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Data-driven Approach to Identify Distortion of Acoustic Signals by Process Contextual Information in LPBF

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Quality Monitoring & Prediction of (De)Manufacturing Processes

Machinebuilders

Goal

- Develop an approach to classify printed cubes based on acoustic signal characteristics while addressing **context-related factors**.

- **Identify invariant frequency features** unaffected by variations in position and laser movement direction.

Motivation

•Acoustic Emission (AE) sensing shows promise for real-time monitoring, but its interpretation is hindered by factors like baseplate thickness and sensor orientation. **Signal distortion** due to wave propagation further complicates the analysis, making it challenging to isolate defect-specific information.

•Enhance quality control by **disentangling** process-related acoustic signals from **structural and environmental influences**.

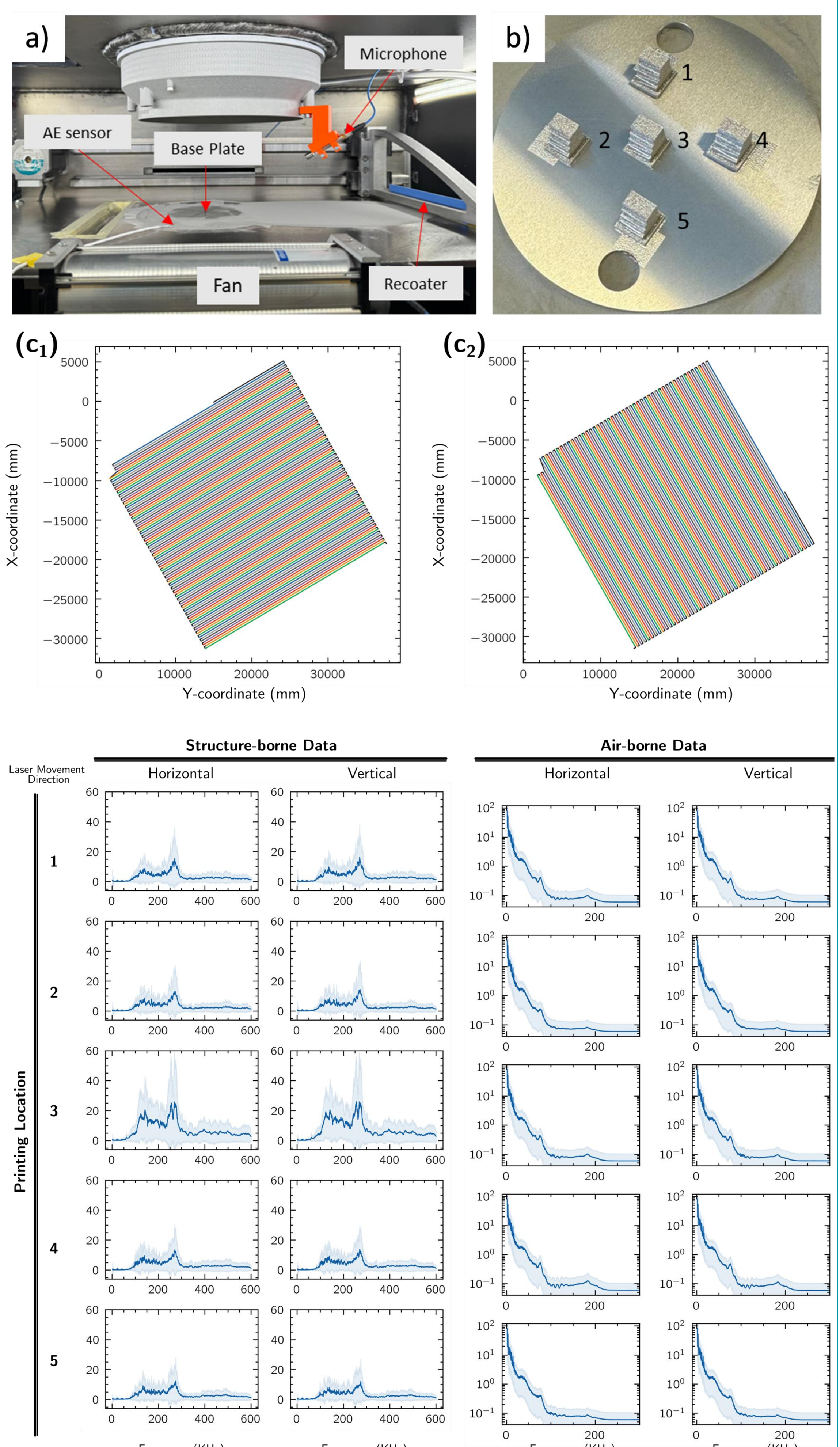

Fig. 1 Experimental setups and signal distortion with different printing direction and position

Approach

•Quantitatively evaluate the influence of contextual factors (e.g., baseplate thickness, and laser movement direction) on frequency characteristics.

•Use a CNN model for classification of printed cubes based on these contextual factors.

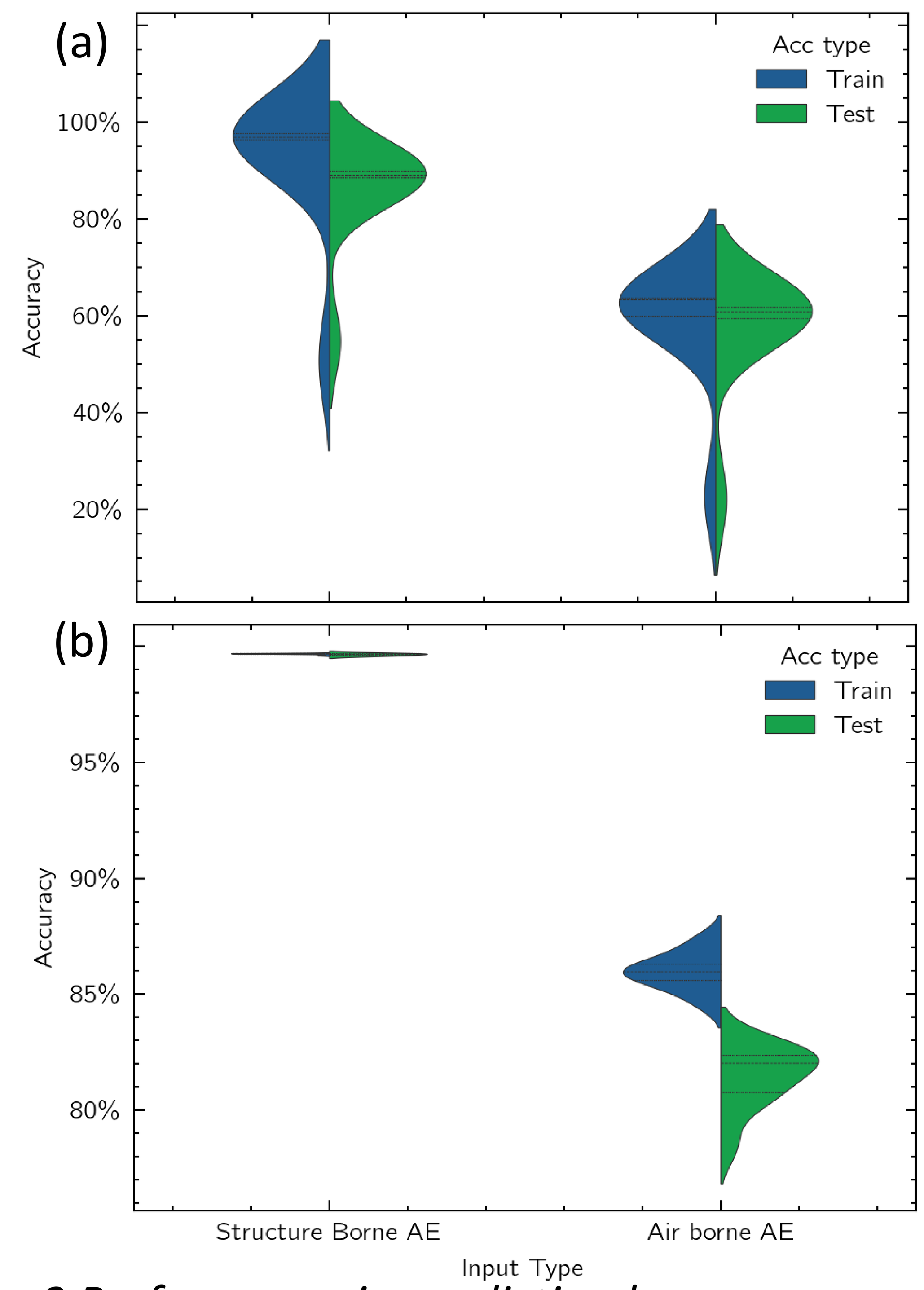

Fig. 2 Performance in predicting laser movement and printing position with (a) laser movement direction and (b) printing position

•Employ Gradient-weighted Class Activation Mapping (Grad-CAM) to identify significant frequency bands for classification.

•Extract invariant frequency features robust to variations in position and laser movement direction, a shown in Fig.4, the non area.

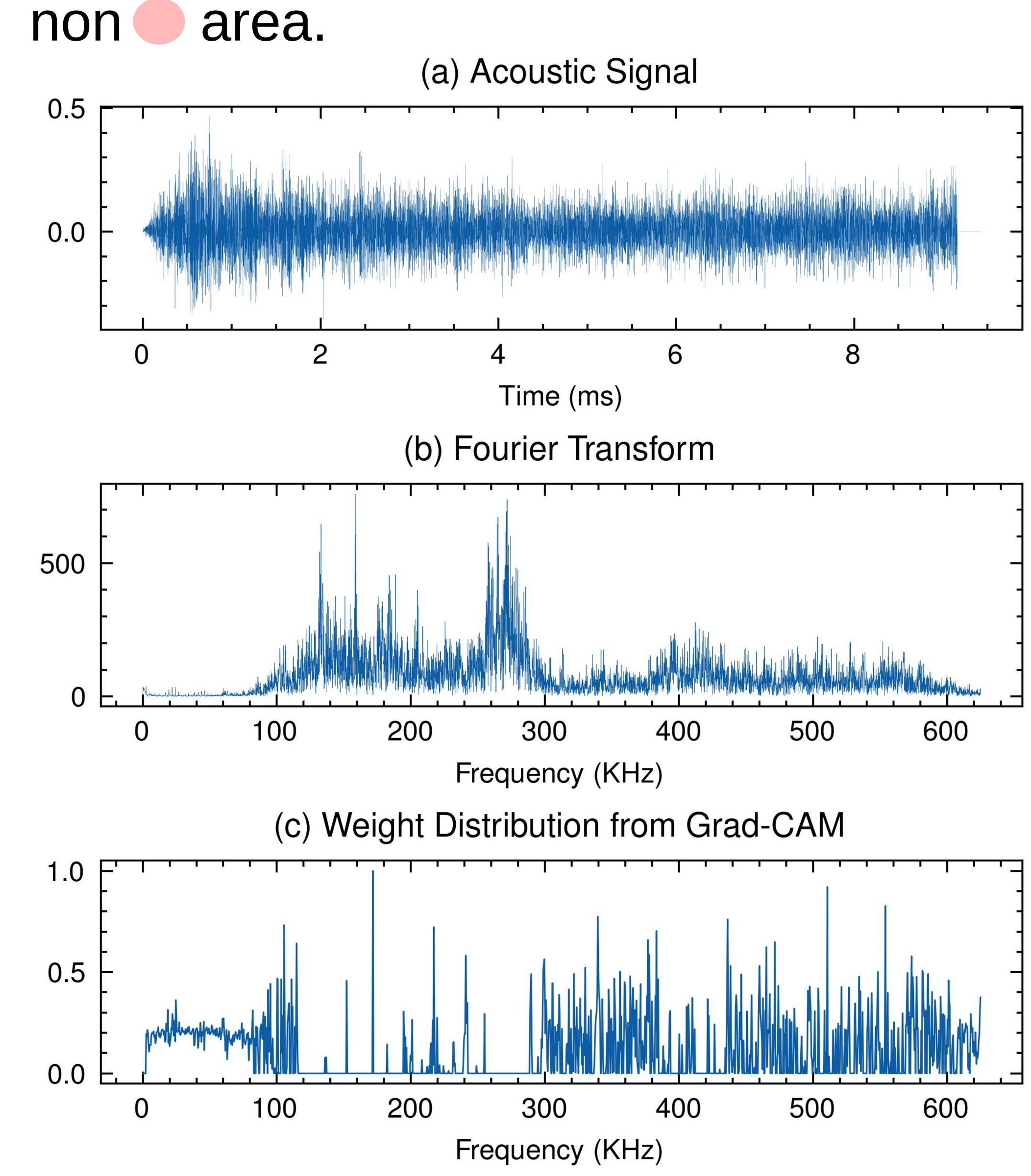

Fig .3 (a) AE signal in time-domain. (b) AE signal in frequency-domain. (c) The activation vector calculated by Grad-CAM which illustrates the relative importance of frequency bands in the CNN's classification decision.

Results

•The application of CNNs to Acoustic AE data enabled effective classification of contextual process conditions.

•**Structure-borne AE** data demonstrated robust performance, achieving high classification accuracy (Fig. 2).

•Airborne AE data successfully classified laser movement direction, with an accuracy of 84.3%, indicating its potential for monitoring certain process aspects (Fig.2).

•Grad-CAM analysis revealed strong correlations between contextual process information and specific frequency bands within AE data (Fig.4).

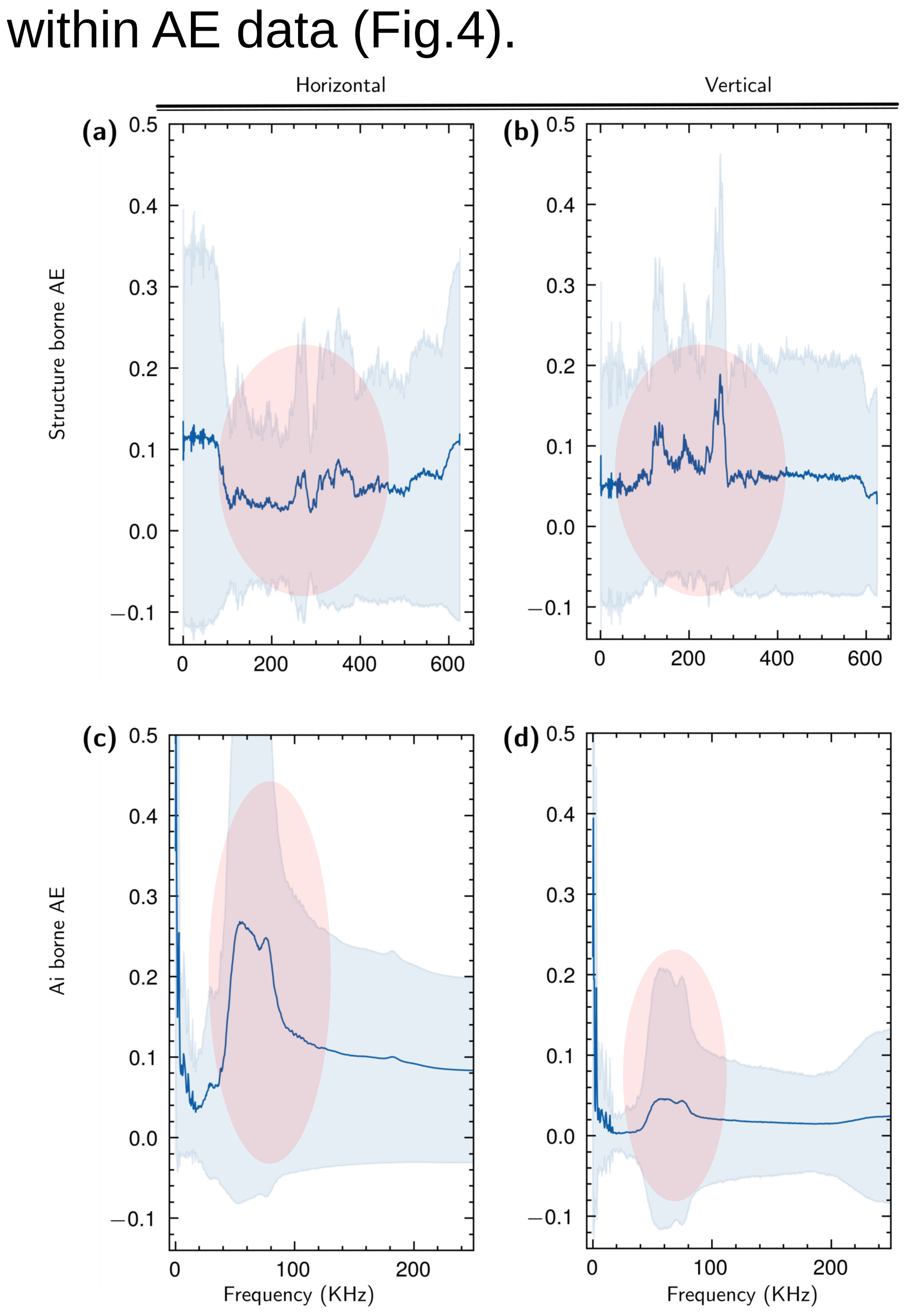

Fig .4 Grad-CAM weight visualizations from CNN models used to classify laser movement directions in frequency domains.

Key take-aways

•**AE data**, particularly structure-borne signals, can reliably distinguish between different process conditions in LPBF.

•Frequency bands identified by explainable AI provide valuable insights into the contextual factors **affecting/distorting** AE signals.

•Future improvements could involve targeting these frequency bands with **filtering and feature extraction** to enhance defect detection and classification.

Further reading

•ref1: Wu et al. (2025), Data-Driven Approach to Identify Acoustic Emission Source Motion and Positioning Effects in Laser Powder Bed Fusion with Frequency Analysis, CIRP CMMO 2025 (submitted)

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Number of poster
157

For Publication