EM 388 F - Fracture Mechanics [Dr. Huang]

Final Project - Study of Mode I Fracture of Self Assembled Monolayer with ABAQUS

April 28, 2008

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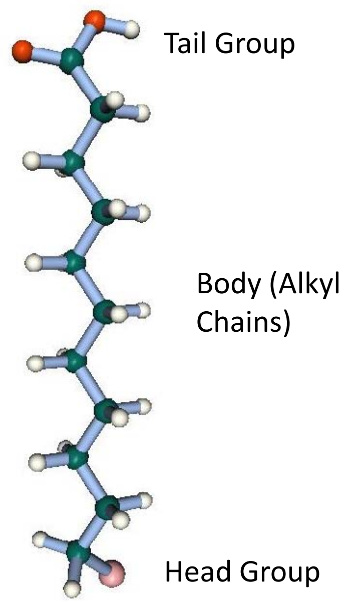
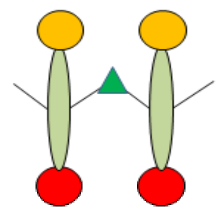
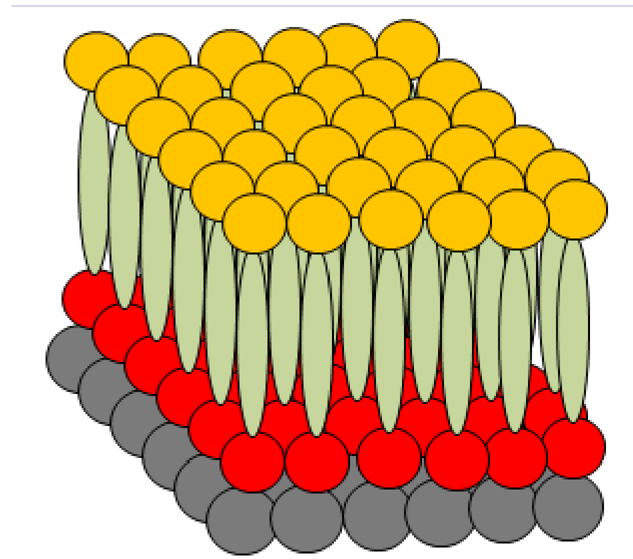
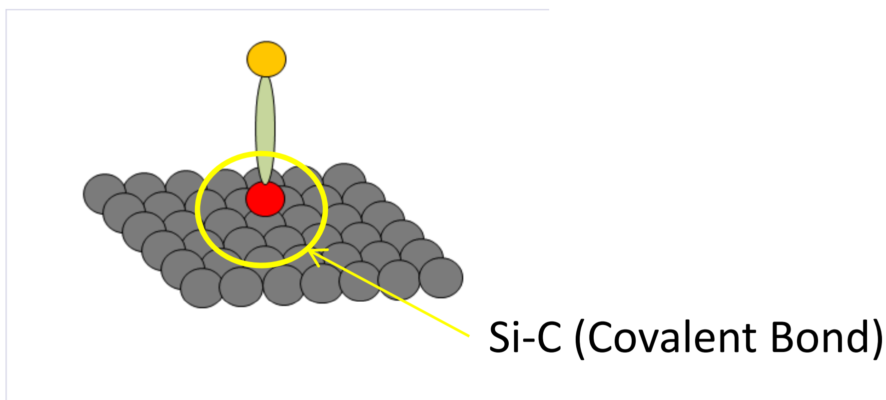
Introduction 1/14

What is Self Assembled Monolayers?









SAMs can be sticky or non-sticky by altering a tail group.
In this study, consider SAM as an <u>ultra thin layer of adhesive.</u>

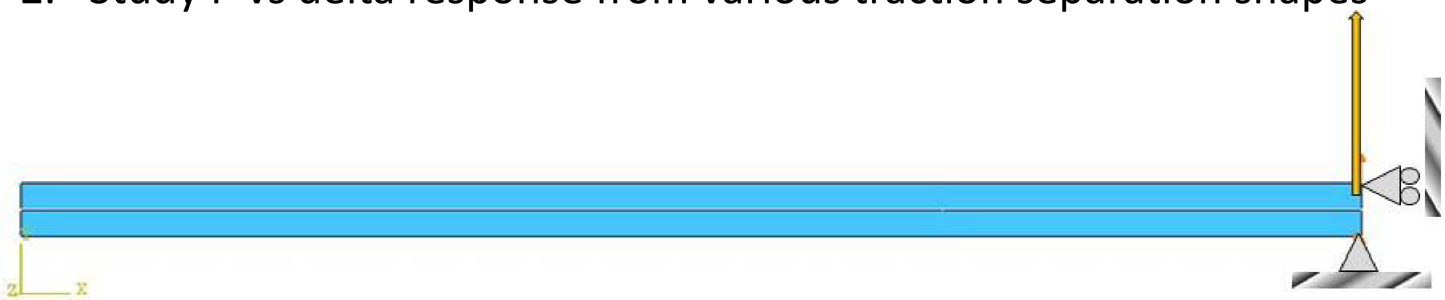
Reference: A. Ulman. Formation and Structure of Self-Assemble Monolayers. *Chemical Reviews* 96: 1533-1554, New York (1996)

Introduction 2/14

When DCB specimen is subjected to ramp input in a Mode I manner, available data are reaction load (P) and displacement (delta) at the location here loading is applied.

Objective of Study:

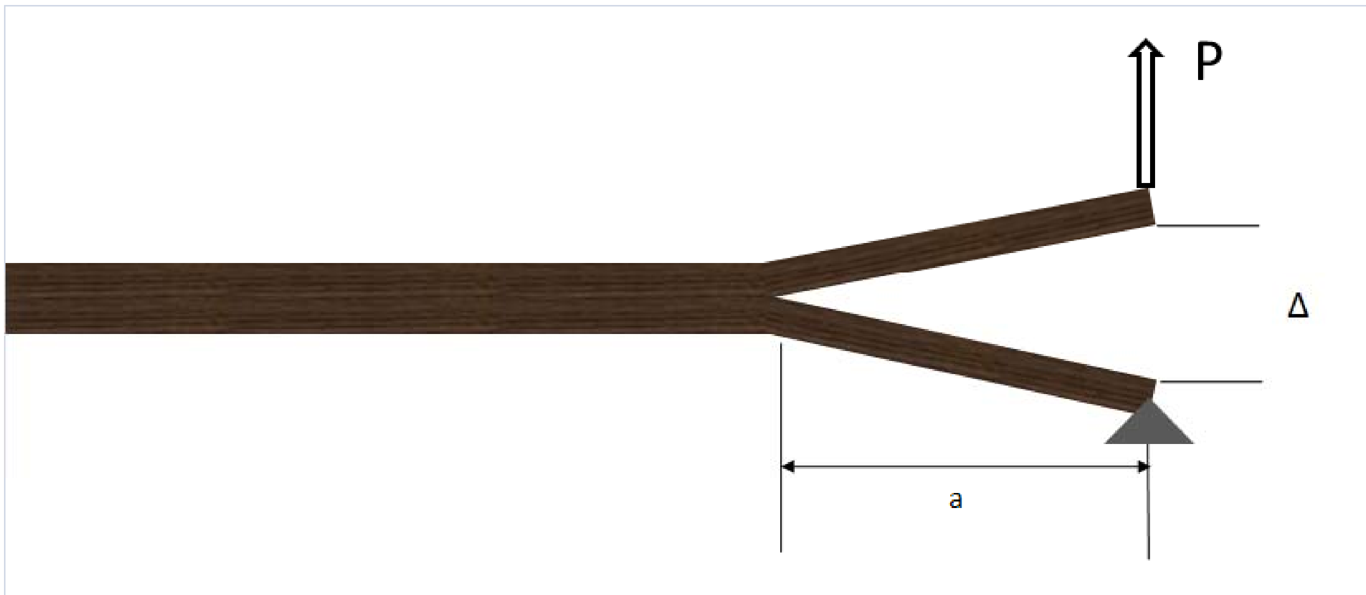
1. Learn ABAQUS program (exp. Cohesive element)
2. Study P vs delta response from various traction separation shapes



			Input is in yellow	
	m base unit		mm Unit	
Material Property		(unit)		(unit)
L	1.60E-02	m	16	mm
b	5.00E-03	m	5	mm
h	3.20E-04	m	0.32	mm
E	1.69E+11	Pa	1.69E+05	N/(mm^2)
nu	3.00E-01		0.22	N/A
Test Property				
BCs	Bottom/Up		Bottom/Up	
Loading rate	1.00E-05	m/s	1.00E-02	mm/ sec

Substrate: Silicon(111)

Theory 3/14 – LEFM Energy Method



Energy Release Rate

$$G_{tip} = \frac{\eta P^2 a^2}{EbI}$$

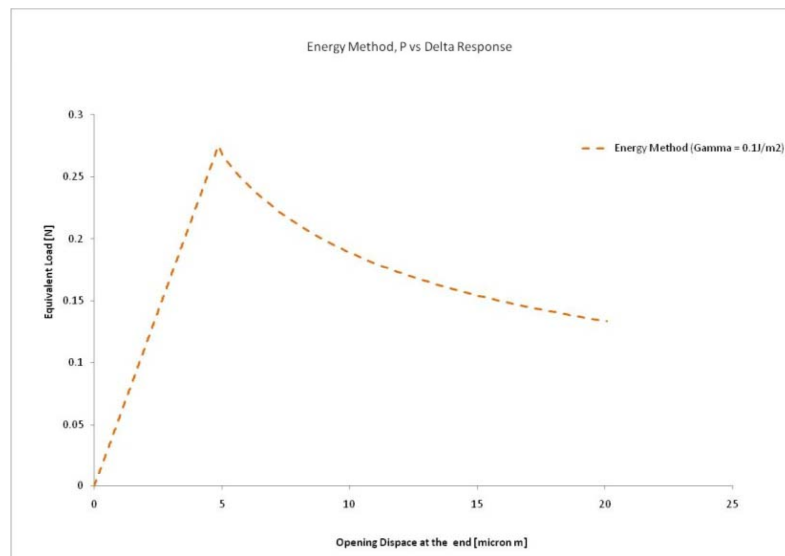
for plane strain,

$$\eta = 1 - \nu^2$$

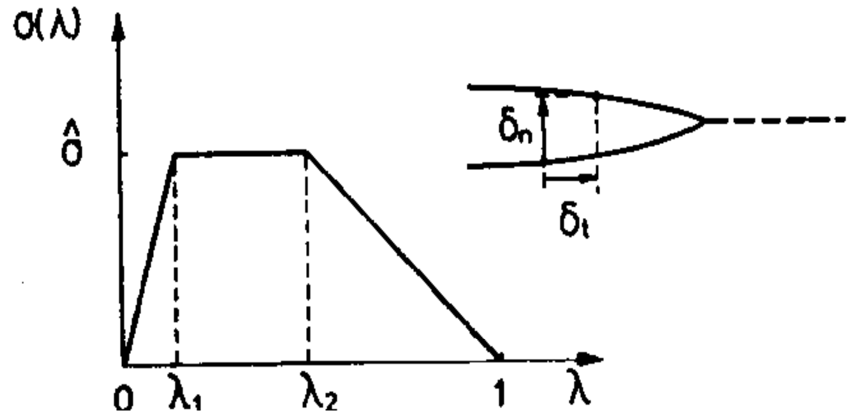
Tip Deflection

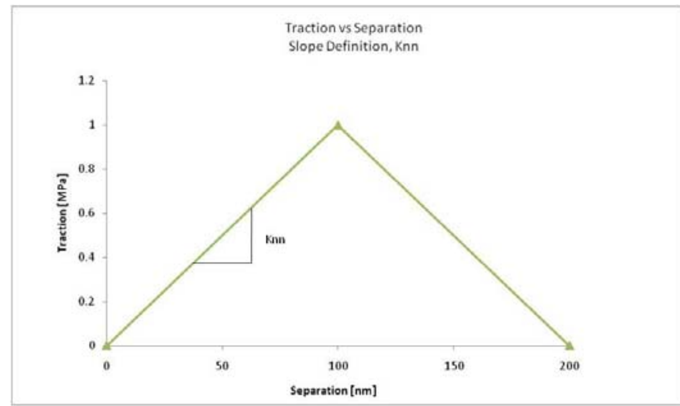
$$\Delta = 2 \times \delta$$

$$\delta = \eta \frac{P a^3}{3EI}$$



Theory 4/14 – Traction Separation





-In 1960's, Dugdale, Bilby, Cottrell, established the concept of traction separation properties of interface fracture driven from atomic separation to void growth (Bao and Suo) +

- When adhesive is thin compared to thickness of a substrate, mode mixity is almost zero (Gdoutos) ++

Referece

+ G. Bao. Z Suo. Ramarks on crack-bridging concepts. Appl. Mech. Rev. vol. 45. (1992)

++ E. Gdoutos. Fracture Mechanics 2nd Edition. Greece (2005)

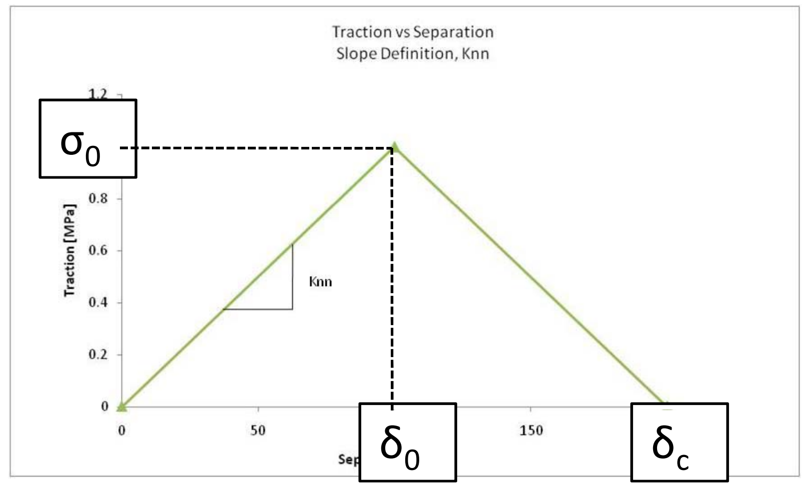
Case Studies 5/14

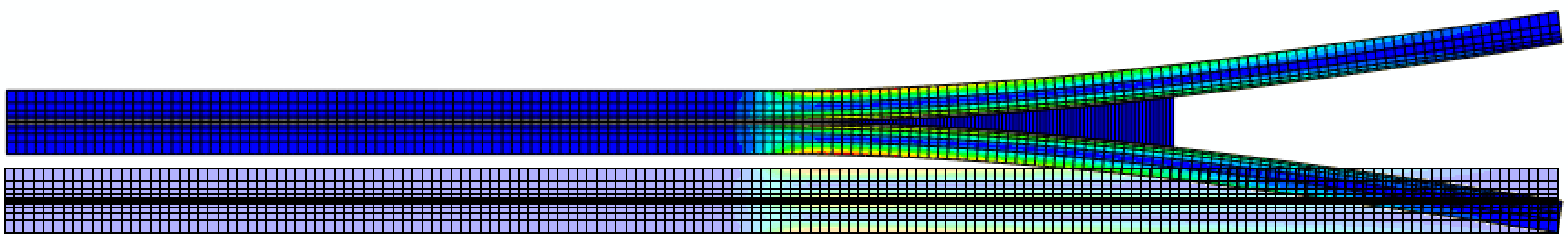
From previous work with OTS by Wang (2004), interfacial fracture energy is set as 0.1 J/m^2 (i.e. area underneath of Traction Separation curve).

** Case 1 [const. fracture energy]*
Keep σ_0 and δ_c constant, vary δ_0

** Case 2 [const. Knn, diff energy]*
Keep Knn and δ_c constant, vary σ_0

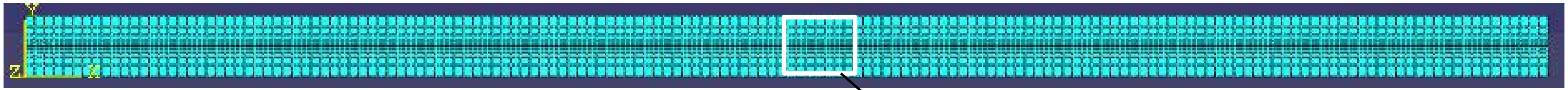
** Case 3 [const. fracture energy]*
Keep Γ_0 constant, vary σ_0, δ_0, and δ_c

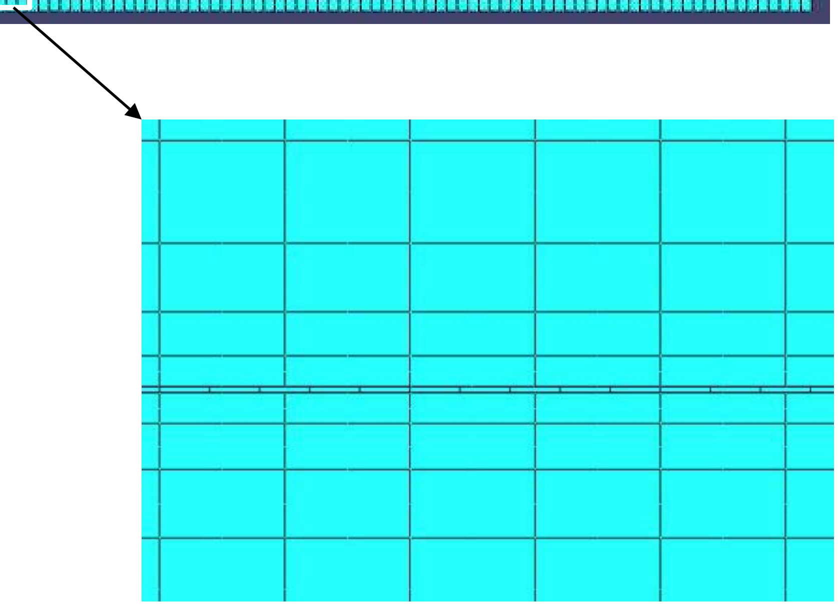




ABAQUS Model 6/14

Parametric Study of Cohesive Element in Mode I - Meshes





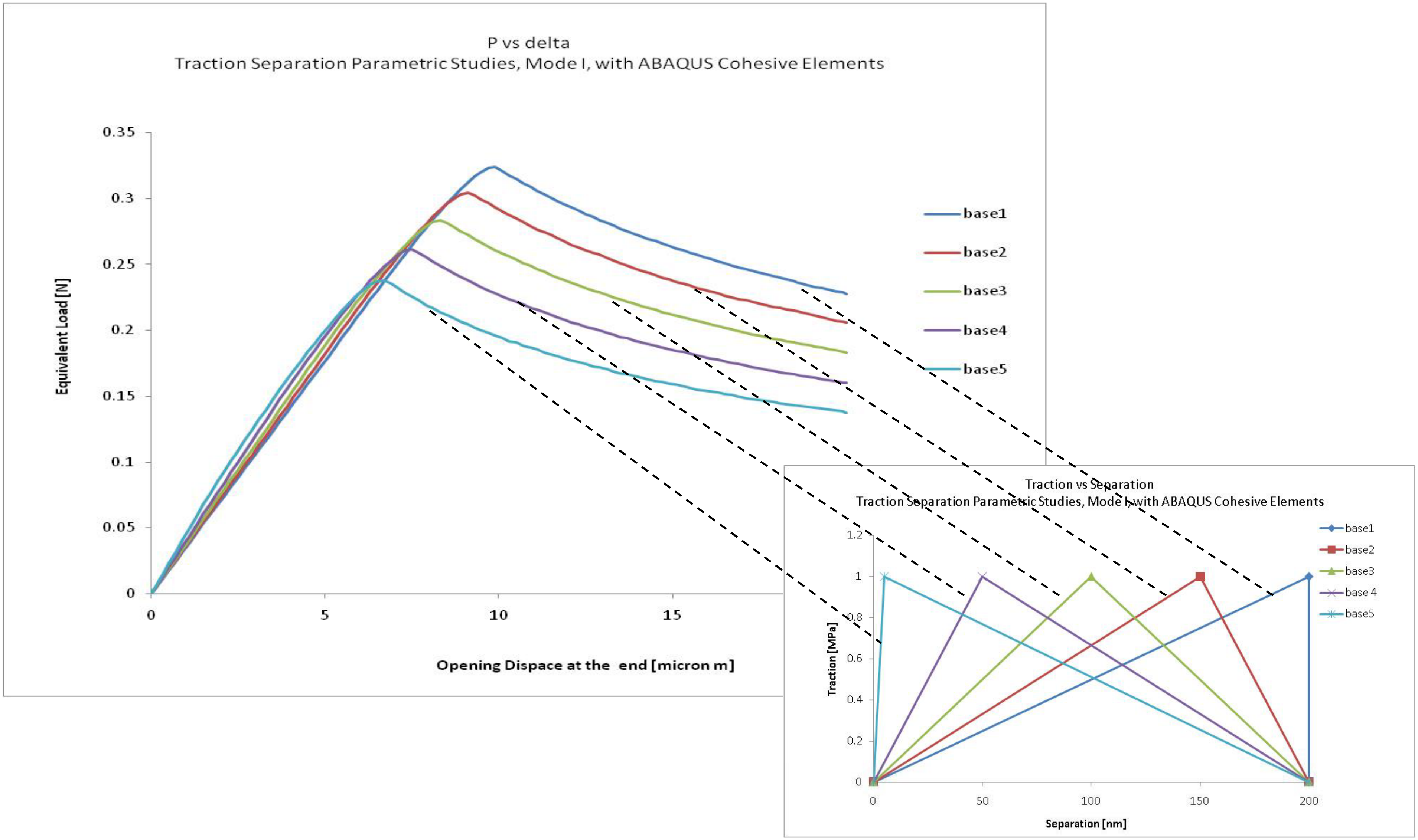
Si wafer: Plain Strain Condition
Element Type: **CPE8R**
An 8-node biquadratic plane strain quadrilateral, reduced integration.

SAM: Plain Strain Condition
Element Type: **COH2D4**
A 4-node two-dimensional cohesive element.
Thickness: Default (i.e. 1)
Maxe damage criterion

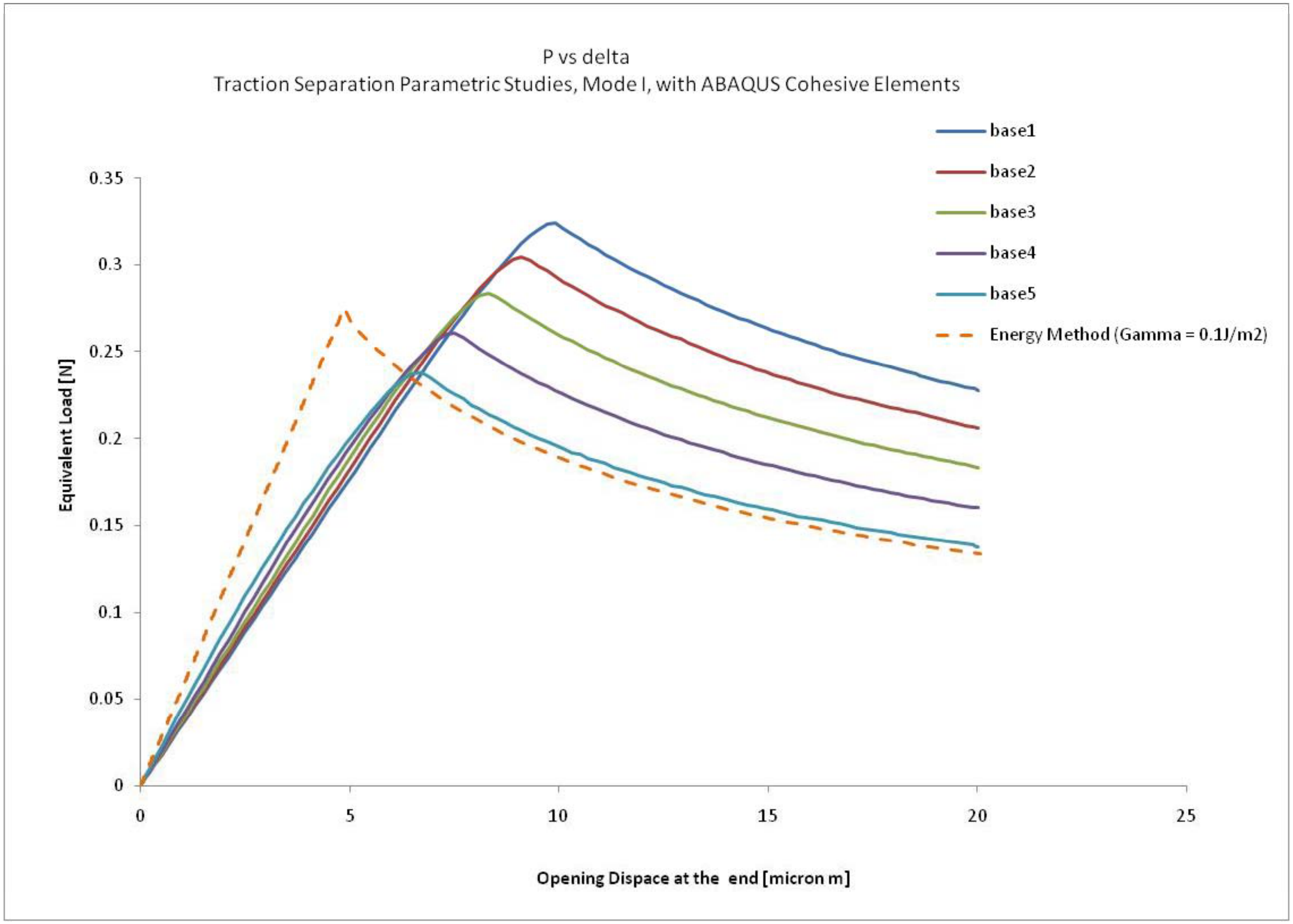
Total number of elements	1900
number of nodes	6064
total number of variables	12128

Case 1 Results 7/14

Case 1 Parametric Study of Cohesive Element in Mode I - Results



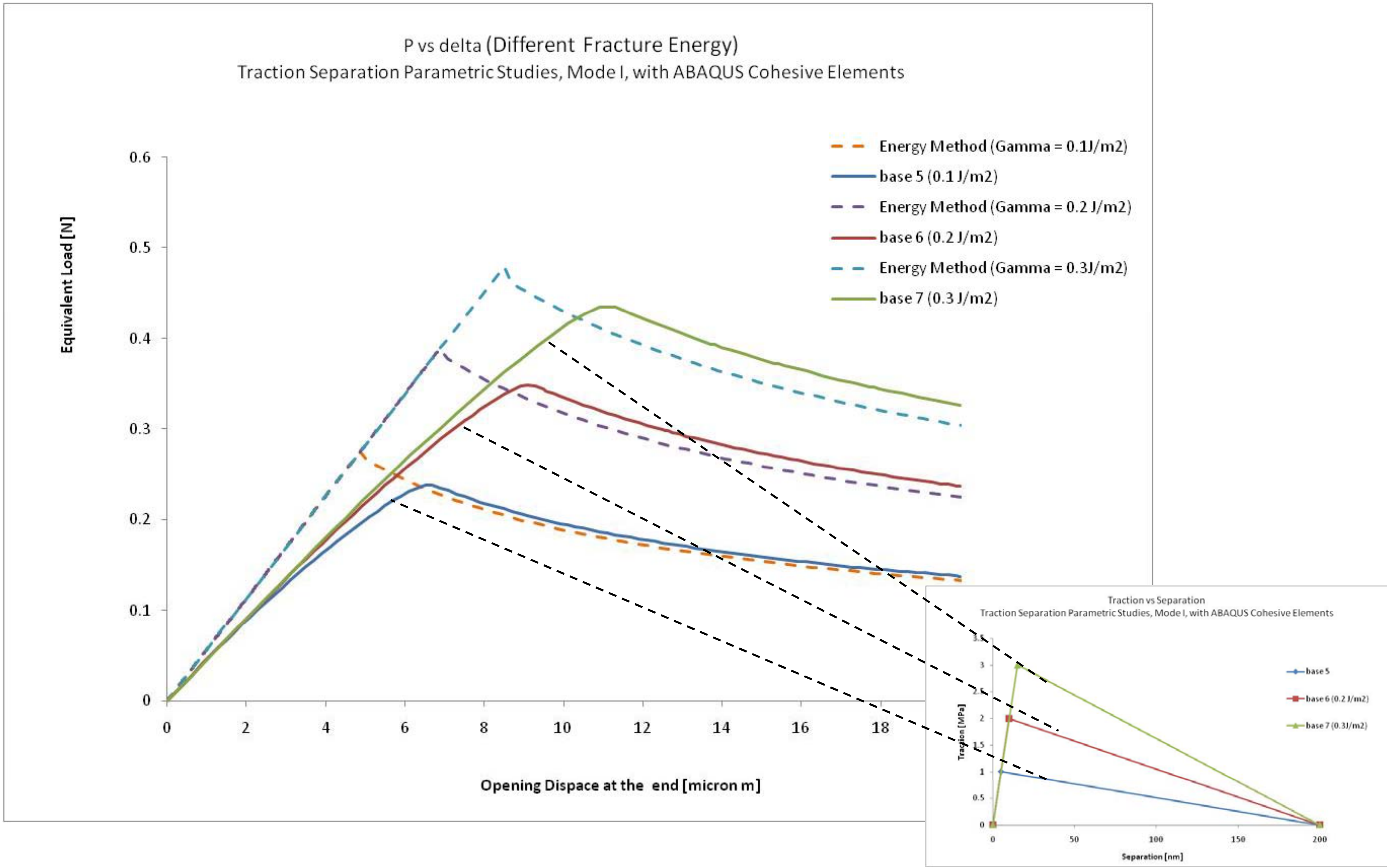
Case 1 Results 8/14



Case 2 Results 9/14

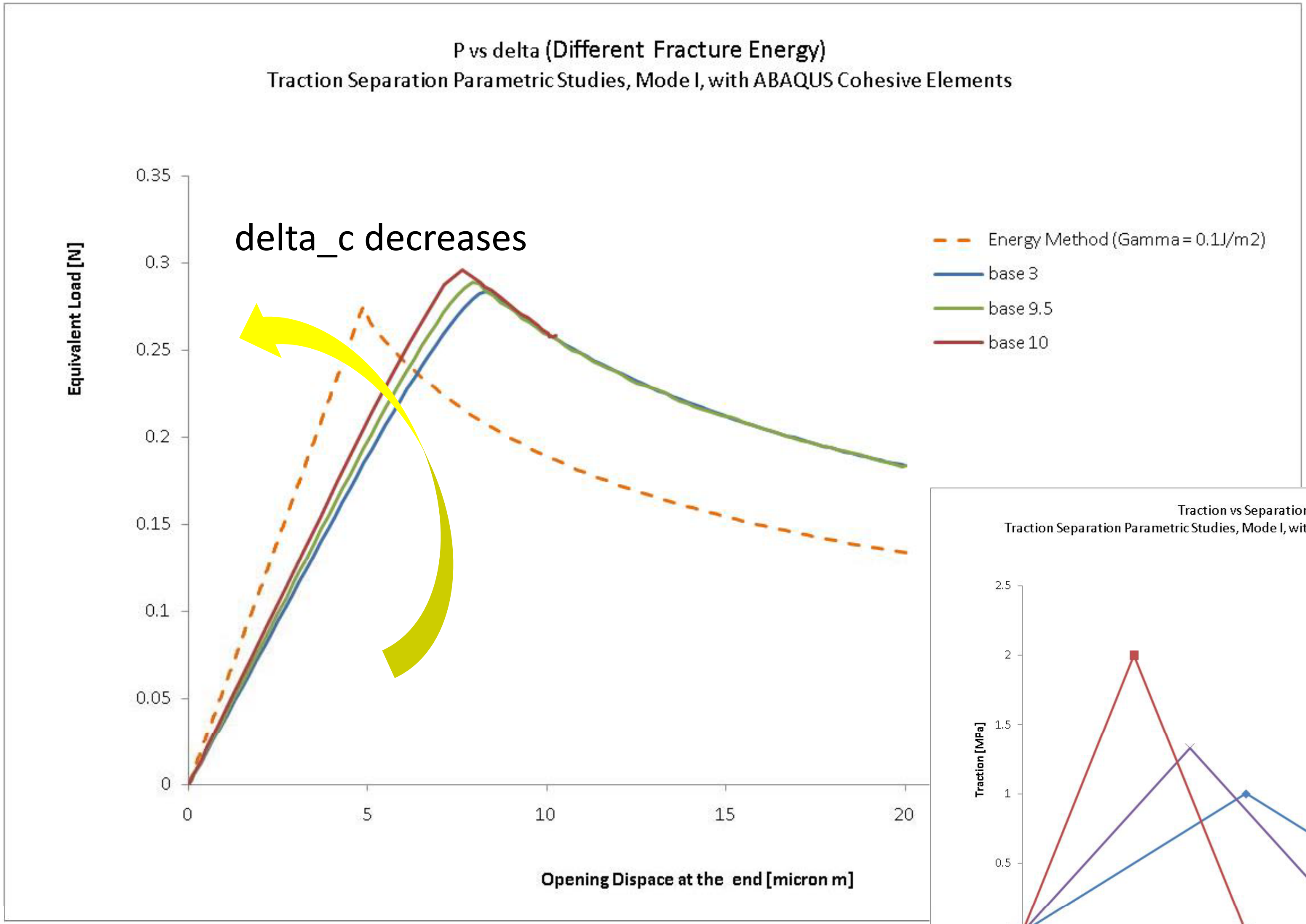
Case 2

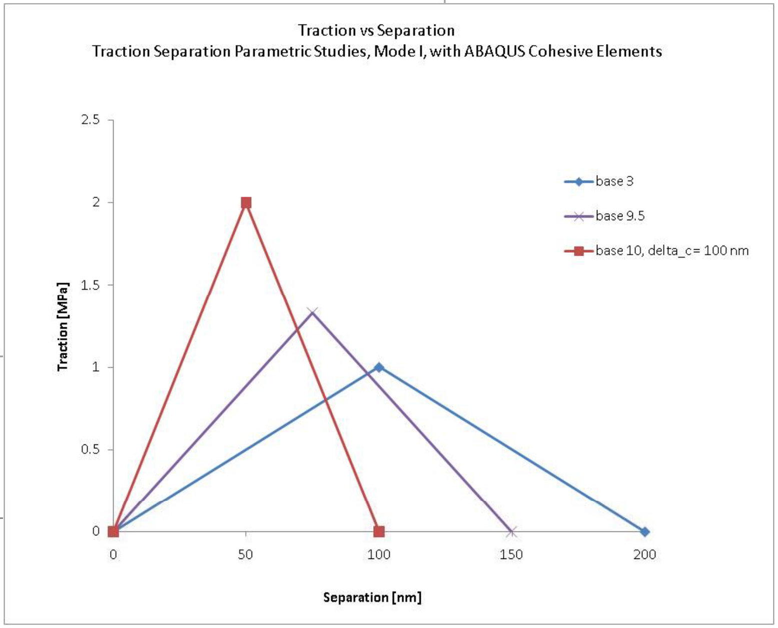
Increase Interfacial Fracture Energy



Case3 Results 10/14

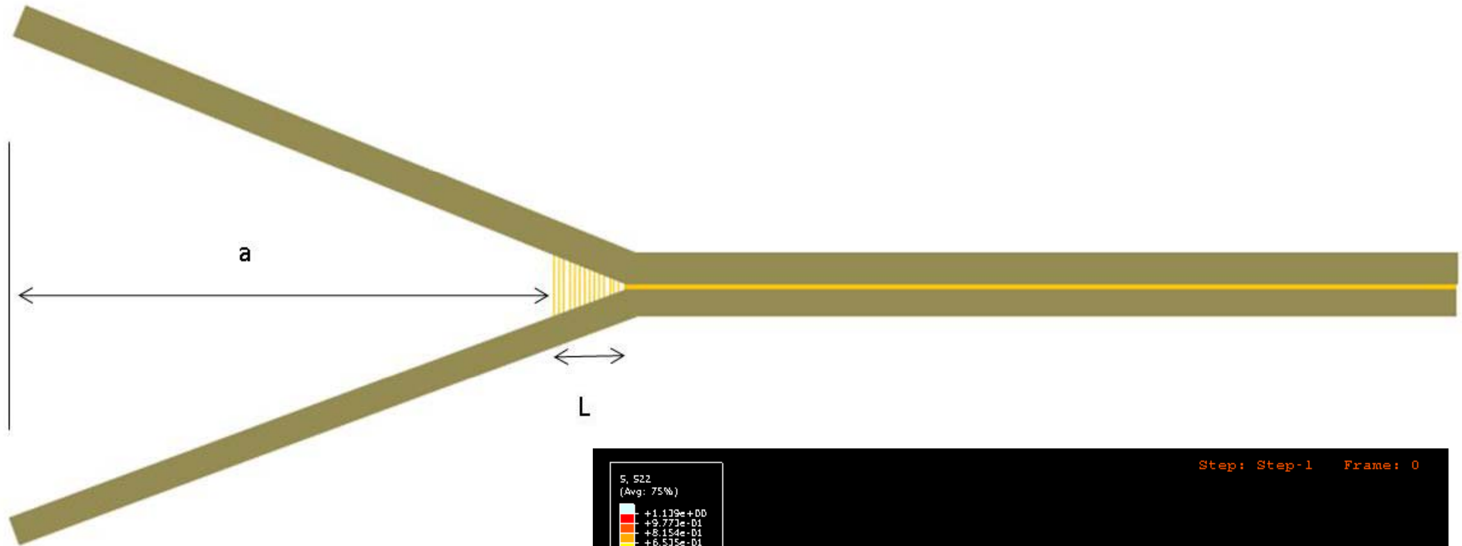
Case 3 Make delta_c (rupture length) shorter

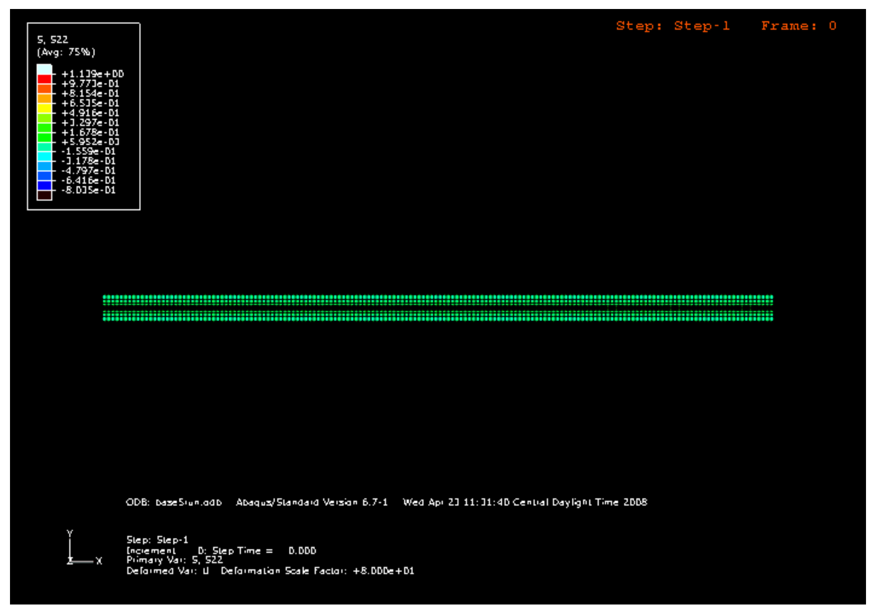




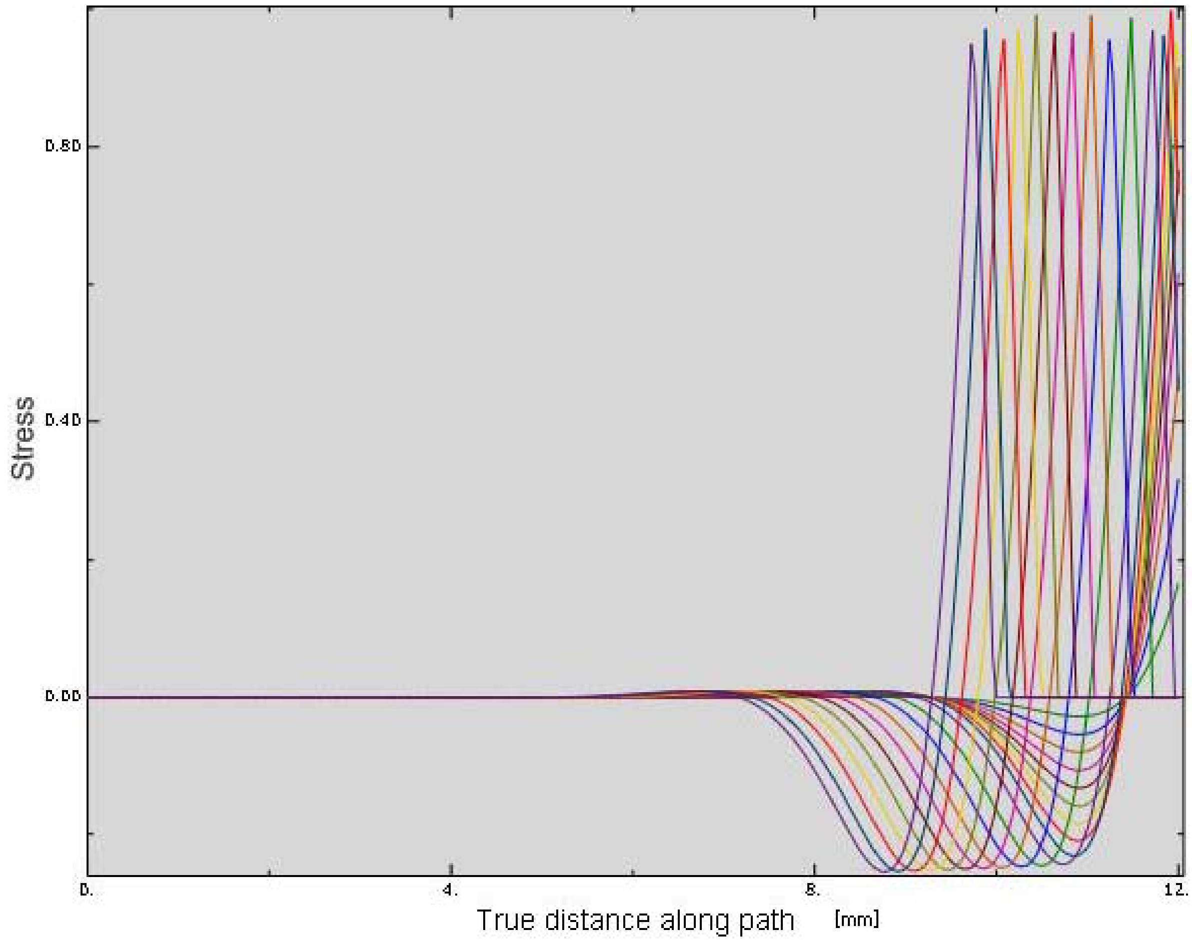
Crack Propagation Results 11/14

How does crack propagate?



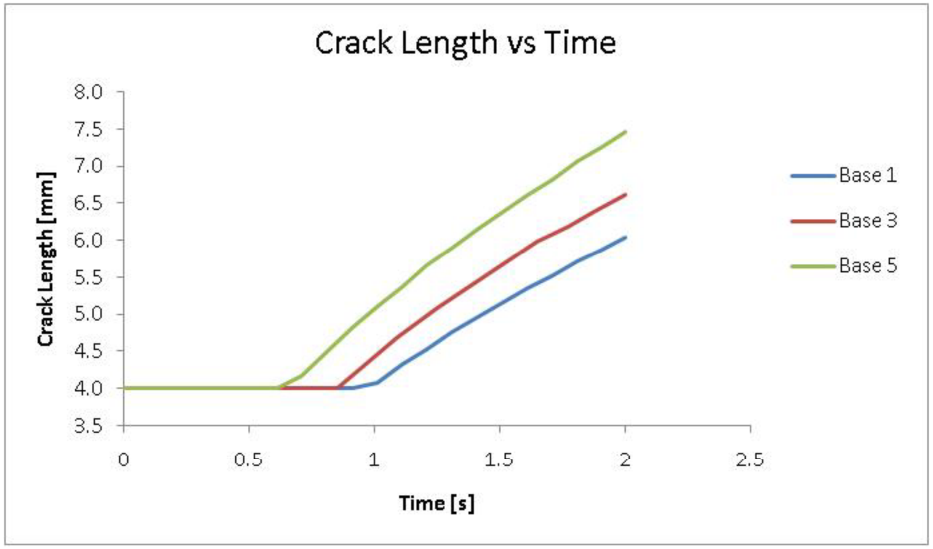


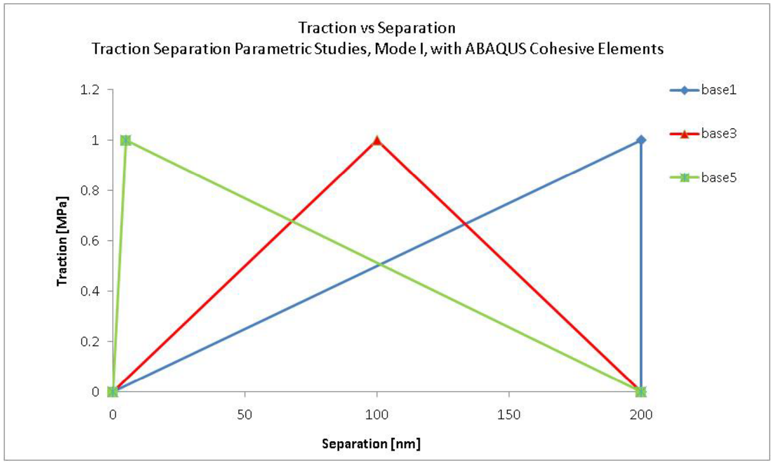
Crack Propagation Results 12/14

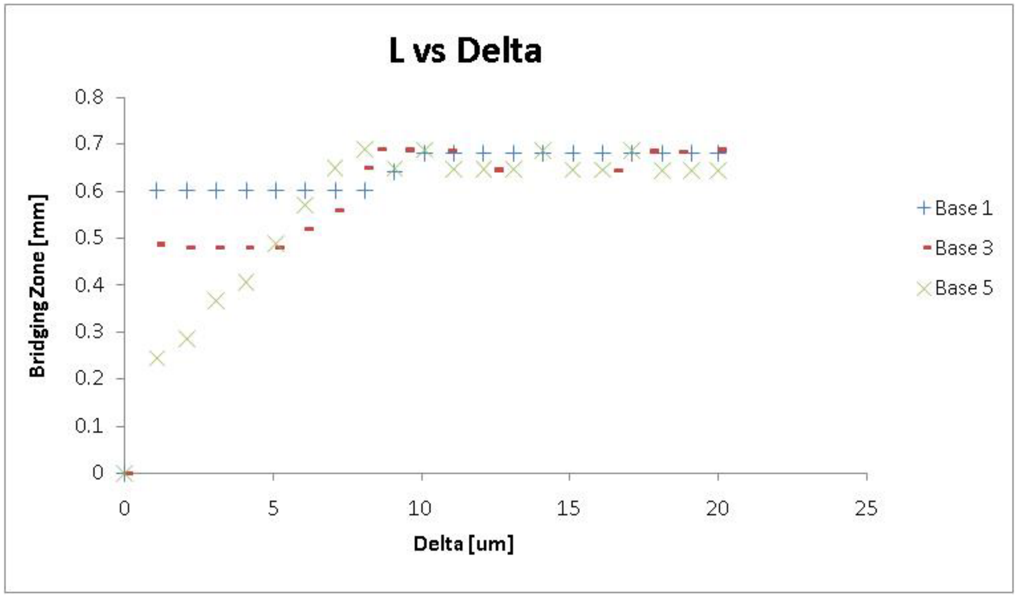


Method: Define a path along cohesive element. Then, take σ22 data for each 0.1 sec. Recall that input (disp) was 0.01 mm/sec.

Crack Propagation Results 13/14







Conclusion14/14

Case 1: As slope of T-S increases (as δ_0 decreases), P required to propagate the crack decreased.

Case 2: As interfacial fracture energy increases, P required to propagate the crack increased.

Case 3: As separation length shortens (as δ_c decreases), slope of P vs delta curve became higher.

Crack Propagation: Although the interfacial fracture energy remains constant, crack propagation depended on the slope of T-S property. However, Lss length was identical to any slope with the same interfacial fracture energy.

Lss was about 0.68 mm, which is larger than thickness of Si substrate. Thus, this problem should be considered as "Large Scale Bridging."

Future Works: Study mix-mode (Mode I and Mode II) conditions