Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 20 (2018) 446–451

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

2nd International Conference on Materials Manufacturing and Design Engineering

Problems on the development of hard and low friction in-situ coatings on Ti-6Al-4V using laser cladding

Barun Haldar[a*] and Partha Saha[b]

[a]Ex-Research Scholar[1] and Assistant Professor[2], [b]Professor[1]
[1]Dept. of Mechanical Engineering, Indian Institute of Technology, Kharagpur-721302, WB, India
[2]School of Mechanical Engineering, Jimma Institute of Technology, Jimma University, Jimma-378, Ethiopia

Abstract

Coatings having high hardness and low coefficient of friction are significant for long service life of engineering components subjected to sliding wear. Some useful applications of such coatings are in various engine components including aerospace industries. Laser surface engineering has promising process characteristics for changing surface properties. In this concern, using laser cladding process hard and low friction coatings were developed on Ti-6Al-4V for improving sliding behavior of its components. To carry out the experimental investigations, the pre-placed powder mixture of B_4C, *h*BN and Ti were used on the Ti-6Al-4V substrates and subsequently laser irradiated to form the improved surface properties. The coatings were developed with a wide range of laser scan speeds. Physical and mechanical characterizations of all samples were done rigorously. For some laser-scan-speeds in the range of studies, developed coatings resulted in very high hardness about 2200 HV. The dry sliding wear tests (against WC ball at 10 N loading) indicated a very low coefficient of friction of about 0.1 to 0.16 for the coatings. The problems experienced during development of the in-situ coatings are highlighted in the paper.

Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.

Keywords: Ultra-low-friction, hard coating, laser cladding, Ti-6Al-4V, in-situ MMC

1. Introduction

Ti and Ti super alloys are important in 'light weight high strength' applications and highly demanding materials

* Corresponding author. Tel.: +251-472115013; fax: +251-471117825.
E-mail address: dr.barun.haldar@ju.edu.et -*and*- barun@aol.in

2351-9789
Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.
10.1016/j.promfg.2018.02.065

in aerospace, automotive, power generation industries. Beyond high specific strength, Ti has promising bulk material characteristics, significant fatigue strength, good corrosion resistance and subzero-to-moderately elevated working temperature [1], Processing of Ti and its alloys by means of turning, milling, grinding, drilling, casting, forming, etc. are difficult due to higher chemical affinity of Ti towards elements like oxygen, nitrogen, carbon, boron, etc. Further, high coefficient of friction restricts its further application possibilities [2] as functional parts related to sliding. Surface engineering of Ti and its super alloys are essential for such kind of applications. In this concern, deposition and post processing of bulk coating is in demand for recent engineering application possibilities of Ti and Ti super alloys.

Surface engineering like hard facing, restoration, repairing and coating of engineering components are becoming popular using laser cladding process which includes several advantages:

- high power density 10^4 to 10^7 kW/cm^2 may reach at temperature up to 10^5 K [3] on a small, pinpointed or selective area,
- faster processing ability [4],
- HAZ and dilution of the substrate may be controlled by using intense laser source with high scanning speed,
- rapid heating-cooling rates (10^4 to 10^{11} K/s), high thermal gradient (10^6 to10^8 K/m), and rapid re-solidification velocity (1 to 30 m/s) may yield fine microstructure and form metastable even amorphous phases[2],
- a wide range of materials like metals, ceramics, MMCs, etc. with different types, shapes, sizes, densities, etc. can be easily mixed and processed,
- bulk coatings like cladding may enhance strength of the coating-substrate system.

As bulk coating shares load, it becomes more effective and useful when hard layers are bonded on relatively much softer substrates like Ti, Al, Mg and their alloys.

Laser cladding provides a number of advantages in material processing, despite it is challenging due to the followings:

- There are about thirty sets of process controlling parameters.
- Complex shaped job needs intelligent control for processing.
- Laser reflectivity, thermal conductivity, heat capacity of work materials affect cladding ability.
- Marangoni flow [5] may cause surface unevenness.
- Microcracks may develop due to thermal stress.
- Dilution control of substrate material is essential for desirable coating properties.
- Working zone needs shielding from severe environmental contamination.
- Material having high reflectivity for laser results in back reflection of the laser beam which may cause damage of the costly optical peripherals.
- Ideal laser beam spot on the irradiated work surface requires a large rectangular cross section with uniform energy distribution is essential for good quality cladding.
- Large number of overlapping in the coating surface increase surface waviness.
- Intense heat concentration may cause uncontrollable melting, surface vaporization, plasma formation, photochemical ablation [6] etc.
- Evaporation of chemical binder [7] may result in porosity and holes in the coating.
- It is difficult to finish the hard clad top surface for desired dimensional accuracy.

Technical challenges and difficulties provide scopes for research and development which are continuously going on in the fields of surface engineering, especially surface coating including laser cladding.

The multi-component/ multi-phase coatings like 'third generation' coatings development are the current research interests. The same coatings are advantageous due to their high strain absorption capacity. Different types of phase boundaries in the microstructure increase the toughness of the coating by increasing the capacity to dissipate strain energy [8]. Improvement of tribological properties [9, 10] of parts, that prone to wear, is essential for prolonging the service life and reliable operation. Some typical experimental investigations were performed earlier on the improvement of tribological properties of Ti alloys by developing multi-component/ multi-phase laser coatings.

WC reinforced MMC coating on Ti and Ti alloys:

The WC reinforced bulk coatings are popular in industries for the hard facing of steels. A few research works were reported on cladding/ hard facing of Ti or Ti alloys using the WC reinforced MMC. Guo et al. 2010 [11] developed hard (up to 1300 HV), wear and corrosion resistant clad layer on pure Ti. Li et al. 2011 [12] worked with