Analysis of the Laser-Cladding Process for Stellite on Steel

A. FRENK, M. VANDYOUSSEFI, J.-D. WAGNIÈRE, A. ZRYD, and W. KURZ

Laser-cladding experiments have been performed with STELLITE 6 powder on mild steel substrates, using a 1.5 kW linearly polarized continuous wave CO_2 laser as a heat source. The clad height, the mass efficiency, the dimensions of the melt pool, as well as the global absorptivity, were measured as functions of the powder feed rate and the scanning speed. A quantitative analytical model of the process is proposed, based on the overall mass and energy balance. It allows the calculation of the mass efficiency and of the global absorptivity, taking into account the incorporation of the powder into the melt pool as well as the energy absorbed by the powder jet and the substrate. It successfully explains the experimental results and demonstrates the role played by the melt pool inclination with respect to the substrate. A processing diagram is given to find rapidly the optimal laser treatment conditions and the desired clad height. It is discussed with respect to the other limiting conditions of the process, the geometrical maximum powder efficiency, the porosity, the dilution, and the maximum power of the laser installation.

I. INTRODUCTION

LASER cladding is a modern process of producing metallurgically well-bonded coatings of a great variety of materials of intermediate thickness (typically between 0.1 and 2 mm). It can produce much better coatings, with minimal dilution from the substrate, minimal distortion of the workpiece, and good surface quality than with other techniques, such as arc welding. Furthermore, with high speed cladding, extremely fine and homogeneous microstructures, characteristic of rapid solidification processes, can be obtained on the surface of massive pieces.[1,2]

In the past, there have been various contributions which have improved the understanding of the process. As early as 1983, Weerasinghe and Steen[3] proposed a numerical model for calculating the heat flux in the process. They took into account effects such as shadowing of the particle cloud, heat absorption of the particles, and overlapping of the traces. Later, Steen *et al.*[4] produced processing maps and qualitatively analyzed the physics of dilution, intertrack porosity, and continuity of clad trace. Hoadley and Rappaz[5] undertook a detailed two-dimensional (2-D) heat flux analysis, which allowed the computation of the steady-state temperature field, the approximate shape of the melt pool, and the position of the liquid with respect to the laser beam axis. They studied the influence of processing parameters such as laser power and processing speed on dilution and clad thickness. Ollier *et al.*[6] also considered in their 2-D heat flux calculations melt convection and angle-dependent power absorption for a *p*-polarized laser beam. Picasso and Hoadley[7] developed a numerical 2-D model for laser remelting and cladding. Convection driven by thermocapillary forces and by the process of particle injection was taken into account. Picasso *et al.*[8] developed an analytical model for the cladding process. This model contains all the important elements of the real process and allows calculation of the temperature field under simplified assumptions. Most of these publications were concerned essentially with modeling aspects of the problem, and detailed quantitative comparisons of the experimental results with the predictions of the models were mostly not included.

An optimal setting of the processing parameters is required to achieve the deposition of dense, porosity-free coatings, presenting a good metallurgical bond with the substrate due to some dilution. It is important to minimize this dilution in order to preserve the chemical composition and the properties of the clad. The complexity of the interaction of the many process variables with the product makes the optimization of this process a difficult task, even more so as a quantitative understanding, which is a prerequisite for any rational process development and on-line control, is still insufficient.

The aim of this article is to contribute to a better quantitative understanding of the laser cladding process by in-depth examination of two key phenomena: (1) energy coupling between the laser beam and the workpiece, given by the global absorption, β_a, which takes into account the energy absorption of the substrate and of the powder; and (2) the mass flow or incorporation of the powder into the molten pool. In the following discussion, these two aspects will be treated in some detail. New experimental results will be presented and compared with physical models.

II. EXPERIMENTAL

Figure 1 shows the principal elements of the process as used by the present authors. A high-power CO_2 laser locally remelts the surface of a workpiece. The hard-facing alloy, in powder form, is injected into the molten pool with the aid of a protective gas through a coaxial nozzle. Powder entering the molten pool is completely remelted and mixed within the liquid due to strong convection currents generated by the high thermal gradients at the surface (Marangoni effect[9]). A single-clad track is formed by moving the specimen relative to the beam in the *y* direction, and wider clad areas are obtained by successive deposition of overlapping tracks.

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Analysis Of The Laser Cladding Process For Stellite On Steel:

Laser Cladding Ehsan Toyserkani,Amir Khajepour,Stephen F. Corbin,2004-08-12 Capitalizing on the rapid growth and reduced costs of laser systems laser cladding is gaining momentum and in some instances replacing conventional techniques of depositing thin films because it can accommodate a great variety of materials achieve uniform thickness and precise widths of layers and provide improved resistance to wear and corrosion in the final product Laser cladding technology also offers a revolutionary layered manufacturing and prototyping technique that can fabricate complex components without intermediate steps Laser Cladding reviews the parameters techniques and equipment process modeling and control and the physical metallurgy of alloying and solidification during laser cladding The authors clarify the interconnections laser cladding has with CAD CAM design automation and robotics sensors feedback and control physics material science heat transfer fluid dynamics and powder metallurgy to promote further development and improved process quality of this growing technology As the first book entirely dedicated to the topic it also offers a history of its development and a guide to applications and market opportunities While a considerable part of Laser Cladding is dedicated to industrial applications this volume brings together valuable information illustrated with real case studies based on the authors vast experience and research and analysis in the field to provide a timely source for both academia and industry **Laser Cladding of Metals** Pasquale Cavaliere,2020-11-05 Laser cladding is an additive manufacturing technology capable of producing coatings due to the surface fusion of metals The selected powder is fed into a focused laser beam to be melted and deposited as coating This allows to apply material in a selected way onto those required sections of complex components The process main properties are the production of a perfect metallurgically bonded and fully dense coatings the minimal heat affected zone and low dilution between the substrate and filler material resulting in functional coatings that perform at reduced thickness so fewer layers are applied fine homogeneous microstructure resulting from the rapid solidification rate that promotes wear resistance of carbide coatings near net shape weld build up requires little finishing effort extended weldability of sensitive materials like carbon rich steels or nickel based superalloys that are difficult or even impossible to weld using conventional welding processes post weld heat treatment is often eliminated as the small heat affected zone minimizes component stress excellent process stability and reproducibility because it is numerical controlled welding process The typical applications are the dimensional restoration the wear and corrosion protection additive manufacturing The wide range of materials that can be deposited and its suitability for treating small areas make laser cladding particularly appropriate to tailor surface properties to local service requirements and it opens up a new perspective for surface engineered materials The main key aspect to be scientifically and technologically explored are the type of laser the powders properties the processing parameters the consequent microstructural and mechanical properties of the processed material the capability of fabrication of prototypes to rapid tooling and rapid manufacturing Distills critical concepts methods and applications from leading full

length chapters along with the authors s own deep understanding of the material taught into a concise yet rigorous graduate and advanced undergraduate text Reinforces concepts covered with detailed solutions to illuminating and challenging industrial applications Discusses current and future applications of laser cladding in additive manufacturing **Advances in Laser Materials Processing** Jonathan R. Lawrence,2017-09-20 Advances in Laser Materials Processing Technology Research and Application Second Edition provides a revised updated and expanded overview of the area covering fundamental theory technology and methods traditional and emerging applications and potential future directions The book begins with an overview of the technology and challenges to applying the technology in manufacturing Parts Two thru Seven focus on essential techniques and process including cutting welding annealing hardening and peening surface treatments coating and materials deposition The final part of the book considers the mathematical modeling and control of laser processes Throughout chapters review the scientific theory underpinning applications offer full appraisals of the processes described and review potential future trends A comprehensive practitioner guide and reference work explaining state of the art laser processing technologies in manufacturing and other disciplines Explores challenges potential and future directions through the continuous development of new application specific lasers in materials processing Provides revised expanded and updated coverage *Virtual Modelling and Rapid Manufacturing* Paulo Jorge da Silva Bartolo,2005-09-15 Virtual Modelling and Rapid Manufacturing presents essential research in the area of Virtual and Rapid Prototyping It contains reviewed papers that were presented at the 2nd International Conference on Advanced Research in Virtual and Rapid Prototyping held at the School of Technology and Management of the Polytechnic Institute of Leiria Portugal from September 28 to October 1 2005 The volume covers a wide range of topical subjects such as medical imaging reverse engineering virtual reality and prototyping biomanufacturing and tissue engineering advanced rapid prototyping technologies and micro fabrication biomimetics and materials and concurrent engineering *7th International Symposium on High-Temperature Metallurgical Processing* Jiann-Yang Hwang,Tao Jiang,P. Chris Pistorius,Gerardo R. F. Alvear F.,Onuralp Yucel,Liyuan Cai,Baojun Zhao,Dean Gregurek,Varadarajan Seshadri,2016-02-08 The technology operation energy environmental analysis and future development of the metallurgical industries utilizing high temperature processes are covered in the book The innovations on the extraction and production of ferrous and nonferrous metals alloys and refractory and ceramic materials the heating approaches and energy management and the treatment and utilizations of the wastes and by products are the topics of special interests This book focuses on the following issues High Efficiency New Metallurgical Process and Technology Fundamental Research of Metallurgical Process Alloys and Materials Preparation Direct Reduction and Smelting Reduction Coking New Energy and Environment Utilization of Solid Slag Wastes and Complex Ores Characterization of High Temperature Metallurgical Process **Metal Additive Manufacturing** Ehsan Toyserkani,Dyuti Sarker,Osezua Obehi Ibhadode,Farzad Liravi,Paola Russo,Katayoon Taherkhani,2021-10-25 METAL ADDITIVE MANUFACTURING A

comprehensive review of additive manufacturing processes for metallic structures Additive Manufacturing AM also commonly referred to as 3D printing builds three dimensional objects by adding materials layer by layer Recent years have seen unprecedented investment in additive manufacturing research and development by governments and corporations worldwide This technology has the potential to replace many conventional manufacturing processes enable the development of new industry practices and transform the entire manufacturing enterprise Metal Additive Manufacturing provides an up to date review of all essential physics of metal additive manufacturing techniques with emphasis on both laser based and non laser based additive manufacturing processes This comprehensive volume covers fundamental processes and equipment governing physics and modelling design and topology optimization and more The text adresses introductory intermediate and advanced topics ranging from basic additive manufacturing process classification to practical and material design aspects of additive manufacturability Written by a panel of expert authors in the field this authoritative resource Provides a thorough analysis of AM processes and their theoretical foundations Explains the classification advantages and applications of AM processes Describes the equipment required for different AM processes for metallic structures including laser technologies positioning devices feeder and spreader mechanisms and CAD software Discusses the opportunities challenges and current and emerging trends within the field Covers practical considerations including design for AM safety quality assurance automation and real time control of AM processes Includes illustrative cases studies and numerous figures and tables Featuring material drawn from the lead author s research and professional experience on laser additive manufacturing Metal Additive Manufacturing is an important source for manufacturing professionals research and development engineers in the additive industry and students and researchers involved in mechanical mechatronics automatic control and materials engineering and science *Heat Treating and Surface Engineering* ASM Heat Treating Society. Conference and Exposition,2003-01-01 *International Journal of Powder Metallurgy* ,2001 *Tailoring of Engineering Material Properties through Laser Cladding* Natarajan Jeyaprakash,Govindarajan Prabu,Che-Hua Yang,2025-05-13 In this comprehensive guide to laser cladding of engineering materials expert contributors provide a detailed yet easy to follow explanation of the process its use for surface modification and the benefits and applications of this technique in different environments and for different purposes The optimization of an engineering material s properties and behavior is vital for economic safety and quality assurance reasons when these materials are applied in various industrial settings This book therefore explains how laser cladding can be used to tailor and control a material s surface layer properties such as its elastic and plastic deformation and permanent detachment in the form of debris during the contact of mating parts Through individual chapter contributions from experts in various elements related to laser cladding this book guides readers through the evaluation of different structures in laser cladded engineering materials The book addresses three key questions What is the influence of micro and nano level structures on mechanical properties How does laser cladding improve a material s wear resistance at the micron

and nano level and determine the material s suitability for particular applications What challenges are related to the laser cladding of different engineering materials In addressing these questions the book enables readers to determine the metallurgical mechanical tribological and corrosion behavior of any type of engineering material Readers will also be able to make informed decisions based on their knowledge of the properties and industrial applications of different laser cladded materials This book is essential for all manufacturing industry personnel who work with materials in various industrial settings and need to control their surface properties and enhance their behavior at the micron and nano levels Students who are building experience prior to entering industry will also benefit from the detailed descriptions step by step approach and focus on practical application **Advanced Laser Process for Surface Enhancement** Jianhua Yao,Bo Li,Liang Wang,2020-11-30 Two typical hybrid laser surface modification processes i e electro magnetic field aided laser process and supersonic laser deposition technology are introduced in the book to solve the common problems in quality control and low efficiency of the laser only surface modification technology high contamination and high consumption of the traditional surface modification technology This book focuses on the principle characteristics special equipment process and industrial applications of the hybrid laser surface modification processes based on the recent research results of the author s group and provides theoretical guidance and engineering reference for the researchers and engineers engaging in the field of surface engineering and manufacturing Titanium Alloys A.K.M. Nurul Amin,2012-03-16 The first section of the book includes the following topics fusion based additive manufacturing AM processes of titanium alloys and their numerical modelling mechanism of case formation mechanism during investment casting of titanium genesis of gas containing defects in cast titanium products Second section includes topics on behavior of the titanium alloys under extreme pressure and temperature conditions hot and super plasticity of titanium alloys and some machinability aspects of titanium alloys in drilling Finally the third section includes topics on different surface treatment methods including nanotube anodic layer formation on two phase titanium alloys in phosphoric acid for biomedical applications chemico thermal treatment of titanium alloys applying nitriding process for improving corrosion resistance of titanium alloys **Metal Powder Deposition for Rapid Manufacturing** ,2002 **Materials Technology Gaps in Metal Additive Manufacturing** Cynthia Waters,2018-04-24 Metal additive manufacturing MAM is an exciting emergent technology that offers the possibility of democratizing metal manufacturing worldwide Many believe it has the ability to revolutionize product manufacturing on a global scale MAM will require a considerable design shift for manufacturers and hence will disrupt conventional thinking and require adaptation Visionaries in the mobility industry can see the transformative possibilities after materials considerations are addressed Materials Technology Gaps in Metal Additive Manufacturing introduces the reader to various opportunities and relationships in the study of material technologies involved in metal based additive manufacturing of aerospace and automotive parts Everything starts and ends with the material feedstock and the intermediate processes that affect a particular metal Each of the choices

in the complex integrated MAM system impacts final part properties Edited by Dr Cynthia K Waters from North Carolina A T State University Materials Technology Gaps in Metal Additive Manufacturing is a highly curated collection of 10 seminal SAE International papers They discuss the various technologies involved in MAM and draw attention to the materials needs in each of the situations addressed The main topics included in Materials Technology Gaps in Metal Additive Manufacturing are Process design and material modeling Metal powder selection and study Additive processing parameters effect on materials properties As more interdependencies of material properties and possible manufacturing processes evolve compatibility interdependence questions if the specific manufacturing process is capable to create the required geometry will also arise Materials Technology Gaps in Metal Additive Manufacturing brings innovative ways to address these and other challenges that are always present in the adoption of novel technologies *Additive Manufacturing* Juan Pou,Antonio Riveiro,J. Paulo Davim,2021-05-21 Additive Manufacturing explains the background theory working principles technical specifications and latest developments in a wide range of additive manufacturing techniques Topics addressed include treatments of manufactured parts surface characterization and the effects of surface treatments on mechanical behavior Many different perspectives are covered including design aspects technologies materials and sustainability Experts in both academia and industry contribute to this comprehensive guide combining theoretical developments with practical improvements from R D This unique guide allows readers to compare the characteristics of different processes understand how they work and provide parameters for their effective implementation This book is part of a four volume set entitled Handbooks in Advanced Manufacturing Other titles in the set include Advanced Machining and Finishing Advanced Welding and Deformation and Sustainable Manufacturing Processes Provides theory operational parameters and latest developments in 20 different additive manufacturing processes Includes contributions from experts in industry and academia with a wide range of disciplinary backgrounds providing a comprehensive survey of this diverse and influential subject Includes case studies of innovative additive manufacturing practices from industry *Recent Advances in Manufacturing, Automation, Design and Energy Technologies* Sendhil Kumar Natarajan,Rajiv Prakash,K. Sankaranarayanasamy,2021-10-11 This book comprises the proceedings of the 1st International Conference on Future Technologies in Manufacturing Automation Design and Energy 2020 The contents of this volume focus on recent technological advances in the field of manufacturing automation design and energy Some of the topics covered include additive manufacturing renewable energy resources design automation process automation and monitoring etc This volume will prove a valuable resource for those in academia and industry

Optimization Methods in Manufacturing Processes Anand J. Kulkarni,2025-08-05 This book presents the result of an innovative challenge to create a systematic literature overview driven by machine generated content Questions and related keywords were prepared for the machine to query discover collate and structure by Artificial Intelligence AI clustering The AI based approach seemed especially suitable to provide an innovative perspective as the topics are indeed both complex

interdisciplinary and multidisciplinary for example climate planetary and evolution sciences Springer Nature has published much on these topics in its journals over the years so the challenge was for the machine to identify the most relevant content and present it in a structured way that the reader would find useful The automatically generated literature summaries in this book are intended as a springboard to further discoverability They are particularly useful to readers with limited time looking to learn more about the subject quickly and especially if they are new to the topics Springer Nature seeks to support anyone who needs a fast and effective start in their content discovery journey from the undergraduate student exploring interdisciplinary content to Master or PhD thesis developing research questions to the practitioner seeking support materials this book can serve as an inspiration to name a few examples It is important to us as a publisher to make the advances in technology easily accessible to our authors and find new ways of AI based author services that allow human machine interaction to generate readable usable collated research content **Solid State Lasers Materials, Technologies and Applications** Federico Pirzio,2018-04-24 This book is a printed edition of the Special Issue Solid State Lasers Materials Technologies and Applications that was published in Applied Sciences **Laser Processing: Surface Treatment and Film Deposition** J. Mazumder,O. Conde,R. Vilar,W. Steen,2012-12-06 Synthesis of nonequilibrium metallic phases has been an area of great interest to the materials processing community since early 1960 Inherent rapid cooling rates in laser processing are being used to engineer non equilibrium microstructures which cannot be rivaled by other processes This lecture will discuss the phenomena involved and its application in designing materials with tailored properties What is non equilibrium Synthesis This is a synthesis method to produce binary or higher order materials where kinetics of the pro cess affects the transport of the constituent elements during phase transformation resulting in a composition or crystallographic configuration which is different from what is observed when the elements arranges themselves with the lowest possible Gibbs Free energy which is the equilibrium condition Figure 1 illustrates the phenomena Phase diagram under equilibrium condition is illustrated by the solid line whereas the no equilibrium phase diagram is represented by the dotted line One can observe the shrinkage of the phase field under non equilibrium condition Any alloy composition between the solidus lines of the equilibrium and non equilibrium phase diagram will be a non equilibrium alloys with extended solid solution

Handbook of Laser-Based Sustainable Surface Modification and Manufacturing Techniques Hitesh Vasudev,Chander Prakash,2023-07-05 This handbook provides an insight into the advancements in surface engineering methods addressing the microstructural features properties mechanisms of surface degradation failures and tribological performance of the components Emphasis is placed on the use of laser cladding methods because they make it simple to deposit new classes of materials such nano composites nanotubes and smart materials Handbook of Laser Based Sustainable Surface Modification and Manufacturing Techniques discusses the main mechanism behind the surface degradation of structural components in strenuous environments It highlights the capacity of laser cladding to operate on a wide range of

substrate materials and shapes as well as presents how laser cladding can offer new possibilities in the reconditioning of components and how in many cases these approaches are the only solution for economic efficiency The handbook illustrates how the type of laser laser optics and the parameters of the process can be efficiently selected and thus the number of applications of laser cladding and its applications can be increased The standard methods of testing used for various types of biomedical devices and tools as well as the advantages of combining laser cladding with simultaneous induction heating are described as well within this handbook Features Discusses the role of claddings fabricated with laser technique to withstand wear and corrosion Highlights the role of laser in the manufacturing of alloys and recent advancements in laser based additive manufacturing processes Presents the possibilities applications and challenges in laser surfacing Illustrates the post treatments of powders and coatings and case studies related to laser surface technology Offers the standard methods of testing applied to various types of biomedical devices and tools Goes over the advantages of combining laser cladding with simultaneous induction heating The technical outcomes of these surface engineering methods are helpful for academics students and professionals who are working in this field as this enlightens their understanding of the performance of these latest processes The audience is broad and multidisciplinary Lasers Based Manufacturing Shrikrishna N. Joshi,Uday Shanker Dixit,2015-04-08 This book presents selected research papers of the AIMTDR 2014 conference on application of laser technology for various manufacturing processes such as cutting forming welding sintering cladding and micro machining State of the art of these technologies in terms of numerical modeling experimental studies and industrial case studies are presented This book will enrich the knowledge of budding technocrats graduate students of mechanical and manufacturing engineering and researchers working in this area

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