Slivers are common elongated surface defects in rolled aluminum sheet that lead to a significant decrease in yield. The hypothesized causes of slivers are an insufficient removal (scalping) of ingot surface macrosegregation and mechanical damage in hot rolling. Examination of the root causes of sliver defects was performed through a scaled replication of the Logan Aluminum rolling process on aluminum alloys 5182 and 3104 and characterization through metallography and compositional analysis. Lack of compositional variations on the scale of the depletion layer in production slivers led to the conclusion mechanical damage is the more likely culprit.

**Project Background**

Slivers are elongated surface defects found in rolled aluminum sheet, seen in Figs. 4A and 5A, and if not removed, result in failure when drawn into a can (Fig. 1). During Direct Chill (DC) casting, ingot-scale segregation, not correctable by heat treatment, occurs due to the solute rejection into the molten aluminum and subsequent fluid motion. Two layers are formed: a strongly solute-rich layer at the surface, and a moderately depleted layer further from the surface. These layers are removed on each rolling face of the ingot by scalping up to 2.5 cm (1 in.), while the side faces are unaltered. Insufficient scalping may leave remnants of a depleted layer which may elongate into sliver defects during rolling.

**Experimental Procedure**

To isolate potential causes of sliver formation, samples of a DC cast 5182 alloy ingot were cut into thin bars and hot rolled with 15% reductions. Samples were rolled with different scalp depths in order to evaluate surface layer effects on finished sheets:

- **Unscalped**: The as-cast surface remains on the casting face of the sample.
- **Logan’s scalp**: The rolling face was at the scalping depth typically used by Logan Aluminum.
- **Over-scalped**: The rolling face was at least 10 cm (4 in.) below the as-cast surface.
- **Transverse**: The rolling face contains the exudation layer at one end and bulk material along the rest.

Over-scalped samples were then rolled with the following modifications:

- **Scoring**: The rolling face was deeply scratched.
- **Debris**: Fine particles or coarse fragments were placed onto the rolling face during rolling.

A transverse sample was tested to illustrate the effect hot rolling had at different depths. Findings led to further rolling experiments with a larger sample having an unscalped and scalped side (edge).

**Production Sliver Characterization**

Production slivers in samples provided by Logan Aluminum were classified as either Smeared (Fig. 4A) or Ruptured Surface (Fig. 5A). Slivers. No distinct compositional or metallographic differences between the smears and ruptures are distinct boundaries; the ruptured surface sliver from the sheet. Slivers responsible for failure during rolling (Fig. 1) share topographical characteristics such as striations with ruptured surface slivers.

**Macrosegregation Analysis**

Composition profiles were measured from the surface into the bulk ingot to characterize the exudation and depleted layer depths and to compare these depths to Logan’s scalp depth. The solute enrichment was measured 1.1 ± 0.3 mm for 5182, and contained up to 2.5 times the nominal Mg content of the alloy’s (4.5wt%). Due to the lower Mg content of 3104 (1wt%), no significant compositional variation near the surface was found. The 5182 exudation layer was found to have a higher content (Fig. 8), due to higher solute content, leading to a decrease in ductility. This results in edge cracks and a potential source of debris on the unscalped sides of the ingot.

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**Rolling Experiments**

The control, scored, and fine debris samples displayed no slivering. Coarse debris caused a sliver attached at one end. A light-colored scar, Fig. 9, formed if coarse debris fell off during rolling. The exudation layer at the head of the transverse sample began to crack and separate (Fig. 10).

**Process Recommendations**

Since compositional differences appear to not be the source of slivers, scalping of rolling surfaces should be limited to removing the exudation layer and obtaining a level rolling surface. To reduce mechanical damage and mitigate edge cracking, a potential source of debris, scalping sides before hot rolling is recommended, as it will remove the harder and less ductile exudation layer.