

Killing

Welding Processes and Thermal Cutting

11.1.4.3	Hinged-Arm Flame-Cutting Machines	174
11.1.4.4	Coordinate-Drive Flame-Cutting Machines	174
11.1.4.5	Flame Cutting Using Industrial Robots	175
11.1.5	Flame-Cutting Quality	176
11.1.6	Special Flame Cutting Processes	177
11.1.6.1	Powder Flame Cutting	177
11.1.6.2	Mineral-Powder Flame Cutting	178
11.1.6.3	Oxygen-Lance Cutting	178
11.2	Plasma-Arc Cutting	178
11.2.1	Principle of Plasma-Arc Cutting	179
11.2.2	Plasma-Forming Media	179
11.2.3	Plasma-Arc Cutting Devices	180
11.2.4	Application of Plasma-Arc Cutting	180
11.2.4.1	Plasma-Arc Cutting Using Pointed Electrodes	180
11.2.4.2	Plasma-Arc Cutting Using Compressed Air	181
11.2.4.3	Plasma-Arc Cutting in Water or under Water	181
11.2.5	Plasma-Arc Cutting Qualities	182
11.2.6	Special Arc Cutting Processes	182
11.2.6.1	Arc-Air Gouging	183
11.2.6.2	Oxygen-Arc Cutting	184
11.3	Laser-Beam Cutting	185
11.3.1	Principle of Laser-Beam Cutting	185
11.3.1.1	Laser-Beam Combustion Cutting	186
11.3.1.2	Laser-Beam Fusion Cutting	186
11.3.1.3	Laser-Beam Sublimation Cutting	187
11.3.2	Cutting Gases	187
11.3.3	Laser-Beam Cutting Devices	187
11.3.3.1	Beam Generator	187
11.3.3.2	Beam Manipulation Systems	188
11.3.3.3	Workpiece Holders	190
11.3.4	Application of Laser-Beam Cutting	190
Literature	193

9.5.1	Electrodes for Projection Welding	142
9.5.2	Projection Shapes	143
9.5.3	Execution of Projection Welding	144
9.5.4	Application of Projection Welding	145
9.6	Lap Seam Welding (Proc. No. 221)	145
9.6.1	Electrodes for Lap Seam Welding	146
9.6.2	Execution of Lap Seam Welding	146
9.6.3	Application of Lap Seam Welding	147
9.7	Resistance Pressure Butt Welding	148
9.7.1	Classification of the Processes	148
9.7.1.1	Resistance Butt Welding (Proc. No. 25)	148
9.7.1.2	Flash Welding (Proc. No. 24)	149
9.7.2	Delimitation between the Processes	149
9.7.3	Application of Pressure Butt Welding	149
10	Special Processes	151
10.1	Electroslag Welding (Proc. No. 72)	151
10.1.1	Principle of Electroslag Welding	151
10.1.2	Electroslag Joining	151
10.1.2.1	Process Variants	151
10.1.2.2	Devices for Electroslag Welding	153
10.1.2.3	Wire Electrodes and Welding Fluxes	153
10.1.3	Electroslag Surfacing	154
10.1.3.1	Processes and Devices	154
10.1.3.2	Electroslag Welding With Wide Strip Electrodes	155
10.1.4	Application of Electroslag Welding	155
10.2	Friction Welding (Proc. No. 42)	157
10.2.1	Principle of the Process	157
10.2.2	Process Variants	158
10.2.3	Machines and Devices for the Welding Process	158
10.2.4	Application of Friction Welding	159
10.3	Arc Pressure Welding	160
10.3.1	Magnetically Impelled Arc Butt Welding (Proc. No. 185)	160
10.3.1.1	Description of the Process	160
10.3.1.2	Application of the Process	161
10.3.2	Arc Stud Welding	162
10.3.2.1	Drawn-Arc Stud Welding (Proc. No. 783)	162
10.3.2.2	Capacitor-Discharge Stud Welding with Tip Ignition (Proc. No. 786)	163
10.3.2.3	Application of Stud Welding	163
10.4	Miscellaneous Processes	165
10.4.1	Cold Pressure Welding (Proc. No. 48)	165
10.4.2	Diffusion Welding (Proc. No. 45)	166
10.4.3	Aluminothermic Welding (Proc. No. 71)	167
11	Thermal Cutting	169
11.1	Autogenous Gas Cutting	169
11.1.1	Fundamentals of Autogenous Gas Cutting	169
11.1.2	The Flame Cutter's Tool	170
11.1.3	Manual Flame Cutting	170
11.1.4	Mechanised Flame Cutting	172
11.1.4.1	Hand-Held Flame-Cutting Machines	172
11.1.4.2	Small Flame-Cutting Machines	173

8	Beam Welding	93
8.1	Electron-Beam Welding (Proc. No. 51)	93
8.1.1	Principle of Electron-Beam Welding	93
8.1.1.1	Beam Generation	93
8.1.1.2	Surrounding Media	94
8.1.2	Effect of the Electron Beam	95
8.1.2.1	Penetration into Metals	95
8.1.2.2	The Deep-Penetration Effect	95
8.1.3	Groove Preparation	96
8.1.4	Weldability of some Materials	98
8.1.5	Beam and Machine Control Systems	99
8.1.6	Electron-Beam Welding Machines and Jigs	100
8.1.6.1	Electron-Beam Generator	100
8.1.6.2	Working Chamber	101
8.1.6.3	Movement Devices	101
8.1.6.4	High-Voltage Supply	102
8.1.6.5	Vacuum Pumps	102
8.1.7	Application of Electron-Beam Welding	103
8.1.8	Economical Considerations	106
8.2	Laser-Beam Welding (Proc. No. 52)	107
8.2.1	Fundamental Principles of the Laser Beam	107
8.2.2	Beam Generation	107
8.2.3	Laser Types	109
8.2.3.1	Solid-State Lasers	110
8.2.3.2	Gas Lasers	112
8.2.3.3	Diode Lasers	114
8.2.4	Effect of the Laser Beam	116
8.2.5	Built-up of Laser Installations	119
8.2.5.1	Beam Manipulation and Beam Forming	119
8.2.5.2	Gas Supply	122
8.2.5.3	Manipulators	122
8.2.6	Application of Laser-Beam Welding	123
8.2.7	Defects in the Case of Laser-Beam Welding	125
9	Resistance Pressure Welding	128
9.1	Definition of Resistance Welding (Proc. No. 2)	128
9.2	Classification of the Resistance Welding Processes	128
9.3	Fundamentals of Resistance Pressure Welding	128
9.3.1	Resistances in the Welding-Current Circuit	128
9.3.2	Thermal Effect of the Current	131
9.3.3	Power Sources for Resistance Welding	131
9.3.4	Switching and Control of Currents	132
9.4	Spot Welding (Proc. No. 21)	134
9.4.1	Welding Machines	135
9.4.2	Electrodes	135
9.4.3	Execution of the Process	138
9.4.3.1	Welding Parameters	138
9.4.3.2	Shunt Effect	139
9.4.3.3	Window Effect	140
9.4.4	Testing of Welded Joints	140
9.4.5	Application of Resistance Spot Welding	141
9.5	Projection Welding (Proc. No. 23)	142

5.2.5	Comparison with TIG Welding	57
5.2.6	Application of Plasma Welding	58
5.2.7	Defects in the Case of Plasma Welding	60
6	Gas-Shielded Metal-Arc Welding (Proc. No. 13)	61
6.1	MIG/MAG Welding (Proc. No. 131/135)	61
6.1.1	Principle of the Process	61
6.1.2	Equipment for MIG/MAG Welding	61
6.1.2.1	Power Sources	62
6.1.2.2	Device Designs	62
6.1.2.3	Wire-Feed Devices	62
6.1.2.4	Torch and Hose Package	62
6.1.3	Arc Operating Modes	64
6.1.3.1	Short Arc	64
6.1.3.2	Spray Arc	65
6.1.3.3	Long Arc	65
6.1.3.4	Intermediate Arc	66
6.1.3.5	Pulsed Arc	66
6.1.3.6	High-Efficiency MAG Welding	66
6.1.3.7	Working Ranges	67
6.1.4	Filler Metals and Adjuvants	68
6.1.4.1	Wire Electrodes	68
6.1.4.2	Properties of Shielding Gases	68
6.1.5	MIG/MAG Welding Technique	70
6.1.5.1	Setting of the Installations	71
6.1.5.2	Ignition of the Arc	72
6.1.5.3	Torch Manipulation	72
6.1.6	Application of MIG/MAG Welding	73
6.1.6.1	Partially Mechanised Welding	73
6.1.6.2	Fully Mechanised Welding	74
6.1.6.3	MIG/MAG Welding Using Industrial Robots	74
6.1.7	Defects in the Case of MIG/MAG Welding	75
7	Covered-Arc Welding	77
7.1	Submerged-Arc Welding (SAW) (Proc. No. 12)	77
7.1.1	Principle of the Process	77
7.1.2	Built-up of Installations	78
7.1.3	Variants of Submerged-Arc Welding	78
7.1.3.1	Twin-Wire Welding (Proc. No. 123)	79
7.1.3.2	Tandem (Multi-Wire) Welding (Proc. No. 123)	80
7.1.3.3	Strip-Electrode Submerged-Arc Welding (Proc. No. 122)	81
7.1.4	Filler Metals and Adjuvants	82
7.1.4.1	Wire (Strip) Electrodes	82
7.1.4.2	Welding Fluxes	83
	Manufacture of Welding Fluxes	83
	Characteristics of Welding Fluxes	84
7.1.5	Execution of the Process	85
7.1.5.1	Influence of the Welding Parameters	86
7.1.5.2	Setting Parameters	86
7.1.5.3	Backing	86
7.1.6	Application of Submerged-Arc Welding	89
7.1.7	Defects in the Case of Submerged-Arc Welding	91

4	Metal-Arc Welding (Proc. No. 101)	29
4.1	Manual Metal-Arc Welding (Proc. No. 111)	29
4.1.1	Principle of the Process	29
4.1.2	Stick Electrodes	29
4.1.2.1	Effect and Purpose of Coverings	30
4.1.2.2	Types of Covering	30
4.1.2.3	Properties of Stick Electrodes	32
4.1.3	Performance of Parameters	33
4.1.3.1	Current-Carrying Capacity	33
4.1.3.2	Recovery	34
4.1.3.3	Deposition Rate	35
4.1.4	Welding Technique	35
4.1.4.1	Ignition of the Arc	35
4.1.4.2	Tack Welding	35
4.1.4.3	Manipulation of the Electrode	36
4.1.5	Application of Manual Metal-Arc Welding	36
4.1.6	Defects in the Case of Manual Metal-Arc Welding	37
4.2	Other Methods of Metal-Arc Welding	38
4.2.1	Gravity (Proc. No. 112) and Spring-Loaded Arc Welding	38
4.2.2	Welding with Self-Shielded Tubular-Cored Wires Electrodes (Proc. No. 114)	39
5	Gas-Shielded Welding with Non-Consumable Electrode (Proc. No. 14)	41
5.1	TIG Welding (Proc. No. 141)	41
5.1.1	Principle of the Process	41
5.1.2	Equipment for TIG Welding	42
5.1.2.1	TIG Welding Devices	43
5.1.2.2	Welding Torch and Accessories	43
5.1.2.3	Tungsten Electrodes	43
5.1.3	Welding Rods and Shielding Gases	44
5.1.4	Welding Technique	45
5.1.4.1	Setting of the Installation	46
5.1.4.2	Ignition of the Arc	46
5.1.4.3	Torch Manipulation	47
5.1.4.4	Back-Up Shielding	47
5.1.5	TIG Welding Using Current Pulses	48
5.1.5.1	Setting Variables	48
5.1.5.2	Effect of the Current Pulses	48
5.1.6	Application of TIG Welding	49
5.1.7	Defects in the Case of TIG Welding	51
5.2	Plasma Arc Welding (Proc. No. 15)	51
5.2.1	Physical Fundamentals	51
5.2.2	Principle of Plasma Arc Welding	51
5.2.3	Classification of Plasma Arc Welding	52
5.2.3.1	Classification According to the Arc Type	52
5.2.3.2	Classification According to the Performance	53
	– Microplasma Welding	53
	– Soft Plasma Welding	54
	– Heavy-Gauge Sheet Plasma Welding	54
5.2.3.3	Classification According to the Purpose of the Welding Process	54
	– Plasma Arc Joining	54
	– Plasma Arc Surfacing	55
5.2.4	Devices for Plasma Welding	56

Contents

Preface

1	Classification of Welding Processes	1
1.1	A Brief History of Welding Technology	1
1.2	Classification of Fabrication Processes	2
1.3	Overview of Welding Processes	2
2	Gas Welding	5
2.1	Gas Fusion Welding (Proc. No. 3)	5
2.1.1	Principle of Gas Fusion Welding	5
2.1.2	Properties of the Gases	5
2.1.2.1	Oxygen	5
2.1.2.2	Fuel Gases	5
2.1.3	The oxyacetylene Flame	7
2.1.3.1	Torches and Accessories	7
2.1.3.2	Flame Setting	9
2.1.4	Methods of Gas Fusion Welding	9
2.1.4.1	Leftward Welding	10
2.1.4.2	Rightward Welding	10
2.1.5	Filler Metals and Adjuvants	10
2.1.6	Application of Gas Welding	11
2.1.7	Defects in the Case of Gas Welding	11
3	Fundamentals of Arc Welding	13
3.1	The Arc	13
3.1.1	Charge Carriers in the Arc	13
3.1.2	Arc Characteristics	14
3.1.3	Magnetic Arc Blow	15
3.2	Metal Transfer in the Case of Arc Welding	16
3.2.1	Types of Metal Transfer	16
3.3	Setting and Regulation of Welding Processes	19
3.3.1	Setting of the Amperage and Arc Voltage	20
3.3.2	Regulation of the Arc Length	20
3.3.2.1	External Regulation	20
3.3.2.2	Internal Regulation	21
3.3.2.3	Comparison of the Regulation Types	22
3.4	Welding Power Sources	22
3.4.1	Designs of Power Sources	22
3.4.1.1	Welding Transformer	23
3.4.1.2	Welding Rectifier	23
3.4.1.3	Welding Generator	24
3.4.1.4	Electronic Power Sources	24
3.4.2	Properties of Power Sources	26
3.4.2.1	Static Characteristic	26
3.4.2.2	Dynamic Properties	27
3.4.2.3	Parameters	27