

Contents

Dedication

Biography

Preface

Acronyms

1. Composite analysis overview

1.1. Introduction	1
1.1.1. History of composites	1
1.1.2. Applications of composites in aircrafts	3
1.2. Composite laminates	5
1.2.1. Definition and constituents	5
1.2.2. Plies	6
1.2.3. Laminates	7
1.3. Analysis schemes	9
1.3.1. Basic analysis schemes	9
1.3.2. Basic equations	11
1.3.3. Existing analysis theories	14
1.3.4. Challenges	16
1.3.5. Future developments	19
1.4. General Hooke's law	20
1.4.1. Hyperelastic materials	20
1.4.2. Monoclinic materials	22
1.4.3. Orthotropic materials	22
1.4.4. Isotropic materials	24
1.4.5. Plane stress-reduced constitutive relations	24
1.4.6. Transformation of material coefficients	25
1.5. Energy principles	27
1.5.1. Virtual displacement principle	27
1.5.2. Hamilton's principle	30
1.5.3. Mixed variational principles	31
References	33

2. Shear deformation theories

2.1. Introduction	35
2.2. Classical laminated plate theory	36
2.2.1. Displacement fields	36
2.2.2. Kinematic equation	38
2.2.3. Constitutive equations	42
2.2.4. Governing equations	45
2.3. First-order shear deformation theory	47
2.3.1. Displacement fields	47

5.5.1.	The fast uniform-grid delamination scheme	208
5.5.2.	Delamination region identification	209
5.5.3.	Numerical examples	212
5.6.	Microfracture analysis of composite laminates	220
5.6.1.	Force-bearing mechanisms of fibers	220
5.6.2.	Modeling scheme	220
5.6.3.	Fibers modeling	222
5.6.4.	Governing equations	223
5.6.5.	Numerical examples	225
	References	231
6.	Multiphysical analysis	235
6.1.	Introduction	235
6.2.	Thermomechanical analysis	236
6.2.1.	Variational principles considering temperature effect	236
6.2.2.	Displacement fields	238
6.2.3.	Euler equations	239
6.2.4.	Constitutive equations	241
6.2.5.	Finite element formulations	243
6.2.6.	Time integrations	245
6.2.7.	Evaluation of SIF for thermomechanical dynamic problems	247
6.2.8.	Numerical examples	248
6.3.	Piezoelectric analysis	250
6.3.1.	Displacement and potential fields	250
6.3.2.	Electromechanical variational principle	252
6.3.3.	Constitutive equations	253
6.3.4.	Finite element formulation	256
6.3.5.	Coupling modeling of laminated plates with piezoelectric patch	258
6.3.6.	Thermo-electromechanical dynamic analysis	260
6.3.7.	Numerical examples	266
6.4.	Chemo-thermomechanical analysis	276
6.4.1.	Chemo-thermomechanical fields	276
6.4.2.	Hamilton principle and Euler equations	277
6.4.3.	Constitutive equations	279
6.4.4.	Finite element formulations	282
6.4.5.	Times integration	285
6.4.6.	Chemomechanical analysis	286
6.4.7.	Numerical examples	287
	References	295
7.	Analysis of complex composites	297
7.1.	Introduction	297
7.2.	Layerwise/solid-element method of composite stiffened shells	299
7.2.1.	Modeling scheme	299
7.2.2.	Finite element formulations of the stiffener	300

7.2.3.	LW/SE method	301
7.2.4.	Numerical examples	302
7.3.	Dynamic thermomechanical analysis of stiffened plates	307
7.3.1.	Dynamic thermomechanical three-dimensional elements	307
7.3.2.	Dynamic thermomechanical XLW/SE	309
7.3.3.	Numerical examples	312
7.4.	Analysis methods of sandwich structures	316
7.4.1.	DLWM for the sandwich plates	316
7.4.2.	Layerwise/solid-element of composite sandwich plates	316
7.4.3.	LW/SE of sandwich plates with multilayer cores	321
7.4.4.	Modeling of the sandwich structures	323
7.4.5.	Numerical examples	324
7.5.	Dynamic thermomechanical analysis of sandwich plates	332
7.5.1.	LW/SE method of sandwich plates with single core	332
7.5.2.	LW/SE method of sandwich plates with multiply cores	337
7.5.3.	Numerical examples	341
7.6.	Dynamic thermo-chemomechanical coupling analysis on aeroengine turbine	346
7.6.1.	Three-dimensional thermo-chemomechanical formulations	346
7.6.2.	Transformation of coordinate system	349
7.6.3.	Modeling of aeroengine turbine with TBCs	351
7.6.4.	Numerical examples	357
	References	363
8.	Progressive failure analysis	365
8.1.	Introduction	365
8.2.	Continuous damage mechanics analysis framework	366
8.2.1.	Damage constitutive	366
8.2.2.	Damage initiation	367
8.2.3.	Damage evolution law	372
8.3.	Progressive failure analysis of low-velocity impact	373
8.3.1.	Mathematic model of impact problem	373
8.3.2.	Contact force based on Hertz's law	375
8.3.3.	FEM implementation	376
8.3.4.	Numerical examples	377
8.4.	Progressive failure analysis of composites	382
8.4.1.	Discrete damage zone model	382
8.4.2.	DDZM-XLWM	384
8.4.3.	Fatigue analysis based on DDZM-XLWM	389
8.4.4.	Fatigue parameters	393
8.4.5.	Numerical examples	397
8.5.	Progressive thermomechanical DDZM-XLWM	408
8.5.1.	Problems descriptions	408
8.5.2.	Interfacial heat transfer	408
8.5.3.	Governing equations	410

8.5.4. Numerical examples	414
References	421
9. Multiscale analysis	423
9.1. Introduction	423
9.2. Layerwise multiscale analysis method	424
9.2.1. Multiscale analysis based on EST	424
9.2.2. Homogenization method	425
9.2.3. Layerwise multiscale analysis method	428
9.2.4. Implementation	431
9.2.5. Numerical examples	432
9.3. Two-scale C^2 of a laminated curved beams	434
9.3.1. TSDT of curved beams	434
9.3.2. Displacement decomposition	438
9.3.3. Finite element formulations	440
9.3.4. Nonlocal quadrature	443
9.4. Three-scale C^2 of laminated curved beams	444
9.4.1. Displacement decomposition	444
9.4.2. Finite element formulations	446
9.4.3. Numerical examples	452
9.5. C^2 of laminated plates	455
9.5.1. Framework of C^2 for laminated plates	455
9.5.2. Two-scale analysis of laminated plates	459
9.5.3. Three-scale analysis of laminated plates	462
References	467
10. Sensitivity analysis	471
10.1. Introduction	471
10.2. Sensitivity analysis based on FEM	472
10.2.1. Static responses	472
10.2.2. Frequency and mode shape	473
10.3. Evaluation methods	475
10.3.1. AM	476
10.3.2. FDM	476
10.3.3. SAM	477
10.3.4. Step sizes of SAM and FDM	477
10.4. Sensitivity analysis based on SST	482
10.4.1. Hybrid governing equations	482
10.4.2. Hybrid governing equation of bonding imperfection problems	484
10.4.3. Implement of sensitivity analysis	486
10.4.4. Numerical examples	488
References	493
11. Analysis codes	495
11.1. Overall framework	495

11.2. Data structures and pre/post process	496
11.2.1. Matrix storage formats	496
11.2.2. Preprocess	497
11.2.3. Post-process tool	500
11.3. Solver models	502
11.3.1. <i>Solver_sdt</i>	502
11.3.2. <i>Solver_sst</i>	504
11.3.3. <i>Solver_rlw</i>	505
11.3.4. <i>Solver_xlw</i>	506
References	509

Index	511
-------	-----