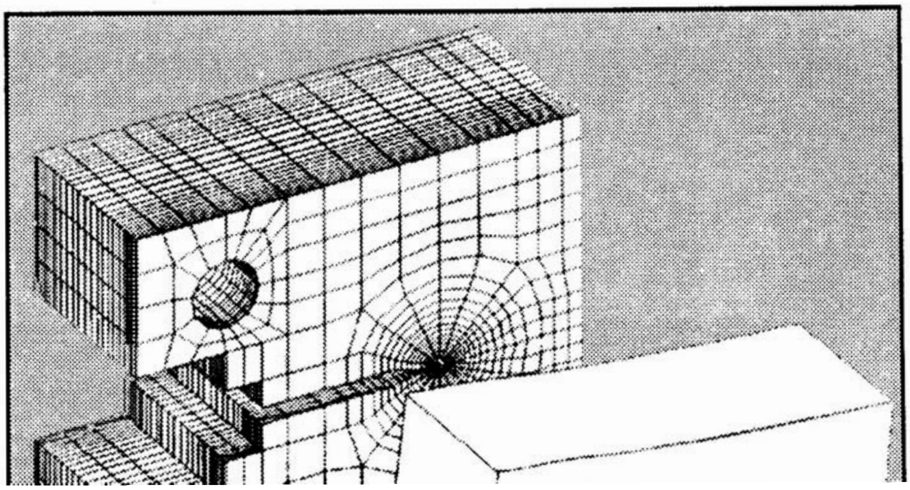
Solutions Manual for

FRACTURE MECHANICS

Fundamentals and Applications

Second Edition



CHAPTER 1

1.2 A flat plate with a through-thickness crack (Fig. 1.8) is subject to a 100 MPa (14.5 ksi) tensile stress and has a fracture toughness (K_{IC}) of 50.0 MPa $\sqrt{m}$ (45.5 ksi $\sqrt{in}$). Determine the critical crack length for this plate, assuming the material is linear elastic.

Ans:

At fracture, $K_{IC} = K_I = \sigma\sqrt{\pi a_c}$. Therefore,

$$50 \text{ MPa}\sqrt{m} = 100 \text{ MPa}\sqrt{\pi a_c}$$

$$a_c = 0.0796 \text{ m} = 79.6 \text{ mm}$$

$$\text{Total crack length} = 2a_c = 159 \text{ mm}$$

1.3 Compute the critical energy release rate ($\mathcal{G}_c$) of the material in the previous problem for E = 207,000 MPa (30,000 ksi).

Ans:

$$\mathcal{G}_c = \frac{K_{IC}}{E} = \frac{\left(50 \text{ MPa}\sqrt{m}\right)^2}{207{,}000 \text{ MPa}} = 0.0121 \text{ MPa mm} = 12.1 \text{ kPa m}$$

$$= 12.1 \text{ kJ/m}^2$$

Note that energy release rate has units of energy/area.

1.4 Suppose that you plan to drop a bomb out of an airplane and that you are interested in the time of flight before it hits the ground, but you cannot remember the appropriate equation from your undergraduate physics course. Your decide to infer a relationship for time of flight of a falling object by experimentation. You reason that the time of flight, t, must depend on the height above the ground, h, and the weight of the object, mg, where m is the mass and g is the gravitational acceleration. Therefore, neglecting aerodynamic drag, the time of flight is given by the following function:

$$t = f(h, m, g)$$

Apply dimensional analysis to this equation and determine how many experiments would be required to determine f to a reasonable approximation, assuming you know the numerical value of g. Does the time of flight depend on the mass of the object?

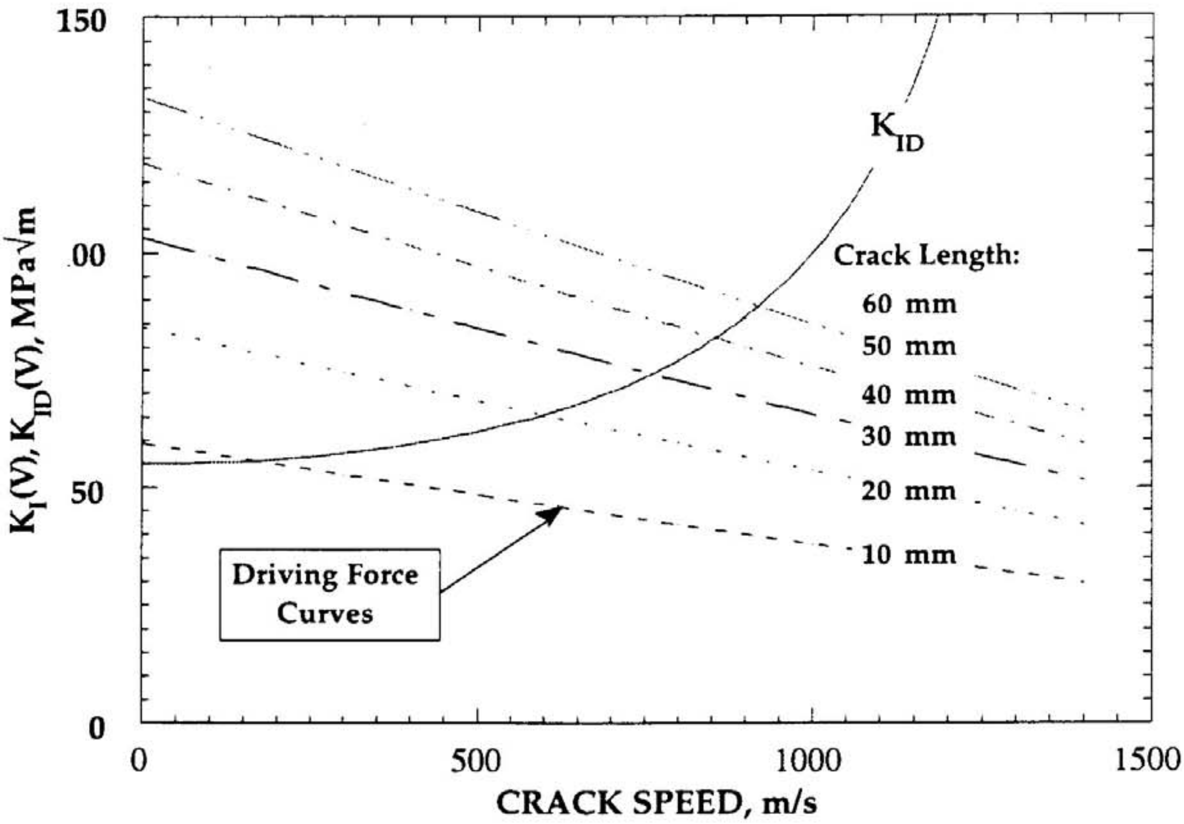


FIGURE S4 Comparison of dynamic toughness and driving force (Problem 4.3).

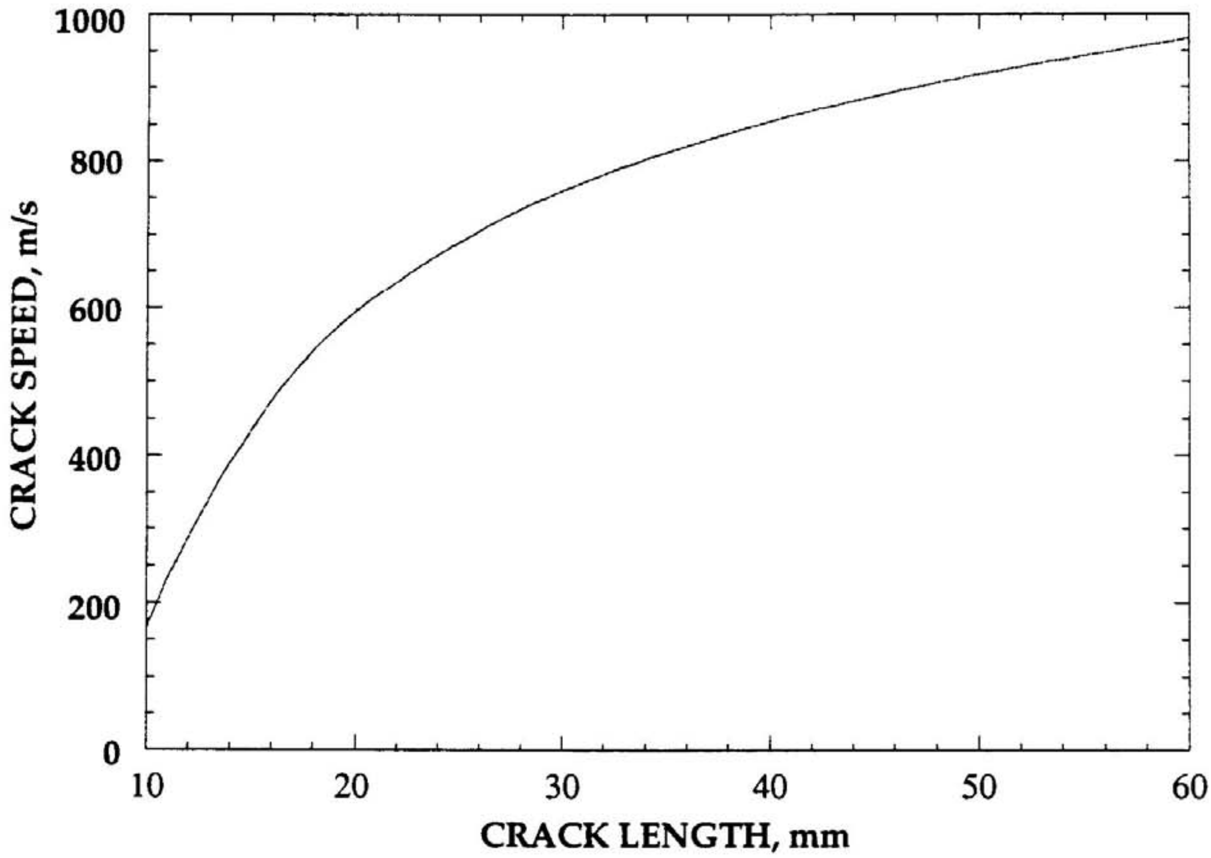


FIGURE S5 Computed crack speed versus crack length (Problem 4.3)

7.10 A crack arrest test has been performed in accordance with ASTM E 1221. The side-grooved compact crack arrest specimen has the following dimensions: W = 100 mm (3.94 in), B = 25.4 mm (1.0 in), and B_N = 19.1 mm (0.75 in). The initial crack length = 46.0 mm (1.81 in) and the crack length at arrest = 63.0 mm (2.48 in). The corrected clip gage displacements at initiation and arrest are V_o = 0.582 mm (0.0229 in) and V_a = 0.547 (0.0215 in), respectively. E = 207,000 MPa (30,000 ksi) and $\sigma_{YS(static)}$ = 483 MPa (70 ksi). Calculate the stress intensity at initiation, K_o, and the arrest toughness, K_a. Determine whether or not this test satisfies the validity criteria in Eq. (7.25). The stress intensity solution for the compact crack arrest specimen is given below.

$$K_I = \frac{E\,V\,f(x)\sqrt{B/B_N}}{\sqrt{W}}$$

where

$$x = a/W$$

$$f(x) = \frac{2.24\,(1.72 - 0.9\,x + x^2)\sqrt{1 - x}}{9.85 - 0.17\,x + 11\,x^2}$$

Ans:

Initiation:

$$a/W = 0.46 \quad f(x) = 0.206$$

$$K_o = \frac{207{,}000\text{ MPa }(5.82 \times 10^{-4}\text{ m})\,(0.206)\sqrt{1.33}}{\sqrt{0.100\text{ m}}} = 90.6\text{ MPa}\sqrt{\text{m}}$$

Arrest:

$$a/W = 0.63 \quad f(x) = 0.150$$

$$K_a = \frac{207{,}000\text{ MPa }(5.47 \times 10^{-4}\text{ m})\,(0.150)\sqrt{1.33}}{\sqrt{0.100\text{ m}}} = 62.0\text{ MPa}\sqrt{\text{m}}$$

Validity checks (Eq. (7.25)):

(a) $W - a_a = 38\text{ mm} > 0.15\,W\ \surd$

(b) $1.25\left(\dfrac{62.0\text{ MPa}\sqrt{\text{m}}}{483 + 205\text{ MPa}}\right)^2 = 10.15\text{ mm} < W - a_a\ \surd$

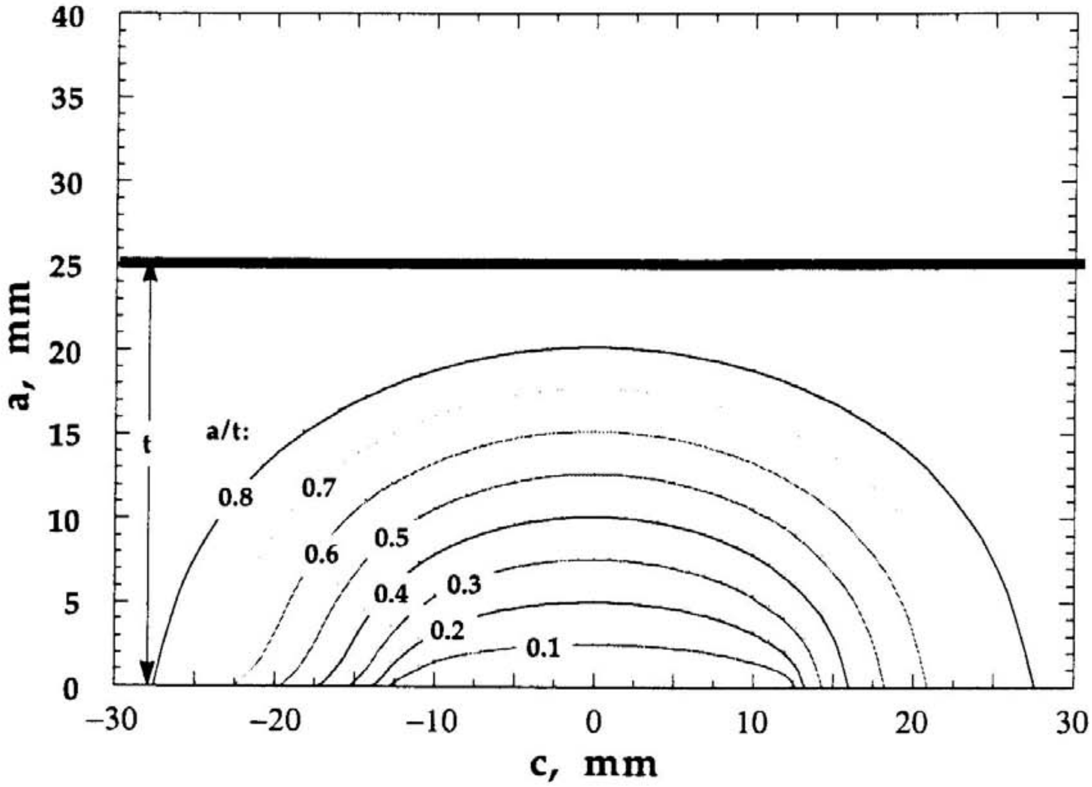


FIGURE S21 Crack profile during fatigue crack growth (Problem 10.5)

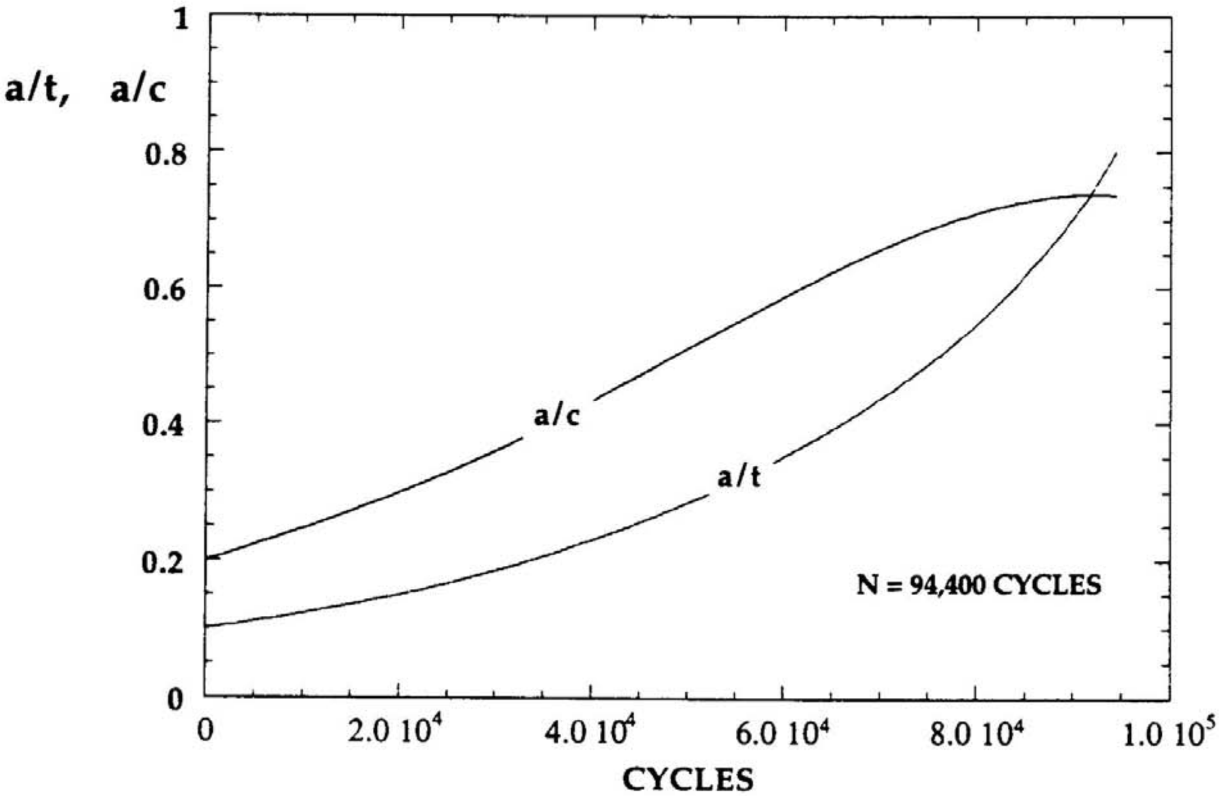


FIGURE S22 Crack depth and aspect ratio versus fatigue cycles (Problem 10.5).

10.6 Estimate U and K_{op} as a function of R and ΔK for the data in Fig. 10.8. Does Eq. (10.19) fit the data adequately or does U depend on K_{max}? Does Eq. (10.20) adequately describe the data? If so, determine the parameter K_o.

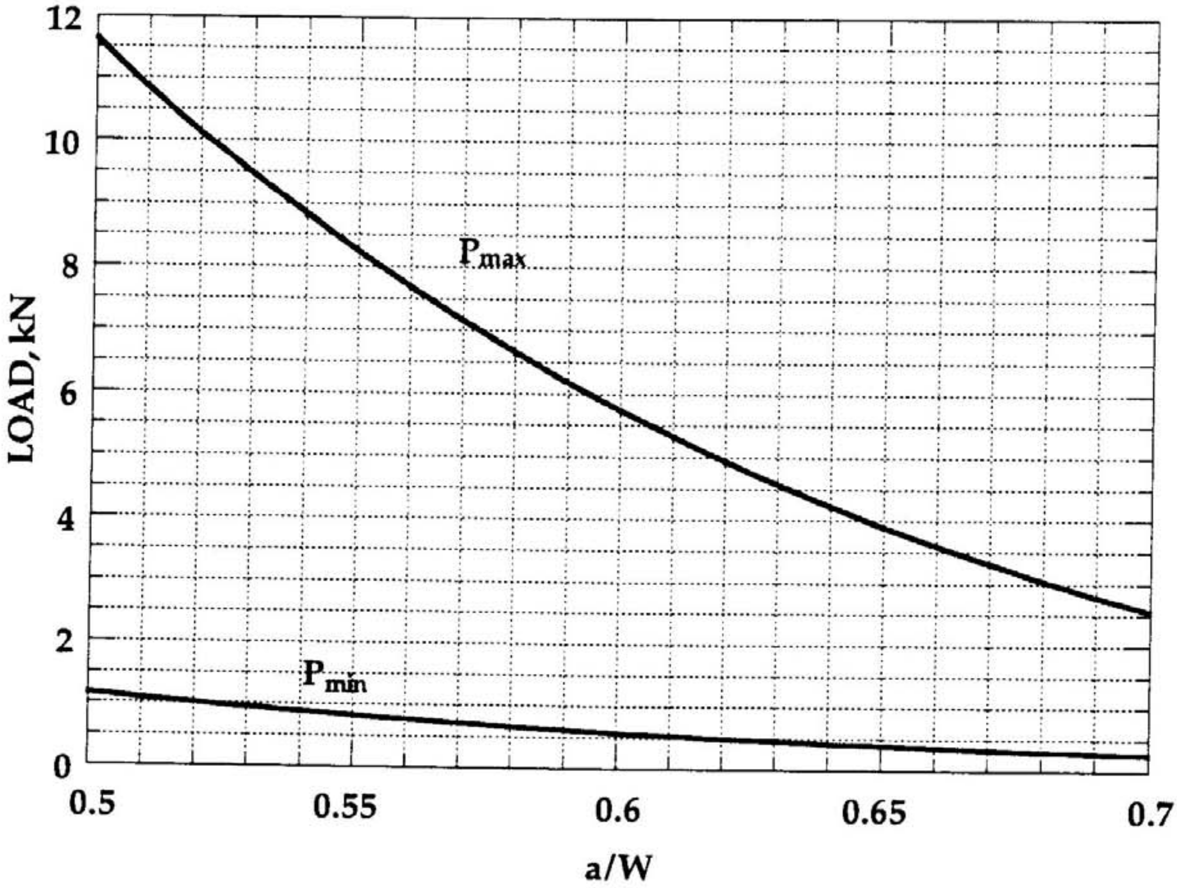


FIGURE S27 Loads required to maintain a K gradiant of - 0.07 mm^{-1} in a 1T compact specimen (Problem 10.8).

CHAPTER 11

11.1 A series of finite element meshes have been generated that model compact specimens with various crack lengths. Plane stress linear elastic analyses have been performed on these models. Nondimensional compliance values as a function of a/W are tabulated below. Estimate the nondimensional stress intensity for the compact specimen from these data and compare your estimates to the polynomial solution in Table 12.2.

$\frac{a}{W}$	$\frac{\Delta B E}{P}$	$\frac{a}{W}$	$\frac{\Delta B E}{P}$	$\frac{a}{W}$	$\frac{\Delta B E}{P}$
0.20	8.61	0.45	29.0	0.70	123
0.25	11.2	0.50	37.0	0.75	186
0.30	14.3	0.55	47.9	0.80	306
0.35	18.1	0.60	63.3	0.85	577
0.40	22.9	0.65	86.3	0.90	1390

Ans:

From Problem 2.17,