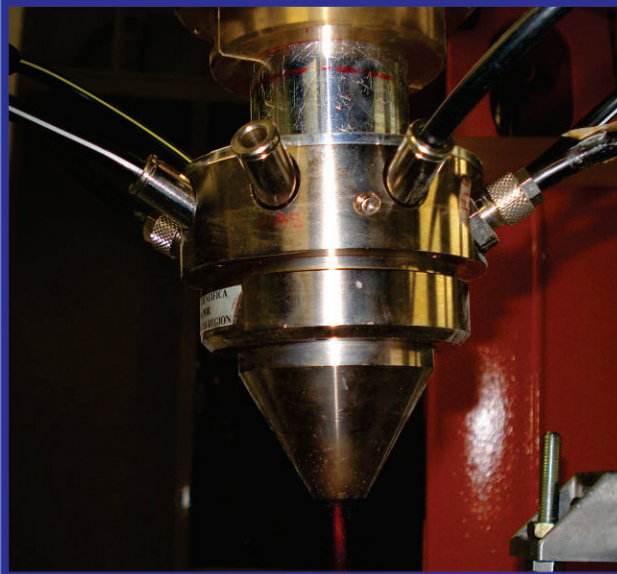


ALEXANDRU PASCU

**PARAMETERS
OF THE
LASER CLADDING PROCESS**



**EDITURA
LUX LIBRIS**

ALEXANDRU PASCU

PARAMETERS OF THE LASER CLADDING PROCESS



Scientific reviewers: Prof. univ. dr. ing. Teodor Machedon
- Universitatea *Transilvania* din Braşov
CSIII dr. ing. Ionuţ Claudiu Roată
- Universitatea *Transilvania* din Braşov
Editorial consulter: Lecturer. dr. eng. **Bogdan Andreescu**
Typewriting: **Alexandru Pascu**
Cover: **Alexandru Pascu**
Proofreading: **Alexandru Pascu**

Descrierea CIP a Bibliotecii Naţionale a României

PASCU, ALEXANDRU

Parameters of the laser cladding process / Alexandru Pascu ; ed.: şef lucr. dr. ing. Bogdan Andreescu. - Braşov : Lux Libris, 2015

Conţine bibliografie

ISBN 978-973-131-344-3

I. Andreescu, Bogdan (ed.)

621.375.826

Copyright © Lux Libris, 2015. All rights reserved.

Publishing house accredited by CNCSIS, code 201

ISBN 978-973-131-344-3

PREFACE

Along with many technological processes that uses the electromagnetic radiation, the laser cladding process of metallic or non-metallic materials became a viable technique that can be used in order to recondition or fabricate new surfaces with superior mechanical properties.

Due to the increasing interest and importance of the studies about the quality of metal pieces active surfaces, some new directions of approach concerning the technological processes of recondition or improvement of metal surfaces have been observed. In most of the industrial sectors, the current technology is adapted in order to implement the laser equipments.

The need to increase the physic-chemical, mechanical and technological characteristics of the metal surfaces in order to improve the exploitation period and the decrease of manufacturing price, represent a major concern in the field of material engineering. According to the current tendencies concerning materials recycling, the recondition of wear parts is a good method to save natural resources and energy consumption. Laser claddings are a modern and efficient technological solution to fulfil these requests.

This book is the translation and revised version of the volume Parametrii procesului de depunere cu laseri si pulberi metalice, LuxLibris publishing house, 2013, ISBN 978-973-131-232-3.

A first role of the book is to determine, by experimental researches, the optimal process parameters window for coaxial laser cladding. The experimental research and analytical determinations are performed to define the parameters influence on the morphological and mechanical properties of the cladded layers are presented.

In terms of experimental tests and in depth characterization, this book allows the determination of required conditions and parameters for a wide range of applications, about the improvement or recondition of metallic surfaces, by the cladding technology with laser and high alloyed Ni based powders.

AUTHOR

TABLE OF CONTENTS

Preface

Table of contents.....	3
------------------------	---

1. Laser technology

1.1. A brief history of laser.....	9
1.2. Stimulated and spontaneous emission.....	11
1.3. Laser principle.....	15
1.4. Proprieties of laser beam.....	19
1.4.1. Coherence.....	19
1.4.2. Directionality.....	20
1.4.3. Monochromaticity.....	21
1.5. Laser types and industrial applications	21
1.5.1. Gas lasers	22
1.5.2. Solid-state lasers	23
1.5.3. Industrial applications	27
1.5.3.1. Laser cutting.....	29
1.5.3.2. Laser welding.....	30

2. Laser cladding: state-of-the-art

2.1. Introduction	35
2.2. Laser cladding process	36
2.2.1. Laser cladding with pre-placed powder	37
2.2.2. Laser cladding by wire feeding	38
2.2.3. Laser cladding by powder injection	40
2.2.3.1. Laser cladding by off-axis powder injections method	40
2.2.3.2. Laser cladding by coaxial powder injections	41
2.3. Laser cladding powders	46

2.3.1. Nickel based powder	47
2.3.2. Cobalt based powder	47
2.3.3. Aluminium based powder	48
2.4. Proprieties of the clad layer	51
2.4.1. Dilution	51
2.4.2. Geometric ratio	52
2.4.3. Wetting angle	53
2.5. Metallurgical considerations concerning the formation and structure of the clad layer	53
2.6. Laser cladding process parameters	58
2.6.1. Power density	59
2.6.2. Cladding speed	61
2.6.3. Powder feed rate.....	62
2.6.4. Cladding angle.....	63
2.7. Physical phenomena of laser cladding process	64
2.7.1. Absorption	64
2.8. Defects in laser cladding process	67
2.9. General considerations concerning wear and recondition of components	71
2.10. Industrial applications of laser cladding process	76
3. One step laser cladding process response	
3.1. Introduction	89
3.1.1. Sample material composition.....	90
3.1.2. Powder/alloy addition.....	91
3.1.3. Experimental set up	95
3.2. The effect of power density on the clad geometry and microstructure.....	98
3.2.1. Power density influence on the clad geometric characteristics, by experimental data-mathematical regressions correlation.....	108
3.3. Power density influence on the clad layer hardness	120
3.4. The effect of cladding speed on the clad geometry and microstructure.....	126

3.4.1. Cladding speed influence on the clad geometric characteristics, by experimental data-mathematical regressions correlation.....	134
3.5. Cladding speed influence on the clad layer hardness	139
3.6. The effect of powder feed rate on the clad geometry and microstructure....	144
3.7. Powder feed rate influence on the clad layer hardness	163
4. Nickel based multi-pass laser cladding process response	
4.1. General aspects concerning the partially overlapped tracks	157
4.2. Optimal process window of overlapped tracks	158
4.2.1. Morphological characterization of laser clad layers	160
4.3. Optimal overlapping degree of multi-pass laser cladding	169
5. In depth characterization of overlapped clad tracks	177
5.1. Introduction	177
5.2. Test samples analyses through scanning microscopy, EDS and XRD.....	178
5.3. Analyses of the clad layer wear resistance.....	211
6. Laser safety	223
REFERENCES	231

- properties of the cladding alloy, ELSEVIER, Surface and Coatings Technology 115 (1999) 270–272.
97. [WBG01] WEISHEIT A., BACKES G., GASSER A., Powder Injection: *The Key to Reconditioning and Generating Components Using Laser Cladding*, Int. Congress on Advanced Mat'ls and Processes, pp 1-7.
 98. [WIE08] WIELLIGH Louis George, *Characterizing the influence of process variables in laser cladding Al-20wt%Si onto an aluminium substrate*, teza de doctorat, Technology at the Nelson Mandela Metropolitan University
 99. [YLZ06] YANG S., LIU W., ZHONG M., *In-situ TiC Reinforced Composite Coating Produced by Powder Feeding Laser Cladding*, J. Mater. Sci. Technol., Vol.22 No.4, 2006
 100. [ZHL07] ZHANG L., LIU B., *Rapidly solidified non-equilibrium microstructure and phase transformation of plasma cladding Fe-based alloy coating*, ELSEVIER, Surface & Coatings Technology 201 (2007) 5931–5936.
 101. [ZTP02] ZHAO C., TIAN F., PENG H., *Non-transferred arc plasma cladding of Stellite Ni60 alloy on steel*, ELSEVIER, Surface and Coatings Technology 155 (2002) 80–84.
 102. [***CAP] http://www.capisci.ro/articole/Regresie_%C5%9Fi_corela%C5%A3ie
 103. [***CLA,a] <http://cladprocess.blogspot.com/>
 104. [***CLA,b] <http://claim.engin.umich.edu/research.html>
 105. [***ENC] [http://www.enciclopedie-auto.ro/termen/default.asp?Termen=cardan+\[ax+cardanic\]+SSID10+TTID32](http://www.enciclopedie-auto.ro/termen/default.asp?Termen=cardan+[ax+cardanic]+SSID10+TTID32)
 106. [***ENG] https://engineering.purdue.edu/LAMPL/research_deposition.html
 107. [***ENW,a] http://en.wikipedia.org/wiki/Transverse_mode
 108. [***ENW,c] http://en.wikipedia.org/wiki/Nucleation#Homogeneous_nucleation
 109. [***ENW] http://en.wikipedia.org/wiki/Optical_cavity
 110. [***ICO] http://www.ico-optics.org/ico_oct09.html
 111. [***ILT] www.ilt.fraunhofer.de
 112. [***LAS,a] http://www.laserfocusworld.com/articles/article_display.html?id=341585
 113. [***LAS,b] http://www.laserfocusworld.com/display_article/363486/12/none/none/Feat/PHOTONICS-APPLIED:-MATERIALS-PROCESSING:-Laser-additive-manufacturing-gains-strengt
 114. [***LAS,c] <http://www.lasercladding.com/enhancement.html>
 115. [***MUC] <http://www.muc.miyachi.com/>
 116. [***NOR] www.northeastlaser.com/Laser_Welding_photos.html.

- 117. [***OPT] <http://www.optoiq.com/index/photronics-technologies-applications.html>
- 118. [***RPF] www.rp-fotonics.com/diode_stacks.html.
- 119. [***RPM] www.rpmclasers.com/Jenoptik%20Data%20Sheets/Bars/JDL-BAB-50-47-940-TE-120-%20bar%20940nm%20120W.pdf
- 120. [***STO] <http://www.stork-gears.com>
- 121. [***SUL,a] <http://www.sulzermetco.com/en/desktopdefault.aspx/tabid-1705/>, accesed: 10.08.09
- 122. [***SUL,b] http://www.sulzermetco.com/en/portaldata/13/Resources//documents/materials/TS_MaterialGuide_06.2010a_web.pdf
- 123. [***YOR] <http://www.yorkshirelaser.co.uk/>
- 124. [***ILT] http://www.ilt.fraunhofer.de/eng/ilt/pdf/eng/products/Themenbrochure_System_Engineering.pdf
- 125. [***SPE] <http://www.specialsteel-jy.com/5140.html>

ISBN 978-973-131-344-3



Braşov, Romania
Str. Cloşca nr. 25, ap. 3
mobil: 004 0755 020 590
E-mail: office@luxlibris.ro