Pre-Filtering Micrograph Data to Train Machine Learning Algorithms to Optimize Medical Metals

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Introduction

Understanding metal deformation is essential in medical device manufacturing. Formability refers to a material's ability to be stretched and shaped without tearing. A key indicator of a metal's formability is the orientation and spacing of slip bands within its grains.

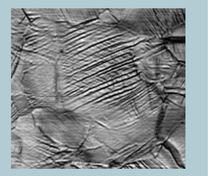


Figure 1: Slip bands on the surface of metal

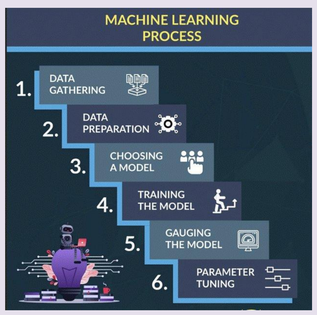
Figure 2: Simplified slip bands, hand generated for initial programing efforts

The goal is to automate the measurement of average slip band spacing within metal grains by creating a filtering algorithm that differentiates individual grains and identifies the average distance between slip bands and the average angle of the slip bands within each grain.

Objective

Complete Steps 1 & 2 of the machine learning process by developing an algorithm that:

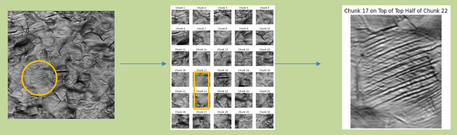
- ❖Segments metal grains in microstructure images.
- ❖Measures slip band spacing and angle within each grain.



This sets the foundation for Steps 3–6: building a predictive model to optimize medical metals and forecast failure.

Methodology

★ Isolate a Single Grain



★ Compare and Mix Filters

- ○Sobel- Detects edges by measuring changes in intensity; good for highlighting sharp transitions
- ○Canny- Sharpens and refines edges while reducing noise
- ○Frangi- Enhances tubular and line-like structures

★ Analyze Slip Bands

- ○Apply Hough Line Transform which finds straight lines in filtered images by grouping edge points into line patterns.
- ○Calculate the width of the grain along with the count & angle of the slip bands

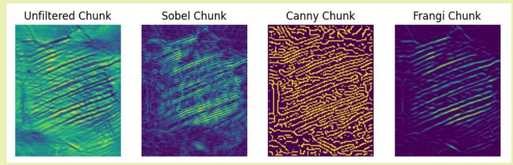
★ Run Algorithm on Each Grain

Analysis

Through testing of various filters, the following workflow was determined the most effective at highlighting slip bands and preparing them for measurement:

1. Applying the Frangi Filter
   - ➢Enhances slip bands but outputs pixel values <1, which are not recognized by the Hough Line Transform.
2. Scale and Expose Pixel Values
   - ➢Increase pixel intensity to ensure compatibility with Hough Line detection
3. Threshold and Clean the Image
   - ➢Isolate slip bands and remove background noise
4. Apply the Canny Filter
   - ➢Sharpens edges
5. Use the Hough Line Transform
   - ➢Detects slip bands for measurement of angle and spacing

Results

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Average Angle of Slip Bands: -21.060976448117053 degrees
Average Distance Between Slip Bands: 3.1721986113149176 pixels
Number of Slip Bands: 28 bands
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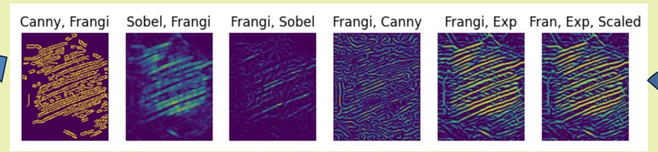
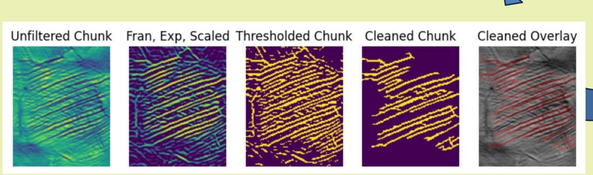
Mix filters and the order of application



Get the optimal workflow



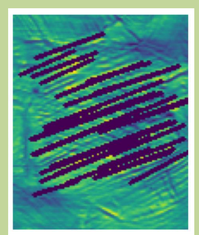
Apply calculations

Conclusion

- ❖Successfully calculated the average angle and slip band spacing for a single grain using a custom filtering pipeline
- ❖The Frangi → Scaling/Exposing → Thresholding → Cleaning-up the Image → Canny → Hough Line Transform sequence worked the best
- ❖Still on Step 2 of the machine learning process
- ❖The developed algorithm facilitates the prediction of stainless steel formability within a machine learning model. This advancement enables medical device manufacturers to minimize material waste by evaluating the quality of the material through detailed surface analysis.

Future Steps

- ❖While most slip bands were detected, some were missed. Focus on fine-tuning filter parameters to improve detection accuracy



- ❖Expand algorithm to detect grain boundaries to isolate individual grains based on angle. First iterations are seen in Figure x.
- ❖Implement the algorithm in the machine learning model

Acknowledgements

- ❖ Transdisciplinary Nanostructured Material Research Team: *Colorado School of Mines, Golden , CO*
- ❖ Confocal images were obtained using the LEXT OLS5100 Olympus Confocal Laser Microscope