LECTURE 1

FINITE ELEMENT ANALYSIS ON THE FRACTURE TOUGHNESS OF RUBBER - MODIFIED POLYMER

Guest Lecture:

Husaini, DR. ENG.

Professor of Mechanical Engineering

Dept. of Mech. Engineering, Syiah Kuala University (UNSYIAH)
Darussalam, Banda Aceh 23111
INDONESIA

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INTRODUCTION

- Over recent years there has been a tremendous upsurge in interest in the fracture behavior of polymers alloy in structural engineering applications such as ABS (acrylonitryle butadiene steryne).
- It is essential to have as complete an understanding as possible of the polymer's fracture behavior
- It is become important to study fracture behavior on those materials, especially for polymer alloy (ABS).
- Addition of rubber particles to brittle plastics yields significant increase in the fracture toughness
- To investigate the role of rubber particles in the rubber-modified polymer by employing the finite element analysis
- Recentlty, polymers alloy are used increasingly in engineering applications due to factors such as lightness, low cost and easy of fabrication.

In this Study:

- The effects of distribution of rubber particles size are investigated. Two types of diameter distribution (monomodal and bimodal) are considered.
- Small scale yield problems of crack specimen are analyzed by FEM.
- Rubber particles are modeled explicitly only in the near-tip field.
- Screening effects of the rubber particles for energy flux into fracture process zone will be discussed.

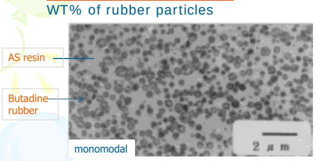
Rubber - Modified Polymer like ABS resin are frequently used in Engineering appliction:

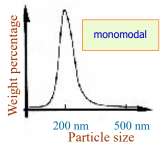
- Electronic appliances
- Business machine and camera housing
- As parts in auotomobiles and motorcycle, etc.

In these case the materials are applied to general loading condition

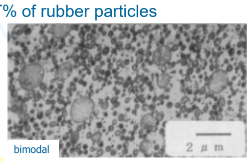
MORPHOLOGY OF ABS MATERIALS

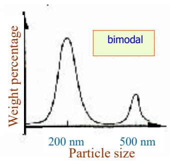
- ABS Resin with Monomodal distribution of particle diameter, contain 18 WT% of rubber particles





- ABS Resin with Bimodal distribution of particle diameter, contain 18 WT% of rubber particles





FINITE ELEMENT MODELING

FEA performed on the deformation field near the crack tip

↓

To investigate the role of rubber Particles

Strategy

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The vicinity of the crack tip is modeled as composite of matrix material and rubber particles

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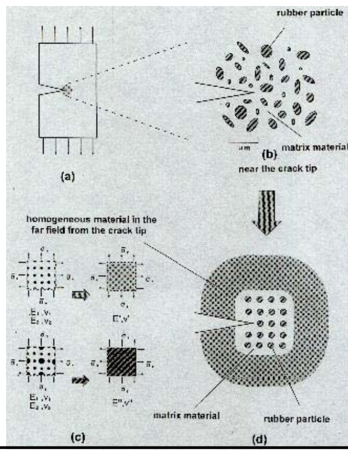
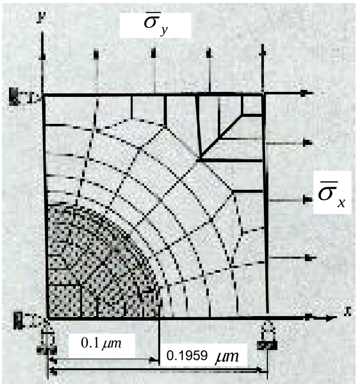
Material property in the far field from the crack tip obtained analyzing a unit cell model of matrix and rubber particles



UNIT CELL MODEL

To obtain:
Stress-strain relation in the far field

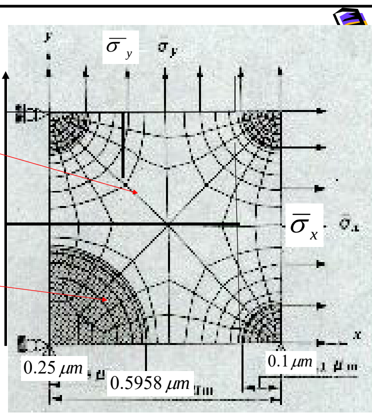


FEM modeling (monomodal)

UNIT CELL MODEL

Matrix material:
Treated as Mises material

Rubber particles:
Treated as Mooney-Rivlin material



FEM modeling (bimodal)

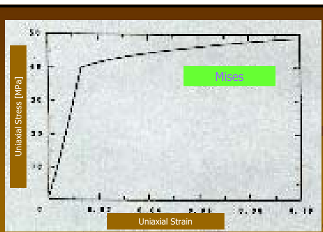
STRESS-STRAIN RELATION

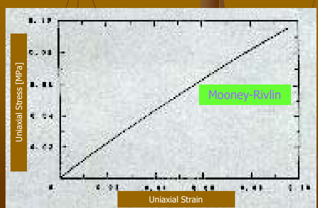
B.C in Unit cell

Applied strain x & y direct.

$\frac{\varepsilon_y}{\varepsilon_x}$ = 0.0, 0.25, 0.5, 0.75, 1.0

Uniaxial stress-strain relation:
Matrix & Rubber Particle treated as Mises and Mooney-Rivlin material



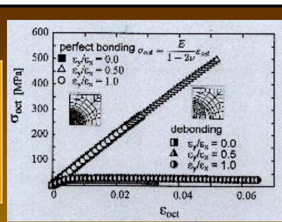


RESULTS

Unit Cell Computation

x-axis: Oct. normal strain
y-axis: Oct. normal stress
Linear curve: corresp. to perfect bonding
Non-linear curve: corresp. to debonding

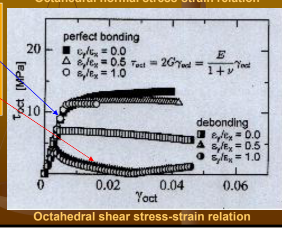
Oct. normal Stress, σ_{oct} greatly reduces affected by debonding condition



Octahedral normal stress-strain relation

x-axis: Oct. shear strain
y-axis: Oct. shear stress
Curve: corresp. to perfect bonding case
Curve: corresp. to debonding case

Oct. shear stress, τ_{oct} greatly reduces affected by debonding condition



Octahedral shear stress-strain relation

Mech Propert., E,v, yield stress of homogeneous mat., are derived from these two curve; corresponding to bonding case

SMALL SCALE YIELDING PROBLEM

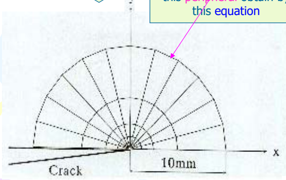
Plane strain and SSY condt. are assumed

Singular stress field (mode I)

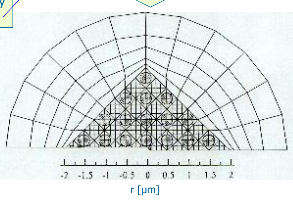
$$\begin{Bmatrix} u \\ v \end{Bmatrix} = \frac{K_I}{2G}\sqrt{\frac{r}{2\pi}} \begin{Bmatrix} \cos\frac{\theta}{2}\left(\kappa - 1 + 2\sin^2\frac{\theta}{2}\right) \\ \sin\frac{\theta}{2}\left(\kappa + 1 - 2\cos^2\frac{\theta}{2}\right) \end{Bmatrix}$$

$$\kappa = 3 - 4\nu \quad (Plane\,Strain)$$

Displacement applied on this peripheral obtain by this equation



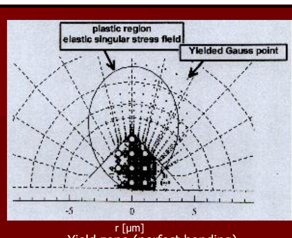
Whole Configuration of Finite Element Mesh



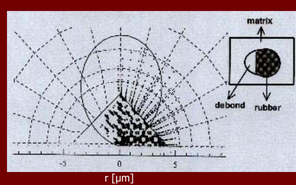
Minute subdivision near crack tip (monomodal)

It also conducted for bimodal type

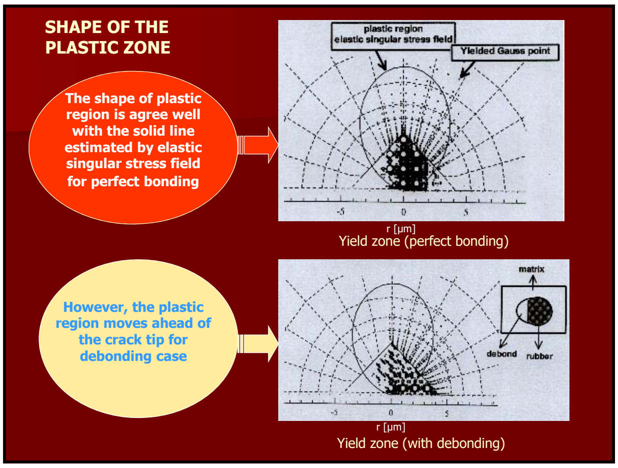
SHAPE OF THE PLASTIC ZONE

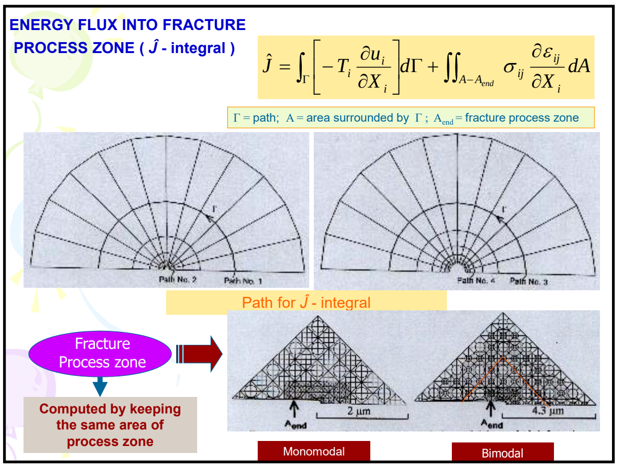


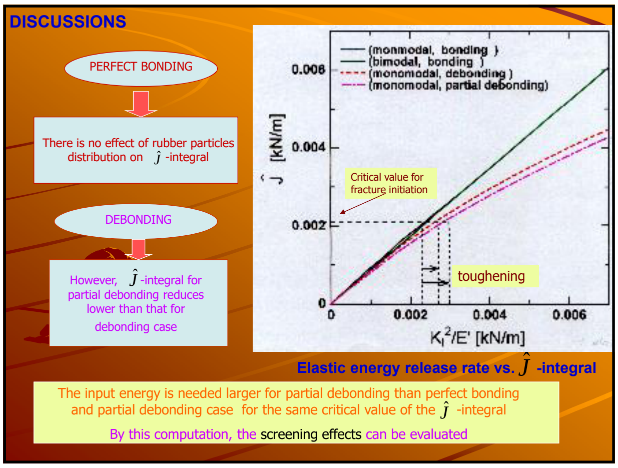
Yield zone (perfect bonding)

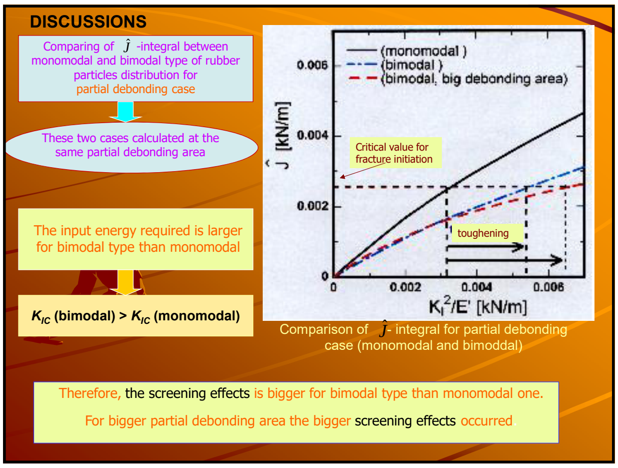


Yield zone (with debonding)









CONCLUSIONS

The conclusions can be drawn as follow:

- The shape of plastic region near the crack tip for bonding case is agree well with that estimated by the elastic singular stress field. However, for partial debonding case, the plastic region moves ahead of the crack tip.
- In the bimodal models, the rate of energy flux into the fracture process region $\hat{J}$ - integral is smaller than that of monomodal model. This behavior largely occurred on the partial debonding case.
- The screening effects of bimodal type are larger than that of monomodal type. Therefore, the fracture toughness of bimodal model is enhanced larger than that of monomodal model.

THANK YOU