Crystallographic Texture Development and Characterization in Hot Rolled AA3104 Sheets

PURDUE UNIVERSITY
Materials Engineering

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Logan Aluminum is adding higher horsepower motors to their three stand tandem hot mill that will increase hot roll speed. The goal of the higher rolling speeds is to improve throughput while maintaining or improving sheet quality. The focus of this project is to understand and characterize the crystallographic texture in the hot rolled AA3104 sheets with increasing roll speeds by investigating residual stress, microstructure, and texture.

LOGAN ALUMINUM

This work is sponsored by Logan Aluminum, Russellville, KY.

Project Background

- The final microstructure of the aluminum sheets begins developing as it is rolled through Logan Aluminum's three stand tandem hot mill. Too low of a temperature or too high strain rates could cause a potential for incorrect textural development, resulting in anisotropic properties inconducive for can manufacturing.
- Logan Aluminum quantifies texture through earing tests. Earing data is taken from a punched disk at specific locations on the coil and drawn into a cup to simulate the can making process. As a result of aluminum's natural anisotropy, the resultant cup that is formed has a wavy edge around the rim. Taller waves of the cup, or ears, have more of a likelihood to flow during cup making, while troughs are areas less prone to flow. The less variation in the wave profile produced allows the customer to minimize trimming on their cans that are being made.

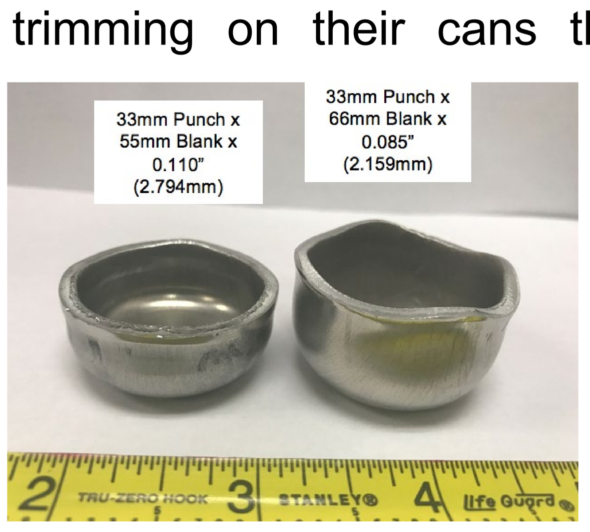

Figure 1: AA3104 sampled eared to quantitatively represent texture, image from Logan Aluminum.

Experimental Procedure

- Logan Aluminum ran test trials for the desired speeds at their desired speeds at 480 RPM, 520 RPM, and 550 RPM. Nine parameters of the coil were analyzed; however, there is a focus on MID-C because it represents the coil as a whole (Fig.2). To analyze the AA3104, three parameters were chosen to be observed: microstructure, residual stress, and texture.
  - **Microstructure:** Aluminum samples are mounted, grinded, and polished under standard metallurgical standard for optical analysis. Optical microscopes and ImageJ are used to identify second phase particles and grain characteristics.
  - **Residual Stress:** Using preset aluminum conditions on the μ-X360 Pulstec Residual Stress tester, different points on each sample were analyzed for residual stress and averaged.
  - **Texture:** Electron Backscattered Diffraction (EBSD) was used to characterize the texture. Matching the aluminum phase Kikuchi bands to those in the sample allowed the distribution of the plane orientations to be identified (Fig.3).

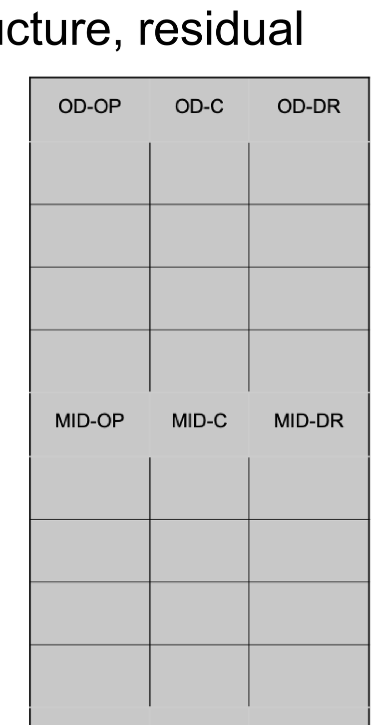

Figure 2: Schematic of aluminum sheet.

Figure 3: Indexed Kikuchi bands in EBSD pattern, adapted from: http://wed.mse.ncku.edu.tw/~lmmp.tw/lecturenotes/texture_2016_P06_kikuchi_v1.pdf.

Microstructural Analysis

Optical microscopy demonstrates the microstructures of AA3104 at the increasing roll speeds observed at the middle and center of the coil. The microstructures from 480 to 550 RPM appears to be consistent (Fig.3). One parameter investigated from the micrographs was particle size. This decreases in average size from 2.77 ± 3.38 μm at 480 RPM to 2.38 ± 1.61 μm at 550 RPM. Overall, the particle size appears to be within the same range.

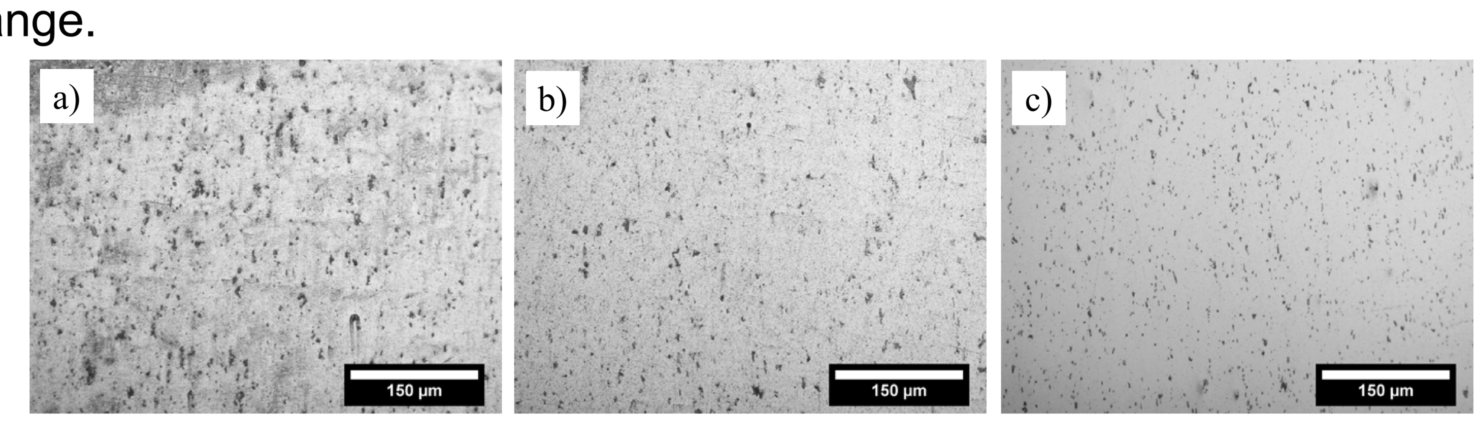

Figure 4: Optical micrographs of AA3104 etched with H_2SO_4 across increasing rolling speeds at MID-C (a) 480 RPM, (b) 520 RPM, and (c) 550 RPM.

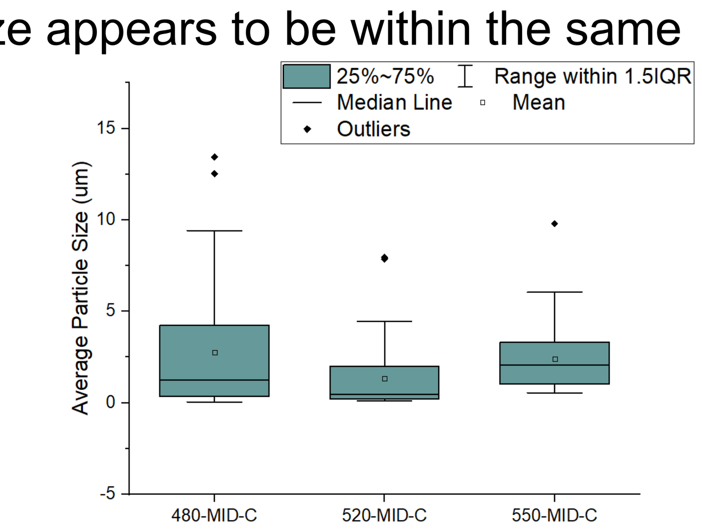

Figure 5: Average particle size of observed AA3104 micrographs in Fig.4.

Residual Stress

Residual stress analyses were conducted with the aluminum processed untouched and aluminum grinded halfway. The goal was to see if the residual stress is consistent throughout the whole sample. The residual stresses were in the same ranges throughout the increasing roll speeds (Fig.5).

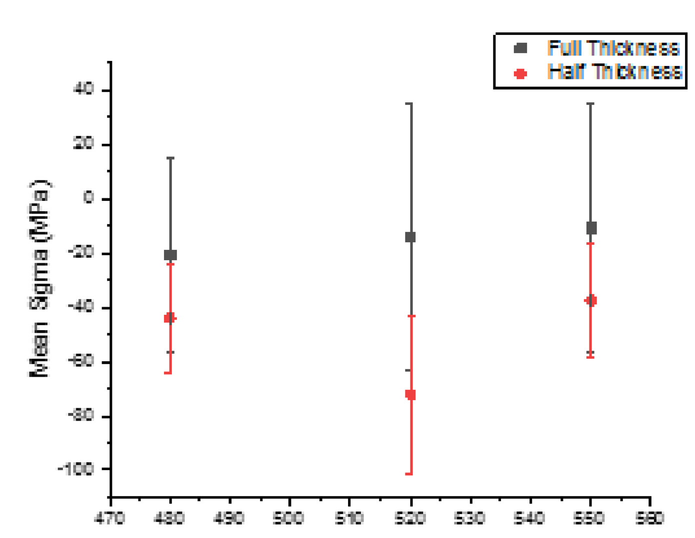

Figure 6: Mean residual stress analysis across the three roll speeds at the surface of AA3104 and at the midpoint of AA3104 at MID-C.

Debye Rings

Residual stress analysis reveals evidence of texture through Debye rings. The ring distributions across the increasing roll speeds are relatively consistent, excluding noise presence (Fig.6).

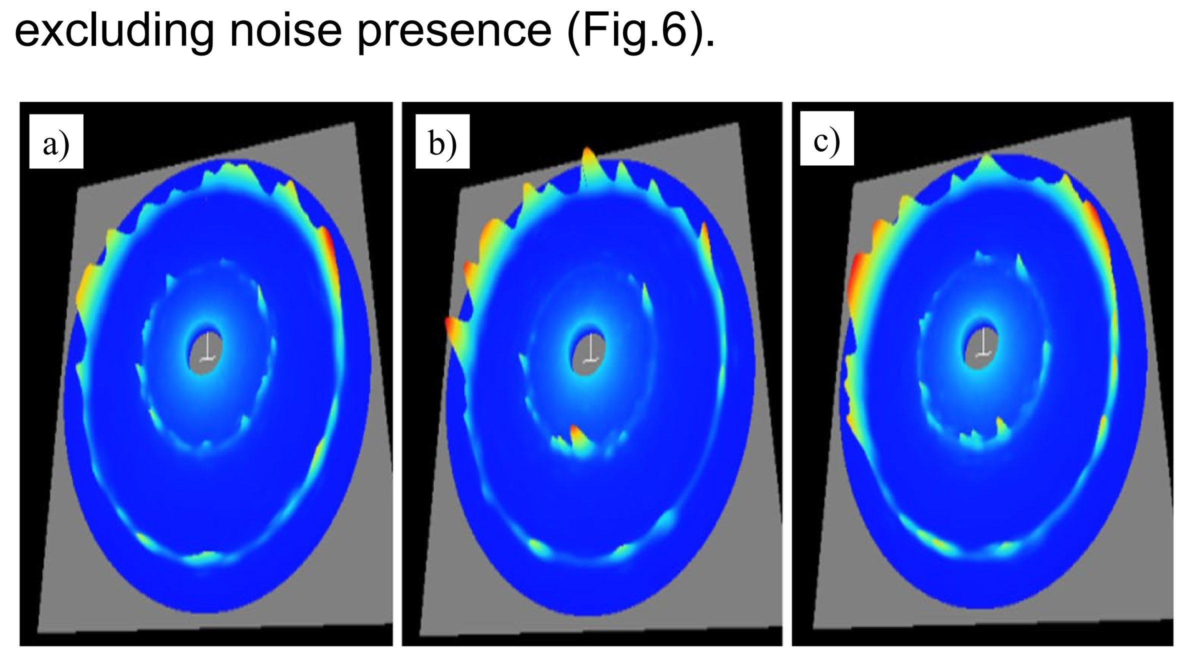

Figure 7: Debye rings developed from residual stress scan of AA3104 at MID-C at (a) 480 RPM, (b) 520 RPM, and (c) 550 RPM.

Textural Analysis

SEM/EBSD scans analyze the crystallographic texture of the aluminum. The inverse pole figure addresses the plane orientations of the scan. The texture is optimal for both the 480 and 550 RPM scans as both scans have a wide array of color present in the inverse pole figure (Fig.7).

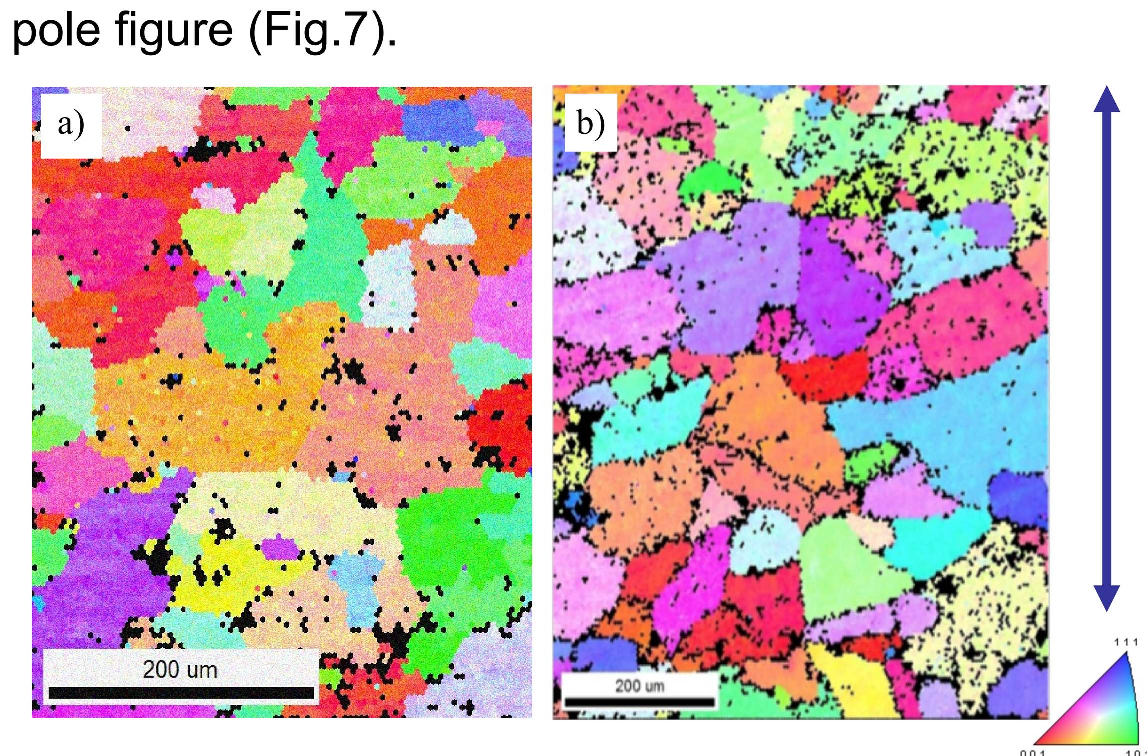

Figure 8: SEM/EBSD scan (using OIM Analysis and TEAM programs) of AA3104 at MID-C (a) 480 RPM and (b) 550 RPM with inverse pole figure. Arrow signifies rolling direction.

Grain Size Distribution

EBSD can report grain size distribution to further analyze the material. The 550 RPM grain size has its peak area fraction at 100μm at 0.12, while 480 RPM has its peak area fraction at 110μm at 0.12 (Fig.8). The 480 RPM scan results could be altered by noise.

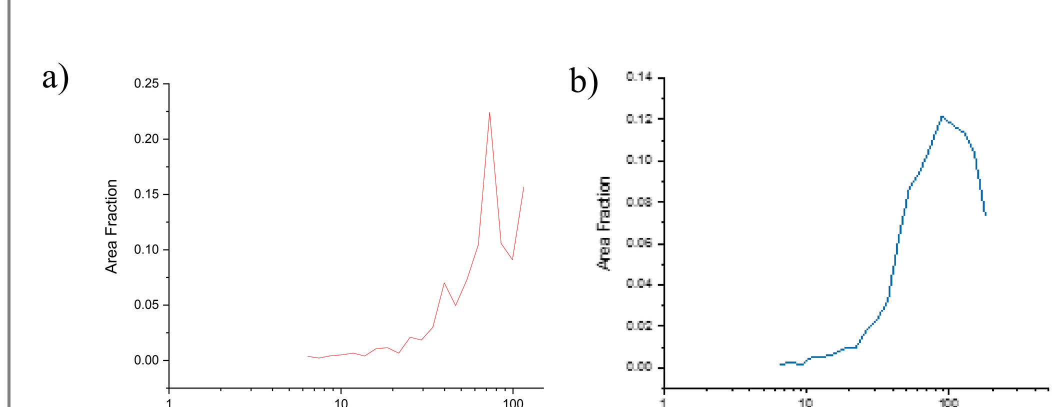

Figure 9: Grain size distribution from SEM/EBSD scan of AA3104 at (a) 480 RPM and (b) 550 RPM.

Recommendations

Since there were no significant differences across the tested parameters, the 550 RPM hot rolling speed can continue to be used; however, further grain size and texture testing should be conducted. Although the tested parameters were relatively consistent across the three speeds, the aluminum may react differently under manufacturing stressors.