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

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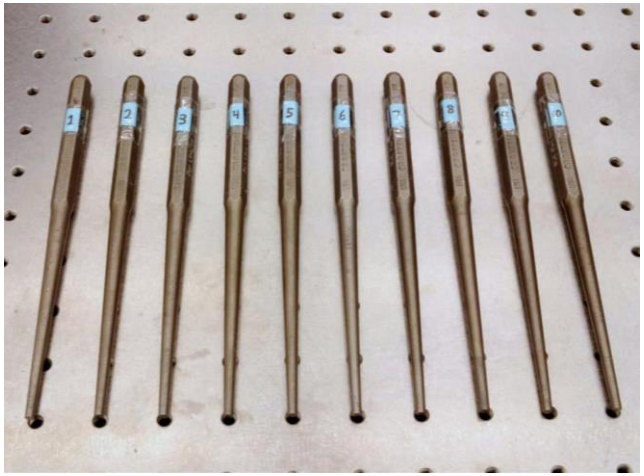

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Certain commercial equipment, instruments, or materials are identified in this report in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

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Project Goal and Motivation

- Consecutively manufactured tools have the highest likelihood of possessing similar surfaces that may lead to false toolmark identifications. It's considered one of the more difficult comparisons and exemplifies the "worst case scenario" in casework.

- 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 using an mathematically derived objective criterion?

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 “pre-marked” directional striations present on the surface that can be comingled with the created toolmarks.

10 Consecutively Manufactured Chisels

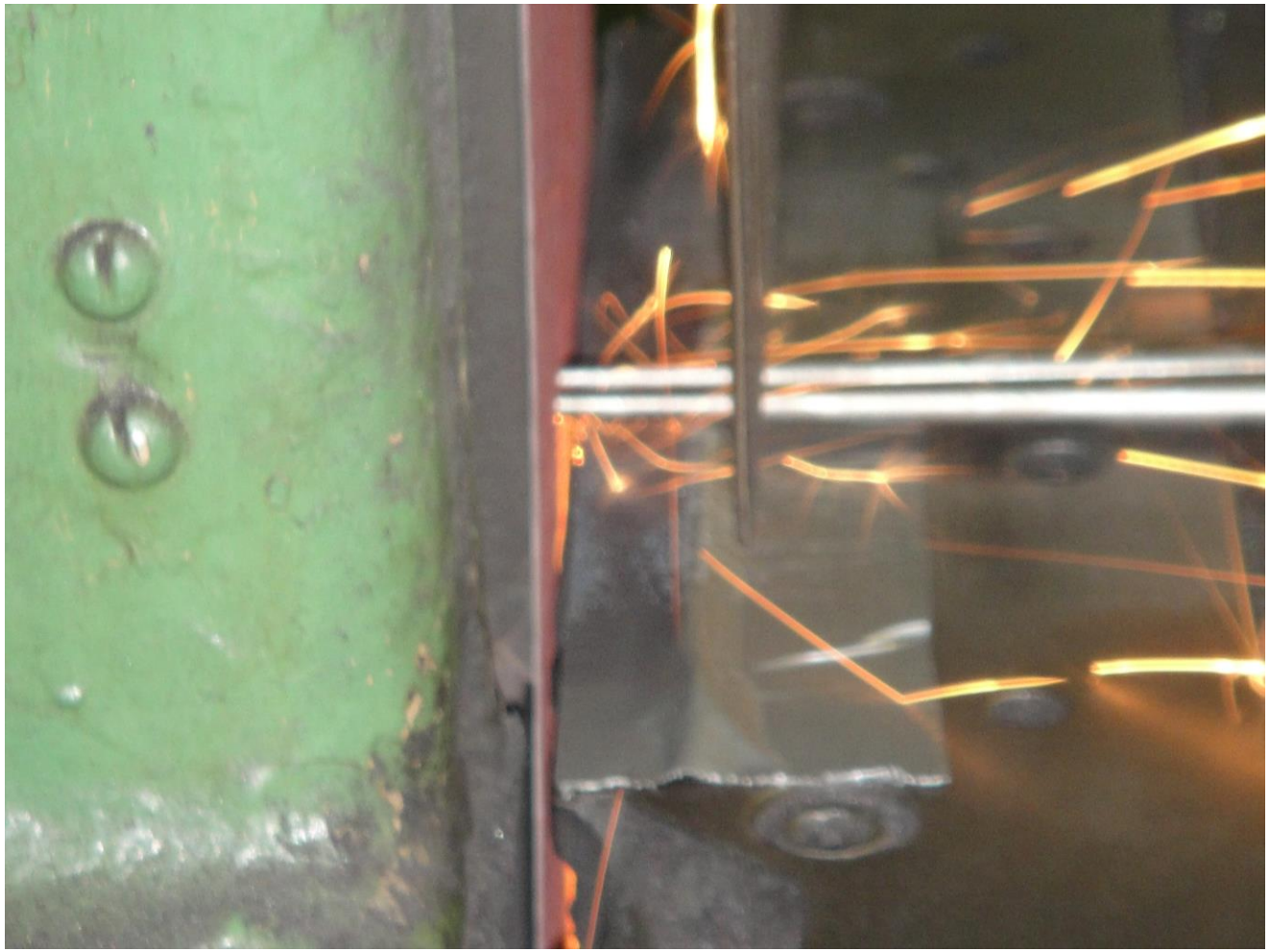
- 10 consecutively manufactured chisels from Western Forge (supplier to Craftsman Tools)
- 2 known marks per chisel to establish known match/non-match distributions
- Hide chisel identities, 2 more marks per chisel (Unknown set)
- Identify unknown toolmarks using CCF_{max}

Chisel Grinding

Both bearing surfaces of each chisel are ground by hand.

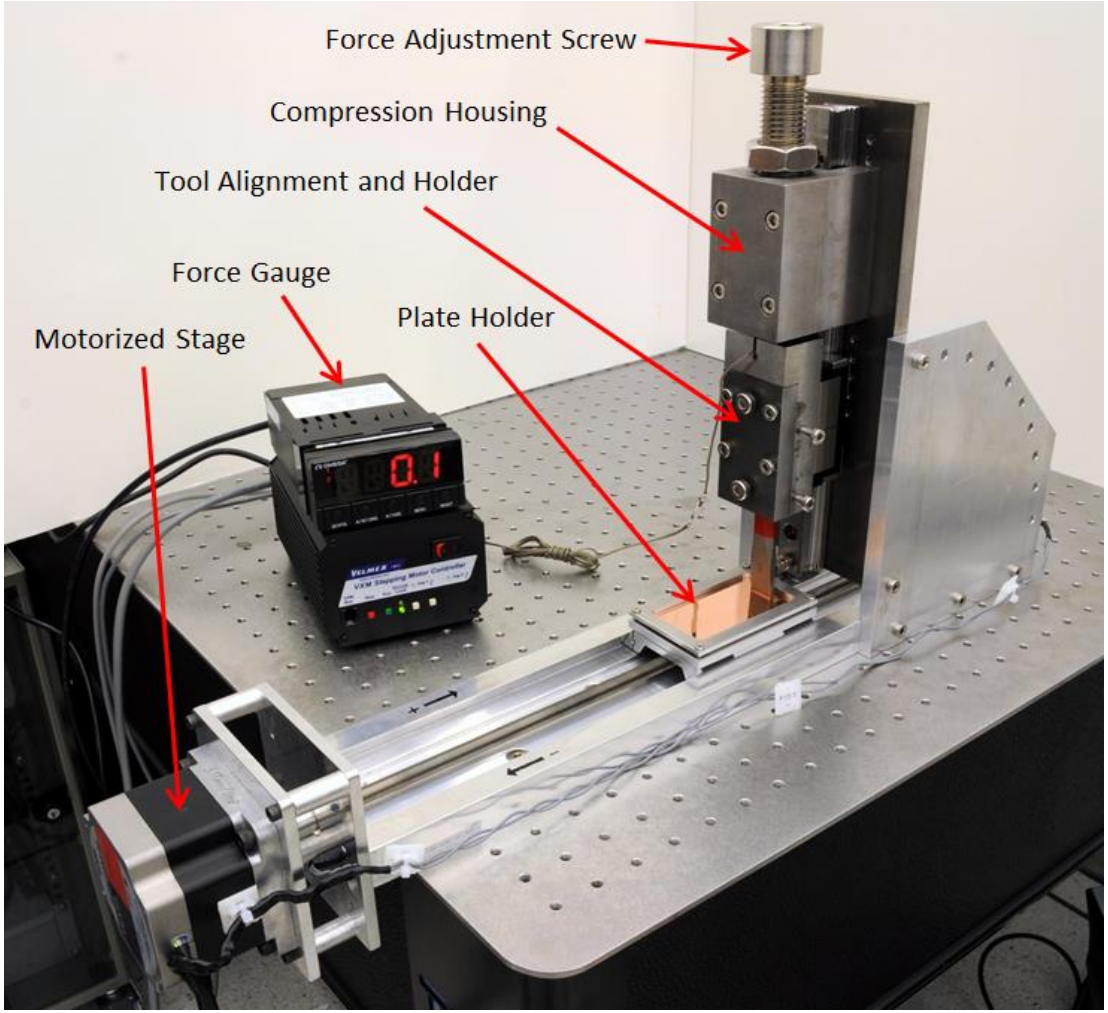
Chisel Grinding

Punch Face Grinding

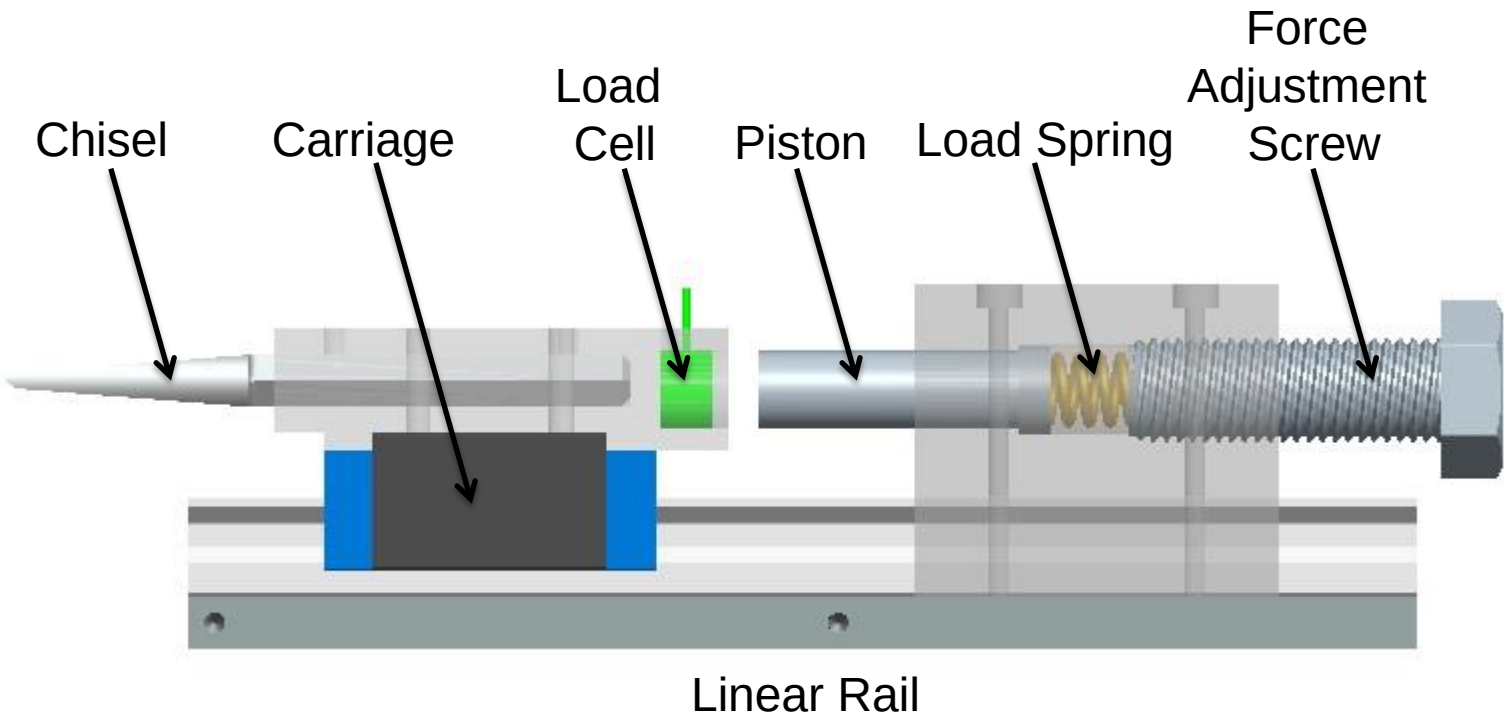


Each flat punch face was ground by hand.

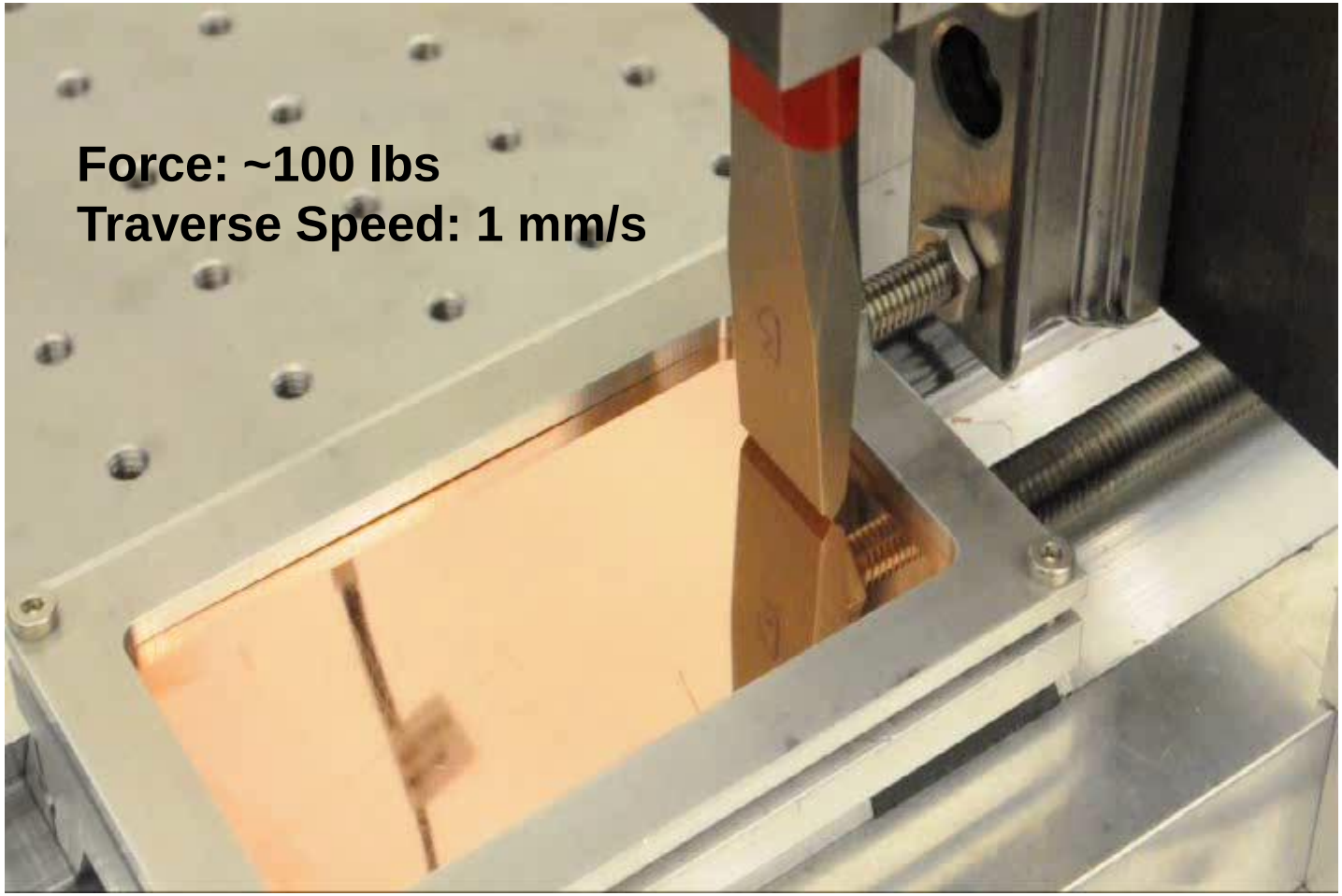
Chisel – Striated Toolmark Creation



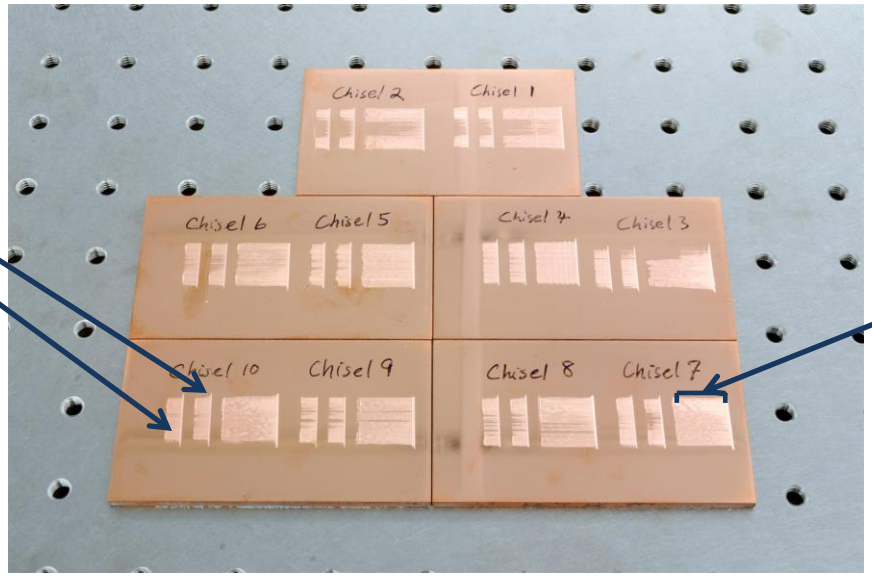
Compression Housing and Tool Holder

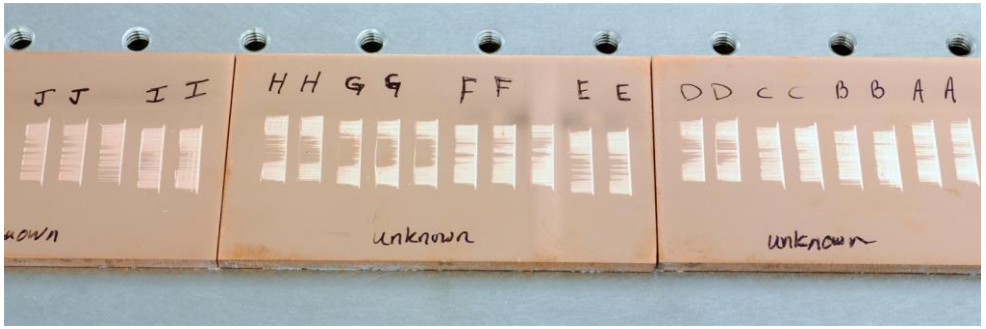


Chisel – Striated Toolmark Creation



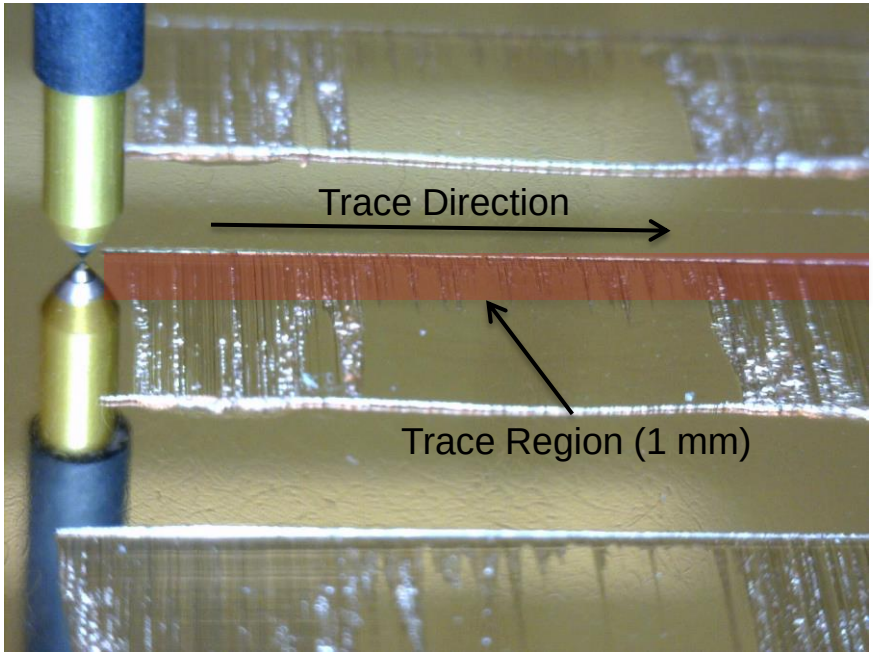
Chisel – Striated Toolmark Creation





Chisel – Measurement and Analysis

Taylor Hobson Ltd



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

Two Dimensional Cross Correlation Function

$$CCF(A,B,\tau) = \frac{CCV(A,B,\tau)}{Rq(A)Rq(B)}$$

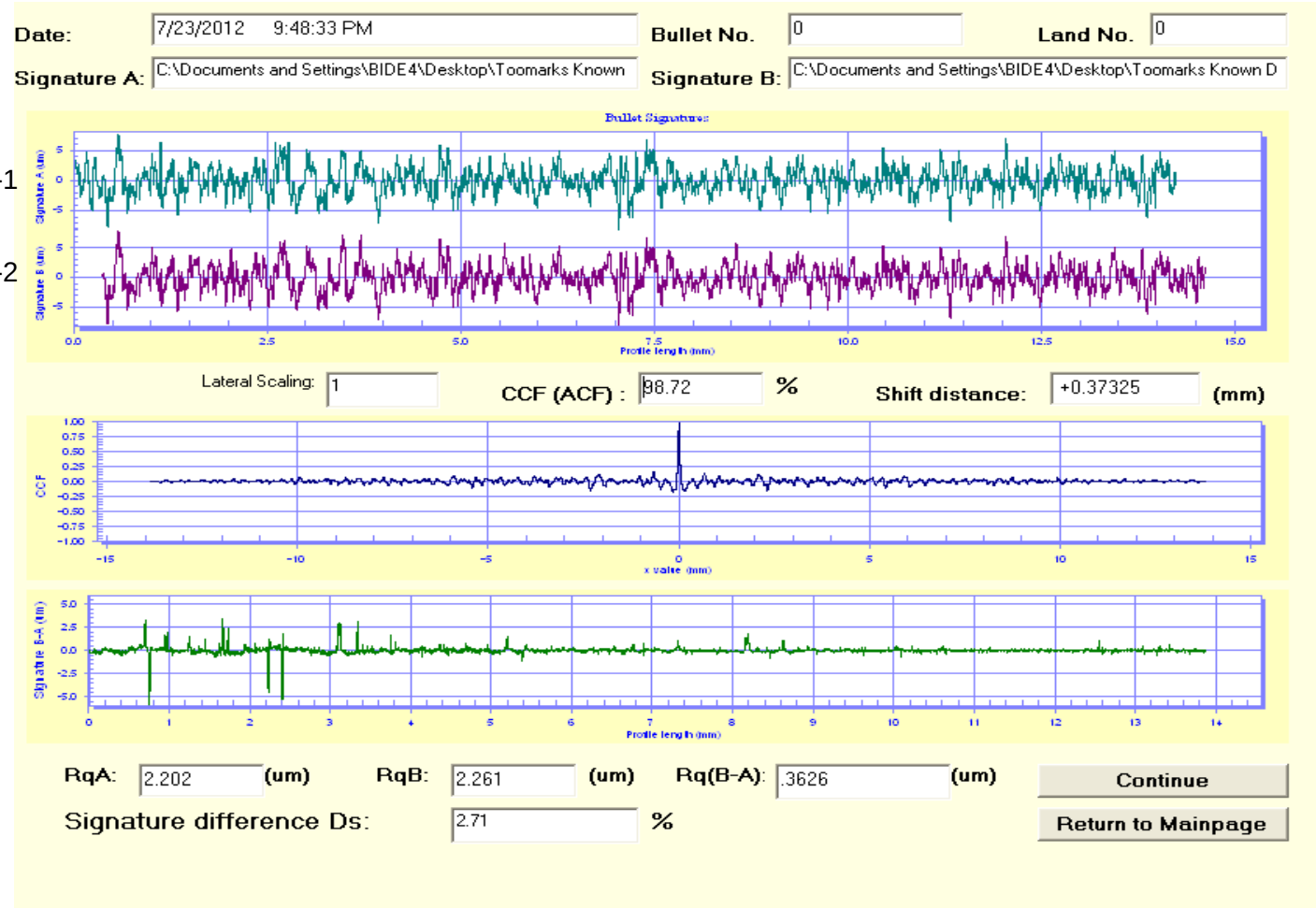
$$Rq = \left[\frac{1}{L}\int_0^L Z^2(x)dx\right]^{\frac{1}{2}} \approx \left[\frac{1}{N}\sum_{i=1}^{N} Z_i^2\right]^{\frac{1}{2}}$$

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

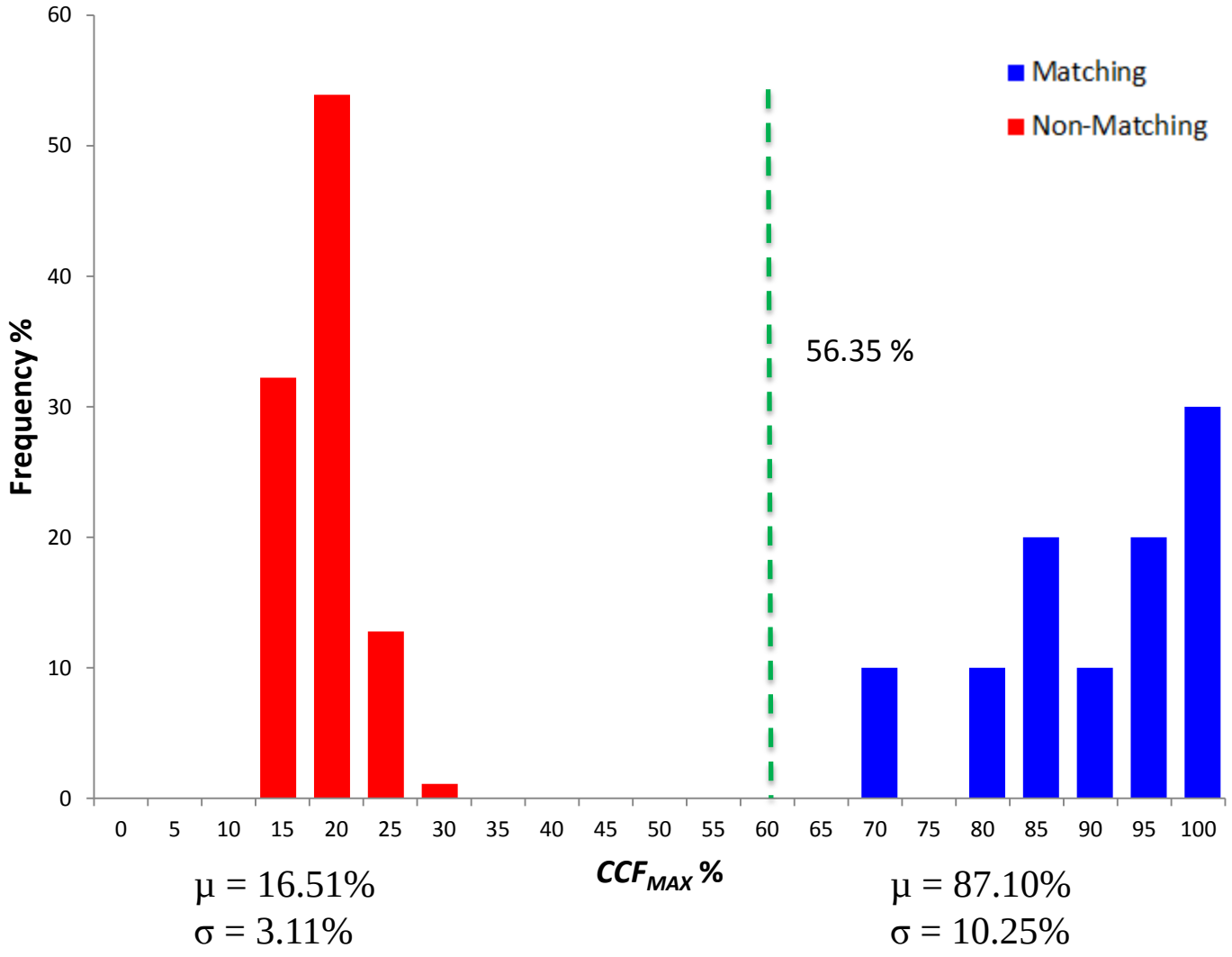
Chisel – Measurement and Analysis

Chisel 6-1

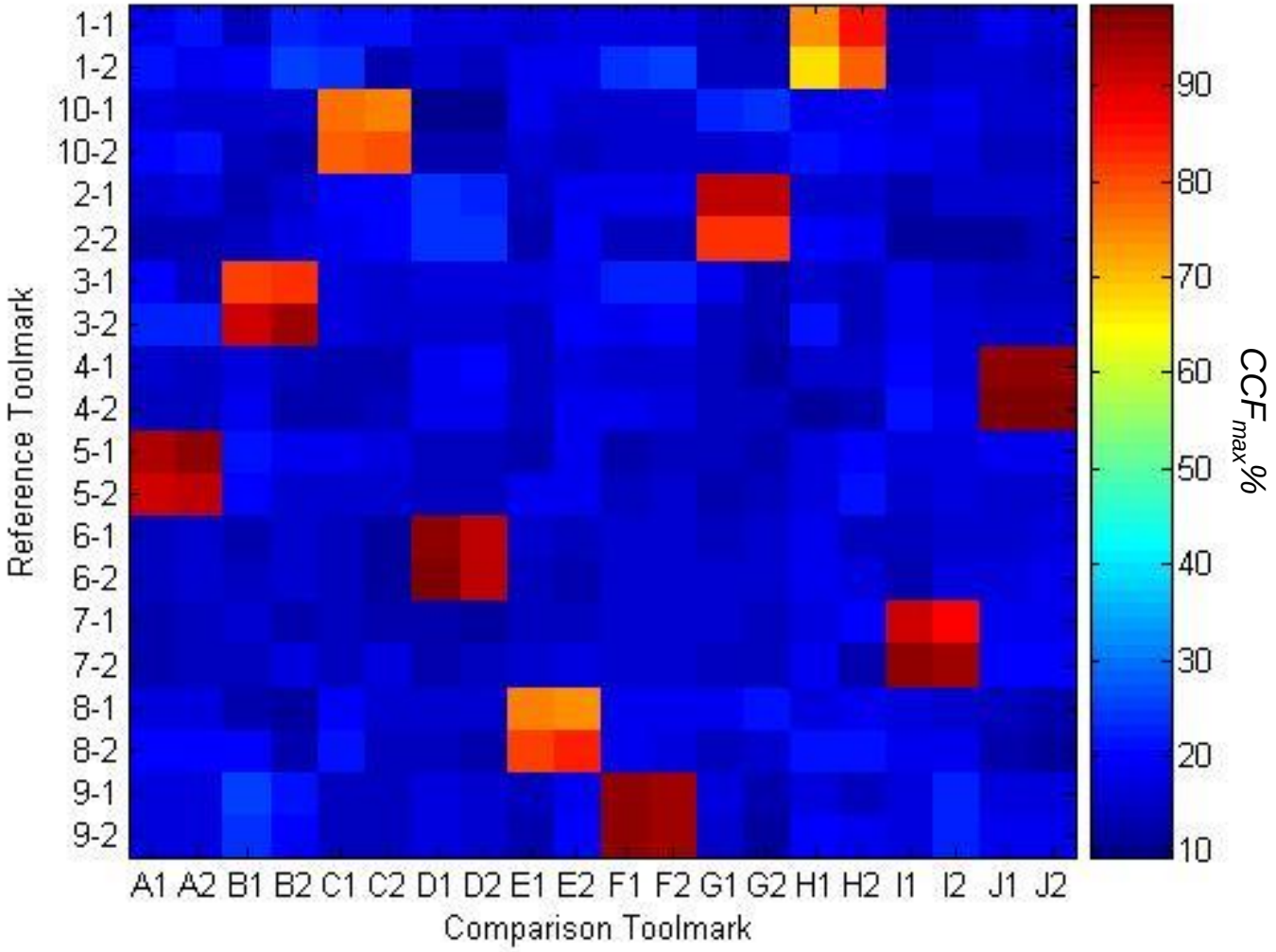
Chisel 6-2



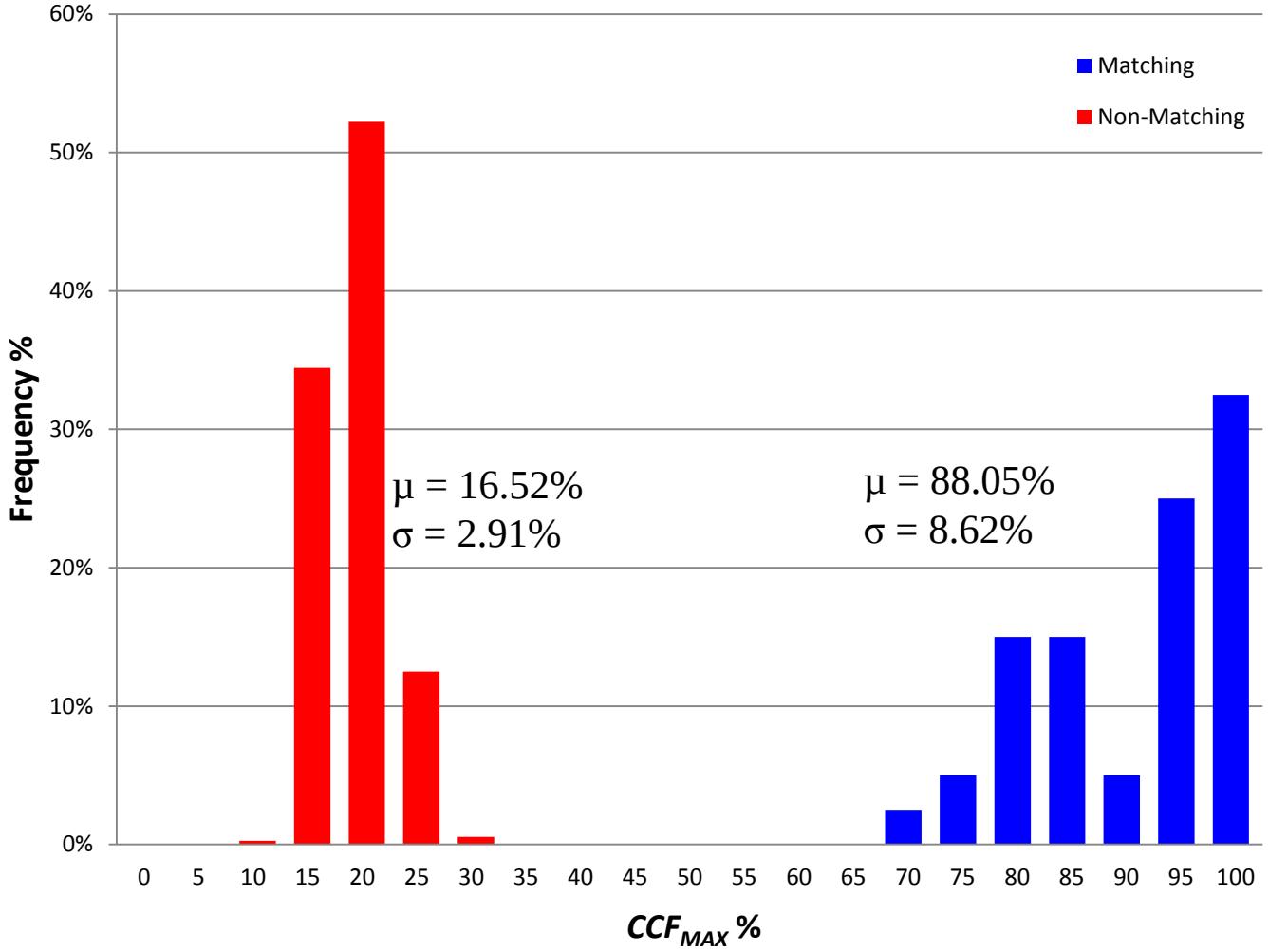
Known Chisel Distribution



Unknown Chisel Identifications

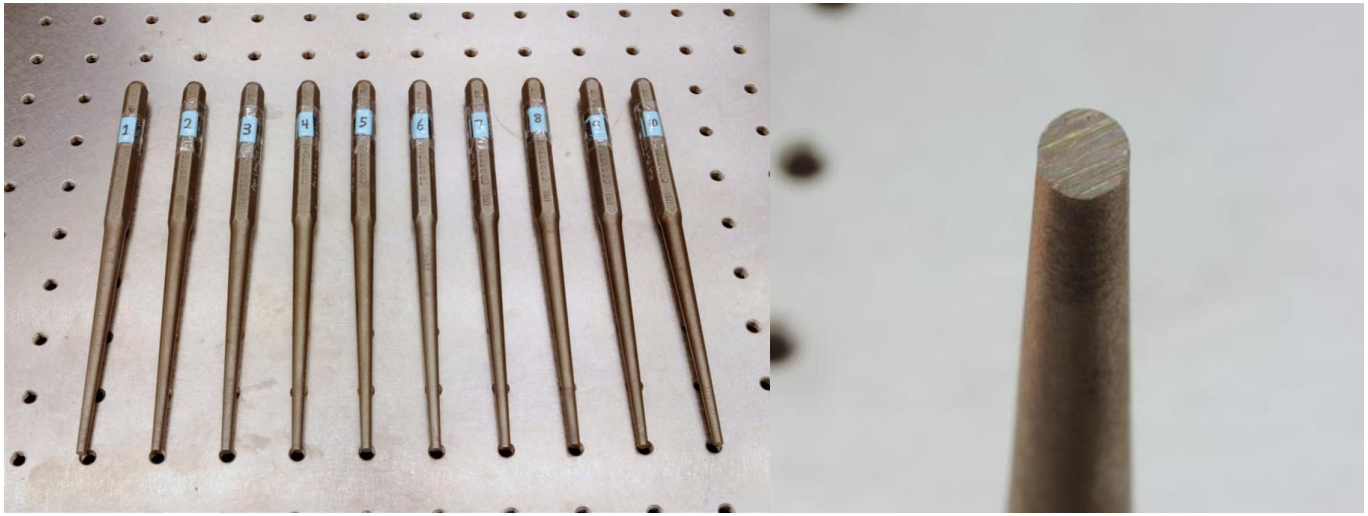


Unknowns Correlated Against Knowns Distribution

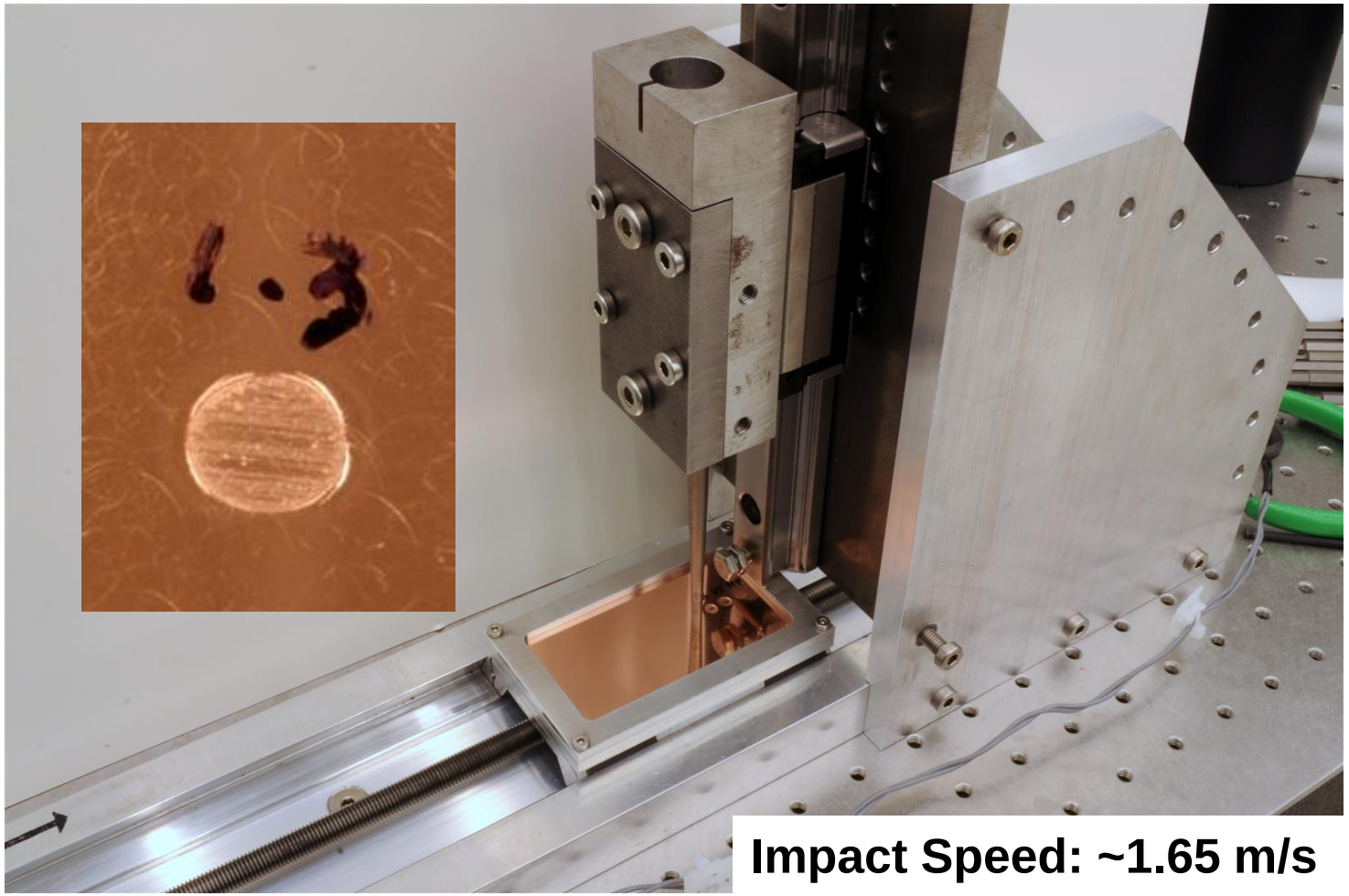


10 Consecutively Manufactured Punches

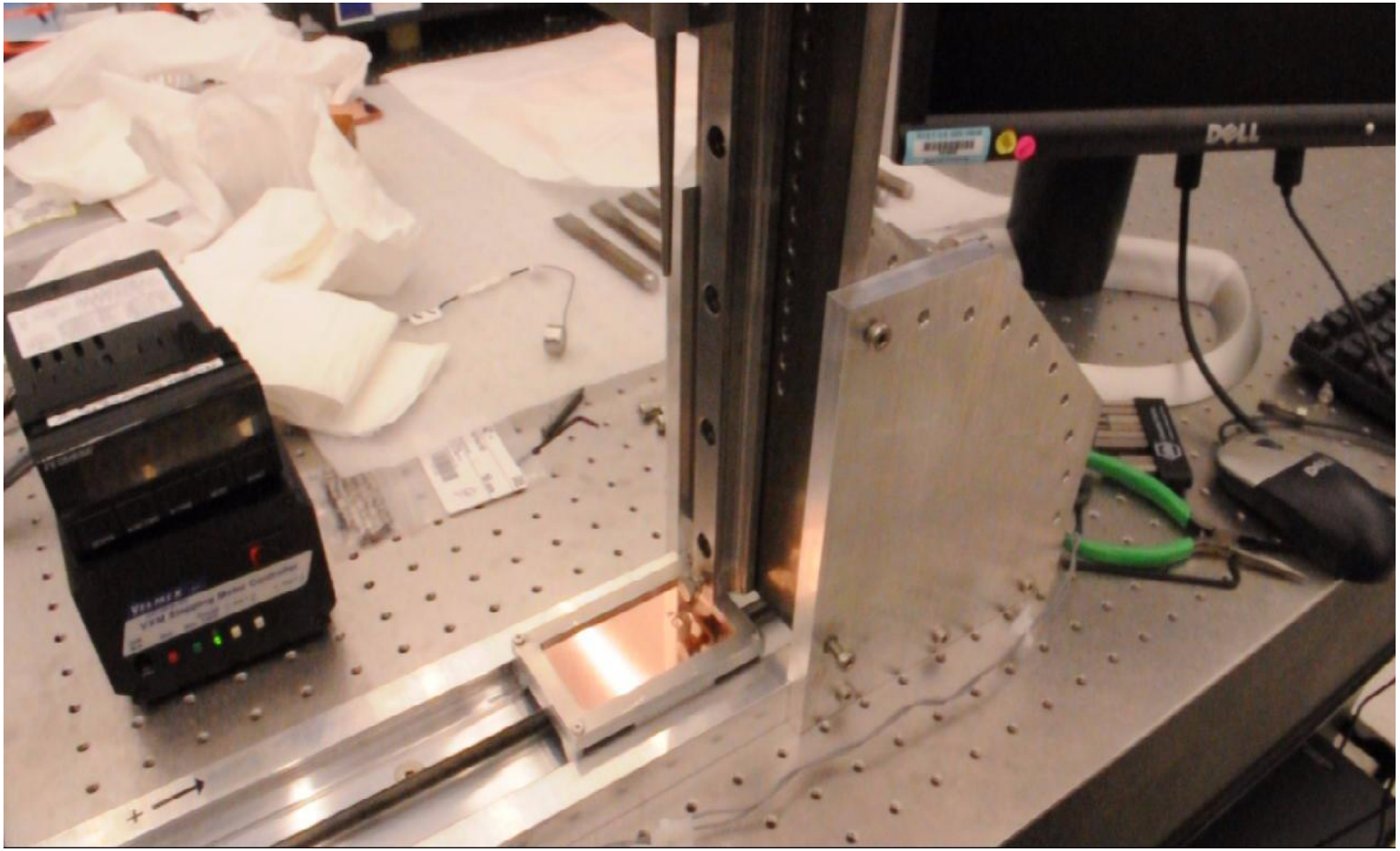
- 10 consecutively manufactured punches from Western Forge (supplier to Craftsman Tools)
- 2 known marks per punch to establish known match/non-match distributions
- Hide punch identities, 2 more marks per punch (Unknown set)
- Identify unknown toolmarks using CCF_{max}



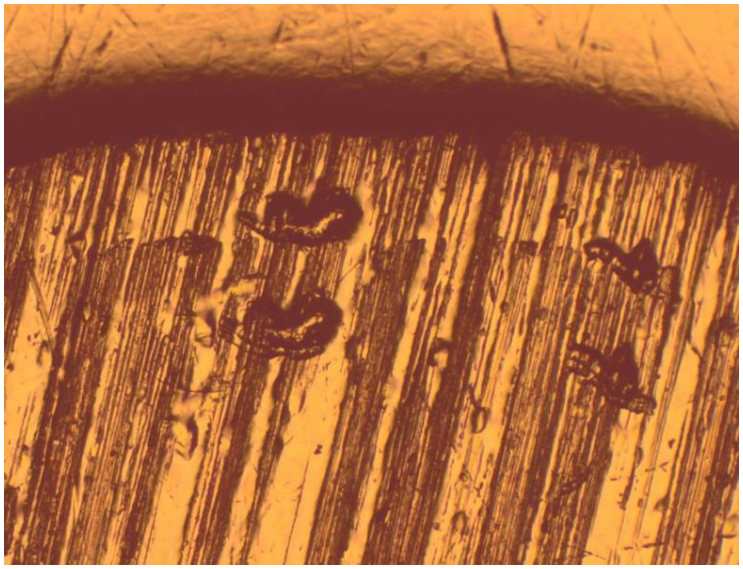
Punch – Impression Toolmark Creation

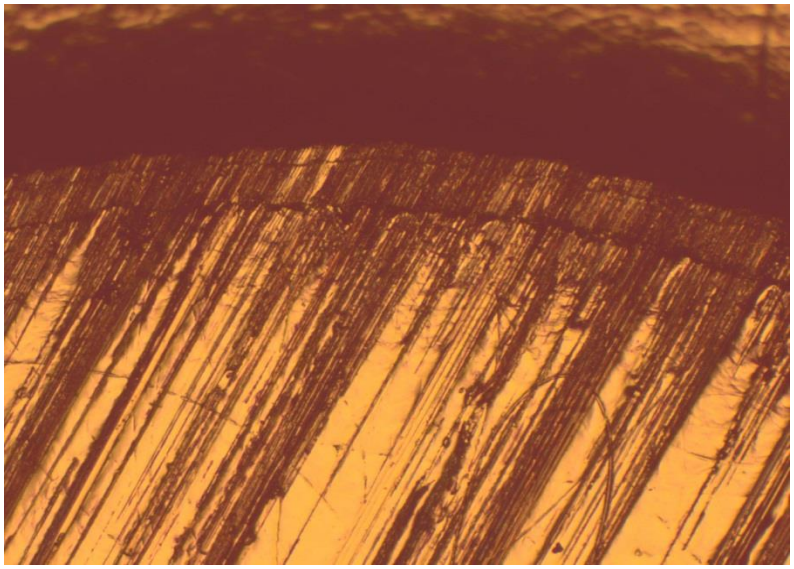


Punch – Impression Toolmark Creation

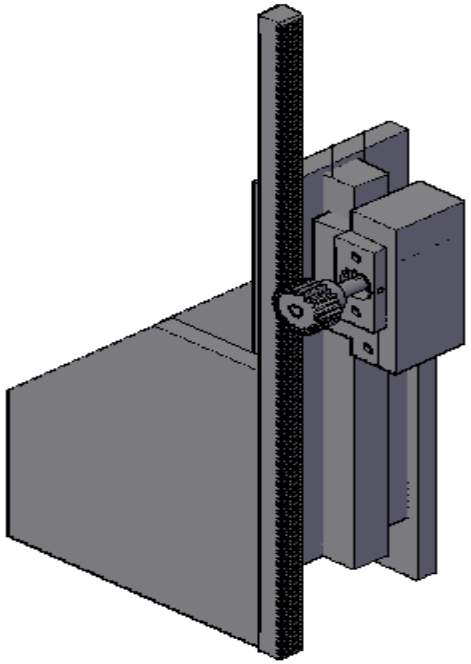


Sample images of punch marks with double impressions.

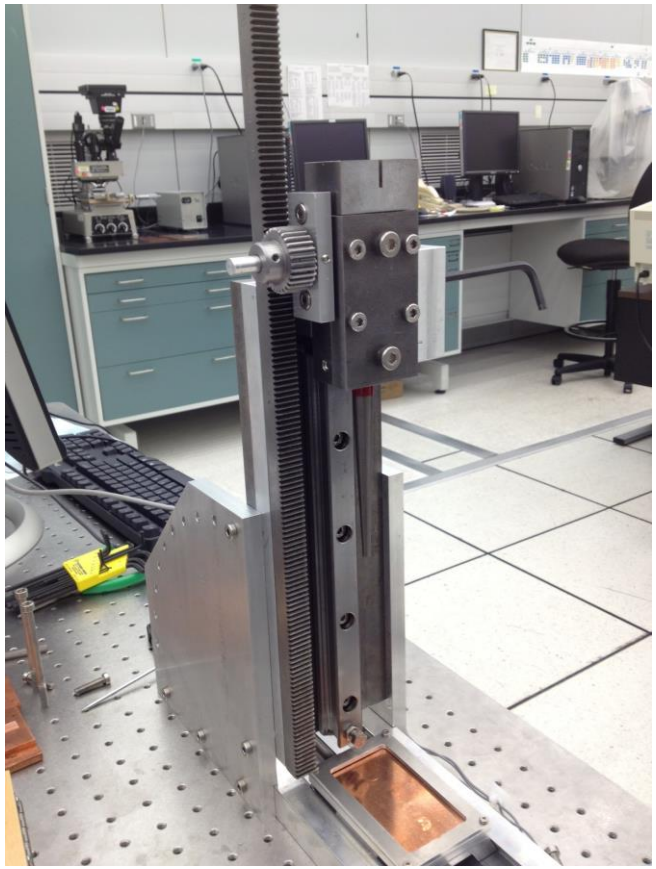




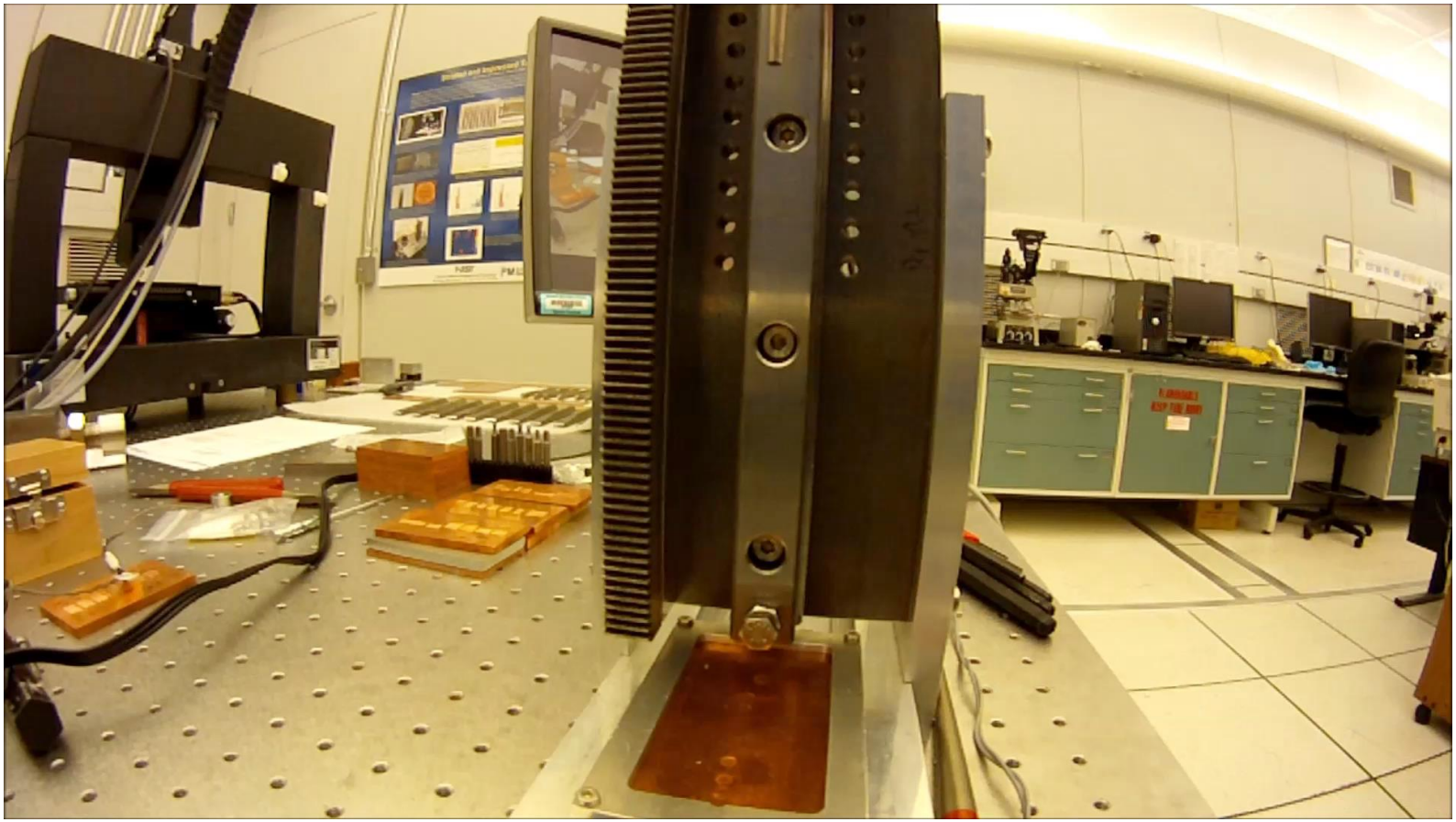
Modifications to the rig to avoid the rebound effect non-pristine copper surfaces



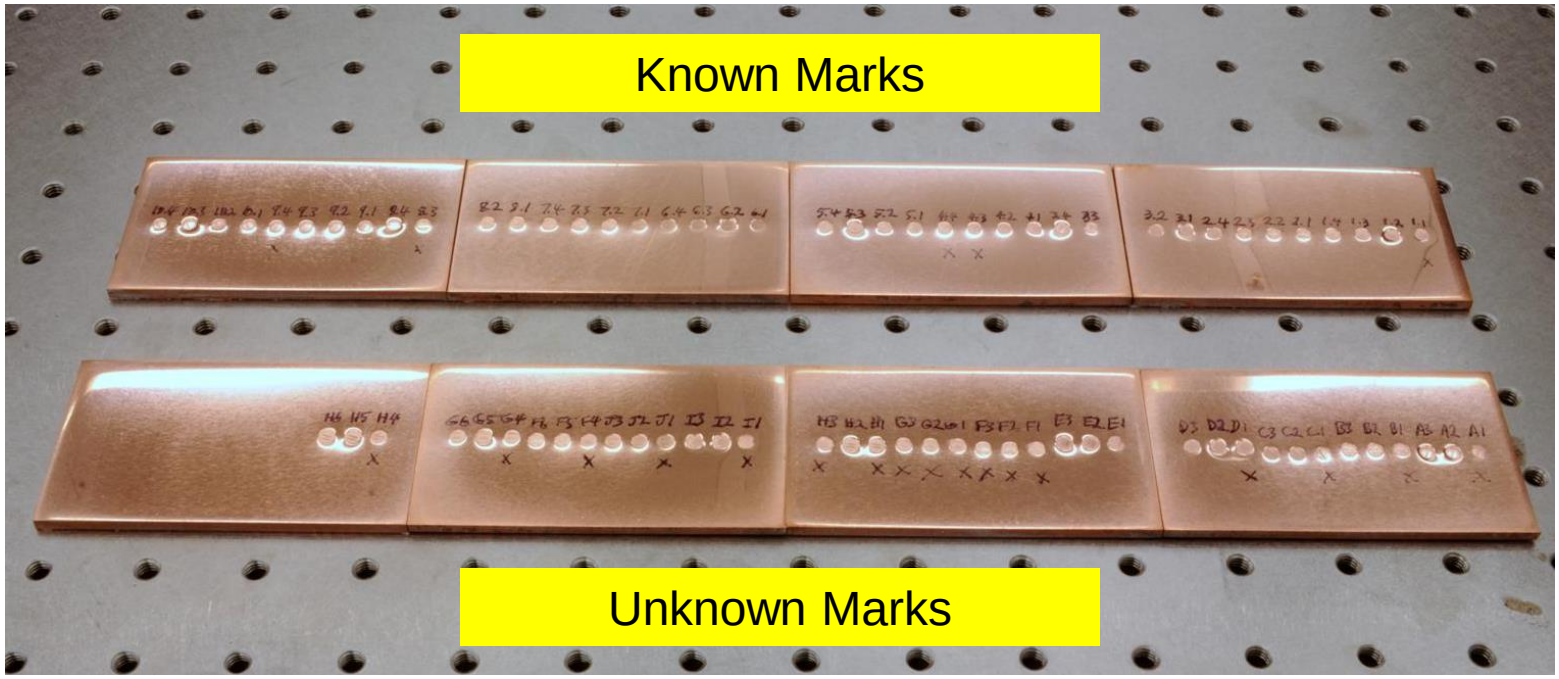
Conceptual Cad Drawing



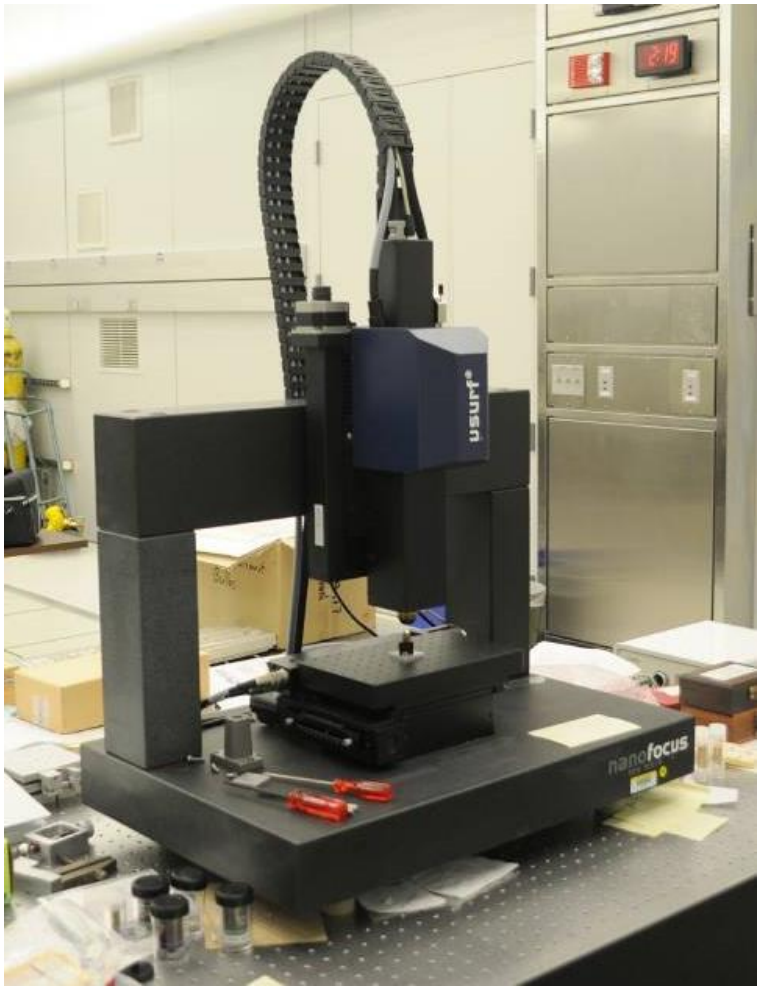
Anti-Rebound Device Implemented



Punch – Impression Toolmark Creation



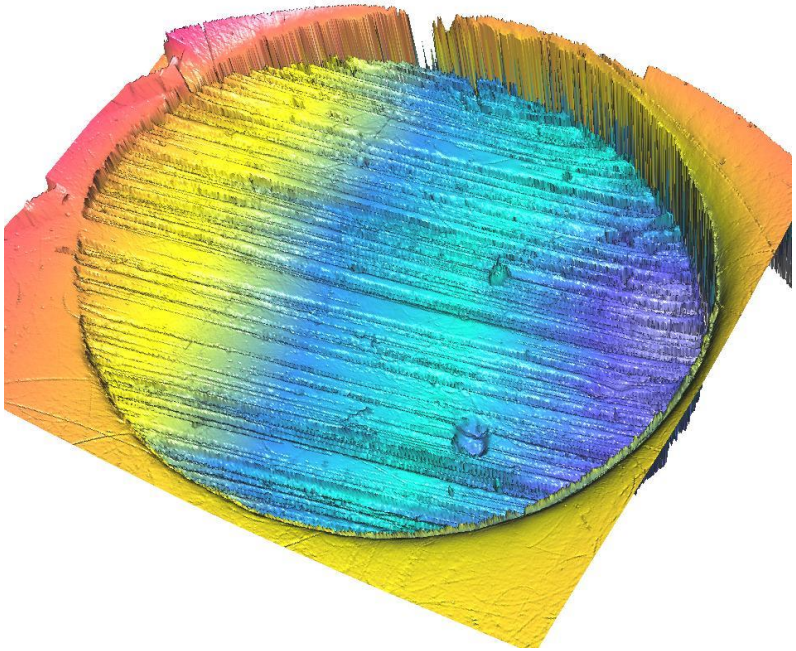
Punch – Measurement and Analysis

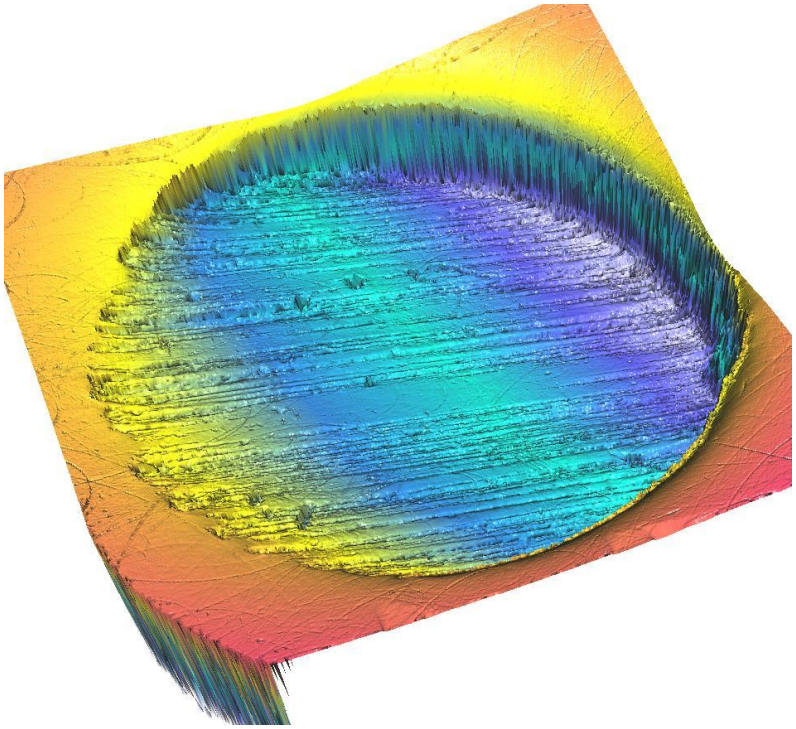


Parameters for data collection:

- 10 x objective
- Z direction step size: 0.2 µm
- Lateral Resolution: 3.125 µm
- Measured Dimension: 4.8 mm x 4.8 mm

Example 3D Punch Topography





Three Dimensional Cross Correlation Function

$$\mathrm{ACCF}(\mathrm{A},\mathrm{B},\tau_x,\tau_\mathrm{y}) = \frac{\mathrm{ACCV}(\mathrm{A},\mathrm{B},\tau_x,\tau_\mathrm{y})}{\mathrm{Sq}(\mathrm{A})\mathrm{Sq}(\mathrm{B})}$$

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

$$\mathrm{ACCV}(\mathrm{A},\mathrm{B},\tau_x,\tau_\mathrm{y}) = \lim_{L_x L_y\to\infty}\left(\frac{1}{L_x L_y}\int_{-L_y/2}^{L_y/2}\int_{-L_x/2}^{L_x/2} Z_\mathrm{A}(x,y)Z_\mathrm{B}(x+\tau_x,y+\tau_y)\,dxdy\right)$$

Punch – Measurement and Analysis

Reference Surface (A): 1-2

Compared Surface (B): 1-3

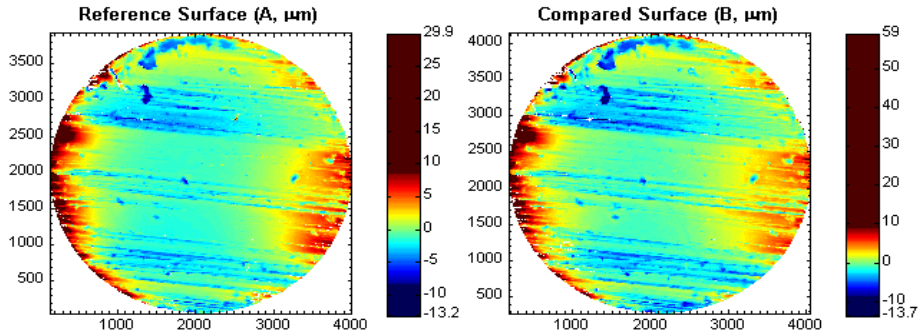
X Data spacing: 6.2500 µm

Y Data spacing: 6.2500 µm

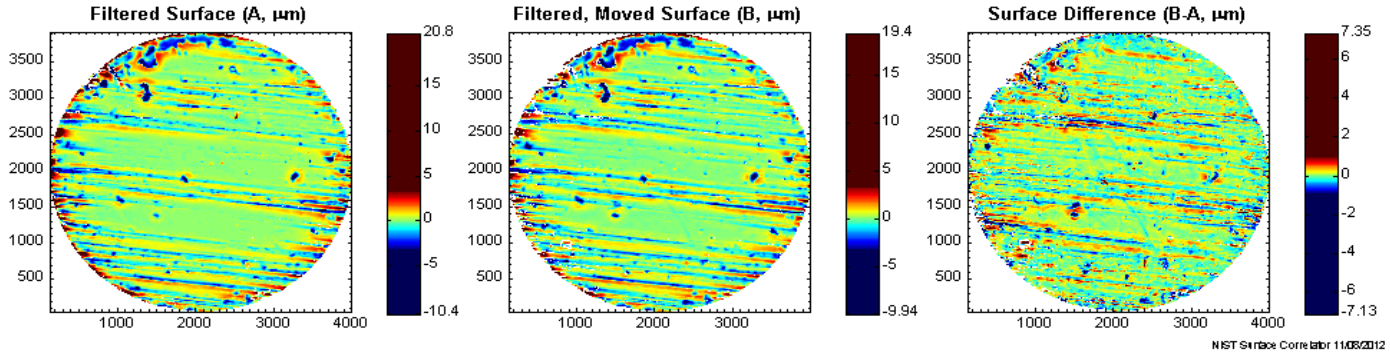
Low pass filter: λ(x) = 40.00 µm λ(y) = 40.00 µm

High pass filter: λ(x) = 400.00 µm λ(y) = 400.00 µm

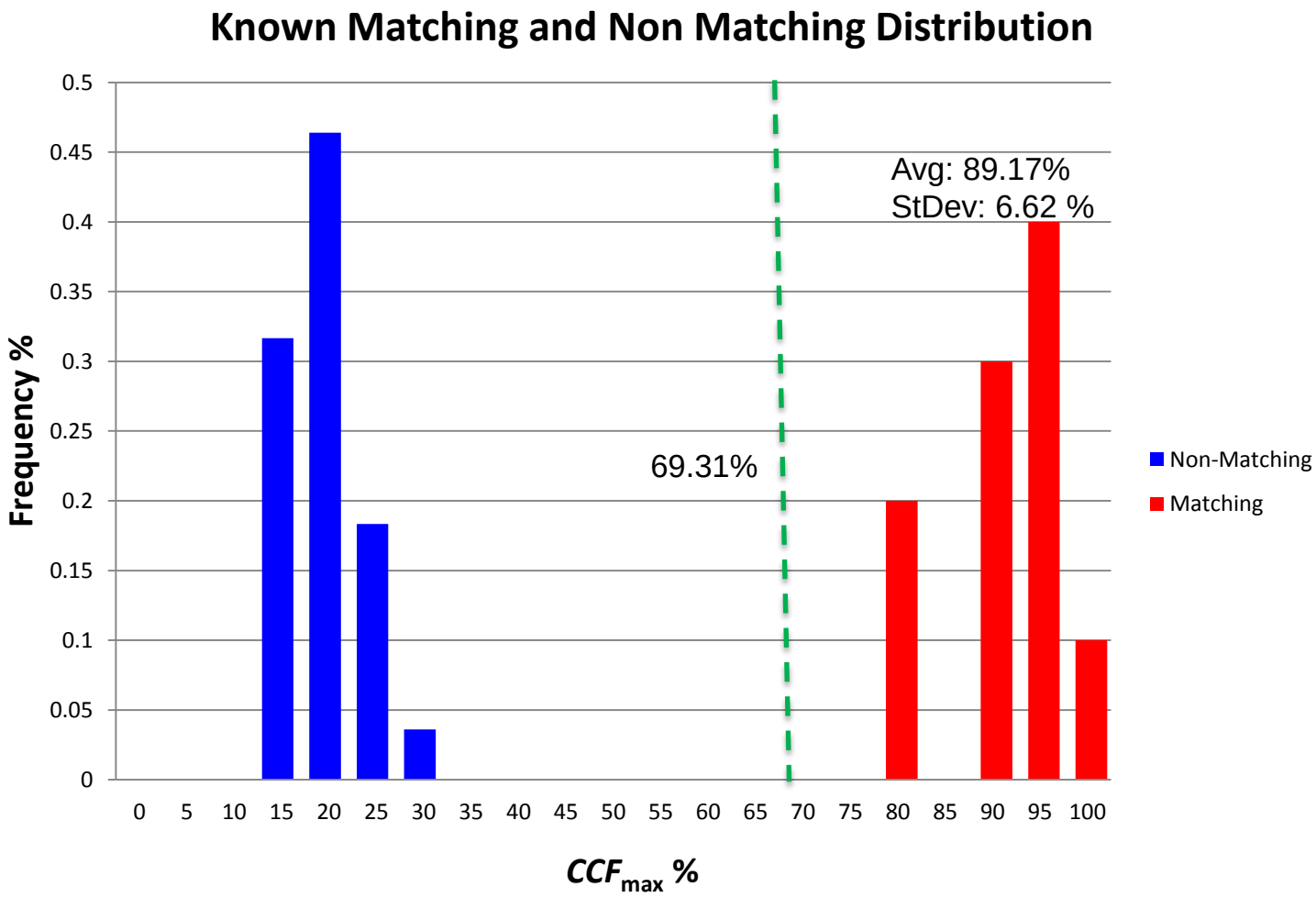
$ACCF_{MAX}$: 95.82%



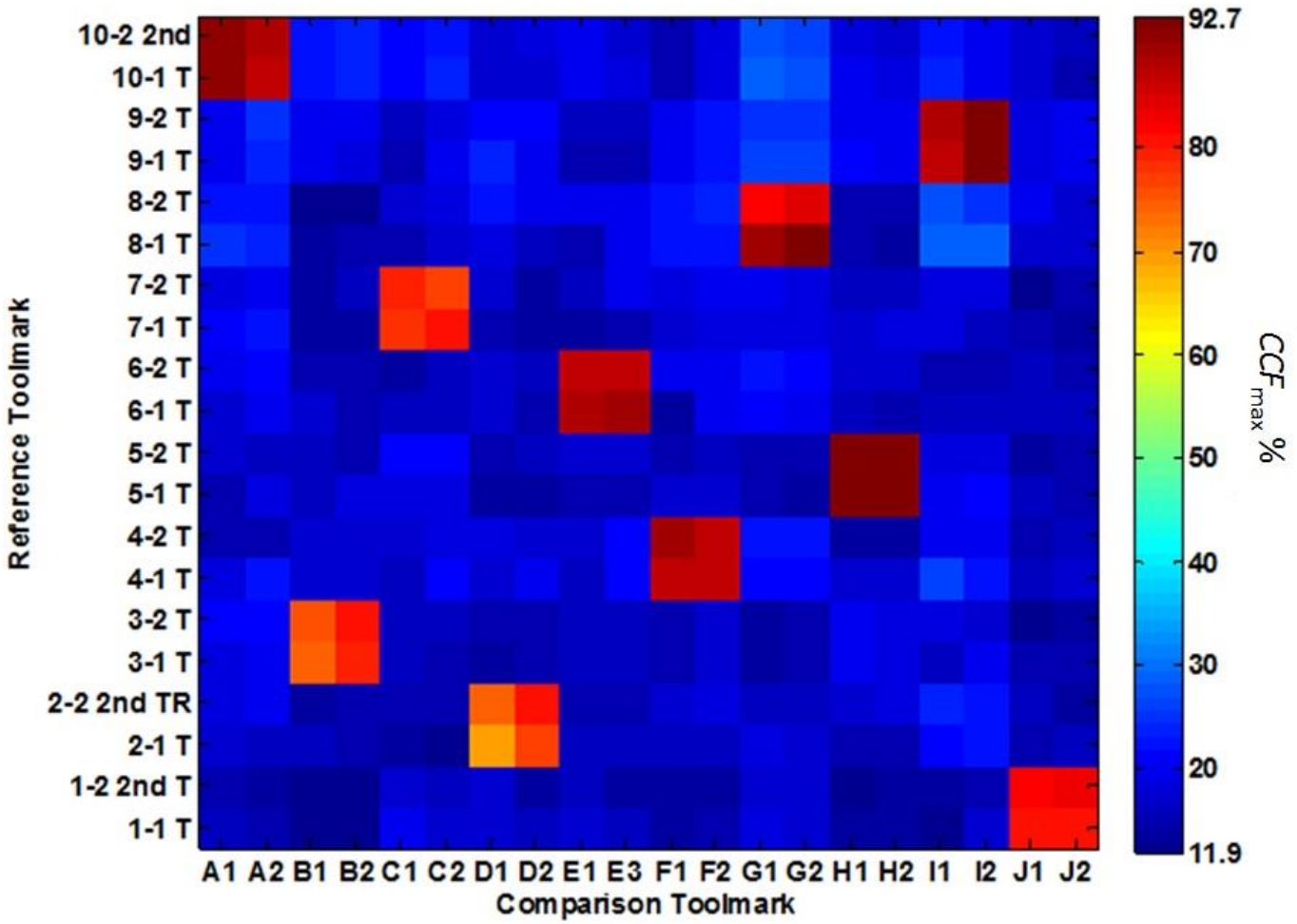
Date comparison:	Nov 27, 2012
ACCFmax:	95.82 %
Sq(A):	0.9834 µm
Sq(B):	1.0657 µm
Sq(B-A):	0.3072 µm
Sign. Diff. Ds :	9.76 %



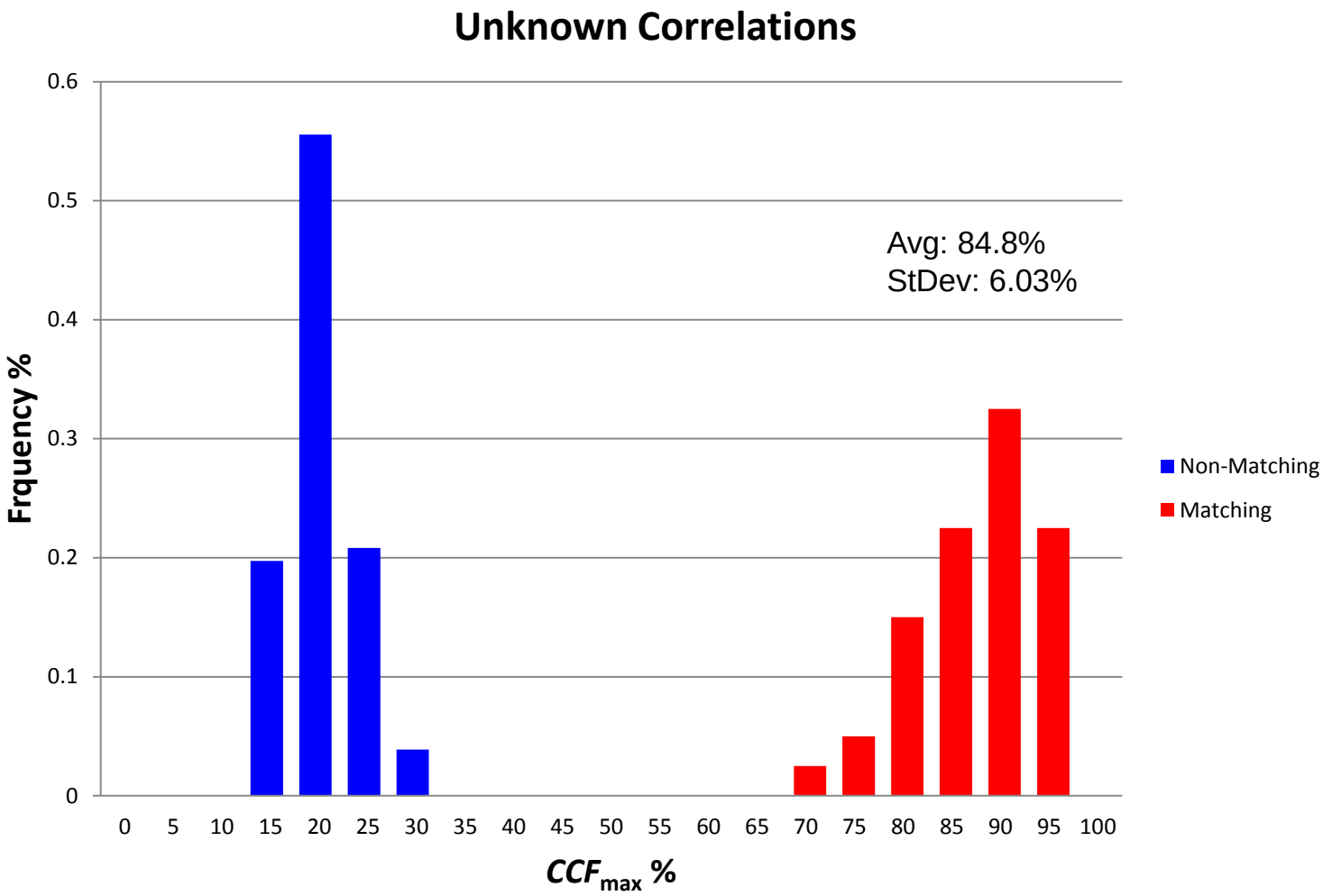
Known Punch Distribution



Unknown Punch Identifications



Unknown Punch Distribution



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
  - The statistical distribution between the known matching and known non-matching are clearly separated with no overlap.
  - All 20 unknown punch toolmarks were correctly identified back to the punch that created them.
- This study adds objective mathematical validation for striated and impressed toolmark identifications.

Thanks for your attention!

Questions?

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