HIGH TEMPERATURE OXIDATION OF EN AW 7075 ALUMINIUM ALLOY

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Abstract

Aluminium alloys are highly valued for their exceptional strength-to-weight ratio, making them a preferred choice in structural applications. Among these alloys, EN AW 7075 stands out for its superior mechanical properties, finding widespread use in industries such as aerospace, mechanical engineering, and sports equipment. This study investigates the high-temperature oxidation behavior of EN AW 7075 alloy. The gathered results can provide valuable insights into the behavior of the mentioned alloy during the selective laser melting (SLM) process. These results can contribute to a better understanding of how the alloy responds to specific conditions and parameters. SLM is an additive manufacturing technique. The process involves the sequential steps of preheating, melting, and rapid cooling of metal powder. To minimize the influence of oxygen, the build chamber is filled with inert gas. A protective argon atmosphere is continuously maintained. However, despite these precautions, oxidation can still occur, leading to potential issues in the final product. Hence, we examined the oxidation kinetics of the EN AW 7075 alloy in an oxygen atmosphere in the temperature range of 300-500 °C. The findings of this investigation significantly contribute to an understanding of the behavior of the alloy during high-temperature oxidation, particularly for ongoing studies focused on processing Al-Zn-Mg-Cu alloys using the selective laser melting technique. Thermogravimetry was employed to analyze the oxidizing behavior, with three samples subjected to a 6-hour exposure in an oxidizing atmosphere at temperatures of 300, 400, and 500 °C. Surprisingly, no oxidation occurred, as indicated by the negligible and negative changes in mass observed across all samples.

Keywords: EN AW 7075, high-temperature oxidation, oxide film, selective laser melting

1. INTRODUCTION

SLM technique has revolutionized the field of additive manufacturing by enabling the production of complex and functional metallic components with excellent mechanical properties. Among the wide range of materials utilized in SLM, aluminium alloys have gained significant attention due to their desirable combination of lightweight, high strength, and excellent corrosion resistance. In particular, EN AW 7075, a popular aluminium alloy known for its exceptional mechanical properties, has shown great potential for various industrial applications [1,2].

EN AW 7075 alloy, belonging to the Al-Zn-Mg-Cu series, offers a high strength-to-weight ratio, superior fatigue resistance, and excellent stress corrosion cracking resistance. These attributes make it an ideal candidate for demanding applications in the aerospace, automotive, and sporting industries [3,4]. However, traditional manufacturing techniques such as casting and forging may present limitations in producing complex geometries with precise control over microstructure and mechanical properties. This is where the SLM technique emerges as a promising solution [1-3].

Upon observing the SLM-produced parts using a scanning electron microscope (SEM), it was evident that the parts exhibited numerous cracks (**Figure 1**). Further analysis using energy-dispersive spectroscopy (EDS) revealed that these cracks were, in fact, composed of oxides (**Figure 2**). Oxidation can occur during the SLM

process due to the presence of oxygen, despite efforts to maintain a protective atmosphere with minimal oxygen concentration. The formation of oxide cracks in EN AW 7075 SLM parts can be attributed to the interaction between the alloy and the surrounding atmosphere where the oxygen concentration does not exceed 200 ppm.

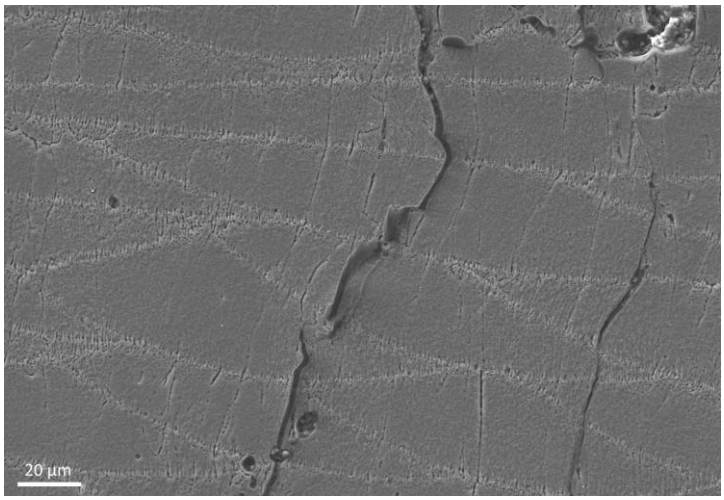

Figure 1 SLM developed microstructure of EN AW 7075 with visible melt-pool boundaries.

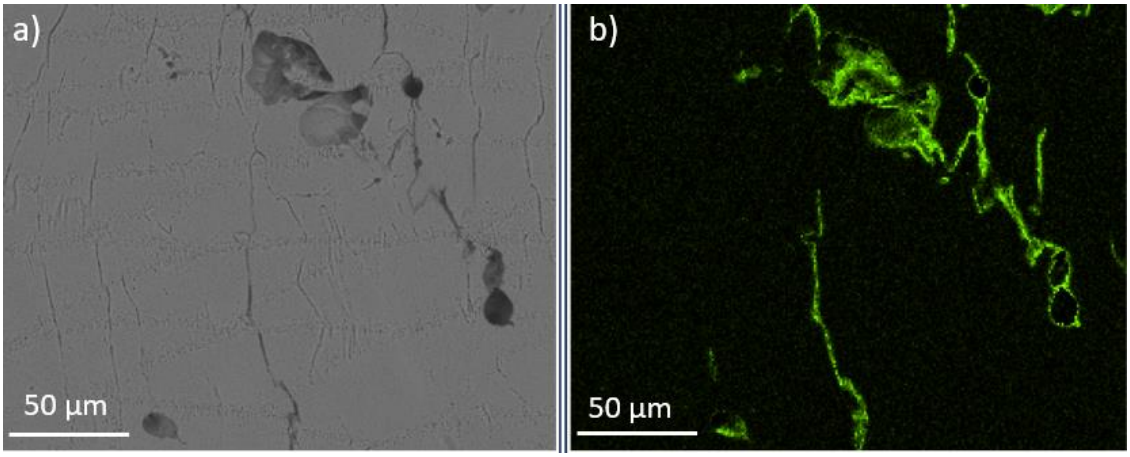

Figure 2 a) Analyzed area of SLM microstructure b) EDS mapping results; oxygen concentration

In this study, main objective is to investigate the alloy behavior of EN AW 7075 under high-temperature conditions using thermogravimetry (TG). By subjecting the alloy to a temperature range from 300 to 500 °C, we aim to elucidate its oxidation kinetics and understand the factors influencing the formation of oxide cracks in SLM-produced parts [6,7]. The results obtained from this analysis will provide valuable insights into the mechanisms underlying crack/oxide formation in EN AW 7075 SLM parts, enabling the development of strategies to mitigate crack formation and improve the reliability of SLM-manufactured aluminium components [1].

2. MATERIALS AND METHODS

For this study samples were machined from a Ø 20 mm extruded bar of EN AW 7075 aluminium alloy. Its chemical composition is given in **Table 1**. The sections were processed using a lathe machine to create cylinders with a diameter of 5 mm and approx. 5 mm in height. The lathe machining process ensured precise dimensions and a smooth surface finish for each sample. We maschined 4 samples. One of the prepared

cylinders was designated as the reference sample, which would be used to compare and evaluate any changes observed in the oxidized samples. The remaining three cylinders were individually placed in separate high-temperature environments corresponding to the desired oxidation temperatures (300 °C, 400 °C, and 500 °C). These oxidation environments were created using specialized equipment. In this case, STA 449 C Jupiter (**Figure 3 b**) was used. Prior to conducting the experiment, the weight of each sample was measured to establish a baseline measurement. This initial weight measurement served as a reference point for comparing any subsequent changes in mass during the experiment.

Table 1 Chemical composition of analysed extruded bar of EN AW 7075 (wt%)

Zn	Cu	Mg	Fe	Mn	Si	Ti	Cr
5.5	1.4	2.3	0.19	0.071	0.063	0.026	0.21

Furthermore, the surface area of each sample was calculated **(Table 2)**. This calculation involved determining the total area of the sample's exposed surface. Accurate knowledge of the surface area is essential for calculating mass changes per unit of surface area and obtaining precise results during the analysis. **Figure 3a** shows the temperature profiles recorded for each sample during the experimental procedure. The temperature profile represents the variation in temperature over time for each sample. Notably, when the temperature approached the isothermal region, a temporary spike in the temperature measurement was observed. This spike can be attributed to the latency of the thermoelement used for temperature measurement.

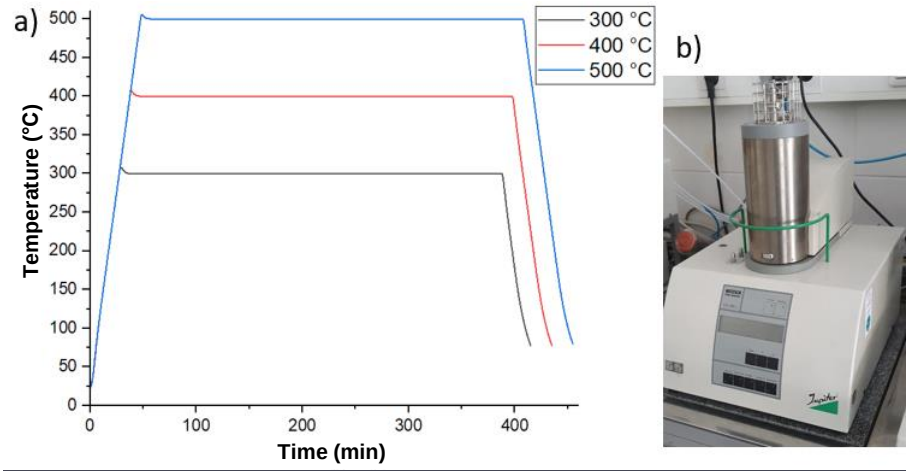

Figure 3 a) Temperature profile during the experiment b) STA 449 C Jupiter used for TG measurements

Table 2 Sample dimensions and surface area

	Temperature	Weight (mg)	Surface (cm^2)
Sample 1	300 °C	270.9	1.193
Sample 2	400 °C	248.1	1.115
Sample 3	500 °C	237.9	1.083

3. RESULTS AND DISCUSSION

3.1 Thermogravimetric results

The results revealed that all three samples exhibited minimal and negative mass changes during the 6 hour exposure period (**Table 3**). This indicates that no significant oxidation occurred within the specified temperature

range. The negligible mass changes indicate the absence of any substantial formation of oxide layers on the surface of the samples. These findings suggest that the EN AW 7075 alloy possesses good resistance to oxidation under the tested conditions.

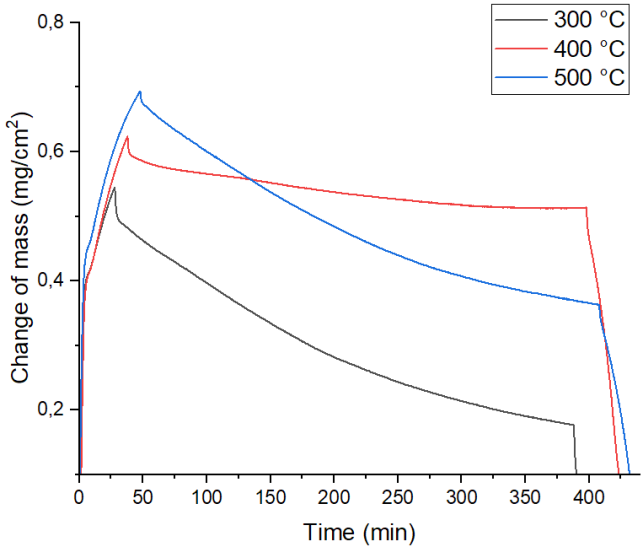

Figure 4 Change of mass during heating, isothermal and cooling intervals for all three samples

Table 3 Change of mass during the isothermal part of the experiment

	Change of wt (g)
Sample 1	-0.16
Sample 2	-0.05
Sample 3	-0.15

3.2 Changes in the microstructure

A comparison of microstructural changes between the reference (extruded state) and the sample exposed to high temperature (500 °C) is presented. **Figure 6** displays two microstructure images, one captured in the reference state and the other after the 6-hour exposure at 500 °C in the oxidating atmosphere. Upon examination, it was observed that the microstructure of the sample subjected to high temperature exhibited an increased presence of precipitates compared to the reference microstructure. These precipitates were identified through visual analysis by SEM and were found to align with the thermodynamic calculations.

The presence of these precipitates suggests that the high-temperature exposure caused a phase transformation within the microstructure. This transformation is attributed to the diffusion and redistribution of alloying elements, resulting in the formation of new phases or the growth of existing precipitates. The agreement between the observed microstructural changes and the thermodynamic calculations further supports the validity and accuracy of the experimental findings. **Figure 5** illustrates the phase stability of aluminium alloy at different temperatures. The *x*-axis represents the temperature range in °C, while the *y*-axis represents the amount of phases present in the alloy.

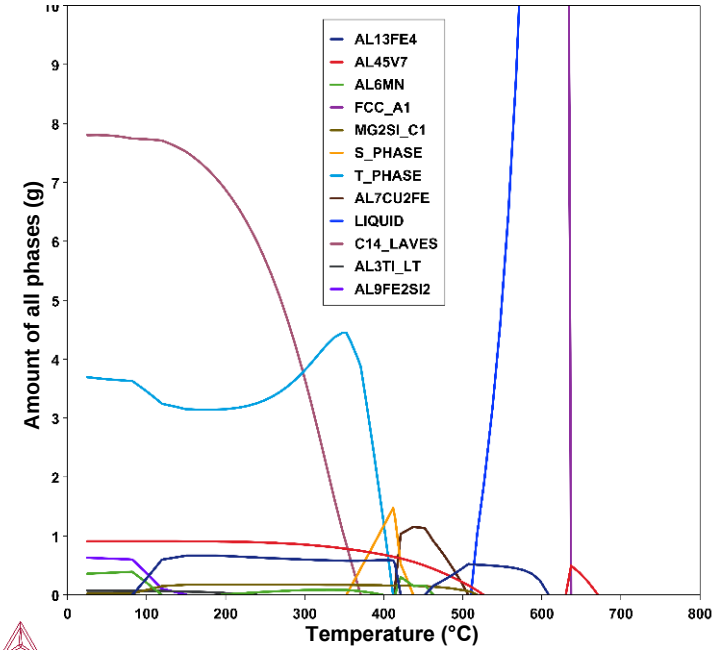

Figure 5 Thermodynamic calculations in Thermocalc

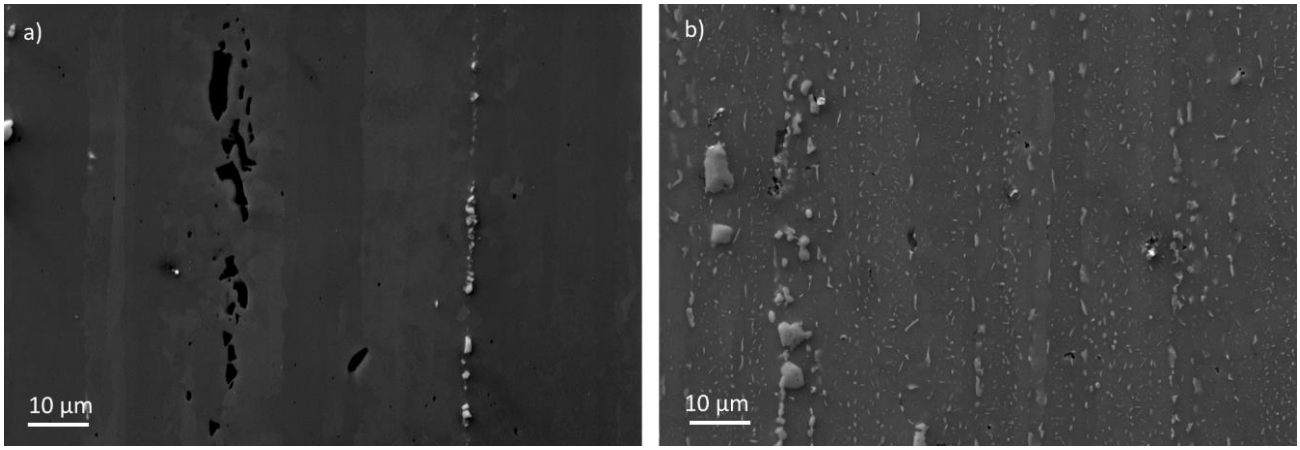

Figure 6 Microstructure images, captured in **a)** the reference state; **b)** after the 6-hour exposure at 500 °C

4. CONCLUSIONS

The results based on TG measurements indicate that there was no oxidation of the samples during the exposure period. Instead, the observed negative change in mass suggests that some of the alloying elements evaporate under the high-temperature conditions.

The sample exposed to 400 °C had the smallest change in mass, indicating that it was the most stable under the experimental conditions. The samples exposed to 300 °C and 500 °C behaved similarly, with comparable changes in mass.

The present study investigated the stability of the pre-existing aluminium oxide layer during the isothermal experiment. Our results indicate that the Al_2O_3 oxide layer was found to be stable under the experimental conditions employed. This study confirms that the EN AW 7075 alloy exhibits predictable microstructural changes under high-temperature conditions, as anticipated by thermodynamic predictions. Such understanding is essential for optimizing processing techniques and enhancing the materials performance in applications that involve elevated temperatures.

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