Quiz 9 Composites and Corrosion

You Should Be Able to:

Composites

- *Predict the composite's strength and stiffness using the Rule of Mixtures. (For a continuous fiber composite, knowing the fiber and matrix properties, and the loading directions (Isostress and Isostrain case))*
- Rank the relative advantages of glass, carbon, and Kevlar fibers, as well as epoxy and polyester matrices with respect to specific strength, specific stiffness, and ductility.
- State two-three advantages of chopped fiber and particulate composites as well as the continuous fiber composites.
- State the advantages of sandwich constructions over monolithic structures.

Corrosion

- *Explain the electrochemistry involved in the corrosion of metals as expressed in oxidation-reduction reactions (including what reactions are likely at the anode and cathode).*
- Name thermodynamic driving force for the corrosion reaction
- Name the four factors required for corrosion.
- For the types of corrosion (galvanic - macro and micro, selective leaching, erosion corrosion, hydrogen damage, pit & crevice corrosion, stress corrosion cracking)
  - Describe conditions for each type and name possible preventive techniques
  - Given a situation, state which type of corrosion is most likely
- Name methods to reduce the problems of corrosion, especially the use of cathodic protections (sacrificial anodes).
- Name the causes for degradation of polymers (radiation, solvents, ozone ...)

Vocabulary

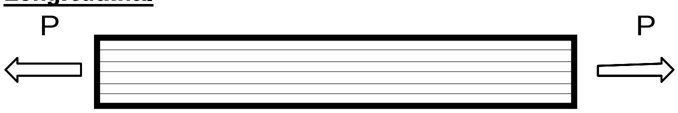
cermet
laminar composite
longitudinal direction
matrix phase
prepreg
rule of mixtures
sandwich panel
transverse direction
whisker
activation polarization
anode
cathode
cathodic protection
concentration polarization
corrosion
crevice corrosion
degradation
electrolyte
emf series
erosion corrosion
galvanic corosion
galvanic series
hydrogen embrittlement
inhibitor
intergranular corrosion
oxidation
passivity
pitting
polarization
reduction
sacrificial anode
scission
selective leaching
stress corrosion

Composites

Types	Examples	Characteristics
Particulate	Concrete, Tires, Cemented carbides, Grinding wheels	• Some strengthening • Fillers can lower cost • Isotropic • Combination of properties
Chopped Fiber	Bathtubs, Corvettes (sheet molding compound, SMC) Bulk molding compound	• Longer reinforcement allows more load transfer to fibers • Easier fabrication than longer fibers.
Continuous Fiber	Tennis racquets, golf clubs, fighter jets	Fibers provide strength, stiffness in the direction of the fibers (if $E_{fiber} > E_{matrix}$)

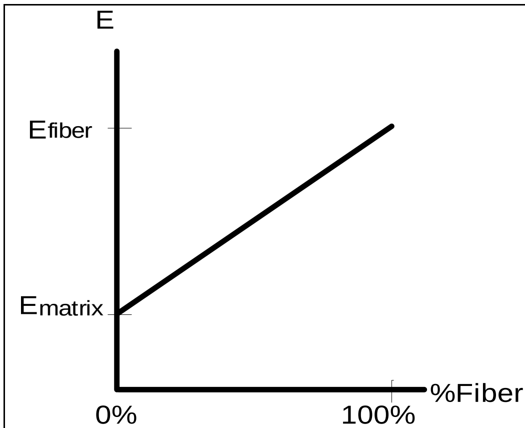
Continuous Fiber Composite Properties
(rule of mixtures)

Longitudinal



Isostrain-equal strain in matrix and fiber, therefore similar to springs in parallel.

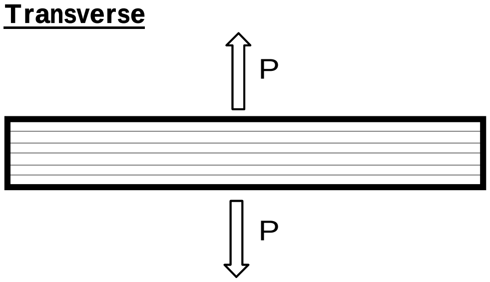
$$E_{longitudinal}=E_{matrix}(V_{matrix}) + E_{fiber}(V_{fiber})$$



Note:

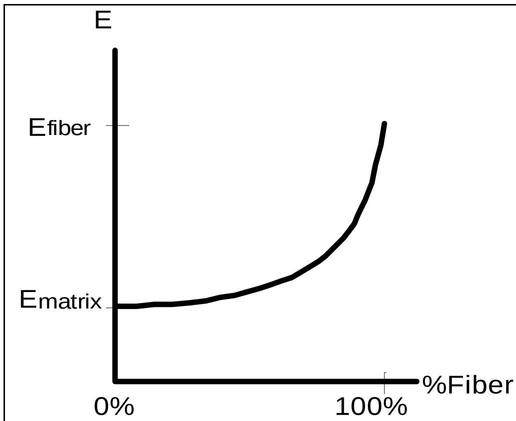
- Typical E for fiber is higher than metals and typical E for matrix is lower than metals. Thus, the combined E is about that of metals.
- Typical range of fiber content is 40-60% for continuous fiber composites

Transverse



Equal Load in matrix and fiber, similar to two springs in series. The less stiff spring (matrix) provides the most deflection, therefore controls response.

$$1/E_{tranverse} = V_{matrix}/E_{matrix} + V_{fiber}/E_{fiber}$$



Note:

- The transverse E for the composite is close to the E for the matrix.
- The typical %fiber is 40-60%

Force Ratio (longitudinal)

We know that when two springs (say a valve spring and a Slinky) are in parallel and pulled with equal deflection, the stiff spring (valve spring will carry the bulk of the load while the less stiff spring deflects without much force. Because glass and carbon fibers are much stiffer than epoxy and polyester, the fibers carry most of the load in high performance composites.

Role of the Parts

Fiber – Provide Strength and Stiffness
Matrix – Provide shape, ductility, and protect the fiber
Interface – transfer load from the matrix to the fiber

Fiber Type	Characteristics	Strengthening
Glass	• Easily made • Lower cost • Good strength • Poor specific stiffness • Chemically inert • Transparent to EM	Glass is amorphous, so alignment is not important. Strength comes from lack of flaws. Surface coating (sizing protects fiber and transfers load.
Carbon/ Graphite	• Excellent specific stiffness or specific strength • Good at high temps • Expensive • Brittle • Electrical conductor	Strength comes from strong bonds in 2-D sheets of hexagonal carbon “rings”. Sheets are continuous and aligned along the fibers.
Aramid (Kevlar)	• Good specific strength and specific stiffness • Excellent toughness • Poor in compression • Expensive	Strength comes from aligned crystalline and amorphous regions. Pulling on primary bonds

Other		
• UHMWPE (Spectra)	Sp. Gr. < one, excellent strength & toughness, low T_{melt}	Same as aramid
• Boron	Light, stiff, difficult to make	
•	Strong but short and very expensive	
• Whiskers		Flaw free

Laminates: multiple layers of fabric or prepreg. Layers usually have different orientation to carry stress in several directions

Sandwich composites: analogous to an I beam, the core is balsa, foam, or honeycomb while the surfaces are composite. High stiffness and strength to weight.

Fabrication

Pultrusion – extrusion and pulling (pipes and tool handles)

Filament Winding – wrapping of wetted or prepreg fibers around a bladder or mandrel (air tanks, golf clubs)

Pre-preg – mix of partly cured resin and fibers than can be handled in sheet or tape form

Spray-up – chopped fiber plus resin are sprayed on a mold

Compression molding – fiber and resin are pressed into a mold

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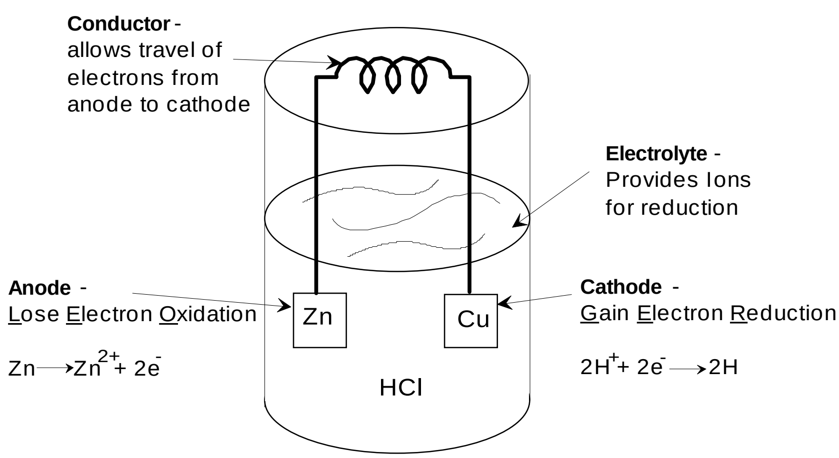
Corrosion



Which metal will be the Anode?

- standard EMF (electromotive force) series
- galvanic series (alloys in sea water)
- active metals (Mg, Al, Zn) tend to be anodic, passive metals (Au, Cu, Pt) cathodic

Polarization

Activation Polarization - reaction rate controlled by some physical or electrical factor (ex. hydrogen film at surface of cathode can act as barrier)

Concentration Polarization - diffusion rate controls reaction rate (ex. if concentration of electrolyte is low, fewer ions must travel further and rate slows)

Types of Corrosion

Type	**Characteristics**	**Example**
Uniform Attack	Most common for bare metals	rust
Galvanic Corrosion	dissimilar metals anodic metal corrodes	galvanized steel (Fe,Zn)
Intergranular	along grain boundaries due to concentration of precipitates (dissimilar metals at micro level)	"sensitized" stainless steel
Erosion-Corrosion	combined wear and corrosion	impellers; bends, elbows in pipes
Hydrogen Embrttlement	small element diffuses in and reduces ductility	high strength steels under stress
Crevice Corrosion	concentration cell forms in regions of stagnation pH decrease in crevice results in surface damage	threads, gaskets, deposits metals that rely on passive films (Al, S/S)
Pitting	very similar mechanism to crevice corrosion but no crevice is needed.	metals that rely on passive films
Selective Leaching	microscopic loss of one component in alloy	dezincification of brass graphitization of CI
Stress-Corrosion	combination of stress and a particular environment	brass and ammonia stainless steel and chlorides

Corrosion Prevention

- Get rid of one of the four factors (Anode, Cathode, Electrolyte, Conductor)
- In general-avoid differences (differences in material, in concentration, in cold work) If parts are identical, there is no anode/cathode
- Barriers prevent contact with electrolyte (coatings-paint, anodizing)
- Prevent electrical connection between anode and cathode (dielectric connections in plumbing)
- Inhibitors - chemicals that slow or stop the process (boilers, power plants)
- Cathodic Protection (sacrificial anodes) (in galvanized steel, the anodic Zn is lost and the cathodic Fe is protected.)

Environmental Degradation of Polymers

Solvents - some polymers are attacked (dissolved) by some chemicals. (ex. latex and petroleum products, PMMA and acetone)

Radiation - many photons (esp. UV) have sufficient energy to break atomic bonds. If a side group bond is broken, cross-linking can occur. If a backbone bond is broken, chain scission occurs and chains get shorter. (ex. old wrinkled sunbathers)

Ozone and other radicals- O_3 has a strong drive to bond and can rupture bonds and cause problems similar to radiation.