

Contents

Non-Traditional Machining Handbook

Testimonials	3
About the Author.....	4
Acknowledgments.....	8

Unit 1

1. Fundamentals of Non-Traditional Machining

Understanding the Processes of Non-Traditional Machining	27
The Machining Revolution	29
The Two Phases of the Computer Revolution	29
A. Computer-controlled Machines:	29
B. Computer-controlled Machines Using Non-traditional Machining Methods.....	29
Six Basic Processes to Alter Material in Non-Traditional Machining	32
A. Electricity	32
B. Water	32
C. Abrasives	32
D. Chemicals.....	32
E. Plasma.....	32
F. Light	32
Speed and Accuracy	33
Understanding Accuracy	33
The Future	34

Unit 2

Wire EDM

2. Fundamentals of Wire EDM

Revolutionizing Machining	39
Wire EDM Beginnings.....	40
Production Wire EDM	41
Capabilities of Wire EDM	42
Wire EDM a Serious Contender With Conventional Machining.....	42
New Demands by Design Engineers.....	43
Fully Automated Wire EDMs	44
How Wire EDM Works.....	45
The Step by Step EDM Process	47
A. Power Supply Generates Volts and Amps	47
B. During On Time Controlled Spark Erodes Material	47
C. Off Time Allows Fluid to Remove Eroded Particles.....	48
D. Filter Removes Chips While the Cycle is Repeated	48
Super Precision Band Saw	49

Independent Four Axis	50
Understanding Independent Four Axis	52
Submersible Cutting.....	53
Staying Competitive.....	54

3. Profiting With Wire EDM

Users of Wire EDM	55
Benefits Of Wire EDM.....	55
A. Production Runs.....	55
B. Various Shapes and Sizes	56
C. Accuracy and Finishes.....	56
D. Eliminates Extra Machining Processes	56
E. Burr Free and Perfectly Straight Machining	57
F. Damaged Parts Can Be Repaired with Inserts	57
G. Less Need for Skilled Craftspersons.....	58
H. Material Hardness Not a Factor	58
I. Computers Can Perform Calculations	58
J. Digitizing is Possible.....	59
K. Miniaturization of Parts	60
L. Machining With Nozzles Away from Workpiece	60
Parts for Wire EDM	61
A. Precision Gauges and Templates	61
C. Shaft Slots	62
D. Collets	62
E. Parting Tubes and Shafts	63
F. Shaft Pockets.....	63
G. Fabrication of Graphite Electrodes for Ram EDM	63
I. Progressive Stamping Dies.....	64
K. Molds	65
L. Special and Production Tool Cutters	65
M. Difficult-to-Machine Shapes	66
N. Other Cost-Reducing Parts.....	66
Cutting Shim Stock Absolutely Burr Free	68
Single Cavity Cut With Wire EDM Into One Side of a Tube	69
Horizontal Wire EDM.....	70
Machining Costs	70

4. Proper Procedures for Wire EDM

Starting Methods for Edges and Holes	71
Three Methods to Pick Up Dimensions.....	71
A. Pick Up Two Edges as in Figure 4:1.....	71
B. Pick Up a Hole as in Figure 4:2.....	71
C. Pick Up an Edge and Holes or Two Holes as in Figure 4:3	72
Edge Preparation	72
A. Square Edges.....	72
1. Machined or Ground.....	72

B. Scale	73
C. Pick-Ups	74
Starter Holes.....	74
A. Automatic Pick-up.....	74
C. Relieved Holes	75
D. Smooth Holes.....	75
E. Placement and Location of Starter Holes	76
Layout	77

5. Understanding the Wire EDM Process

Accuracy and Tolerances	79
Finishes	79
Wire Path.....	80
A. Wire Kerf.....	80
Skim Cutting	81
A. Barreling Effect and Wire Trail-Off.....	82
B. Metal Movement	83
C. Finishes and Accuracy.....	83
Carbide.....	84
Polycrystalline Diamond.....	84
Ceramics	85
Flushing	85
Cutting Speed.....	86
Impurities	86
Recast and Heat-Affected Zones	87
AC Non-Electrolysis Power Supplies.....	87
Isolated Pitting	88
Heat-Treated Steels	89
Cutting Large Sections.....	89
Cutting Sections From a Block	90
A. Leaving a Frame.....	90
B. Strength of Frame.....	91
C. Material for Clamping.....	91
Understanding the Wire EDM Process	91

6. Reducing Wire EDM Costs

Create One Slug	93
Keeping Flush Nozzles on the Workpiece	95
Machining After Wire EDM	96
Cutting Multiple Plates and Sheet Metal Parts	97
Production Lots	98
Stipulating Wire Sizes.....	99
Pre-Machining Non-Complicated Shapes.....	100

7. Wire EDM Applications

Production Wire EDM	97
A Great Problem	99
Examples of Wire EDM.....	99
A. Tall Parts.....	99
B. Modified Machines.....	100
Submersible Cutting.....	100
C. Large Heavy Gears.....	101
D. Various Tall Parts	102
E. Overhanging Parts	102
F. Long Tubes.....	103
G. Other Applications	103
Splitting Machined Parts	105
Cutting a Test Specimen	106
Advantages of Wire EDM for Die Making.....	106
A. Old-Fashioned Tool and Die Making.....	106
B. The Revolution	109
C. Advantages of Wire EDM Dies.....	109
1. One-Piece Die Sections.....	109
2. Exact Spare Parts	110
3. Dowel Holes EDMed	110
4. Better Tool Steels.....	110
5. Accuracy	110
6. Die Repairs.....	110
7. Fine Textured Finish	111
8. Eliminates Distortion	111
9. Inserts for High Wear Areas.....	111
10. Smaller Dies.....	111
11. Longer Lasting	111
12. Punches and Dies From One Piece of Tool Steel.....	112
13. Cutting Stripper and Die Section Together	112
Wave of the Future.....	113

Unit 3

Ram EDM

8. Fundamentals of Ram EDM

Ram EDM Machining.....	117
Ram EDM Beginnings.....	119
How Ram EDM Works	121
The Step-by-Step Ram EDM Process.....	122
Polarity	124
No-Wear	124
Fuzzy Logic	124
Fumes from Ram EDM	124
Benefits of Understanding the Process	124

9. Profiting With Ram EDM

Uses of Ram EDM	125
Benefits of Ram EDM	126
A. Different Shapes and Sizes	126
B. Accuracy and Finishes.....	127
C. Workpiece Hardness Not a Factor	127
D. EDMing Threads Into Hardened Parts.....	127
A. Molds	128
B. Blind Keyways	128
E. Helical Gear Machining	129
Micro Machining for Ram EDM	130
Machining Large Pieces.....	130
Materials for Ram EDM	131
Speeding the Mold Processing	131
EDMing Carbide	131
Proper Procedures for Ram EDM	131

10 Ram EDM Electrodes and Finishing

Electrodes.....	133
A. Function of the Electrode.....	133
B. Electrode Selection.....	133
C. Type of Electrode Materials	134
D. Galvano Process for Metallic Electrodes	135
E. Custom Molded Metallic Electrodes	135
F. Graphite Electrodes.....	135
H. Electrode Wear	137
I. Abrading Graphite Electrodes	138
I. Ultrasonic Machining for Graphite Electrodes.....	140
J. Wire EDMing Metallic and Graphite Electrodes	140
K. Electrodes and C Axis	141
H. Electrode Overcut	141
Recast and Heat-Affected Zone	142
Finishing	143
Mirror Finishing and Diffused Discharge Machining.....	144
Micro Machining	145

11. Dielectric Oil and Flushing for Ram EDM

Dielectric Oil.....	149
Coolant System	150
Flash Point	150
Flushing	150
A. Proper Flushing	150
B. Volume, Not Pressure	150
C. Types of Flushing	151

1. Pressure Flushing	151
a. Pressure Flushing Through the Electrode	151
b. Pressure Flushing Through the Workpiece	152
2. Suction Flushing	153
3. Combined Pressure and Suction Flushing	154
4. Jet Flushing	154
5. Pulse Flushing	155
a. Vertical Flushing	155
b. Rotary Flushing.....	156
c. Orbiting Flushing	157
Filtration System.....	158
The Challenge of New Procedures	158

12. Reducing Costs for Ram EDM

Preparing Workpieces for Ram EDM	159
Difference Between Ram and Wire EDM in Reducing Costs	159
Prolonging Electrode Life With No-Wear EDMing and No Premachining	160
Electrode and Workpiece Holding Devices	161
Orbiting.....	162
Manual Machines Mounted With Orbiting Devices	166
Repairing Molds With Microwelding	166
Abrasive Flow Machining.....	167
Automatic Tool Changers	167
Future of Ram EDM	169

Unit 4

13. Small Hole EDM Drilling

How Small Hole EDM Drilling Works	175
A. Dielectric and Flushing Pressure.....	176
B. The Electrode	176
C. Electrode Guides	178
D. Servo Motors.....	178
Metal Disintegrating Machines Compared to Small Hole EDM Drilling	179
Other Methods to Produce Holes	179
Disadvantages in Small Hole EDM Drilling	179
A. Electrode Wear.....	179
B. Reduced Speed for Large Holes.....	179
C. Blind Holes are Difficult to Control.....	179
Advantages in EDM Drilling.....	180
A. Drilling on Curved and Angled Surfaces	180
B. Drilling Hardened Materials.....	180
C. Materials That Produce Chips that Cling to Cutters	180
D. Drilling Deep Holes	180
E. No Hole Deburring	181
F. Preventing Broken Drills	181

G. Creating Straight Holes	181
Accuracy of Small Hole EDM Drilling	181
Versatility of Small Hole EDM Drilling	182
Conclusion	183

Unit 5

14. Abrasive Flow, Thermal Energy Deburring, and Ultrasonic Machining

Abrasive Flow Machining.....	187
A. How Abrasive Flow Machining Works.....	189
B. Abrasives	191
C. Viscosity	191
D. Extrusion Pressure.....	192
E. Finishes.....	192
Thermal Energy Deburring	194
Disadvantages and Advantages of Thermal Energy Deburring	195
Ultrasonic Machining and Polishing.....	196
How Ultrasonic Machining Works	196
Conclusion	197

Unit 6

15. Photochemical Machining

Fundamentals of Photochemical Machining.....	201
Designing the Part.....	201
Imaging	201
Etching and Stripping	203
Materials and Products for Photochemical Machining	205
Tolerances	205
Corner Radii.....	205
Beveling	206
Cutting and Etching in One Operation.....	207
Three Dimensional Chemical Machining	208
Disadvantages of Photochemical Machining.....	208
A. Bevel Slots and Holes	208
B. High Run Production.....	208
C. Limited Metal Thicknesses	208
Advantages of Photochemical Machining	208
A. Eliminates the Need for Hard Tooling	208
B. Just In Time Machining.....	208
C. Freedom of Burrs	208
D. Stress-Free Machining	208
E. Delicate and Complex Parts Can be Produced	209
Photochemical Machining of Micro-Etched Screens	209
Electroformed Process for Micro-Etched Screens	210
Conclusion	211

Unit 7

16. Electrochemical Machining

How Electrochemical Machining Works	215
Disadvantages of Electrochemical Machining.....	217
A. The Shaped Workpiece is Not a Replica of the Electrode	217
B. Shaped Electrodes are Difficult to Machine.....	217
C. Electrolyte and Sludge Removal	217
Advantages of Electrochemical Machining.....	218
A. Practically No Electrode Wear	218
B. No Recast Layer or Thermal Stress.....	218
C. Material Hardness and Toughness Not a Factor.....	218
D. Rapid Metal Removal	218
E. Deburring and Radiusing of Holes	218
Stem Drilling.....	220
Capillary Drilling.....	221
Conclusion	221

Unit 8

17. Plasma and Precision Plasma Cutting

How Plasma Cutting Works.....	226
Plasma Processes	227
A. Conventional Plasma Cutting.....	227
B. Dual Gas Plasma Cutting	228
C. Water Shield Plasma Cutting.....	228
D. Water Injection Plasma Cutting	228
E. Precision Plasma Cutting.....	228
Difference Between Regular Plasma and Precision Plasma Cutting	230
A. Beveled Cuts	231
B. Double Arcing	231
Materials for Plasma Cutting	231
Heat Distortion and Heat Affected Zone	231
Accuracy	231
Consumables	232
Plasma and Shield Gases	232
Advantages and Disadvantages of Plasma Cutting Systems	232
Plasma and Turret Punch Presses.....	232
Other Applications for Plasma	234
Understanding Plasma Cutting	235

Unit 9

18. Waterjet and Abrasive Waterjet Machining

Fundamentals of Waterjet and Abrasive Waterjet Machining.....	239
Introducing Abrasive Into the Waterjet.....	241
Abrasives for Cutting.....	243
The Abrasive System	243
The Abrasive Cutting Head.....	244
Motion Control Systems	244
Catcher System	246

19. Profiting With Waterjet and Abrasive Waterjet Cutting

Materials Cut With Waterjet	249
Materials Cut With Abrasive Waterjet	250
Accuracy	251
Safety	251
Disadvantages of Waterjet and Abrasive Waterjet Machining.....	252
A. Frosting From Abrasive Waterjet Cutting	252
B. Slower Speed Rates and Higher Costs Than Plasma and Lasers ..	253
C. Catchers Needed With Multi-Axis Cutting	253
D. Large Cuts Become Stratified	253
Advantages of Waterjet and Abrasive Waterjet Machining	253
A. Material Savings	253
B. No Special Tooling Required	253
C. Moisture Absorption Not a Problem	253
D. Focusing the Waterjet is Not Critical	253
E. Simple Fixtures Required	253
F. Entry Hole Not Required	254
G. No Heat Affected Zone or Microcracking	254
H. No Fumes	254
I. Eliminates Some Difficult Cutting Problems	255
J. Burr Free Cutting.....	255
K. Easily Attached to Robots	255
Cutting With Multiple Heads and Stacking Materials	255
Glass Sculpturing	255
Turning With Abrasive Waterjet	256
Waterjet and Abrasive Waterjet Capabilities.....	256

Unit 10

Lasers

20. Fundamentals of Lasers

Lasers: The Revolutionary Concept.....	261
Laser Cutting.....	261
How Lasers Work.....	264
Resonator	264
Laser Mirrors	264
Laser Optics	266
Assist Gases	266
The Laser Cut.....	267
Sensing Unit.....	268
Laser Safety	268
Fumes From Laser Cutting	269

21. Understanding Laser Cutting

Kerf Width	271
Material Distortion.....	271
Heat-affected Zone.....	271
Edge Quality	272
Test Cuts.....	272
Reducing Costs	272
Speed of Lasers.....	272
Tolerances	272
Surface Condition	273
Beam Quality	273
Beam Focal Length.....	274
Quantity.....	274
Redesigning Parts.....	275
Lasers and Turret Punch Presses.....	275
Cutting Laser Increasingly in Demand	276

22. Various Lasers and Their Configurations

How YAG Lasers Work	277
Increasing Power for Nd:YAG Lasers	278
Various Lasers	278
Benefits of Nd:YAG Lasers	278
1. Fiber Optics.....	278
2. Smaller Focusing Beam	279
Excimer Lasers.....	279
How Excimer Lasers Work	280
Capabilities of Excimer Lasers	280

Optical Microlithography—Laser for Integrated Circuits	284
Traveling Methods of Laser Cutting Machines	285
1. Beam Traveling	285
2. Workpiece Traveling	285
3. Combination of Beam and Workpiece Traveling	285
Custom-Made Laser Systems	285
Beam Splitting	286

23. Profiting With Laser Cutting

Materials for Laser Cutting.....	289
Determining Factors on Material Thickness.....	289
Lacquered Metals.....	290
Tube Cutting	290
Multiaxis Laser Cutting	291
Lasers With Pallet Changers or Sheet Loaders	292
Lasers With Robots	293
Part Trimming	294
Time Sharing.....	294
Advantages of Laser Cutting	295
1. Material Savings	295
2. Minimum Heat-Affected Zone	295
3. Edge Quality	295
4. Minimum Distortion and Thermal Stress	296
5. Close Nesting of Parts.....	296
6. Thin Webs	296
7. Elimination of Hard Tooling	297
8. Just-In-Time (JIT) Machining.....	297
9. Various Shapes and Sizes	297
10. Material Hardness	298
11. Consistent Laser Beam.....	298
12. Prototypes Can be Fabricated Easily	298
13. Repeatability	298
14. Ideal for Short Run Production.....	298
Disadvantages of Lasers	298

24. Lasers for Welding, Cladding, Alloying, Heat Treating, Marking, and Drilling

I. Laser Welding	301
A. Laser Welding Compared to Electron Beam Welding	302
B. Two Types of Laser Welding: Spot and Continuous Welding.....	302
C. Welding Dissimilar Metals	304
D. Keyhole Welding.....	304
E. Focusing the Beam and Through-The-Lens TV Viewer	305
F. Considerations for Laser Welding.....	305

II. Laser Cladding	306
A. Conventional Cladding	306
B. Advantages of Laser Cladding	307
III. Laser Surface Alloying	307
A. Lasers the Ideal Tool for Surface Alloying	307
B. Difference Between Laser Alloying and Laser Cladding.....	307
IV. Laser Heat Treating	308
A. Procedures for Laser Heat Treating	308
B. Advantages and Disadvantages of Surface Heat Treating.....	309
V. Laser Marking	309
A. How Laser Marking Works	310
B. Advantages of Laser Marking	311
VI. Laser Drilling.....	312
A. How Laser Drilling Works	312
B. Disadvantages of Laser Drilling.....	313
C. Advantages of Laser Drilling	314
The Future of Lasers	314

Unit 11

25. Rapid Prototyping and Manufacturing

The Photopolymer Rapid Prototyping Process	319
A. Computer Aided Design.....	319
B. Laser Drawing	319
C. Photopolymerization	319
D. Translator	319
E. Sweep and Z-Wait	319
F. Postcuring	321
G. Finishing	321
H. Size Capabilities.....	321
Selective Laser Sintering	322
The 3D Keltool™ Process	324
Solid Ground Curing.....	325
Fused Deposition Prototyping	326
Multi-Jet Modeling Prototyping	328
The ProMetal Process	329
Advantages of Office Modeling Systems	331
Expanding Field of Manufacturers and Methods.....	331

26. Understanding the Rapid Prototyping and Manufacturing Process

Advantages of Rapid Prototyping and Manufacturing	333
A. Eliminates Time-Consuming and Costly Model Making	333
B. Fast Turnarounds	334
C. Redesigned Models Easily Produced	335

D. Enhanced Visualization for Design Verification	336
E. Rapid Prototyping and Investment Casting	336
F. Producing Hard Tooling With Rapid Prototyping.....	337
Rapid Milling for Prototypes	337
New Developments.....	337
Conclusion	337

Unit 12

27. Purchasing Equipment

Staying Abreast With New Technology	341
Benefits of Purchasing Equipment.....	341
Making the Right Selection	342
A. Selecting the Right Process.....	342
B. Selecting the Right Machine	344
Various Machines and Their Cutting Capabilities*	345
A. Wire EDM	345
B. Laser (1500 watt CO ₂)	345
C. Precision plasma (70 amp)	346
D. Abrasive water jet.....	346
Choosing the Brand of Machine	346
A. Service.....	347
B. Capability	347
C. Reliability of Company	347
Retrofitting or Building a Machine	348
Factors in Purchasing Equipment	348
A. Can the machine process the material?	348
B. Does the process meet accuracy requirements?	348
C. Is the surface finish satisfactory?	348
D. Does the process affect the material, for example: unsatisfactory heat affected zone, surface cracks, or burrs?	348
E. Is this the most cost effective method?.....	348
F. In the long term, is this the best process for various operations? ..	348
G. Which manufacturer has the best and most reliable equipment? ..	348
H. What is the financial health of the company?	348
I. Does the machine manufacturer have excellent service and sufficient spare parts inventory in case of machine breakdowns?	348
J. What are the initial as well as the additional costs associated with having this equipment in house?.....	348
K. Does the company really need to invest in this machine, or would it be wiser to invest the money to enhance other machining operations? (This issue will be discussed in the next chapter.).....	348
Machine Installation.....	349
Decision Making	349

Unit 13

28. Outsourcing

Advantages of Job Shops	354
A. Competitive Outsourcing	354
B. Guaranteed Quality	354
C. Reliable Service.....	354
D. Efficiencies of Job Shops	354
Costs to be Considered For In-House Work	354
A. Fixturing and Machine Modification	354
B. Programming and Inspecting Equipment.....	355
C. Training Personnel	355
D. Costly Support Equipment.....	356
E. Cost of Unused Machines Due to Economic Slowdown.....	356
F. Machine Maintenance	356
G. Machine and Operation Costs.....	357
The Final Decision.....	358
Maximizing Core Competency	359

Unit 14

29. The Revolutionary Future Non-Traditional Machine

The Problem.....	363
Possible Solutions	363
A. Develop an intensifier that will use a magnetic field to spin and accelerate electrons with plasma.....	363
B. Use a magnetic field with high-intensity laser light.....	363
C. Have a high-energy magnetic field to guide plasma or laser.....	363
D. Create a powerful laser wave length that will not diffuse.....	364
E. Combine high-energy light, plasma, and electricity.....	364
F. Use controlled atomic energy.....	364
G. Apply star wars technology for cutting.....	364
Conclusion	364

Unit 15

30. Questions

Chapter 1 Fundamentals of Non-Traditional Machining.....	367
Chapter 2 Wire EDM Fundamentals.....	367
Chapter 3 Profiting With Wire EDM	368
Chapter 4 Proper Procedures for Wire EDM	369
Chapter 5 Understanding the Wire EDM Process.....	369
Chapter 6 Reducing Wire EDM Costs	370
Chapter 7 Various Wire EDM Applications.....	371
Chapter 8 Fundamentals of Ram EDM.....	371

Chapter 9 Profiting With Ram EDM.....	372
Chapter 10 Ram EDM Electrodes and Finishing.....	372
Chapter 11 Dielectric Oil and Flushing for Ram EDM	373
Chapter 12 Reducing Costs for Ram EDM.....	374
Chapter 13 Fast Hole EDM Drilling.....	375
Chapter 14 Abrasive Flow, Thermal Energy Deburring, and Ultrasonic Machining.....	375
Chapter 15 Photochemical Machining.....	376
Chapter 16 Electrochemical Machining.....	377
Chapter 17 Plasma and Precision Plasma Cutting	377
Chapter 18 Waterjet and Abrasive Waterjet Machining.....	378
Chapter 19 Profiting With Waterjet and Abrasive Waterjet Cutting	379
Chapter 20 Fundamentals of Lasers.....	379
Chapter 21 Understanding Laser Cutting	380
Chapter 22 Various Lasers and Their Configurations	381
Chapter 23 Profiting With Laser Cutting	382
Chapter 24 Lasers for Welding, Drilling, Cladding, Alloying, Heat Treating, Marking, and Drilling.....	383
Chapter 25 Rapid Prototyping and Manufacturing.....	384
Chapter 26 Understanding the Rapid Prototyping and Manufacturing Process.....	386
Chapter 27 Purchasing Equipment.....	386
Chapter 28 Outsourcing	387
Chapter 29 The Revolutionary Future Non-Traditional Machine.....	388
Index	389

Index

Notes