

## Index

### **a**

absorption-desorption processes 218  
 acoustic emission test 143–144  
 acrylic adhesives 79–80, 113, 161  
 active chemical processes 59–62  
 adherend quality control  
 contact angle 129–131  
 mechanical properties 129  
 surface energy 129–131  
 surface roughness 131–133  
 wettability 129–131  
 adherends 2  
 failure 177–180  
 strength 187  
 adhesion  
 adsorption theory 37–38, 39  
 and cohesion work 35–36  
 diffusion theory 41  
 electrostatic theory 41–42  
 mechanical theory 38, 40  
 spreading 36–37  
 surface roughness 31–32  
 wettability 32–35  
 adhesion promoters 60, 65–67  
 adhesion work 35, 171  
 adhesive(s) 1  
 acrylic 79–80  
 aged adhesive testing 100  
 application precautions 164  
 aromatic 81  
 crash resistant 78

elastomeric 81  
 epoxy 77–78  
 extreme temperature testing 99–100  
 failure in 176  
 fatigue testing 101–102  
 films 116  
 flexibilizers 70  
 forms 74  
 formulations 70  
 hotmelt 82–83  
 humidity 109  
 impact testing 101  
 inorganic 83, 162  
 light and UV radiation 110  
 liquid 114–115  
 loading conditions testing 98, 99  
 mechanical properties of 102–105  
 mechanical testing of 88–89  
 metering 111  
 mixing 111–114  
 paste 115–116  
 phenolic 80  
 polyester 82  
 polyurethane 78–79  
 pressure sensitive adhesives (PSAs)  
 76–77  
 selection flowchart 85  
 severe environmental testing 98–99  
 shear testing of 91–93  
 storage temperature 109–110  
 storage time 108–109

- adhesive(s) (*Contd.*)
    - structural 77, 81
    - test and characteristics 88, 102
    - thread locking 76, 79
    - tougheners and flexibilizers 70
  - adhesive bonding
    - aeronautical industry 8–11
    - benefits and limitations 4–7
    - civil engineering 15–18
    - definition of basic concepts 2
    - electronic devices 23
    - footwear industry 24–25
    - historical context 3–4
    - labelling and packaging industry 18–19
    - medical applications and devices 19–23
    - naval industry 13–15
    - packaging industry 18–19
    - road transport and rail industry 11–13
    - sport equipment 23–24
  - adhesive breakage 36
  - adhesive classification
    - chemical composition 77
    - implementation method 75–77
    - mechanical properties 74–75
    - molecular structure 70–74
    - physical form 74
  - adhesive failure 27, 128, 140, 170–171, 176, 178, 198, 202, 220, 238
  - adhesive fillet 189
  - adhesive hardening 120
    - evaporation based processes 125–126
    - heat curing processes 121–125
  - adhesive joints 28, 29
    - defects and weak spots in 42–43
    - failure of 43
    - geometries 169–171
    - implementation of 107
    - loading modes on 168–169
    - loadings acting on 169
    - manufacturing 108
    - mechanical behaviour of 46
    - quality control of 127
    - strength prediction 171–172
  - stresses acting on 172–175
  - thermal stresses effect 212
  - weak spots in 42
  - adhesive quality control
    - mechanical properties 128
    - viscosity 128
  - adhesive selection 43, 69–105, 246
    - for automotive industry 84–88
  - adhesive thickness control 119
  - adhesive thickness effect 183–184
  - adsorption theory 37–39
  - aged adhesive testing 100
  - anaerobic adhesive 79, 161
  - analytical methods 171–180
  - anchoring systems 15–16
  - anti-oxidation coating 5
  - ARCAN 92–93
  - Arcan testing 219, 225
  - aromatic adhesives 81, 161–162
  - Asymmetric Double Cantilever Beam (ADCB) 98
  - atomic force microscopy (AFM) 133, 139
- b**
- bio-adhesives 5, 22–23
  - bond fabrics 82
  - bonded joints, defects in 137, 138
  - bonding-based technology 16
  - bondline 6, 16, 78–79, 82, 113, 115–116, 122, 126, 142, 149
  - building facades 16–17
  - butt joint 93, 117–118
- c**
- carcinogen 60, 161
  - carcinogenic products 154
  - cartridges, adhesive 111, 116
  - case studies
    - aeronautical applications 239–240
    - flexible cooling circuits 241–243
    - food packaging 248–249
    - glass to metal bonding 243–244
    - passenger trains, seat fixation in 237–239
    - roof coverings 245–246

- shoe manufacture 246–248  
 vehicle construction 235–237
- catalyser 108–109  
 cavitation 55, 72, 73  
 cellulose nitrate 4  
 chemisorption 38  
 classical riveting based joining processes 9  
 classical structural joining technologies 11  
 cleaning agents 48, 52–54  
 clinching 12  
 cohesion work 35–36  
 cohesive failure mode 171  
 cohesive law 182–183, 208  
 cohesive zone modelling 192, 205–208  
 cohesive zone models (CZMs) 182, 205  
 Compliance Based Beam Method (CBBM) 96–97  
 Compliance Calibration Method (CCM) 94  
 composite materials 8, 12, 48, 62–64, 129, 179–180, 202, 204  
 contact angle 33–34, 36, 46–47, 129–131  
 containers, adhesive 111  
 continuous mechanics 168  
 conventional fastening 239  
 Corona discharge treatment (CDT) 64, 65  
 Corrected beam theory (CBT) 96  
 crack propagation 70, 73, 78, 94, 102, 143–144, 206, 223, 225, 227–229  
 crash resistant adhesives 78, 87, 88, 236  
 creep 80, 81, 84, 229–233, 243–244  
 creep tests 128, 230, 232, 244, 247  
 critical stress intensity factor 93  
 curing cycle 121, 124  
 curing method 75  
 curing reaction 108–109
- d**
- damping factor 136  
 data processing algorithm 146  
 data reduction schemes 94  
 degree of elasticity 172  
 destructive testing 138  
 fractography analysis 139–141  
 proof testing 139  
 deviatoric stress condition 88  
 dielectric heating technique 122  
 differential scanning calorimetry (DSC) 134–136  
 differential straining 172–173  
 diffusion theory 41  
 direct beam theory (DBT) 96  
 diverse flammable products 156  
 dogbone 219–220  
 dogbone shape 89, 128, 129, 232  
 double cantilever beam (DCB) 94, 98, 104, 182, 219  
 test 94, 95, 97, 102, 182  
 double lap joint (DLJ) 170, 173–174  
 Dupré analysis 35  
 dynamic mechanical analysis (DMA) 100, 134, 136  
 Dyne pen test 34, 47, 129
- e**
- ecological footprint 1, 13, 15  
 eddy current test 145  
 elastomeric adhesives 73, 81  
 elastomers 48, 70, 72–74, 81  
 electromechanical impedance spectroscopy (EMIS) 146–148  
 electronegativity 52  
 electrostatic theory 37, 41–42  
 end loaded split (ELS) test 97  
 end notch flexure (ENF) test 96, 97, 102, 104, 219  
 energy dispersive X-ray spectroscopy (EDS) 139  
 environmental effects  
   hygrothermal ageing 214–220  
   temperature 220–221  
 environmental protection 164  
   air 165  
   soil 166  
   water 165  
 Environmental Risk Prevention Program (ERPP) 158

- epoxy adhesives 69, 77–78, 86–88, 160, 194, 198, 202–206, 236, 240  
 epoxy resins 69, 78, 82, 160, 161  
 evaporation based processes 125–126  
 exothermal reaction 75, 113  
 extreme temperature testing 99–100
- f**  
 failure, adhesive 27, 128, 140, 170–171, 176, 178, 198, 202, 220, 238  
 fatigue 221  
   crack growth rate 228  
   crack propagation 225, 229  
   failure 222  
 fatigue life (S-N) approach 223–225, 227  
 Fick's law 100, 215–217  
 film adhesives 116  
 finishing steps 126  
 finite element analysis (FEA) 180–181, 183, 192, 205, 208, 209  
 finite element method (FEM) 180, 225, 233  
 flame treatment 62–63, 65  
 flexible cooling circuits 241–243  
 flow-drill screwing 12  
 Fourier-transform infrared spectroscopy (FTIR) 134, 136–137, 218  
 fractography analysis 139–141  
 fracture crack growth (FCG) approach 101–102  
 fracture energy 49–50, 88, 93–94, 96–97, 105, 128, 182–183, 219–221, 227–228  
 fracture mechanics tests 128, 219, 221, 227  
 fracture process zone 96  
 fracture tests  
   mixed mode 97–99  
   mode I 94–96  
   mode II 96–97  
 friction stir welding 12
- g**  
 gamma-ray 145  
 gas metal arc welding (GMAC) 12  
 glass transition temperature 41, 100, 215
- Goland and Reissner model 173, 174, 176, 179, 203–205  
 grip punch-riveting 12
- h**  
 handheld thermocouple thermometer 134–135  
 handling adhesives 153  
   pictograms 154–157  
   training for 157, 160  
 hardening method  
   by chemical reaction 75, 76  
   via physical process 76  
 Hart-Smith model 175, 176, 186  
 hazardous characteristics  
   acrylic adhesives 161  
   aromatic adhesives 161–162  
   epoxy resins 160–161  
   phenolic adhesives 161  
   polyurethanes 161  
 heat curing adhesives 121  
 heat curing processes 121–125  
 hetero-adhesion 41  
 hot glues 69, 71, 76  
 hot melt adhesives 82–83, 162  
 hybrid adhesive 70, 78  
 hybrid materials 72–74  
 hygrothermal ageing 214–220
- i**  
 immersion process 53  
 induction heating technique 122  
 inorganic adhesives 83, 162  
 interfacial disbonding 149  
 inverse method 183
- j**  
 joint assembly 119, 121  
   adhesive thickness 119  
   moulds and fixtures 117–119  
 joint strength  
   prediction 180–183
- k**  
 Kellopsos 3  
 Kelvin model 233

***l***

- Lamb wave based testing 146, 148
- laser based testing 149–150
- laser beam welding 12
- linear-elastic fracture mechanics (LEFM)
  - analysis 93, 99
- liquid adhesives 34, 79, 114–115
- liquid-gas interface 34
- load cycle 222, 228
- loading conditions
  - creep 229–233
  - fatigue 221–229

***m***

- manual cleaning 51, 53
- manufacturing process, quality control 133–137
- Maxwell approach 233
- mechanical extensometer 90
- mechanical testing 88–102
- mechanical theory 37–40
- methyl methacrylates 80, 86
- Mixed Mode Bending (MMB) 98, 227
- mixed-mode loading 92, 168
- modern adhesive
  - composition of 69–70
- monomers 70, 121, 161
- mutagenic products 154

***n***

- Nadai correction 93
- nanoscale scanning tip 139
- neoprene-phenolic adhesives 80
- nitrile-phenolic adhesives 80
- non-destructive tests
  - acoustic emission test 143–144
  - eddy current test 145
  - electromechanical impedance spectroscopy (EMIS) 146–148
- Lamb wave based testing 146, 148
- laser based testing 149–150
- radiography test 144–145
- tap test 142–143
- thermal infrared method 146, 147
- ultrasonic test 143
- visual inspection 141–142

**non-polar agents** 52

- non-structural adhesives 81, 83
  - hot melt adhesives 162
  - inorganic adhesives 162
  - polyesters 162
  - synthetic rubbers 162
- numerical methods 180–183, 232

***o***

- optical extensometer 90
- organic chemistry 83
- overflow, adhesive 110, 141
- overlap length effect
  - and adherend strength 186–187
  - and adhesive behaviour, 185–186
  - and composite adherends 187
  - temperature effect 187–189
  - thermal stresses 187–189
- oxidizing agents 156, 157

***p***

- paint primer 5
- Paris law 101, 102, 228, 229
- Paris' law approach 101, 102
- passive chemical processes 51, 53
  - immersion process 53–54
  - manual cleaning 53
  - spray methods 54
  - ultrasound degreasing process 55
  - vapour degreasing method 54–55
- passive mechanical processes 55
  - manual abrasion 56, 68
  - shot blasting 56–58
  - vibration surface treatment process 58
- paste adhesives 74, 115–116
- personal protective equipment (PPE) 154, 156–160, 162
- phenolic adhesives 80, 138, 161
- phosphatization 59
- physical ageing 217, 220, 223
- physical-chemical processes 62
  - Corona discharge treatment 64–65
  - flame treatment 62–63
  - plasma treatment 63–64
- pictograms 154–157
- piezoelectric transducers 146

- plastic deformation 4, 5, 12, 89, 93, 174–178, 192, 197, 198, 200, 208
- plasticisation process 218
- Poisson's coefficient 205
- polar agents 52
- polyester adhesives 82
- polyesters 82, 162
- polyethylene terephthalate (PET) 82
- polymeric adherends 6, 249
- polymerization process 70
- polyurethane adhesives 78–79, 109, 177, 193
- polyurethanes 78–82, 86, 87, 109, 110, 159, 161, 169, 172, 176, 177, 186, 192–194, 236, 248
- post-treatment surface 67–68
- pressure sensitive adhesives (PSAs) 37, 41, 75–77, 117, 120
- pressure sensitive tape adhesives (PSA) 41
- primer 2, 5, 65–67, 78, 86, 238, 247
- primers promoters 65–67
- proof testing 139
- q**
- quality assessment 127–129, 139, 142, 149, 150
- quality control
- manufacturing process 137
  - on bonded structures 137–150
- quasi-static testing conditions 98
- r**
- R ratio 102, 222
- radiography test 144–145
- recycling 152, 166
- repairability 152
- resistance spot welding 12
- roller hemming 12
- rollover tests 139
- room temperature vulcanizing (RTV) 239–242
- rotational viscometer 128
- s**
- sandwich structures 10, 78
- saturated polyester adhesives 82
- scanning electron microscopy (SEM) 139–141
- self-adhesion 41, 50
- semi-hollow punch-riveting 12
- shear stress distribution 87, 92, 93, 172, 173, 185, 189
- shear testing 91–93
- shot blasting 55, 56–58
- shrinkage 77, 78, 124, 125, 138
- silicone rubbers 81
- single lap joints (SLJ) 91, 117, 140, 168, 170–174, 176, 179, 181, 192, 201, 202, 205, 207, 209, 225
- Single Leg Bending (SLB) 98
- smart adhesive bonding 152
- spray methods 54
- strength tests 89–93, 128, 183, 219
- stress-life (S-N) approach 101
- structural adhesives 2, 4, 8, 69, 74, 75, 77–83, 101, 102, 105, 160–162, 169, 239
- substrate materials, classes
- composites 48–49
  - metals 47
  - other materials 49
  - polymers 47–48
- super glue 69, 79
- surface energy 34–38, 47, 49, 59, 61–63, 68, 77, 78, 119, 129–131, 242, 249
- surface free energy 33, 51, 131
- surface preparation 162, 164
- active processes 59–65
  - classes of substrate materials 47–49
  - classification of 50–51
  - objectives of 45–47
  - over evaluation of 47
  - passive processes 51–58
  - post-treatment, conservation of 67–68
  - primers and adhesion promoters 65–67

surface roughness 31–32, 57, 59,  
131–133

surface tension 34–36, 65, 115

sustainable application 151

swelling, adhesive 218

synthetic rubbers 162

## **t**

tackifiers 76, 77

tap test 142–143

tapes 18, 74, 77, 117

tensile stress 172

tensile testing 89–91, 93, 99, 129,  
202

thermal infrared method 146, 147

thermally expandable particles (TEPs)  
152

thermography method 146

thermoplastics 41, 70–72, 82, 220

thermosets 70, 71, 78, 220

thick adherend shear test (TAST) 91–93,  
104, 128, 219

thread locking adhesives 76, 79

threshold energy 228

time temperature superposition 243–244

toxicity 53, 82, 153, 164

tungsten inert gas (TIG) welding 12

## **u**

ultrasonic test 143, 146

ultrasound degreasing process 55

ultraviolet (UV) light 76

ultraviolet (UV) radiation 108

uniform stress distribution 5, 6, 89, 186  
unsaturated polyester adhesives 82

## **v**

van der Waals bonds 38

van der Waals forces 28, 38, 77

vapour degreasing method 54, 55

variable amplitude fatigue loading 222,  
223

vibration surface treatment process 58

vinyl-phenolic adhesives 80

viscoelasticity effect 233

viscosity 36, 38, 45, 69, 70, 74, 108, 109,  
114, 115, 128, 134, 247

visual inspection 126, 141–142

## **w**

water absorption 100, 214–218

water break test 34, 130

water desorption 217–218

water striders 34

welding methods 239

wettability 31–35, 38, 45, 46, 63, 128,  
129–131, 247

wiping 52, 53

wooden construction 17–18

## **x**

X-ray 139, 145

## **y**

yield stress 89, 92, 175, 176, 182

Young's equation 33, 35, 131

Young's modulus 90

