UDC 621.785

L. A. DOBRZAŃSKI
Institute of Advanced Manufacturing Technology, Poland
T. TAŃSKI, K. LABISZ, W. PAKIEŁA
Institute of Engineering Materials and Biomaterials, Silesian University of Technology, Poland

STRUCTURE AND PROPERTIES OF ALMG5SI2MN AFTER LASER FEEDING

Abstract – In this paper was presented the investigations results concern the influence of laser feeding on the structure and mechanical properties of aluminium alloy [1]. The goal of this investigations was to improve wear resistance and mechanical properties of the surface layers of the aluminium alloy by the laser feeding of the aluminium alloy by the hard silicon carbide particles. The SiC powder has been introduced in the liquid metal using gravity feeder at a constant rate of 1 g/min. In order to remelting the aluminium alloy surface, there has been used the high power diode laser HPDL, with an applied power of the laser beam in the range between 1.6 kW and 2.0 kW. The linear laser scan rate of the beam was set as much as 0.4 m/min. As a result of laser feeding of aluminium alloy a composite layer with greater hardness and wear resistance compared to the based material has been obtained.
Keywords: laser feeding, wear resistance

Л.А. ДОБЖАНСЬКИЙ
Інститут передових технологій виробництва, Польща
Т. ТАНСЬКІ, К. ЛАБІШ, В. ПАКЄЛА
Інститут технології матеріалів та біоматеріалів, Сілезький технологічний університет, Польща

СТРУКТУРА І ВЛАСТИВОСТІ ALMG5SI2MN ПІСЛЯ ЛАЗЕРНОГО ЗМІЦНЕННЯ

У даній статті представлені результати дослідження щодо впливу лазерного зміцнення на структуру і механічні властивості алюмінієвих сплавів [1]. Метою даного дослідження було підвищити зносостійкість і механічні властивості поверхневих шарів з алюмінієвого сплаву методом лазерного зміцнення жорсткими частинками карбіду кремнію. SiC порошок було введено в рідкий метал з допомогою гравітації на постійній швидкості 1 г/хв. В цілях переплавлення поверхні сплаву алюмінію, було використано лазерний діод HPDL високої потужності з потужністю променя лазера в діапазоні від 1,6 до 2,0 кВт. Лінійна швидкість сканування лазерного променя була встановлена в обсязі 0,4 м/хв. В результаті лазерного зміцнення алюмінієвого сплаву було отримано композитний шар з більшою твердістю і зносостійкістю в порівнянні з базовим матеріалом.
Ключові слова: лазерне зміцнення, зносостійкість.

Introduction

The dynamic development of the industrial economy makes it necessary to find new, more advanced and much better engineering materials able to meet the new demands [1–5]. Very interesting possibilities they give light alloys such as aluminium and magnesium [1]. Low density of aluminium or magnesium compared to the steel and relatively simple possibility the improve mechanical properties and wear resistant the causes are increasingly being used in particular applications where it is important to reduce the mass of elements and keep the high corrosion resistance of products used in the automotive industry, aerospace and air transport [1, 2]. Very significant treatment enhancing properties of the engineering materials such as aluminium, magnesium, cooper or steel is developed and widely used surface laser treatment technologies [2, 3]. Laser beam provides very precise delivery of energy and consequently the can better and faster to implement technological operations in the technology of layer treatment. The obtained layer must by characterized high fatigue strength and impact resistance as well as resistance to high and low temperature, thermal shock and the appropriate thermal conductivity, high hardness and toughness. The obtained properties of the surface layers to a large extent depend on their structure, porous, material discontinuities, uniform chemical composition and phase composition. The laser radiation is also very often used for improvement of mechanical, corrosion resistance, tribological properties and also to reduce porosity and discontinuity in the different engineering materials.

Materials and experimental procedure and results

To improve mechanical properties of the aluminium alloy the silicon carbide particles has been used. The size of the applied powder was in the range from 45 to 180μm. The shape and size of applied powder is presented on the Fig. 1. As the substrate material has been used aluminium alloy EN-AC AlMg5Si2Mn. The chemical composition of applied alloy are presented in Table 1. To the melting of the precision selected area on the surface has been used High-Power Diode Laser (HPDL).

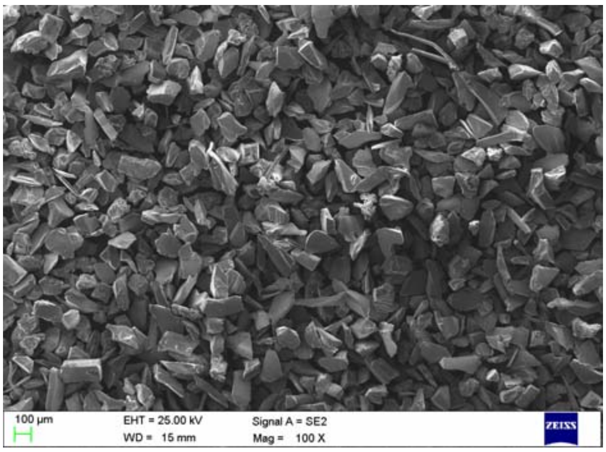

Fig. 1. The morphology of the silicon carbide powder in the initial state

The high power diode laser has been characterized very high power density of the laser beam under normal conditions of up to 10^7 W/cm^2. This makes the thermal impact on the detail is limited and thus causes only minor thermal stress and strain [2–4]. To limited diffusion of hydrogen, oxygen and nitrogen gas from the atmosphere the process of melting of the surface, has been carried in argon atmosphere. For the remelting of the top surface metal was used high power diode laser HPDL [1–7]. The silicon carbide powder was been introduce in the liquid metal using gravity feed at a constant rate of 1 g/min. In order to remelting the aluminium alloy surface, there has been used the high power diode laser HPDL, with an applied power of the laser beam 1.6 and 2.1 kW (Fig. 2).

Table 1

Chemical composition of aluminium alloys

Aluminium alloy	Mass concentration of alloying elements in the examined alloys, %								
	Si	Fe	Cu	Mn	Mg	Zn	Ti	Inne	Al
EN AC-51-500	2.1	0.25	0.05	0.45	5.2	0.07	0.25	0.15	Rest

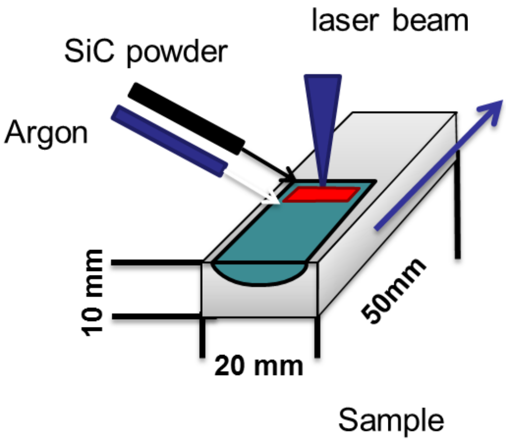

Fig. 2. The process of laser feeding of aluminium alloy ENAC-AlMg5Si2Mn

The mechanical and tribological properties of the composite layer has been checked by the measure of the surface hardness, micro-hardness measured along the cross section and wear test "ball on plate". The shape and distribution of silicon carbide particles in the aluminium alloy matrix was examined by scanning electron microscopy (SEM). The shape and size of the distribution SiC particles in the solidification molten pool has been determined by the scanning electron microscopy SEM. The structure of the solidification molten pool after the laser feeding is presented in the Figure 3.

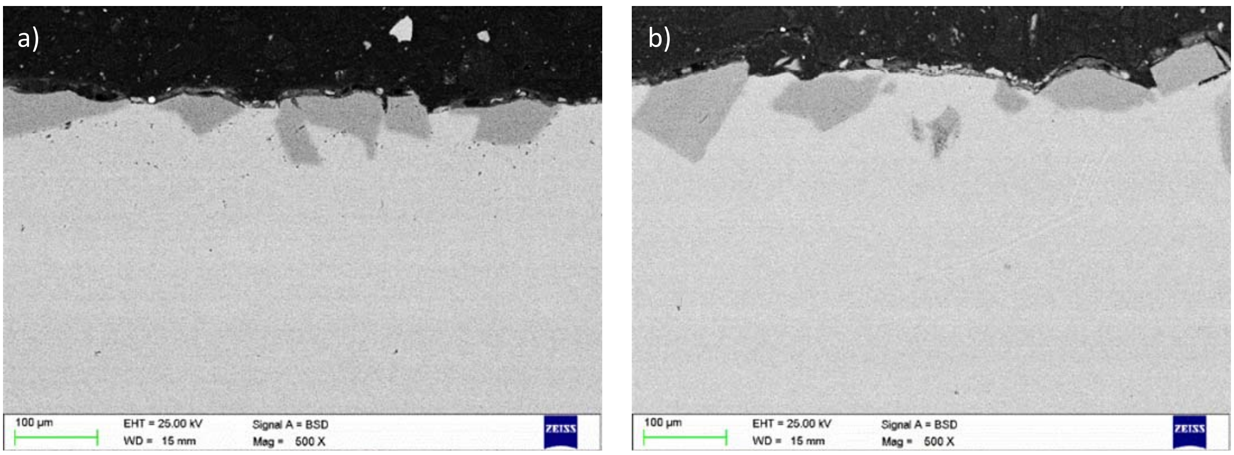

Fig. 3. The structure of the composite layers after the laser treatment with power of laser beam: a) 1.6 kW, b) 2.1 kW

The greatest concentration of the silicon carbide powder in the top surface on the depth about 100 μm has been observed for the smallest applied laser power 1.6 kW. The applied higher power of the laser beam is caused destruction of the silicon carbide powder. Powder is also absorbent of laser radiation, and thus the heat carrier in the remelting zone. Observation of the cross section layer showed absence of porosity and discontinuity in the material. Analysis of cross-section that the silicon carbide particles are closely associated with the aluminium alloy matrix. The parameters of wear resistant test is presented in the table 2. In results of carried examinations of analysed materials by high resolution scanning electron microscope with a chemical composition analysis system EDS have confirmed presence of particles of silicon carbide in the solidification molten pool (Fig. 4).

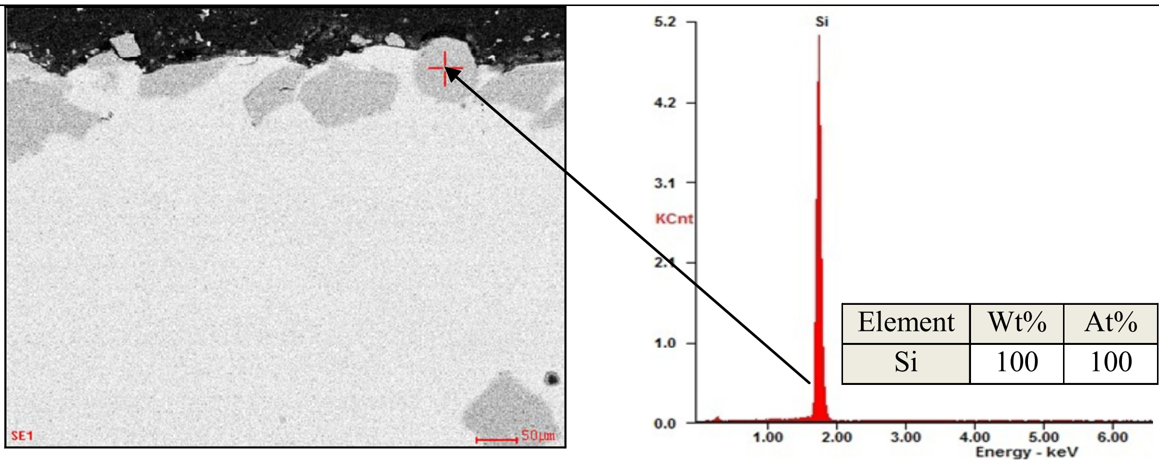

Fig. 4. Analysis of the chemical composition in the point on the top surface in the area enriched in the silicon carbide particles

Tribological properties obtained by laser treatment the composite layers was examined using test "ball on plate" [8]. The tested surface before the test has been grinding with abrasive paper of grain size 68µm. Counter sample in the test was a ceramic ball Al_2O_3 (6 mm diameter). The wear resistance of the analysed materials has been tested on the distance 250 m with apply load 11N. The velocity movement of the sample was 4 cm/s. The length of the tested section was 4 mm. The largest volume of abrasion was observed for the sample without the laser treatment and the lowest for the material after laser treatment with power 1.6 kW. This fact confirms the increase the wear resistance of the sample with composite layers obtained by the laser treatment (Tab. 2). The smallest roughness of the wear track was measured for the material after the laser treatment beam with power 1.6 kW and the highest for the material based. The wear profile after ball on plate test is presented on the Figure 5.

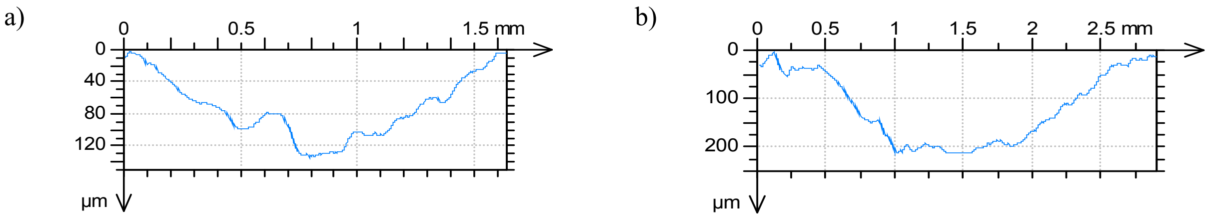

Fig. 5. Roughness and wear profile after the "ball on plate" test samples with composite surface layers obtained using laser treatment with power of laser beam: a) 1.6 kW, b) 2.1 kW

Table 2

Roughness and hardness of the surface before the wear test, friction coefficient registered during the process and dimension of the wear track after "ball on plate" test

Power of the laser beam, kW	Roughness of the surface Ra µm	Friction coefficient	Volume, mm^3
Aluminium alloy ENAC 51-500 before the laser treatment			
-	7.84	0.62	1,01
Aluminium alloy ENAC 51-500 after the laser treatment			
1.6	4.89	0.50	0,45
2.1	5.74	0.54	1,46

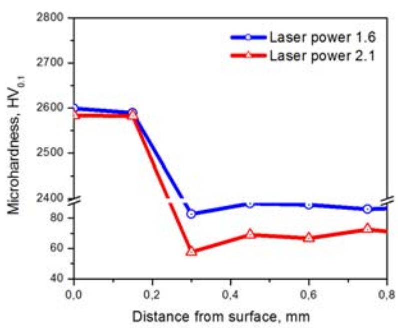

Fig. 6. Microhardness along the cross section of composite layers obtained at different laser powers

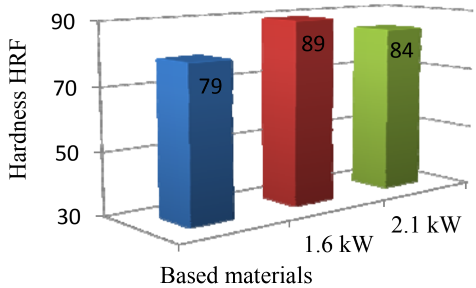

Fig. 7. Hardness of the ENAC AlMg5Si2Mn and the aluminium alloy after laser feeding with the different power of the laser beam

Results of hardness measurement of the composite layer and base materials showed a significant increase of the hardness of the surface layer of about 79 to over 89 HRF (Fig. 7). Microhardness measurement along the cross-section of composite layers has showed only increase of the hardness in the area of carbides presence at a depth of about 150-200 μm (Fig. 6).

Conclusion

The analysis of this investigation has confirmed the increase of mechanical and tribological properties of the surface after laser feeding of the aluminium alloy using silicon carbide particles. The tribological test has shown that the best properties of wear resistance have a composite layers which was obtained using the lowest power laser 1.6 kW. The increase of the laser beam power during the process of introduce the silicon carbide particles in the aluminium alloy matrix by the high power diode laser (HPDL) wasn't caused growth the wear resistance obtained composite layers. Microhardness test has showed the significant increase of the hardness of the top surface on the depth in the range from 150 μm to 200 μm. Analysis by the scanning electron microscopy of the cross section solidification molten pool obtained by the laser feeding has showed absence of porosity and discontinuity in the material.

References

1. Dobrzański L.A., Tomiczek B., Pawlyta M., Król M. Aluminium AlMg1SiCu matrix composite materials reinforced with halloysite particles, Archives of Metallurgy and Materials 59/1 (2014). P. 335–338.

2. Brytan Z., Bonek M., Dobrzański L.A., Pakieła W. Surface layer properties of sintered ferritic stainless steel remelted and alloyed with FeNi and Ni by HPDL Laser, Advanced Materials Research, 2011. vol. 291–294. P.1425–1428.

3. Bonek M. Laser Surface Alloying. In: Wang Q., Chung Y. (Ed.) Encyclopaedia of Tribology, Springer-Verlag Berlin Heidelberg, 2013. P. 1938–1948.

4. Bonek M. Effect of high power diode laser surface alloying of tool steels, Chiang Mai Journal of Science, 40(5), 2013, pp. 849–856.

5. Bonek M.: Effect of high power diode laser surface alloying on wear resistance of high speed steel, Journal of Achievements in Materials and Manufacturing Engineering 61(2), 2013, pp. 349–359.

6. Brytan Z., Grande M.A., Rosso M., Bidulsky R., Dobrzanski L.A., Stainless steels sintered form the mixture of prealloyed stainless steel and alloying element powders, Materials Science Forum, vol. 672 (2011).

7. Dobrzański L.A., Labisz K., Jonda E., Klimpel A. Comparison of the surface alloying of the 32CrMoV12-28 tool steel using TiC and WC powder, Journal of Materials Processing Technology 191/1-3 (2007). P. 321–325.

8. Bidulsky M. Actis Grande, A. Zago, Zbigniew Brytan, J. Bidulska, Wear resistance of various type sintered steels, Arch. Metall. Mater. 2010 vol. 55. issue 3. P. 623–629.

Рецензія/Peer review : 20.4.2014 р. Надрукована/Printed :16.5.2014 р.