

---

## Contents

|          |   |          |
|----------|---|----------|
| <b>1</b> | <b>Metal Cutting Mechanics, Finite Element Modelling.....</b>                             | <b>1</b> |
|          | <i>Viktor P. Astakhov and José C. Outeiro</i>   |          |
| 1.1      | Advanced Metal Cutting Mechanics .....  | 1        |
| 1.1.1    | Objective of Metal Cutting Mechanics .....  | 1        |
| 1.1.2    | State of the Art .....  | 1        |
| 1.1.3    | Advanced Methodology .....  | 4        |
| 1.1.4    | Combined Influence of the Minor Cutting Edge.....   | 7        |
| 1.1.5    | Influence of the Cutting Speed, Depth of Cut<br>and Cutting Feed on Power Partition ..... | 9        |
| 1.1.6    | Concluding Remarks.....   | 11       |
| 1.2      | Finite Element Analysis (FEA) .....   | 13       |
| 1.2.1    | Numerical Formulations .....  | 14       |
| 1.2.2    | Modelling Chip Separation from the Workpiece<br>and Chip Segmentation .....               | 15       |
| 1.2.3    | Mesh Design .....   | 16       |
| 1.2.4    | Work Material Modelling .....   | 18       |
| 1.2.5    | Modelling of Contact Conditions.....  | 19       |
| 1.2.6    | Numerical Integration .....   | 19       |
| 1.2.7    | Errors .....  | 20       |
| 1.2.8    | Example .....   | 20       |
| 1.2.9    | Advanced Numerical Modelling .....  | 21       |
| 1.2.10   | Model Validation .....  | 22       |
|          | References.....   | 25       |

|          |  |           |
|----------|--|-----------|
| <b>2</b> | <b>Tools (Geometry and Material) and Tool Wear.....</b>                          | <b>29</b> |
|          | <i>Viktor P. Astakhov and J. Paulo Davim</i>                                     |           |
| 2.1      | Essentials of Tool Geometry .....  | 29        |
| 2.1.1    | Importance of the Cutting Tool Geometry .....                                    | 29        |
| 2.1.2    | Basic Terms and Definitions .....  | 31        |
| 2.1.3    | System of Considerations.....  | 32        |
| 2.1.4    | Basic Tool Geometry Components .....   | 33        |
| 2.1.5    | Influence of the Tool Angles.....  | 35        |
| 2.2      | Tool Materials .....   | 37        |
| 2.2.1    | Carbides .....   | 39        |
| 2.2.2    | Ceramics .....   | 43        |
| 2.2.3    | Cubic Boron Nitride (CBN) .....  | 44        |
| 2.2.4    | Polycrystalline Diamond (PCD)<br>and Solid Film Diamond (SFD) .....              | 45        |
| 2.3      | Tool Wear.....   | 48        |
| 2.3.1    | Tool Wear Types.....   | 48        |
| 2.3.2    | Tool Wear Evolution.....   | 50        |
| 2.3.4    | Mechanisms of Tool Wear .....  | 52        |
| 2.4      | Tool Life.....   | 52        |
| 2.4.1    | Taylor's Tool Life Formula .....   | 53        |
| 2.4.2    | Expanded Taylor's Tool Life Formula.....   | 55        |
| 2.4.3    | Recent Trends in Tool Life Evaluation.....                                       | 55        |
|          | References.....  | 57        |
| <b>3</b> | <b>Workpiece Surface Integrity.....</b>  | <b>59</b> |
|          | <i>Joël Rech, Hédi Hamdi and Stéphane Valette</i>                                |           |
| 3.1      | What Does Surface Integrity Mean?.....   | 59        |
| 3.1.1    | Link Between Surface Integrity<br>and its Manufacturing Procedure .....          | 62        |
| 3.1.2    | Impact of the Surface Integrity<br>on the Dimensional Accuracy .....             | 64        |
| 3.1.3    | Impact of the Surface Integrity on Fatigue Resistance.....                       | 67        |
| 3.2      | Material and Mechanical Aspects of Surface Integrity.....                        | 68        |
| 3.2.1    | Mechanisms Leading to Material and Mechanical<br>Modifications in Machining..... | 68        |
| 3.2.2    | Modelling of Residual Stresses .....   | 74        |
| 3.2.3    | Experimental Approach .....  | 80        |
|          | References.....  | 91        |

|          |  |            |
|----------|--|------------|
| <b>4</b> | <b>Machining of Hard Materials .....</b>   | <b>97</b>  |
|          | <i>Wit Grzesik</i>   |            |
| 4.1      | Basic Features of HM.....  | 97         |
| 4.1.1    | Definition of Hard Machining.....  | 97         |
| 4.1.2    | Comparison with Grinding Operations .....  | 98         |
| 4.1.3    | Technological Processes Including Hard Machining.....                              | 100        |
| 4.2      | Equipment and Tooling .....  | 101        |
| 4.2.1    | Machine Tools .....  | 101        |
| 4.2.2    | Cuting Tools and Materials .....   | 102        |
| 4.2.3    | Complete Machining Using Hybrid Processes.....                                     | 104        |
| 4.3      | Characterization of Hard Machining Processes .....                                 | 105        |
| 4.3.1    | Cutting Forces.....  | 105        |
| 4.3.2    | Chip Formation .....   | 105        |
| 4.3.3    | Cutting Temperature .....  | 108        |
| 4.3.4    | Wear of Ceramic and PCBN Tools .....   | 110        |
| 4.3.5    | Modelling of Hard Cutting Processes .....  | 110        |
| 4.4      | Surface Integrity in Hard Machining Processes .....                                | 113        |
| 4.4.1    | Surface Roughness.....   | 113        |
| 4.4.2    | Residual Stresses.....   | 114        |
| 4.4.3    | Micro/Nanohardness Distribution<br>and White-Layer Effect.....                     | 115        |
| 4.4.4    | Modification of Surface Finish in Hybrid Processes.....                            | 117        |
| 4.4.5    | Cutting Errors and Dimensional Accuracy .....                                      | 118        |
| 4.5      | Applications of Hard Machining Processes.....                                      | 119        |
| 4.5.1    | Hard Turning.....  | 119        |
| 4.5.2    | Hard and High-Speed Milling of Dies and Moulds .....                               | 120        |
| 4.5.3    | Hard Reaming .....   | 121        |
| 4.5.4    | Hard Broaching .....   | 122        |
| 4.5.5    | Hard Skive Hobbing.....  | 122        |
| 4.5.6    | Optimization of Hard Machining Processes.....                                      | 123        |
|          | References.....  | 124        |
| <b>5</b> | <b>Machining of Particulate-Reinforced Metal Matrix Composites .....</b>           | <b>127</b> |
|          | <i>A. Pramanik, J.A. Arsecularatne and L.C. Zhang</i>                              |            |
| 5.1      | Introduction .....   | 127        |
| 5.2      | Effect of Reinforcement Particles on Surface Integrity<br>and Chip Formation ..... | 129        |
| 5.2.1    | Strength of MMC During Machining.....  | 130        |
| 5.2.2    | Chip Shape .....   | 131        |

|          |  |            |
|----------|--|------------|
| 5.2.3    | Surface Integrity.....   | 135        |
| 5.2.4    | Shear and Friction Angles.....   | 142        |
| 5.2.5    | Relation Between Shear and Friction Angles.....  | 144        |
| 5.2.6    | Forces.....  | 145        |
| 5.3      | Modelling.....   | 147        |
| 5.3.1    | Forces.....  | 147        |
| 5.3.2    | Tool-Particle Interaction.....   | 157        |
| 5.4      | Tool Wear.....   | 159        |
| 5.4.1    | Performance of Cutting Tools.....  | 159        |
| 5.4.2    | Modelling of Tool Wear.....  | 161        |
|          | Acknowledgements.....  | 162        |
|          | References.....  | 162        |
| <b>6</b> | <b>Drilling Polymeric Matrix Composites.....</b>   | <b>167</b> |
|          | <i>Edoardo Capello, Antonio Langella, Luigi Nele, Alfonso Paoletti, Loredana Santo, Vincenzo Tagliaferri</i> |            |
| 6.1      | Introduction.....  | 167        |
| 6.1.1    | What Are Polymeric Matrix Composites?.....   | 167        |
| 6.1.2    | The Importance of Drilling.....  | 171        |
| 6.2      | Drilling Technology of Polymeric Matrix Composites.....  | 173        |
| 6.2.1    | Conventional Drilling Process.....   | 173        |
| 6.2.2    | Unconventional Drilling Processes.....   | 178        |
| 6.3      | Modelling of Conventional Drilling.....  | 179        |
| 6.3.1    | The Need for Modelling.....  | 179        |
| 6.3.2    | Cutting Force Modelling.....   | 180        |
| 6.4      | Damage Generated During Drilling<br>and Residual Mechanical Properties.....                                  | 183        |
| 6.4.1    | Structural Damage.....   | 183        |
| 6.4.2    | Residual Mechanical Properties.....  | 186        |
| 6.5      | Damage Suppression Methods.....  | 188        |
| 6.5.1    | Introduction.....  | 188        |
| 6.5.2    | Process Parameters Selection.....  | 188        |
| 6.5.3    | Drilling Conditions.....   | 189        |
| 6.5.4    | Special Tools.....   | 190        |
|          | References.....  | 191        |
| <b>7</b> | <b>Ecological Machining: Near-dry Machining.....</b>   | <b>195</b> |
|          | <i>Viktor P. Astakhov</i>  |            |
| 7.1      | Introduction.....  | 195        |
| 7.2      | Amount and Cost.....   | 196        |
| 7.3      | Health and Environmental Aspects.....  | 197        |
| 7.4      | Principal Directions in the Reduction of MWF Economical,<br>Ecological and Helth Impacts.....                | 198        |

|          |  |            |
|----------|--|------------|
| 7.5      | Nearly Dry Machining (NDM).....                                    | 201        |
| 7.5.1    | How NDM Operates .....   | 201        |
| 7.5.2    | Classification of NDM .....  | 202        |
| 7.5.3    | Why NDM Works.....   | 212        |
| 7.5.4    | Consideration of the NDM System Components .....                   | 217        |
|          | References.....  | 221        |
| <b>8</b> | <b>Sculptured Surface Machining .....</b>                          | <b>225</b> |
|          | <i>L. Norberto López de Lacalle and A. Lamikiz</i>                 |            |
| 8.1      | Introduction .....   | 225        |
| 8.2      | The Manufacturing Process .....                                    | 227        |
| 8.2.1    | Technologies Involved .....  | 228        |
| 8.2.2    | Five-axis Milling.....   | 229        |
| 8.3      | The CAM, Centre of Complex Surfaces Production .....               | 231        |
| 8.4      | Workpiece Precision.....   | 233        |
| 8.4.1    | Cutting Forces .....   | 235        |
| 8.5      | Workpiece Roughness .....  | 237        |
| 8.6      | Tool Path Selection Using Cutting Force Prediction .....           | 239        |
| 8.6.1    | Three-axis Case.....   | 240        |
| 8.6.2    | Five-axis Case.....  | 241        |
| 8.7      | Examples .....   | 242        |
| 8.7.1    | Three-axis Mould.....  | 242        |
| 8.7.2    | Five-axis Mould .....  | 243        |
| 8.7.3    | Three-axis Deep Mould .....  | 245        |
| 8.8      | Present and Future .....   | 246        |
|          | Acknowledgements.....  | 246        |
|          | References.....  | 247        |
| <b>9</b> | <b>Grinding Technology and New Grinding Wheels .....</b>           | <b>249</b> |
|          | <i>M.J. Jackson</i>  |            |
| 9.1      | Introduction .....   | 249        |
| 9.2      | High-efficiency Grinding Using Conventional Abrasive Wheels .      | 250        |
| 9.2.1    | Introduction.....  | 250        |
| 9.2.2    | Grinding Wheel Selection .....                                     | 251        |
| 9.2.3    | Grinding Machine Requirements<br>for High-efficiency Dressing..... | 253        |
| 9.2.4    | Diamond Dressing Wheels.....                                       | 253        |
| 9.2.5    | Application of Diamond Dressing Wheels.....                        | 256        |
| 9.2.6    | Modifications to the Grinding Process.....                         | 257        |
| 9.2.7    | Selection of Grinding Process Parameters .....                     | 257        |
| 9.2.8    | Selection of Cooling Lubricant Type and Application.....           | 258        |

|           |   |            |
|-----------|---|------------|
| 9.3       | High-efficiency Grinding Using CBN Grinding Wheels.....                           | 258        |
| 9.3.1     | Introduction.....   | 258        |
| 9.3.2     | Grinding Wheel Selection .....  | 259        |
| 9.3.3     | Grinding Machine Requirements<br>for High-efficiency CBN Grinding .....           | 264        |
| 9.3.4     | Dressing High-efficiency CBN Grinding Wheels.....                                 | 265        |
| 9.3.5     | Selection of Dressing Parameters<br>for High-efficiency CBN Grinding .....        | 266        |
| 9.3.6     | Selection of Cooling Lubrication<br>for High-efficiency CBN Grinding Wheels ..... | 266        |
| 9.4       | Internet Resources.....   | 267        |
|           | References.....   | 269        |
| <b>10</b> | <b>Micro and Nanomachining .....</b>  | <b>271</b> |
|           | <i>M.J. Jackson</i>   |            |
| 10.1      | Introduction .....  | 271        |
| 10.2      | Machining Effects at the Microscale .....   | 272        |
| 10.2.1    | Shear Angle Prediction .....  | 275        |
| 10.2.2    | Plastic Behaviour at Large Strains .....  | 278        |
| 10.2.3    | Langford and Cohen's Model .....  | 278        |
| 10.2.4    | Walker and Shaw's Model.....  | 279        |
| 10.2.5    | Usui's Model.....   | 280        |
| 10.2.6    | Saw-tooth Chip Formation in Hard Turning .....                                    | 281        |
| 10.2.7    | Fluid-like Flow in Chip Formation .....   | 281        |
| 10.3      | Size Effects in Micromachining .....  | 282        |
| 10.4      | Nanomachining.....  | 282        |
| 10.4.1    | Nanometric Machining .....  | 283        |
| 10.4.2    | Theoretical Basis of Nanomachining .....  | 284        |
| 10.4.3    | Comparison of Nanometric Machining<br>and Conventional Machining .....            | 294        |
|           | Acknowledgements.....   | 295        |
|           | References.....   | 295        |
| <b>11</b> | <b>Advanced (Non-traditional) Machining Processes.....</b>                        | <b>299</b> |
|           | <i>V.K. Jain</i>  |            |
| 11.1      | Introduction .....  | 299        |
| 11.2      | Mechanical Advanced Machining Processes (MAMP).....                               | 301        |
| 11.2.1    | Ultrasonic Machining (USM) .....  | 301        |
| 11.2.2    | Abrasive Water Jet Cutting (AWJC).....  | 304        |
| 11.3      | Thermoelectric Advanced Machining Processes .....                                 | 307        |
| 11.3.1    | Electric Discharge Machining (EDM) and Wire EDM....                               | 307        |
| 11.3.2    | Laser Beam Machining (LBM).....   | 312        |

|           |  |            |
|-----------|--|------------|
| 11.4      | Electrochemical Advanced Machining Processes .....                             | 313        |
| 11.4.1    | Electrochemical Machining (ECM) .....  | 313        |
| 11.4.2    | ECM Machine.....   | 315        |
| 11.5      | Fine Finishing Processes .....   | 317        |
| 11.5.1    | Abrasive Flow Machining (AFM) .....  | 317        |
| 11.5.2    | Magnetic Abrasive Finishing (MAF).....   | 320        |
| 11.5.3    | Magnetic Float Polishing (MFP).....  | 323        |
| 11.6      | Micromachining .....   | 324        |
| 11.7      | Finished Surface Characteristics.....  | 325        |
|           | References.....  | 325        |
| <b>12</b> | <b>Intelligent Machining: Computational Methods<br/>and Optimization .....</b> | <b>329</b> |
|           | <i>Sankha Deb and U.S. Dixit</i>   |            |
| 12.1      | Intelligent Machining .....  | 329        |
| 12.2      | Neural Network Modelling.....  | 332        |
| 12.3      | Fuzzy Set Theory.....  | 339        |
| 12.4      | Neuro-fuzzy Modelling .....  | 344        |
| 12.5      | A Note on FEM Modelling.....   | 347        |
| 12.6      | Machining Optimization.....  | 348        |
| 12.6.1    | Objective Functions and Constraints .....                                      | 348        |
| 12.6.2    | Optimization Techniques .....  | 350        |
| 12.7      | Future Challenges .....  | 355        |
|           | References.....  | 356        |
|           | <b>Index .....</b>   | <b>359</b> |



<http://www.springer.com/978-1-84800-212-8>

Machining

Fundamentals and Recent Advances

Davim, J.P. (Ed.)

2008, XIV, 362 p., Hardcover

ISBN: 978-1-84800-212-8