Archives of Materials Science and Engineering

Volume 30
Issue 2
April 2008
Pages 113-116

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Laser surface treatment of magnesium alloy with WC powder

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Received 01.02.2008; published in revised form 01.04.2008

ABSTRACT

Purpose: The aim of this work was to improve the surface layer cast magnesium alloy EN-MCMgAl6Zn1 by laser surface treatment. The purpose of this work was also to determine the laser treatment parameter.

Design/methodology/approach: The laser treatment of an EN-MCMgAl6Zn1 magnesium alloy with alloying WC powders was carried out using a high power diode laser (HDPL). The resulting microstructure in the modified surface layer was examined using scanning electron microscopy. Phase composition was determined by the X-ray diffraction method using the XPert device. The measurements of microhardness of the modified surface layer was also studied.

Findings: The morphology of the alloyed zone are dendrites. Microhardness of laser surface melted layer was significantly improved as compared to alloy without laser treatment.

Research limitations/implications: This investigation presents different speed rates feed by one process laser power and in this research was used one powder with the particle size over 5μm.

Practical implications: The results obtained in this investigation were promising to compared other conventional processes. High Power Diode Laser can be used as an economical substitute of Nd:YAG and CO_2 to improve the surface magnesium alloy by feeding the carbide particles.

Originality/value: The originality of this work is applying of High Power Diode Laser for alloying of magnesium alloy using hard particles like tungsten carbide.

Keywords: Surface treatment; Magnesium alloy; High Power Diode Laser (HPDL); Laser cladding

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

Magnesium alloys have gained interested recently, due to their lightweight and good mechanical properties. Advantageous are good castability, good weldability under controlled atmosphere. Magnesium also has high thermal conductivity and good electromagnetic shielding characteristics. Despite these properties, magnesium alloys have some undesirable properties, such as high chemical reactivity, poor corrosion and wear resistance, poor creep resistance, which restricted wider application of magnesium alloys [1,3,7-15].

One of the methods to improve magnesium alloys surface is laser surface modification process, which hardness and corrosion resistance is developed to achieve better improvement. A high power laser beam may be used as a source of heat to melt, clad or alloy the near surface region of a substrate [2,4-7,10].

Majumdar et al. [8,9] have studied magnesium alloys surface cladding by CO_2 laser, they concluded that properties such as corrosion and wear resistance were improved. Laser surface alloying of AZ91E alloy with SiC and TiC hard particles by injection process into the molten pool of magnesium, has been used to modify magnesium alloy to improve resistance to sliding wear [11]. Modification of surface layer of Mg alloys AZ91 by laser cladding was also investigated using two different compositions of powder [13]. The powder mixtures were based on NiCrBSi compositions and NiCr with WC powder.

In the present study, the laser surface modification was conducted by melting EN-MCMgAl6Zn1 alloy surface and feeding the WC particle using High Power Diode Laser (HDPL Rofin DL 020). The effect of the laser parameters on the microstructure was investigated. Phase composition was determined and microhardness values of the laser treated samples were measured.

2. Experimental procedure

In the present investigation, MCMgAl6Zn1 magnesium alloy test piece in the for of plates of 50x18x10mm was used as the substrate material. Its chemical composition is listed in Table 1. The alloy was made using the induction crucible furnace with a protective salt bath Flux 12, equipped with two ceramic filters at the melting temperature of 750±10ºC, suitable for the manufactured material. The heat treatment involved the solution heat treatment (warming material in temperature 375 ° C the 3 hours, it later warming in the temperature to 430° C, holding for 10 hours) and cooling in air and then ageing at temperature of 190°C and cooling in air. These plates were polished with 1200-grit SiC paper prior to laser surface treatment to obtain smooth surface and then cleaned with alcohol and dried.

The clad material was tungsten carbide powder, the mesh sizes were up 5μm. The WC powders was supplied by side injection rate of 6 g/min.

The laser cladding was performed by high power laser diode HPDL Rofin DL 020 under an argon shielding gas. Argon was used during laser re-melting to prevent oxidation of the coating and the substrate. The parameters are presented in Table 2. The process parameters during the present investigation were: laser power - 1.6 kW, scan rate - 0.5-1.0 m/min (every 0.25) and powder feed rate of 6g/min.

After the laser treatment, specimens were sectioned, ground and polished with 1μm diamond paste. The samples were mounted in thermosetting resin. Next the samples were etched in nital at room temperature.

The microstructure of the modified layer was examined on the electron scanning microscope Opton DSM-940 using the secondary electron detection.

The X-ray qualitative microanalysis and the analysis of the surface distribution of element made on transverse microsections on the Opton DSM-940 scanning microscope with the Oxford EDS LINK ISIS dispersive radiation spectrometer at the accelerating voltage of 15 kV and on the JEOL JCXA 733 x-ray microanalizer.

X-ray diffraction patterns were registered on XPert device with a cobalt lamp with 40 kV voltage. The measurement was performed in the angle range of 2 ϴ: 20º - 130º.

The cross-section microhardness of the modified surface layer was measured on Fully-Automatic Microhardness Testing System with a loading time of 15 s and the testing load of 50 g.

3. Results

Laser surface modification was conducted by remelting MCMgAl6Zn1 surface and feeding of WC particle. Hard WC particles are immediately distributed throughout the molten zone during laser surface melting operation to form the composite layer distributed in alloyed zone. It is due to a large difference in density between the particles and matrix and differential absorption between the WC particles and MCMgAl6Zn1 alloy.

The coating of the cross-section of the microstructure is shown in Fig. 1a. Fig. 1b and 1c shows the top surface of the coating (laser power: 1.6 kW, scan rate: 0.75 m/min, powder feed rate: 6 g/min), and interface between modified zone and the substrate (laser power: 1.6 kW, scan rate: 0.5 m/min, powder feed rate: 6 g/min), respectively. The microstructure of the coating is defect-free. The morphology of the alloyed zone are mainly dendrites of primary magnesium with Mg in the interdendritic spacing. There was no observed significant variation of distribution of WC particles with depth in the surface modified layer of modified alloy with WC. Scan rate has an influence on the modified layer which varies with as the scan rate grows. The width of the alloyed zone decreases with scan rate. Increase in scan rate reduces the interaction time and reduces the coupled energy density. However, one has to mention that using scan rate which is too low leads to surface evaporation and crater formation, however using a high scan rate may cause inadequate melting and intermixing leading to inhomogeneous distribution of the alloying element in the MCMgAl6Zn1 matrix.

X-ray diffraction patterns for different laser treated layers as well as that for the substrate are shown in Fig. 2. Mg and WC are phases existing in the laser treated layers.

The chemical analysis (Fig. 4) of the surface element composition and the qualitative microanalysis made on the transverse microsections of the magnesium alloys after laser treatment (laser power: 1.6 kW, scan rate: 0.5 m/min, powder feed rate: 6g/min) using the EDS system have confirmed the concentrations of magnesium, aluminium, tungsten, carbide and zinc which has also effected by laser modification.

Table 1.
Chemical composition of investigation alloy

Al	Zn	Mn	Si	Fe	Mg	Rest
5.92	0.49	0.15	0.037	0.007	93.33	0.0613

Table 2.
HPDL parameters

Parameter	Value
Laser wave length, nm	940±5
Focus length of the laser beam, mm	82/32
Power density range of the laser beam in the focus plane [kW/cm^2]	0.8-36.5
Dimensions of the laser beam focus, mm	1.8x6.8

a)

b)

c)

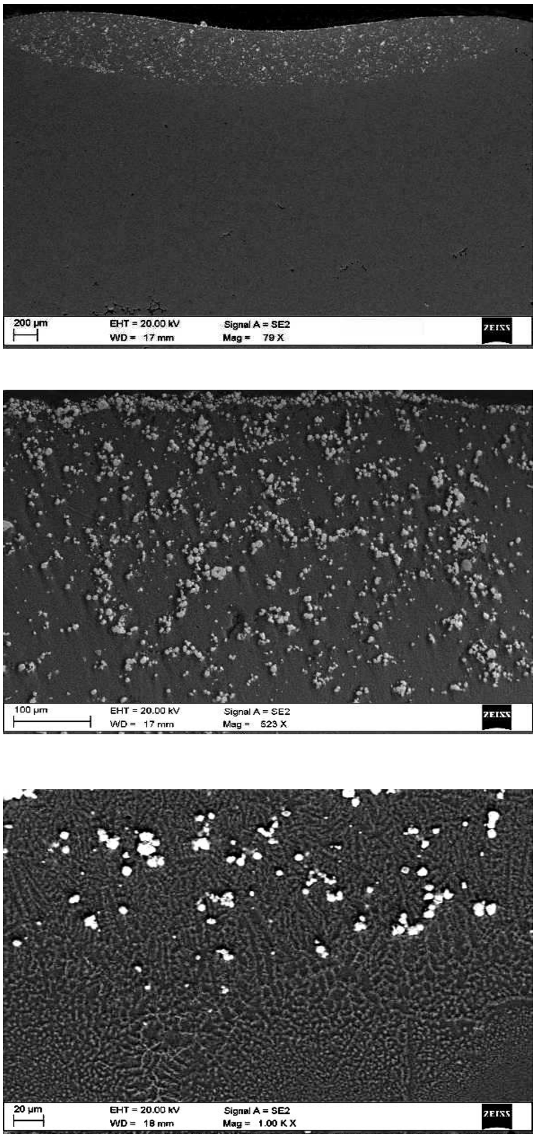

Fig. 1. Scanning electron micrograph laser surface modified MCMgAl6Zn1 with WC particle a) of the cross-section of the coating (laser power: 1.6 kW, scan rate: 0.5 m/min, powder feed rate: 6g/min), b) top surface of the coating (laser power: 1.6 kW, scan rate: 0.75 m/min, powder feed rate: 6 g/min), b) interface between modified zone and the substrate (laser power: 1.6 kW, scan rate: 0.5 m/min, powder feed rate: 6 g/min)

The zinc vapour pressure is by an one order of magnitude bigger than the pressure of magnesium in molten state. It is due to strong zinc loss occurs. Area fraction of particles decreases with increase in scan rate, due to a lower interaction time, at a higher scan rate, leading to a lower powder input. It was observed that too slow scan rate led to surface crater formation, because of the increased interaction time.

The microhardness of the modified surface was measured from the top towards the clad-substrate interface along the cross-sectional plane. Fig. 3 shows the microhardness curves of the cross-section of the coating. The microhardness of the modified zone is increased as compared to that of as-received Mg alloy, due to the enhancement of hard particles WC and also the grain refinement has positive effect on the improvement of the microhardness. Average microhardness of the surface layer decreases with the scan rate growing, because of the reduced particle input as a result of lowering interaction time associated with a higher scan rate. There is the little fluctuation in the readings in some region, possibly because of the random distribution of hard WC particles in the surface modified layer. The microhardness of surface layers varied in the ranges 70-250 $HV_{0.05}$.

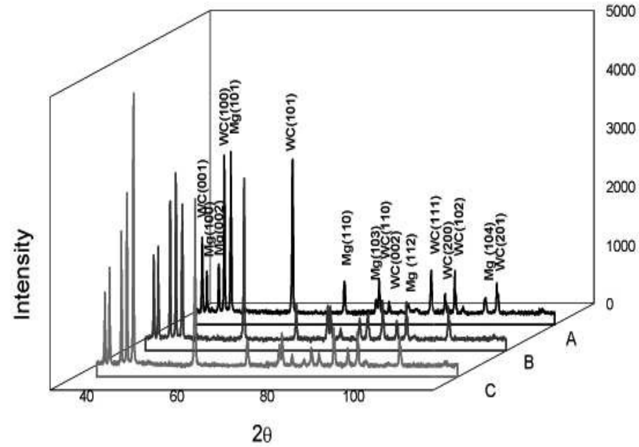

Fig. 2. XRD results of the laser treated layer with WC powders (A-laser power:1.6 kW, scan rate 0.5m/min, B-laser power:1.6 kW, scan rate 0.75m/min, C-laser power: 1.6 kW, scan rate 1.0 m/min)

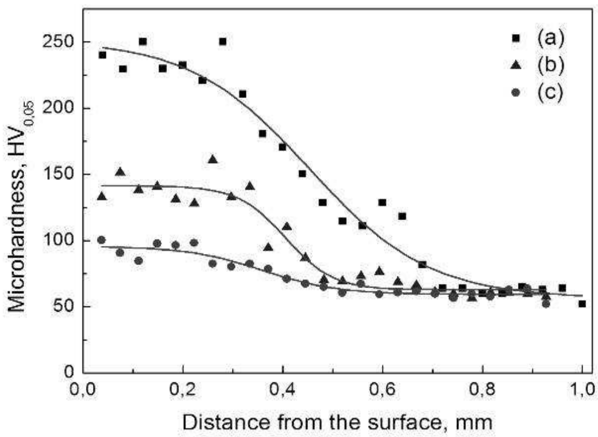

Fig. 3. Cross-section microhardness profile from the surface, laser power: 1.6 kW, scan rate: a) 0.5m/min, b) 0.75 m/min, c) 1.0 m/min

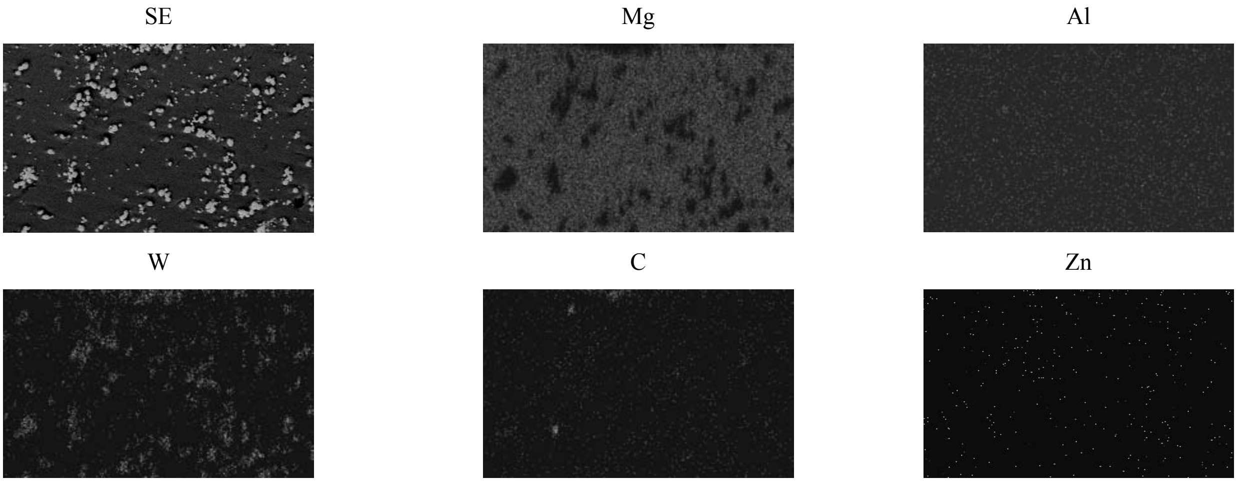

Fig. 4. X-ray mapping of the microstructure ENMCMgAl6Zn1 cladding layer and the distribution of Mg, Al, Zn, W, C

4. Conclusions

The composite surface layer can be successfully produced by laser modification and feeding the WC powder on the MCMgAl6Zn1 using High Diode Power Laser.

The microstructure of the surface modified layer consists of WC particles in the matrix Mg and Al. The morphology of the alloyed zone are predominantly dendrites of primary magnesium. The detailed X-ray diffraction analysis shows the presence of mainly Mg and WC peaks. The surface modified layer microhardnes was significantly improved compared to the substrate microhardness value.

Acknowledgements

This research work is financed in part within the framework of science financial resources in the period 2007-2008 as a research and development project R15 0702 headed by Prof. L.A. Dobrzański.

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