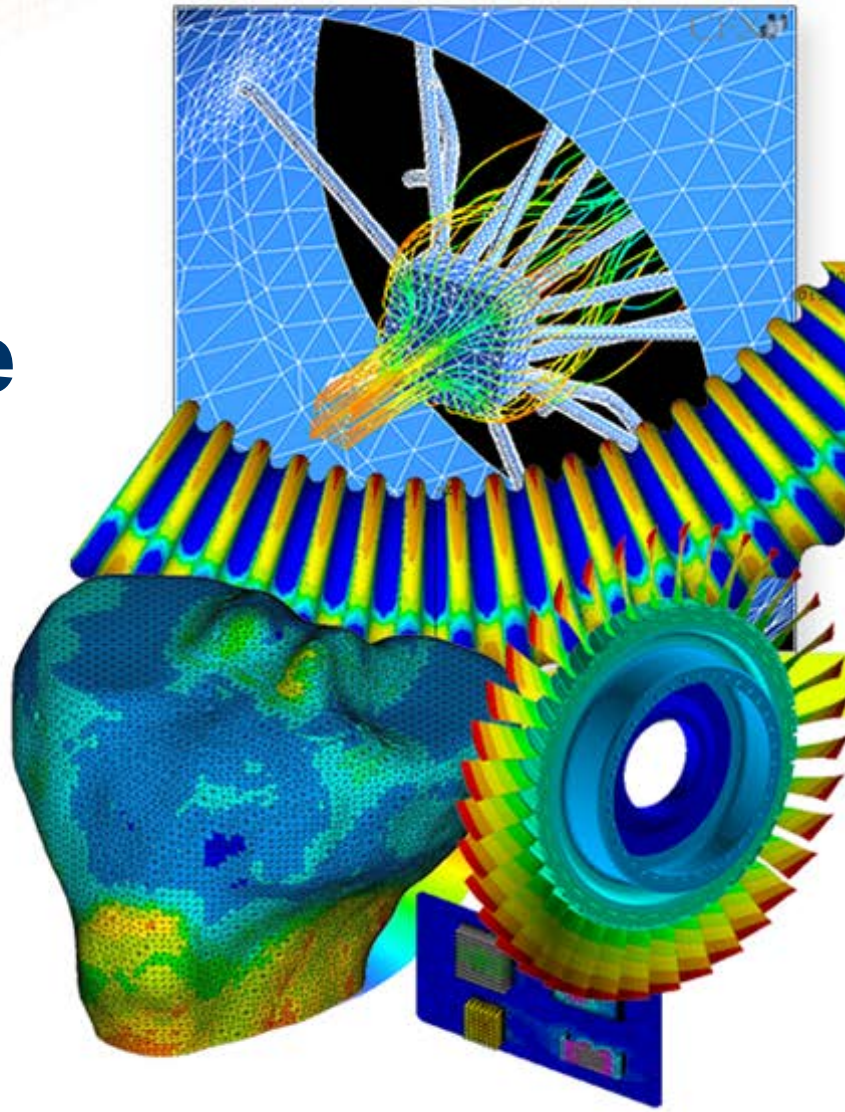
CAE ASSOCIATES

ENGINEERING ADVANTAGE

Virtual Crack Closure Technique (VCCT) in ANSYS

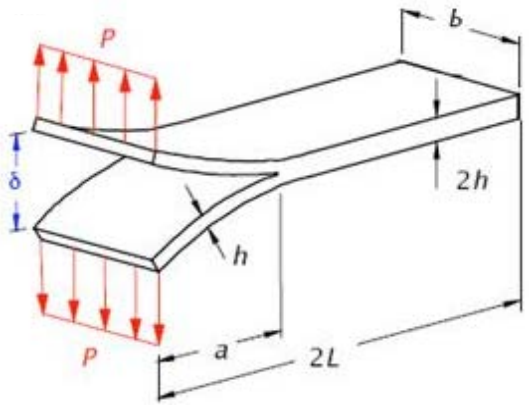


Delamination Techniques

- Two techniques exist in ANSYS to simulate the behavior of delamination of layers in a composite material:
  - Virtual crack closure technique (VCCT).
  - Cohesive zone model (CZM).

- Both techniques use special elements (interface or contact) along a pre-defined interface to model the delamination of cracks.

- The procedure selected by the analyst is based on considerations of the strengths and weaknesses of both methods.



Delamination Techniques

- CZM relates interfacial tractions to displacement discontinuities.
  - Strengths:
    - Predicts initiation and growth of delamination without a priori assumptions about the crack.
    - Applicable to complex structures subjected to complex loading states.
  - Weaknesses:
    - Characterization data can be difficult to obtain.
    - Accurate assessments are strongly tied to element size.

- VCCT calculates energy-release rate, with the assumption that the energy needed to separate a surface is the same as the energy needed to close the same surface.
  - Strengths:
    - Mature fracture mechanics-based technique with large body of work.
    - The growth criteria is the energy release rate, G.
  - Weaknesses:
    - Assumptions about cracks must be made (number, location, size).
    - Can be difficult to incorporate for complex structures and loading.

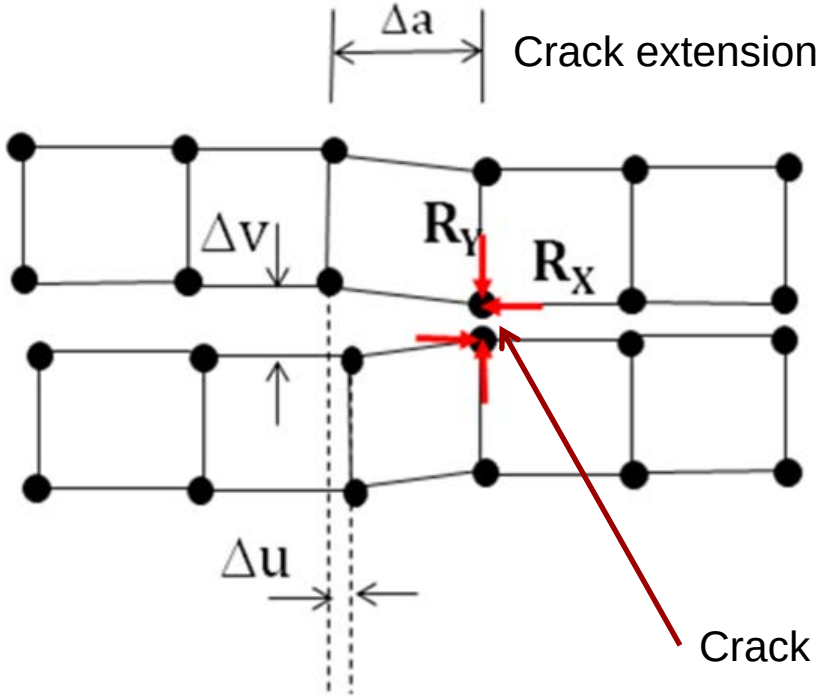
VCCT: Energy Release Rate Calculation

- The mode I and II energy release rate expressions used in VCCT, assuming a 2D crack geometry and lower order elements:
  - Approach can be extended to 3D and higher order elements.

$$G_I = \frac{1}{2\Delta a} R_y \Delta v \qquad G_{II} = \frac{1}{2\Delta a} R_x \Delta u$$

Δu and Δv:

Relative displacements of crack face



R_x and R_y :

Reaction forces at crack tip node

VCCT: Energy Release Rate Calculation

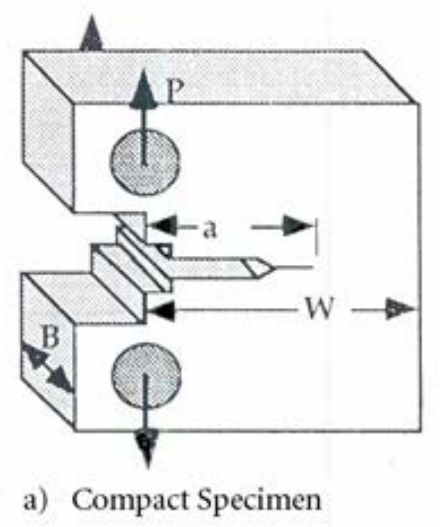
- The ANSYS procedure for calculating the VCCT energy release rate uses the CINT command.
  - Similar to J-Integral calculation in ANSYS.

- CINT command used to define:
  - Crack location: crack tip (2D) or crack front (3D) node component.
  - Crack extension direction: by identifying node on the open side of crack or a local coordinate system axis.
  - Option to indicate that the crack runs along a symmetry plane.

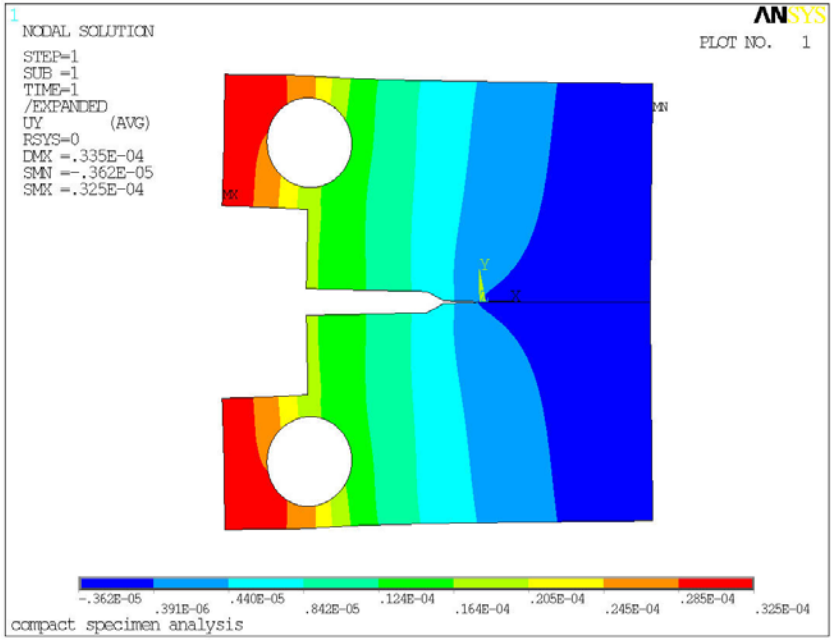
- This procedure is used to calculate the energy release rate for a given crack of a specific length and position.

VCCT Example

- Returning to demonstration problem of compact specimen:
  - Use ANSYS VCCT method and compare with previous results.



a) Compact Specimen



VCCT Example

- Demonstration problem: ANSYS VCCT method.
  - CINT commands used to define crack tip node and crack path.
  - Same model as in J-Integral but with lower-order elements.

- Energy release rates determined by ANSYS:

```
***** POST1 VCCT RESULT LISTING *****

 CrackID =    1
  Crack Front Node =    10
   ENERGY RELEASE RATE          Values =  0.15960E-02   0.0000        0.0000        0.15960E-02
```

G_I = 0.00160 lb/in

- Using previous expression for linear elastic isotropic plane strain assumption, calculate K_I:

$$J = \frac{K_I^{\,2}\left(1-\nu^2\right)}{E} = G$$

K_I = 229.4 psi-in$^{1/2}$

K_I Comparison

- Summary of results:

Method	K_I
Empirical	227.7
Special Crack Tip Elements	225.6
J-Integral	225.3
VCCT	229.4

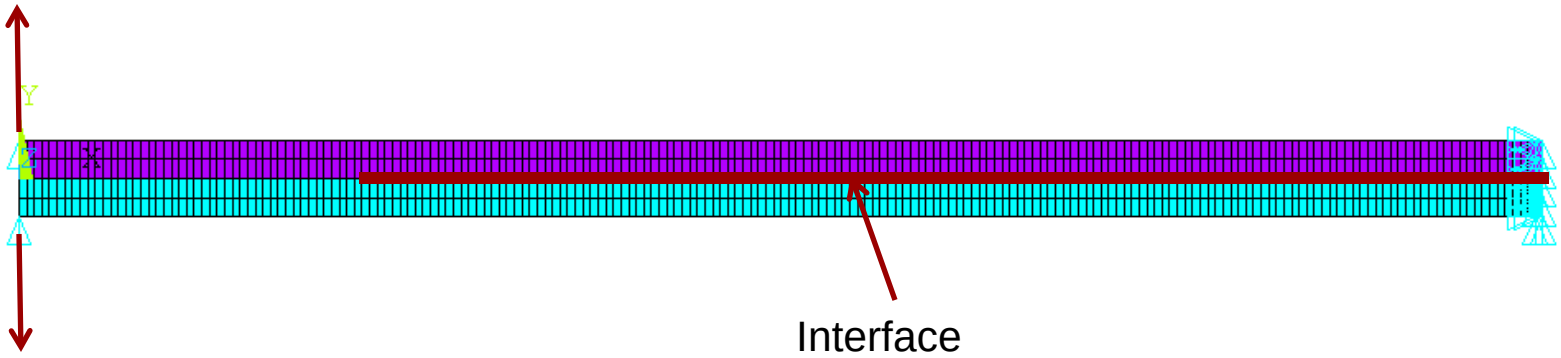
VCCT Crack Growth (Coming in V14)

- An automated crack growth simulation procedure, using the VCCT energy release rate calculation, is available in ANSYS.

- Assumptions:
  - Available with lower order current technology elements PLANE182 and SOLID185.
  - Crack growth along predefined path – new command CGROW.
  - The path is defined with interface elements INTER202 and INTER205.
  - Static analysis.
  - Linear elastic material.
  - Isotropic, orthotropic or anisotropic materials can be used.
  - Several fracture criteria are available including a user-defined option.
  - Multiple cracks are allowed.

VCCT Crack Growth

- Example case – run in version 13 (undocumented).
  - Double cantilever beam, separating along interface.
    - INTER202 elements define interface (CZMESH command).
  - Linear fracture criterion defined based on critical energy release rates.
    - Undocumented TB,CGCR option.
  - Crack growth automated with undocumented CGROW command.
    - Defines crack path, fracture criterion, time steps.



VCCT Crack Growth

- There are 7 fracture criteria that can be defined using the TB,CGCR material definition option.
  - All criteria are based on some definition of the critical energy release rate G_c.
  - For example, the linear fracture criterion:

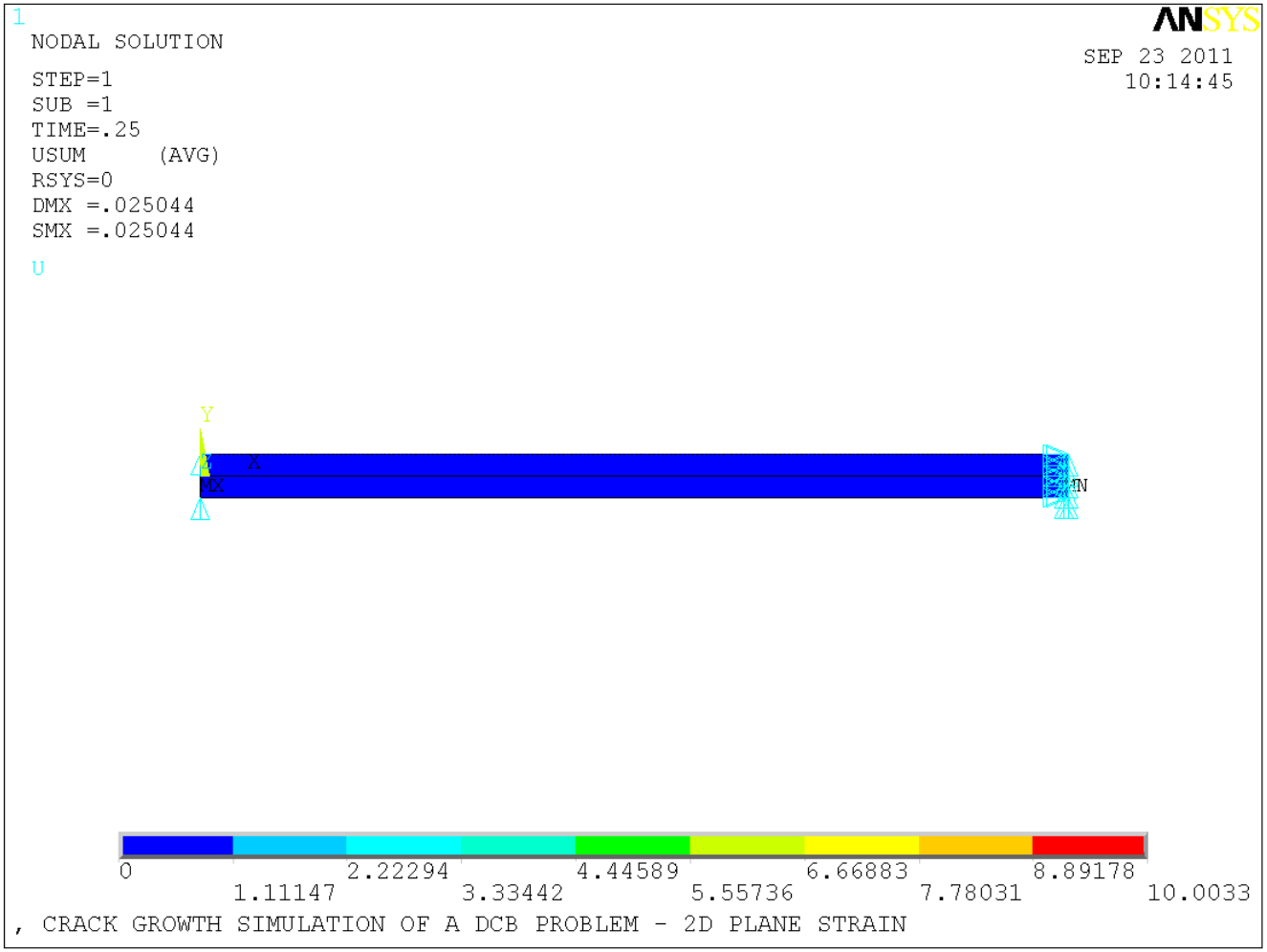
$$f = \frac{G_T}{G_T^C} \qquad G_T = G_I + G_{II} + G_{III}$$

    - G_T^C = critical energy release rate.

- Fracture occurs when: $f \geq 1$

VCCT Crack Growth

- Animation of displacement.



VCCT Crack Growth

- Force vs. deflection of delamination.