Ref. 668.3 ADHb

Contents

Contributor contact details xiii

Part I Fundamentals of adhesive bonding

1 History of adhesive bonding 3
P A FAY, UK

1.1 Early days 3
1.2 The industrialisation of glue making 10
1.3 The advent of synthetic polymers 15
1.4 References 19

2 What are adhesives and sealants and how do they work? 23
J COMYN, Loughborough University, UK

2.1 Introduction 23
2.2 Adhesives which harden by loss of solvent 24
2.3 Adhesives which harden by loss of water 24
2.4 Adhesives which harden by cooling 26
2.5 Adhesives which harden by chemical reaction 27
2.6 Adhesives which do not harden – pressure-sensitive adhesives 34
2.7 Adhesion by physical adsorption 35
2.8 Adhesion by chemical bonding 41
2.9 The electrostatic theory of adhesion 45
2.10 Mechanical interlocking 45
2.11 Adhesion by interdiffusion 45
2.12 Weak boundary layers 47
2.13 Pressure-sensitive adhesion 47
2.14 Future trends 49
2.15 Sources of information 49
2.16 References 50

3 Surfaces: how to assess 52
J F WATTS, University of Surrey, UK

3.1 Introduction 52
3.2 Surface topography 53
3.3 Surface thermodynamics 64
3.4 Surface chemical analysis 67
3.5 Concluding remarks 73
3.6 Acknowledgements 73
3.7 References 73

4 Surfaces: how to treat 75
D BREWIS, Loughborough University, UK

4.1 Introduction 75
4.2 Pretreatments for metals 76
4.3 Pretreatments for inorganic materials 78
4.4 Pretreatments for plastics 80
4.5 Pretreatments for elastomers 85
4.6 Summary and future trends 86
4.7 Literature 87
4.8 References 87

Part II Mechanical properties

5 Stress analysis 91
A CROCOMBE, University of Surrey, UK

5.1 Introduction 91
5.2 A qualitative description of adhesive joint stresses 91
5.3 Closed form, global stress analysis of adhesive joints 97
5.4 Finite element analyses of adhesive joints 107
5.5 Future developments 118
5.6 References 119

6 Environmental (durability) effects 123
J COMYN, Loughborough University, UK

6.1 Introduction 123
6.2 Additives to reduce photo-oxidative degradation 123
6.3 Behaviour of structural joints to metals in wet surroundings 125
6.4 Water and adhesives 133
6.5 Water and adhesive interfaces 137
6.6 Other fluids 140

6.7	Timber joints	140
6.8	Future trends	140
6.9	Further information	141
6.10	References	141
7	Non-destructive testing P CAWLEY, Imperial College, UK	143
7.1	Introduction	143
7.2	Conventional ultrasonics	145
7.3	Bond testers	152
7.4	Rapid scanning methods	154
7.5	Cohesive property measurement	159
7.6	The interface problem and monitoring environmental degradation	160
7.7	Conclusions	161
7.8	References	161
8	Impact behaviour of adhesively bonded joints C SATO, Tokyo Institute of Technology, Japan	**164**
8.1	Introduction	164
8.2	Experimental method for impact test of adhesives and adhesively bonded joints, and characteristics of adhesives under high rate loading	165
8.3	Stress distribution and variation in adhesively bonded joints subject to impact load	181
8.4	Actual joint design considering impact load	185
8.5	Future trends and further information	187
8.6	Conclusion	187
8.7	References	187
9	Fracture mechanics of adhesive bonds D A DILLARD, Center for Adhesive and Sealant Science, USA	189
9.1	Introduction	189
9.2	An energy criterion for failure	190
9.3	The stress intensity factor approach	191
9.4	The energy release rate approach	194
9.5	Thermodynamic, intrinsic, and practical adhesion energy	196
9.6	The effect of mode mixity	197
9.7	Experimental evaluation of fracture energy	199
9.8	Durability	201
9.9	Designing with fracture mechanics	202
9.10	Recent developments and current research areas	203

9.11 Conclusions 205
9.12 References 205

10 Fatigue 209
I A ASHCROFT, Loughborough University, UK

10.1 lntroduction 209
10.2 The stress-life approach 213
10.3 The fatigue crack growth (FCG) approach 226
10.4 Summary and future trends 235
10.5 Further information 236
10.6 References 237

11 Vibration damping 240
M HILDEBRAND, FY-Composites Oy, Finland

11.1 lntroduction 240
11.2 Damping in joints 241
11.3 Prediction methods of vibration damping 242
11.4 Experimental data on vibration damping of adhesively bonded joints 244
11.5 Future trends 251
11.6 References 252

Part III Applications

12 Joining similar and dissimilar materials 257
E J C KELLAR. The Welding Institute, UK

12.1 lntroduction 257
12.2 Joint design 258
12.3 Adhesive selection 265
12.4 Surface pre-treatments 268
12.5 Assembly issues and hybrid joining 270
12.6 Future trends 275
12.7 Bibliography 277

13 Bonding of composites 279
P DAVIES, Materials and Structures Group, France

13.1 lntroduction 279
13.2 The specific nature of composite materials 279
13.3 Design of bonded composite assemblies 280
13.4 Surface preparation 285
13.5 Testing 287

13.6 Influence of bondline thickness 291
13.7 Examples of bonded composite structures 291
13.8 Durability and long-term performance 296
13.9 Future trends 296
13.10 Sources of information 300
13.11 References 301

14 Building and construction – steel and aluminium 305
IJ J VAN STRAALEN, TNO Environment and Geosciences, The Netherlands AND M J L VAN TOOREN, Delft University of Technology, The Netherlands

14.1 Basic needs 305
14.2 Adhesive characteristics required 306
14.3 Surface preparation 309
14.4 Strength and durability 311
14.5 Common failures 319
14.6 Inspection, testing and quality control 320
14.7 Repair and strengthening 324
14.8 Other industry-specific factors 325
14.9 References 327

15 Building and construction –timber 328
E SERRANO AND B KALLANDER, SP Swedish National Testing and Research Institute, Sweden

15.1 Introduction and overview 328
15.2 Basic needs and applications 328
15.3 Wood characteristics 331
15.4 Adhesive characteristics needed 333
15.5 Surface preparation and bond formation 337
15.6 Strength and durability 339
15.7 Common failures 345
15.8 Inspection, testing and quality control 346
15.9 Repair 348
15.10 Examples of use 348
15.11 Future trends and further reading 351
15.12 References 354

16 Automobiles 357
K DILGER, Technische Universitat Braunschweig, Germany

16.1 Introduction 357
16.2 Basic needs 358

16.3 Adhesive characteristics required 371
16.4 Surface preparation 375
16.5 Strength and durability 377
16.6 Common failures 380
16.7 Inspection, testing and quality control 381
16.8 Repair and recycling 381
16.9 Other industry-specific factors 381
16.10 Examples of use 382
16.11 References 383

17 Boats and marine 386
M HENTINEN, VTT Industrial Systems, Finland

17.1 Introduction 386
17.2 Basic needs 386
17.3 Adhesive characteristics required 393
17.4 Surface preparation 397
17.5 Strength and durability 399
17.6 Common failures 404
17.7 Inspection, testing and quality control 404
17.8 Repair 405
17.9 Examples of use 405
17.10 Future trends 415
17.11 References 416

18 Shoe industry 417
J M MARTÍN-MARTÍNEZ, University of Alicante, Spain

18.1 Introduction 417
18.2 Upper materials in shoes 419
18.3 Sole materials in shoes 421
18.4 Types of adhesive used in shoes 424
18.5 Solvent-borne polyurethane adhesives 424
18.6 Waterborne polyurethane adhesives 428
18.7 Polychloroprene (neoprene) adhesives 433
18.8 Waterborne polychloroprene adhesives 436
18.9 Testing, quality control and durability 439
18.10 Future trends 442
18.11 Acknowledgements 449
18.12 References 449

19 Electrical 455
J-A PETIT AND V NASSIET, Ecole Nationale d'Ingénieurs de Tarbes, France

19.1 Introduction 455
19.2 Basic needs 456
19.3 Adhesive characteristics 458
19.4 Surface preparation 466
19.5 Strength and durability: reliability 468
19.6 Common failures 473
19.7 Inspection, testing and quality control 476
19.8 Examples of use 478
19.9 Conclusion 484
19.10 References 485

20 Aerospace 489
L J HART-SMITH, Boeing, USA

20.1 Basic needs 489
20.2 Adhesive characteristics required for design and analysis 490
20.3 Surface preparation 495
20.4 Design of adhesively bonded joints 500
20.5 Design features ensuring durability of bonded joints 505
20.6 Load redistribution around flaws and porosity 509
20.7 Effects of thermal mismatch between adherends on strength of bonded joints 514
20.8 Inspection, testing and quality control 515
20.9 Bonded repairs 520
20.10 Other industry-specific factors 521
20.11 Examples of use of adhesive bonding in aircraft structures 522
20.12 References 525

Index 528