

# Subject Index

## A

- Absorption, effect on interlaminar fracture toughness, 107
- Adhesive joints, Mode I behavior under mixed-mode loadings, 187
- Aligned carbon/epoxy laminates, fatigue failure, 686
- Aluminum plies, fatigue properties, 772
- Angle-ply laminates, 56
- APC-2 composite, fiber microbuckling, 393
- ARALL laminates, damage and performance, 772
- ARALL-2 laminates, effective crack lengths, 791
- Aramid aluminum laminates (*see* ARALL-2 laminates)
- AS4/3501-5A graphite fabric-reinforced epoxy, delamination growth, 359
- AS4/3501-6 carbon/epoxy composites, compression testing, 439
- AS4 fibers, PEEK composites with, 70
- AS4/PEEK composites
  - effects of T-tabs and large deflections, 169
  - fatigue behavior, 581
  - fiber microbuckling, 393
  - Mode II delamination, 226
- ASTM standards
  - D 695-80, 72
  - D 695-89, 550, 581
  - D 790-86, 667
  - D 3410-87, 439, 550
  - E 399, 211

## B

- Bending tests, for bulk flexural strength, 667
- Biaxial fatigue, interlaminar stress effects, 659
- Boron/aluminum composites, fracture, 696
- Brittle fracture, ARALL-2 laminates, 806
- Buckling, cylindrical composite panels with implanted delaminations, 373

## C

- Cantilever beams
  - double, fatigue delamination onset prediction, 312
  - split, Mode III delamination testing, 243
- Carbon/bismaleimide laminates, fracture strength, 667
- Carbon/epoxy laminates
  - fatigue failure, 686
  - fracture strength, 667
  - low-velocity impact damage, 457
  - stabilized end notched flexure test, 210
  - thick-sections, compression testing, 439
- Carbon fiber composites, Mode II delamination, 226
- Carbon fiber/PEEK composites, cooling rate effects, 70
- Carbon fiber/polymer composites, mixed-mode fracture, 143
- Carbon fiber-reinforced plastics, stacking sequence effects, 476
- Circular delamination, 373
- Compliance method, effective crack lengths for ARALL-2 laminates, 791
- Composite laminates (*see also* specific laminate)
  - matrix cracking, 30
  - transverse ply cracking, 9
- Composite plates, filament-wound, effects of quasi-static impact events, 528
- Compression after impact strength, quasi-isotropic laminates, 476
- Compression behavior
  - delamination effects, 359
  - fiber-reinforced composite materials, review, 550
- Compression fatigue
  - CF/PEEK, 581
  - hole effect in T300/N5208 composites, 638
- Compression strength
  - edge effects, 393
  - transverse, composite plates, 528

Compression testing  
 fiber-reinforced composite materials,  
 review, 550  
 thick-section composites, 439  
 Computer-aided testing, for crack length  
 and fracture toughness, 210  
 Cooling rate effects  
 on carbon fiber/PEEK composites, 70  
 on fatigue behavior of CF/PEEK  
 composites, 581  
 Corner radii, tensile stress, porosity effects,  
 126  
 Crack bridging, in metal matrix composites,  
 711  
 Cracked-lap shear specimens, Mode I strain  
 energy release rate, 187  
 Crack growth, interlaminar Mode II, 210  
 Crack lengths  
 computer-aided testing system, 210  
 effective, for ARALL-2 laminates, 791  
 Crack opening displacement, surface  
 opening displacement and, 187  
 Crack shear displacements, direct  
 measurement, 210  
 Creep, carbon fiber/PEEK composites,  
 cooling rate effects, 70  
 Cross-ply laminates  
 fatigue damage growth, 617  
 with matrix cracks, 56  
 Crystallinity, cooling rate effects in CF/  
 PEEK, 70  
 Cylindrical composite panels, effects of  
 inserted circular delaminations, 373

## D

Damage growth  
 notched graphite/epoxy laminates, 617  
 and strain energy release rate, 617  
 Damage mechanics  
 ARALL laminates subjected to tensile  
 cyclic loading, 772  
 fatigue-related, notched graphite/epoxy  
 laminates, 617  
 notched strength modeling, 596  
 Damage modeling, damage zone in T300/  
 N5208 composites, 638  
 Damage tolerance, low-velocity impacts,  
 457  
 Deflections, effects on double cantilever  
 beam tests, 169  
 Delamination  
 carbon fiber/PEEK composites, cooling  
 rate effects, 70

combined matrix cracking and free edge  
 effects, 287  
 direct measurement of crack shear  
 displacements, 210  
 edge, 89, 107  
 effects of T-tabs and large deflections, 169  
 effects on  
 compression behavior, 359  
 stress distribution in zero degree ply,  
 596  
 free-edge, 269  
 growth in compressively loaded  
 composites, 359  
 implanted within cylindrical composite  
 panel, 373  
 interply, in SCS-6/TI-15-3 composites,  
 732  
 local, shear deformation model, 269  
 Mode I under mixed-mode loadings, 187  
 Mode II in toughened composites, 226  
 in tapered composite laminates, 312  
 transverse crack-tip, 269  
 Discontinuities, in fibrous metal matrix  
 composites, 696  
 Double cantilever beams  
 effects of large deflections and T-tabs, 169  
 fatigue delamination onset prediction, 312  
 Dropped ply, 312

## E

Edge delamination  
 moisture effects, 89  
 partially saturated, tension test, 107  
 Edge effects, in fiber microbuckling, 393  
 Effective crack lengths  
 for ARALL-2 laminates, 791  
 and stress intensity factor, 791  
 End notched flexure test, stabilized, 210  
 Environmental effects  
 jet fuel absorption on delamination, 107  
 moisture and notch geometry effects on  
 fracture toughness, 667

## F

Fatigue behavior  
 ARALL laminates subjected to tensile  
 cyclic loading, 772  
 carbon/epoxy laminates, 686  
 carbon fiber/PEEK composites, cooling  
 rate effects, 70  
 uniaxial zero-to-tension, of graphite/  
 epoxy tubes, 659

- Fatigue cracks
    - growth in unidirectional SCS-6/TI-15-3 composites, 711
    - growth rate testing, ARALL-2 laminates, 791
    - initiation, in notched SCS-6/TI-15-3 composites, 753
  - Fatigue damage, growth modeling, 617
  - Fiber bridging, and crack growth in ARALL-2 laminates, 791
  - Fiber composites
    - fatigue failure, 686
    - mixed-mode fracture, 143
  - Fiberglass/epoxy composites, compression testing of thick sections, 439
  - Fiber-matrix debonding, in SCS-6/TI-15-3 composites, 732, 753
  - Fiber microbuckling, edge effects, 393
  - Fiber-reinforced composites
    - compressive response, review, 550
    - notched, fatigue damage mechanics, 617
    - stabilized end notched flexure test, 210
    - tapered laminates, delamination analysis, 340
  - Fiber-reinforced plies, fatigue properties, 772
  - Fiber shear, notched composite laminates, 393
  - Fiber stress, zero degree, 732
  - Fiber type, effects CF/PEEK fatigue behavior, 581
  - Fibrous metal matrix composites, fracture, 696
  - Fickian moisture diffusion, 89
  - Filament-wound composite plates, effects of quasi-static impact events, 528
  - Filament-wound motor cases, nonvisible damage and residual tensile strength, 501
  - Finite element analyses
    - fibrous metal matrix composites with discontinuities, 696
    - maximum delamination stress in thermomechanical fatigue, 732
    - splitting and delamination effects on stress distribution, 596
    - unidirectional tapered laminates with ply drops, 312
  - Finite element analyses, three-dimensional combined effect of matrix cracking and free edge, 287
    - prediction of delamination onset in compressively loaded composites, 359
    - split cantilever beam Mode III delamination testing, 243
    - weave effects on composite moduli and stresses, 417
  - Finite element modeling
    - fatigue damage growth, 617
    - plane strain, 373
  - Flange-web corners, porosity effects, 126
  - Flexural strength, effects of notch geometry and moisture, 667
  - Fracture behavior
    - carbon fiber/PEEK composites, cooling rate effects, 70
    - fibrous metal matrix composites with discontinuities, 696
  - Fracture strength, effects of notch geometry and moisture, 667
  - Fracture toughness, interlaminar
    - absorption effects, 89, 107
    - computer-aided testing system, 210
    - effects of
      - large deflections, 169
      - moisture, 667
      - notch geometry, 667
      - T-tabs, 169
    - fiber composite laminates, 143
    - Mode II, 226
    - Mode III testing of split cantilever beams, 243
  - Fracture toughness, translaminar, effects of notch geometry and moisture, 667
  - Free edge, and matrix cracking, combined effects, 287
  - Free-edge delamination, fracture analysis, 269
- G**
- Geometric nonlinearity, large deflection- and T-tab-related, 169
  - Graphite/epoxy laminate composites, 30
    - edge delamination, 107
    - impactor shape effects, 501
    - notched, cross-ply, damage-based strength models, 596
  - Graphite/epoxy tubes, uniaxial zero-to-tension fatigue behavior, 659
  - Graphite/PEEK composites, edge delamination, 107
  - Growth law, notched graphite/epoxy laminate damage, 617

**H**

Hertz's law, 501  
 Hole effect, in compression fatigue of T300/  
 N5208 composites, 638  
 Holes, effect on fracture strength, 696  
 Hole size, effects on strength, 596

**I**

IM6/5245C composites, Mode II  
 delamination, 226  
 IM6 fibers, PEEK composites with, 70  
 IM6/PEEK composites, fatigue behavior,  
 581  
 IM7/8551-7  
 effects of T-tabs and large deflections, 169  
 low-velocity impact damage, 457  
 matrix cracking, 30  
 Mode II delamination, 226  
 Impact  
 carbon fiber/PEEK composites, cooling  
 rate effects, 70  
 low-velocity  
 effect on composite structures, 457  
 impactor shape effects, 457  
 temperature effects on ARALL-2  
 laminates, 806  
 Impact damage  
 ARALL-2 laminates, temperature effects,  
 806  
 resistance, stacking sequence effects, 476  
 in stitched laminates, 457  
 Impact energy, effect on damage to bonded  
 stiffened structures, 457  
 Impactors, shape effects, 501  
 Interlaminar fracture toughness, fiber  
 composite laminates, 143  
 Interlaminar layers, resin-rich, 30  
 Interlaminar stresses, effects on graphite/  
 epoxy tube fatigue, 659  
 Interlaminar tensile strength, porous  
 structures, 126  
 Internal state variable concept, 56  
 Internal stresses, carbon fiber/PEEK  
 composites, cooling rate effects, 70  
 Interply delamination, in SCS-6/TI-15-3  
 composites, 732  
 Isothermal fatigue, in quasi-isotropic metal  
 matrix composites, 732

**J**

Jet fuel absorption, effect on interlaminar  
 fracture toughness, 107

**L**

Linear elastic fracture mechanics  
 damage-based notch strength modeling,  
 596  
 effective crack lengths for ARALL-2  
 laminates, 791  
 Load-displacement curves, nonlinearity, 226  
 Loading tabs, effects on double cantilever  
 beam tests, 169  
 Low-velocity impact  
 effect on composite structures, 457  
 impactor shape effects, 501

**M**

Matrix cracking  
 and free edge, combined effects, 287  
 in IM7/8551-7 composites, 30  
 in SCS-6/TI-15-3 composites, 753  
 upper bounds of reduced axial and shear  
 moduli, 56  
 Matrix cracks, in composite laminates, 9  
 Matrix crack tip delamination, fracture  
 analysis, 269  
 Matrix plasticity, ARALL-2 laminates, 806  
 Matrix structure, carbon fiber/PEEK  
 composites, cooling rate effects, 70  
 Metal matrix composites  
 damage growth, 753  
 fatigue crack growth, 711  
 fatigue crack initiation, 753  
 temperature effects on impact damage  
 and residual tensile strength, 806  
 Mixed-mode loading  
 composite laminates, delamination onset  
 of, 359  
 delamination, Mode I behavior, 187  
 Mixed-mode tests, fiber composite  
 materials, 143  
 Mode I strain energy release rate, 187  
 Mode II delamination, in toughened  
 composites, 226  
 Mode II interlaminar crack growth, 210  
 Mode III delamination testing, split  
 cantilever beams, 243  
 Moisture, effect on fracture strength, 667  
 Motor cases, nonvisible damage and  
 residual tensile strength, 501

**N**

Nondestructive inspection  
 porosity effects on flange-web corner  
 strength, 126

- stacking sequence effects on impact damage and residual strength, 476
- Nonlinearity
  - geometric, double cantilever beams, 169
  - Mode II delamination in toughened composites, 226
- Nonvisible damage, impactor shape effects, 501
- Notched, cross-ply graphite/epoxy laminates, damage-based strength models, 596
- Notched composites
  - fatigue crack initiation, 753
  - fiber microbuckling, 393
- Notched strength modeling, damage-based, 596
- Notches
  - effect on fracture strength in fibrous metal matrix composites, 696
  - geometry, effect on fracture strength, 667

## O

- Open-hole/notched composites, fiber microbuckling, 393

## P

- Plastic zone, from discontinuities, 696
- Ply drops, 312
- Ply group thickness, 30
  - effect on damage resistance and residual strength, 476
- Porosity, effects on flange-web corner strength, 126
- Pulse-echo ultrasonics, 476

## Q

- Q3DG program, 89, 107
- Quasi-isotropic laminates
  - fatigue damage growth, 617
  - stacking sequence effects, 476
- Quasi-isotropic metal matrix composites, thermomechanical fatigue, 732
- Quasi-static impact, effects on composite plates, 528

## R

- Radiography, damage monitoring with, 596
- Rayleigh-Ritz energy method, 528
- Reduced axial, upper bounds, 56

- Residual strength
  - ARALL-2 laminates, temperature effects, 806
  - and impact damage, 457
  - notched graphite/epoxy laminates, 617
  - stacking sequence effects, 476
  - thick graphite/epoxy composites, impactor shape effects, 501
- Residual stress, SCS-6/TI-15-3 composites, 732
- Resin-rich interlaminar layers, 30

## S

- S2/3501-6 fiberglass/epoxy composites, thick-sections, compression testing, 439
- S2/SP250 glass/epoxy laminates, tapered, delamination analysis, 340
- Scanning electron microscopy
  - ARALL-2 impact damage, 806
  - damage modes to SCS-6/TI-15-3 composites, 732
  - for damage monitoring, 596
  - fatigue crack growth in metal matrix composites, 711
- SCS-6/Ti-15-3 composites
  - fatigue crack growth, 711
  - notched, fatigue crack initiation and growth, 753
  - thermomechanical fatigue, 732
- Shear deformation model, for local delamination, 269
- Shear moduli, upper bounds, 56
- Split cantilever beams, Mode III delamination testing, 243
- Splitting, effects on stress distribution in zero degree ply, 596
- Stabilized end notched flexure test, 210
- Stacking sequence, effect on damage resistance and residual strength, 476
- Stiffness reduction
  - cross-ply laminates, 56
  - and fatigue damage, 772
- Stitched laminates, impact damage, 457
- Strain energy release rate, 9
  - and damage growth, power law relationship, 617
  - mixed mode, 89, 107
  - Mode I, in cracked-lap shear specimens, 187
  - Mode III delamination testing, 243
  - notched graphite/epoxy laminates, 617
  - tapered laminates, 312
  - tapered laminates under tensile loading, 340

Strain measurement, optical, 596  
 Stress analyses, woven composites, 417  
 Stress distribution in zero ply, splitting and delamination effects, 596  
 Stress intensity factor  
   and effective crack length, 791  
   of transverse ply cracking, 9  
 Subcritical damage, effect on notched strength of cross-ply composites, 596  
 Surface opening displacement, calculation, 187

## T

T300/914C carbon-fiber epoxy composites, fatigue damage mechanics, 617  
 T300/934 graphite/epoxy laminates, transverse crack-tip and free-edge delamination, 269  
 T300/5208 composites, effects of T-tabs and large deflections, 169  
 T300/N5208 composites, hole effect in compression fatigue, 638  
 Temperature effects  
   on ARALL-2 laminates, 806  
   on fatigue behavior of CF/PEEK composites, 581  
 Tensile loading, delamination of tapered laminates under, 340  
 Tensile residual strength  
   ARALL-2 laminates, temperature effects, 806  
   impactor shape effects, 501  
 Tensile strength, interlaminar, 126  
 Tension cyclic loading, ARALL laminates, 772  
 Tension fatigue, CF/PEEK, 581  
 Tension-tension cyclic loading, effects on T300/914C laminates, 617  
 Thermomechanical fatigue, in quasi-isotropic metal matrix composites, 732  
 Thermoplastic composites, fatigue behavior, 581

Ti/SCS composites (*see* SCS-6/Ti-15-3 composites)  
 Toughened matrices, stacking sequence effects, 476  
 Transverse microcracking, SCS-6/Ti-15-3 composites, 732  
 Transverse ply cracking, composite laminates, 9  
 Tropical exposure, effects of notch geometry and moisture, 667  
 Tubular specimens, interlaminar stress effects on fatigue behavior, 659  
 Two-degree of freedom model, composite plates subjected to transverse impacts, 528

## U

Ultrasonic signals, attenuation loss, 126  
 Unidirectional boron/aluminum composites, fracture, 696  
 Unidirectional SCS-6/Ti-15-3 composites, fatigue crack growth, 711  
 Upper bounds, reduced axial and shear moduli, 56

## V

Virtual crack closure technique, 287

## W

Water absorption, effect on interlaminar fracture toughness, 107  
 Wavelength dispersive spectroscopy, thermomechanical fatigue of SCS-6/Ti-15-3 composites, 732  
 Weaves, effect on composite moduli and stresses, 417  
 Weibull statistics, residual strength calculation with, 617  
 Woven composites, three-dimensional stress analysis, 417