

Graham T. Smith

Cutting Tool Technology

Industrial Handbook

 Springer

Contents

1	Cutting Tool Materials	1			
1.1	Cutting Technology – an Introduction	2			
1.1.1	Rationalisation	2			
1.1.2	Consolidation	4			
1.1.3	Optimisation	4			
1.2	The Evolution of Cutting Tool Materials	7			
1.2.1	Plain Carbon Steels	7			
1.2.2	High-Speed Steels	7			
1.2.3	Cemented Carbide	8			
1.2.4	Classification of Cemented Carbide Tool Grades	12			
1.2.5	Tool Coatings: Chemical Vapour Deposition (CVD)	14			
1.2.6	Diamond-Like CVD Coatings	14			
1.2.7	Tool Coatings: Physical Vapour Deposition (PVD)	17			
1.2.8	Ceramics and Cermets	19			
1.2.9	Cermets – Coated	23			
1.2.10	Cubic Boron Nitride (CBN) and Poly-crystalline Diamond (PCD)	25			
1.2.11	Natural Diamond	29			
2	Turning and Chip-breaking Technology	33			
2.1	Cutting Tool Technology	34			
2.1.1	Turning – Basic Operations	34			
2.1.2	Turning – Rake and Clearance Angles on Single-point Tools	34			
2.1.3	Cutting Insert Edge Preparations	36			
2.1.4	Tool Forces – Orthogonal and Oblique	39			
2.1.5	Plan Approach Angles	41			
2.1.6	Cutting Toolholder/Insert Selection	43			
2.2	History of Machine Tool Development and Some Pioneers in Metal Cutting	50			
2.2.1	Concise Historical Perspective of the Development of Machine Tools	50			
2.2.2	Pioneering Work in Metal Cutting – a Brief Resumé	51			
2.3	Chip-Development	54			
2.4	Tool Nose Radius	62			
2.5	Chip-Breaking Technology	66			
2.5.1	Introduction to Chip-Breaking	66			
2.5.2	The Principles of Chip-Breaking	68			
2.5.3	Chip-Breakers and Chip-Formers	69			
2.5.4	Helical Chip Formation	71			
2.5.5	Chip Morphology	75			
2.5.6	Chip-Breaker Wear	79			
2.6	Multi-Functional Tooling	79			
3	Drilling and Associated Technologies	87			
3.1	Drilling Technology	88			
3.1.1	Introduction to the Twist Drill's Development	88			
3.1.2	Twist Drill Fundamentals	88			
3.1.3	The Dynamics of Twist Drilling Holes	96			
3.1.4	Indexable Drills	103			
3.1.5	Counter-Boring/Trepanning	107			
3.1.6	Special-Purpose, or Customised Drilling	110			
3.1.7	Deep-Hole Drilling/Gun-Drilling	113			
3.1.8	Double-Tube Ejector/Single-Tube System Drills	115			

3.1.9	Deep-Hole Drilling – Cutting Forces and Power	117	5.4	Threading Dies	189
3.2	Boring Tool Technology – Introduction	117	5.5	Thread Turning – Introduction	191
3.2.1	Single-Point Boring Tooling	118	5.5.1	Radial Infeed Techniques	193
3.2.2	Boring Bar Selection of: Toolholders, Inserts and Cutting Parameters	122	5.5.2	Thread Helix Angles, for Single-/Multi-Start Threads	195
3.2.3	Multiple-Boring Tools	124	5.5.3	Threading Insert Inclination	195
3.2.4	Boring Bar Damping	126	5.5.4	Thread Profile Generation	198
3.2.5	‘Active-suppression’ of Vibrations	127	5.5.5	Threading Turning – Cutting Data and Other Important Factors	200
3.2.6	Hard-part Machining, Using Boring Bars	128	5.6	Thread Milling	203
3.3	Reaming Technology – Introduction	133	5.7	Thread Rolling – Introduction	206
3.3.1	Reaming – Correction of Hole’s Roundness Profiles	135	5.7.1	Thread Rolling Techniques	209
3.3.2	Radially-Adjustable Machine Reamers	139	6	Modular Tooling and Tool Management	211
3.3.3	Reaming – Problems and Their Remedies	142	6.1	Modular Quick-Change Tooling	212
3.4	Other Hole-Modification Processes	142	6.2	Tooling Requirements for Turning Centres	216
4	Milling Cutters and Associated Technologies	149	6.3	Machining and Turning Centre Modular Quick-Change Tooling	221
4.1	Milling – an Introduction	150	6.4	Balanced Modular Tooling – for High Rotational Speeds	230
4.1.1	Basic Milling Operations	151	6.5	Tool Management	233
4.1.2	Milling Cutter Geometry – Insert Axial and Radial Rake Angles	155	6.5.1	The Tool Management Infrastructure	238
4.1.3	Milling Cutter – Approach Angles	158	6.5.2	Creating a Tool Management and Document Database	240
4.1.4	Face-Milling Engagement – Angles and Insert Density	160	6.5.3	Overall Benefits of a Tool Management System	244
4.1.5	Peripheral Milling Cutter Approach Angles – Their Affect on Chip Thickness	163	6.5.4	Tool Presetting Equipment and Techniques for Measuring Tools	245
4.1.6	Spindle Camber/Tilt – when Face-Milling	166	6.5.5	Tool Store and its Presetting Facility – a Typical System	261
4.2	Pocketing, Closed-Angle Faces, Thin-Walled and Thin-Based Milling Strategies	169	6.5.6	Computerised-Tool Management – a Practical Case for ‘Stand-alone’ Machine Tools	264
4.3	Rotary and Frustum-Based Milling Cutters – Design and Operation	172	7	Machinability and Surface Integrity	269
4.4	Customised Milling Cutter Tooling	177	7.1	Machinability	270
4.5	Mill/Turn Operations	177	7.1.1	Design of Machinability Tests and Experimental Testing Programmes	270
5	Threading Technologies	181	7.2	Machined Roundness	285
5.1	Threads	182	7.2.1	Turned Roundness – Harmonics and Geometrics	291
5.2	Hand and Machine Taps	182	7.3	Chatter in Machining Operations	294
5.3	Fluteless Taps	189			

7.3.1	Chatter and Chip Formation – Significant Factors Influencing its Generation	297	8.8.1	Product Mixing – Preparation of a Aqueous-Based Cutting Fluids	410
7.3.2	Chatter – Important Factors Affecting its Generation	297	8.8.2	Monitoring, Maintenance and Testing of Cutting Fluid – in Use	411
7.3.3	Stability Lobe Diagrams	300	8.9	Multi-Functional Fluids	417
7.4	Milled Roundness – Interpolated Diameters	301	8.10	Disposal of Cutting Fluids	417
7.5	Machined Surface Texture	305	8.11	Health and Safety Factors – Concerning Cutting Fluid Operation and Usage	418
7.5.1	Parameters for Machined Surface Evaluation	308	8.11.1	Cutting Fluid-Based Health Issues	420
7.5.2	Machined Surface Topography	317	8.12	Fluid Machining Strategies: Dry; Near-Dry; or Wet	425
7.5.3	Manufacturing Process Envelopes	324	8.12.1	Wet- and Dry-Machining – the Issues and Concerns	425
7.5.4	Ternary Manufacturing Envelopes (TME's)	326	8.12.2	Near-Dry Machining	426
7.6	Machining Temperatures	326	9	Machining and Monitoring Strategies	431
7.6.1	Finite Element Method (FEM)	328	9.1	High Speed Machining (HSM)	432
7.7	Tool Wear and Life	330	9.1.1	HSM Machine Tool Design Considerations	434
7.7.1	Tool Wear	331	9.2	HSM Dynamics – Acceleration and Deceleration	445
7.7.2	Tool Life	337	9.2.1	HSM Dynamics – Servo-Lag ..	446
7.7.3	Return on the Investment (ROI)	342	9.2.2	Effect of Servo-lag and Gain on Corner Milling ...	448
7.8	Cutting Force Dynamometry	343	9.2.3	Effect of Servo-Lag and Gain Whilst Generating Circular Paths	448
7.9	Machining Modelling and Simulation	350	9.2.4	CNC Processing Speed	449
7.10	Surface Integrity of Machined Components – Introduction	360	9.3	HSM – with Non-Orthogonal Machine Tools and Robots	451
7.10.1	Residual Stresses in Machined Surfaces	360	9.4	HSM – Toolholders/Chucks	458
8	Cutting Fluids	381	9.4.1	Toolshank Design and Gripping Pressures	458
8.1	Historical Development of Cutting Fluids	382	9.4.2	Toolholder Design and Spindle Taper	465
8.2	Primary Functions of a Cutting Fluid ..	383	9.5	Dynamic Balance of Toolholding Assemblies	467
8.3	High-Pressure Jet-Assisted Coolant Delivery	383	9.5.1	HSM – Problem of Tool Balance	469
8.4	Types of Cutting Fluid	387	9.5.2	HSM – Dynamic Balancing Machine Application	472
8.4.1	Mineral Oil, Synthetic, or Semi-Synthetic Lubricant? ..	392	9.6	HSM – Research Applications	474
8.4.2	Aqueous-Based Cutting Fluids	395	9.6.1	Ultra-High Speed: Face-Milling Design and Development	474
8.4.3	Water Quality	397	9.6.2	Ultra-High Speed: Turning Operations	480
8.5	Cutting Fluid Classification – According to Composition	398	9.6.3	Ultra-High Speed: Trepanning Operations	484
8.6	Computer-Aided Product Development	398			
8.6.1	Cutting Fluid – Quality Control	404			
8.7	Selecting the Correct Cutting Fluid	407			
8.7.1	Factors Affecting Choice	407			
8.7.2	Selection Procedure	408			
8.8	Care, Handling, Control and Usage – of Cutting Fluids	409			

9.6.4	Artefact Stereometry: for Dynamic Machine Tool Comparative Assessments	486	9.10.3	Nano-Machining and Machine Tools	526
9.7	HSM: Rotating Dynamometry	493	9.11	Machine Tool Monitoring Techniques	531
9.8	Complex Machining: of Sculptured Surfaces	496	9.11.1	Cutting Tool Condition Monitoring	531
9.8.1	Utilising the Correct Tool for Profiling: Roughing and Finishing	496	9.11.2	Adaptive Control and Machine Tool Optimisation	535
9.8.2	Die-Cavity Machining – Retained Stock	498	9.11.3	Artificial Intelligence: AI and Neural Network Integration	538
9.8.3	Sculptured Surface Machining – with NURBS	502	9.11.4	Tool Monitoring Techniques – a ‘Case-Study’	538
9.8.4	Sculptured Surface Machining – Cutter Simulation	505	Appendix		549
9.9	Hard-Part Machining	507	About the Author		587
9.9.1	Hard-Part Turning	508	Subject Index		589
9.9.2	Hard-Part Milling	511			
9.10	Ultra-Precision Machining	516			
9.10.1	Micro-Tooling	518			
9.10.2	Micro-Machine Tools	525			