Deformation and Fracture Experiments on Advanced Aerospace Materials

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ABSTRACT

Advanced aerospace materials continue to be developed in order to address the continuing need for materials with high specific strength and stiffness. Materials properties of interest include strength, toughness, high cycle fatigue, and fatigue crack growth, among other important considerations. In this work, the Center for Mechanical Characterization of Materials at CWRU and the unique equipment housed therein is being utilized to mechanically evaluate both conventional and advanced aerospace materials. High-strength 4340 steel, carbon-carbon composite, and Carbon-Silicon Carbide composite were tested in order to examine their relative properties.

MATERIALS AND DESIRED DATA

Carbon-Carbon Composite (T300 & SWB): Crack Resistant, Bond Strength, Toughness, High Cycle Fatigue, Fatigue Crack Growth

Carbon-Carbon Composite (C/SiC Composite (CESIC®)): Notch Toughness of C-C composites:

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• High-strength 4340 steel, carbon-carbon composite, and Carbon-Silicon Carbide composite were tested in order to examine their relative properties.

• Ashby Plots show properties of various classes of materials, including tested materials.

MECHANICAL TESTING

• The following ASTM standards were used to guide testing:

  - ASTM E-647 Annex Potential Drop Measurement of Crack Growth
  - ASTM E-647 Cylindrical Tension Samples
  - ASTM E-647 Crack Gage used to measure crack growth

  • Crack monitoring for assessment of fatigue and fatigue crack growth

  • Uses the ASTM standard to guide testing

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TYPICAL FATIGUE CRACK GROWTH DATA

Cost fatigue crack threshold (da/dN) vs. Life (cycles) in material

\[ \frac{da}{dN} = \text{Cost fatigue crack threshold} \]

Fatigue Crack Growth (da/dN vs DaK) of ALLCOMP C-C Composite:

• 3 Point Bending
• Frequency = 10-20 Hz
• Load Ratio, R: 0.1, 0.4, 0.47, 0.5
• Spans tested to avoid premature failure due to cracking
• Surfaces/hard at high fraction of load strength
• Arrows indicate sample did not fail
• Crushing observed at spans < 10.2 cm, fatigue life reduced

Fracture Toughness:

• Fatigue pre-cracked
• Crack growth monitored with Crack Monitoring

Fracture Toughness:

\[ K = \frac{\sigma}{\sqrt{2\pi}c} \]

• ALLCOMP Carbon-Carbon Composite
• C-C supplied in two forms
• T300: C-C composite containing continuous PAN T300 fibers
• SWB: Chopped Fiber Composite containing SWB fibers

Crack Resilience:

• C-C composite may damage due to crushing
• Crushing observed at spans < 10.2 cm, fatigue life reduced

Heat Treatment Conditions:

• Austenitized, Quenched, and Tempered

Tensile Testing:

• Physical Tensile Samples
• Test Temperatures: RT, 107°C, 232°C
• Stress Ratio: 0.001 / sec
• Properties Measured:

  - Stress (ALLCOMP C-C, 4340)
  - Crushing (ALLCOMP C-C, 4340)

CONCLUSIONS

• Mechanical Properties Measured on:
  - ALLCOMP C-C Composite
  - 4340 Steel
  - C-C Composite

• Properties Measured:
  - Crack Resilience (ALLCOMP C-C)
  - Strength (ALLCOMP C-C, 4340)
  - High-Cycle Fatigue (ALLCOMP C-C)
  - Fatigue Crack Growth (ALLCOMP C-C, 4340)

• Crack monitoring successfully conducted via:
  - Potential Drop (PD)
  - K-Log Gage

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