

Contents

Part I Fundamentals

1	Single Point Diamond Turning Technology	3
	References.....	6
2	Factors Influencing Machined Surface Quality	7
	2.1 Machine Tools.....	7
	2.2 Vibration in Machining.....	8
	2.3 Cutting Conditions.....	9
	2.4 Single Point Diamond Tools.....	11
	2.5 Environmental Conditions.....	12
	2.6 Workpiece Materials.....	13
	2.7 Deformation Behaviour of Materials in Machining.....	15
	References.....	17
3	Modelling and Simulation for Ultra-Precision Machining	21
	3.1 Analytical and Numerical Methods for Machining Process Modelling.....	21
	3.1.1 Slip-Line Field Modelling of Machining.....	21
	3.1.2 Molecular Dynamics Simulation of Machining.....	22
	3.1.3 Quasicontinuum (QC) Method.....	23
	3.1.4 Meshfree Method.....	24
	3.1.5 Discrete Element Method.....	26
	3.1.6 Finite Element Method.....	27
	3.2 Models of Chip Formation and Shear Bands Theory.....	29
	3.2.1 The Chip Formation Process and Models in Metal Cutting.....	29
	3.2.2 Shear Band Formation and Chip Morphology.....	32
	3.2.3 The Shear Angle Relationship.....	34
	References.....	35

**Part II Materials Characterisation in Ultra-Precision
DiamondTurning**

4	Machinability of Single Crystals in Diamond Turning	43
4.1	Key Aspects in Diamond Turning of Single Crystals	43
4.1.1	The Ultra-Precision Machine	43
4.1.2	Diamond Tools	43
4.1.3	Measurement of Surface Roughness	46
4.1.4	Measurement of Cutting Force	50
4.1.5	Work Materials and Cutting Conditions	50
4.2	Effect of Crystallography on Surface Roughness	52
4.2.1	Surface Features with Crystallographic Orientation	52
4.2.2	Surface Roughness Profiles Along Radial Sections	56
4.2.3	Degree of Roughness Anisotropy (DRA)	57
4.3	Variation of Cutting Force	59
4.3.1	Effect of Feed Rate on the Cutting Force	59
4.3.2	Effect of Depth of Cut on the Cutting Force	60
4.4	Observation on Chip Formation	61
	References	68
5	Materials Deformation Behaviour and Characterisation	71
5.1	Techniques for Materials Characterisation	71
5.1.1	X-ray Diffraction	71
5.1.2	Nano-indentation Measurements	73
5.1.3	Nanoscratch Testing	76
5.1.4	Transmission Electron Microscopy (TEM)	77
5.2	Characterisation of the Diamond-Turned Surface Layer	79
5.2.1	X-ray Diffraction Line Profile Analysis	79
5.2.2	Microhardness and Elastic Modulus of Machined Surface	79
5.2.3	Friction Coefficient	81
5.2.4	Dislocation Density and Structure of Diamond-Turned Surface Layers	82
5.3	Influences of Material Swelling upon Surface Roughness	89
5.3.1	Materials Swelling Effect	89
5.3.2	Characterisation Techniques	95
5.3.3	Formation of Surface Roughness in Machining	101
	References	103
6	Material Electropulsing Treatment and Characterisation of Machinability	105
6.1	Basics of Electropulsing Treatment	106
6.1.1	Development of Electropulsing Treatment	106
6.1.2	Theory of Electropulsing Treatment	106

6.2	Effect of Electropulsing Treatment on Microstructural Changes	112
6.2.1	Technical Aspects of Electropulsing Treatment.	112
6.2.2	Phase Transformation and Microstructural Changes	116
6.2.3	Dislocation Identity	127
6.2.4	Driving Forces for Phase Transformations	129
6.2.5	Electropulsing Kinetics	130
6.3	Machinability Enhancement by Electropulsing Treatment.	131
	References.	144
7	Microplasticity Analysis for Materials Characterisation.	147
7.1	Shear Angle and Micro-Cutting Force Prediction	147
7.1.1	Microplasticity Model for Shear Angle Prediction	147
7.1.2	Texture Softening Factor.	151
7.1.3	Criterion for Shear Angle Prediction.	154
7.1.4	Prediction of Micro-Cutting Forces Variation	156
7.2	Variation in Shear Angle and Cutting Force.	159
7.2.1	Shear Angle Predictions and Experimental Methods	160
7.2.2	Power Spectrum Analysis of Cutting Force.	168
7.3	Microstructural Characterisation of Deformation Banding	175
7.3.1	Typical Cutting-Induced Shear Band.	175
7.3.2	Orthogonal Cutting-Induced Kink Band	177
7.3.3	Cutting Induced Kinking Within the Sliding Region.	179
	References.	184
 Part III Theory and Mechanism of Ultra-Precision Diamond Turning		
8	Shear Bands in Ultra-Precision Diamond Turning	189
8.1	Shear Band Theory for Deformation Processes in Machining.	189
8.2	Regularly Spaced Shear Bands and Morphology of Serrated Chips	191
8.3	Finite Element Method Modelling for Elastic Strain-Induced Shear Bands	197
8.3.1	Characterisation of Elastic Strain-Induced Shear Bands	197
8.3.2	Finite Element Method Modelling.	198
8.4	Analytical Model of Shear Band Formation and Influences	207
8.4.1	Onset of the Formation of Shear Bands	208
8.4.2	Formation of Shear Bands.	210
8.4.3	An Analytical Model of Cyclic Fluctuation of Cutting Force	211
8.4.4	The Cyclic Fluctuation of the Displacement of the Tool Tip	213
8.5	Generalised Shear Angle Model	215
	References.	217

9	Tool-Tip Vibration at High Frequencies	219
9.1	Identification of Tool-Tip Vibration by Power Spectrum Analysis	219
9.2	Characteristic Twin Peaks and Material Properties	221
9.3	Modelling of Tool-Tip Vibration	226
9.3.1	An Impact Model Without Damping	226
9.3.2	Non-harmonic Periodic Excitation with Process Damping Effect	229
9.4	Representative Measurement Method	234
9.4.1	Influence of Tool-Tip Vibration on the Machined Surface	234
9.4.2	Effect of Sample Locations on Surface Roughness	240
9.4.3	Effect of Sample Area Ratios and Representative Measurement	242
9.5	Modelling and Characterisation of Surface Roughness Generation	246
9.5.1	Surface Generation Model with Tool-Tip Vibration	246
9.5.2	Formation of Spiral Marks on the Machined Surface	248
9.5.3	Spatial Error on the Profile in the Feed Direction	250
	References	250
10	Dynamic Modelling of Shear Band Formation and Tool-Tip Vibration in Ultra-Precision Diamond Turning	253
10.1	A Transient Analysis for Shear Band Formation	256
10.2	Dynamic Model for Shear Band Formation	257
10.2.1	Dynamic Model	257
10.2.2	The Effect of Equivalent Cutting Velocity	259
10.2.3	Validation and Application	260
	References	265