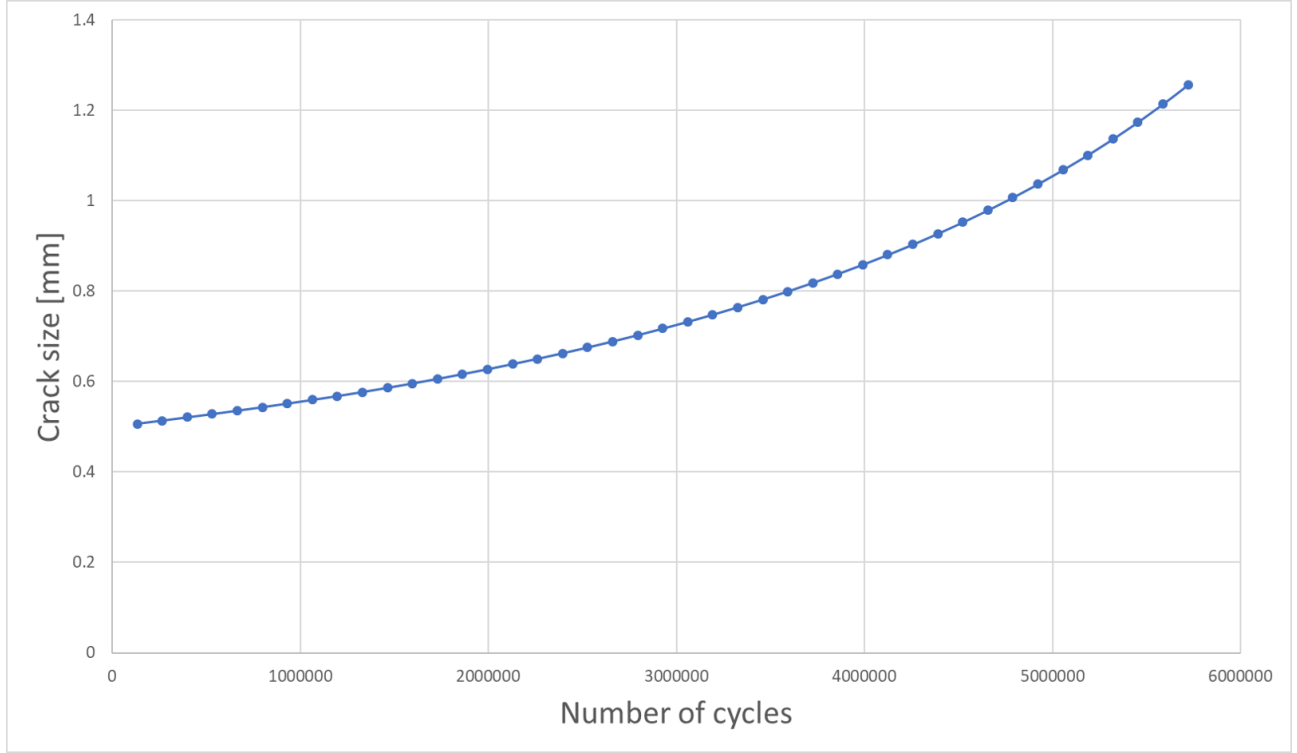
Figure 2: Crack growth until the rupture, dots are representing blocks.

## d

Curve for fracture toughness $K_c$ with respect to the panel width is given in Figure 4. For $w = 10\,\mathrm{in} = 254\,\mathrm{mm}$ and $w = 40\,\mathrm{in} = 1016\,\mathrm{mm}$, critical crack length is going to be calculated using Figure 4.

For $w = 10\,\mathrm{in} = 254\,\mathrm{mm}$, $K_c = 70\,\mathrm{ksi}\sqrt{\mathrm{in}} = 2432.39\,\mathrm{MPa}\sqrt{\mathrm{mm}}$; for $w = 40\,\mathrm{in} = 1016\,\mathrm{mm}$, $K_c = 147\,\mathrm{ksi}\sqrt{\mathrm{in}} = 5108.0271\,\mathrm{MPa}\sqrt{\mathrm{mm}}$ and $t = 1.6002\,\mathrm{mm}$, critical crack sizes are $c_{10} = 87.7917\,\mathrm{mm}$ and $c_{40} = 362.1016\,\mathrm{mm}$ respectively.

The strength of the plate is reduced due to material property. Panel width converges as width increases.

## e

Table 2: Inspection table for $t = 3\,\mathrm{mm}$, $w = 100\,\mathrm{mm}$

| Crack Location | Part Thickness, t | Crack Type | Crack Dimension, a* | Crack Dimension, c* | Nasgro Model | Total no. Of cycles | Final a | Final c | First inspection | Second inspection |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Eddy Current NDE** | | | | | | |
| Open Surface | t 1.27 | Through | t | 1.27 | | | | | | |
| | t >1.27 | PTC1 | 0.51 | 2.54 | SC01 | 6651500 | 2.57274 | 5.59981 | 2217167 | 4434333 |
| | | | 1.27 | 1.27 | SC01 | 7582710 | 2.60408 | 5.5812 | 2527570 | 5055140 |
| Edge or Hole | t 1.91 | Through | t | 2.54 | | | | | | |
| | t >1.91 | Corner | 1.91 | 1.91 | CC01 | 3591810 | | 7.90695 | 1197270 | 2394540 |
| | | | | **Penetrant NDE** | | | | | | |
| Open Surface | t 1.27 | Through | t | 2.54 | | | | | | |
| | 1.27<1.91 | Through | t | 3.81-t | | | | | | |
| | t >1.91 | PTC | 0.64 | 3.18 | SC01 | 4789080 | 2.58048 | 5.76605 | 1596360 | 3192720 |
| | | | 1.91 | 1.91 | SC01 | 3990900 | 2.59065 | 5.33395 | 1330300 | 2660600 |
| Edge or Hole | t 2.54 | Through | t | 3.81 | | | | | | |
| | t >2.54 | Corner | 2.54 | 3.91 | CC01 | 798180 | | 6.93042 | 266060 | 532120 |
| | | | | **Magnetic Particle NDE** | | | | | | |
| Open Surface | t 1.91 | Through | t | 3.18 | | | | | | |
| | t >1.91 | PTC1 | 0.97 | 4.78 | SC01 | 1995450 | 2.46253 | 6.02138 | 665150 | 1330300 |
| | | | 1.91 | 3.18 | SC01 | 2261510 | 2.58834 | 5.54979 | 753837 | 1507673 |
| Edge or Hole | t 1.91 | Through | t | 6.35 | | | | | | |
| | t >1.91 | Corner | 1.91 | 6.35 | CC01 | 665150 | | 8.17675 | 221717 | 443433 |
| | | | | **Radiographic NDE** | | | | | | |
| Open Surface | t 2.72 | PTC | 0.7t | 1.91 | | | | | | |
| | t >2.72 | PTC | 0.7t | 0.7t | SC01 | 3325750 | 2.62319 | 5.3505 | 1108583 | 2217167 |
| | | Embedded | 2a=0.7t | 0.7t | EC01 | 4922110 | | 25.8796 | 1640703 | 3281407 |
| | | | | **Ultrasonic NDE** | | | | | | |
| Open Surface | t 2.54 | PTC | 0.76 | 3.81 | SC01 | 3458780 | 2.54985 | 5.84001 | 1152927 | 2305853 |
| | | | 1.65 | 1.65 | SC01 | 5188170 | 2.59221 | 5.45731 | 1729390 | 3458780 |
| | | Embedded** | 0.43 | 2.21 | EC01 | 55207450 | | 27.1301 | 18402483 | 36804967 |
| | | | 0.99 | 0.99 | EC01 | 67446211 | | 25.6516 | 22482070 | 44964141 |
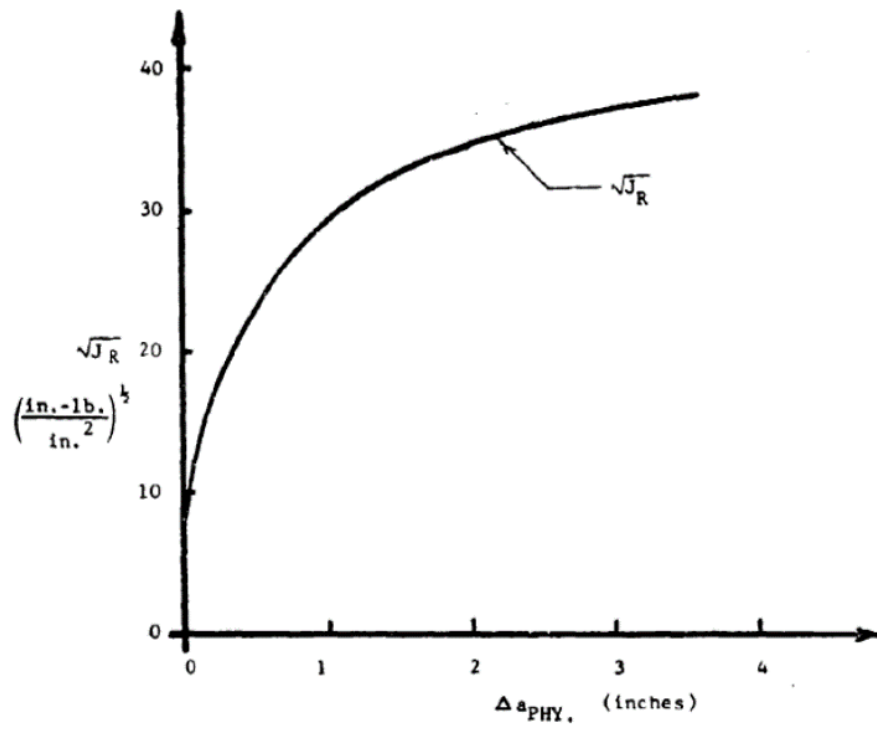
Figure 3: R-curve.
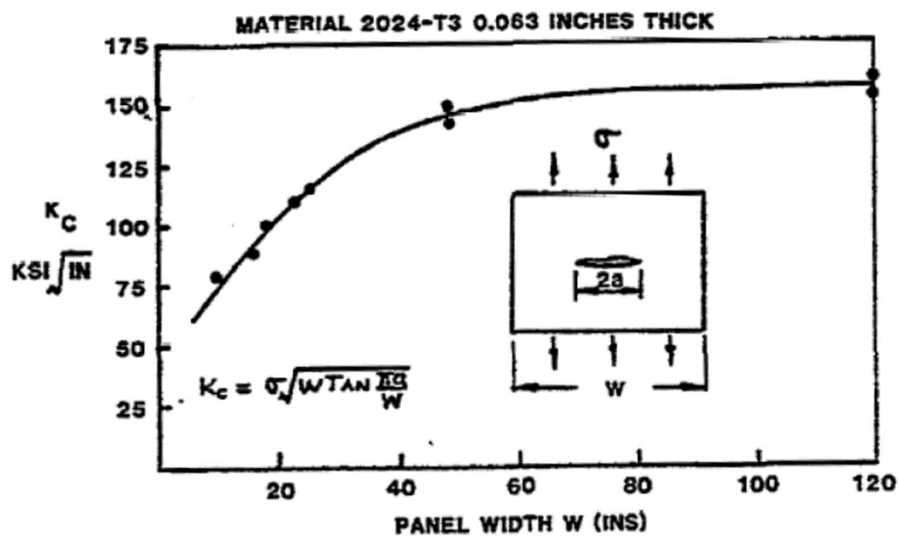


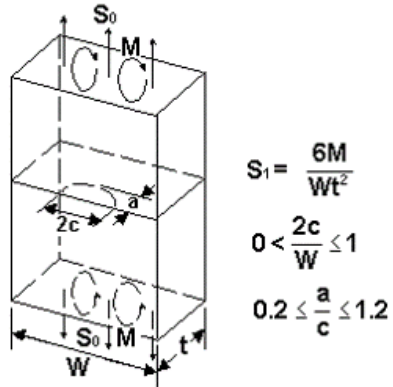Figure 4: Change in $K_c$ with respect to the panel width.

## SC01



$$S_1 = \frac{6M}{Wt^2}$$

$$0 < \frac{2c}{W} \leq 1$$

$$0.2 \leq \frac{a}{c} \leq 1.2$$
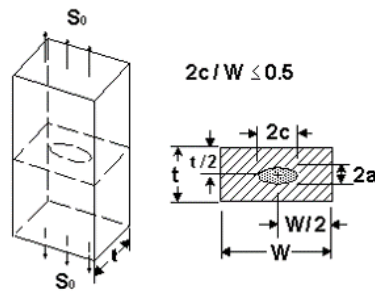
Figure 5: Surface crack.

## EC01



$$2c / W \leq 0.5$$

Figure 6: Embedded crack.

## CC01



Figure 7: Corner crack.

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