Name..Student I.D....................................

Department of Mining and Materials Engineering

Faculty of Engineering

Prince of Songkla University

Mid-term Examination for Semester: 1 Academic Year: 2013

Date: July 31, 2013 Time: 09.00 - 12.00

Subject: 237-407 Failure Mechanics and Analysis Room: A401

Instructions

1. There are 3 problem sets (9 pages including cover). Please do all of them. Write your answers in the space provided.
2. Dictionary and calculator are allowed.
3. Text books and course notes are not allowed.
4. This mid-term exam is accounted for 25 % of total grade.

Asst. Prof. Dr. Thawatchai Plookphol

Problem no.	Full score	Student's score
1	30	
2	30	
3	40	
Total	100	

Name...Student I.D.......................................

Problem 1 (30 points)

Explain the following terms: (please give example and/or draw picture, diagram to support your answer)

1.1 Cleavage (5 points)

....
....
....
....
....
....
....
....
....

1.2 Slip (5 points)

....
....
....
....
....
....
....
....
....

1.3 Griffith's fracture theory for brittle materials (5 points)

....
....
....
....
....
....
....
....
....

Name..Student I.D......................................

1.4 Irwin's concept of stress intensity factor K (5 points)

....
....
....
....
....
....
....
....
....
....

1.5 Fracture toughness, K_{IC} (5 points)

....
....
....
....
....
....
....
....
....
....

1.6 Plastic zone (5 points)

....
....
....
....
....
....
....
....
....
....

Name..Student I.D....................................

Problem 2 (30 points)

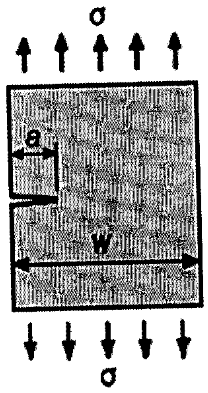
Consider a plate made of steel 4340 with an edge crack (see figure). The plate thickness is such that a plane strain condition is present.

Given: W = 1000 mm

σ_{ys} = 1470 MPa

σ_{UTS} = 1820 MPa

K_{IC} = 47.4 MPa·m$^{1/2}$



2.1 Does fracture occur at a stress $\sigma = \frac{2}{3}\sigma_{ys}$ and a crack length a = 1 mm? (10 points)

2.2 What is the critical defect size at a stress $\sigma = \frac{2}{3}\sigma_{ys}$? (10 points)

2.3 What is the maximum stress for the crack length a = 1 mm to cause fracture? (10 points)

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Name...Student I.D....................................

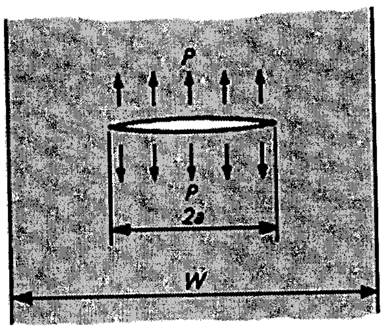
Problem 3 (40 points)

In service a construction part made of a high strength steel is subjected to a constant stress of 1200 MPa. However, in course of time the part fails. Inspection of the fracture surface points to non-stable crack extension from an embedded circular crack, normal to the load direction and with a diameter of 100 μm.

3.1 How high is the stress intensity factor K_I for this defect as a result of the externally applied load? (10 points)

It is suspected that the failure is due to hydrogen-induced cracking, i.e. a high hydrogen pressure which has developed inside the crack.

3.2 Using the superposition principle (hint: a picture equation), derive formula K_I for this defect due to an internal pressure (P) only. (20 points)



3.3 The fracture toughness for this steel is known: $K_{IC} = 27.5$ MPa·m$^{1/2}$. How high was the hydrogen pressure inside the crack at the moment of failure? (10 points)

....

....

....

....

....

....

....

....

....

....

....

....

Name...Student I.D.......................................

Given Formula

Theoretical cohesive strength $$\sigma_c = \sqrt{\frac{2E\gamma_s}{b}}$$

Inglis' formula $$\sigma_f = \sqrt{\frac{E\gamma_s}{4a}}$$

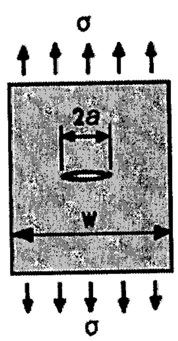
Griffith's equation (plane stress): $$\sigma_f = \sqrt{\frac{2E\gamma_s}{\pi a}}$$

Griffith's equation (plane strain): $$\sigma_f = \sqrt{\frac{2E\gamma_s}{\pi(1-\nu^2)a}}$$

Modified Griffith's equation: $$\sigma_f = \sqrt{\frac{2E(\gamma_s+\gamma_p)}{\pi a}}$$

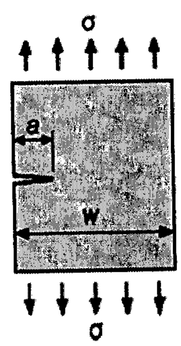
Energy release rate: $$G = \frac{\pi\sigma^2 a}{E}$$

For a central through thickness crack:



$$K_I = \sigma\sqrt{\pi a}$$

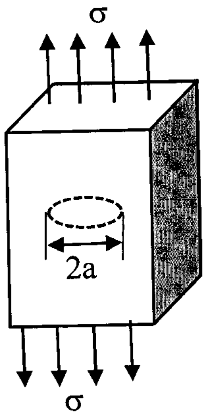
For an edge crack:



$$K_I = 1.12\sigma\sqrt{\pi a}$$

Name...Student I.D.......................................

For an embedded penny crack:



$$K_I = \frac{2}{\pi}\sigma\sqrt{\pi a}$$

At fracture: $K_I = K_{IC}$

Irwin's plastic zone (plane stress) $$r_p = \frac{1}{\pi}\left(\frac{K_I}{\sigma_{ys}}\right)^2$$

Irwin's plastic zone (plane strain) $$r_p = \frac{1}{3\pi}\left(\frac{K_I}{\sigma_{ys}}\right)^2$$

Dugdale's plastic zone $$\rho = \frac{\pi}{8}\left(\frac{K_I}{\sigma_{ys}}\right)^2$$

Plastic zone shape (based on distortion energy yielding theory):

Plane stress: $$r_y = \frac{K_I^2}{4\pi\sigma_{ys}^2}\left(1 + \frac{3}{2}\sin^2\theta + \cos\theta\right)$$

Plane strain: $$r_y = \frac{K_I^2}{4\pi\sigma_{ys}^2}\left(\frac{3}{2}\sin^2\theta + (1-2v)^2(1+\cos\theta)\right)$$

Plastic zone shape (based on maximum shearing stress yielding theory):

Plane stress: $$r_y = \frac{K_I^2}{2\pi\sigma_{ys}^2}\left(\cos^2\frac{\theta}{2} + \sin\frac{\theta}{2}\right)^2$$

Plane strain: $$r_y = \frac{K_I^2}{2\pi\sigma_{ys}^2}\cos^2\frac{\theta}{a}\left(1 - 2v + \sin\frac{\theta}{2}\right)^2$$