Fracture and Fatigue of a Self-Healing Polymer Composite Material

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Motivation and Concept

- Thermosetting polymers are used in a wide range of applications, but are susceptible to damage in the form of cracking.
- Cracks are often deep in a structure where detection is costly and difficult.
- Repair of cracks by external intervention is often impossible.

Microencapsulated Healing Agent, Dicyclopentadiene (DCPD)

Epoxy Matrix, EPON 828/DETA

Grubbs Ru Catalyst

Crosslinked polymer network

Cracking in cross-ply laminate Jennings (1990)
**TDCB Load - Displacement Data**

- Load (N) vs. Displacement (µm)
- Virgin and Healed comparisons
- Stick-Slip Failure
- Efficiency $\eta = 90.3\%$

*Brown et al/Experimental Mechanics 2002*
Fracture Mechanism of Neat Epoxy

Plastic Zone Size:

- Measured plastic zone size ~ 37 µm
- Theoretical plastic zone size = 39µm

\[ r_y = \frac{1}{2\pi} \left( \frac{K_c}{\sigma_{ys}} \right)^2 = \frac{1}{2\pi} \left( \frac{0.55 \text{MPa} \sqrt{m}}{35 \text{MPa}} \right)^2 \]

Brown et al. Journal of Materials Science 2004
Low-Cycle In Situ Healing

Healed *in situ* with rest period under $K_{\text{max}}$ loading

\[ \lambda = 118\% \]

\[ \Delta K_I = 0.405 \text{ MPa m}^{1/2}, \ K_{\text{max}} = 0.450 \text{ MPa m}^{1/2}, \ K_{\text{min}} = 0.045 \text{ MPa m}^{1/2}, \ R = 0.1, \text{ and } f = 5 \text{ Hz} \]
Conclusions

• Recover over 90% of virgin fracture toughness

• Addition of microcapsules significantly toughens the epoxy

• *In situ* healing while under constant load provides crack tip shielding that retards or completely arrests fatigue crack growth

• ………..the introduction of smart materials with autonomic functionality enables a paradigm shift in how we design for material failure