

Healing mechanism and strength improvement of a new high-strength healable Al-Mg alloys produced by LPBF

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Additively manufactured aluminum alloys are commonly employed in aerospace and aeronautics, where they are susceptible to damage from operational overloads. An emerging approach to reduce the need for part replacement is the use of materials capable of healing at damage sites.

This research focuses on the development of a novel high-strength healable Al alloy produced by Laser Powder Bed Fusion (LPBF). The rapid cooling rates characteristic of LPBF promote the formation of a fine microstructure, consisting of α -Al cells encased in a magnesium-rich eutectic phase with a low melting point. This eutectic network acts as a healing agent, functioning similarly to biological vascular systems. In the event of damage, a healing heat treatment (HHT) triggers the melting of the eutectic phase, allowing it to infiltrate cracks or voids and subsequently solidify, effectively sealing and repairing the defects.

To improve both mechanical strength and healing functionality, zirconium (Zr) is incorporated into the Al-Mg alloy, leading to the formation of strengthening precipitates. In this work, the static mechanical properties of the resulting Al-Mg-Zr alloy, referred to as Almazium, were assessed in the as-built state and after various healing heat treatments (HHT) involving different temperatures and durations. Under optimized printing conditions, the addition of Zr significantly enhanced the yield strength, increasing it from 150 MPa to an average of 366 MPa in the as-built samples. The HHT parameters were carefully optimized to limit the coarsening of strengthening precipitates, as excessive growth could impair the alloy's mechanical properties.

Finally, the healing capability of Almazium was evaluated through in-situ damage-healing cycles performed during synchrotron X-ray nano-tomography experiments at beamline ID16B of the ESRF. This approach allowed for direct observation of damage initiation, localized healing processes, and the potential re-opening of previously healed regions under subsequent mechanical loading.