Meso-mechanical Modelling on Ridging or Roping of Aluminium Alloys

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Introduction

- Roping or ridging is
  - a series of ridges and valleys in RD
  - appear after some stretching of the metal sheet
  - a long-wave heterogeneous deformation

Types

- Roping types depend on the material
- Roping is accentuated by a tensile test
  - in RD (ferritic stainless steel)
  - in TD (aluminium alloys)
Observation of length scales

- An AA6xxx alloy
  - strong roping or ridging
- EBSD orientations
  - grains tend to be clustered in RD!

= observed wavelength of ridging
Simple Mechanical Analysis

- What if things were easy ...
  - only one layer of grains
  - completely elongated along RD
Let us do a tensile test in RD ...

Out-of-plane shearing of the longitudinal grains.
Simple Mechanical Analysis

- Takechi Model
- Corrugated pattern in ferritic stainless steel

Simple Mechanical Analysis

• Let us now do a tensile test in TD ...
Simple Mechanical Analysis

• Let us now do a tensile test in TD ...

![Diagram showing the orientation of grains in TD and RD directions. It shows soft and hard grain areas within a valley and ridge structure.](image-url)
Simple Mechanical Analysis

- Wittridge & Knutsen Model
- Ribbed pattern in aluminum alloys
  - Example for AA3002

Simple Mechanical Analysis

- Objections:
  - Usually: not a ribbed, but an *irregular* roping profile!

Roping or ridging wavelength > Thickness of the plate!
Grain size < Thickness of the plate
Simple Mechanical Analysis

- Grain size discussion

Top layer ← longitudinal grains

Midplane of the plate
Simple Mechanical Analysis

- Grain size discussion
  - Roping or ridging profile after a tensile test in TD
Simple Mechanical Analysis

• Problem:
  – Wavelength of the roping or ridging pattern ≈ Grain size!
  – Objection example
    • Roping wavelength: 1~3 mm
    • Grain size: 100 μm

= observed wavelength of roping
Simple Mechanical Analysis

• HYPOTHESES:
  
  – Invisible length scale
  
  – LARGE ELONGATED GRAINS at an earlier stage develop
  
  – Grain Clusters with contrasting textures
    • Different clusters have different plastic anisotropy
How to find the invisible length scale

• First attempt:
  – a quantitative parameter \( \text{texture} \)
    • \( r \)-value
    • \( r_\alpha = \frac{\varepsilon^p_{\text{width}}}{\varepsilon^p_{\text{thickness}}} \)
  
  – MOVING WINDOW method
    • \( r \)-values calculated
    • EBSD scan of sheet surface
    • textures in the moving windows
How to find the invisible length scale

- Moving windows
  - varying width in TD: " xWid "
  - displacement step size, xOffs
$r_{TD}$ vs. position of the moving window

- = observed wavelength of ridging

Distance of box position from the left edge of the EBSD scan (μm)
Results and discussions

• Selection of the window size matters
  – Window sizes smaller than 500\(\mu\)m \(\rightarrow\) noise
  – Window sizes larger than 1200\(\mu\)m \(\rightarrow\) flattened
  – Window sizes between 500\(\mu\)m and 1200\(\mu\)m \(\rightarrow\) optimal

• Peak or minimum \(r_{TD}\) does not necessarily correspond to one Cube or Goss texture component band
Results and discussions

distance of box position from the left edge of the EBSD scan (µm)
Results and discussions

• Choice of the texture parameter
  – Hypothesis could be, that the thickness changes of the grain clusters at the surface are correlated with
    \[ \varepsilon_{ND} = -\frac{\varepsilon_{TD}}{1 + r_{TD}} \]
  – This would be the strain in thickness of the grain clusters if it would behave as a standard tensile test sample
  – \( h \) = the original thickness in ND of the top half of the grain cluster at the surface
    • \( h = 0.5 \times \text{Wid} \)
    • \( \times \text{Wid} = \) width of the moving window in TD.
  – Assume \( \varepsilon_{TD} = 0.15 \)
Results and discussions

Change of the $h$ due to stretching:

$$\Delta h = \frac{xWid}{2} \varepsilon_{ND}$$

Distance of box position from the left edge of the EBSD scan ($\mu$m)
Simulation vs. experimental

Simulation is satisfactory

Wavelength

distance of box position from the left edge of the EBSD scan (µm)
Conclusion

• Roping or ridging can be interpreted as a result of the existence of “windows" with contrasting textures

• The oscillations of the average r-value of the moving window could be used to identify the window size

• It can be calculated using MTM-FHM software

• Peak or minimum $r_{TD}$ does not necessarily correspond to one Cube or Goss texture component band
Future work

• A more refined mechanical analysis is required to check whether $r_{TD}$ is the best texture parameter to characterise the texture contrast between the clusters

• The patterning of the texture parameter on the surface layer and the central layer should be investigated

• The patterning of the texture parameter on the cross-section should be studied
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