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Automated Detection of Material Defects for High-throughput Electron Micrographs Analysis

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Background

Detailed analysis of material's microstructure is required for predicting material properties and fine-tuning manufacturing parameters to achieve the desired characteristics. This feedback process is particularly important when it comes to developing new production techniques such as metal additive manufacturing (AM).

Our goal is to provide a holistic solution that enables reliable materials characterization using a high -throughput approach in a scanning electron microscope (SEM) with automatic detection of characteristic microstructural features, especially defects such as cracks and pores. The scope of the detection framework that we cover includes all aspects of pre-processing the raw images from the microscope, defect identification and visualization of statistical results. In this way, it serves to overcome the current need for automation, providing researchers with a transparent and customizable process for their structural analysis. The customizable definitions of the parameters used in our algorithm also enable optimizations for applications in other fields of imaging, such as optical microscopy in biomedical research.

Methods

We acquired large-area secondary electron (SE) and backscattered electron (BSE) SEM images of an additively manufactured metal sample (316L steel) thereby varying dwell times from 10 microseconds to 100 nanoseconds and pixel size (i.e. magnification) from 391 to 49 nm. This allowed us to develop our image analysis algorithm to identify structural defects across a wide range of imaging conditions and systematically investigate the loss of precision in detection as image acquisition time was lowered (i.e. lower dwell time, larger pixel size). Once the micrographs were acquired, they were passed through a boundary detection procedure which isolates the relevant sample area. Filtering was then performed using multiple thresholding and convolution layers.

Results

Preliminary results have shown great promise in comparison to the manually labelled sections and flexibility to different imaging conditions. Performance metrics have also been compared with the most widely used classical tools in the field as well as with AI tools with which our software overlaps in scope.

The defects were characterized and selected according to user specifications in order to output statistical results and sample descriptors directly from the software interface. The robustness of the detection process has been verified using methods including comparisons with manually labelled sections and results obtained at highest dwell time and magnification. In this way, the development focuses on optimizing result consistency with shorter SEM image acquisition time, focusing on high-throughput analysis.

Conclusion

We have demonstrated in a systematic study the effect of SEM image acquisition parameters, such as dwell time and magnification, on the robustness of automatically detecting defects in AM 316L. This now enables the selection of optimised image acquisition parameters and a minimised data acquisition time (high throughput).

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The scope of our developed approach is more comprehensive than any currently available tool can offer. The aim of this development is to make defect analysis more transparent and reliable by providing a unifying platform.

Graphic:

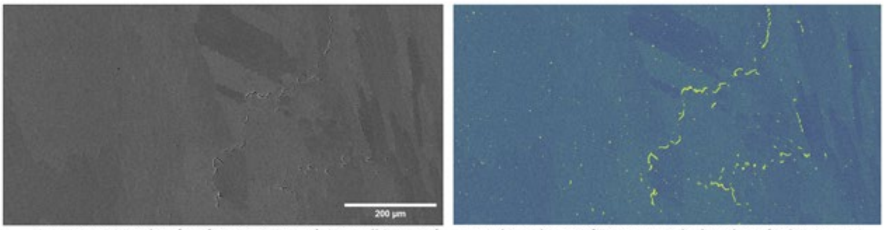

Figure 1: Example of Defect Detection for Dwell Time of 1 μs and Pixel Size of 200 nm with the Identified Features Highlighted in Yellow

Keywords:

Electron Microscopy, High-throughput Defect Analysis