EFFECT OF HIGH POWER DIODE LASER SURFACE ALLOYING ON THE STRUCTURE OF MAGNESIUM ALLOYS

Leszek A. DOBRZAŃSKI, Tomasz TANSKI, Szymon MALARA

Silesian University of Technology, Gliwice, Poland, leszek.dobrzanski@polsl.pl, tomasz.tanski@polsl.pl, zymon.malara@polsl.pl

ABSTRACT

The structure of the MCMgAl12Zn1 cast magnesium alloy after laser surface treatment is presented in this paper. The aim of this work was to improve the properties of the surface layer of the MCMgAl12Zn1 cast magnesium alloy by melting and simultaneous feeding silicon carbide particles into the weld pool. Laser alloying of the MCMgAl12Zn1 magnesium alloy bars with silicon carbide was carried out using a high power diode laser HPDL (High Power Diode Laser). The structural examination was carried out using a light and scanning electron microscope. The qualitative phase composition was determined by employing the X-ray diffraction method using the XPert device.

Keywords: magnesium alloys, surface treatment, laser treatment, silicon carbide

INTRODUCTION

During the last few decades the world has seen a rapid growth ~~of~~ in the application of magnesium and its alloys in almost ~~in~~ every field of today's industry. This is due to the numerous characteristics of the metal examined here, which permit its use both as a structural element, and as a chemical addition to other metal alloys. The metal is lighter than aluminum and has greater tensile strength than steel. Magnesium alloys have low density and other benefits such as: ~~a~~ good vibration damping, high dimension stability, small casting shrinkage, combination of low density and huge strength with compared to its small mass, the possibility of machine application, and the ease ~~to~~ of recycling. [3,4,5,7]. Many obvious advantages offered by magnesium and its alloys are due to its special characteristics that are incomparable. The automotive industry has crossed the threshold from using magnesium in a protected environment, predominantly interior applications, to an unprotected environment. Production magnesium components currently emphasize interior applications, such as steering column brackets, instrument panel, seat frames, steering wheel, and sunroof track assembly etc [3,4,7,7]. Magnesium alloys have also found their application in the manufacture of mowers, saws, robots, office equipment including computer hardware, sport and medical appliances, in the production of movie and video cameras, for rocket parts, space ships, and others [3,4,5,7].

A lot of light metal applications require ~~a~~ special properties of the material's surface layer. The method which allows the achievement of an improvement in the chemical, mechanical and tribological properties of the surfaces is ~~a~~ high power laser treatment. The aim of laser treatment (cladding) is to deposit a cladding onto the surfaces of the work pieces. The material is deposited by pre-placed powder, powder injection or by wire feeding. The laser beam melts a thin layer of the surface of the work piece together with additional material. After solidification, a small mixture of the top part of the work piece and the coating provides the bonding between substrate and coating. In the laser melt injection process, solid particles are injected in the melt pool, which are trapped after solidification [1,2,6,8,9]. The goal of this paper is to present the investigation results of the MCMgAl12Zn1 casting of magnesium alloy after laser treatment.

MATERIALS AND INVESTIGATIONS

The investigations have been carried out on test pieces of MCMgAl12Zn1 magnesium alloy after heat treatment. The chemical composition of the investigated material is given in Table 1. The heat treatment involved the solution heat treatment (heating the material ~~in~~ at a temperature of 375 C for 3 hours, later heating it to 430 C, maintaining this for 10 hours) and air cooling, followed by ageing at a temperature of 190 C and cooling in air again. The process of sample~~s~~ preparation depends on surface polishing using sandpaper with a granulation of 1200. Laser alloying was performed by high power diode laser, the HDPL Rofin DL020, with the introduction of hard silicon carbide particles under an argon shielding gas (Table 2, Fig. 1). Argon was used during laser re-melting to prevent oxidation of the surface layer and the substrate. The particle size of the silicon carbide powder was below 75 µm. The process parameters during the present investigation were: laser power – 1.0-2.0 kW, scan rate – 0.5-1.0 m/min and powder injection rate – 8-9 g/min.

Table 1. Chemical composition of investigation alloy

The mass concentration of main elements, %						
Al	Zn	Mn	Si	Fe	Mg	Rest
12,1	0,62	0,17	0,047	0,013	86,96	0,0985

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

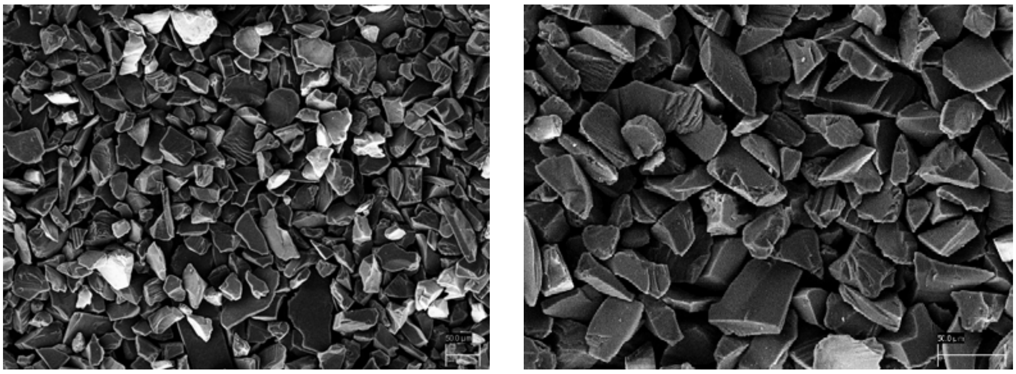

Fig.1 Morphology of silicon carbide.

Metallographic examinations have been made on magnesium cast alloy specimens mounted in thermo hardening resins. In order to disclose grain boundaries and the structure and to distinguish precisely the particular precipitations in magnesium alloys as an etching reagent, a natal of 5% has been used. The observations of the investigated cast materials have been made on the light microscope, the LEICA MEF4A, and on the Zeiss SUPRA 35 electron scanning microscope. The

X-ray qualitative and quantitative microanalysis, and the analysis of ~~a~~ the surface distribution of cast elements in the examined magnesium cast alloy specimens in as-cast, and after heat laser treatment have been made on transverse microsections on the Zeiss SUPRA 35 scanning microscope with the EDAX Trident XM4 dispersive radiation spectrometer at the accelerating voltage of 20 kV. X-ray diffraction patterns were registered on the XPert device with a cobalt lamp with 40 kV voltage. The measurement was performed at an angle range of 2 ϴ: 20º ÷ 130º.

RESULTS OF MATERIALS INVESTIGATION

Selection of the process parameters was determined after ~~in~~ introductory investigations to ensure the resulting compound quality, uniform distribution of alloying particles inside the alloyed zone, and surface layer face geometry after the laser treatment. The process parameters were determined as: laser power 1.2-2.0 kW, scan rate 0.75 m/min and powder feed rate 8-9 g/min (to ensure the most stable feeding). Surface layer faces after laser alloying with the selected parameters are regular and flat (Fig. 2).

a) b)

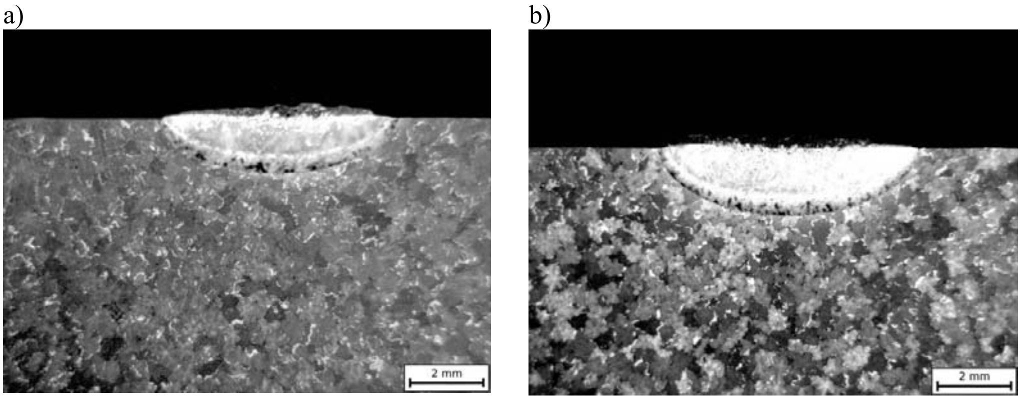

Fig. 2 Surface layer of MCMgAl12Zn1 alloy after laser alloying with SiC powder: laser power: a) 1.2 kW, b) 1.6 kW, scan rate: 0.75 m/min, powder feed rate: 8-9 g/min

Metallographic examinations revealed the presence of several zones after laser alloying: alloyed zone (AZ), heat affected zone (HAZ) and substrate material in all the investigated cases (Figs. 3, 4).

a) b)

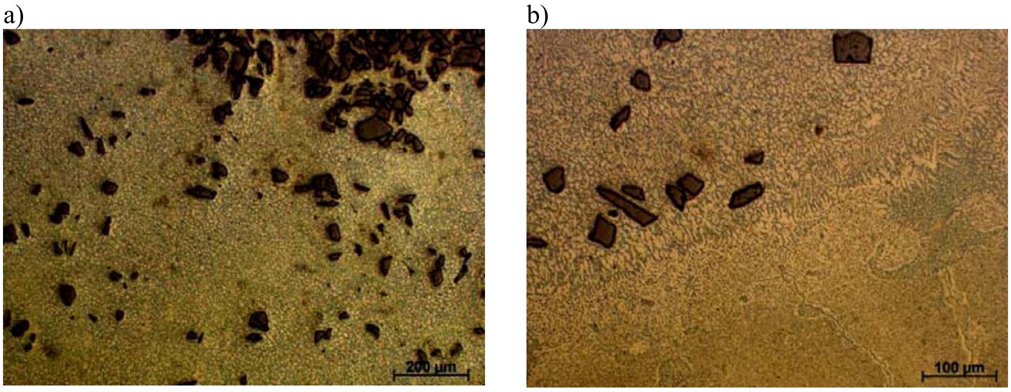

Fig 3 Microstructure of central area of SiC powder alloyed zone – laser power 2.0 kW (a) and boundary between alloyed zone and heat affected zone – laser power 1.6 kW (b) of MCMgAl12Zn1 alloy, scan rate: 0.75 m/min, powder feed rate: 8-9 g/min.

The shape and thickness of these zones depend on laser power and the scan rate. The results of the metallographic examinations show that the structure of material solidifying after laser remelting is characterised by the occurrence of areas with diversified morphology, something which is connected with the crystallisation of the magnesium alloys. As a result of laser alloying, the defect free structure develops with the clearly state grain refinement (Fig. 3). During metallographic examinations of the MCMgAl12Zn1 alloy a uniform distribution was observed of the employed SiC particles in the entire alloyed zone (Figs. 3). In the case of alloying with SiC particles with a laser power of 1.2 and 1.6 kW, carbides are distributed mainly at the layer surface, whereas at 2.0 kW power, the alloying particles are spread throughout the entire alloyed zone due to the violent mixing of the molten metal in the pool. The microstructure of the laser modified layer is comprised mainly of the employed SiC dispersive particles in the Mg-Al-Zn alloy matrix. The morphology of the alloyed area is composed mostly of dendrites with the $Mg_{17}Al_{12}$ lamellar eutectic and Mg in the interdendritic areas, whose main axes are oriented according to the directions of the heat transfer (Fig. 4 and Table 3).

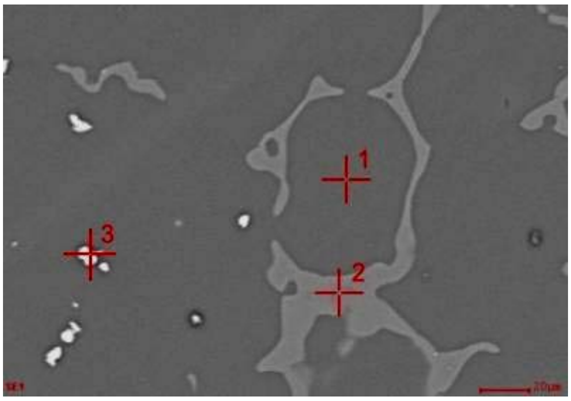

Fig. 4 Microstructure of heat affected zone of MCMgAl12Zn1 alloy after laser alloying with SiC particles with laser power 1.2 kW

Table 3. Summary of EDS analysis of the regions marked in Fig. 5

Region	Element	The mass concentration of main elements, %	
		mass	atomic
1	Mg	90,31	31,18
	Al	9,69	8,82
2	Zn	3,13	1,23
	Mg	63,64	67,17
	Al	33,23	31,60
3	Mg	5,77	7,77
	Al	58,51	70,95
	Mn	35,72	21,28

This may be explained by the occurrence of abnormal eutectic with the extremely low α-Mg content in the eutectic mixture. The dendritic structure is present in the alloyed zone, developed according to heat transfer direction along with the undissolved silicon carbide particles. The morphology of the alloyed area, including the content and distribution of carbide particles, is also dependent on applied laser parameters. The results of the qualitative X-ray diffraction analysis carried out on the investigated alloys confirmed the occurrence of phases: Mg, $Mg_{17}Al_{12}$ and SiC (Fig. 5). Other phases containing silicon were not revealed, ~~what~~ which confirms the failure of the alloying particles to dissolve.

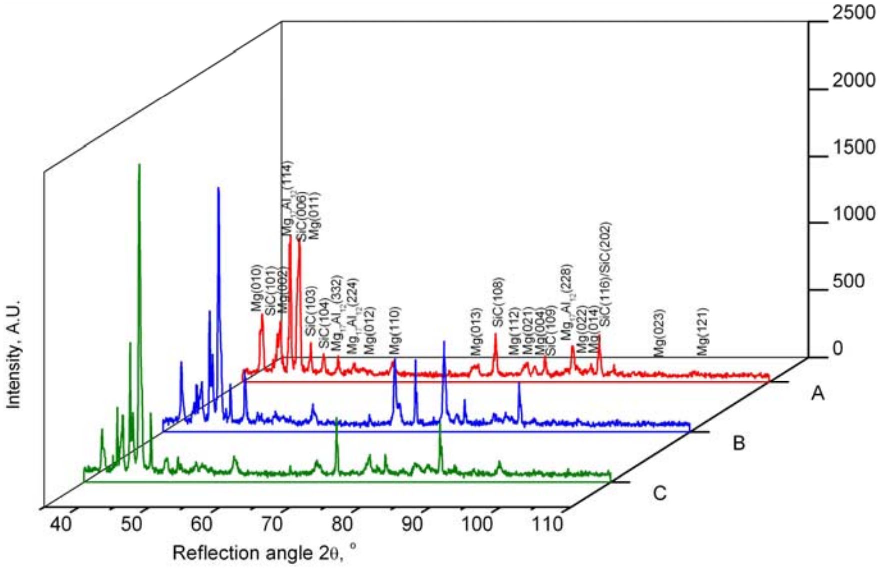

Fig.5 XRD patterns of the MCMgAl12Zn1 alloy after laser alloying with SiC particles and laser power: A – 1.2 kW, B – 1.6 kW, C – 2.0 kW.

Element~~s~~ distribution analysis using an X-ray energy dispersive spectrograph (EDS) (Fig. 6) made on the transverse section of the surface layers of the Mg-Al-Zn casting magnesium alloy with SiC powder, confirm the occurrence of magnesium, aluminium, zinc, carbon, and also silicon in the laser modified layer and indicate the failure of the alloying particles to dissolve.

SUMMARY

The results of investigations indicate that laser treatment of cast magnesium alloy MCMgAl12Zn1 with silicon carbide particles is feasible. Laser power is the main parameter, which influences the structure, quality and thickness of the surface. Performed coatings are free of cracks and porosity. Magnesium alloy, after laser alloying, reveals an alloyed zone (AZ) and a heat affected zone (HAZ). As a result of laser alloying, the structure developed a clear refinement of grains containing mainly dispersive carbide particles in the casting magnesium alloy matrix. The structure of the alloyed zone is mainly dendritic primary magnesium with α-Mg eutectic, β-$Mg_{17}Al_{12}$ intermetallic phase and undissolved alloyed SiC particles. The failure of the SiC particles to dissolve was confirmed by line-wise EDS microanalysis and also by X-ray diffraction examinations.

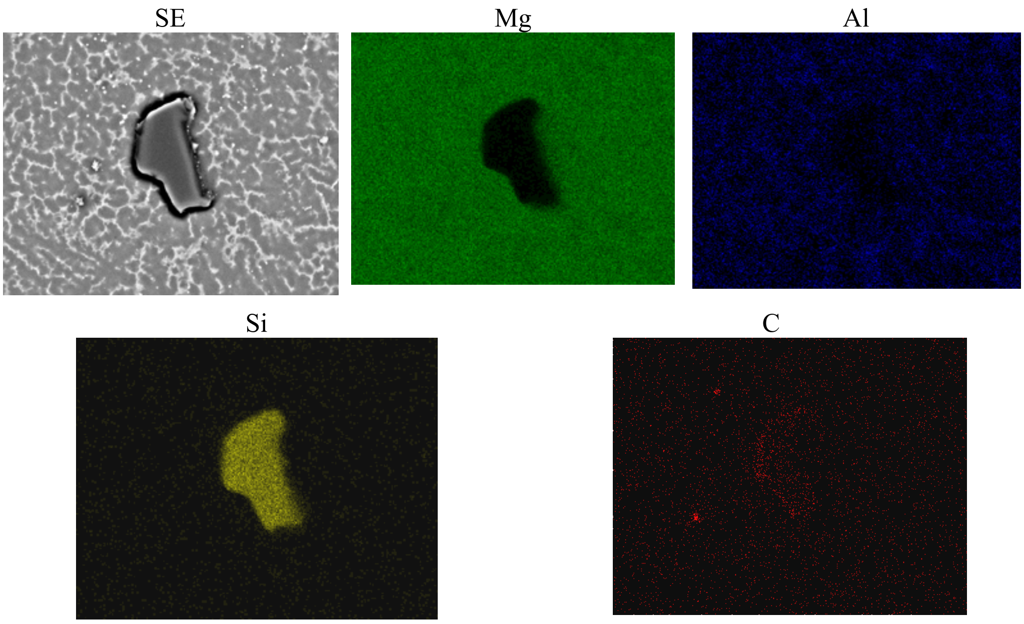

Fig. 6 X-ray mapping of the microstructure MCMgAl12Zn1 alloying layer and the distribution of Mg, Al, Si, C.

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