

# Predicting Failure Behavior of Polymeric Composites (IM- 7/977-2) Using a Unified Constitutive Model

PI:

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# Modeling Cracks

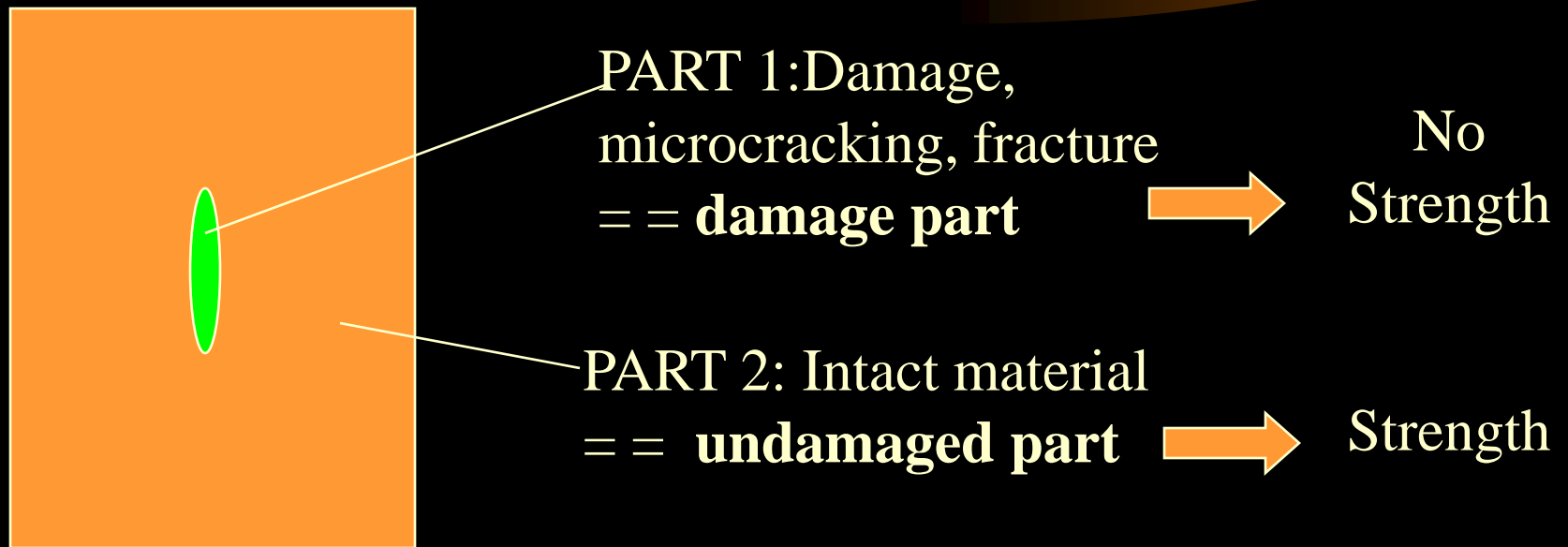


## Traditional Methods

- Classical continuum damage
- Continuum damage mechanics
- Crack tip propagation
- Crack opening displacement
- J-Integral

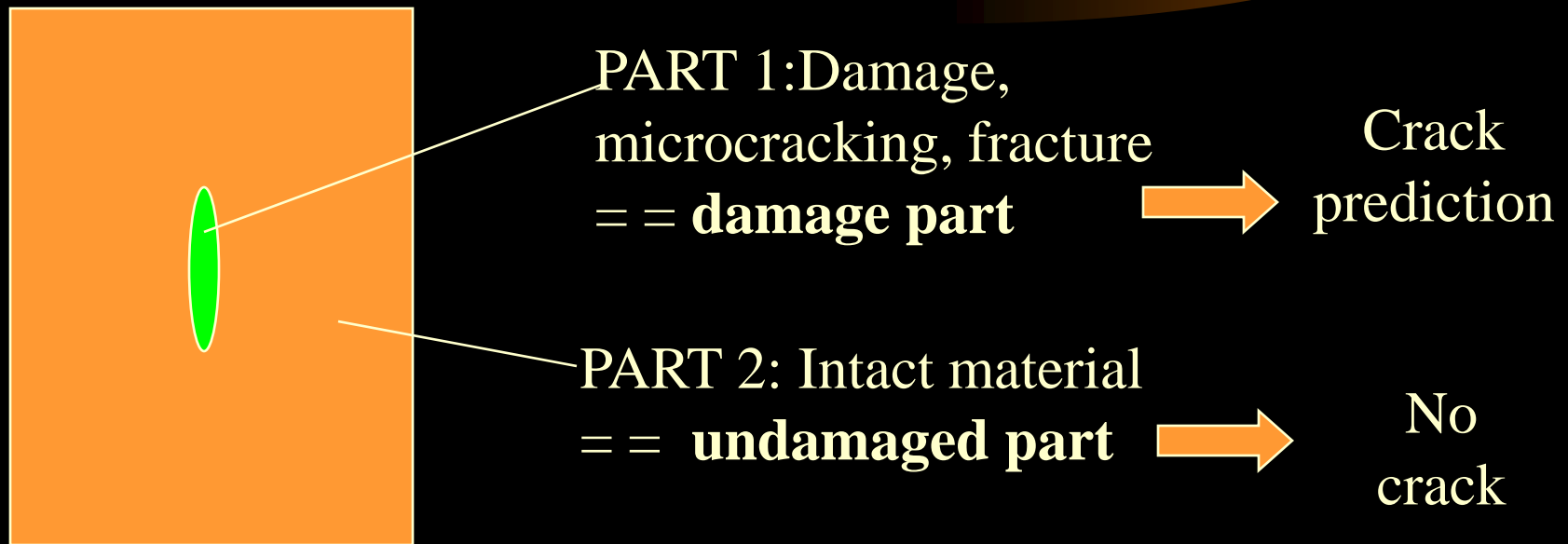
**Proposed Method - Disturbed State Concept**

# Continuum Damage Models



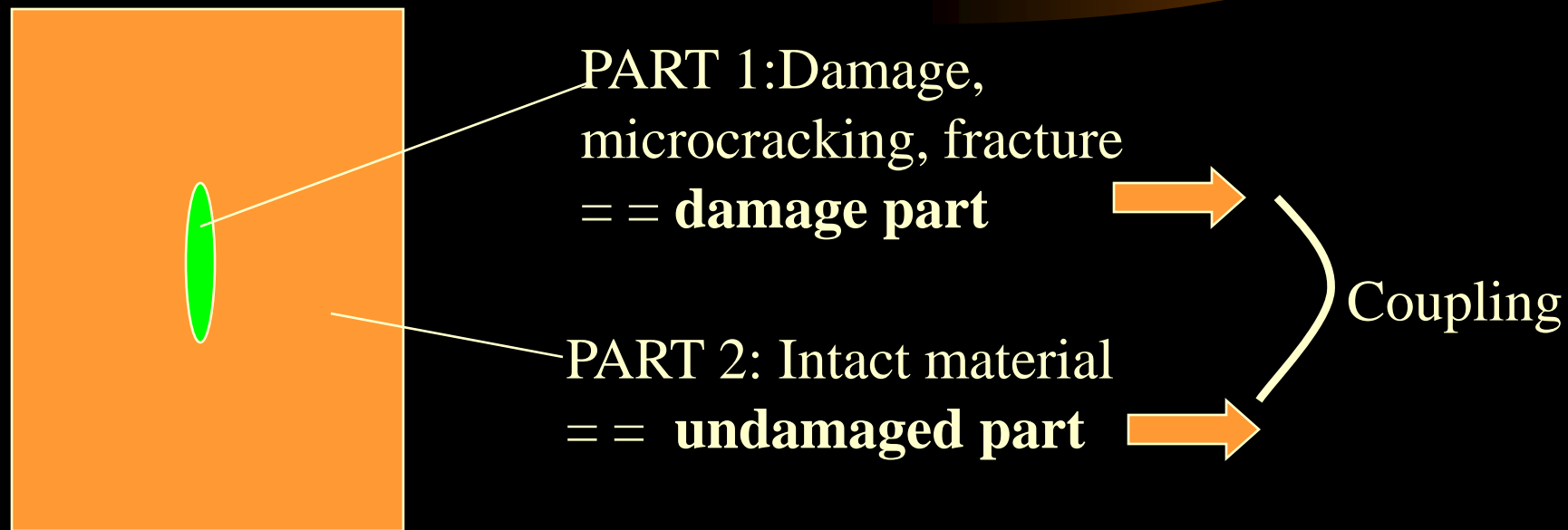
- Combined Stiffness or strength,  $E = \text{function}(E_1 = 0, E_2)$
- No Coupling/interaction between damaged and undamaged part

# Fracture Mechanics Model



- Crack Growth Prediction = function (crack geometry, length, direction, load, etc)

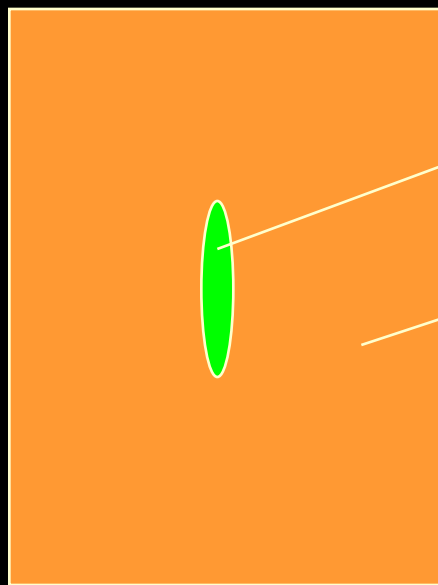
# Disturbed State Concept



- The observed response of a material can be expressed in terms of the responses of its constituents (damage and undamaged part), connected by the coupling or disturbance function

# Disturbed State Concept

The observed material state is considered to represent disturbance or deviation with respect to the behavior of the material for appropriately defined reference states.



PART 1: Adjusted state

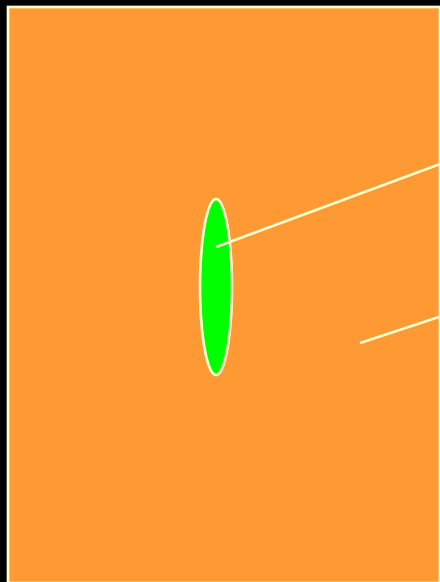
Area =  $A^c$  and Force =  $F^c$

PART 2: Intact State

Area =  $A^i$  and Force =  $F^i$

Average or Observed Force,  $F^a = F^c + F^i$

# Disturbed Function



PART 1: Adjusted state

Area =  $A^c$  and Force =  $F^c$

PART 2: Intact State

Area =  $A^i$  and Force =  $F^i$

Average or Observed Force,  $F^a = F^i + F^c$

$$\frac{F^a}{A} = \left( \frac{F^i}{A^i} \right) \left( \frac{A^i}{A} \right) + \left( \frac{F^c}{A^c} \right) \left( \frac{A^c}{A} \right)$$

$$\sigma^a = \sigma^i (A^i/A) + \sigma^c (A^c/A)$$

$$\sigma^a = \sigma^i (1-D) + \sigma^c (D)$$

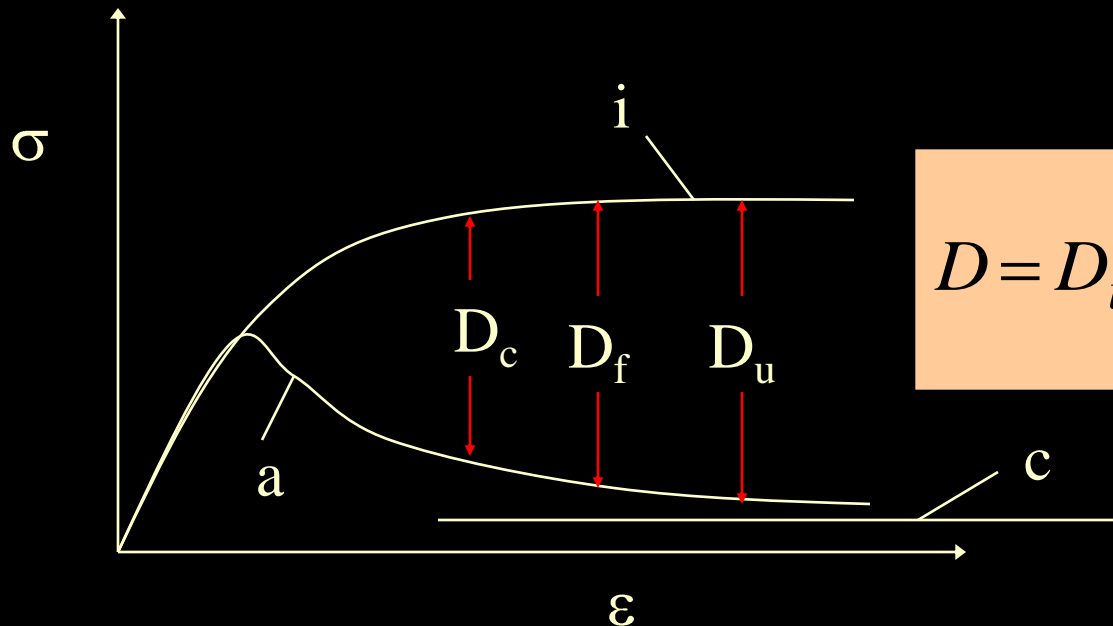
The constitutive incremental equation for the DSC



$$d\sigma_{ij}^a = (1-D) C_{ijkl}^i d\varepsilon_{kl}^i + D C_{ijkl}^c d\varepsilon_{kl}^c + dD (\sigma_{ij}^c - \sigma_{ij}^i)$$

# Disturbed State Concept

The observed material state is considered to represent disturbance or deviation with respect to the behavior of the material for appropriately defined reference states.



$$D = D_u (T, \dot{\delta}) \left[ 1 - e^{-A(T, \dot{\delta}) \xi_{vp} Z(T, \dot{\delta})} \right]$$

# Finite Element Model

## Two Steps

- Intact State Response is characterized by a classical models (von Mises, Tresca, Mohr-Coulomb, Drucker-Prager, critical-state, cap, hierarchical single-surface, etc)
- The Adjusted State Response (i.e. microcracks, damage, fracture) is characterized by the disturbance function

# Tasks

- **Task 1** : Determination of Intact Material Parameters, [ $C_i$ ]
  - Done.
  - Simple tension - Young's modulus,  $E$  and Poisson's ratio,  $\nu$  are used *for* elastic behavior.
  - For plastic behavior - Yield stress,  $\sigma_y$  in von Mises
- **Task 2** : Determination of Cracked Material Parameters, [ $C_c$ ]
  - Done.

# Tasks



- *Task 3* : Determination of Disturbance Function,  $D$ 
  - Done.
  
- *Task 4* : Implementation of Unified Constitutive Model in FEM
  - Mostly done (some errors, we are fixing it)
  
- Task 4* : **Model Validation**
  - Not started



QUESTION?

Thank you.