

---

# Contents

Preface	xi
Acknowledgments	xvii
List of Acronyms	xix
List of Symbols	xxiii
<b>Chapter 1. Material Removal Processes</b>	<b>1</b>
1.1 Introduction	1
1.2 History of Machining	1
1.3 Traditional Machining	5
1.3.1 Machining by cutting	5
1.3.2 Machining by abrasion	6
1.4 Nontraditional Machining	8
1.4.1 Single-action nontraditional machining	9
1.4.2 Hybrid machining	10
References	13
<b>Chapter 2. Mechanical Processes</b>	<b>15</b>
2.1 Ultrasonic Machining	15
2.1.1 Introduction	15
2.1.2 The machining system	15
2.1.3 Material removal process	22
2.1.4 Factors affecting material removal rate	24
2.1.5 Dimensional accuracy and surface quality	26
2.1.6 Applications	28
2.2 Water Jet Machining	32
2.2.1 Introduction	32
2.2.2 The machining system	32
2.2.3 Process parameters	34
2.2.4 Applications	35
2.2.5 Advantages and disadvantages of WJM	38
2.3 Abrasive Jet Machining	39
2.3.1 Introduction	39
2.3.2 Machining system	39
2.3.3 Material removal rate	40
2.3.4 Applications	42
2.3.5 Advantages and limitations of AJM	42

2.4	Abrasive Water Jet Machining	43
2.4.1	Introduction	43
2.4.2	The machining system	44
2.4.3	Process capabilities	45
2.5	Ice Jet Machining	46
2.5.1	Introduction	46
2.5.2	Process description	46
2.6	Magnetic Abrasive Finishing	48
2.6.1	Introduction	48
2.6.2	The machining system	48
2.6.3	Material removal process	49
2.6.4	Applications	50
	References	52
<b>Chapter 3. Chemical Processes</b>		<b>55</b>
3.1	Chemical Milling	55
3.1.1	Introduction	55
3.1.2	Tooling for CHM	57
3.1.3	Process parameters	61
3.1.4	Material removal rate	61
3.1.5	Accuracy and surface finish	62
3.1.6	Advantages	63
3.1.7	Limitations	64
3.1.8	Applications	64
3.2	Photochemical Milling	66
3.2.1	Introduction	66
3.2.2	Process description	66
3.2.3	Applications	67
3.2.4	Advantages	68
3.3	Electropolishing	70
3.3.1	Introduction	70
3.3.2	Process parameters	73
3.3.3	Applications	73
3.3.4	Process limitations	74
	References	75
<b>Chapter 4. Electrochemical Processes</b>		<b>77</b>
4.1	Electrochemical Machining	77
4.1.1	Introduction	77
4.1.2	Principles of electrolysis	77
4.1.3	Theory of ECM	78
4.1.4	ECM equipment	79
4.1.5	Basic working principles	84
4.1.6	Process characteristics	87
4.1.7	Process control	95
4.1.8	Applications	97
4.1.9	Micro-ECM	98
4.1.10	Advantages and disadvantages of ECM	98
4.1.11	Environmental impacts	99
4.2	Electrochemical Drilling	100
4.3	Shaped Tube Electrolytic Machining	102

4.4	Electrostream (Capillary) Drilling	105
4.5	Electrochemical Jet Drilling	108
4.6	Electrochemical Deburring	109
	References	112
<b>Chapter 5. Thermal Processes</b>		<b>115</b>
5.1	Electrodischarge Machining	115
5.1.1	Introduction	115
5.1.2	Mechanism of material removal	115
5.1.3	The machining system	120
5.1.4	Material removal rates	125
5.1.5	Surface integrity	127
5.1.6	Heat-affected zone	129
5.1.7	Applications	130
5.1.8	Process control	137
5.1.9	EDM automation	138
5.1.10	Environmental impact	139
5.2	Laser Beam Machining	140
5.2.1	Introduction	140
5.2.2	Material removal mechanism	141
5.2.3	Applications	144
5.2.4	Advantages and limitations	156
5.3	Electron Beam Machining	157
5.3.1	Introduction	157
5.3.2	Basic equipment and removal mechanism	157
5.3.3	Applications	163
5.3.4	Advantages and disadvantages	165
5.4	Plasma Beam Machining	166
5.4.1	Introduction	166
5.4.2	Machining systems	166
5.4.3	Material removal rate	169
5.4.4	Accuracy and surface quality	169
5.4.5	Applications	171
5.4.6	Advantages and disadvantages	172
5.5	Ion Beam Machining	172
5.5.1	Introduction	172
5.5.2	Material removal rate	173
5.5.3	Accuracy and surface effects	175
5.5.4	Applications	176
	References	177
<b>Chapter 6. Hybrid Electrochemical Processes</b>		<b>181</b>
6.1	Introduction	181
6.2	Electrochemical Grinding	182
6.2.1	Introduction	182
6.2.2	Material removal rate	183
6.2.3	Accuracy and surface quality	187
6.2.4	Applications	188
6.2.5	Advantages and disadvantages	188
6.3	Electrochemical Honing	189
6.3.1	Introduction	189
6.3.2	Process characteristics	189

6.3.3 Applications	191
6.4 Electrochemical Superfinishing	192
6.4.1 Introduction	192
6.4.2 Material removal process	193
6.4.3 Process accuracy	195
6.5 Electrochemical Buffing	196
6.5.1 Introduction	196
6.5.2 Material removal process	196
6.6 Ultrasonic-Assisted ECM	197
6.6.1 Introduction	197
6.6.2 Material removal process	198
6.7 Laser-Assisted ECM	199
References	201
<b>Chapter 7. Hybrid Thermal Processes</b>	<b>203</b>
7.1 Introduction	203
7.2 Electroerosion Dissolution Machining	204
7.3 Electrodischarge Grinding	212
7.4 Abrasive Electrodischarge Machining	216
7.5 EDM with Ultrasonic Assistance	218
7.6 Electrochemical Discharge Grinding	221
7.7 Brush Erosion-Dissolution Mechanical Machining	224
References	226
<b>Chapter 8. Material Addition Processes</b>	<b>229</b>
8.1 Introduction	229
8.2 Liquid-Based Techniques	230
8.2.1 Stereolithography	230
8.2.2 Holographic interference solidification	232
8.2.3 Beam interference solidification	232
8.2.4 Solid ground curing	233
8.2.5 Liquid thermal polymerization	235
8.2.6 Fused deposition modeling	235
8.2.7 Multijet modeling	238
8.2.8 Ballistic particles manufacturing	239
8.2.9 Shape deposition manufacturing	240
8.3 Powder-Based Processes	241
8.3.1 Selective laser sintering	241
8.3.2 Laser engineered net shaping	242
8.3.3 Three-dimensional printing	243
8.4 Solid-Based Techniques	244
8.4.1 Solid foil polymerization	244
8.4.2 Laminated object modeling	245
References	246
Index	249