

Contents

1	Introduction	1
1.1	The Economic Significance of Machine Tools	4
1.2	Historical Development of Machine Tools	7
1.3	Basic Demands on Machine Tools	10
1.4	Categorizing Manufacturing Processes and Machine Tools by Description	11
1.4.1	Subdividing Manufacturing Processes	11
1.4.2	Categorization of Machine Tools	11
1.4.3	Designation of Machine Tools	12
1.5	Basic Principles of Machine Tool Automation	14
	References	19
2	Primary Forming Machines and Systems	21
2.1	Cost-Effective Machining of Cast Parts	25
2.2	Systems for Expendable-Mold Casting	26
2.3	Systems for Casting Using Permanent Molds	28
2.3.1	Centrifugal Casting Machines	28
2.3.2	Die Casting Machines	28
2.3.3	Continuous Casting Machines	30
2.3.4	Systems for Fettling	31
2.4	Systems for Sintering	33
2.5	Systems for Casting Reaction Resin Concrete	34
2.6	Machines for Additive Manufacturing	38
	References	39
3	Forming and Severing Machines	41
3.1	Forming Machines	44
3.1.1	Hammers	49
3.1.2	Screw Presses	53
3.1.3	Eccentric and Crank Presses	59
3.1.4	Toggle Presses	73
3.1.5	Wedge Presses	74
3.1.6	Hydraulic Presses and Forming Machines Using Hydraulic Principles of Operation	76
3.1.7	Servo Presses	84
3.1.7.1	Servo Presses in Monoblock / Tie Rod Design (Direct Drive)	86
3.1.7.2	Toggle Presses with Servo Drive	86
3.1.8	Radial Forging Machines	87
3.1.9	Rolling Machines	88
3.1.9.1	Stretch Rolling Machines	88
3.1.9.2	Cross Rolling Machines	88
3.1.9.3	Ring Rolling Machines	89
3.1.9.4	Closed-Die Rolling Machines	90
3.1.9.5	Pressure Rolling Machines	91
3.1.9.6	Reverse Pressure Rolling Machines	92
3.1.9.7	Spin Forming Machines	94
3.1.10	Bending Machines	95
3.1.10.1	Press Brakes	95
3.1.10.2	Automatic Bending Cells	96
3.1.10.3	Sheet Round Bending Machines	97
3.1.10.4	Swivel Bending Machines	99
3.1.11	Drawing Machines	100
3.1.12	Straightening Machines	102
3.1.13	Guards and Safety Devices on Forming Machines	104

3.2	Severing Machines	106
3.2.1	Shearing Machines	107
3.2.2	Cutting Presses	107
	References	111
4	Metal Cutting Machines for Tools with Geometrically Defined Cutting Edge (Chip Removal)	113
4.1	Sawing Machines	116
4.1.1	Hacksawing Machines	118
4.1.2	Band Sawing Machines	119
4.1.3	Circular Sawing Machines	120
4.1.4	Sawing Centers	122
4.2	Drilling Machines	122
4.2.1	Pillar Drilling Machines	122
4.2.2	Cantilever Drilling Machines	125
4.2.3	Deep Drilling Machines	125
4.3	Milling Machines and Machining Centers	132
4.3.1	Machines with Horizontal Tool Spindle	134
4.3.1.1	Machines with Cross-Bed Design	134
4.3.1.2	Machines with Moving Column Design	139
4.3.2	Machines with Vertical Tool Spindle	140
4.3.2.1	Machines with Moving Column Design	141
4.3.2.2	Knee-and-Column Design Machines	142
4.3.2.3	Portal Milling Machines	143
4.3.2.4	Machines with Modified Gantry Design	144
4.3.2.5	Special Machining Center Designs	146
4.3.3	Machines with Parallel Kinematic Structures	147
4.4	Lathes	152
4.4.1	Universal or Workshop Lathes	155
4.4.2	Automatic Lathes	155
4.4.3	Sliding Headstock Lathe	158
4.4.4	Multi-Carriage Automatic Plunge-Cut Lathes	159
4.4.5	Multi-Spindle Automatic Lathes	160
4.4.6	Lathes with Vertical Spindle	163
4.4.7	Large-Scale Lathes	165
4.4.7.1	Horizontal Large-Scale Lathes	165
4.4.7.2	Vertical Large-Scale Lathes	168
4.4.7.3	Bar Peeling Machines	168
4.4.8	High-Precision and Ultra-Precision Lathes	172
4.4.9	Combination Machines	174
4.4.9.1	Milling-Turning Center	174
4.4.9.2	Turning-Grinding Machine	174
4.5	Slotting and Drawing Machines	174
4.6	Broaching Machines	177
4.6.1	Internal Broaching Machines	178
4.6.2	External Broaching Machines	182
	References	184
5	Metal Cutting Machines for Tools with Geometrically Undefined Cutting Edges (Chip Removal)	185
5.1	Grinding Machines	189
5.1.1	Cylindrical Grinding Machines	190
5.1.2	Face Grinding Machines	195
5.1.3	Tool Grinding Machines	196
5.1.4	Dressing Systems	197
5.1.5	Balancing Units	203
5.1.6	Measuring Equipment	205

5.2	Honing Machines	206
5.3	Lapping Machines	211
5.3.1	Conventional Lapping Machines	211
5.3.2	Ultrasonic Lapping Machines	213
5.4	Machines for Mechanical Deburring	216
5.5	Slide Grinding Machines	216
5.6	Water Jet Cutting Systems	218
	References	221
6	Material Removal Machines	223
6.1	Chemical Etching Systems	226
6.2	Electrochemical Machining Systems	227
6.3	EDM Machines	232
6.3.1	EDM Sinking Machines	232
6.3.2	EDM Cutting Machines	238
6.4	Systems for Thermal Removal by an Electron Beam	240
6.5	Thermo-Chemical Deburring Machines	242
	References	246
7	Machines for Laser Machining	247
7.1	Laser Beam Sources	250
7.1.1	Gas Lasers (CO ₂ Lasers)	253
7.1.2	Solid-State Lasers	255
7.1.2.1	Rod Lasers	256
7.1.2.2	Fiber Lasers	256
7.1.2.3	Disk Lasers	257
7.1.3	Semiconductor Lasers (Diode Lasers)	258
7.2	Beam Guidance/Shaping System	259
7.3	Laser Cutting Machines	262
7.4	Laser Ablation Machines	263
7.5	Machines for Additive Manufacturing	265
7.6	Laser-Assisted Machining Systems	268
7.6.1	A 5-Axis Hybrid Machine for Milling and Additive Manufacturing of Components	268
7.6.2	System Technology for Laser-Assisted Milling	269
	References	271
8	Single-Purpose Machines	273
8.1	Gear Cutting Machines	276
8.1.1	Rolling Gear Manufacturing Machines	279
8.1.1.1	Gear Hobbing Machines	279
8.1.1.2	Gear Shaping Machines	281
8.1.1.3	Gear Skiving Machines	283
8.1.1.4	Gear Shaving Machines	284
8.1.1.5	Gear Grinding Machines	286
8.1.1.6	Gear Honing Machines	289
8.1.2	Profile Gear Cutting Machines	291
8.1.2.1	Profile Milling Machines	291
8.1.2.2	Profile Grinding Machines	292
8.1.2.3	Gear Broaching Machines	295
8.1.3	Special-Purpose Gear Cutting Machines	295
8.1.3.1	Mechanical Bevel Gear Milling Machines	296
8.1.3.2	6-Axis Universal Milling Machines	296
8.1.3.3	Bevel Gear Grinding Machines	300
8.1.3.4	Bevel Gear Lapping Machines	301
8.1.3.5	5-Axis Milling Machines	301

8.1.4	Forming Gear Manufacturing Machines	302
8.1.4.1	Rolling Machines.....	302
8.1.4.2	Orbital Forming Presses	303
8.2	Machines for Crankshaft Production	304
8.2.1	Crankshaft Milling.....	304
8.2.1.1	Internal Milling with a Fixed Workpiece.....	305
8.2.1.2	Internal Milling with a Rotating Workpiece.....	306
8.2.1.3	External Milling with Parallel Axes (Turn-Milling)	306
8.2.1.4	External Milling (Face Turn-Milling)	307
8.2.2	Crankshaft Turning and (Turn-) Turn-Broaching	309
8.2.2.1	Turning.....	309
8.2.2.2	Turn-Broaching	310
8.2.2.3	Turn-Turn Broaching	310
8.2.3	Crankshaft Grinding.....	311
8.2.4	Crankshaft Rolling.....	313
8.3	Machines for Camshaft Production	315
8.3.1	Camshaft Milling Machines.....	316
8.3.2	Camshaft Grinding Machines	317
8.4	Machines for Producing Threaded Spindles	318
	References	323
9	Multi-Machine Systems	325
9.1	Fundamentals of Machine Interlinking	328
9.1.1	Manufacturing Forms	329
9.1.2	Interlinked Machines in Machine Systems	330
9.1.2.1	Machine Tools	331
9.1.2.2	Cleaning Machines.....	333
9.1.3	Interlinking Systems.....	335
9.2	Handling Systems	337
9.2.1	Placement Devices and Industrial Robots.....	337
9.2.1.1	Placement Systems	337
9.2.1.2	Industrial Robots.....	337
9.2.2	End Effectors	342
9.2.2.1	Grippers	342
9.2.2.2	Gripper Systems	345
9.2.2.3	Tailored Tool Change Systems in Multi-Machine Systems.....	346
9.3	Special-Purpose Machine Tools	348
9.3.1	Rotary Index Machines	348
9.3.2	Linear Transfer Machines	349
9.4	Transfer Lines	349
9.4.1	Fixed Transfer Lines	349
9.4.2	Flexible Transfer Lines.....	349
9.5	Flexible Manufacturing Cells	354
9.6	Flexible Manufacturing Systems	357
	References	360
10	Equipment Components for Machine Tools	361
10.1	Overview	364
10.2	Peripherals for Machine Tools	366
10.2.1	Cooling Systems	366
10.2.2	Cooling Lubricant Supply	369
10.2.2.1	Basics of Cooling Lubricant Supply	369
10.2.2.2	Systems for Minimum Quantity Cooling Lubrication.....	371
10.2.2.3	Separating Processes for Cleaning Cooling Lubricants.....	375
10.2.2.4	Fire Protection Using Water-Immiscible Cooling Lubricants	379

10.2.3	Systems for Handling Chips	382
10.2.3.1	Chip Conveyors	382
10.2.3.2	Chip Centrifuges	385
10.2.3.3	Briquetting	386
10.2.4	Central Lubrication Systems	388
10.2.4.1	Single-Line Systems	388
10.2.4.2	Progressive Systems	389
10.2.4.3	Dual-Line Systems	390
10.2.4.4	Multi-Line Systems	390
10.2.4.5	Restrictor Systems	390
10.2.4.6	Compressed Air Lubrication Systems	391
10.2.5	Hydraulic Units	393
10.2.5.1	Functions and Importance of Hydraulic Systems	393
10.2.5.2	Basic Structure of a Hydraulic System	394
10.2.5.3	Design Variants of Hydraulic Units	396
10.3	Tool Systems	397
10.3.1	Tool Systems for Drilling and Milling Machines	397
10.3.1.1	Mechanical Interface Between Spindle and Tool (Tool Interface)	397
10.3.1.2	Tool Clamping Systems	400
10.3.1.3	Tool Types (Modular Tools/Tool Holders)	403
10.3.1.4	Change Equipment and Magazine for Tools	407
10.3.1.5	Identification Systems for Tools	416
10.3.2	Tool Systems for Lathes	417
10.3.2.1	Tool Types in Lathes	417
10.3.2.2	Turret Interface	419
10.3.2.3	Tool Holders for Lathes	421
10.3.2.4	Modular Tools	424
10.3.3	Mechanical Tool Interface Properties	427
10.4	Workpiece Clamping and Supply Systems	435
10.4.1	Functions of Workpiece Clamping and Supply Systems	435
10.4.1.1	Clamping	437
10.4.1.2	Workpiece Handling	439
10.4.2	Workpiece Clamping Systems and Fixtures on Drilling and Milling Machines	439
10.4.2.1	Workpiece Clamps and Fixtures	439
10.4.2.2	Workpiece Carriers and Pallets	445
10.4.2.3	Pallet Changing Equipment and Magazines	451
10.4.3	Workpiece Clamping, Supporting and Supply on Lathes	452
10.4.3.1	Clamping Systems	452
10.4.3.2	Support of Long Workpieces	458
10.4.3.3	Change Equipment and Magazines for Workpieces	459
	References	464
11	Design Examples of Selected Machine Tools	467
11.1	Machining Center	470
11.1.1	Company Profile	470
11.1.2	Overview	470
11.1.3	General Description	470
11.1.4	Machine Network	471
11.1.5	Table Bed	471
11.1.6	Column Bed	472
11.1.7	Column	476
11.1.8	Horizontal-Vertical Head	476
11.2	Grinding Machine	480
11.2.1	Company Profile	480
11.2.2	Overview	480
11.2.3	General Description	480

11.2.4	Front Base and Table	482
11.2.5	Rear Base.....	484
11.2.6	Column	484
11.2.7	Spindle.....	485
11.2.8	Dressers.....	486
11.2.9	Engineering Solutions and Production Systems	489
11.3	Lathe	491
11.3.1	Company Profile	491
11.3.2	Overview.....	491
11.3.3	General Description	491
11.3.4	Machine Bed	492
11.3.5	Turret Slide.....	494
11.3.6	Main and Counter Spindles.....	494
11.3.7	Carriage for Motor Milling Spindle A and B-Axes.....	497
11.3.8	Motor Milling Spindle and A-Axis.....	498
	Supplementary Information	
	Formula Directory.....	504
	Abbreviations.....	507
	Index	509