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HPDL Remelting of Anodised Al-Si-Cu Cast Alloys Surfaces

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Abstract

The results of the investigations of the laser remelting of the AlSi9Cu4 cast aluminium alloy with the anodised and non-anodised surface layer and hardness changes have been presented in this paper. The surface layer of the tested aluminium samples was remelted with the laser of a continuous work. The power density was from $8{,}17 \cdot 10^3$ W/cm^2 to $1{,}63 \cdot 10^4$ W/cm^2. The metallographic tests were conducted in form of light microscope investigations of the received surface layer. The main goal of the investigation was to find the relation between the laser beam power and its power density falling on a material, evaluating the shape and geometry of the remelted layers and their hardness. As the substrate material two types of surfaces of the casted AlSi9Cu4 alloy were applied – the non–treated as cast surface as well the anodized surface. As a device for this type of surface laser treatment the High Power Diode Laser was applied with a maximum power of 2.2 kW and the dimensions of the laser beam focus of 1.8 x 6.8 mm. By mind of such treatment it is also possible to increase hardness as well eliminate porosity and develop metallurgical bonding at the coating-substrate interface. Suitable operating conditions for HPDL laser treatment were finally determined, ranging from 1.0 to 2.0 kW. Under such conditions, taking into account the absorption value, the effects of laser remelting on the surface shape and roughness were studied. The results show that surface roughness is reduced with increasing laser power by the remelting process only for the non-anodised samples, and high porosity can be found in the with high power remelted areas. The laser influence increases with the heat input of the laser processing as well with the anodisation of the surface, because of the absorption enhancement ensured through the obtained alumina layer.

Keywords: Innovative foundry technologies and materials, Remelting of the surface layer, Cast aluminium alloys, Anodisation, HPDL laser

1. Introduction

Aluminium alloys combined with its low density present at present excellent mechanical properties, is wear and corrosion resistant and widely used in different industries such as medical, aerospace, automotive and petrochemical. The aluminium silicon copper alloy is one of the mostly used cast alloys. employed in industry. The modification of its properties, especially on the surface can be achieved with convectional heat treatments and/or with laser processing. Laser remelting and alloying is a technology applied to the Al-Si-Cu but also to other alloys like steel, magnesium, titanium alloy by other authors with excimer and Nd-Yag laser. One of the major problems is to ensure a suitable laser beam energy absorption on the surface of the treated samples. For this reason the surface of the investigated alloy was anodised.

The anodic layers are produced mainly for the reason of protective and decorative function. Anodic oxides layers connected fixedly with aluminium substrate are resistant on corrosion. The intermetallic phase of copper with aluminium dissolve during anodizing, which causes lowering the hardness and thickness of coats, and the enlargement the porosity The gain in thickness of the anodic layer in relation to the thickness of the formed oxide film amounts about to 0.001 µm per 1V. A total thickness of the porous alumina layer has ca. 10-20 µm reaching from the basic layer, which is dissolved by electrolyte. [1-12].

In the present research work, high power diode laser (HPDL) laser remelting was applied for the first time to anodised Al-Si-Cu surface, to investigated the influence of this type of surface layer in absorption increase of the laser beam energy. Also the possibility was taking into account to use the anodised alumina layer for properties enhancement instead of Al_2O_3 powder applied in laser alloying.

The evaluation of the laser treatment parameters influence on shape, geometry and hardness of the surface layer with and without the anodised layer has been also done in this paper. The relations between the treatment parameters especially the laser power have been pointed out in relation to and the surface geometry and hardness as well as the absorption behaviour.

2. Investigation methodology

The samples were remelted with the HPDL laser beam of the continuous work with parameters presented in Table 1. The power of the laser beam was 1.0; 1.5 and 2.0 kW, and the speed of the travel was v=0,25 m/s applied on a laser tray length of ca 4 cm. The samples were remelted with a distance from the focal point to the laser head of ca. 80 mm. The calculated maximal power density value crucial for the absorption of the beam energy was $1{,}63\cdot10^4$ W/cm^2. Also pure argon shielding gas to prevent oxidation was applied. The anodised surface layer presented on Fig 1. has a thickness of ca. 10-15 µm.

Structure investigation was performed using the light microscope Leica MEF4A supplied by Zeiss with a magnification of 1000x. The micrographs of the microstructures were made by mind of the KS 300 program using the digital camera. Also a stereoscope was used for imaging of the laser tray surface. Hardness measurements results were performed for each of the remelted areas according to the power used. For this reason the Rockwell hardness tester supplied by Zwick was used according to the HRF scale, by a load of 60 kgf. The received surface layer consists in a cross section view of the remelted material zone, heat influence zone and the substrate material.

Table 1.
Processing parameters used during the study

No	Parameter	Value
1.	Laser power	P1 = 1.0, P1 = 1.5, P1 = 2.0 kW
2.	The travel speed of the laser beam	v = 0,25 m/s
3.	Beam diameter after focusing	1.8 x 6.8 mm (0,1224 cm^2)
4.	Lens focal	f = 80 mm
5.	Laser wave length, nm	940 ± 5
6.	Power density of the laser beam	Q1=$8{,}17\cdot10^3$ W/cm^2, Q2=$1.23\cdot10^4$ W/cm^2, Q3=$1{,}63\cdot10^4$ W/cm^2

3. Investigation results

The shape of the remelted zone in a top view depending on the power density of the laser beam is presented in fig. 2 to 7. The maximum heat amount achieved by 2.0 kW laser power provided to the surface of the treated material causes remelting of the surface layer in all samples [Fig. 4 and 7]. Whereas for the non-anodised material the power of 1.0 kW was to low to remelt the aluminium surface, because of a low absorption rate of the surface [Fig. 5]. The measured and calculated values like: density, width and surface field after the laser remelting are presented in table 2.

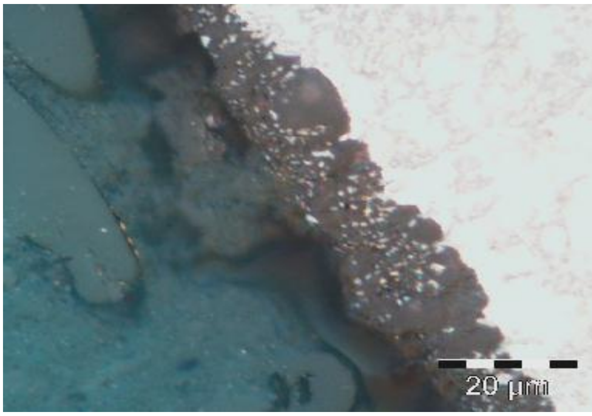

Fig. 1. Anodised layer on the AlSi9Cu4 alloy

Table 2.
The measured and calculated parameters of the remelted zones obtained during the laser treatment

Power density [W/cm^2]	Laser power [kW]	Remelting width [mm]	Surface field [mm^2]
$8{,}17\cdot10^3$	1	2,4	96
$1.23\cdot10^4$	1.5	2,9	116
$1{,}63\cdot10^4$	2.0	3,2	128

It can be clearly confirmed, that the anodisation surface layer of a thickness of ca 10 µm improves the energy absorption. There is also a clear relationship between the power density and the remelting width, which increase together with the applied laser power.

The biggest width of the remelting zone of 3.2 mm was received in the sample worked out with the higher power density Q3=$1{,}63\cdot10^4$ W/cm^2. The smallest width of the remelting was in a sample remelted with the power density of $8{,}17\cdot10^3$ W/cm^2.

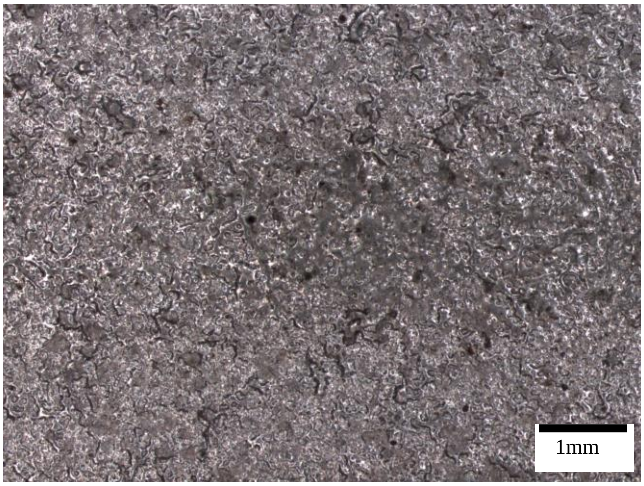

Fig. 2. Non-anodised surface, laser power 1.0 kW

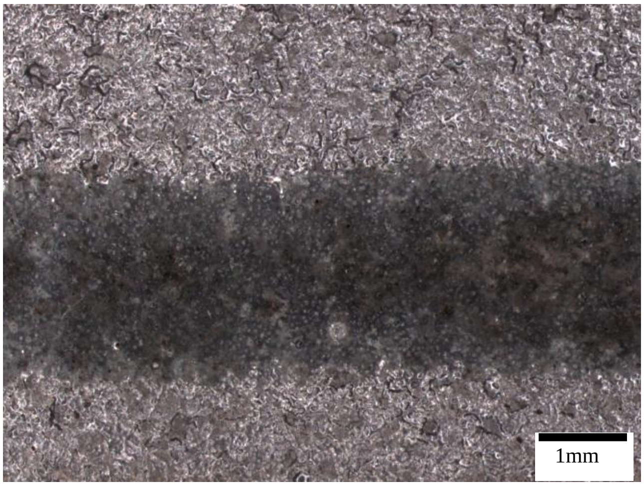

Fig. 3. Non-anodised surface, laser power 1.5 kW

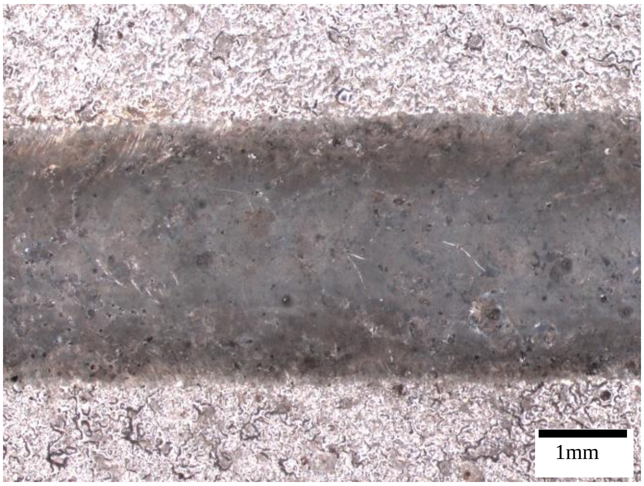

Fig. 4. Non-anodised surface, laser power 2.0 kW

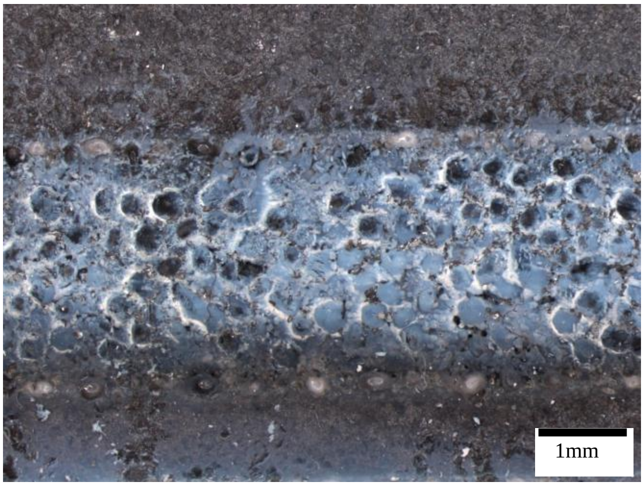

Fig. 5. Anodised surface, laser power 1.0 kW

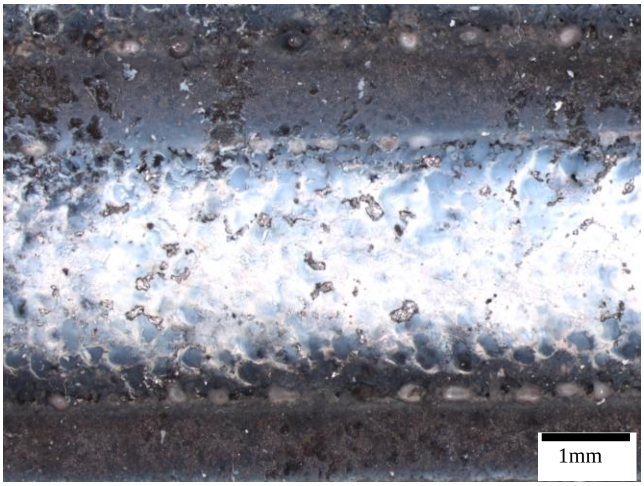

Fig. 6. Anodised surface, laser power 1.5 kW

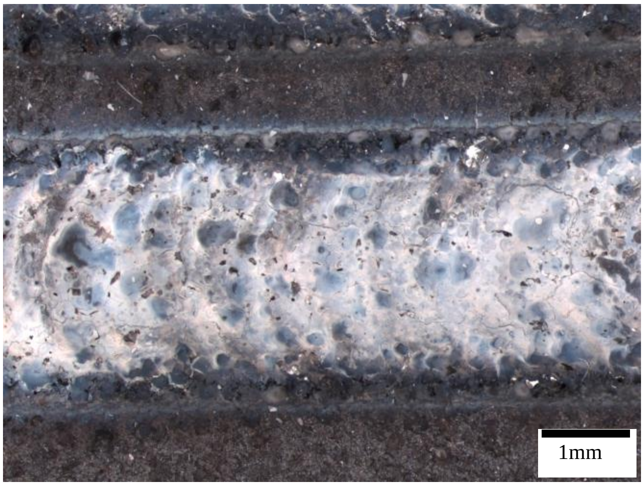

Fig. 7. Anodised surface, laser power 2.0 kW

The measured hardness of the laser treated surface is presented in Fig. 8. The hardness values given in the HRF scale are similar for the anodised as well non-anodised surface – 72 and 79 HRF. For the non-anodised samples the hardness increases together with the laser power and achieves a value of 97 HRF for 2.o kW, whereas for the anodised surface the hardness decreases in relation to the laser power to achieve only 53 HRF for 2.0 kW. So the alumina layer increases the hardness only in case relatively low laser power of 1.0 kW.

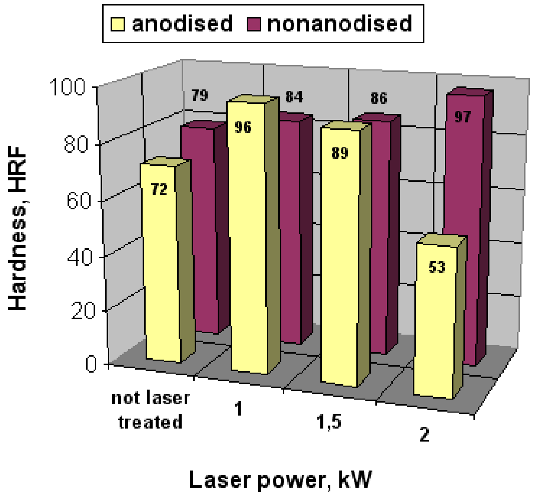

Fig. 8. Hardness measurements results of the anodised and non-anodised surface after laser treatment

4. Conclusions

The performed investigations of the microstructure evaluation of the Al-Si-Cu alloys, carried out using light microscope, allow to evaluate the surface roughness achieved after the laser remelting. The laser power determination leads the conclusion, that the optimal value is ca. 1.5 kW. A lower value of ca 1.0 kW does not to achievement of an completely homogeny remelting tray on the sample surface, whereas a to high power of 2.0 kW makes a very rough uneven surface. Also the anodisation causes a higher absorption rate of the sample, so it can be achieved Remelting for the 1.5 kW too. Particularly the following can be state:

(1) the investigated alloy has average hardness value of 40 HV after solution heat treatment and ageing and 35 HV in the as cast state,

(2) the optimal laser power is in the range of < 1.0 - 2.0 > kW.

(3) the optimal laser scan rate during treatment of the aluminium alloy surface was determined as 0.25 to 0.5 m/s. A to high scan rat leads to a non-homogeny laser tray on the surface.

(4) the alumina layer achieved by anodisation increases the hardness only for the lowest laser power of 1.0 kW, by higher power the hardness decreases below the reference values of not treated material.

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