

# Developing an Interface with ABAQUS for analysis of impact damage in laminated composites

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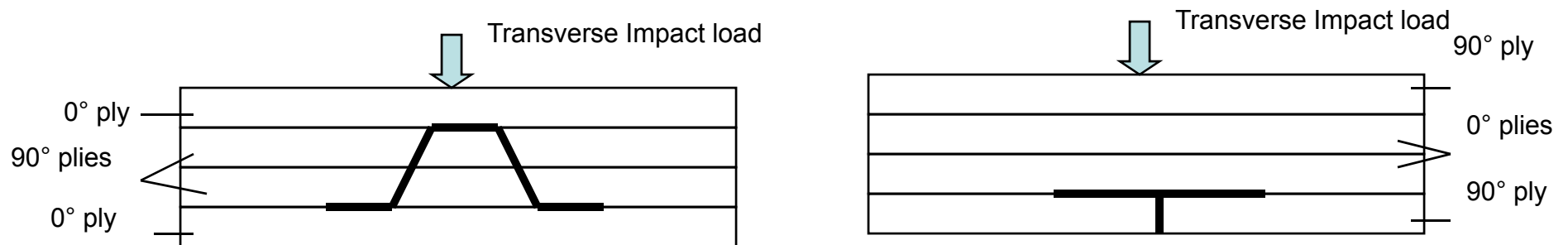
## Introduction: Impact Damage Model and Analysis

Motivation: “Transverse low velocity impact on the laminated composites induces intra-ply matrix cracking and inter-ply de-laminations”

Analytical model for estimating the location of the impact damage and the extent of the damage was developed by ‘Choi, Hyung Yun’ in his Phd Thesis titled ‘Damage in graphite/epoxy composites due to low velocity impact’, Stanford University, 1991

Conclusions :

- a.) Matrix cracking is the initial failure mode
- b.) Matrix cracking can lead to interface de-laminations
- c.) The occurrence of cracks is primarily due to the inter-laminar transverse shear stress and transverse in-plane stress of the concerned layer.
- d.) De-lamination growth at the interface is governed by the state of stresses of the constraining plies or ply groups having different orientations



## Model for De-lamination Growth :

*Initial mode of impact damage:*

Hashin's Failure criteria for matrix failure:

$$((\sigma_{YY} + \sigma_{ZZ}) / Y_t)^2 + ((\sigma_{YZ})^2 + (\sigma_{XZ})^2 + (\sigma_{XY})^2 - (\sigma_{YY} * \sigma_{ZZ})) / S^2 \geq 1$$

Since ' $\sigma_{ZZ}$ ' is negligible for thin laminated composites, the criteria for 3D-impact damage is being proposed as:

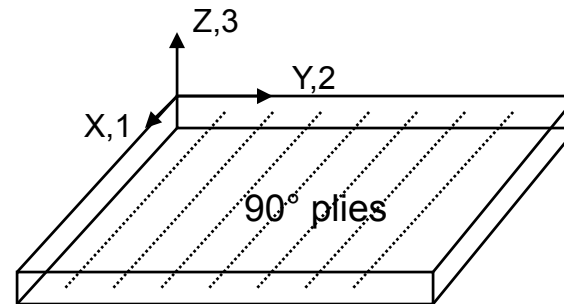
$$(\sigma_{YY} / Y_t)^2 + ((\sigma_{YZ})^2 + (\sigma_{XZ})^2 + (\sigma_{XY})^2) / S^2 \geq 1$$

where  $Y_t$  – In-situ transverse tensile strength

S - In-situ transverse shear strength

### References:

- Choi's Phd. Thesis, Stanford University, 1991
- Failure Criteria for Unidirectional Fiber Composites, Z.Hashin, Journal of Applied Mechanics, 1980, Vol.47, Pg, 329-334



Laminated Composite Plate

## De-lamination Growth Criteria: Algorithm for UMAT

$$D_A [ {}^n(\sigma_{YZ} / S)^2 + {}^{(n+1)}(\sigma_{XZ} / S)^2 + {}^{(n+1)}(\sigma_{YY} / Y)^2 ] \geq 1$$

(Reference: Choi's Phd. Thesis,)

Where  $n$  – upper layer of the interface

$n+1$  – lower layer of the interface

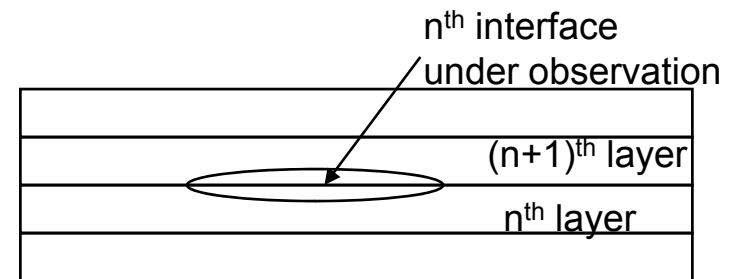
$Y$  – Transverse strengths;  $Y_C$  (compression) or  $Y_t$  (tension, in-situ strength)

$S$  – In-situ shear strength

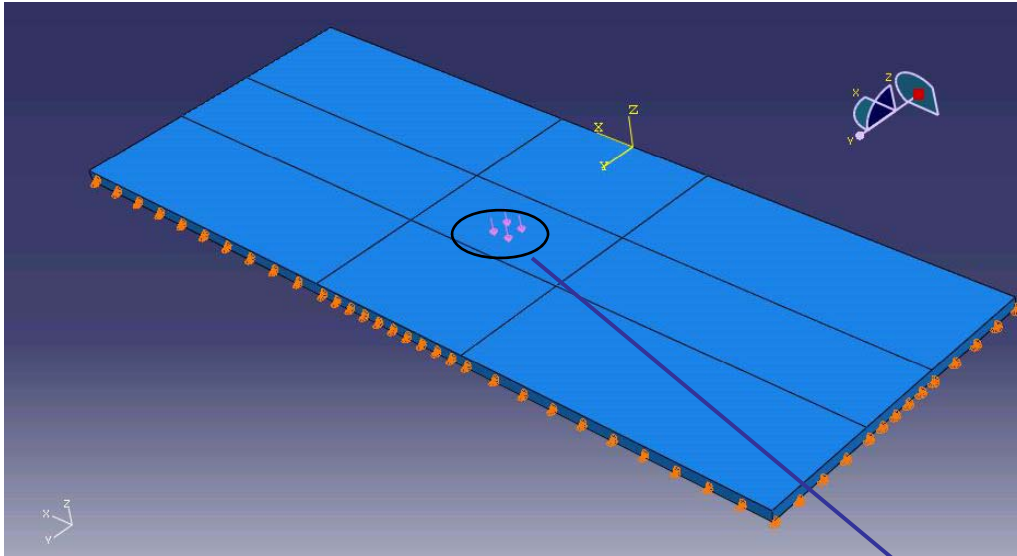
$D_A$  – Empirical constant

### Proposed Algorithm for implementation in UMAT:

1. Start with the state of stress of the bottom-most layer
2. Update the state variables for the presence of matrix cracks at each integration point in the  $n^{\text{th}}$  layer and  $(n+1)^{\text{th}}$  layer
3. If matrix cracks exist in either  $n^{\text{th}}$  layer or  $(n+1)^{\text{th}}$  layer obtain the re-distributed stresses at that integration point based on the material degradation model
4. Apply the de-lamination criteria only if the constraining plies 'have different fiber orientations'
5. If de-lamination failure criteria is satisfied then update the state variable at that integration point representing the de-lamination of the lower interface of that layer.



## Preliminary Results: Model Description



### Dynamic Implicit Analysis:

A Composite flat plate is modeled in ABAQUS using '3D composite solid elements (**C3D8**)' with the time varying pressure load applied at a small portion in the central region of the top surface.

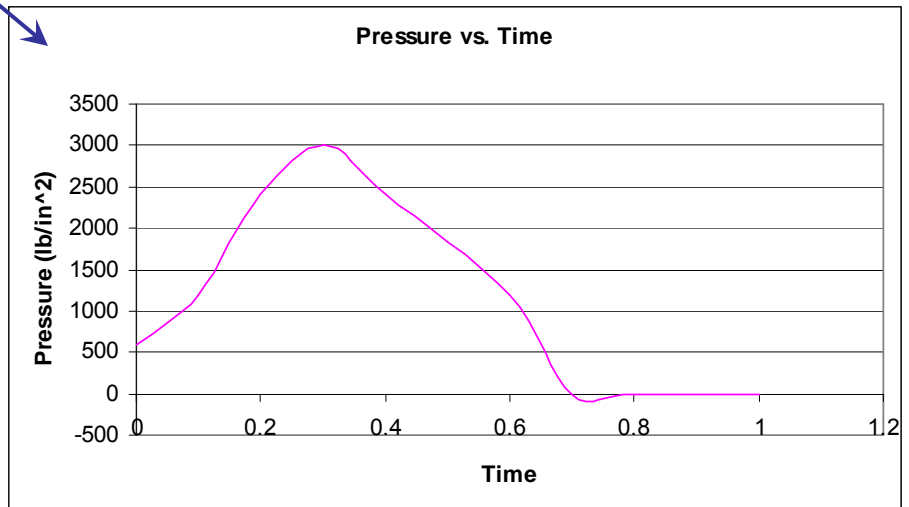
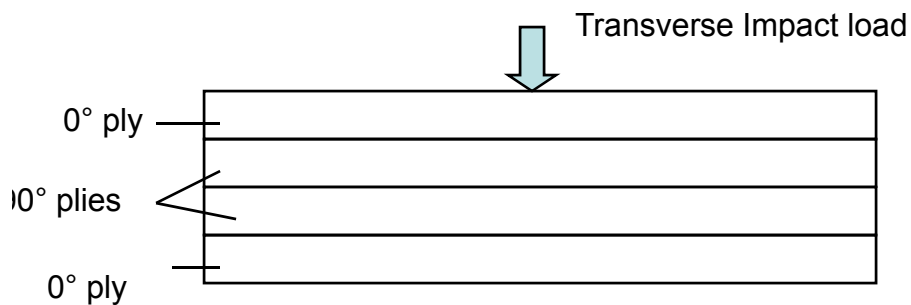
Geometry: Rectangular Flat Plate 50"x20"x1"

Material: T800H (material properties from literature)

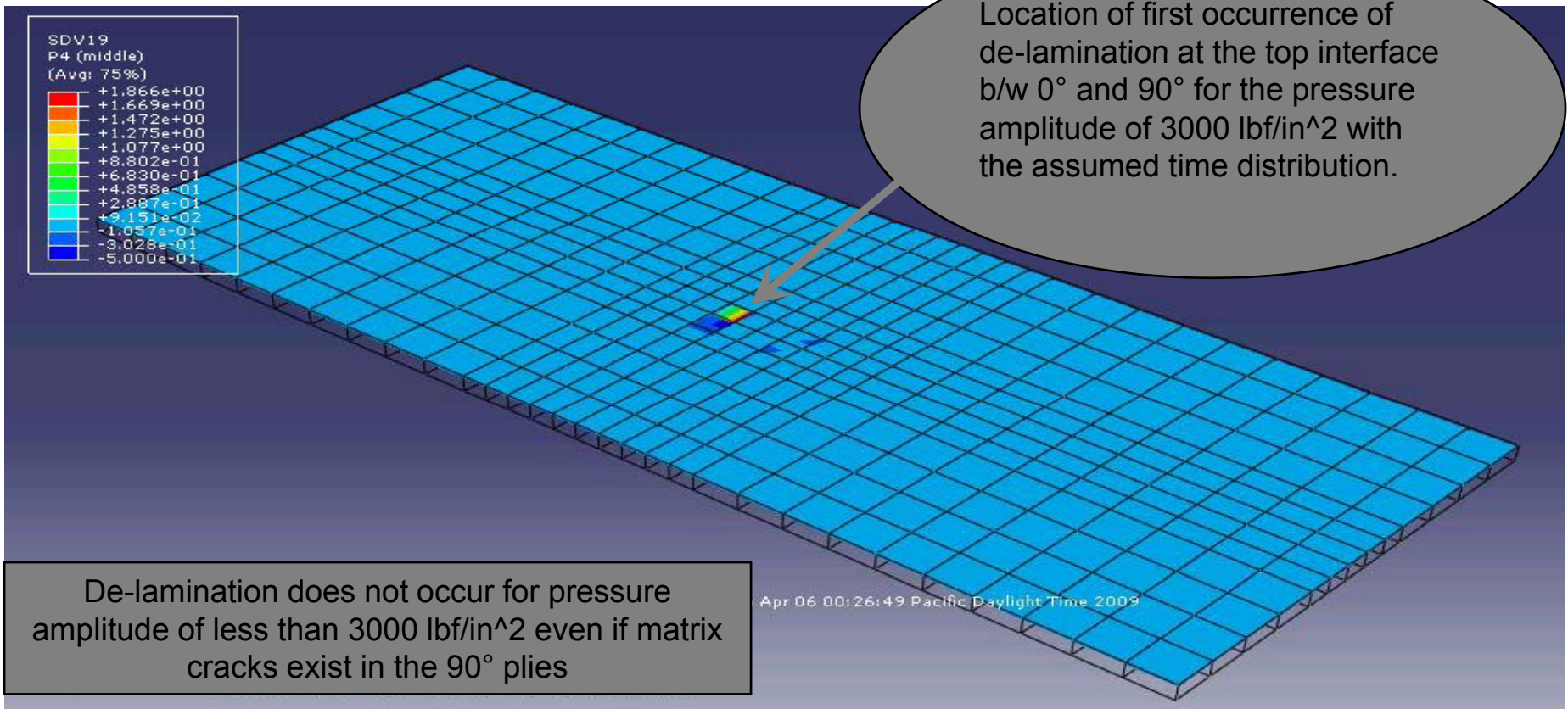
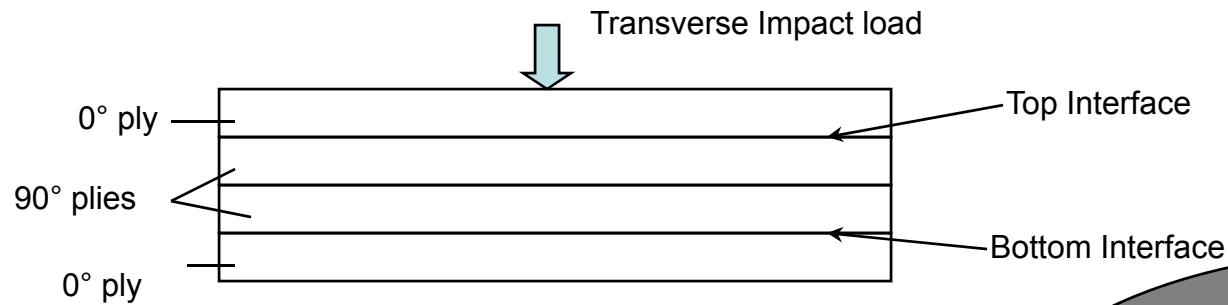
Lay up: 0°/90°/90°/0°

Boundary Conditions: Simply Supported all around the edges

Loading Condition: Time varying pressure load with distribution as shown below



## Preliminary Results: De-lamination Prediction



## Bio-Sketch:

Surajit Roy:

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### Education:

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- **Master of Technology, Engineering Mechanics (CGPA- 9.689/10)** August 2003- July 2005  
Indian Institute of Technology, Delhi
- **Bachelor of Technology, Mechanical Engineering (CPI- 77.95/100)** November 1999- June 2003  
Guru Gobind Singh Indraprastha University, Delhi

### Work Experience:

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- **Design Engineer, TATA MOTORS Ltd., Pune, India** August 2005 – August 2008  
'A leading commercial vehicle manufacturer in India with the design philosophy of continuous improvement in quality at reduced costs'.