Optics & Laser Technology 77 (2016) 98–103

Contents lists available at ScienceDirect

Optics & Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Review

# Optimization of the laser remelting process for HVOF-sprayed Stellite 6 wear resistant coatings

Costel-Relu Ciubotariu [a,*], Doina Frunzăverde [a], Gabriela Mărginean [b], Viorel-Aurel Şerban [c], Aurel-Valentin Bîrdeanu [d]

[a] University "Eftimie Murgu" from Resita, Traian Vuia Square no. 1-4, 320085 Resita, Romania
[b] Westfälische Hochschule, University of Applied Sciences Gelsenkirchen, Germany
[c] University Politehnica of Timisoara, Faculty of Mechanical Engineering, M. Viteazu Ave., no. 1, Timisoara, Romania
[d] National R&D Institute for Welding and Material Testing-ISIM Timişoara, M. Viteazu Ave., no. 20, 300222 Timisoara, Romania

ARTICLE INFO

*Article history:*
Received 25 March 2015
Received in revised form
26 August 2015
Accepted 4 September 2015
Available online 12 September 2015

*Keywords:*
Stellite 6
HVOF-spraying
Laser remelting
Cavitation erosion
Coatings

ABSTRACT

Cobalt base alloys are used in all industrial areas due to their excellent wear resistance. Several studies have shown that Stellite 6 coatings are suitable not only for protection against sliding wear, but also in case of exposure to impact loading. In this respect, a possible application is the protection of hydropower plant components affected by cavitation. The main problem in connection with Stellite 6 is the deposition procedure of the protective layers, both welding and thermal spraying techniques requesting special measures in order to prevent the brittleness of the coating. In this study, Stellite 6 layers were HVOF thermally sprayed on a martensitic 13-4 stainless steel substrate, as usually used for hydraulic machinery components. In order to improve the microstructure of the HVOF-sprayed coatings and their adhesion to the substrate, laser remelting was applied, using a TRUMPF Laser type HL 124P LCU and different working parameters. The microstructure of the coatings, obtained for various remelting conditions, was evaluated by light microscopy, showing the optimal value of the pulse power, which provided a homogenous Stellite 6 layer with good adhesion to the substrate.



**Contents**



## 1. Introduction

The technological development of recent years is a consequence of increasing performance requirements for industrial equipment, especially regarding the surface properties. Hydropower quality is conditioned by durability and reliability of the hydraulic machineries. Surface damages caused by fatigue, corrosion and wear, in particular cavitation erosion, are among the main causes that lead to failure of hydropower plant components. For this reason, special attention is granted to procedures applied both for the initial protection and for the repair of damaged surfaces. In case of repair procedures, the most commonly used method, easily to apply also on site, is repair welding [1,3]. But one has to take into account that the important heat input during the welding process is generating internal stresses as well as structural modifications, affecting both the filler material and the base material [2,4].

A heat treatment of the components on site, in order to reduce the internal stresses, is difficult to realize, so that, after repair

* Corresponding author.
*E-mail address:* r.ciubotariu@uem.ro (C.-R. Ciubotariu).

http://dx.doi.org/10.1016/j.optlastec.2015.09.005
0030-3992/

**Table 1**
Thermal spraying parameters for the achievement of the samples with Stellite 6 coatings.

| Deposition parameter | Value | Deposition parameter | Value |
|---|---|---|---|
| Oxygen pressure [bar] | 10 | Carrier gas flow [l/min] | 13 |
| Propane pressure [bar] | 5.8 | Powder feed [g/min] | 40 |
| Air pressure [bar] | 6.2 | Spraying distance [mm] | 230 |
| Oxygen flow [l/min] | 300 | Spraying rate [m/min] | 108 |
| Propane flow [l/min] | 68 | Speed control [mm/sec] | 11 |
| Air flow [l/min] | 358 | **Coating thickness [μm]** | **396** |
| Carrier gas pressure ($N_2$) [bar] | 8.9 | Powder particle size [μm] | 45/15 |

welding without subsequent stress relief treatment the components exposed to operating conditions are often failing after a reduced number of working hours. Therefore, the development of alternative repair techniques could increase the life of hydropower components and in this way the overall system efficiency. In the last two decades, an increased attention was given to the thermal spraying techniques, due to their capacity to strengthen almost any material which has a stable molten phase and to produce relatively homogeneous and fine grained layers [5]. Among the thermal spraying procedures, the High Velocity Oxy Fuel (HVOF) method is nowadays often successfully used for the surface protection [6–8], especially due to the low temperature of the flame used and the relatively good quality of the coatings obtained by the supersonic pressures of the jet.

When components are exposed to impact loading, such as operating under cavitation conditions, the relatively high porosity, the presence of oxides and unmelted particles in the HVOF-sprayed coatings, as well as their poor adhesion to the substrate are inconveniences, which strongly limit the suitability of the method. In such cases, subsequent treatments can be applied, in order to refine the layers structure and to improve their adhesion to the substrate, treatments which assure the remelting of the layer using an oxy-acetylene flame [9], a laser [10] or an electron beam [11].

A lot of literature concerning state of the art in respect to cavitation resistance of Stellite 6 coatings reports even about welded [12,13] or HVOF sprayed Stellite 6 coatings [14–16]. There is no reference about the properties respectively the cavitation resistance of remelted HVOF sprayed Stellite 6 coatings. The present paper aims the optimization of the laser remelting parameters for HVOF sprayed Stellite 6 coatings deposited on martensitic stainless steel.

## 2. Experimental procedure

Stellite 6 coatings were applied by HVOF-spraying on samples manufactured from martensitic stainless steel type 1.4313. The thermal spraying procedure was realized at the Tampere University of Technology in Finland, using a DJH 2700 pistol and the deposition parameters presented in Table 1. The chemical compositions of the layers and the substrate are indicated in Table 2.

Because the coatings deposited by thermal spraying usually present a mixture of lamellar melted and half melted or unmelted particles, a certain content of oxide and/or porosity (see Fig. 1) for particular applications a post-deposition treatment is advisable, in order to refine the structure of the layers and to improve their adhesion to the substrate. Therefore, the Stellite 6 coatings were subjected to laser remelting, carried out at the National Research & Development Institute for Welding and Material Testing in Timişoara (ISIM).

The laser system used at ISIM Timişoara is presented in Fig. 1 and did include: a flexible laser beam micro-processing unit with an inertial table and a positioning system for the laser head, a programmable pulsed Nd:YAG Trumpf HL 124P LCU laser, with a maximum average power output of 150 W and a Cartesian xOy robot, type YAMAHA FXYX-A1. For all experiments, the surface protection was assured by an argon (4.8) gas flow, using a laser protection nozzle, which was fitted off-axis to the laser beam. The flow rate of the argon was set at 12 l/min.

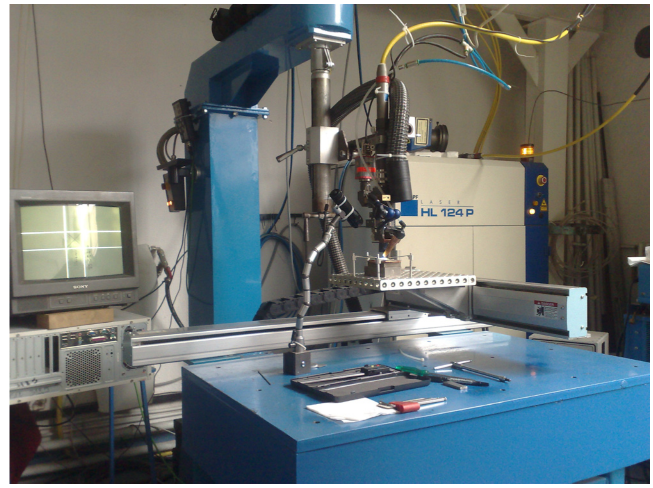


**Fig. 1.** Experimental setup for the laser remelting processes of the HVOF-sprayed Stellite 6 coatings.

**Table 3**
Working parameters applied for the remelting of the HVOF-sprayed Stellite 6 coatings.

| Pass no. | Argon gas flow [l/min] | Pulse repetition frequency [Hz] | Travel speed [mm/sec] | Pulse duration [ms] | Focal setup | Pulse peak power [W] |
|---|---|---|---|---|---|---|
| 1 | 12 | 10 | 4,07 | 10 | Focused la- | 750 |
| 2 | | | | | ser beam | 850 |
| 3 | | | 2,85 | | Off-focused | 850 |
| 4 | | | | 6 | laser beam | 650 |
| 5 | | | | | (+5 mm) | 550 |
| 6 | | | | | | 650 |
| 7 | | | | | | 750 |
| 8 | | | | | | 850 |
| 9 | | | | | | 950 |
| 10 | | | | | | 1050 |
| 11 | | | | | | 1150 |
| 12 | | | | | | 1250 |
| 13 | | | | | | 1350 |
| 14 | | | | | | 1550 |

**Table 2**
Chemical composition of the substrate and the coating.

| **Chemical element** | **C** | **Si** | **Mn** | **Cr** | **Ni** | **Co** | **Mo** | **P** | **Fe** | **S** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1.4313 (Substrate) | 0.03 | 0.46 | 0.71 | 12.64 | 3.63 | – | 0.53 | 0.025 | Base | 0.001 |
| Stellite 6 (Powder) | 0.9–1.4 | – | – | 27–32 | 3.26 | Base | 4–6 | – | 2.26 | – |