Understanding the role of glaze layer with multiple surface characterization techniques aligned by computer vision algorithms

Chuchu Zhang, Richard W. Neu

Motivation
- Materials selection for low friction, low wear in high temperature applications is difficult.
- "Glaze layer" may form spontaneously at the contact interfaces and largely reduces friction and wear.
- Study distribution of glaze layer is challenging:
  - "Shiny, smooth, highly oxidized, superficial layer"
  - No hardware can do-it-all at high resolution.

Computer vision algorithms
- Homography transformation
  - translate between two individual 2D images of same planar object
  \[
  \begin{bmatrix}
  x_1 \\
  y_1 \\
  1 
  \end{bmatrix}
  = H_t
  \begin{bmatrix}
  x_2 \\
  y_2 \\
  1 
  \end{bmatrix}
  \]
- HSV color space
  - Segment essential information: true color[H] and brightness[V]

Image alignment workflow
- Input
- Rough match
- Precise match
- Tentative \( H_t \)
- Error < \epsilon
  - Yes
  - No
- \( H_t = H_t \)
- Align OM to height map with \( H_t \)
- Edge trim
- Final output pair
- Pixel-to-pixel matched OM-Height map pair
  - Sub pixel error, resolution up to 0.73\( \mu \)m

Glaze layer identification workflow
- H-V criterion:
  \[
  \begin{cases}
  H_{\text{max}} \geq H_i \
  V_i \geq V_{\text{min}}
  \end{cases}
  \]
  - H-V criterion validation

Applications
- Height analysis:
  - Glaze layer is always higher than non-glaze layer
  - Glaze layer is more likely to be in contact, strong evidence to sintering theory
  - May reduce real contact area
- Coverage analysis:
  - 36% threshold
  - Glaze coverage increase with temperature
  - 3 stages of coverage increasing
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Significance
- Open-source workflow that enable multi-spectrum analysis without upgrading existing hardware, easily transferable to all other applications in academia and industry.
- Quantitative criterion that enables fast, accurate, and automatic glaze layer identification and reveal new knowledge.