

Robert B. Heimann

Plasma-Spray Coating

Principles and Applications



Weinheim • New York • Basel • Cambridge • Tokyo

Contents

List of Symbols and Abbreviations	xiii
1 Introduction	1
1.1 Coatings in the Industrial Environment	2
1.2 Surface Coating Techniques	3
1.3 Brief History of Thermal Spraying	8
1.4 Synergistic Nature of Coatings.	13
1.5 Applications of Thermally Sprayed Coatings	14
References	15
2 Principles of Thermal Spraying.	17
2.1 Characterization of Flame versus Plasma Spraying.	21
2.2 Concept of Energy Transfer Processes	22
2.3 Unique Features of the Plasma Spray Process	22
References	25
3 The First Energy Transfer Process: Electron–Gas Interactions	27
3.1 The Plasma State	27
3.1.1 Characteristic Plasma Parameters	28
3.1.1.1 Langmuir Plasma Frequency	28
3.1.1.2 Debye Screening Length	29
3.1.1.3 Landau Length	29
3.1.1.4 Collision Path Length	30
3.1.1.5 Collision Frequency	31
3.1.2 Classification of Plasmas	31
3.1.2.1 Low Density Plasmas.	32
3.1.2.2 Medium Density Plasmas	32

3.1.2.3	High Density Plasmas	35
3.1.3	Equilibrium and Nonequilibrium Plasmas.	35
3.1.4	Maxwellian Distribution of Plasma Energies	37
3.1.5	Equilibrium Compositions of Plasma Gases (Phase Diagrams).	38
3.2	Plasma Generation.	38
3.2.1	Plasma Generation through Application of Heat.	40
3.2.2	Plasma Generation through Compression	43
3.2.3	Plasma Generation by Radiation.	43
3.2.4	Plasma Generation by Electric Currents (Gas Discharges).	44
3.2.4.1	Glow Discharges.	45
3.2.4.2	Arc Discharges	46
3.2.4.3	Modeling of the Arc Column	48
3.2.4.4	Structure of the Arc Column	50
3.3	Design of Plasmatrons	55
3.3.1	Arc Discharge Generators and their Applications	57
3.3.1.1	Electrode-supported Plasmas	59
3.3.1.2	Electrodeless Plasmas.	63
3.3.1.3	Hybrid Devices	66
3.3.2	Stabilization of Plasma Arcs.	68
3.3.2.1	Wall-stabilized Arcs	68
3.3.2.2	Convection-stabilized Arcs	68
3.3.2.3	Electrode-stabilized Arcs	69
3.3.2.4	Other Stabilization Methods	69
3.3.3	Temperature and Velocity Distribution in a Plasma Jet	70
3.3.3.1	Turbulent Jets	70
3.3.3.2	Quasi-laminar Jets	74
3.4	Plasma Diagnostics: Temperature, Enthalpy, and Velocity Measurements	77
3.4.1	Temperature Measurements.	77
3.4.1.1	Spectroscopic Methods	77
3.4.1.2	Two-wavelength Pyrometry	80
3.4.2	Velocity Measurements	81
3.4.2.1	Enthalpy Probe and Pitot Tube Techniques	81
3.4.2.2	Laser Doppler Anemometry (LDA)	83
3.4.2.3	Other Methods	88
	References	88
4	The Second Energy Transfer Process: Plasma-Particle Interactions	91
4.1	Injection of Powders	91
4.2	Feed Material Characteristics	91