Journal of Manufacturing Processes 20 (2015) 79–87

Contents lists available at ScienceDirect

Journal of Manufacturing Processes

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

Technical Paper

Development and analysis of tribological behavior of microwave processed EWAC + 20% WC10Co2Ni composite cladding on mild steel substrate

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ARTICLE INFO

Article history:
Received 4 April 2015
Received in revised form
15 September 2015
Accepted 15 September 2015
Available online 9 October 2015

Keywords:
Microwave processing
Hybrid heating
Composite cladding
Microhardness
Sliding wear
Characterization

ABSTRACT

The present work is based on the surface modification of mild steel by depositing composite cladding of EWAC + 20% WC10Co2Ni powder through novel technology of hybrid microwave heating. Claddings of approximately 300 μm thickness were developed in domestic microwave applicator at 2.45 GHz frequency and 900 W of power. Microstructural analysis and mechanical characterizations were carried out on the developed clads using relevant techniques of XRD, SEM, EDS, Vickers microhardness and wear tests. Pin on disk tribometer was used to evaluate the tribological properties (weight loss) of developed clads under the different loadings and sliding velocities at ambient temperature. Results revealed that clads are formed with good metallurgical bonding with melting and diffusion of substrate material. Developed clads showed the presence of hard carbides in the form of a skeleton like structure within a soft nickel matrix. The wear resistance of composite clads increased by approximately 128 times in comparison to mild steel and average Vickers microhardness of 980 ± 52 HV has been reported by microwave processed clads.

1. Introduction

The applications of microwaves in material processing are not new; however, newer advancements are taking place in the field of processing of metals through microwaves. The earlier developments in this field were mainly related to the processing of ceramics, fiber composites and materials which were good absorbers of microwaves [1–6]. However, after the removal of fallacy that metal cannot be processed by microwaves, Roy et al. [7] paved the research in the field of metallic material processing through microwaves. After this research, a lot of work was carried out in this field of metallic powder processing [8–11], but still processing of bulk metals was unsuccessful due to the lower depth of penetration of microwaves in the metals, which often causes reflection of microwaves and plasma formation. Further, researchers [12–14] focused on hybrid heating systems to couple the metals with microwaves, such that the initial heating of metals by microwaves increases the depth of penetration and causes heating of metallic materials. The successful processing of bulk metallic material in the form of joining of metallic material was carried out by Sharma et al. [15] in the year 2009, by using the domestic microwave applicator and principles of microwave hybrid heating. This research allowed the successful joining of many metallic materials [16,17]. The work on processing of metal claddings on metallic substrate was further successfully attempted by Gupta and Sharma [18] in the year 2010. Gupta and Sharma [19] extended their research by developing copper coating on austenitic stainless steel using the principles of hybrid microwave heating. The mechanism of coating was described in detail and it was reported that developed coatings were uniform, dense and homogeneous; however, the presence of some microspores was detected. Microstructure revealed that 3D array of fused copper particles was obtained, which was obtained by necking, agglomeration and fusion by melting of copper powder and the obtained average Vickers microhardness was 270 ± 30 HV. Another work of authors [20], reported the sliding wear performance of the WC10Co2Ni cladding on austenitic stainless steel (SS-316), which was developed by novel microwave hybrid heating. It was reported that dense and uniform cladding was obtained with Vickers microhardness of 1064 ± 99 HV and porosity was significantly reduced to 0.89%. Tribological investigations revealed that the developed clad was 84 times better wear resistant than SS-316 steel and unstable oxide

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http://dx.doi.org/10.1016/j.jmapro.2015.09.007
1526-6125/

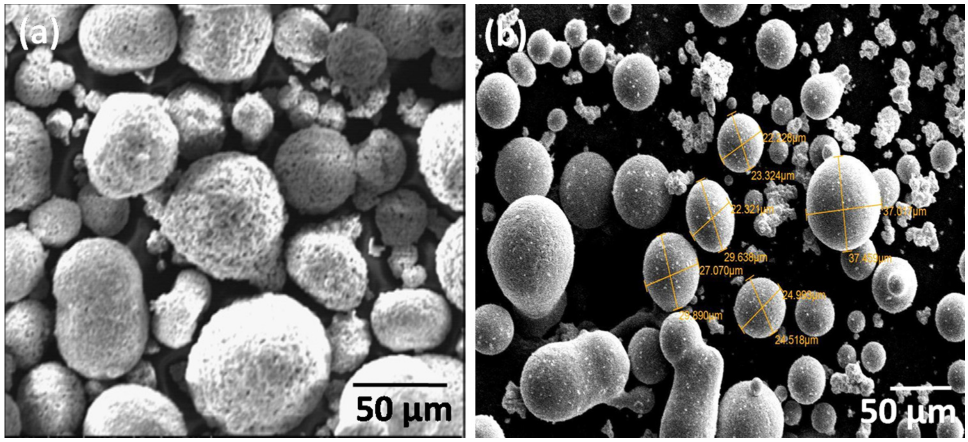

Fig. 1. SEM image showing spherical morphology of (a) EWAC and (b) 20% WC10Co2Ni powder.

tribo layer partially helped the clad by lowering the material loss. The work of Sharma and Gupta [21] focused on the development of metal–ceramic composite cladding through microwave heating of the SS-316 substrate. It was reported that harder phases were detected in the XRD analysis, which contributed to the high hardness of 416 ± 20 HV in comparison to metallic substrate and flexural strength of 629 ± 8 N was reported. Further, Gupta and Sharma [22], reported the microwave processing of clads as a new approach in surface engineering, due to the inherent characteristics of microwave processing mainly lower cost and lower processing defects. The research on development of WC–12Co clad on AISI 304 SS was carried out by Zafar and Sharma [23]. Clads of approximately 1 mm thickness were developed in industrial 1.6 kW multimode microwave applicator. It was reported that the microstructure of the clad mainly consists of skeleton structured carbides rooted in tough metallic phase. The phase analysis of the clad indicated the presence of various stable and complex carbides like Co_6W_6C, Co_3W_3C and Fe_6W_6C, which increased the hardness up 1135 ± 49 HV. The work of Zafar et al. [24] investigated the dry erosive wear performance of the cladding of Inconel 718 on SS-304 substrate and reported that that the improved wear performance of the clads was due to presence of strengthening intermetallic phases (Ni3Ti, Ni3Al) in the tough Ni–Fe–Cr matrix. A lot of research is still going on in the field of processing of metals by microwave or microwave assisted technologies [25–27].

To the best of the author's knowledge, no literature is available on the cladding of mild steel through microwave heating and further no characterization in terms of tribological properties has been carried out. This provides a good opportunity to focus on the development of composite cladding of EWAC + 20% WC10Co2Ni on the mild steel substrate by using a domestic microwave applicator. The developed claddings will be characterized by relevant techniques and wear performance using a pin on disk apparatus will be compared with substrate material.

2. Experimentation

2.1. Materials

2.1.1. Substrate material

Mild steel is widely used in different engineering industries for making various components. The wide acceptability of this material is due to cheap cost, easy machinabilty, deformability and weldability, etc. However, mild steel exhibits poor friction and wear characteristic which leads to catastrophic failure of the component during the service. To extend its service life the low carbon steel (mild steel) has been used as substrate material for the present work and chemical composition is presented in Table 1. The specimens of dimensions 10 mm × 10 mm × 6 mm were machined for the development of cladding.

Table 1
Elemental composition of mild steel.

Element	C	Mn	Si	Fe
Weight (%)	0.25%	0.4–0.7	0.1–0.5	Bal.

Table 2
Elemental composition of EWAC powder.

Element	Cr	C	Si	Ni
Weight (%)	0.15–0.17	0.2	2.8	Bal.

Table 3
Elemental composition of WC10Co2Ni clad powder.

Element	W	C	Co	Ni
Weight (%)	82	6	10	2

2.1.2. Hardfacing powder

In the present study a composite nickel based (EWAC + 20% WC10Co2Ni) powder has been selected as clad material. The selected powder has an average particle size of 40 µm and morphology of particles is shown in Fig. 1(a and b), which shows spherical nature of EWAC and WC10Co2Ni powder. The chemical composition of selected hard facing powder is shown in Tables 2 and 3 respectively. The typical X-ray diffraction spectrum of powders is shown in Fig. 2(a and b), which shows the presence of tungsten carbide along with nickel and cobalt phases.

2.2. Experimental setup

The development of metallic cladding on a mild steel substrate is a challenging task with the application of microwave radiations, due to incompatibility of metals with microwaves. In the present work, wear resistant claddings have been developed on the mild steel substrate by using the multimode domestic microwave applicator as a heating source at a frequency of 2.45 GHz and at power of 900 W. The heating of metallic powder via microwaves is carried out by using the principles of microwave hybrid heating (MHH), which initially allows the heating of the microwave absorbing material i.e. susceptor in the form of fine grained charcoal. This heat is transferred via conventional modes to the metallic