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Application of DCPD to monitor study fatigue crack growth of internal and surface cracks in additively manufactured Scalmalloy®

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Powder bed fusion laser based (PBF-LB) manufacturing of aluminium alloys is increasingly adopted in aerospace and space applications due to its design flexibility, versatility and high mechanical performance. However, the presence of intrinsic manufacturing defects remains a critical issue for the fatigue behaviour and certification of safety-critical components. A different crack growth behaviour between embedded and surface defects has been observed in literature. These preliminary studies have shown that cracks initiated from volumetric defects, which are not exposed to the open environment, have a lower fatigue crack propagation rates and higher threshold stress intensity factors compare to surface fractures, resulting in significantly longer fatigue lives and higher fatigue strength. However, a robust experimental characterization for the propagation rate of internal cracks is still missing.

This work investigates the fatigue behaviour of internally-initiated failures in PBF-LB/Scalmalloy®. Traditionally used for surface crack monitoring, the direct current potential drop (DCPD) technique is proposed as an innovative method by being applied on specimens containing artificial CAD-seeded internal flaws, to measure growth rates of internal fatigue cracks. The evolution of the electrical potential drop across the crack plane is correlated to crack advancement by means of both finite elements analyses and experimental measurements. DCPD enables continuous and high-resolution monitoring of internal crack propagation during fatigue loading without the need for complex specimen geometries or advanced in-situ facilities (e.g. synchrotron X-ray tomography).

The experimental results demonstrate the capability of the DCPD technique to reliably track the growth of internal cracks in Scalmalloy®. The measurements show a clear reduction in crack growth rate for internally-initiated fractures in comparison with surface cracks. The identified trend is in agreement with previous literature studies on other alloys, confirming the existence of a distinct internal crack propagation behaviour which can be account in refined life prediction models. The proposed approach represents a practical and versatile tool for the experimental characterization of internal crack growth, providing a promising route towards the standardization of embedded crack propagation testing.

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