Subject Index

Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM D 429, 84 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	A	ASTM D 903, 84
Adherend flexural stiffness, effect, double cantilever beam, 126-128 Adherend modulus, chevron-notched specimens, 80-81 Adherend transverse stiffness, effect, double cantilever beam, 128-130 Adhesive, as fastener, 265 Adhesive carrier cloth, 163 Adhesive failure, versus temperature, 285 Asymptotic expansion, 145 Asymptotic expansion method matched, moderately thin joints, 152-155 stress distribution, 187 Biater specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Bilster test, 83 ruber-to-	A	ASTM D 1002, 292, 294
cantilever beam, 126-128 Adherend modulus, chevron-notched specimens, 80-81 Adherend transverse stiffness, effect, double cantilever beam, 128-130 Adhesive, as fastener, 265 Adhesive carrier cloth, 163 Adhesive failure, versus temperature, 285 Adhesive failure criterion, 214 Adhesive nonlinearity, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 ASTM D 3433, 184 ASTM D 3933, 292, 294 ASTM E 229, 28, 54 Asymptotic expansion, 145 Asymptotic expansion, 145 Asymptotic expansion, 145 Asymptotic expansion method matched, moderately thin joints, 152-155 stress distribution, 150 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 87 Strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Botits, 229 ultimate shear strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental directs, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond directions and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Botity to the very stream of the stream		ASTM D 1781, 84
Adherend modulus, chevron-notched specimens, 80-81 Adherend transverse stiffness, effect, double cantilever beam, 128-130 Adhesive, as fastener, 265 Adhesive failure, versus temperature, 285 Adhesive failure, versus temperature, 285 Adhesive failure criterion, 214 Adhesive nonlinearity, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Acrospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM D 3933, 292, 294 ASTM D 393, 1924 ASTM D 3933, 292, 294 ASTM D 393, 292, 294		ASTM D 3167, 84, 294
mens, 80-81 Adherend transverse stiffness, effect, double cantilever beam, 128-130 Adhesive, as fastener, 265 Adhesive carrier cloth, 163 Adhesive failure criterion, 214 Adhesive nonlinearity, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 alkesive as fastener, 265 adhesive as fastener, 265 adhesive as fastener, 269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 extensometer test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 36, 241 ASTM A 388, 232 ASTM D 3983, 28, 43 ASTM D 3933, 28, 54 ASTM E 229, 28, 54 ASYM D 299, 5, 4 Asymptotic expansion, 145 Asymptotic expansion, 140 asymptotic expansion, 145 Asympto		ASTM D 3433, 184
Adherend transverse stiffness, effect, double cantilever beam, 128-130 Adhesive, as fastener, 265 Adhesive carrier cloth, 163 Adhesive failure, versus temperature, 285 Adhesive failure, versus temperature, 285 Adhesive inonlinearity, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive also skin-doubler apoint, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen elastic stresses, 122-125 interface stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM D 429, 84 ASTM D 3983, 28, 54 ASTM E 229, 28, 54 ASTM E 229, 28, 54 ASTM E 229, 28, 54 ASYmptotic expansion method matched, moderately thin joints, 152-155 stress distribution, 150 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 87 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 12-73 wedge opening, 73-75 cyclic stress durability, 290 environmental effects, fracture, 276 shear strength, 229 Bonded system, integral equa		ASTM D 3933, 292, 294
Adhesive, as fastener, 265 Adhesive carrier cloth, 163 Adhesive failure criterion, 214 Adhesive inonlinearity, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 352, 232 ASTM D 429, 84 ASTM D 429, 84 ASTM E 229, 28, 54 Asymptotic expansion, 145 Asymptotic exp		
Cantilever beam, 128-130 Adhesive, as fastener, 265 Adhesive carrier cloth, 163 Adhesive failure, versus temperature, 285 Adhesive failure criterion, 214 Adhesive nonlinearity, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 358, 232 ASTM D 429, 84 Asymptotic analysis, 39, 43 Asymptotic expansion method matched, moderately thin joints, 152-155 stress distribution, 150 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 87 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress distribution, 277-278 static strength, 290 environmental durability, 289 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 290 Bondline tion, 225-227 Bonde endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43		
Adhesive cartier cloth, 163 Adhesive failure, versus temperature, 285 Adhesive failure criterion, 214 Adhesive nonlinearity, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 ASTM A 36, 241 ASTM A 368, 232 ASTM D 429, 84 Asymptotic expansion method matched, moderately thin joints, 152-155 stress distribution, 150 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 87 Biister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boolits-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formula- tion, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 249		
Adhesive failure, versus temperature, 285 Adhesive failure criterion, 214 Adhesive nonlinearity, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125-stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 358, 232 ASTM D 429, 84 Asymptotic expansion method matched, moderately thin joints, 152-155 stress distribution, 150 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 87 Bilister test, 83 rrubber-to-metal bonds, 85-87 strain energy release rate, 87 Blister test, 83 rrubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formula- tion, 225-227 Bonded matched, moderately thin joints, 150 B Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 87 Blister test, 83 rrubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength, 250 Bolts-to-member strength, 250 Bolts-to-member strength, 250 Bolts-to-member strength, 250 Bolts-to-metal bonds, 84-86 see also Mixed-m		Asymptotic expansion, 145
Adhesive failure criterion, 214 Adhesive hickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Allginment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 125-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 ASTM A 36, 241 ASTM A 36, 241 ASTM A 588, 232 ASTM D 429, 84 matched, moderately thin joints, 152-155 stress distribution, 150 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 290 environmental durability, 290 environmental durability, 290 environmental effects, fracture, 276 shear strength, 250 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43		
Adhesive Indinicative, 209 Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 ssee also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 150 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 87 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 29 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43		
Adhesive thickness, effect, double cantilever beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 36, 241 ASTM A 388, 232 ASTM D 429, 84 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental effects, fracture, 276 shear stress durability, 290 environmental effects, fracture, 276 shear stress durability, 290 environmental du		
beam, 126-127 Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 36, 241 ASTM A 388, 232 ASTM D 429, 84 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Beemsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 299 environmental durability, 289 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bond strength, 5, 43		
Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 36, 241 ASTM A 388, 232 ASTM D 429, 84 Astensometer for shear strain, 265-269 Beamsplitter, 17 Bimaterial constant, rubber-to-metal bonds, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43		
Aerospace adhesive joints, 289 Aircraft primary structure, 264-275 adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 36, 241 ASTM A 388, 232 ASTM D 429, 84 Beamsplitter, 17 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Beamsplitter, 17 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 299 environmental durability, 289 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 250 Bond integrity, 290 Bond integrity, 290 Bond integrity, 290 Bond integrity, 290 Bond strength, 5, 43		R
adhesive as fastener, 265 adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84		
adhesive shear stress-strain properties, 273-274 extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 36, 241 ASTM A 388, 232 ASTM D 429, 84	Aircraft primary structure, 264-275	Beamsplitter, 17
extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 358, 232 ASTM A 588, 232 ASTM D 429, 84 Blister specimen deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 5, 43	adhesive as fastener, 265	Bimaterial constant, rubber-to-metal bonds,
extensometer for shear strain, 265-269 F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM D 429, 84 deflections and predictions, 85-88 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	adhesive shear stress-strain properties,	
F-18 aircraft, bonded attachment of wing to fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM D 429, 84 elastomers, 85-87 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	273-274	Blister specimen
fuselage, 272-274 fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125- stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 358, 232 ASTM D 429, 84 strain energy release rate, 87 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental deffects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43		deflections and predictions, 85-88
fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125- stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 358, 232 ASTM A 588, 232 ASTM D 429, 84 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bolds, 229 set also Mixed-mode debonding Boeing wedge specimen, 93 Bolts, 229 sultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental deffects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43		elastomers, 85-87
fatigue test data, 273 FM 300K adhesive quality control, 273-275 joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 358, 232 ASTM A 588, 232 ASTM D 429, 84 Blister test, 83 rubber-to-metal bonds, 84-86 see also Mixed-mode debonding Bocing wedge specimen, 93 Bolts, 229 ultimate shear strength, 250 Bondst joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bond integrity, 290 Bond integrit	fuselage, 272-274	strain energy release rate, 87
joint design, 265 Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 ASTM A 36, 241 ASTM A 365, 232 ASTM A 588, 232 ASTM A 588, 232 ASTM D 429, 84 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43		
Krieger extensometer test method, 265-268 stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM A 588, 232 ASTM D 429, 84 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	FM 300K adhesive quality control, 273-275	rubber-to-metal bonds, 84-86
stress analysis, 264 see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM A 588, 232 ASTM D 429, 84 Bolts, 229 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bondline thickness, 252 ultimate shear strength, 250 Bonded specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	joint design, 265	see also Mixed-mode debonding
see also Skin-doubler specimen Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM A 588, 232 ASTM D 429, 84 ultimate shear strength, 250 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	Krieger extensometer test method, 265-268	Boeing wedge specimen, 93
Alignment, 5 Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM A 588, 232 ASTM D 429, 84 Bolts-to-member strength ratio, 231-232 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	stress analysis, 264	Bolts, 229
Aluminum, 39, 252 adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 368, 232 ASTM D 429, 84 Bonded joint chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	see also Skin-doubler specimen	ultimate shear strength, 250
adherends, 277 fracture toughness, 81 DCB specimens elastic stresses, 122-125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 chevron-notched specimens load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	Alignment, 5	Bolts-to-member strength ratio, 231-232
fracture toughness, 81 DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 load relaxation, 71-73 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	Aluminum, 39, 252	Bonded joint
DCB specimens elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 wedge opening, 73-75 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	adherends, 277	chevron-notched specimens
elastic stresses, 122-125 interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 cyclic stress durability, 290 environmental durability, 289 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	fracture toughness, 81	load relaxation, 71-73
interface stress distributions, 125 stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 environmental durability, 289 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	DCB specimens	wedge opening, 73-75
stress distribution, 122-124 yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 environmental effects, fracture, 276 shear stress distribution, 277-278 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43		cyclic stress durability, 290
yield zone area and height, 130-131 double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	interface stress distributions, 125	environmental durability, 289
double-lap joint, 41 Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 Static strength, 229 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	stress distribution, 122-124	environmental effects, fracture, 276
Apparent modulus, 58 Applied moment, 100 Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 Bonded system, integral equations formulation, 225-227 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	yield zone area and height, 130-131	shear stress distribution, 277-278
Applied moment, 100 tion, 225-227 Araldite, 14-15 Bond endurance, 289, 295-296 stress-strain behavior, 16 Bond integrity, 290 ASTM A 36, 241 Bondline ASTM A 325, 232 thickness, 252 ASTM A 588, 232 ultimate shear strength, 249 ASTM D 429, 84 Bond strength, 5, 43	double-lap joint, 41	static strength, 229
Araldite, 14-15 stress-strain behavior, 16 ASTM A 36, 241 ASTM A 325, 232 ASTM A 588, 232 ASTM D 429, 84 Bond endurance, 289, 295-296 Bond integrity, 290 Bondline thickness, 252 ultimate shear strength, 249 Bond strength, 5, 43	Apparent modulus, 58	Bonded system, integral equations formula-
stress-strain behavior, 16 Bond integrity, 290 ASTM A 36, 241 Bondline ASTM A 325, 232 thickness, 252 ASTM A 588, 232 ultimate shear strength, 249 ASTM D 429, 84 Bond strength, 5, 43	Applied moment, 100	
stress-strain behavior, 16 Bond integrity, 290 ASTM A 36, 241 Bondline ASTM A 325, 232 thickness, 252 ASTM A 588, 232 ultimate shear strength, 249 ASTM D 429, 84 Bond strength, 5, 43	Araldite, 14-15	Bond endurance, 289, 295-296
ASTM A 325, 232 thickness, 252 ASTM A 588, 232 ultimate shear strength, 249 ASTM D 429, 84 Bond strength, 5, 43	stress-strain behavior, 16	
ASTM A 588, 232 ultimate shear strength, 249 ASTM D 429, 84 Bond strength, 5, 43	ASTM A 36, 241	
ASTM A 588, 232 ultimate shear strength, 249 ASTM D 429, 84 Bond strength, 5, 43	ASTM A 325, 232	thickness, 252
ASTM D 429, 84 Bond strength, 5, 43	ASTM A 588, 232	
	ASTM D 429, 84	
	ASTM D 897, 5	button tensile adhesion tests, 10

Bulk specimen, 54	as function of crack length, double canti-
Butt joint, 54, 67	lever sandwich beam, 92-93
elastic analysis, 137-141	Compliance-stiffness matrix, 136-137
elastic parameters, 55-58	Composite materials, 39, 145, 194, 209
finite element meshes, 57	fibrous, 210
normal stress distribution along interface,	Conformal mapping, 145
139, 141–143	very thin joints, 155-157
schematic, 138	Continuity conditions, 133
shear stress distribution along interface,	Corrosive environments, 83
139-142	Crack closure, 276
specimen, 56	Cracked-lap-shear specimens, 195
geometry, 138	crack growth rate, 164
Button tensile adhesion tests, 5-12	critical value of strain-energy-release rate,
alignment index, 11	164
alignment problems, 6-7	debonded surfaces, 200-201
bond strength, 10	preparation and configuration, 195-196
grips, 5-6	Crack growth
with ball joint added, 7, 9	beneath adhesively bonded doubler, 210
modified, 7-8	mixed-mode I-III, scarf joint, 166
hydraulic shock absorbers, 7-8	Crack growth rate, 163
linkages, 5, 7	cracked lap shear specimen, 164
specimen, 6	double-cantilever-beam specimen, 164,
test	171-179
with modified grips, 11	0° scarf angle, 172-174
with standard grip, 9-11	45° scarf angle, 173, 175
	Cracking, 163-182
C	fracture toughness, 167, 171
-	initiation, finite element analysis, 279-281
Cathodic debonding process, 85-86, 95	materials, 167
Chevron-notched specimens, 69-81	profiles, following growth reinitiation, 19,
adhesive thickness influence, 79	21
data reduction, 71-76	specimens, 166-167
experiment, 70-71	velocity, chevron-notched specimens, 78-
fracture energy, 75	79
direct measurement, 77-78	Crack length
fracture toughness, 75	compliance as function, 92-93
geometric factors, 76	stiffness as function of, 102-103
influence of adherend modulus, 80-81	Crack mouth opening rate
load relaxation, 71-73	influence on fracture toughness, 78
load versus mouth opening displacement,	velocities, 78
71–72	Crack mouth opening displacement, versus
mouth opening rate influence, 78-79	load, chevron-notched specimens, 71-72
reproducibility, 77	
specimen dimensions, 70	Crack opening displacement
test temperature influence, 79-80	examination, 19, 21–26
very thin joint approximation, 75	linear elastic fracture parameters, 21–22
Chisholm-Jones shear specimen, 30, 32, 35-36	measurement, 17
Clamped beam, compliance, 185	near-tip, 24-25
Cleavage test, 184	nonlinear fracture parameters, 22, 24-26
Compact tension specimen, geometric fac-	profiles, 19, 21
tors, 76	variation of ratio of tangential and normal,
Compliance	22-23
calibration of contoured TDCB specimen,	Crack opening interferometry, 13, 16
170	Crack propagation, 39
clamped beam, 185	Crack tip, 119
double cantilever beam specimens, 185	stress distribution ahead of, 123-124

Cyclic stress durability, 289, 301	Double-lap joint, 39-53, 145
apparatus layout, 290, 292	configuration, 41
bonded joint, 290	deformations curves, 45, 48
bond endurance, 295-296	displacement field, 151-152
fixture, 293	equipment, 42
specimen configuration, 292, 295	extensometric strain gages, 42-43
	joint unevenness, 50-51
D	longitudinal stress, 42
Dilai. I	matched asymptotic expansion method for
Debond	moderately thin joints, 152-155
fracture energy, 95	microcracks, 52
growth rates, 202–205	numerical method, 47–48 outer adherends, 46
length, versus fatigue cycles, 197	plastic adaptation, 52
mechanism, woven Kevlar composites, 197-199	rectangular, elastic equilibrium, 149-151
	schematic, 147–148
power-law relationship, 203	simplified theory, 46-47
predicted, stringer, 209, 214, 217-223 linear adhesive, 218-220	specimen preparation, 43
nonlinear adhesive, 221–222	stresses far from lap ends, 151-152
propagation, 194	subjected to shear in traction, 45, 48
size and shape effect on stress-intensity fac-	tangent modulus, 45, 48-50
tor, 215–217	theory, 43–46
Delamination, stress ahead of, double canti-	undergoing traction force, 151
lever beam, 122–123	very thin, conformational mapping, 155-
DIN 54451, 54-55, 59	157
Displacement equations, continuity, 226	Young's modulus, 152
Displacement fields, 107	Dynamic mechanical analysis, 301
Double cantilever beam, 83, 305	,
comparison of aluminum and graphite/ep-	17.
comparison of aluminum and graphite/epoxy specimens, 126, 129	${f E}$
oxy specimens, 126, 129	E EA9309.2NA adhesive, load rate dependency,
	-
oxy specimens, 126, 129 compliance, 185	EA9309.2NA adhesive, load rate dependency,
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184	EA9309.2NA adhesive, load rate dependency,
oxy specimens, 126, 129 compliance, 185 contoured, 168–169, 184 compliance calibration, 170	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141
oxy specimens, 126, 129 compliance, 185 contoured, 168–169, 184 compliance calibration, 170 crack growth rate, 164, 171–179	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76 material properties, 121	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120-	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120- 121	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120- 121 stress intensity factor, 121-122	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120- 121 stress intensity factor, 121-122 Double cantilever sandwich beam	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120- 121 stress intensity factor, 121-122 Double cantilever sandwich beam Boeing wedge specimen, 93	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120- 121 stress intensity factor, 121-122 Double cantilever sandwich beam Boeing wedge specimen, 93 compliance as function of crack length, 92-	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60 thick adherend lap shear joint, 58-60
oxy specimens, 126, 129 compliance, 185 contoured, 168-169, 184 compliance calibration, 170 crack growth rate, 164, 171-179 critical strain-energy-release rate, 164, 185 elastic stresses, 119-132 aluminum specimens, 122-125 finite-element analysis, 120-122 graphite/epoxy specimens, 125-130 yield zone estimates, 130-131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120- 121 stress intensity factor, 121-122 Double cantilever sandwich beam Boeing wedge specimen, 93 compliance as function of crack length, 92- 93	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60 thick adherend lap shear joint, 58-60 sensitivity of in situ and bulk methods, 66
oxy specimens, 126, 129 compliance, 185 contoured, 168–169, 184 compliance calibration, 170 crack growth rate, 164, 171–179 critical strain-energy-release rate, 164, 185 elastic stresses, 119–132 aluminum specimens, 122–125 finite-element analysis, 120–122 graphite/epoxy specimens, 125–130 yield zone estimates, 130–131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120– 121 stress intensity factor, 121–122 Double cantilever sandwich beam Boeing wedge specimen, 93 compliance as function of crack length, 92– 93 fixture for compliance measurement, 91–92	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60 thick adherend lap shear joint, 58-60 sensitivity of in situ and bulk methods, 66 verification, 62
oxy specimens, 126, 129 compliance, 185 contoured, 168–169, 184 compliance calibration, 170 crack growth rate, 164, 171–179 critical strain-energy-release rate, 164, 185 elastic stresses, 119–132 aluminum specimens, 122–125 finite-element analysis, 120–122 graphite/epoxy specimens, 125–130 yield zone estimates, 130–131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120– 121 stress intensity factor, 121–122 Double cantilever sandwich beam Boeing wedge specimen, 93 compliance as function of crack length, 92– 93 fixture for compliance measurement, 91–92 iso-G loading, 93–95	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60 thick adherend lap shear joint, 58-60 sensitivity of in situ and bulk methods, 66 verification, 62 Elastic stress
oxy specimens, 126, 129 compliance, 185 contoured, 168–169, 184 compliance calibration, 170 crack growth rate, 164, 171–179 critical strain-energy-release rate, 164, 185 elastic stresses, 119–132 aluminum specimens, 122–125 finite-element analysis, 120–122 graphite/epoxy specimens, 125–130 yield zone estimates, 130–131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120– 121 stress intensity factor, 121–122 Double cantilever sandwich beam Boeing wedge specimen, 93 compliance as function of crack length, 92– 93 fixture for compliance measurement, 91–92 iso-G loading, 93–95 peel stresses, 95	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60 thick adherend lap shear joint, 58-60 sensitivity of in situ and bulk methods, 66 verification, 62 Elastic stress double cantilever beam, 119-132
oxy specimens, 126, 129 compliance, 185 contoured, 168–169, 184 compliance calibration, 170 crack growth rate, 164, 171–179 critical strain-energy-release rate, 164, 185 elastic stresses, 119–132 aluminum specimens, 122–125 finite-element analysis, 120–122 graphite/epoxy specimens, 125–130 yield zone estimates, 130–131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120– 121 stress intensity factor, 121–122 Double cantilever sandwich beam Boeing wedge specimen, 93 compliance as function of crack length, 92– 93 fixture for compliance measurement, 91–92 iso-G loading, 93–95 peel stresses, 95 rubber-to-metal bonds, 90–96	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60 thick adherend lap shear joint, 58-60 sensitivity of in situ and bulk methods, 66 verification, 62 Elastic stress double cantilever beam, 119-132 graphite/epoxy, 125-130
oxy specimens, 126, 129 compliance, 185 contoured, 168–169, 184 compliance calibration, 170 crack growth rate, 164, 171–179 critical strain-energy-release rate, 164, 185 elastic stresses, 119–132 aluminum specimens, 122–125 finite-element analysis, 120–122 graphite/epoxy specimens, 125–130 yield zone estimates, 130–131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120– 121 stress intensity factor, 121–122 Double cantilever sandwich beam Boeing wedge specimen, 93 compliance as function of crack length, 92– 93 fixture for compliance measurement, 91–92 iso-G loading, 93–95 peel stresses, 95 rubber-to-metal bonds, 90–96 specimen dimensions, 92	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60 thick adherend lap shear joint, 58-60 sensitivity of in situ and bulk methods, 66 verification, 62 Elastic stress double cantilever beam, 119-132 graphite/epoxy, 125-130 Elastic stress analysis, 54
oxy specimens, 126, 129 compliance, 185 contoured, 168–169, 184 compliance calibration, 170 crack growth rate, 164, 171–179 critical strain-energy-release rate, 164, 185 elastic stresses, 119–132 aluminum specimens, 122–125 finite-element analysis, 120–122 graphite/epoxy specimens, 125–130 yield zone estimates, 130–131 geometric factors, 76 material properties, 121 specimen configuration and loading, 120– 121 stress intensity factor, 121–122 Double cantilever sandwich beam Boeing wedge specimen, 93 compliance as function of crack length, 92– 93 fixture for compliance measurement, 91–92 iso-G loading, 93–95 peel stresses, 95 rubber-to-metal bonds, 90–96	EA9309.2NA adhesive, load rate dependency, 11 EA9321 adhesive system, shear stress-strain curve, 37 Elastic analysis, butt joints, 137-141 Elastic equilibrium, rectangular double-lap joint, 149-151 Elasticity generalized matrix, 136 two-dimensional, 133 Elastic limit, 39 Elastic parameters, 54-67 bulk constants, 60-61 gradients, 63 in situ constants, 55-60 butt joint, 55-58 evaluation, 60 thick adherend lap shear joint, 58-60 sensitivity of in situ and bulk methods, 66 verification, 62 Elastic stress double cantilever beam, 119-132 graphite/epoxy, 125-130

Finite element analysis, 28, 54, 101, 119, 252

elastic stresses in DCB specimens, 120-122

crack initiation, 279-281

Finite element model

tube-and-socket joint, 257-258 woven Kevlar composites, 199-202

Elastomer-to-metal bonding, 84 determination of specimen stiffness, 103 Environmental durability, 289-303 double cantilever beam, 121-122 floating roller peel strengths, 298-299 Floating roller peel strengths, 298-299 glass transition temperature, 298-299 FM 300K, 55 quality control, 273-275 materials and processing parameters, 294-Fracture, 39 mechanical analysis, 297-298 appearance, scarf joints, 174–175, 180–181 mechanical tests, 294 see also Environmental effects, fracture shear storage and loss moduli, 299-301 Fracture energy, 13-14 stress durability, 290-292 chevron-notched specimens, 75 stress hygrothermal analysis, 295-297 debonding, 95 thermal analysis, 298-301 direct measurement, 77-78 thermal spectroscopy, 292, 294 Mode I, versus temperature, 284-285 Environmental effects, fracture, 276-287 statistical analysis, 189 adhesive failure versus temperature, 285 versus surface treatment, 188-189 aluminum adherends, 277 Fracture mechanics, 98, 183, 194 analysis, 279-283 Fracture strength, static, woven Kevlar comcritical failure loads versus degree of adheposites, 205 sive failure, 286-287 Fracture toughness, 69, 83, 163 experiments, 277-279 adhesive thickness effect, 79 finite element analysis, 279-281 aluminum and steel adherends, 81 glass transition temperature, as function of chevron-notched specimens, 75 moisture, 279 critical values, 69 double-cantilever-beam specimen, 167, 171 Mode I fracture energy versus temperature, 284-285 Mode I opening, 187-189 shear modulus, versus temperature, 278mouth opening rate effect, 78 temperature influence, 79-80 Fringe patterns, 19-20 stress-energy-release rate, 281-282 ultimate shear stress, versus temperature, 278-280 G Epoxy, 5, 14, 39, 108, 252 construction industry applications, 229 Glass/epoxy, 13 glass transition temperature, 298-299 Glass transition temperature, 289, 294 epoxy structural adhesives, 298-299 moisture uptake, 297-298 nylon-modified, 69 as function of moisture, 279 thermal analysis, 297 stress-strain behavior, 15-16 Extensometry, 39 Graphite/epoxy DCB specimens, elastic stresses, 125-130 shear strain, 265-269 adherend flexural stiffness effect, 126-128 strain gages, 42-43 adherend transverse stiffness effect, 128see also Krieger extensometer test method adhesive thickness effects, 126-127 stress distributions, constant flexural stiffness, 127-128 F-18 aircraft, bonded attachment of wing to Grips, 5 fuselage, 272-274 modified, 7-8 Failure mechanisms, 305 Failure loads, critical, versus degree of adhe-H sive failure, 286-287 Fatigue cracking, 69-70 Hooke's law, 150 Fatigue damage mechanism, 195 Hygrothermal analysis, stressed, 295-297

I

Interfacial debonding, 13 Interfacial stress analysis, 133-143

Hygrothermal exposure, 289

examination, 19, 21-26 boundary conditions at edge point, 141-142 measurement, 17 butt joints, 137-141 crack tip response, 22 compliance-stiffness matrix, 136-137 continuity conditions, 133 critical value of α , 22 data acquisition and reduction, 17, 19 edge effects, 141 linear elastic fracture parameters, 21-22 elementary load vector, 136 loading device, 16-18 elimination process, 134-136 generalized elasticity matrix, 136 nonlinear fracture parameters, 22, 24-26 power law exponent, 24, 26 rectangular finite elements derivation, 134specimen geometry and preparation, 14-16 variation of critical values of \sqrt{r} coefficient, relocalization process, 136-137 stress vectors, 134 triangular finite elements derivation, 135, see also Crack opening displacements Mixed mode specimen, 28 Mode I fracture, 163 Young's modulus ratio effects, 140-141 Mode I-III fracture, 163 Iso-G loading, 93-95 Mode I opening, 183-193 characteristics of tested structures, 188 J critical strain energy release rate, 192 Joint elements of analysis, 188-189 design, 265 fracture energy versus surface treatment, geometry, 252 188-189 see also specific types of joints fracture toughness, 187-189 load-displacement plots, 186-187 materials, 186 K R curves, 189-192 Kolossov functions, 156-157 techniques, 186 Moiré interferometry, 107, 109 Krieger extensometer test method, 265-268 fringe patterns, thick adherend lap joint, data reduction, 267-268 shear stress-strain curve, 267-268 110-114 tube-and-socket joint, 254 optical arrangement, 107, 109 Moisture uptake, epoxy, 297-298 L Lagrangian strain-displacement relationships, 113-114 Napkin-ring method, 28 Lap shear tensile strength, after hygrothermal Nonlinear fracture parameters, 22, 24-26 exposure, 298 Linear elastic fracture mechanics, 21-22, 276 0 Load vector, elementary, 136 Orthotropic materials, 209 Overlap length, 252 M tensile failure load versus, 258-259 Mechanical analysis, environmental durabil- Overlap joint, stress analysis, 253 ity, 297-298 Mechanical properties, 39 P Microcrack, 52 progressive initiation and flaw fast propa- Paste adhesives, 252 gation, 49 Peel stress, 281 Microdefects, 43 Plastic adaptation, 52 Microstrains, along outer surfaces of adher- Plastic zone size, chevron-notched specimens, ends, 49 79 Mixed finite elements, 133 Plate theory, 85 rectangular, 134-137 Potential energy, relation to stress intensity factor, 99 triangular, 135, 137 Mixed-mode debonding, 13-27 Power law exponent, 24, 26

Pure shear testing, 28

crack opening displacements

R	versus reduced distance to edge, 140
Radial stress, distributions along tube-and-	skin-doubler specimen, 268, 270
socket joint overlap, 258-260	integral equations, 212-213
Ramberg-Osgood relation, 16	thick adherend lap joint, 111
R curves, Mode I opening, 189-192	Shear stress-strain curve, 215, 264
annealed galvanized steel, 191	aircraft primary structure, 273-274
hot galvanized steel, 190	data, thick-adherend and skin-doubles
Reissner's variational principle, 134	specimens, 269-272
Replication technique, 107, 109	FM 300K adhesive quality control, 273-275
Rubber-to-metal bonds, 83-96	Krieger extensometer test method, 267-268
bimaterial constant, 87	properties, aircraft primary structure, 273-
blister specimen, 85-87	274
blister test, 84-86	room temperature, 269-271
cathodic debonding process, 95	tube-and-socket joint, 255
debonding fracture energy, 95	Shear test, 39
debond rates, 89	Skin-doubler concept, as model joint, 264-
double cantilever sandwich beam, 90-96	265
experimental setup for accelerated cathodic	Skin-doubler specimen, 264
delamination, 93-95	adhesive strain, nonlinear range, 269
strain energy, 87	stress analysis, 264–265
strip blister specimen, 87-90	verification, 268, 270
tests, 84-85	stress-strain data, 269–272
Running cracks, 70	Slip coefficient, 234
•	Slip resistance, 229
	Specimen
S	constant stress intensity factor, 98-104 designs, 69
Socutions 54	9 ,
Scarf joint, 54	see also specific types of specimens Splices, 229
with clip gages applied, 63 finite element mesh, 64	beam, 230-231
	four-bolt, 245-246
mixed-mode I-III crack growth, 166 numerical and analytical study results, 64–	load-elongation curves, 244–245, 247
65	six-bolt, 243–245
specimen, 62	slip data, 244
stiffness, 66–67	tension flange contact surface, 247
Shadow moiré technique, 90	two-bold, 246-247
Shear forces, 100	bonded, 241
Shear loss modulus, 289, 299-301	nonbonded, 241
Shear modulus, 264	push-out specimens, load-elongation curve,
versus temperature, 278-279	241-243
Shear storage modulus, 289, 299-301	tensile
Shear strain, 37	bonded one-bolt, 239-241
extensometer for, 265-269	bonded two-bolt, 236-239
thick adherend lap joint, 113, 114	load-elongation curves, 234, 240
Shear strength, 252	nonbonded one-bolt, 239-240
ultimate	nonbonded two-bolt, 235-236
bolts, 250	slip data, 236-237
bondline, 249	Static strength, 229-250
versus temperature, 278-280	beam splices
Shear stress, 289	comparison with previous work, 248
displacements as function of, 112, 115	comparison with tensile specimens, 248
versus distance to free edge, 143	experimental design, 242
distribution	four-bolt, 245-246
along interface, 139-142	load-elongation curves, 244-245, 247
along tube-and-socket joint overlap, 258,	six-bolt, 243-245
261	slip data, 244
bonded joint, 277-278	two-bolt, 246-247

bolts-to-member strength ratio, 231-232 design recommendations, 249-250	distances between, 49 electrical, 145
fabrication, 233	orthogonal layout, 43
material properties, 232-233	Stress, 5
slip coefficient, 234	distribution, 119, 145-159
specimens, 230-231	ahead of crack tip, 123-124
tensile specimens	ahead of delamination, 122-123
bonded one-bolt splices, 239-241	asymptotic expansions method, 150
bonded two-bolt splices, 236–239	comparison between measurements and
comparison with previous work, 241	theoretical results, 158-159
experiment design, 235	conformal mapping, very thin joints,
load-elongation curves, 234, 240 nonbonded one-bolt splices, 239–240	155–157 far from lap ends, 151–152
nonbonded two-bolt splices, 235–240	functions, 149
slip criteria, 238	holomorphic function, 156
slip data, 236–237	Hooke's law, 150
slip interaction diagram, 240	interface, DCB specimens, 125
testing procedure, 233-234	matched asymptotic expansion method
Static stress durability, 289, 291	for moderately thin joints, 152-155
bond endurance, 295-296	material properties, 146-147
joint performance, 290	principle of mechanical measurements,
specimen configuration, 292, 295	148-149
Steel, 229	specimen-loading conditions, 147-148
adherends, fracture toughness, 81	stress-traction, 154
surface treatment, 186	normal, distribution, 277-278
Stiff adherend specimen, 29-30	along interface, 139, 141-143
compliance change rate, 36	Stress analysis, 252-253, 304-305
deformed shape, 32-33	aircraft primary structure, 264
stress distribution in adhesive layer, 34	skin-doubler specimen, 264-265
Stiffness, 264	verification, skin-doubler specimen, 268,
change in, constant stress intensity factor,	270
100	Stress-concentration factors, 157
flexural, 126-128	Stress durability, 290-292
as function of crack length, 102-103	Stress-energy-release rate, 276, 283
transverse, 128-130	versus crack length, 281-282
Strain, 107	Mode I and II components, 281-282
adhesive, thick adherend lap joint, 116-117	Stress intensity factor, 21
longitudinal, thick adherend lap joint, 115,	constant
117	applied moment, 100
nonlinear range, skin-doubler specimen,	change of specimen stiffness, 100
269	displacement in loading point, 100-101
Strain-energy-release rate, 29-30, 32, 35, 194	final shape and dimensions of specimen,
versus applied load, 202	101-102
blister specimen, 87	forces acting on specimen, 99
Chisholm-Jones shear specimen, 30	shear forces, 100
critical, 29, 164	specimen development, 99-104
double cantilever beam specimens, 185	determination, 213
fracture initiation and propagation, 192	double cantilever beam, 121–122 as function of
mode II effects, 165	
versus debond length, 202	crack length and debond height, 216-217
delamination growth, 121-122	debond aspect ratio, 216-217 debond width and height, 215-216
linear and elastic materials, 30	
mixed-mode loading, 163 mode I, at fracture, 165	integral equations for shear stresses, 212- 213
strip blister specimen, 87, 89	predicted, 220-224
Strain gages, 39	problem formulation, 211-212
distance from free end of joint, 148	relation to potential energy, 99

stringer debond size and shape effect, 215-217	finite element meshes, 57 specimen, 56, 266
stringer panel, 210-211	deformed shape, 32-33
Stress-strain curve, 227, 252	mechanical drawing, 277
EA9321 adhesive system, 37	stress distribution in adhesive layer, 34
Stress-tensor, first invariant, 156	stress-strain data, 269-272
Stringer panel, 209-210	test data, 271
debond size and shape effect on stress-in-	Thick adherend test, 54
tensity factor, 215-217	
model, 210-211	Tube-and-socket joint, 252–262
predicted debonding, 217-223	adhesive application and fixturing, 255
linear adhesive, 217-225	256
	adhesive shear behavior determination, 25
nonlinear adhesive, 219	analytical/experimental work, 258-261
stress-intensity factor, 210, 211, 220–222	finite element analysis, 257-258
stress-intensity factor, 210-211	geometry, 256
superposition model, 225	Krieger extensometer test method, 254
Strip blister specimen	mechanical properties, 257-258
clamped, 89	radial stress distributions along tube-and
closed-form and finite solutions with exper-	socket joint overlap, 258-260
imental deflections, 90-91	shear stress distributions along joint over
digital analysis system for shadow moire, 90	lap, 258, 261
rubber-to-metal bonds, 87-90	shear stress-strain curve, 255
strain energy release rate, 87, 89	specimen preparation, 254-255
Superposition model, 225	tensile failure load versus overlap length
	258-259
T	tension test method, 255
T	test matrix, 253
Tangent modulus, 45, 48-50	
Tensile failure load, versus overlap length,	
258-259 Thornal analysis anninomeratal dynability	U
Thermal analysis, environmental durability, 298-301	II-ifa 20 20
	Uniform pure shear testing specimen, 28-38
Thermal spectroscopy, 292, 294 Thick adherend longicint, 107, 118, 264	Chisholm-Jones shear specimen, 30, 32
Thick adherend lap joint, 107-118, 264	35-36
displacement field	compliance change rate, 36
fringe patterns, 111-114	evaluation, 29–30, 32, 35
preliminary test, 108, 110	procedure and results, 35, 37
displacements	stiff adherend specimen, 29-30
as function of shear stress, 112, 115	thick adherend lap shear joint, 28-29
variation across adhesive thickness, 115-	
116	
interpretation and results, 112-117	V
Lagrangian strain-displacement relation-	VISTA, 85, 87
ships, 113-114	V10171, 00, 07
preliminary tests, 108-109	
shear stress, displacement and strain his-	
tory, 111	W
specimen, 108	WKB method, 51
strain along adhesive/adherend interfaces,	
115-117	Woven Kevlar composites, 194–205
test sequence and fringe patterns, 109, 111-	adhesive properties, 197
112 Thick adherend lap shear joint, 28-29, 67	bridging fibers, 198-199 composite properties, 196
	debond
elastic parameters	growth rates, 202-205
analytical study, 58-59	mechanism, 197-199
experimental results, 59-60	debonded surfaces, 200-201
numerical study, 59	acconded surfaces, 200-201

finite element analysis, 199-202 specimen preparation and configuration, 195-196 static fracture strength, 205 testing procedure, 196-197 Y

Yield zone, double cantilever beam, 130-131 Young's modulus double-lap joint, 152 ratio, stress distribution and, 140-141