

Contents

Preface

vii

1 Introduction

1

2 Anisotropic material

7

2.1 Notation of coordinate system	7
2.2 Hooke's law	8
2.3 Voigt notation	9
2.4 Generally anisotropic material	11
2.5 Orthotropic material	12
2.6 Transversely isotropic material	16
2.7 Isotropic material	17

3 Lamina

19

3.1 Constituent volume ratio	19
3.2 Constituent mass ratio	20
3.3 Composite density	20
3.4 Lamina thickness	22
3.5 Netting theory	23

3.6	Determination of elastic constants	25
3.6.1	Young's modulus in longitudinal direction	25
3.6.2	Young's modulus in transverse direction	27
3.6.3	Poisson's ratio	28
3.6.4	Shear modulus	29
3.7	Transformation of lamina properties	30
3.8	Reduced compliance matrix	33
3.9	Transformed reduced compliance matrix	34
3.10	Reduced stiffness matrix	35
3.11	Transformed reduced stiffness matrix	36
3.12	Polar plots	37
3.13	Transformation matrix in 3D	40
4	Material data	41
5	Mikromechanical models	59
5.1	Fibre arrangement	62
5.2	Phenomenological models	65
5.2.1	Voigt model	67
5.2.2	Reuss model	68
5.2.3	Ekvall model	71
5.2.4	Hart-Smith model	72
5.2.5	Krenchel factor	73
5.3	Semi-empirical models	80
5.3.1	Modified rule of mixture	80

5.3.2	Hill notation	82
5.3.3	Halpin-Tsai equations	84
5.3.4	Spencer model	90
5.3.5	Nielsen model	92
5.3.6	Noga-Woodhams model	96
5.3.7	Sedleckyj model	99
5.3.8	Smith model	100
5.3.9	Hewitt-Malherbe model	101
5.3.10	Tsai model	103
5.3.11	Tsai-Hahn model	107
5.3.12	Hopkins-Chamis model	110
5.3.13	Chamis model	115
5.3.14	Foye model	118
5.3.15	Shaffer model	119
5.3.16	Jacquet models	120
5.3.17	Moraes model	121
5.3.18	Huber model	122
5.3.19	Wilczynski model	123
5.4	Elasticity approach models	134
5.4.1	CCA model	134
5.4.2	Hashin model	138
5.4.3	Hashin-Rosen model	139
5.4.4	Hashin-Shtrikman model	148
5.4.5	Whitney-McCullough model	150

5.4.6	Christensen model	151
5.4.7	Christensen-Lo model	155
5.4.8	Hahn model	158
5.4.9	Hermans model	161
5.4.10	Self-consistent model	163
5.4.11	Mori-Tanaka model	165
5.4.12	Bridging model	166

Conclusion

179

References

181

Index

185

5.1.1.3	Transformation matrix in 3D	111
5.1.2	Material data	111
5.1.3	Film-mechanical models	59
5.1.3.1	Fibre arrangement	62
5.1.3.2	Phenomenological models	63
5.1.3.3	Voigt model	63
5.1.3.4	Reuss model	63
5.1.3.5	Eikvil model	63
5.1.3.6	Hart-Smith model	63
5.1.3.7	Koenich factor	63
5.1.3.8	Semi-empirical models	63
5.1.3.9	Modified rule of mixtures	63