Fracture Toughness Testing

Organization for Expts. 5 and 7 (weeks of 4/2 and 4/16)

Experiment 5

- Lab in 127 Norris
- Can visit lab in advance Monday 4/2 and Monday 4/16 from 9am-12pm
- Submit logbook preparation to TA in advance as normal
- Two teams working together to test three samples. Lab is over when samples tested and logbooks complete (may not take full lab period).
- Your regular TA will be there.
- Each team submits their completed logbook to their TA before leaving lab

Experiment 7

- Lab in Stability Tunnel
- Can visit in advance Friday 3/30 and Friday 4/13 from 8am to 12pm and 1pm to 5pm.
- Submit logbook preparation to TA in advance as normal
- First team* arrives at start of lab period. Has 75 mins to complete test. Second team arrives 90 minutes after start of lab, has 75 mins for test.
- Regular TA not there. Submit logbook to wind tunnel operator before leaving lab

Don't forget laptops

* First team is the team with the lowest number on the experiment schedule

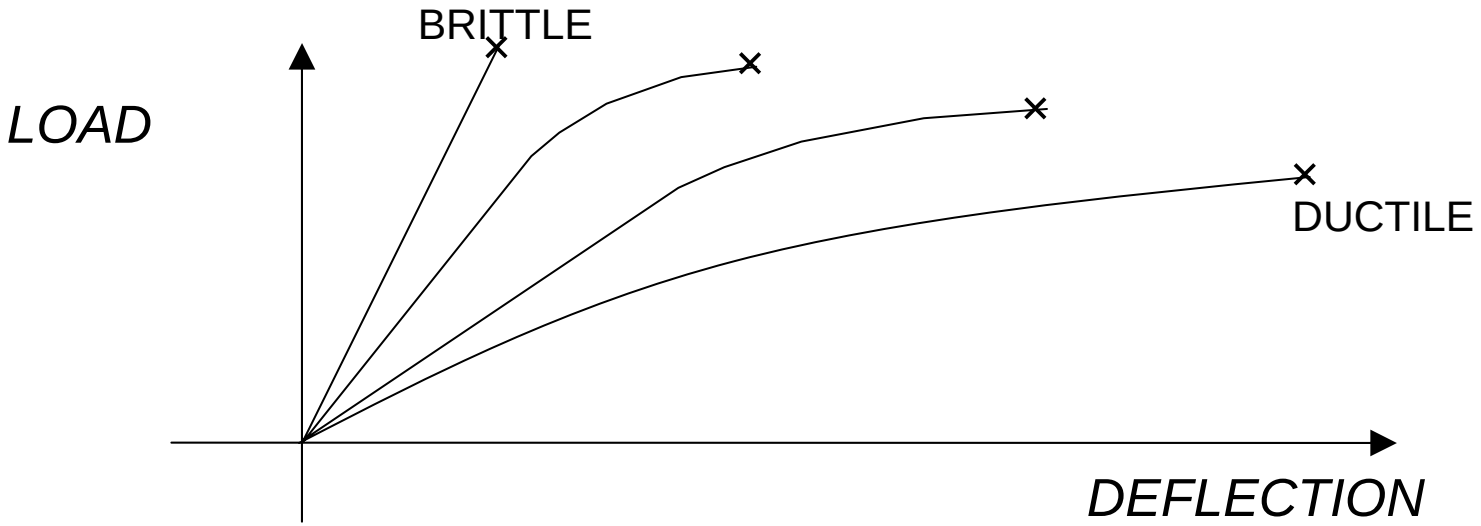
Organization for 5th Instrumentation Lab Period (week of 4/9)

- Lab in Randolph 25 (next to the open-jet tunnel)
- Apply digital data acquisition and processing, including your own LabView programs, to the dynamic beam structure of Experiment 6
- Works just like a regular experiment
  - Read manual (chapter 5 of instrumentation lab)
  - Meet with your team in advance
  - Visit the lab
  - Do a logbook preparation
  - Logbook submitted and end of lab is graded
- Note your logbook preparation should be submitted to Dustin Grissom (dgrissom@vt.edu) not your regular TA.

Don’t forget laptops

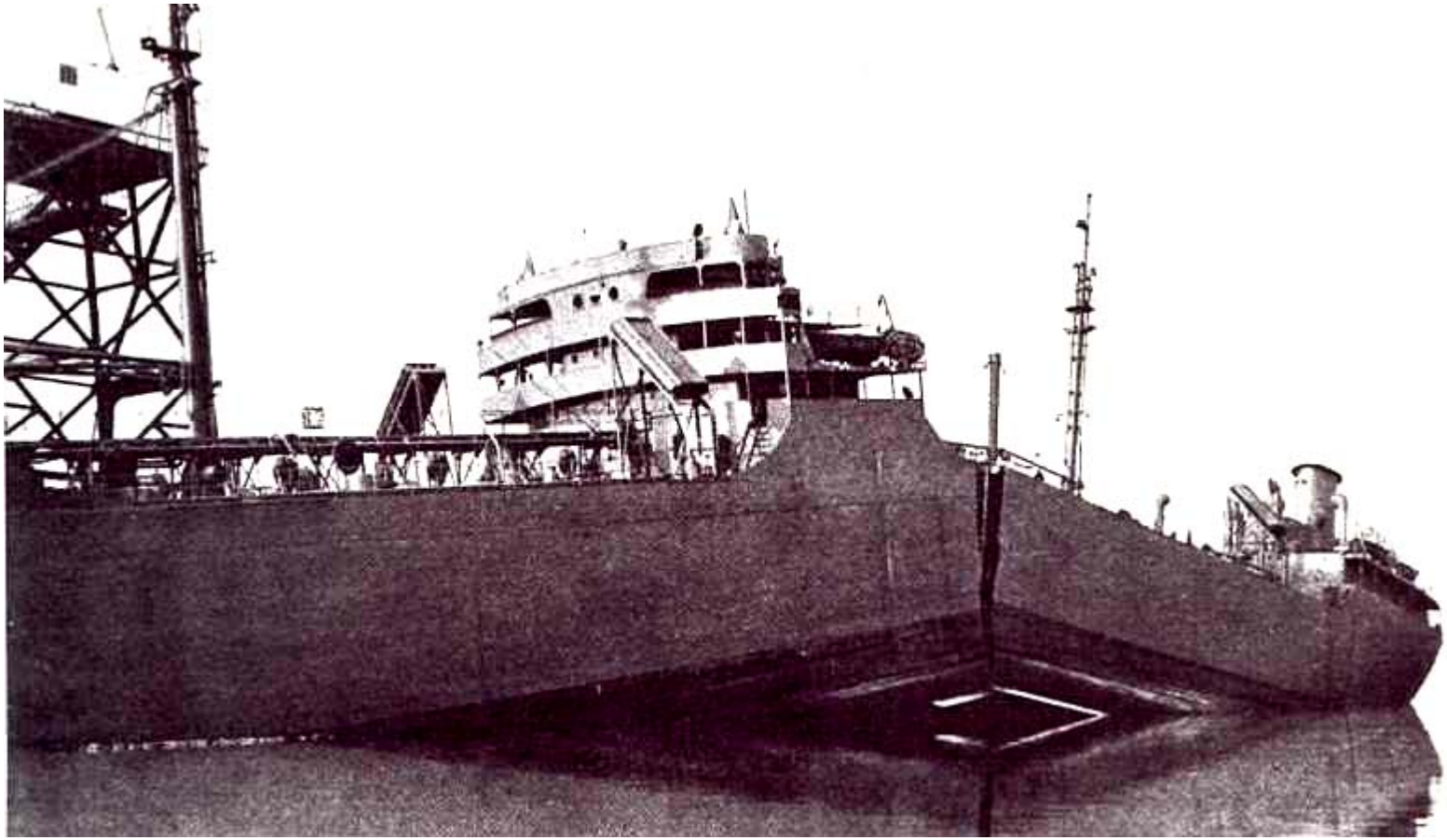
Fracture

- Breaking of structural components into two or more parts
- Brittle fracture - low energy absorption
- Ductile fracture - large energy absorption

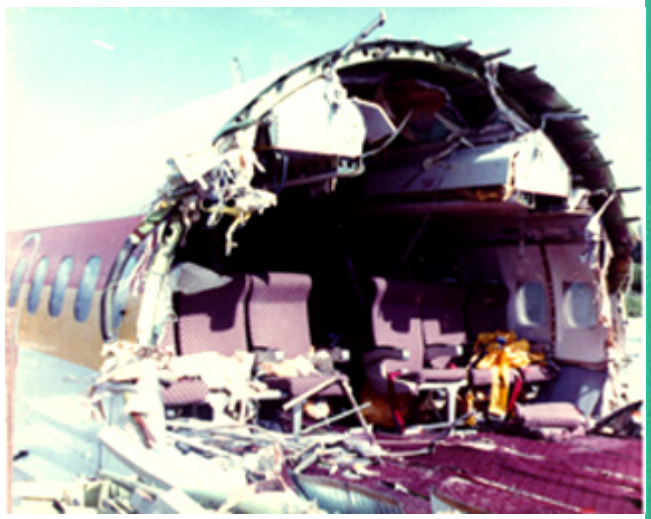


Tanker SS Schenectady

(24 hours after launch)



Aloha Airlines

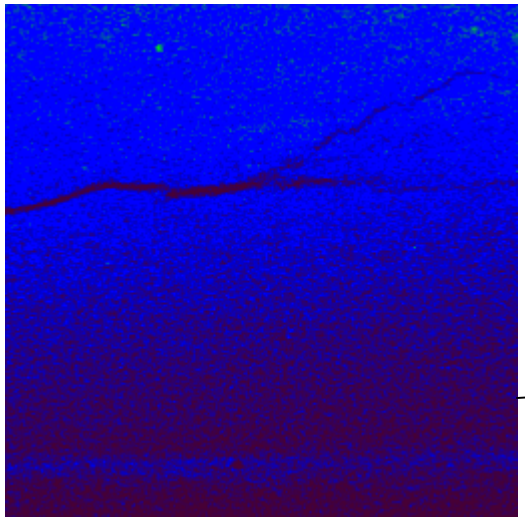


Aloha Airlines

Why does fracture occur?

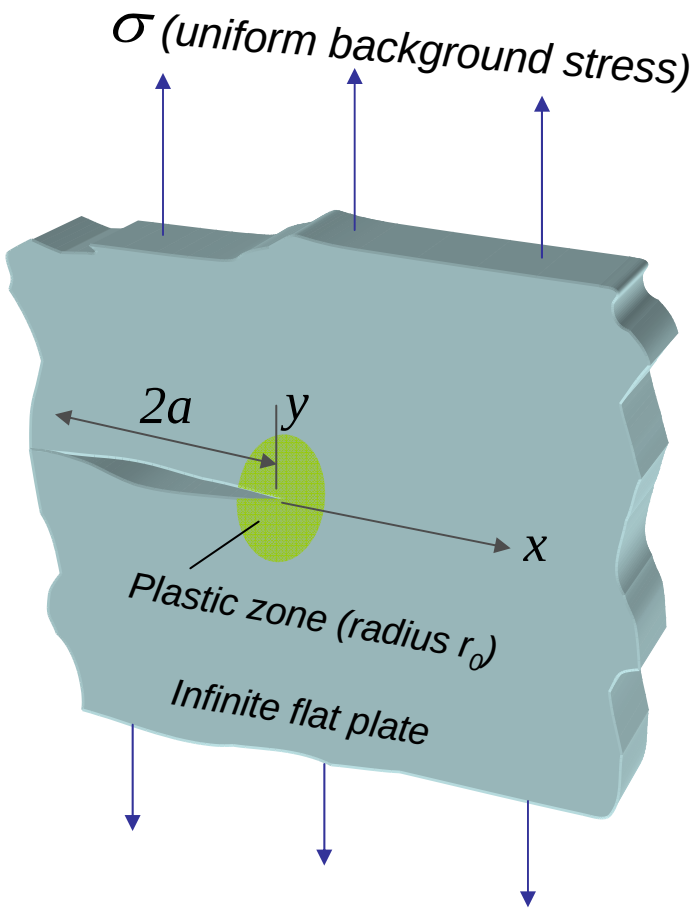
- Load increases to a point where cracks grow catastrophically.
- There are always cracks
  - They form as part of the manufacturing
  - They develop over time as a result of fatigue
- The strength of materials in the presence of cracks is therefore critical in defining when they will fail.

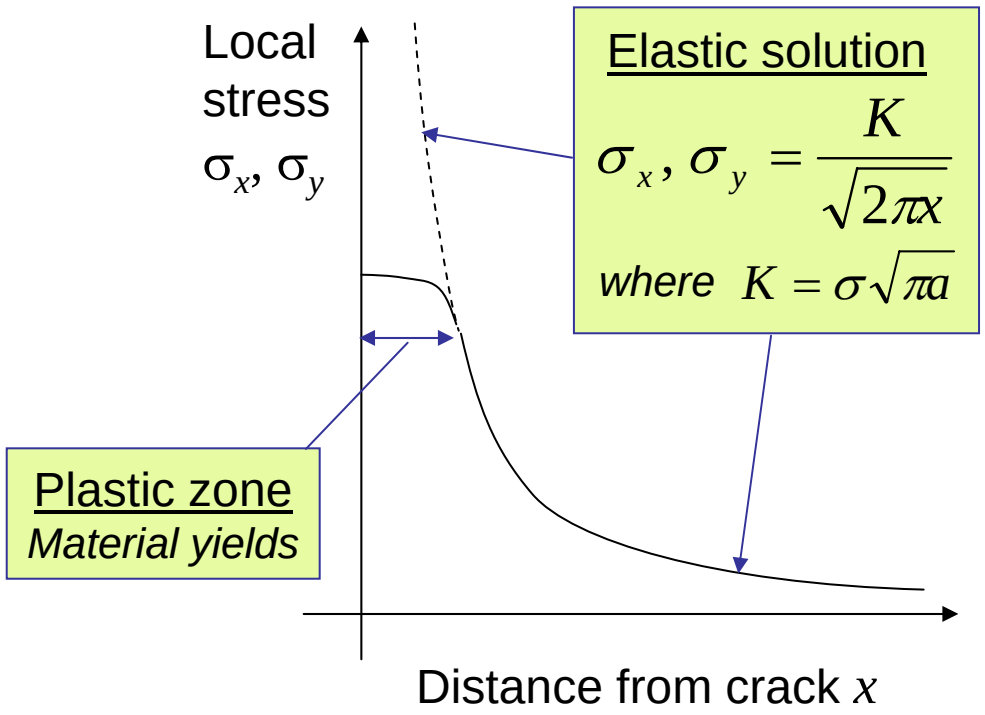
F-111 Crack



The Ideal Crack

The Linear Elastic Fracture Mechanics (LEFM) Approach



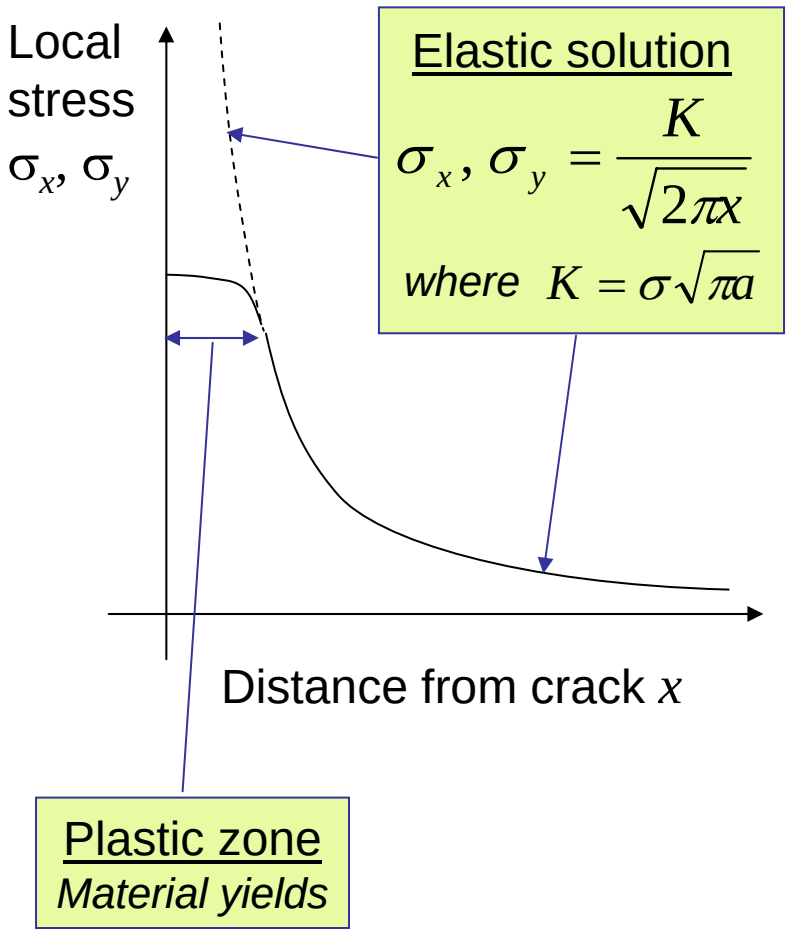


Even though the crack is embedded in a plastic zone, it is the elastic solution, in particular *K* that determines the stress field through which the crack would advance

Stress Intensity Factor *K*

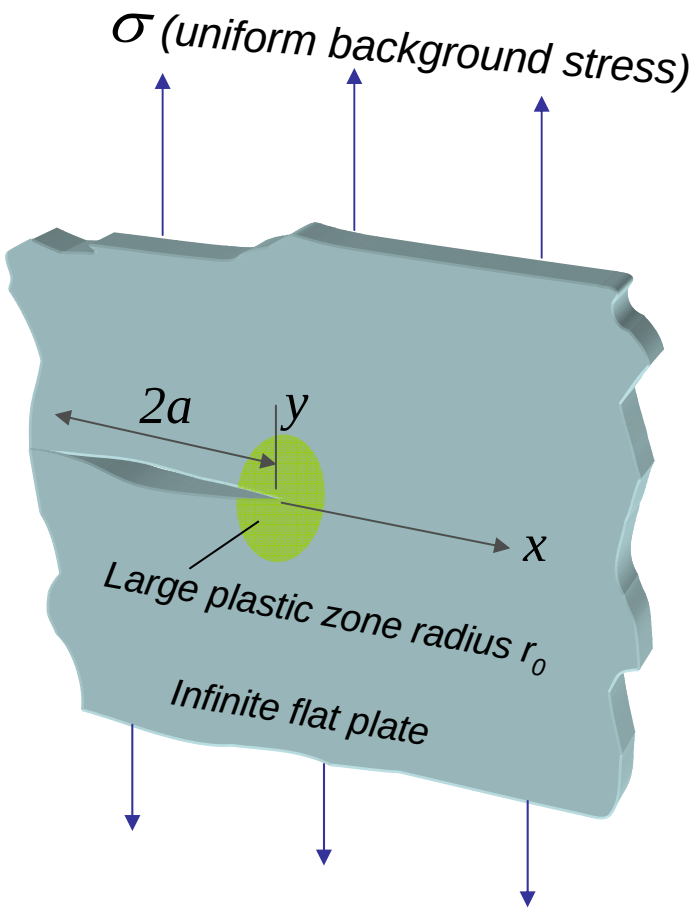
The Linear Elastic Fracture Mechanics (LEFM) Approach

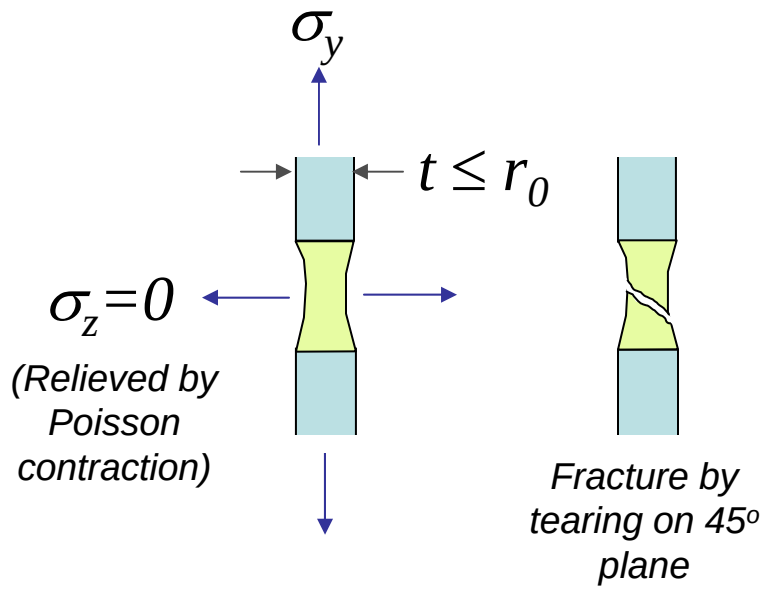
- Scale of the elastic stress field generated by the crack
- Units of
  - Pa√m (usually MPa√m)
  - p.s.i.√in (usually k.s.i.√in)
- The stress intensity when the crack advances catastrophically is a measure of the strength of the material in the presence of a crack.
- This is called the Fracture Toughness K_c



Effect of Thickness

Thin Plate



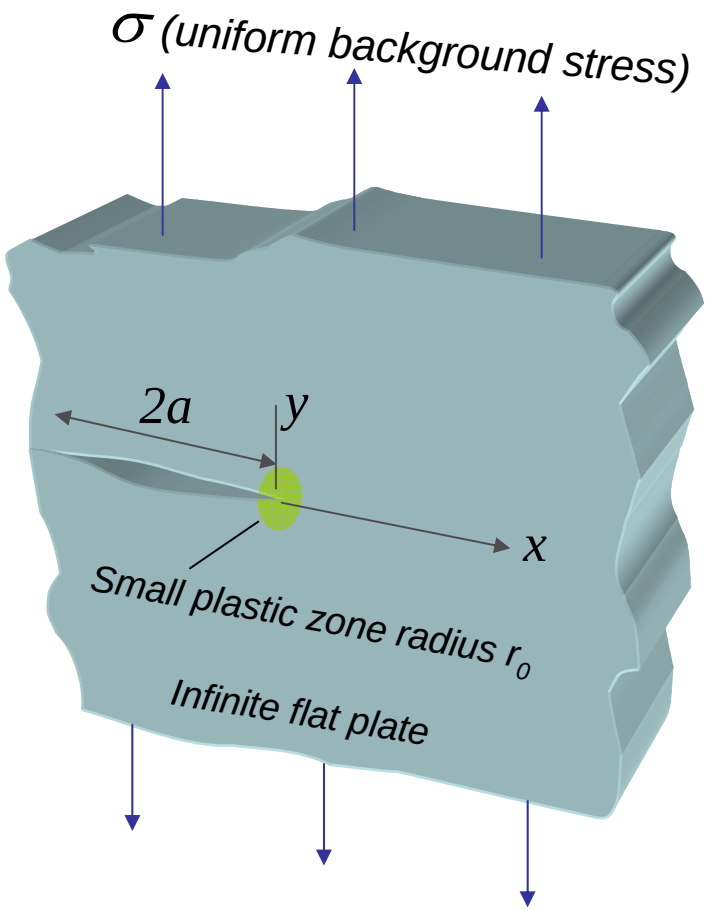


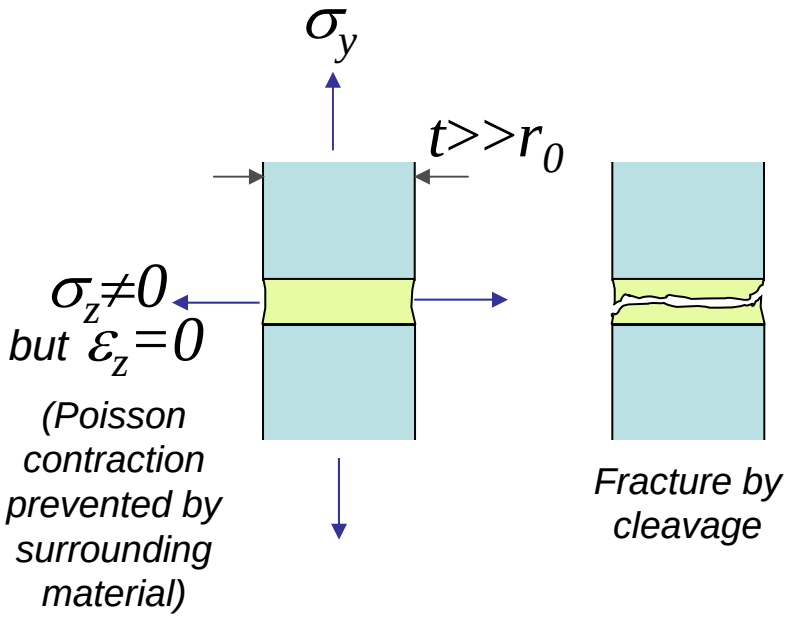
Deformation in *z* results in:

- stresses in only *x* and *y* - **Plane Stress**
- relief of some of the stress around crack
- a large fracture toughness, that depends on thickness
- ductile fracture takes place by tearing on 45^{o} plane

Effect of Thickness

Thick Plate

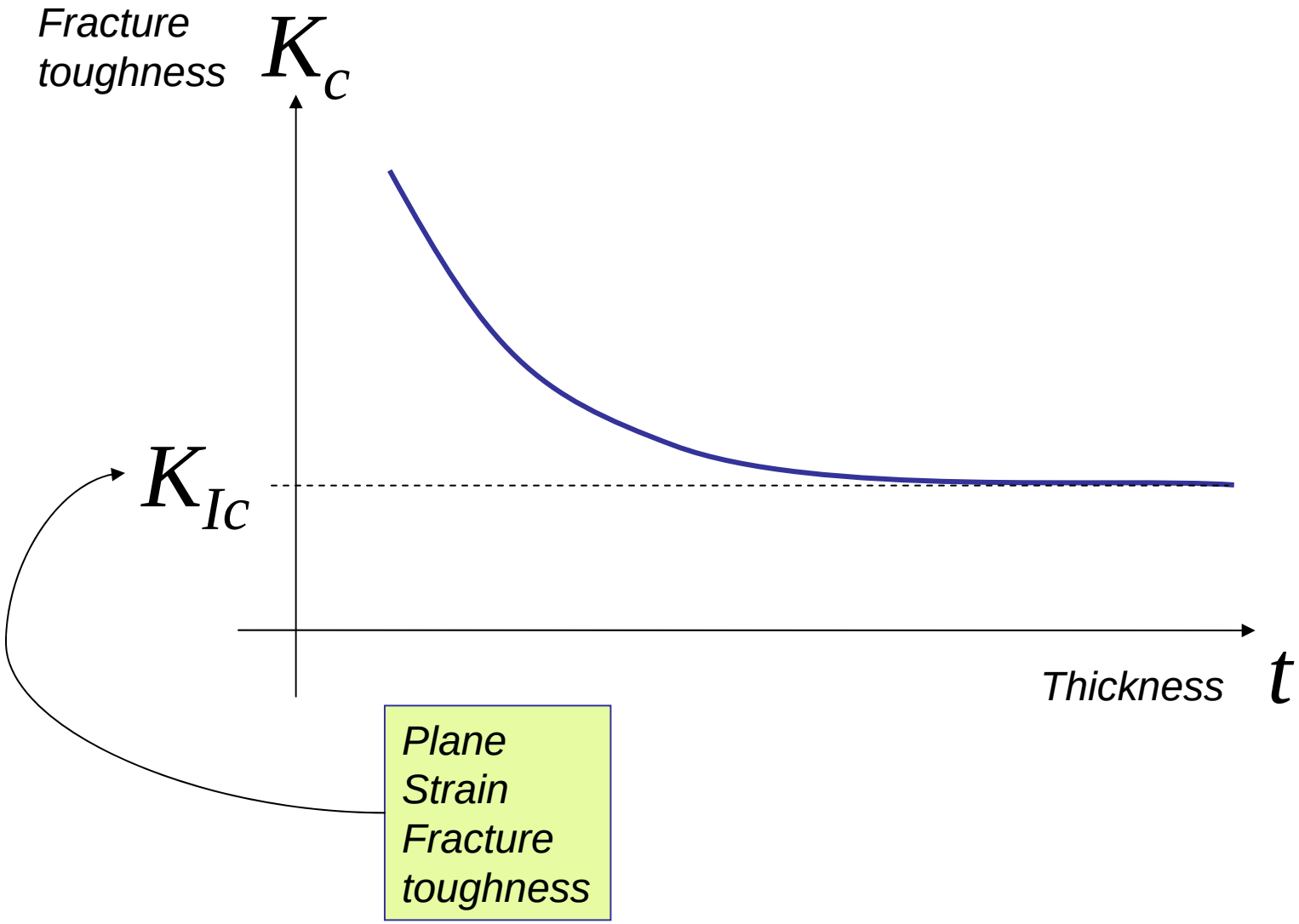




Lack of deformation in *z* results in:

- strain in only *x* and *y* - **Plane Strain**
- no relief of stress around crack
- a lower fracture toughness, that is independent of thickness
- brittle fracture on horizontal plane

Effect of Thickness



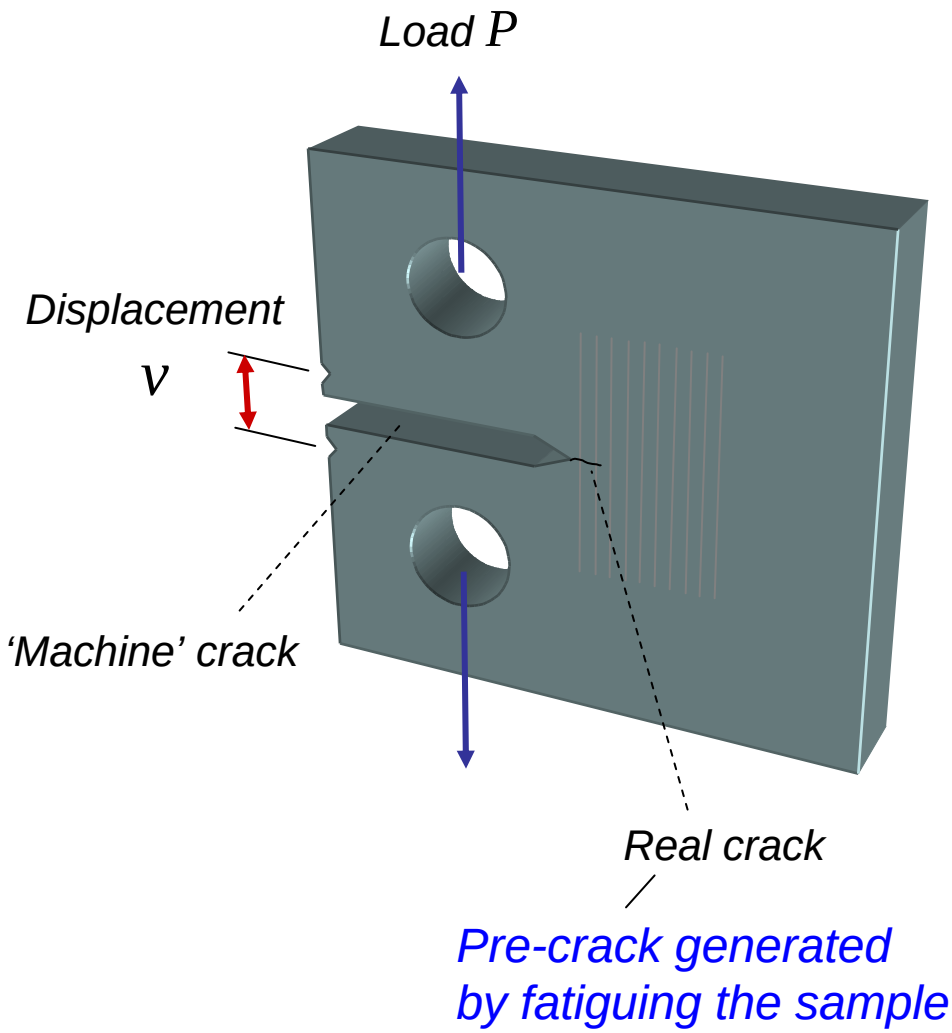
K_{Ic} for different materials

material		yield	toughness
		MPa	MPa√m
Aluminium	2024-T851	455	26
	7075-T651	495	24
Titanium	Ti-6Al-4V	910	115
	*Ti-6Al-4V	1035	55
Steel	4340	860	99
	*4340	1515	60
	52100	2070	14
* heat treated for higher strength			

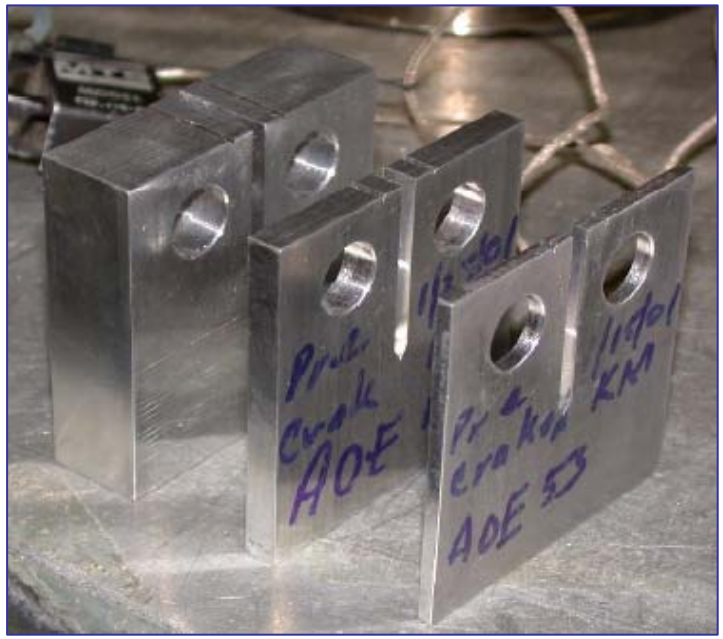
Experiment 5

- Objective
  - To measure this material property, the plain strain fracture toughness, for Aluminum
- Approach
  - Break samples of different thickness using fracture toughness testing procedures specified in ASTM Standard No. E399
- Organization
  - Two teams of students have 3 samples between them
- Location
  - ESM Materials Lab, Norris 127

Samples

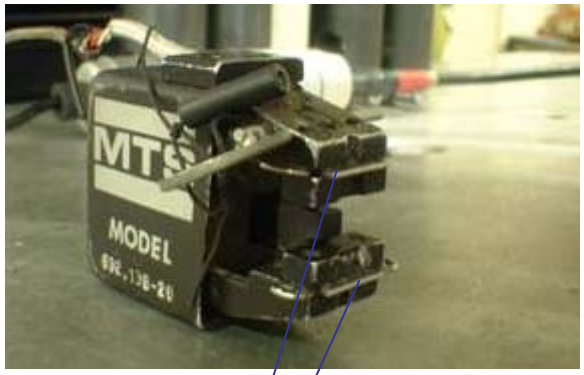


- Measure displacement vs. load until sample breaks.
- Identify load at fracture P_Q
- Use this to determine fracture toughness



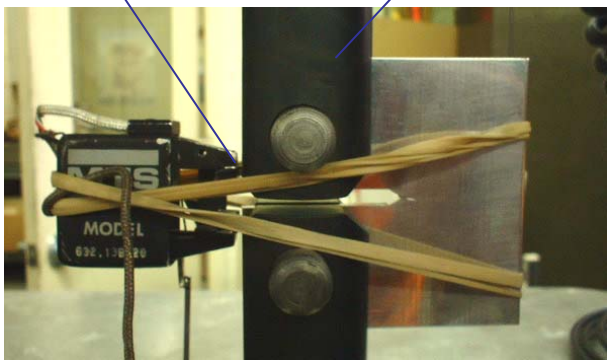
Load and Displacement

Extensometer
(senses crack opening displacement)



Jaws fit in notches in side of sample

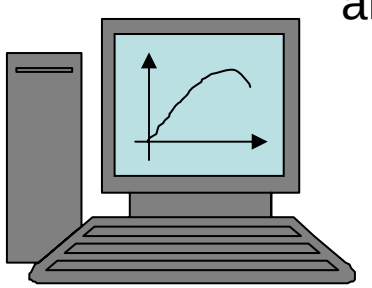
Clevis grips hold sample in machine



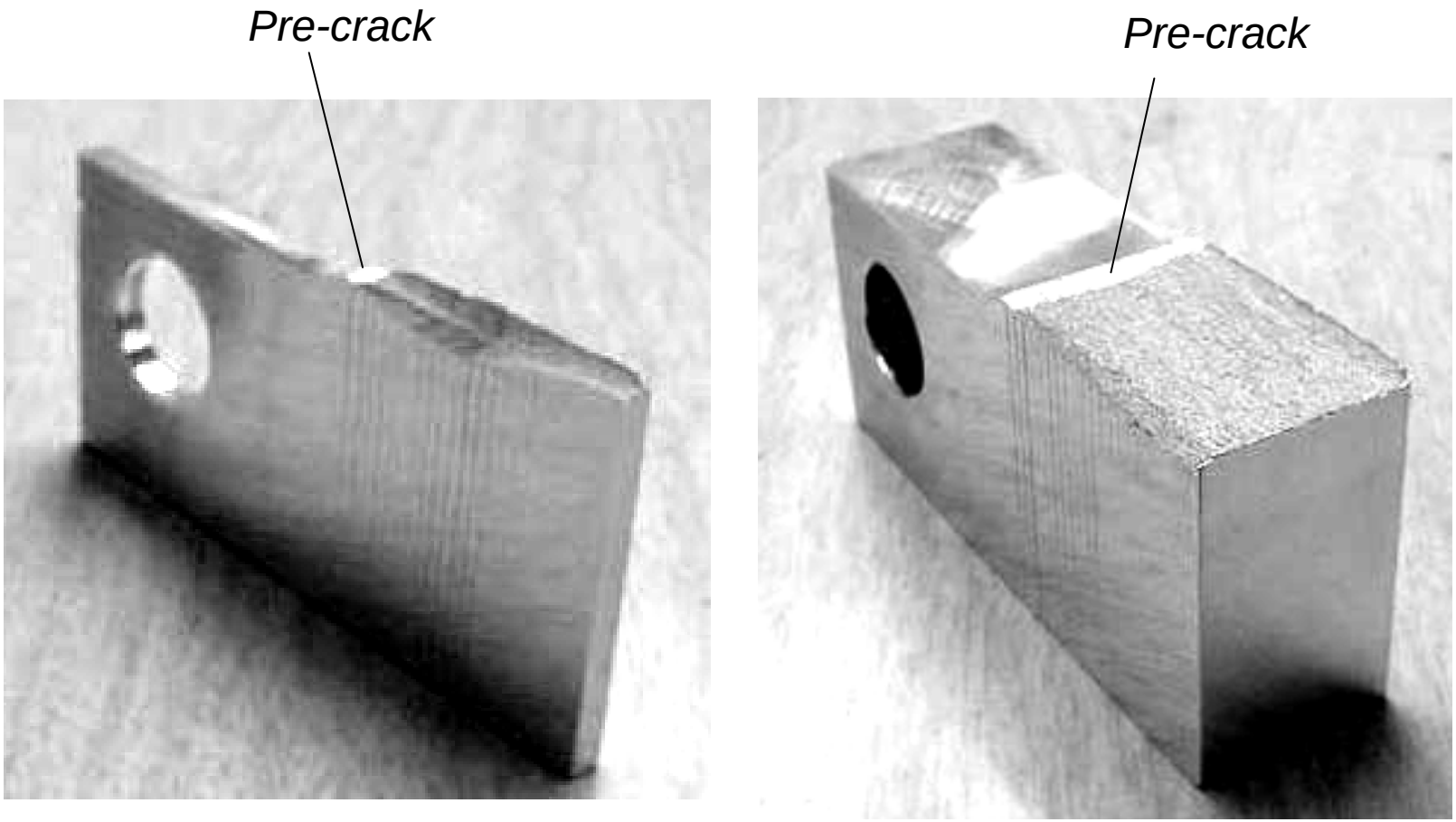
Testing machine
(applies displacement, senses force)

Controller and A/D

Computer with LabView
(reads and records load and displacement)

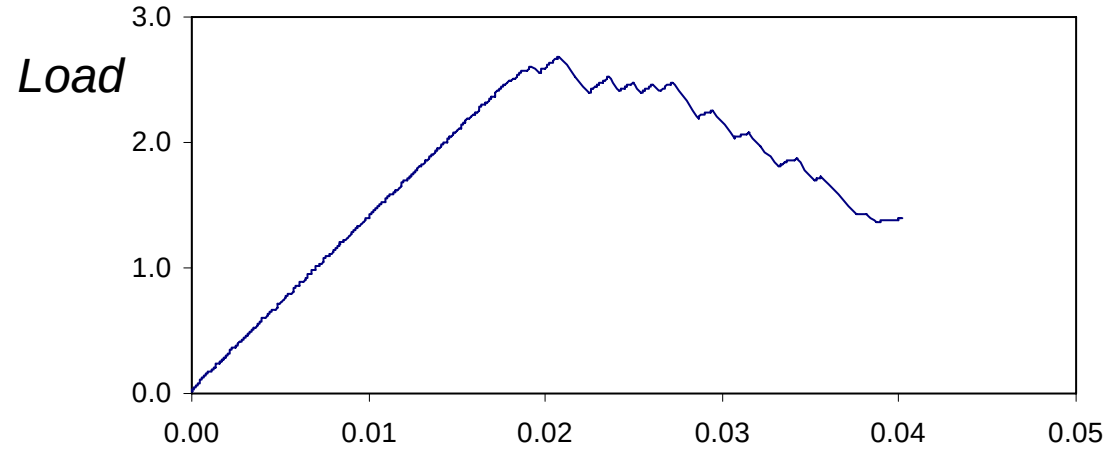


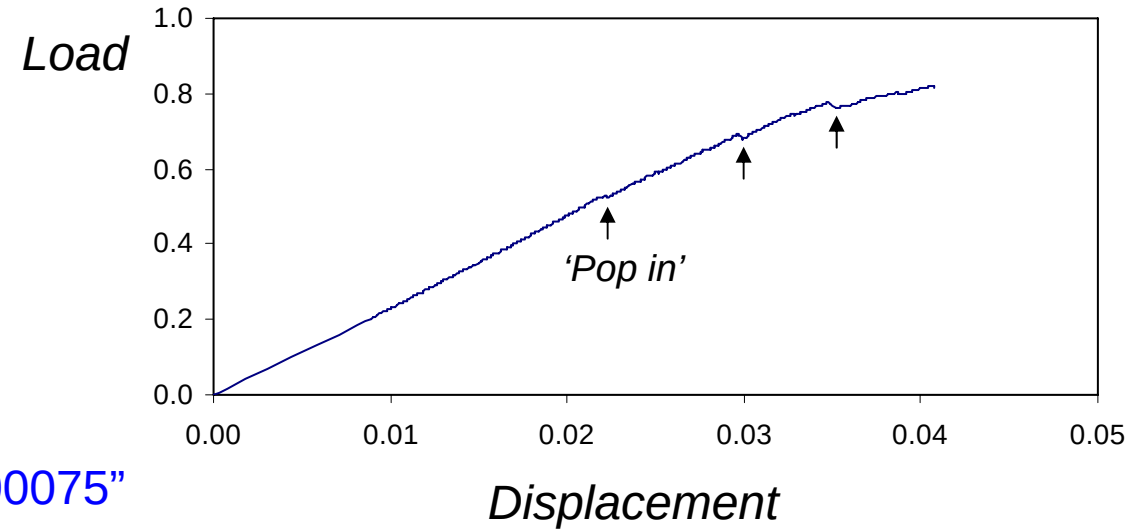
Broken Samples



Load at Fracture?

- Ductile or brittle?
- Elastic or plastic?
- Note that deciding when fracture occurs involves some choices.

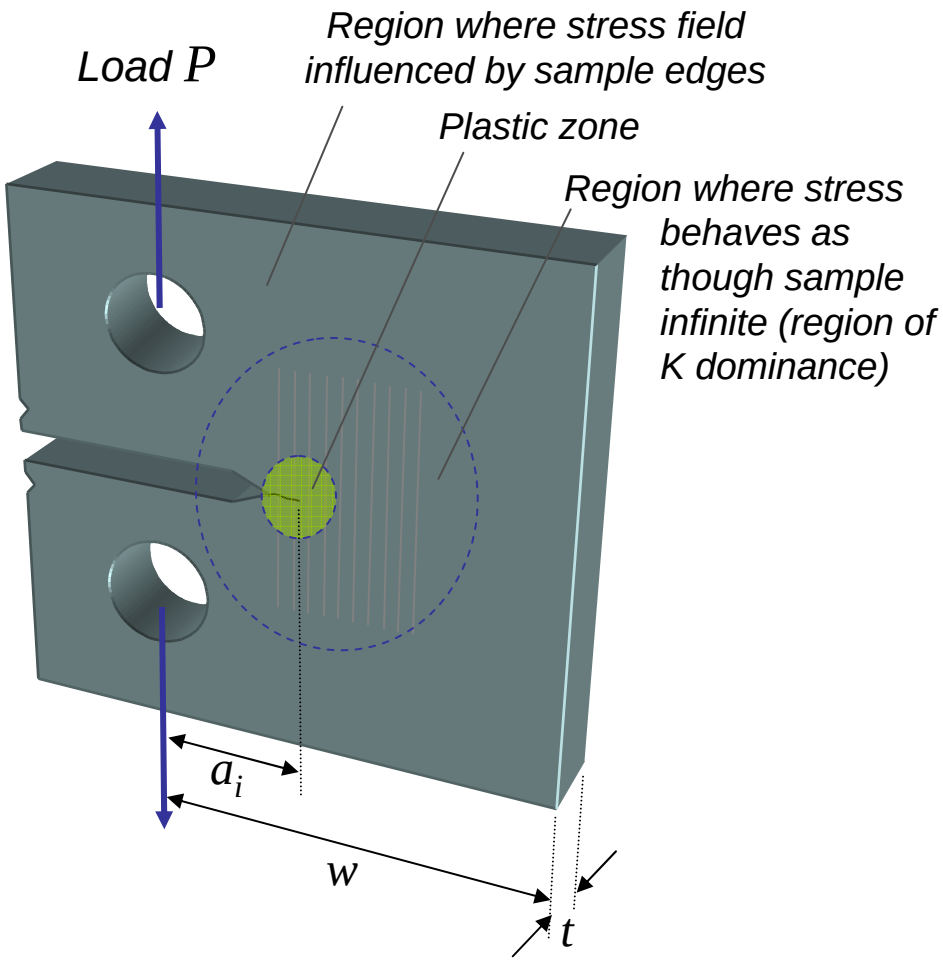




Loadcell range 10 kips
Extensometer range 0.075“

Manufacturer gives:
Loadcell accuracy 10lbs
Extensometer accuracy 0.000075”

Fracture Toughness?



- Real sample is finite and applied stress is not uniform
- However, if plastic zone is small enough then a region exists where stress field behaves as though sample is infinite.
- The stress intensity in this region is a function of the applied load and the sample geometry. This function is known in the form of a curve fit, derived from finite element analysis.

$$K = \frac{P}{t\sqrt{w}} f\left(\frac{a_i}{w}\right)$$

In ∞ case $K = \sigma\sqrt{\pi a}$

Ex. 5 Summary

- Pre-defined goal and procedures
- Two teams collaborate to break 3 samples
- Measure/photo samples before and after fracture
- Analyze the load vs displacement curves and the sample dimensions are analyzed to yield
  - The fracture toughness
  - The plastic zone size
  - Whether the sample is in plane stress or plane strain
- When you have completed all analysis, and have a plot of fracture toughness vs. sample thickness you are done.