EXPERIMENTAL MEASUREMENT OF MODE-I FRACTURE TOUGHNESS & TRACTION LAWS FOR DELAMINATION IN PLAIN WEAVE COMPOSITES

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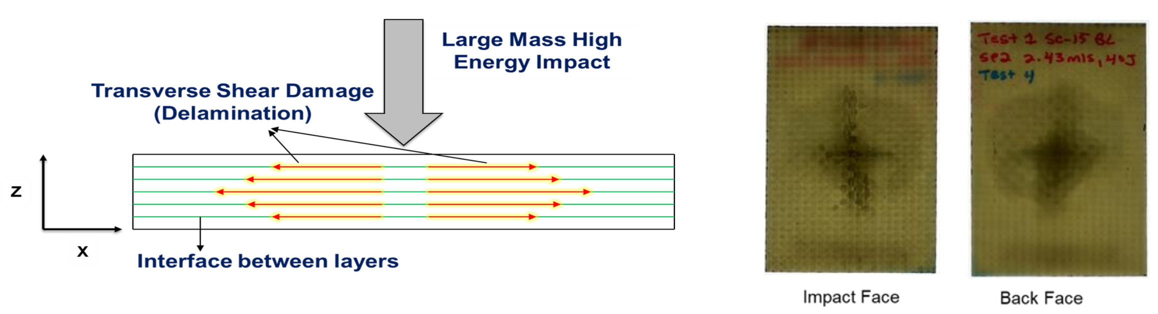
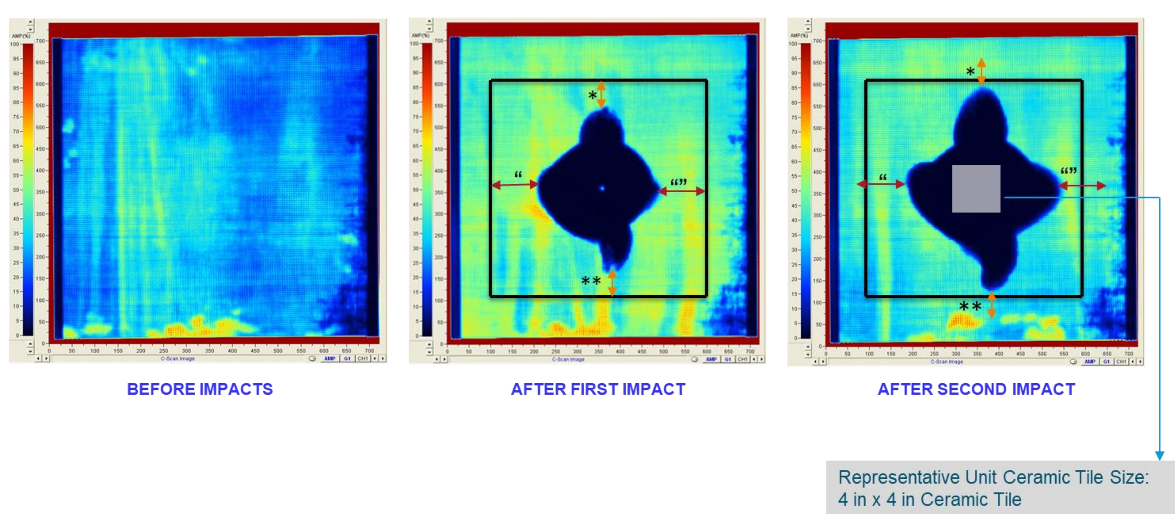
Introduction

Low-velocity impact refers to the application of forces at slow speeds, but can still cause significant damage or failure in these materials.



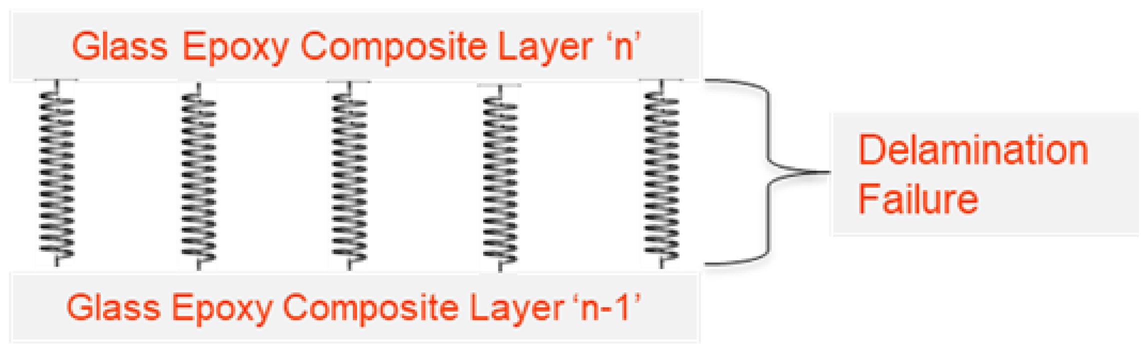


The main mechanism through which composites absorb energy in non-penetrating low velocity impacts is interlaminar delamination.

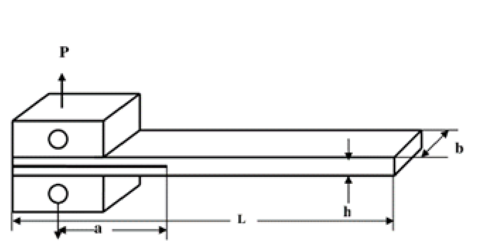
This delamination or separation of layers comes with an associated loss of stiffness, with interlaminar stresses causing the initiation and propagation of delamination between layers.

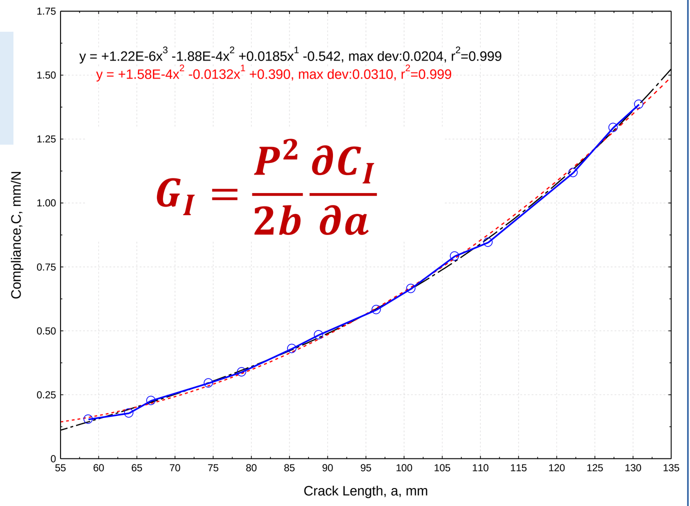
Objective:
- Improve Delamination Resistance (Durability)
- Increase Stiffness Retention (Damage Tolerance)

Mode-I Fracture Characterization



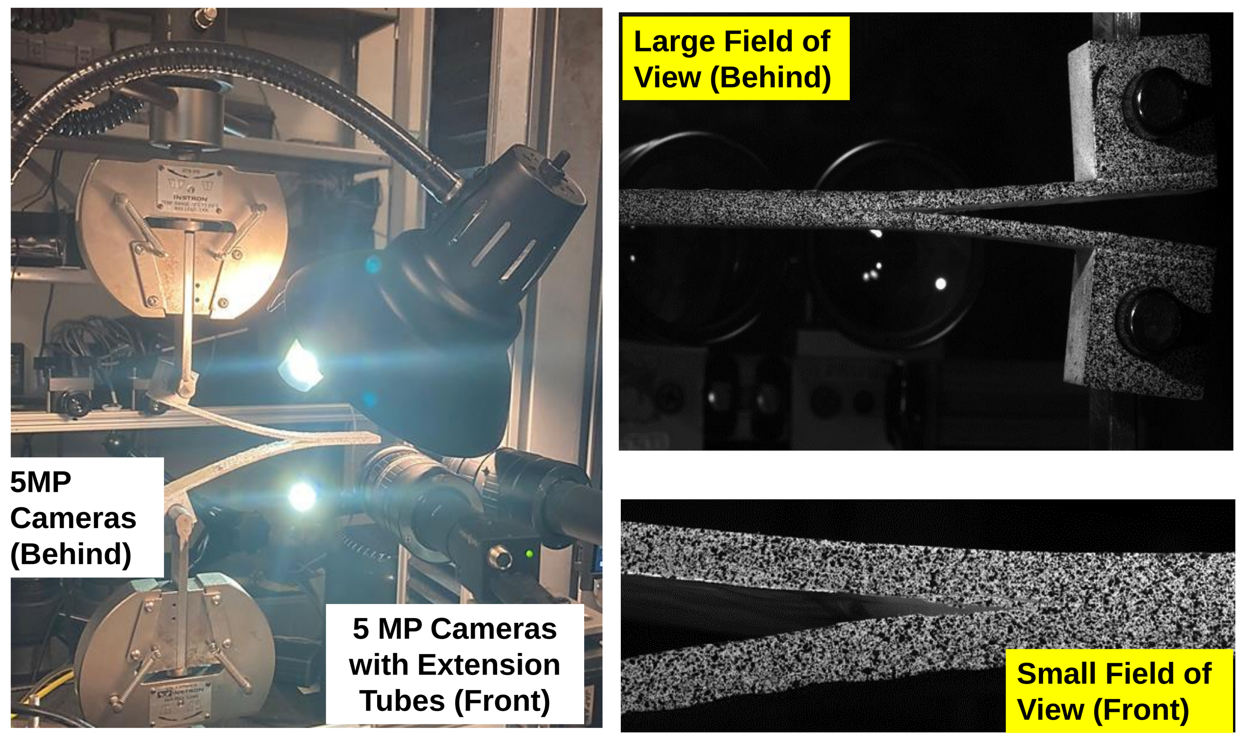
Pure Mode-I Fracture (Double Cantilever Beam)





$$G_I = \frac{P^2}{2b}\frac{\partial C_I}{\partial a}$$

Experimental Setup using Digital Image Correlation (DIC)

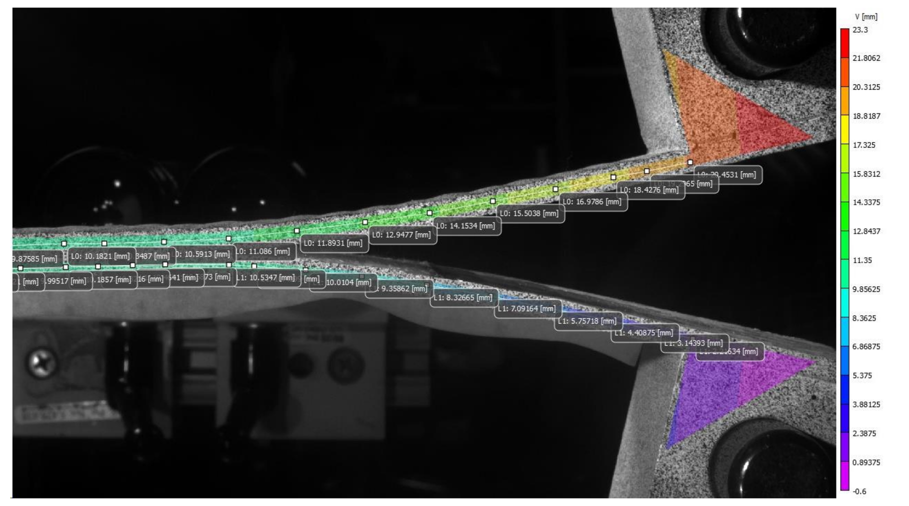


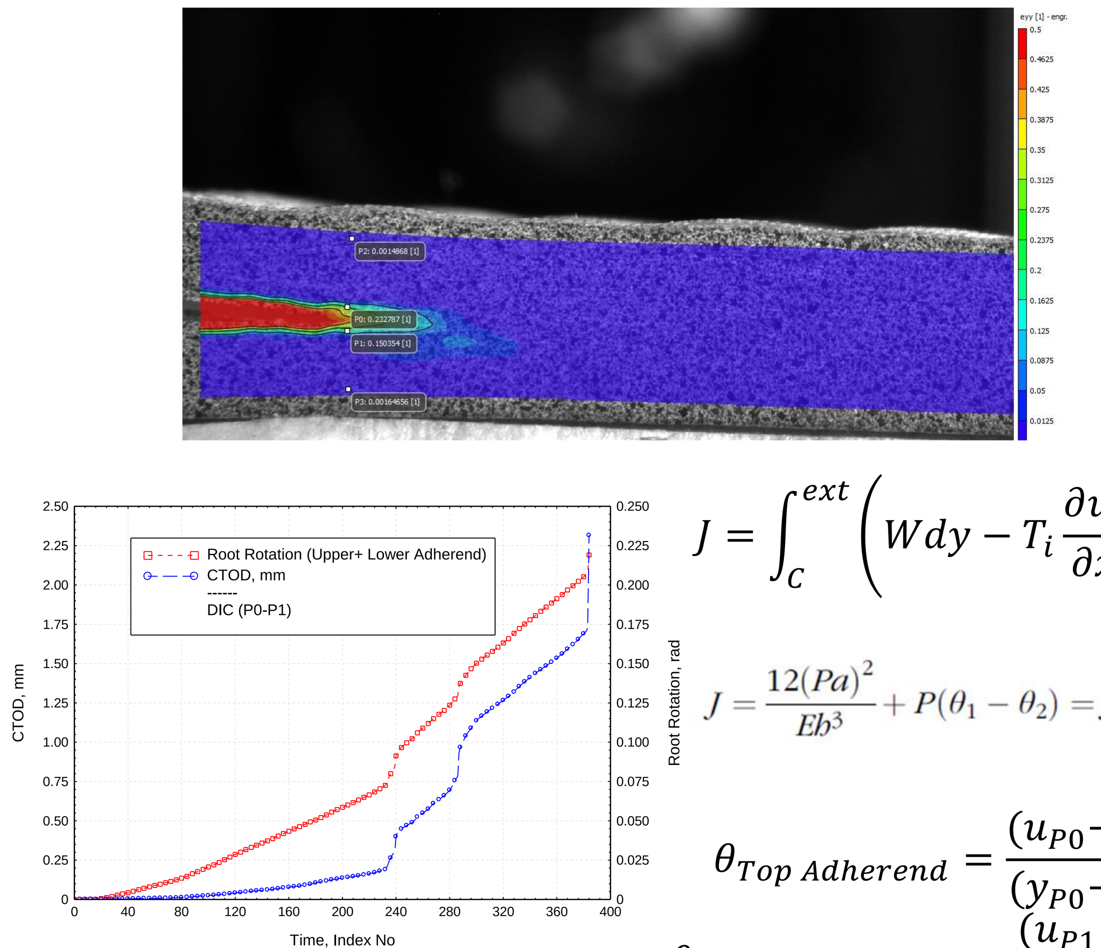
DIC Measurements:

FOV (Front): around 12 um/pixel
1. Crack opening displacement (under 200 microns)
2. Root Rotation (calculated at the crack tip)

FOV (Behind): 50 um/pixel
1. Crack Length/propagation
2. Rotation of the adherends (under the load point)

J-Integral Fracture Toughness (J_{Ic})





$$J = \int_C^{ext}\left(W\,dy - T_i\frac{\partial u_i}{\partial x}dC\right)$$

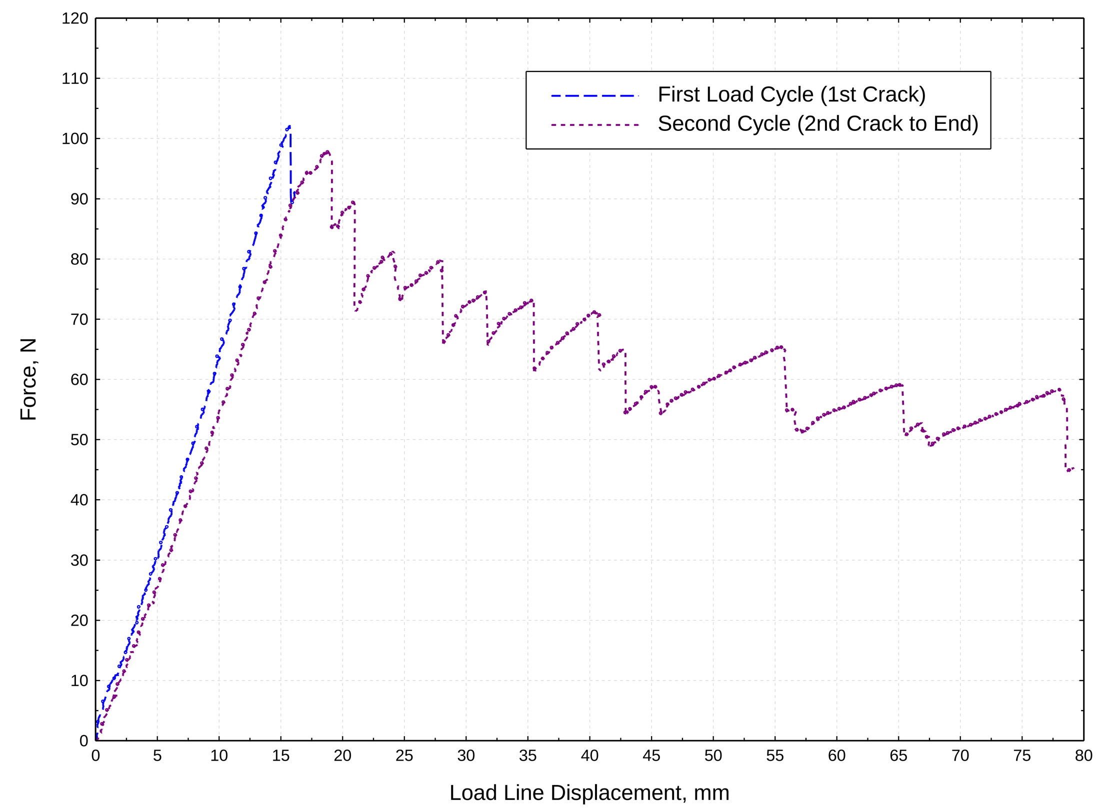
$$J = \frac{12(Pa)^2}{Eb^3} + P(\theta_1 - \theta_2) = J_1 + J_2,$$

$$\theta_{Top\ Adherend} = \frac{(u_{P0}-u_{P2})}{(y_{P0}-y_{P2})}$$

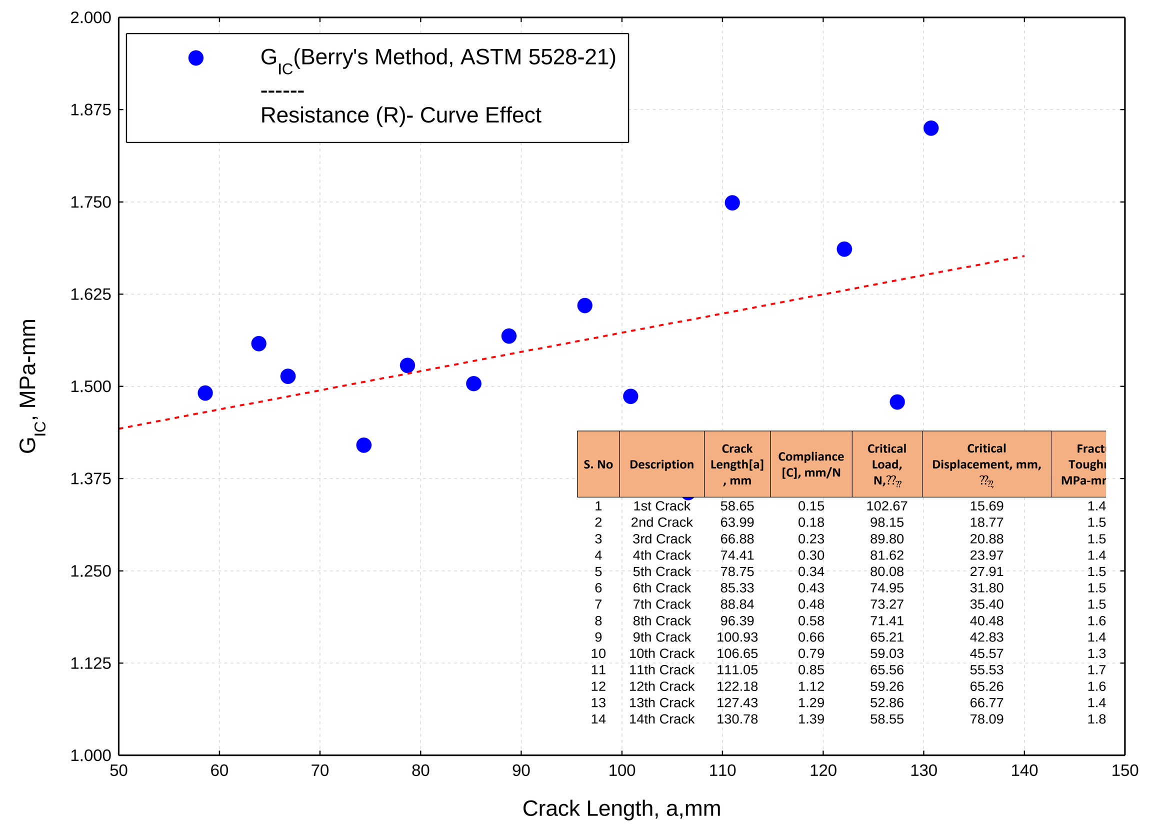
$$\theta_{Bottom\ Adherend} = \frac{(u_{P1}-u_{P3})}{(y_{P1}-y_{P3})}$$

Results

Force-Load Line Displacement:

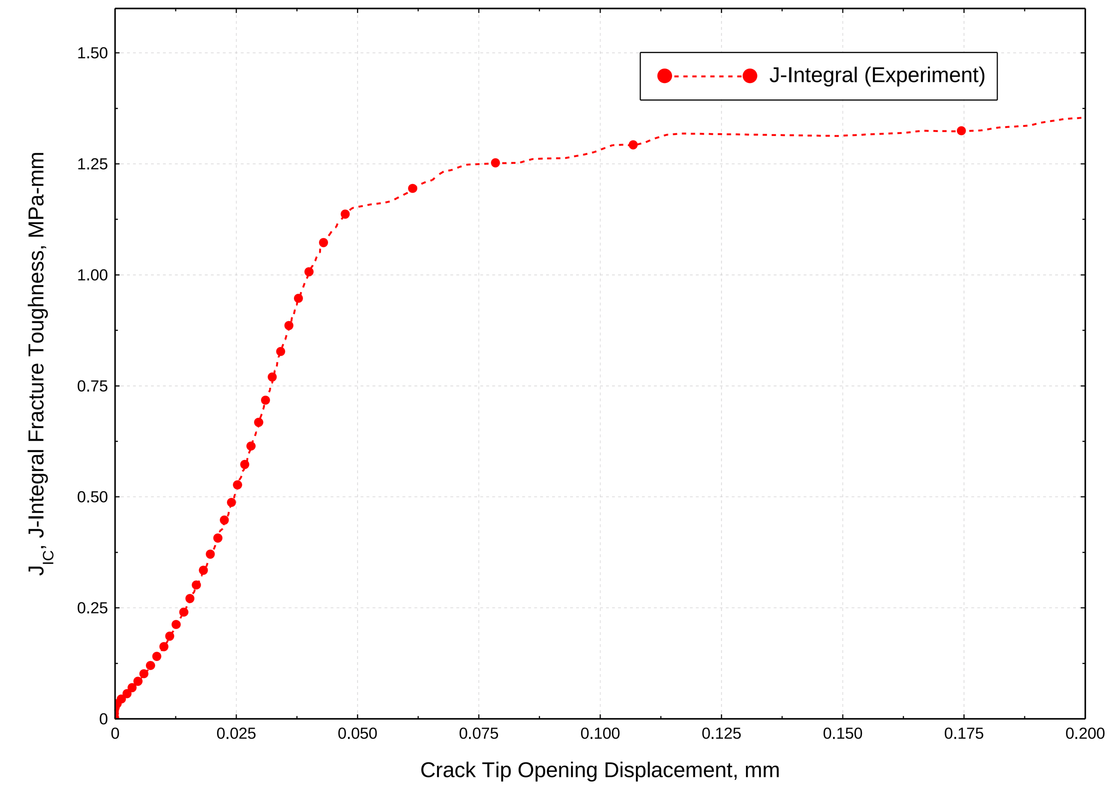


Resistance Curve Effect



S. No	Description	Crack Length[a], mm	Compliance [C], mm/N	Critical Load, N	Critical Displacement, mm	Fract. Tough. MPa-mm
1	1st Crack	58.65	0.15	102.67	15.69	1.4
2	2nd Crack	63.99	0.18	98.15	18.77	1.5
3	3rd Crack	66.88	0.23	89.80	20.88	1.5
4	4th Crack	74.41	0.30	81.62	23.97	1.4
5	5th Crack	78.75	0.34	80.08	27.91	1.5
6	6th Crack	85.33	0.43	74.95	31.80	1.5
7	7th Crack	88.84	0.48	73.27	35.40	1.5
8	8th Crack	96.39	0.58	71.41	40.48	1.6
9	9th Crack	100.93	0.66	65.21	42.83	1.4
10	10th Crack	106.65	0.79	59.03	45.57	1.3
11	11th Crack	111.05	0.85	65.56	55.53	1.7
12	12th Crack	122.18	1.12	59.26	65.26	1.6
13	13th Crack	127.43	1.29	52.86	66.77	1.4
14	14th Crack	130.78	1.39	58.55	78.09	1.8

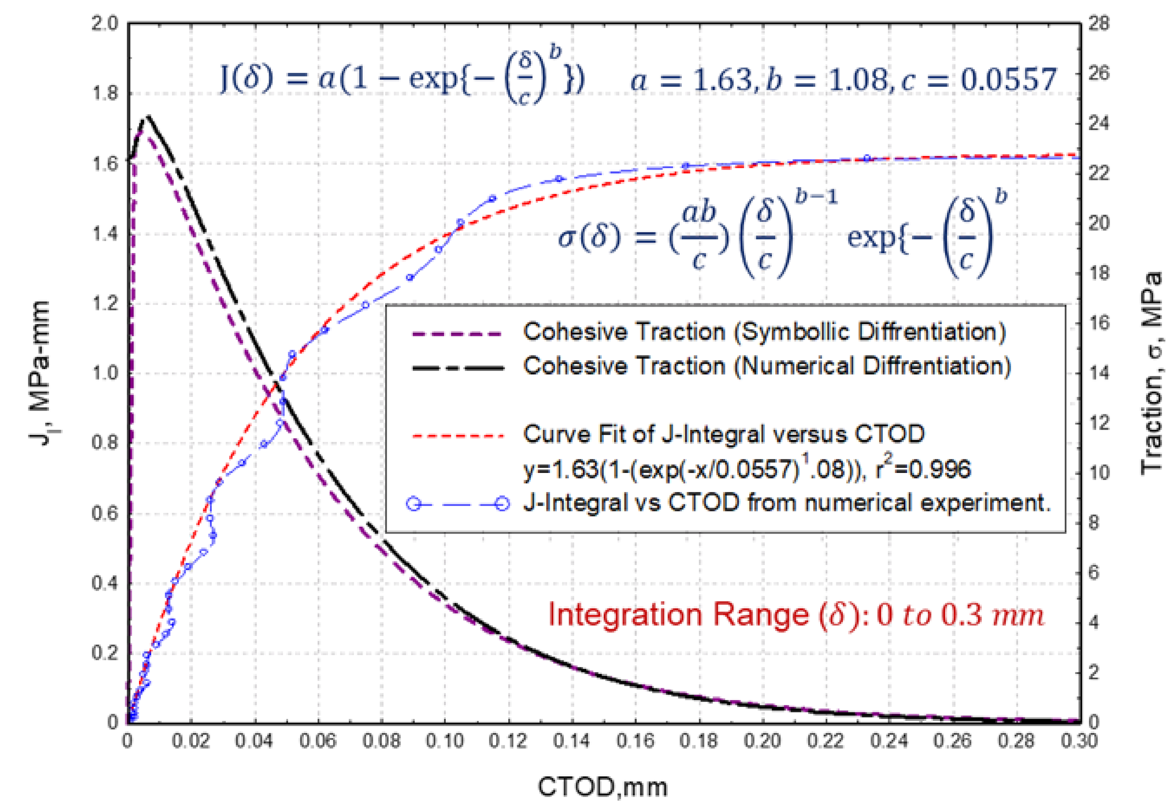
J-Integral Fracture Toughness vs Crack Tip Opening Displacement



Cohesive Zone Modeling(CZM)

Qty.	Input
Fracture Toughness	1.4 MPa-mm
Peak Traction	20 MPa

CZM in LS-DYNA ®:
- MAT_138 (Bi-linear Rate Independent TSL)
- MAT_186 (Actual Shape of TSL)
- MAT_240 (Trapezoidal TSL with rate effects



Conclusions & Future Work:

The Mode-I fracture toughness of Plain Weave S-2 Glass/SC-15 Epoxy composite was determined using the Double Cantilever Beam experiment G_{Ic} and J_{Ic} values are reported.

A resistance curve effect is noticeable as the delamination crack propagates.

Future Work includes Mode-II and Mixed Mode testing for developing Traction Laws to model delamination.

Acknowledgements

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