In-situ Crack detection during Laser Direct Energy Deposition using acoustic spectral analysis

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Abstract

Cracks are defects that can occur during laser-directed energy deposition (DED-LB/M) for example when working with nickel based super alloys. Non-Destructive Inspection(NDI) could allow quick identification of cracks and therefore potential scrap parts in-situ, when integrated into the industrial process chain. Existing in-situ NDI tools include optical, infrared and X-ray imaging [1]. Of these, only X-ray imaging offers insight into the interior of printed parts, but it is also the most challenging to implement in practice[1]. Acoustic Emission Testing is already in use to detect faults in pressure vessels and other structures or machinery. By detecting and analyzing the intensity of the acoustic energy emitted during the process, it becomes possible to detect events that rapidly release localized stress energy, such as cracks. Adapting this approach for DED-LB/M faces challenges from signal interference due to the noisy process environment and variations in acoustic behavior between different process set-ups [2]. However, by analyzing both the intensity and the frequency of the emitted acoustic signals it should be possible to distinguish cracks from random acoustic interference. A single-track wall was produced by Laser Wire Direct Energy Deposition of Ti-6Al-4V, without shielding gas. The substrate was firmly secured in a vice. An acoustic sensor was attached to the vice via a threaded bore, and linked to an Optimizer4D industrial computer. This setup was utilized to monitor acoustic emissions during both the deposition and cooling processes. Acoustic intensity was recorded across 512 frequency bands ranging from 6.1 kHz to 3124 kHz. Multiple acoustic emissions were detected during deposition and the cooling process. These involved frequency bands from 6,1 kHz to 1397.58 kHz, with the strongest emission being recorded in the 42.72 kHz band at 750,53 V. Furthermore, the total Energy ver all bands reached values up to 3350 V. The resulting sample was examined using dye penetrant testing to confirm the presence of cracks identified through acoustic spectral analysis. As a reference for random acoustic interference, such as that resulting from axis engine braking, the resulting acoustic emissions from hammer strikes on the substrate were also recorded. These were observed to result in significant acoustic emissions in frequency bands from 6,1 kHz to 152.57 kHz with the strongest emission being recorded in the 18.3 kHz band at 34,18 V. The total Energy over all bands stayed below 350 V. Based on these observations it has been concluded that it's possible to differentiate cracks from random interference using acoustic spectral analysis. Further research needs to be conducted to quantify the exact values of total energy or the frequency bands involved to identify critical cracks.

Literature

[1] Kononenko et al., An in-situ crack detection approach in additive manufacturing based on acoustic emission and machine learning, Additive Manufacturing Letters, Volume 5, 2023
[2] Koester et al., Acoustic monitoring of additive manufacturing for damage and process condition determination. AIP Conf. Proc. 8 May 2019