

# 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<sub>2</sub> 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.<sup>1-3</sup>

In the past, there have been various contributions which have improved the understanding of the process. As early as 1983, Weerasinghe and Steen<sup>4</sup> 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.*<sup>5</sup> produced processing maps and qualitatively analyzed the physics of dilution, intertrack porosity, and continuity of clad trace. Hoadley and Rappozzi<sup>6</sup> 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.*<sup>7</sup> 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<sup>8</sup> 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.*<sup>9</sup> 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,  $\beta_g$ , 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<sub>2</sub> 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<sup>10</sup>). 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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**PT Brinkman**



## **Analysis Of The Laser Cladding Process For Stellite On Steel:**

**International Journal of Powder Metallurgy** ,2001      **Metal Powder Deposition for Rapid Manufacturing** ,2002

**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      *Proceedings of the ASME International Design Engineering Technical Conferences and Computers and Information in Engineering Conferences--2005* ,2005      *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

**Recent Trends in Design, Materials and Manufacturing** Manvandra Kumar Singh,Rakesh Kumar Gautam,2022-04-29 The book presents the select proceedings of the International Conference on Recent Advances in Design Materials and Manufacturing ICRADMM 2020 The topics covered include structural mechanics kinematics and dynamics of machines mechanical structures and stress analysis noise and vibration analysis fault detection and condition monitoring optimization techniques mechatronics robotics product design and development tribology The book also discusses various properties and performance attributes of modern age design in mechanical engineering including their durability workability and carbon footprint The book will be a valuable reference for researchers and professionals interested in sustainable development in mechanical engineering design and allied fields

*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

Sustainable Smart Manufacturing Processes in Industry 4.0 Ramesh Kumar,Arbind Prasad,Ashwani Kumar,2023-10-16 The text discusses both theoretical and technological aspects of the Industry 4 0 based manufacturing processes It covers important topics such as additive manufacturing laser based manufacturing processes electromagnetic welding and joining processes green manufacturing processes and friction welding processes Illustrates sustainable manufacturing aspects in robotics and aerospace industries Showcases additive manufacturing processes with a focus on innovation and automation Covers environment friendly manufacturing processes resulting in zero waste and conserves natural resources Synergizes exploration related to the various properties and functionalities through extensive theoretical and experimental modeling Discusses impact welding for joining of dissimilar materials The text discusses the recent manufacturing techniques and methodologies such as impact welding for joining of dissimilar materials It further covers techniques such as additive manufacturing and electromagnetic manu facturing resulting in minimum or negligible waste The text elaborates important topics such as friction stir welding energy consumption analysis and industry waste recycling for sustainable development It will serve as an ideal reference text for

senior undergraduate graduate students and researchers in the fields including mechanical engineering aerospace engineering manufacturing engineering and production engineering

[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

**Laser Surface Treatments for Tribological Applications** Jeyaprakash Natarajan,2021-11-22 This reference presents comprehensive information about laser surface treatments for tribological applications Chapters of the book highlight the importance of laser technology in modifying materials to optimize the effects of friction and lubrication by explaining a range of surface modification methods used in industries These methods include hardening melting alloying cladding and texturing The knowledge in the book is intended to give an in depth understanding about the role of laser technology in tribology and the manufacture of industrial materials and surfaces for special applications Key Features 10 chapters on topics relevant to tribology and industrial applications of laser material processing Comprehensively covers laser surface modification of metals and alloys Explains a wide range of surface modification methods hardening melting alloying cladding and texturing Covers material and tribological characterization of surfaces Presents information in a simple structured layout for easy reading with

introductory notes for learners Provides references for further reading This book is an ideal reference for students and learners in courses related to engineering manufacturing and materials science Researchers industrial professionals and general readers interested in laser assisted machining processes and surface modification techniques will also find the book to be an informative reference on the subject     *Mechanical and Electrical Technology VI* Nopbhorn Leeprechanon,Kali Pada Maity,Guang Hsu Chang,2014-08-18 Selected peer reviewed papers from the 2014 6th International Conference on Mechanical and Electrical Technology ICMET 2014 July 17 18 2014 Bangkok Thailand     *Issues in Materials and Manufacturing Research: 2011 Edition* ,2012-01-09 *Issues in Materials and Manufacturing Research 2011 Edition* is a ScholarlyEditions eBook that delivers timely authoritative and comprehensive information about Materials and Manufacturing Research The editors have built *Issues in Materials and Manufacturing Research 2011 Edition* on the vast information databases of ScholarlyNews You can expect the information about Materials and Manufacturing Research in this eBook to be deeper than what you can access anywhere else as well as consistently reliable authoritative informed and relevant The content of *Issues in Materials and Manufacturing Research 2011 Edition* has been produced by the world s leading scientists engineers analysts research institutions and companies All of the content is from peer reviewed sources and all of it is written assembled and edited by the editors at ScholarlyEditions and available exclusively from us You now have a source you can cite with authority confidence and credibility More information is available at [http www ScholarlyEditions com](http://www.ScholarlyEditions.com)     *Design Study of Advanced Model Support Systems for the National Transonic Facility (NTF)* ,1987     *Journal of Physics* ,2004     **Laser Processing of Advanced Materials and Laser Microtechnologies** Friedrich Dausinger,2003     **Laser Technology VI.** Wiesław Woliński,Zdzisław Jankiewicz,2000     **Laser Technology VII.** Wiesław Woliński,Zdzisław Jankiewicz,Ryszard S. Romaniuk,2003 Proceedings of SPIE present the original research papers presented at SPIE conferences and other high quality conferences in the broad ranging fields of optics and photonics These books provide prompt access to the latest innovations in research and technology in their respective fields Proceedings of SPIE are among the most cited references in patent literature     *Metals Abstracts* ,1998-04     **Second International Conference on Surface Engineering** Welding Institute,Surface Engineering Society,1988     **Proceedings of the 4th International Tribology Conference, AUSTRIB '94** Gwidon W. Stachowiak,1994

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