

Mathesius · Krömmer

# **Practice of thermal spraying**

Guidance for technical personnel

**Bibliographic information published by the Deutsche Nationalbibliothek**

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at <http://dnb.dnb.de>.

**English Edition  
Volume 10**

ISBN 978-3-945023-07-5

All rights, also for translation, are reserved. The reproduction of this volume or of parts of it only with approval of the DVS Media GmbH, Düsseldorf.

© DVS Media GmbH, Düsseldorf · 2014  
Printing: Thiebes Druck GmbH, Hagen

## Preface

The contents of this book have originated from an accumulation of experience gathered in numerous years of training thermal sprayers to become European Thermal Sprayers (ETSS) and in many years of our own practical experience in coating plants.

It is a difficult undertaking to portray and explain the practice of thermal spraying in all its aspects. On the way to the formulation, the respective descriptions have almost assumed the character of a work of reference. For example, words are marked with \* in the texts of the individual chapters and the explanations of them can be found in the glossary. Perhaps, the reader also feels that a lot of things are indeed more difficult to express than they evidently turn out to be.

We would like to thank all the people who have helped us with this book in word and deed. This gratitude goes, above all, to Mrs. A. Ohliger-Volmer and Mr. R. Huber who have tirelessly provided material and reports. Further information, photographs and notes have been made available by the following firms and institutions:

Association of Thermal Sprayers (GTS), Unterschleißheim

ElektroPhysik Dr. Steingoever GmbH & Co. KG, Cologne

GTV Verschleißschutz GmbH, Luckenbach

Ibeda Sicherheitsgeräte & Gastechnik GmbH & Co. KG, Neustadt/Wied

Linde AG, Unterschleißheim

Munk + Schmitz Oberflächentechnik GmbH & Co. KG, Cologne

Praxair Surface Technologies GmbH, Ratingen

H. C. Starck GmbH, Goslar

Struers GmbH, Willich

Sulzer Metco Europe GmbH, Kelsterbach

Thermico GmbH & Co. KG, Dortmund

Welding Training and Research Institute (SLV) Munich, branch of GSI mbH, Munich

Wheelabrator Group GmbH, Metelen

Zierhut Messtechnik, Neubiberg

Furthermore, we would like to express our gratitude to the editor from DVS Media, Mr. Lothar Knittel, and Dr.-Ing. Hellmuth Behnisch who, with their experience, have made a not inconsiderable contribution to the final version of the book.

We are glad that this book has been turned into reality. Thus, we are also helping to attain an important objective: *The coating of components with thermal spraying processes should only be carried out by specialist personnel!*

Wolfenbüttel and Landshut, April 2014

Hans Mathesius and Werner Krömmer

## **Foreword**

In today's fleeting, fast-moving way of life, the courage to write a technical reference work was well rewarded by the very positive response to the first edition of the book you are now reading. In a compact and clearly presented second edition, the two authors have successfully put to paper the theory, practice and latest developments pertinent to thermal spray technology.

With its lucid structure and train of thought, which take the reader through the entire field of thermal spraying, the book has made itself indispensable as the reference guide for both seasoned experts and newcomers to the technology.

The strength of this work lies in its extensive wealth of information underscored by the breadth and depth of the knowledge imparted. By the same token, the well-illustrated practical approach combined with the theoretical principles of thermal spraying confer the book the high ranking it deserves among the many different surface treatment methods.

This second edition has been revised and extended and, as hoped for, also translated into English. This continues to render it the most up-to-date reference work for thermal sprayers.

Congratulations to the two authors Dr Hans A. Mathesius and Werner Krömmmer and the publisher DVS Media GmbH on this outstanding compendium.

Unterschleißheim, April 2014

Peter Heinrich

Member of the Executive Board of the Association  
of Thermal Sprayers (GTS e. V.)

# Table of contents

Preface

Foreword

<b>1</b>	<b>Introduction to thermal spraying .....</b>	1
1.1	Stresses on sprayed components .....	1
1.2	Overview of the various surface coatings .....	1
1.3	Principle of the thermal spraying process .....	2
1.4	Applications of thermal spraying .....	4
<b>2</b>	<b>Preparation for thermal spraying .....</b>	7
2.1	Degreasing (chemical cleaning) .....	7
2.2	Masking (covering) for the blasting operation .....	9
2.3	Roughening for the coating operation .....	9
2.3.1	Rough turning .....	10
2.3.2	Rough grinding .....	10
2.3.3	Blasting (as the most common method) .....	10
	General fundamentals .....	10
	Practical examples .....	10
	Blasting parameters .....	11
	Types of blasting materials .....	11
	Care of the blasting materials .....	12
	Sizes and shapes of the blasting materials .....	13
	Blasting principle .....	13
	Recycling of the blasting materials .....	15
	Blasting pressure, blasting angle and blasting distance .....	16
2.4	Removal of the masking (covering) from the blasting operation .....	18
2.5	Masking for the coating operation .....	18
2.6	Subsequent cleaning .....	19
<b>3</b>	<b>Fundamentals of thermal spraying .....</b>	20
3.1	Coating build-up and coating structure .....	20
3.2	Designing components in a way appropriate for spraying .....	21
3.3	Relative spraying velocity .....	23
3.4	Cooling .....	24
3.5	Shielding gas shroud .....	27
3.6	Defect prevention and defect recognition .....	27
<b>4</b>	<b>Thermal spraying processes .....</b>	29
4.1	Wire flame spraying .....	29
	Torch types .....	29
	Spraying consumables .....	30
	Variations in the torch assembly .....	30
	Care of the installations .....	30
4.2	Arc spraying .....	34
	Torch types .....	34
	Spraying consumables and coating properties .....	37
	General care of the torches .....	38
	Troubleshooting .....	39

4.3	Powder flame spraying .....	41
	Plastic flame spraying .....	41
	Torch types (guns) .....	42
	General care .....	43
	Spraying consumables .....	43
4.4	High-velocity oxy-fuel (HVOF) spraying .....	44
	Fuel gases/fuels .....	44
	HVOF spraying torch types .....	45
	Spraying consumables and coating properties .....	50
4.5	Plasma spraying .....	52
	Plasma gases .....	52
	Technical plasmas .....	54
	Plasma torch types .....	56
	Components of a plasma spraying installation .....	59
4.6	Vacuum plasma spraying .....	63
4.7	Detonation spraying or flame shock spraying n .....	67
4.8	Cold spraying .....	68
<b>5</b>	<b>Post-treatment of sprayed coatings .....</b>	<b>73</b>
5.1	Overview of the various possibilities .....	73
5.2	Thermal post-treatment .....	73
5.2.1	Fusion with the flame .....	75
5.2.2	Furnace sintering .....	77
5.2.3	Induction sintering .....	77
5.3	Mechanical post-treatment .....	77
5.3.1	Smoothing .....	78
5.3.2	Turning .....	78
5.3.3	Grinding and honing .....	79
5.3.4	Polishing and lapping .....	79
5.3.5	Compression blasting .....	80
5.4	Chemical post-treatment .....	80
5.4.1	Sealing .....	80
5.4.2	Painting .....	81
5.4.3	Pickling .....	81
5.5	Coating removal (stripping) .....	81
<b>6</b>	<b>Materials and gases .....</b>	<b>83</b>
6.1	Base materials .....	83
6.2	Spraying consumables .....	84
6.2.1	Wires .....	84
6.2.2	Powders .....	85
6.2.3	Overview of the most important spraying consumables .....	89
6.3	Technical gases .....	92
6.3.1	Fuel gases .....	93
6.3.2	Plasma gases .....	95
6.3.3	Cooling gases .....	96
6.3.4	Carrier gases .....	96
6.3.5	Shroud gases .....	96
6.3.6	Provision, storage and piping systems .....	96

<b>7</b>	<b>Quality assurance for sprayed coatings .....</b>	98
7.1	Maintenance, calibration and gauging (adjustment) of the installations .....	98
7.2	Testing and measurement of the parameters .....	99
7.3	Testing and measurement of sprayed coatings before, during and after the coating operation .....	103
	Temperature measurement .....	104
	Coating thickness measurement (for details, see ISO 2064) .....	104
	Coating thickness growth .....	106
	Visual inspection for irregularities .....	106
	Crack testing (penetration procedure, see ISO 3452-1 or ASTM E 165) .....	106
	Hardness measurement .....	107
	Bending test .....	108
	Metallographic section (for details, see the DVS 2310 technical bulletin) .....	109
	Determination of the bond strength .....	113
	Cross-hatch adhesion test (for details, see ISO 2063) .....	113
	Adhesive tensile strength (for details, see ISO 14916) .....	113
	Adhesive shear strength (for details, see EN 15340) .....	114
	Testing for certain properties .....	114
<b>8</b>	<b>Training in thermal spraying .....</b>	117
8.1	Training and quality assurance in thermal spraying .....	117
8.2	Significance of the EWF training guidelines .....	119
8.3	Association of Thermal Sprayers (GTS) .....	119
8.4	Quality requirements on thermally sprayed coatings (ISO 14922) .....	120
8.5	Supervisor for thermal spraying according to ISO 12690 .....	121
8.6	Qualification testing of thermal sprayers according to ISO 14918 .....	121
8.7	ETSS (European Thermal Spraying Specialist) training according to the EWF 459 guideline .....	122
8.8	ETSP (European Thermal Spraying Practitioner) training according to the EWF 592 guideline .....	122
8.9	ETS (European Thermal Sprayer) training according to the EWF 507 guideline .....	123
8.10	Implementation and experience from the practice of spraying technology training .....	124
<b>9</b>	<b>Mechanisation and automation of the spraying process .....</b>	125
	Teach-in procedure .....	126
	Playback procedure .....	126
	Combination of a gantry and an industrial robot .....	127
<b>10</b>	<b>Safety at work and environmental protection .....</b>	129
10.1	Significance of safety at work .....	129
10.2	Hazards during thermal spraying .....	129
10.2.1	Hazard analysis .....	129
10.2.2	Hazards caused by electric current .....	131
10.2.3	Hazards caused by radiation .....	133
10.2.4	Hazards caused by noise .....	134
10.2.5	Hazards caused by harmful substances such as gases, fumes or dusts .....	135
10.2.5.1	Definitions, effects as well as limiting and guide values .....	135
10.2.5.2	Hazards caused by gases .....	136
10.2.5.3	Hazards caused by fumes and fine dusts .....	138
10.3	Protective measures for averting hazards .....	140
10.3.1	Protective measures when dealing with electricity .....	140

10.3.2	Protective measures when dealing with rays .....	141
10.3.3.	Protective measures when dealing with noise .....	141
10.3.4	Protective measures when dealing with harmful substances such as gases, fumes or dusts .....	143
10.3.4.1	Protective measures for gases .....	143
10.3.4.2	Protective measures against fumes and dusts during spraying .....	146
10.3.4.3	Protective measures when dealing with robots .....	149
10.3.4.4	Protective measures during the activities before and after thermal spraying .....	149
<b>11</b>	<b>Standards, technical bulletins, technical codes and guidelines for thermal spraying .....</b>	<b>151</b>
11.1	Standards .....	151
11.2	Technical bulletins, technical codes and guidelines .....	154
<b>Glossary</b>	.....	<b>156</b>