The Application of Strain Gauges to Composites

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Introduction

- Requires special considerations
  - Strain gauge selection
  - Adhesive selection
  - Surface preparation
  - Instrumentation
  - Special applications
Strain Gauge Selection

- Gauge Type
- Size
- Resistance
- STC (Self Temperature Compensation)
Gauge Type

- Encapsulated Gauge Ideal
  - Easier to handle and solder

- Open Faced
  - Lower reinforcing effect
    - Use on thin or low-modulus materials

- Pre-Leaded
  - Highly heat-sensitive materials
    - Reduced installation flexibility
    - May compromise glueline thickness
Strain Gauge Selection

Gauge Type

- **Strain Range**
  - 3 to 5% typical for constantan STC foil
  - Up to 20% for annealed constantan

- **Fatigue Life**
  - Karma
  - Iso-elastic
Size

- Fits on Specimen
  - Matrix size, not grid size!
- Gauges Detect Average Strain Under Grid
  - Grid length/width
  - Consider weave size
    - 5 x aggregate is a good guide
- 6mm Grid Length Considered Optimum in Many Cases
Resistance

- Poor Heatsink
  - Low thermal mass
  - Low thermal conductivity
- Gauge Self-Heating
  - Grid power density
    - 350 ohms minimum
    - 1000 ohms becoming more popular
STC
(Self Temperature Compensation)

- Thermal Output
  - Match to substrate material
    - TCE of substrate must be known
    - Composites are directional!

- Use Stock Gauges
  - 06 (steel) and 13 (aluminium) common
  - 00 stocked in popular patterns
Adhesive Selection

- Surface Finish
- Temperature
- Test Duration
- Installation Requirements
Surface Finish

- Smooth Surface
  - Install gauge directly onto surface
- Textured Surface
  - Adhesive must gap-fill
    - 2-step installation process
Cyanoacrylates

- **Instant**
  - Short term only (9-12 months max)
  - Will not gap-fill
  - -25 to +65 normal use
  - 3 to 5% or higher elongation

- **Be Wary of Generic Cyanoacrylates**
  - Use strain gauge certified adhesives only
Epoxy (100% solids)

- Wider Temperature Range
  - -195 to +95°C (room temperature cure)
  - As wide as -269 to +300°C

- Gap Filling Capability
  - Both filled and unfilled are suitable
  - Use on textured surfaces

M-Bond AE10, AE15, GA61
Epoxy (100% solids)

- Some Require Heat Curing
  - As low as 50°C
- Long Term (Years)
  - Highly moisture resistant
- As High as 15% Elongation

M-Bond AE10, AE15, GA61
Epoxy Phenolic

- Widest Temperature Range
  - -269 to +400°C
- Long Term (Years)
- Require Heat Curing
  - As low as 80°C

M-Bond 600, 610, 43B, 450
Epoxy Phenolic

- Will Not Gap Fill
  - Solvent thinned for 3-5 micron gluelines
    • Smooth composites only
- Elongation up to 4%

M-Bond 600, 610, 43B, 450
Polyester

- Special Applications Only
  - Not recommended for general-purpose use
- Room Temperature Cure
- Will Work to 150°C Without Further Curing
- Elongation up to 2%
Special Epoxy

- Special Applications Only
  - Not recommended for general-purpose use
- High Elongation
  - Up to 20%
- Requires Special Usage Considerations
Surface Preparation

- **Degrease**
  - Check for compatibility
    - Many aerosols will attack material
    - IPA safe on many plastics
  - Be aware of release agents
    - Silicone oils are difficult to remove
      - Heated acidic solution required
Surface Preparation

- Abrade
  - Smooth
    • 320 or 400 grit
  - Textured
    • Air abrade
    • Brush/paste
  - Special
    • Pumice powder and cotton bud
Instrumentation

- Variable Bridge Excitation
  - Minimise grid power density
    - 2V maximum
- Should Accept Common Resistances
  - 350 ohms
  - 1000 ohms
  - 500 ohms (more on this later!)
Special Applications

- High Cyclic Fatigue
- Avoiding Localised Failure
- Ultra-High Elongation (>20%)
- Shear Modulus Testing
High Cyclic Fatigue

- Metallic Gauge Will Fail Eventually
  - Constantan – lowest fatigue rating
  - Karma – significantly better fatigue life
  - Iso-elastic – better fatigue than Karma
- ‘Reference’ Gauge
  - Relate two gauges, one in lower strain area
- Re-Install Gauges at a Convenient Point in Test
Localised Failure

- Single-Strand Failure Causes High Localised Strain
  - Strain gauge fails with no indication of high strain
    - Gauge detects average strain

- Mitigate Strain Level
  - Apply Kapton film layer under gauge
Ultra-High Elongation

- Gauges and Adhesives up to 20% Strain Only
  - Use extensometer
    - Displacement sensor
    - ‘Top hat’ cross-section with strain gauge on top
Shear Modulus Testing

Iosipescu and Compact Specimens

- Non-uniform strain between notches
  - Unreliable results from conventional patterns
    - Can be as much as 30% error!
  - Average strain required
    - Strain gauges give average strain automatically!
- Special patterns available
  - 500 ohms
    - Use as quarter or half bridge
Shear Modulus Gauges

90° Fibres

0° Fibres

Strain distribution

Average Strain
QUESTIONS?
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