2D/3D Topography Comparisons of 10 Consecutively Manufactured Chisels and Punches Through the Cross Correlation Function

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What is a Toolmark?

- Almost anything can create a toolmark as long as the tool is harder than the surface it’s being used on.

- The surface topography of the tool is imparted onto the surface. The resulting toolmark can be later used to identify the tool.
Traditional Comparison Microscopy

MO Dept. Of Public Safety

Leica Microsystems
Project Goal and Motivation

• Consecutively manufactured tools have a high likelihood of containing sub-class characteristics which can lead to false positives. It’s considered the most difficult comparison.

• Our goal is to provide objective mathematical comparisons of toolmarks created by 10 consecutively manufactured chisels (striated toolmarks) and punches (impression toolmarks).

• Can consecutively manufactured tools still be uniquely identified from the toolmarks that they created?
Sample Preparation

• The surface that the tools will be marking is a soft copper plate. The copper plate has been sanded with 1000 grit sand paper and polished using a metal polish.

• The surface preparation ensures that there are no directional striations present on the surface that can be confused with the created toolmarks.

Ra ~ 70 nm  Ra ~ 20 nm
10 Consecutively Manufactured Chisels

- 10 consecutively manufactured chisels from Western Forge (supplier to Craftsman Tools)
- 2 known marks per chisel to establish known match/non-match distributions
- Hide chisel identities, 2 more marks per chisel (Unknown set)
- Identify unknown toolmarks using $CCF_{max}$
Chisel – Striated Toolmark Creation
Chisel – Striated Toolmark Creation
Chisel – Striated Toolmark Creation
Chisel – Measurement and Analysis

- Z-resolution: 0.8 nm
- X-Point spacing: 0.25 µm
- Nominal Stylus Tip Radius: 2 µm
- Trace Length: 25 mm
Chisel – Measurement and Analysis

Date: 7/23/2012 9:48:33 PM
Bullet No. 0
Land No. 0

Signature A: C:\Documents and Settings\ABIDE4\Desktop\Toymarks Known
Signature B: C:\Documents and Settings\ABIDE4\Desktop\Toymarks Known D

Chisel 6-1
Chisel 6-2

Lateral Scaling: 1
CCF (ACF): 88.72 %
Shift distance: +0.37325 (mm)

RqA: 2.202 (um)  RqB: 2.261 (um)  Rq(B-A): 3625 (um)
Signature difference Ds: 271 %
Two Dimensional Cross Correlation Function

\[ \text{CCF}(A, B, \tau) = \frac{\text{CCV}(A, B, \tau)}{R_q(A)R_q(B)} \]

\[ R_q = \left[ \frac{1}{L} \int_{0}^{L} Z^2(x) dx \right]^{\frac{1}{2}} \approx \left[ \frac{1}{N} \sum_{i=1}^{N} Z_i^2 \right]^{\frac{1}{2}} \]

\[ \text{CCV}(A, B, \tau) = \lim_{L \to \infty} \left( \frac{1}{L} \int_{-L/2}^{L/2} Z_A(x)Z_B(x + \tau) dx \right) \]
Known Toolmark Distribution

\[ \mu = 16.51 \quad \sigma = 3.11 \]

\[ \mu = 87.10 \quad \sigma = 10.25 \]
Unknown Toolmark Distribution

- Blue distribution:
  - $\mu = 16.60$
  - $\sigma = 3.06$

- Red distribution:
  - $\mu = 88.71$
  - $\sigma = 8.60$
Unknown Toolmark Identification

![Heatmap showing comparison of reference and comparison toolmarks with CCF values]
10 Consecutively Manufactured Punches

• 10 consecutively manufactured punches from Western Forge (supplier to Craftsman Tools)
• 2 known marks per punch to establish known match/non-match distributions
• Hide punch identities, 2 more marks per punch (Unknown set)
• Identify unknown toolmarks using $CCF_{max}$
Punch – Impression Toolmark Creation
Punch – Impression Toolmark Creation
Punch – Impression Toolmark Creation

Known Marks

Unknown Marks
Punch – Measurement and Analysis

Parameters for data collection:

- 10 x objective
- Z direction step size: 0.2 μm
- Lateral Resolution: 3.125 μm
- Measured Dimension: 4.8 mm x 4.8 mm
Punch – Measurement and Analysis
Filter Parameters

Apply Gaussian filter with:
\[ \lambda_L = 400 \, \mu m \]
\[ \lambda_S = 40 \, \mu m \]
Three Dimensional Cross Correlation Function

\[
\text{ACCF}(A, B, \tau_x, \tau_y) = \frac{\text{ACCV}(A, B, \tau_x, \tau_y)}{\text{Sq}(A)\text{Sq}(B)}
\]

\[
\text{Sq} = \left[ \frac{1}{L_x L_y} \int_{-L_x/2}^{L_x/2} \int_{-L_y/2}^{L_y/2} Z^2(x, y) dx dy \right]^{1/2} \approx \left[ \frac{1}{MN} \sum_{k=1}^{M} \sum_{j=1}^{N} Z^2(j, k) \right]^{1/2}
\]

\[
\text{ACCV}(A, B, \tau_x, \tau_y) = \lim_{L_x L_y \to \infty} \left( \frac{1}{L_x L_y} \int_{-L_y/2}^{L_y/2} \int_{-L_x/2}^{L_x/2} Z_A(x, y) Z_B(x + \tau_x, y + \tau_y) dx dy \right)
\]
Punch – Measurement and Analysis

• Final results of this study will be published in 2013.
• Below is an example of a matching correlation.

**ACCF\text{max}**: 95.82%
Example of a non-matching correlation.

Reference Surface (A)

B2

X Data spacing: 6.2500 μm
Y Data spacing: 6.2500 μm

Low pass filter: λ(x) = 40.00 μm
High pass filter: λ(x) = 400.00 μm

ACCFmax: 13.38%

Compared Surface (B)

2.3

X Data spacing: 40.00 μm
Y Data spacing: 400.00 μm

ACCFmax: 13.38%

Date comparison: Nov 27, 2012

ACCFmax: 13.38%
Sq(A): 1.0617 μm
Sq(B): 1.0823 μm
Sq(B-A): 1.4111 μm
Sign. Diff. %: 176.65%
Conclusions

• 10 Consecutively Manufactured Chisels
  • The statistical distribution between the known matching and known non-matching are clearly separated with no overlap.
  • All 20 unknown striated toolmarks were correctly identified back to the chisel that created them.

• 10 Consecutively Manufactured Punches
  • To be determined
Thanks for your attention!

Questions?

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