

---

# Contents

---

<b>Preface</b> .....	ix
<b>Introduction</b> .....	xi
<b>Chapter 1. Basic Tools for Reliability Analysis</b> .....	1
1.1. Introduction .....	1
1.2. Advantages of numerical simulation and optimization .....	2
1.3. Numerical simulation by finite elements .....	3
1.3.1. Use .....	3
1.3.2. Principle .....	4
1.3.3. General approach .....	5
1.4. Optimization process .....	6
1.4.1. Basic concepts .....	7
1.4.2. Problem classification .....	10
1.4.3. Optimization methods .....	22
1.4.4. Unconstrained methods .....	23
1.4.5. Constrained methods .....	43
1.5. Sensitivity analysis .....	56
1.5.1. Importance of sensitivity .....	56
1.5.2. Sensitivity methods .....	57
1.6. Conclusion .....	61
<b>Chapter 2. Reliability Concept</b> .....	63
2.1. Introduction .....	63
2.1.1. Preamble .....	63
2.1.2. Reliability history .....	63

2.1.3. Reliability definition . . . . .	65
2.1.4. Importance of reliability . . . . .	66
2.2. Basic functions and concepts for reliability analysis . . . . .	66
2.2.1. Failure concept . . . . .	67
2.2.2. Uncertainty concept . . . . .	67
2.2.3. Random variables . . . . .	68
2.2.4. Probability density function . . . . .	69
2.2.5. Cumulative distribution function . . . . .	69
2.2.6. Reliability function . . . . .	70
2.3. System reliability . . . . .	71
2.3.1. Series conjunction . . . . .	71
2.3.2. Parallel conjunction . . . . .	72
2.3.3. Mixed conjunction . . . . .	73
2.3.4. Delta-star conjunction . . . . .	74
2.4. Statistical measures . . . . .	77
2.5. Probability distributions . . . . .	81
2.5.1. Uniform distribution . . . . .	82
2.5.2. Normal distribution . . . . .	86
2.5.3. Lognormal distribution . . . . .	91
2.6. Reliability analysis . . . . .	97
2.6.1. Definitions . . . . .	97
2.6.2. Algorithms . . . . .	105
2.6.3. Reliability analysis methods . . . . .	106
2.6.4. Optimality criteria . . . . .	110
2.7. Conclusion . . . . .	112
 <b>Chapter 3. Integration of Reliability Concept into Biomechanics . . . . .</b>	113
3.1. Introduction . . . . .	113
3.2. Origin and categories of uncertainties . . . . .	115
3.3. Uncertainties in biomechanics . . . . .	116
3.3.1. Uncertainty in loading . . . . .	117
3.3.2. Uncertainty in geometry . . . . .	118
3.3.3. Uncertainty in materials . . . . .	118
3.4. Bone-related uncertainty . . . . .	119
3.4.1. Bone behavior law . . . . .	120
3.4.2. Contribution to the characterization of the bone's mechanical properties . . . . .	125
3.5. Bone developments and formulations . . . . .	126
3.5.1. Current formulation . . . . .	126
3.5.2. Generalized formulation . . . . .	127

---

3.5.3. Optimized formulation . . . . .	128
3.5.4. Extension to orthotropic behavior formulation . . . . .	130
3.6. Characterization by experimentation of the bone's mechanical properties . . . . .	133
3.6.1. Characterization by bending test . . . . .	134
3.6.2. Characterization by compression test . . . . .	135
3.7. Conclusion . . . . .	136
<b>Chapter 4. Reliability Analysis of Orthopedic Prostheses . . . . .</b>	<b>137</b>
4.1. Introduction to orthopedic prostheses . . . . .	137
4.1.1. History of prostheses . . . . .	139
4.1.2. Evolution of prostheses . . . . .	139
4.1.3. Examples of orthopedic prostheses . . . . .	140
4.2. Reliability analysis of the intervertebral disk . . . . .	140
4.2.1. Functional anatomy . . . . .	140
4.2.2. The lumbar functional spinal unit . . . . .	141
4.2.3. Intervertebral disk prosthesis . . . . .	145
4.2.4. Numerical application on the intervertebral disk . . . . .	147
4.3. Reliability analysis of the hip prosthesis . . . . .	154
4.3.1. Anatomy . . . . .	154
4.3.2. Presentation of the total hip prosthesis . . . . .	158
4.3.3. Numerical application of the hip prosthesis . . . . .	161
4.3.4. Boundary conditions . . . . .	164
4.3.5. Direct simulation . . . . .	164
4.3.6. Probabilistic sensitivity analysis . . . . .	166
4.3.7. Integration of reliability analysis . . . . .	167
4.4. Conclusion . . . . .	173
<b>Chapter 5. Reliability Analysis of Orthodontic Prostheses . . . . .</b>	<b>175</b>
5.1. Introduction to orthodontic prostheses . . . . .	175
5.2. Anatomy of the temporomandibular joint . . . . .	176
5.2.1. Articular bone regions and meniscus . . . . .	177
5.2.2. Ligaments . . . . .	179
5.2.3. Myology, elevator muscles and depressor muscles . . . . .	179
5.3. Numerical simulation of a non-fractured mandible . . . . .	183
5.3.1. Description of the studied mandible . . . . .	183
5.3.2. Numerical results . . . . .	185

5.4. Reliability analysis of the fixation system of the fractured mandible . . . . .	188
5.4.1. Description of a fractured mandible . . . . .	188
5.4.2. Fixation strategy using mini-plates. . . . .	189
5.4.3. Study of a homogeneous and isotropic structure. . . . .	190
5.4.4. Study of a composite and orthotropic structure . . . . .	198
5.4.5. Result discussion . . . . .	207
5.5. Conclusion . . . . .	208
<b>Appendices . . . . .</b>	<b>209</b>
<b>Appendix 1: Matrix Calculation . . . . .</b>	<b>211</b>
<b>Appendix 2: ANSYS Code for the Disk Implant . . . . .</b>	<b>217</b>
<b>Appendix 3: ANSYS Code for the Stem Implant . . . . .</b>	<b>221</b>
<b>Appendix 4: Probability of Failure/Reliability Index . . . . .</b>	<b>235</b>
<b>Bibliography . . . . .</b>	<b>237</b>
<b>Index . . . . .</b>	<b>245</b>