Plasma Electrolytic Oxidisation of L-PBF AlSi10Mg alloy

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Introduction

AlSi10Mg, the most researched additive manufacturing (AM) Al alloy, is an age-hardening alloy with excellent properties in terms of hardness and strength, ideal for applications in which good thermal properties and low weight are required. Therefore, AM of Al alloys has become of great interest especially in aerospace and automotive industries where lightness and reliability are essential prerogatives. The main advantage of AM of AlSi10Mg is the high process cooling rate, which allows obtaining of a unique refined grain structure and the fine precipitation of intermetallic phases. However, a major issue for this Al alloy, mostly used in aerospace and automotive fields, is poor wear and corrosion properties. Consequently, in recent years the attention of many researchers has focused on surface treatment techniques aimed at improving the corrosion and wear-resistance of these alloys. Plasma Electrolytic Oxidation (PEO) is an advanced anodizing technique [1], which can deposit a solid oxide layer on the surface to improve the corrosion resistance and tribological properties.

Aim & Objectives

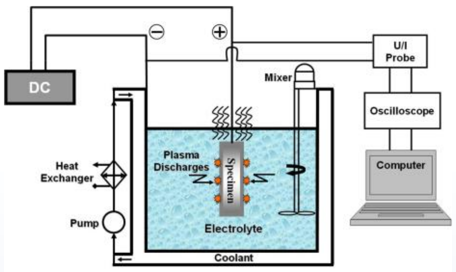

Figure 1: Functional diagram for the Plasma Electrolytic Oxidation (PEO) system [1].

The aim of this research is to evaluate the properties of PEO coating (Fig. 1) deposited on Laser Powder Bed Fusion (L-PBF) AlSi10Mg alloy. The results in terms of oxidized layer thickness and surface properties were studied and compared with the as-build L-PBF material. Furthermore, microhardness, coefficient of friction (CoF) and wear rate were determined.

Experimental Procedure

1. PEO coated specimens cross section were analysed and coating thickness was determined by SEM and EDX Analysis (Fig. 2a).
2. XRD was performed to analyse the difference in phases between the as-build and PEO treated L-PBF samples.
3. 3D Surface Topology was performed to estimate the general surface quality of all the configurations through a profilometer, Alicona (Fig. 2b).
4. Micro-hardness (Fig. 2c) of the PEO layer was determined to see any difference with the as-build counterpart.
5. Wear tests were performed to evaluate coefficient of friction, CoF, and wear rate of PEO coated specimen. After the wear test (Fig. 2b), the loss of material from the surface due to the relative motion between pin and material was evaluated using optical and electron microscopy. SEM and profilometer were used to acquire and measure the general quality and width of the wear track.

Figure 2: (a) SEM Hitachi 3030+; (b) 3D Profilometer Alicona; (c) Micro-harness Wilson; (d) Wear Test system.

Different configurations were tested and the effect of the PEO on different surface condition of the specimens were evaluated.
In particular, some of the AlSi10Mg samples, manufactured via L-PBF, were subjected to a polishing operation upstream of the PEO process to evaluate the influence of the surface quality.
The configuration analysed and the acronym are explained below:

- AlSi10Mg as-built, processed via L-PBF (AB);
- Material processed via L-PBF and subject to a polishing operation (ABP);
- AlSi10Mg as-built, and coated with PEO treatment (CT);
- Material as-built, subjected to a polishing operation and coated with PEO treatment (CTP).

Results

Coating Cross-Section analysis

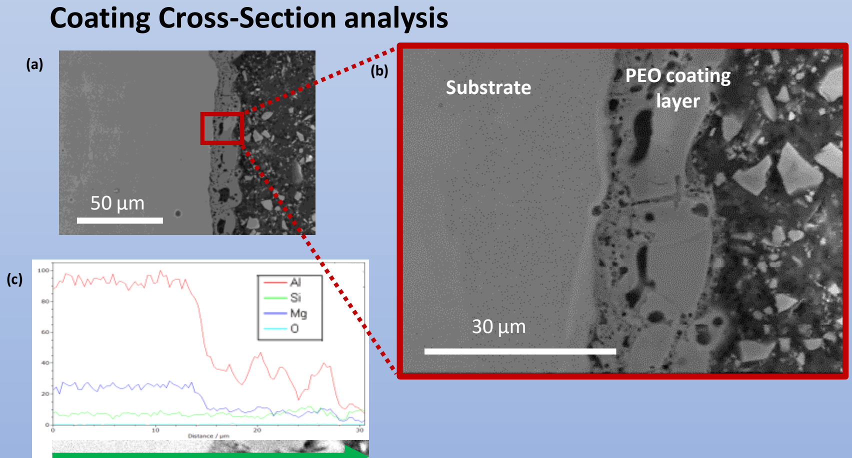

Figure 3: (a) SEM micrograph of PEO layer; (b) detail at higher magnification of the coating layer; (c) EDX analysis for thickness valuation

SEM micrographs shown in Fig. 3 confirm the success of an oxidised layer formed after the PEO treatment. The coating analysed was homogeneous on all tested specimens. Finally, the micrographs were used to measure experimentally the thickness of the oxidised layer and the difference between the configurations CT and CTP is represented in Fig. 4. Furthermore, the thickness was confirmed by the EDX analysis, performed as shown in Fig. 3c, starting from the substrate. The distance where the curves drop before tending to zero turns out to be the coated layer.

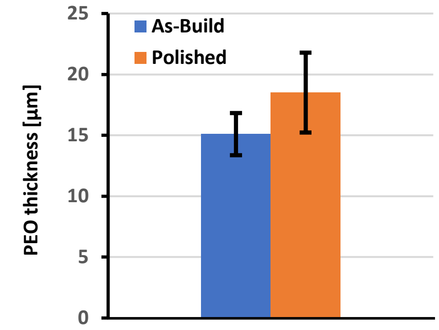

Figure 4: PEO Layer thickness measurement for the two configuration (polished and not polished)

Microhardness and XRD analysis

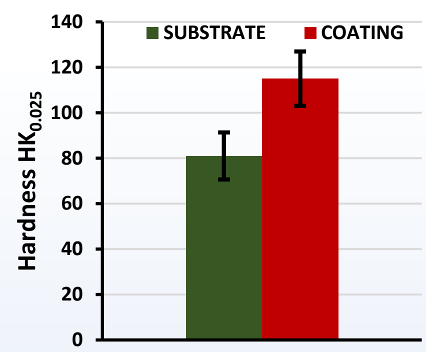

Figure 5: Microhardness of substrate and PEO coated layer

Microhardness tests were carried out on the substrate (AMed AlSi10Mg) and coated layer, and the results are presented in Fig. 5. The substrate has an average hardness of 80 $HK_{0.025}$, normal for the material. The coating instead has an increment expressed in percentual of the 50% in the hardness. XRD analysis (Fig. 6) was carried out to assess the correct correlation between the presence of alumina on the surface and the oxide layer created via the PEO process, responsible for the increase in hardness, and Figure 6 shows the results. The difference of the peaks between the as-built material and the treated surface shows the presence of the phases corresponding to the aluminium oxide.

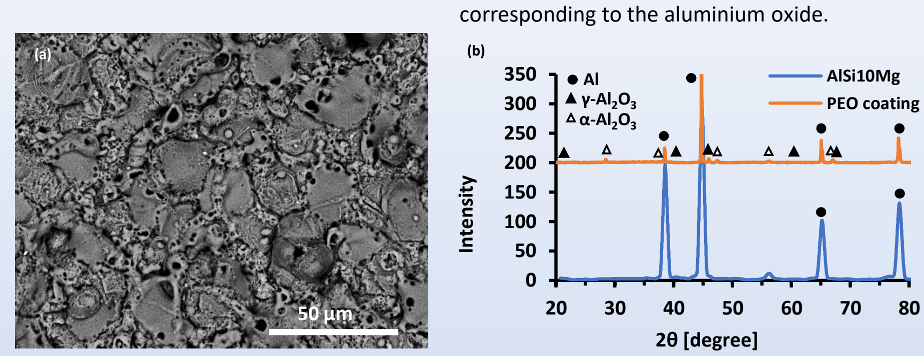

Figure 6: SEM of PEO coating surface and XRD analysis of As-build and coated configuration

As shown in Fig. 6a the PEO coating exhibits the typical pancake shape with craters called volcanoes, which increases the surface roughness, but without bringing it to high levels. The peaks of Aluminium is common for both the configuration analysed but the PEO coating shows a large presence of alumina phases and this indicates that the treatment was successful and the layer is made up mostly of alumina.

Wear Test analysis

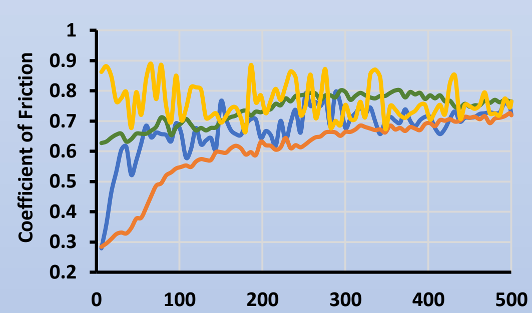

Figure 7: CoF measured for all the 4 configurations

Table 1: Coefficient of Friction legend and mean value.

Test Name	Line	Mean vale
AB		0.74
ABP		0.76
CT		0.68
CTP		0.59

Wear tests in Fig. 7 show the possibility of increasing wear resistance through a coating due to PEO. Without coating, the average friction value (Tab. 1) results are similar, while the best PEO coating configuration is CTP.

Conclusions

- PEO surface treatment was successfully performed on the AlSi10Mg alloy processed via L-PBF and the obtained layer showed a homogeneous thickness in both the analysed surface conditions (as-built and polished).
- XRD data showed the presence of alumina phases, unlike the uncoated condition. This led to the increase in mechanical properties (hardness) and wear resistance.
- The results highlight the CTP configuration as the optimal to ensure the best coated L-PBF AlSi10Mg material properties.

References
[1] Khan et al., Surf. Eng. 30 (2) (2014) 102-108

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