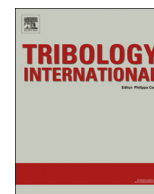




ELSEVIER

Contents lists available at ScienceDirect

Tribology International

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

Sliding wear characteristics of molybdenum containing Stellite 12 coating at elevated temperatures

Amir Motallebzadeh^a, Erdem Atar^b, Huseyin Cimenoglu^{a,*}

^a Istanbul Technical University, Department of Metallurgical and Materials Engineering, Maslak, 34469 Istanbul, Turkey

^b Gebze Technical University, Department of Materials Science and Engineering, 41400 Gebze, Kocaeli, Turkey

ARTICLE INFO

Article history:

Received 17 March 2015

Received in revised form

20 May 2015

Accepted 10 June 2015

Available online 17 June 2015

Keywords:

Sliding

High temperature

Wear-resistant

Raman

ABSTRACT

The addition of 10 wt% Mo encouraged a eutectic reaction to form $\text{Co}_6\text{Mo}_6\text{C}$ complex carbide and Co_3Mo intermetallic in addition to Cr_{23}C_6 while causing solid solution hardening of the Co-rich dendritic matrix in the microstructure of the PTA deposited Stellite 12 coating. The addition of molybdenum not only imposed a higher hardness but also enhanced wear resistance. Under oxidation dominated wear conditions (500 and 700 °C), the addition of molybdenum provided a remarkable increase in wear resistance in comparison to the lower temperatures (RT and 300 °C), due to the development of a protective oxide film on the worn surface.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Hardfacing is a technique used to enhance the performance of metallic components typically utilized in applications that require high resistance to wear in aggressive environments [1,2]. For this purpose, multi-component hardfacing alloys (Co-, Ni- or Fe-based alloys) are deposited on the surface of relatively soft materials (such as carbon and low alloy steels) mostly by arc welding processes such as shielded metal arc welding (SMAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) and plasma transferred arc (PTA) hardfacing process [1,3]. PTA represents a very good alternative to SMAW, GMAW and GTAW processes in terms of its high deposition rate, lower heat input, excellent arc stability and, most importantly, the wide range of choices of materials [2,4]. It also has advantages over laser cladding, which uses a high power laser beam to melt the feedstock materials and deposit a hardfacing coating on the selected area of metal substrates, in terms of lower capital and maintenance costs, higher thickness capability, higher deposition efficiency and rate and ease of integration into certain production settings due to its small size [2,5].

Compared to other Ni- and Fe-based hardfacing alloys, Co-based hardfacing alloys are suitable for the protection of components used in aerospace, gas turbines, power plants, chemical and petrochemical industries requiring good combination of wear, corrosion and

heat-resistance properties [6–8]. Stellite alloys, the most popular cobalt-based hardfacing group, are commercially available in several modifications and grades such as Stellite 1, 6 and 12. The main difference between these Stellite hardfacing alloys is their carbon content and thus the carbide volume fraction formed in the microstructure during solidification. As the highest carbon content member of the group, Stellite 1 (2.5 wt% carbon) is the most wear resistant hardfacing alloy but it has a high risk of cracking during deposition. Stellite 6 (1.2 wt% carbon) has a lower wear resistance than Stellite 1 owing to the formation of a relatively small amount of hard carbides in the microstructure [9]. Stellite 12 (1.6 wt% carbon) can be considered as an intermediate hardfacing alloy between Stellite 6 and Stellite 1, and has become more popular in the last few years for wear resistant applications. Despite the successful performance of Stellite 12 coated engineering components, wear is still a serious problem that influences their service life at higher ambient temperatures and/or heavy loads.

Being motivated by the necessity for further enhancement in wear resistance, several attempts have been made to modify Stellite hardfacing alloys by adding alloying elements or reinforcing with hard ceramic particles [4,7,10–14]. Promising enhancements in room temperature (RT) wear resistance have been reported upon introduction of molybdenum into Stellite 6 and low carbon Stellite alloys as the result of its solid solution hardening effect and carbide forming tendency [4,11,14]. To the best of the authors' knowledge, the effect of the addition of molybdenum on the sliding wear performance of Stellite 12 coating, especially at high temperatures, has not been investigated yet. In the present study the influence of the addition of 10 wt% Mo on the wear behavior of Stellite 12

* Corresponding author. Tel.: +90 212 285 6834; fax: +90 212 285 3427.

E-mail address: cimenoglu@itu.edu.tr (H. Cimenoglu).

coatings deposited on AISI 4140 steel have been investigated at RT, 300, 500 and 700 °C after determining the changes in the microstructure.

2. Materials and methods

In this study Stellite 12 and Stellite 12+Mo coatings were deposited on AISI 4140 steel by a PTA technique under identical hardfacing process parameters (current 92 A, voltage 32 V, travel speed 85 mm/min). For deposition of Stellite 12+Mo coatings, commercially available Stellite 12 powder was mixed with commercially available molybdenum (Sulzer, Amdry 313X) powder at 10 wt%. The sizes of the Stellite 12 and molybdenum powders were 53–150 and 38–75 μm, respectively. The welding procedure was carried out in a single layer with a thickness of 5 mm. After PTA deposition, the surfaces of the specimens were ground to make a flat hardfacing layer with a thickness of 2.5 mm.

Phase analysis and microstructure of the coatings were examined by X-ray diffractometer (XRD) with Cu K α radiation (GBC, Australia) and field emission scanning electron microscope (SFEG SEM, Philips, Holland) equipped with energy dispersive X-ray (EDX) spectrometer. SEM examinations of the microstructure were conducted on the cross-sections of the samples, which were prepared using standard metallographic procedures and etching with 80% HCl+20% H₂O₂ solution.

The surfaces of coatings were ground with SiC papers and polished with 1 μm diamond paste in order to remove surface roughness prior to hardness measurements and wear tests. A conventional microhardness tester (Shimadzu, HMV2, Japan) with indentation load of 2 kg was used in order to obtain the hardness values in HV scale. Five measurements were made on the surfaces of each coating and the average was the final result of hardness. Furthermore, depth sensing indentation test (CSM, Switzerland) was conducted on the matrices of coatings under load of 100 mN with a Vickers pyramid indenter.

Wear tests were performed by using a ball-on-disc type tribometer (CSM High temperature tribotester, Switzerland) under normal load of 3 N at RT, 300, 500 and 700 °C. A ball made of alumina (Al₂O₃) with diameter of 6 mm was used as the counterface under dry sliding contact conditions. The sliding speed was set at 0.1 m/s. The Al₂O₃ ball followed a circular path of 5.5 mm in radius for the total sliding distance of 500 m over the surfaces of the samples. The test procedure involved ultrasonic cleaning of the specimens in acetone before each experimental run. The samples

were heated in ambient conditions and the test was started when the desired temperature was reached. At least three tests were run under the same conditions for each sample to ensure the reproducibility of data. The frictional force data was continuously recorded during the wear tests. At the end of the tests, the wear tracks developed on the surfaces of the samples were monitored using a 2-D contact surface profilometer (Dektak-6M, Veeco, USA). Profilometric measurements were made at eight different locations of each wear track. After determining the average depth and width of each wear track, the volume loss (mm³) obtained by multiplying the cross-sectional area of wear track with its circular length was used for calculating wear rate (mm³/Nm) by considering normal load (3 N) and total sliding distance (500 m). The worn surfaces of the samples were also examined by EDX equipped SFEG SEM and Raman spectroscopy (Renishaw, inVia Reflex spectrometer, UK) using an excitation wavelength of 532 nm.

3. Results

3.1. Microstructure of the coatings

Cross-sectional microstructures of the examined coatings are presented in Fig. 1. In general, the microstructures exhibited characteristic features of the PTA deposited Stellite coatings consisting of dendritic matrix (light gray region) and compounds appearing in dark gray and white colors in lamellar morphology. Table 1 lists the results of EDX analyses of the microstructural constituents along with their average volume fractions quantified by the linear intercept method. According to Table 1, the dendritic matrix of the Stellite 12 coating (Fig. 1a) mainly consisted of cobalt and chromium with a small amount of tungsten, nickel and iron (i.e. a Co-rich solid solution). While the dark gray compounds were identified by their high chromium content, the white compounds mainly consisted of cobalt, chromium and tungsten. EDX analysis conducted on the Stellite12+Mo coating revealed that a limited amount of molybdenum was dissolved in the dendritic matrix and dark gray compounds (about 3 at%) and white compounds were remarkably enriched by molybdenum (about 17 at%). It should be noted that introducing 10 wt% Mo into Stellite 12 increased the volume fraction of the white colored compounds in the microstructure from 5.6% to 29.4%, while reducing the volume fraction of the dark gray compounds and the matrix from 35.6% to 18.2% and 58.8% to 52.4%, respectively.

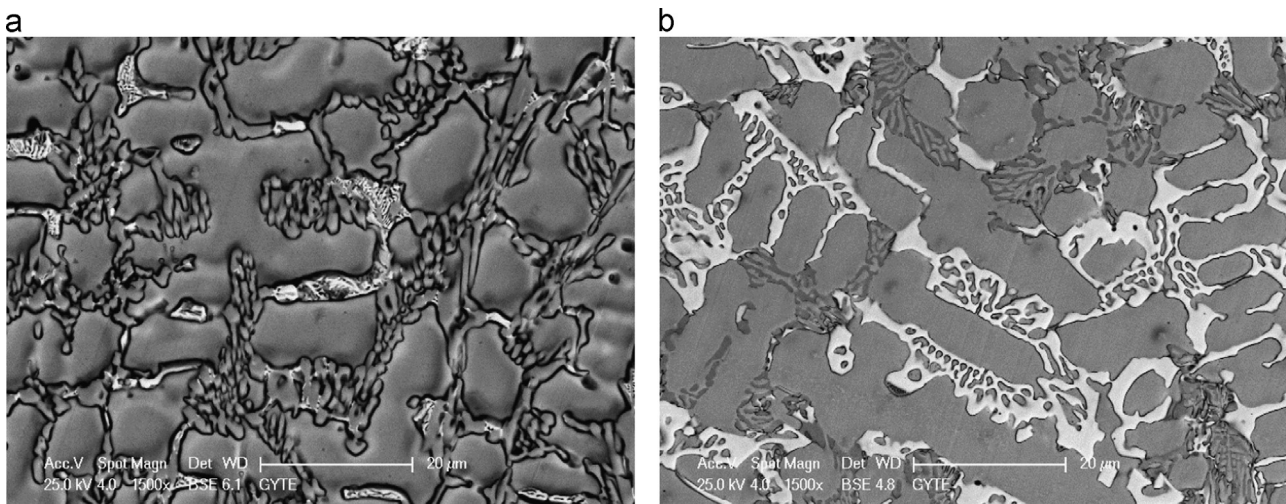


Fig. 1. Cross-sectional SEM micrographs of (a) Stellite 12 and (b) Stellite 12+Mo coatings.

Download English Version:

<https://daneshyari.com/en/article/614401>

Download Persian Version:

<https://daneshyari.com/article/614401>

[Daneshyari.com](https://daneshyari.com)