SAND2008-5827C

Meso-Scale High-Strength Metal Clock Plate

Not Yet Reviewed by Review and Approval

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Ronald L. Wild
PMTS

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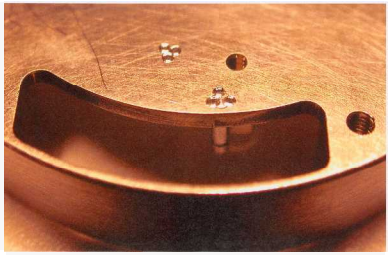
NNSA National Nuclear Security Administration

Sandia National Laboratories

Mechanism Tolerances

Miniature-Scale
Precision Milled Parts



+/- 20 to 50 Microns

Meso-Scale
LIGA or Micro-Wire EDM Parts

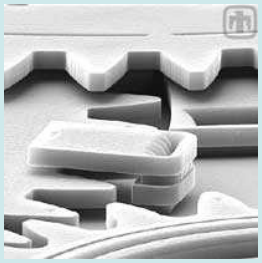
EDM Teeth

Size & Tolerance Range Of Interest

+/- Microns

Manually Assembled Mechanisms using High-Strength Metal Parts

Micro-Scale
MEMS Silicon Parts



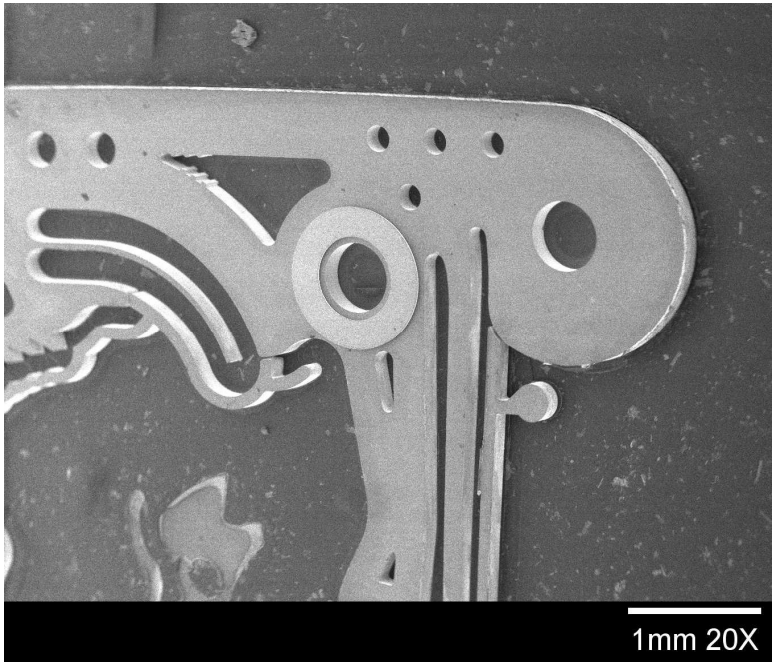
+/- Sub-Micron

Size

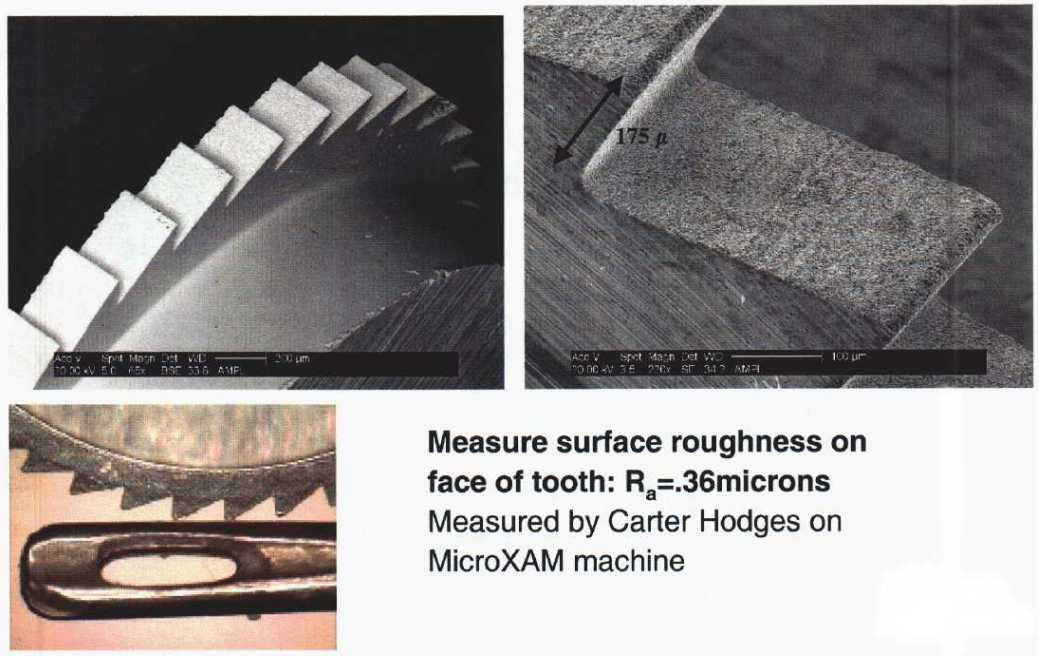
Acceptable Dimensional Tolerance

Meso-Scale High-Strength Metal Parts

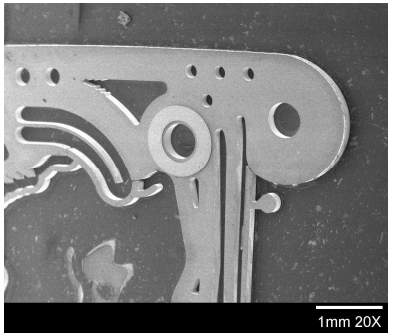
LIGA Parts
(Lithographie Galvanoformung Abformung)



Micro-Wire EDM Parts
(Electro-Discharge Machining)



LIGA Technology



Metalized Silicon Wafer

PMMA Sheet

X-Ray Mask

Synchrotron

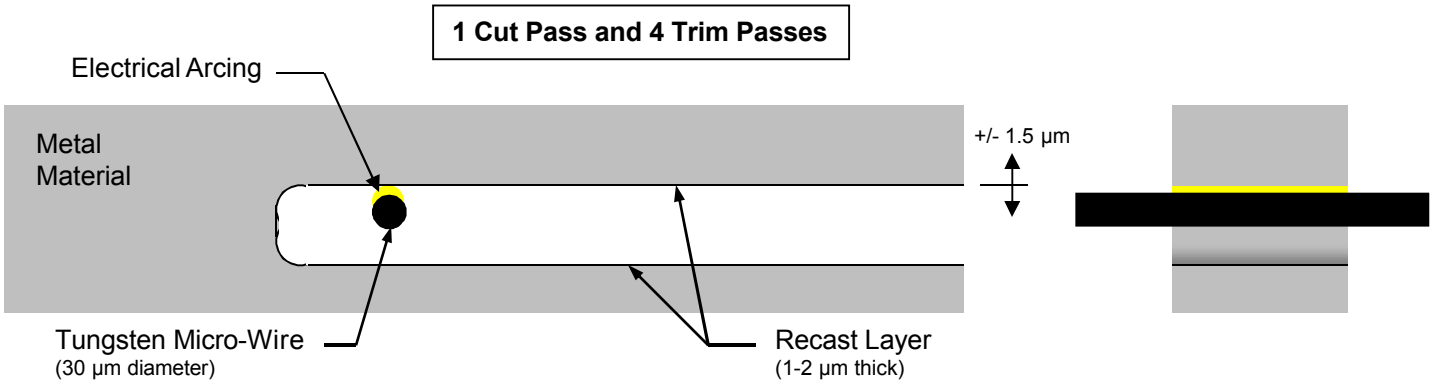
PMMA Development Bath

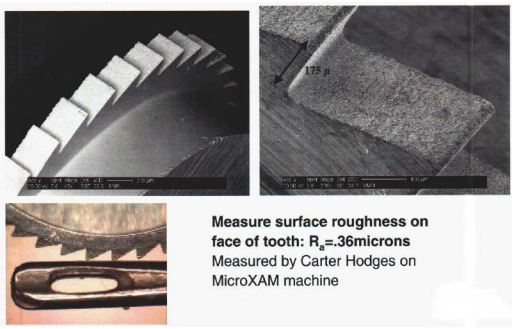
Electroforming Bath

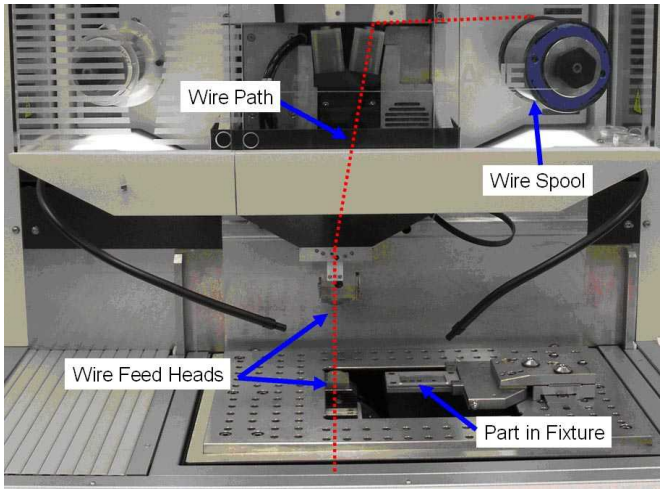
Lapping Station

Part Releasing Bath

Micro-Wire EDM Technology

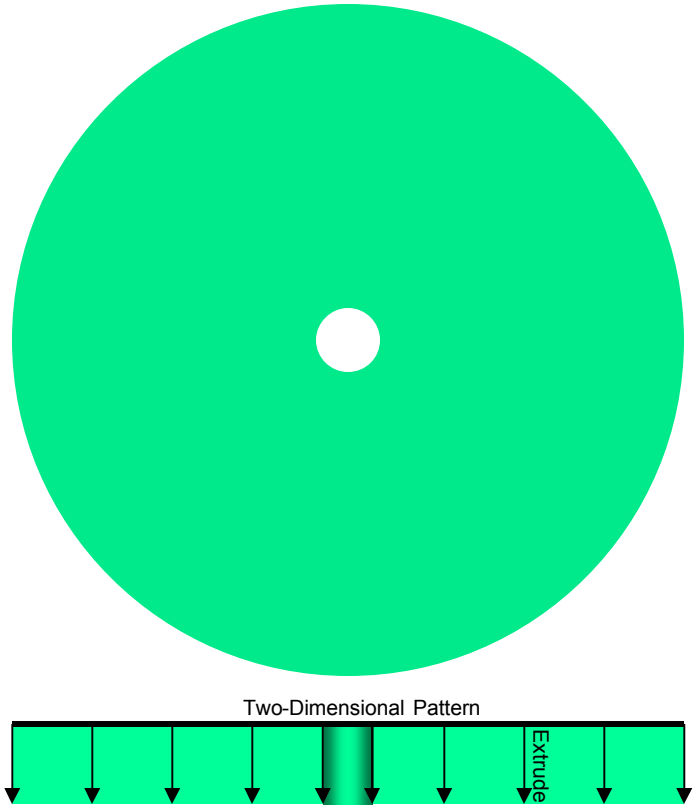


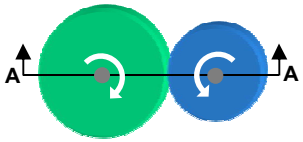




LIGA & Micro-Wire EDM Parts

Precision Features on these types of Meso-Scale Parts follow a Two-Dimensional Pattern





Consider a Simple Meso-Scale Gear Train Using LIGA or EDM Gears

Gear Train - Section A-A

Cover Plate

Spur Gear

Spur Gear

Pivot Pin

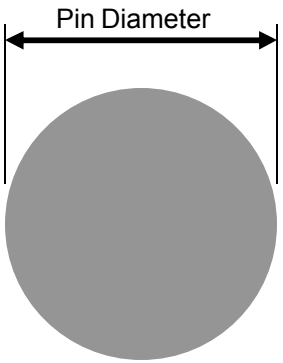
Pivot Pin

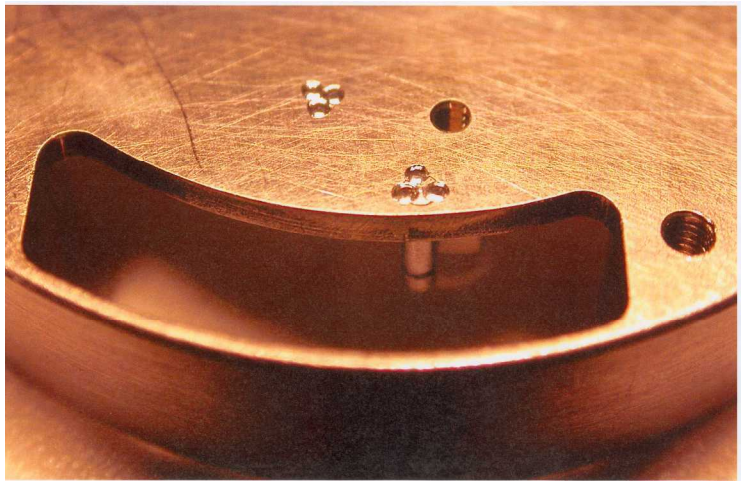
Clock Plate

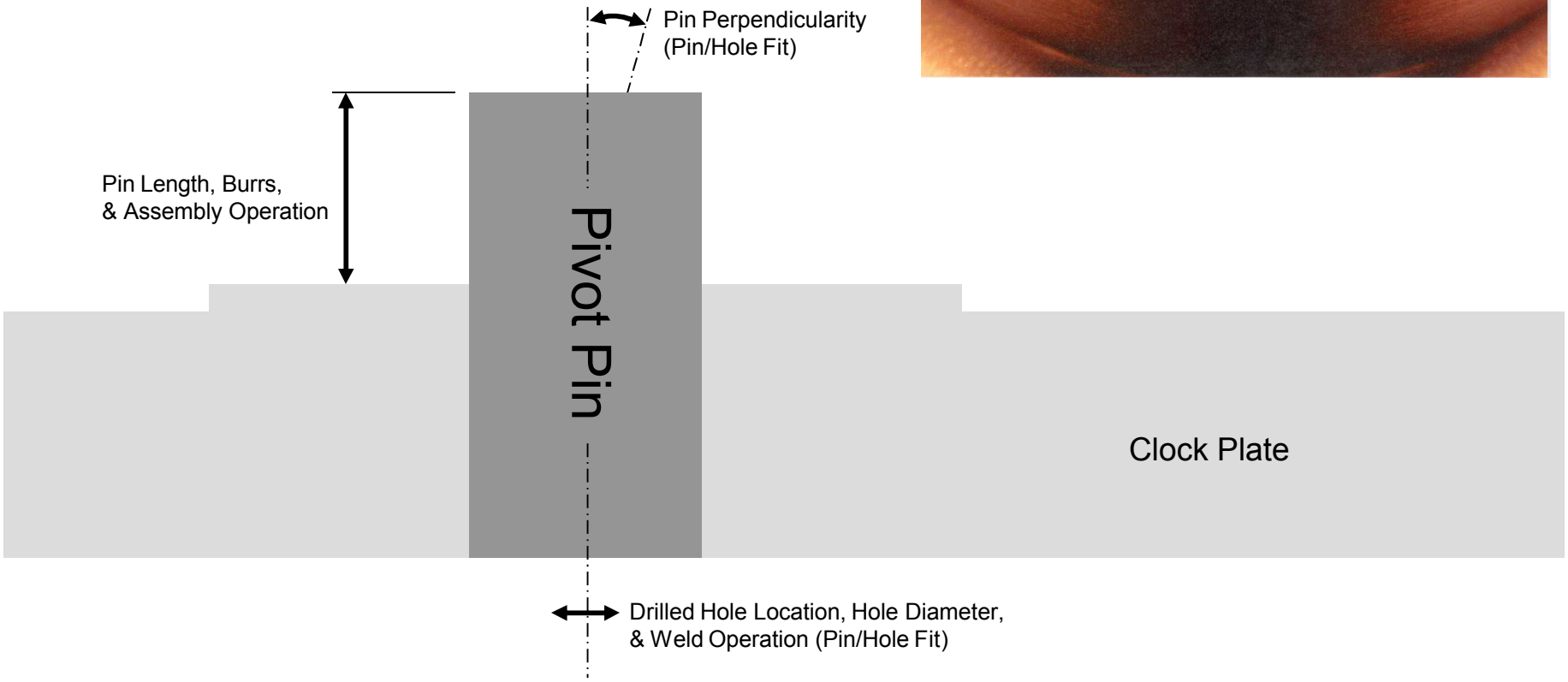
Focus Of Presentation

Assembled and Welded Pivot Pin

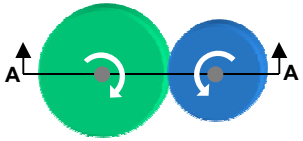
Consider Geometry Variation

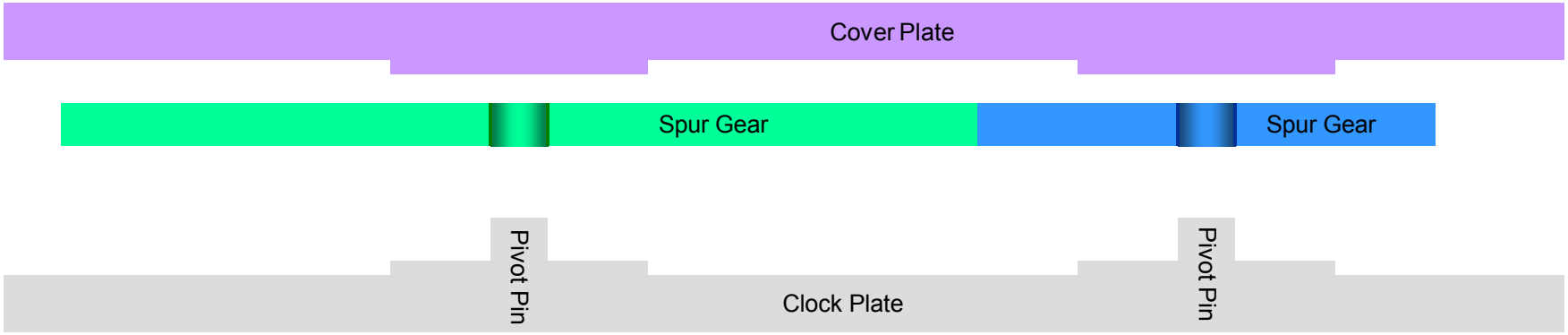






Integrate the Pivot Pins into the Clock Plate

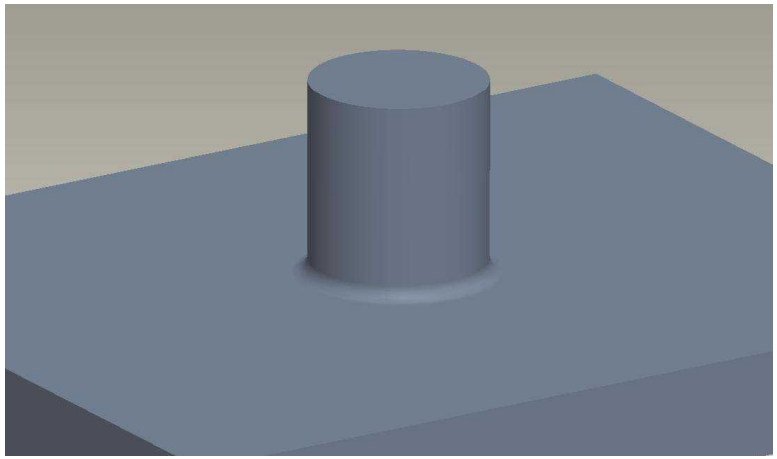


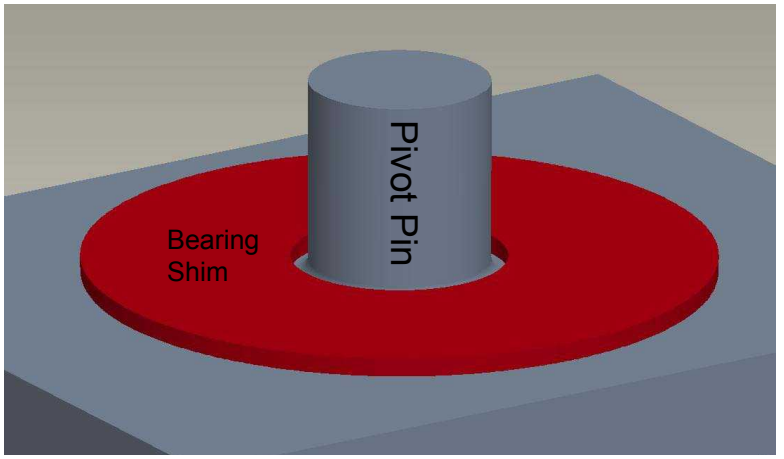


Integral Pivot Pins

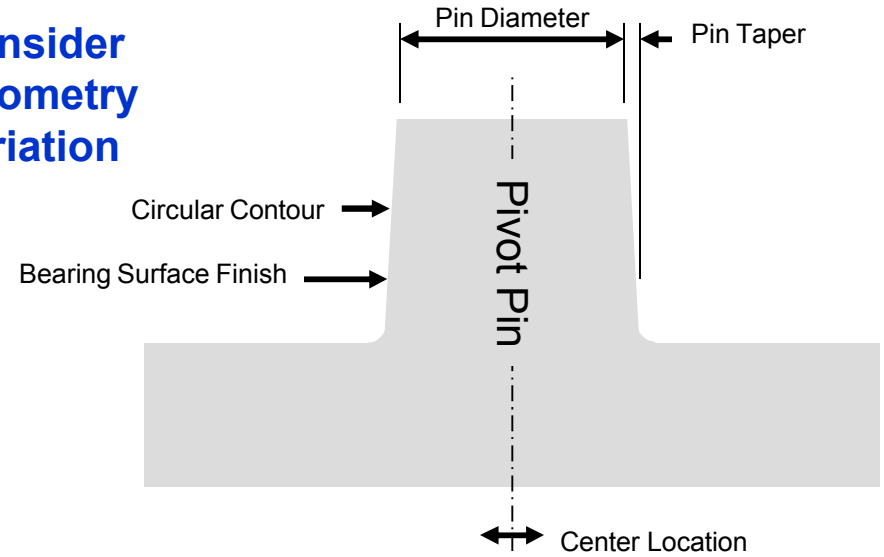
- Eliminates Pin Assembly
- Eliminates Pin Welding
- Reduces Pin Variation

Integrated Precision Milled Pivot Pin

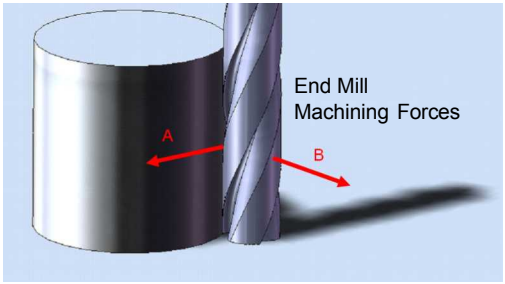




Consider Geometry Variation

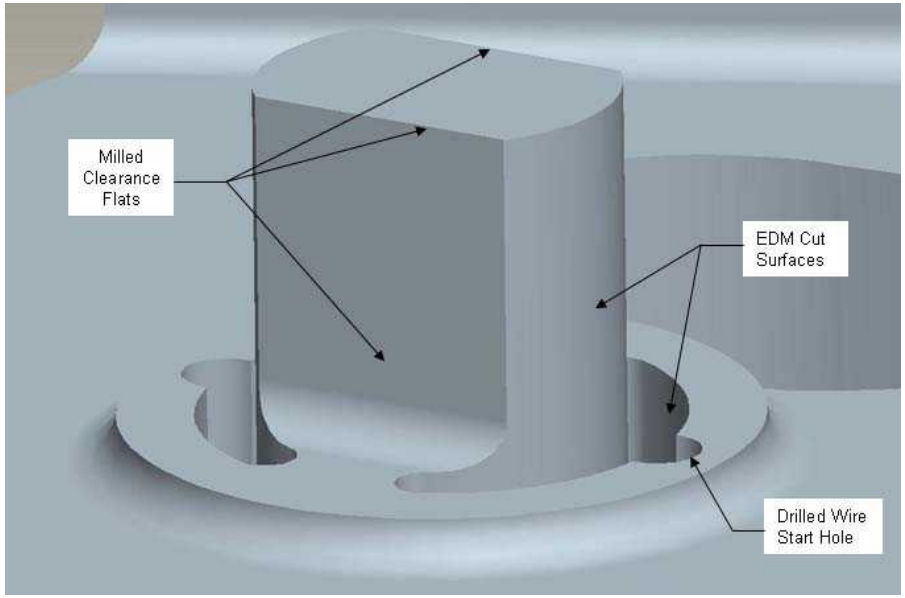


Prototype Pivot Pin Specification
Diameter: 0.942 +/- 0.005 mm
Center Deviation: 0.010 mm Maximum



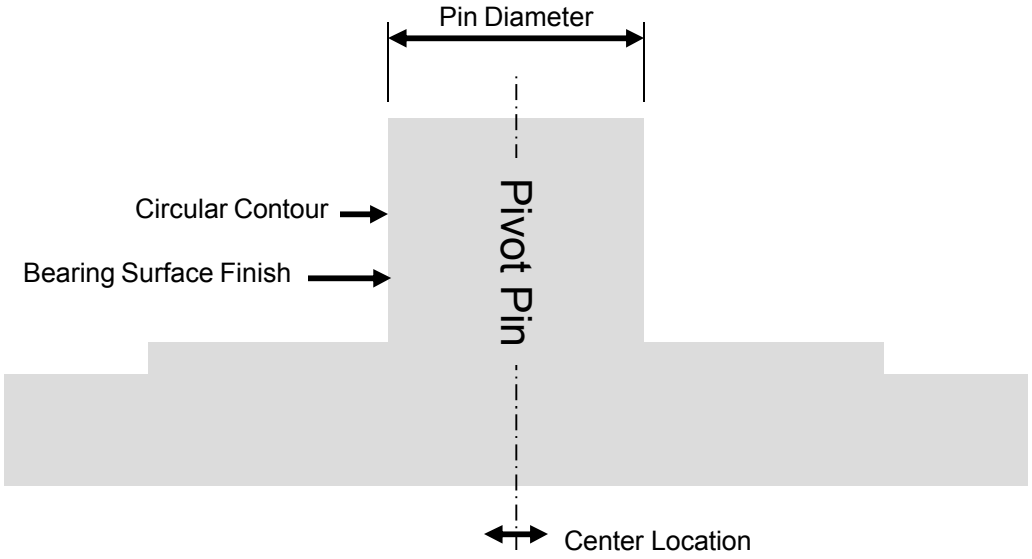
Milling High-Strength 21-6-9 Stainless Steel
Machinability: 30% based on 100% for AISI 1212 steel

Two-Step Machined Integrated Pivot Pin

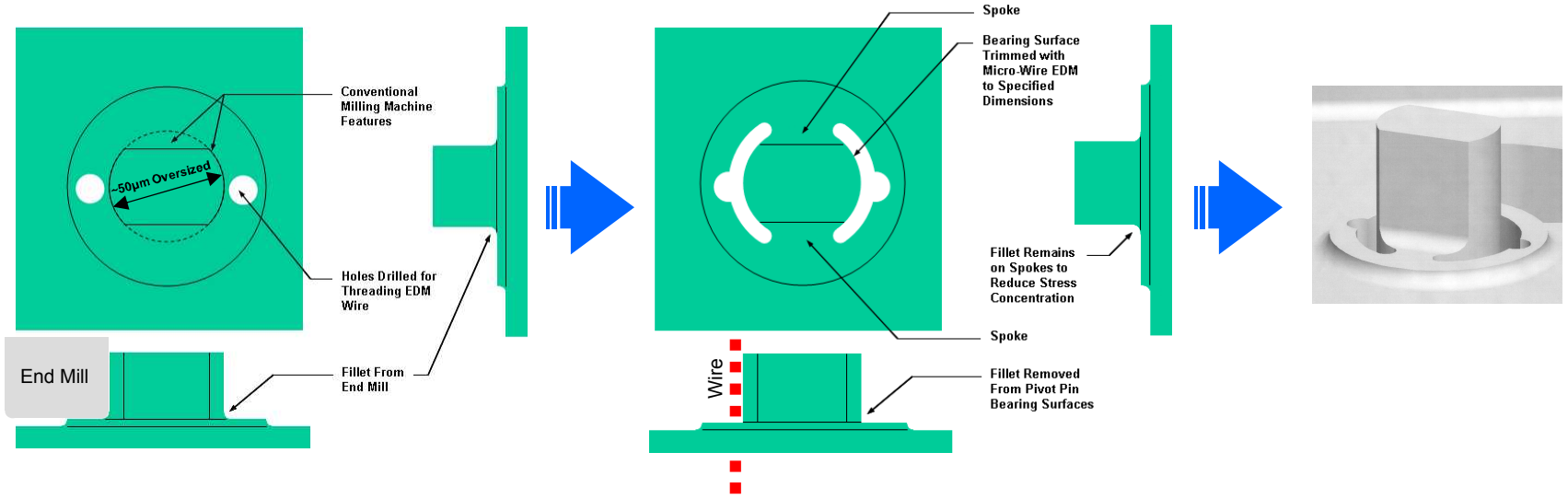


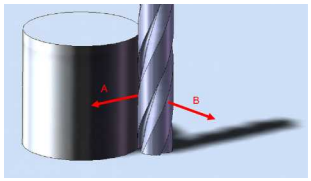
Prototype Pivot Pin Specification
Diameter: 0.942 +/- 0.005 mm
Center Deviation: 0.010 mm Maximum

Consider Geometry Variation



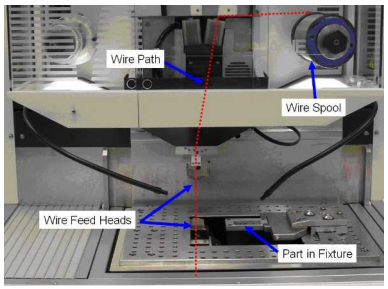
Integrated Pivot Pin
Using a Two-Step Machining Process





Precision Milling

1

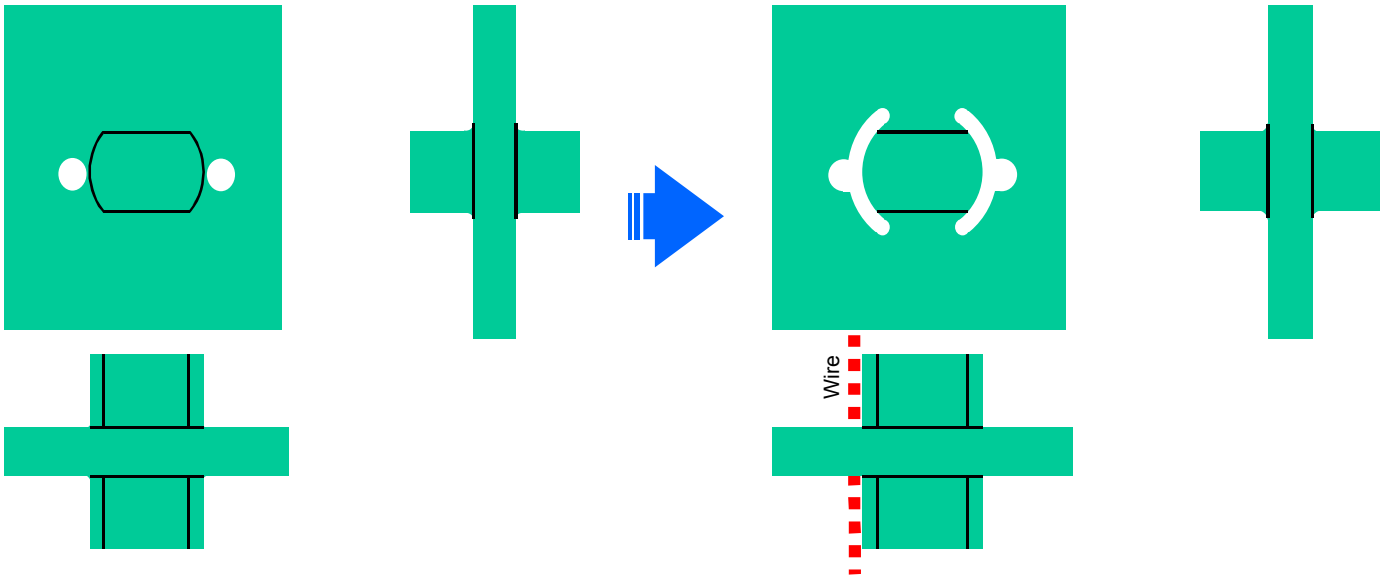


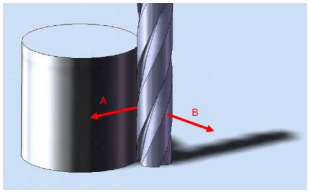
Higher-Precision Micro-Wire Electro-Discharge Machining

2

Integrated Front-To-Back Registration Pin

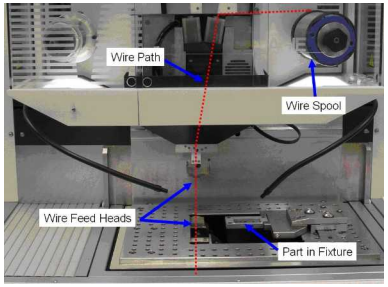
(Two-Step Machining Process)





Precision Milling on Both Sides Similar to the Pivot Pin Operation

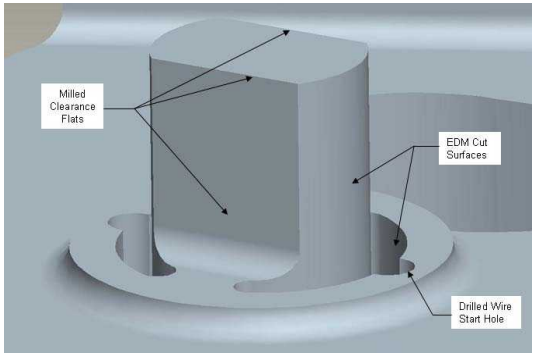
1

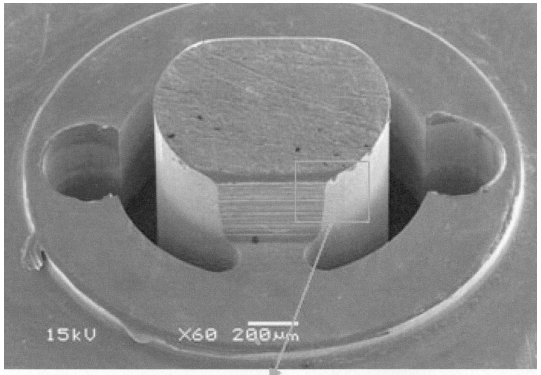


Higher-Precision Micro-Wire Electro-Discharge Machining

2

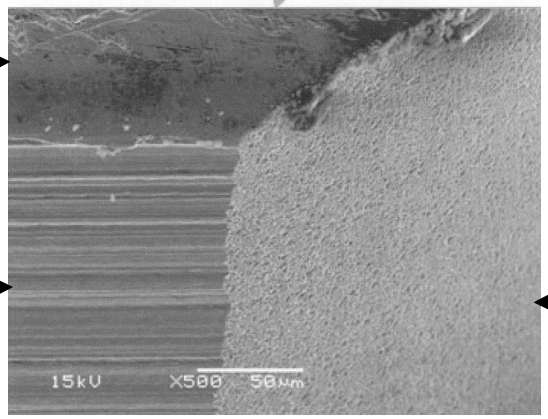
Prototyped Meso-Scale Pivot Pin





Prototype Pivot Pin Specification
Diameter: 0.942 +/- 0.005 mm
Center Deviation: 0.010 mm Maximum

Lapped
Surface Finish

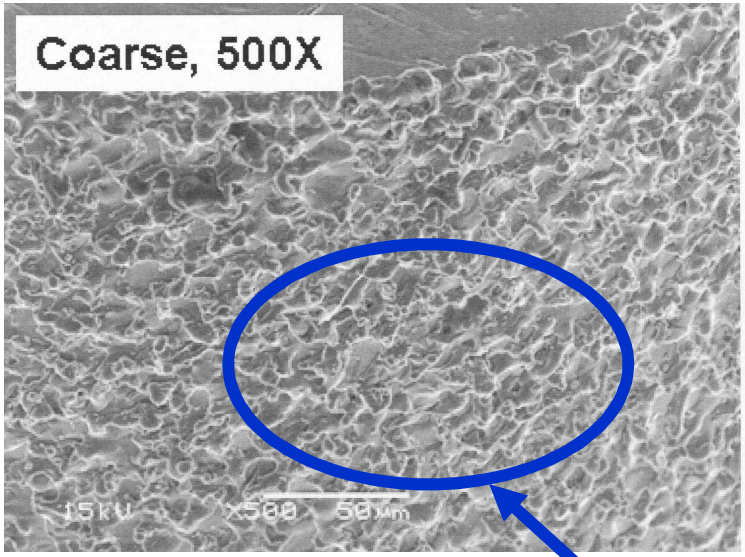


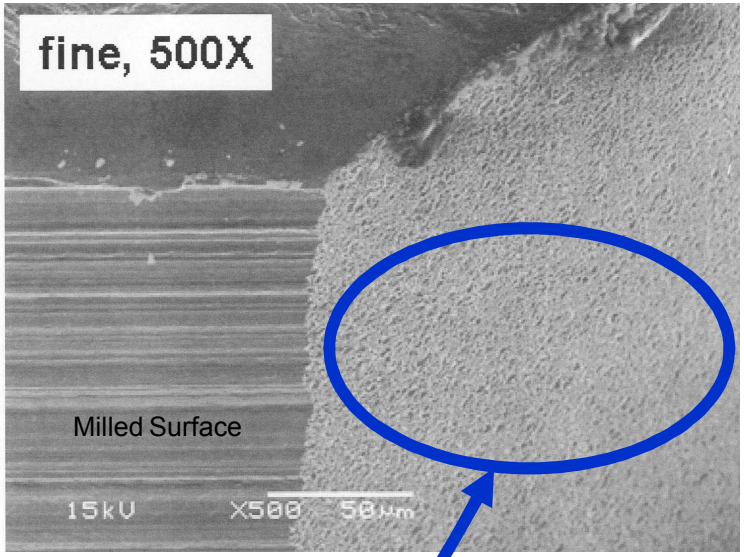
End Mill Machining
Surface Finish

Electro-Discharge Machining
Recast Layer Surface Finish

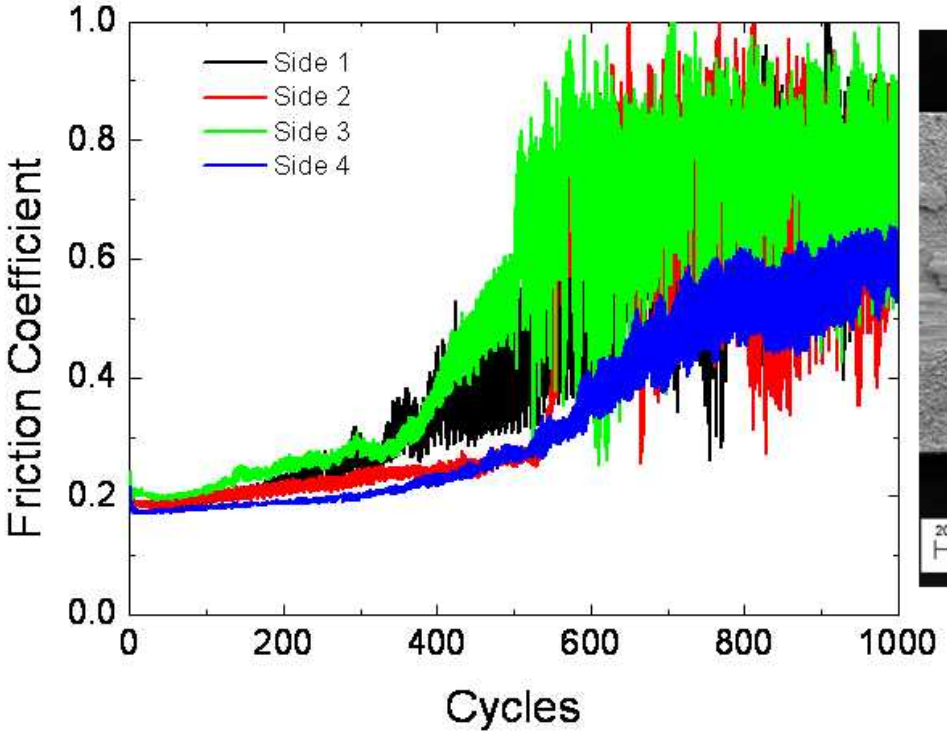
Micro-Wire EDM Recast Layer Surface Finish Variation

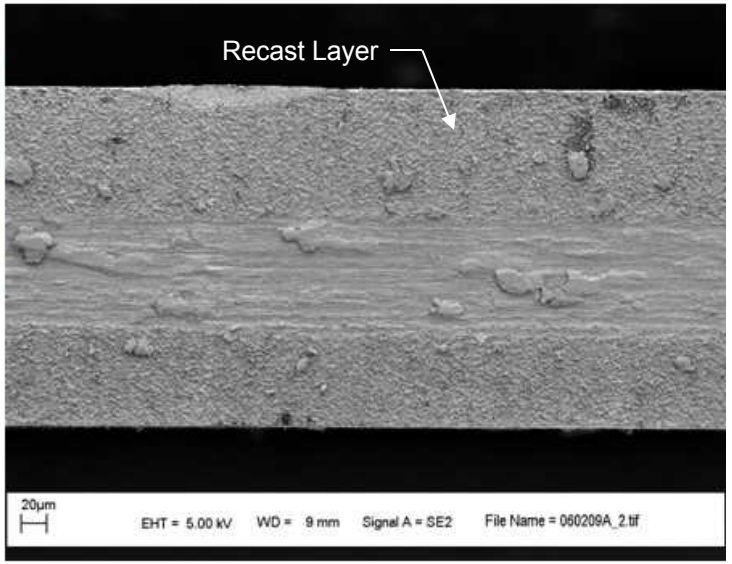
The average surface roughness, Ra, of the recast layer was determined to be 0.906 micron. Note that for the recast layer the maximum and minimum values of the peak heights and depressions are ±1 micron.





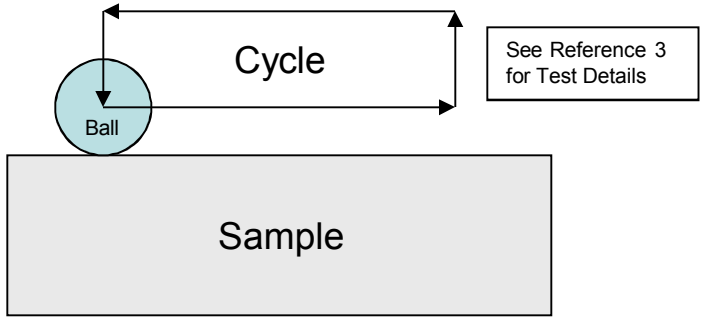
Friction & Wear Behavior of a Micro-Wire EDM Recast Layer Surface



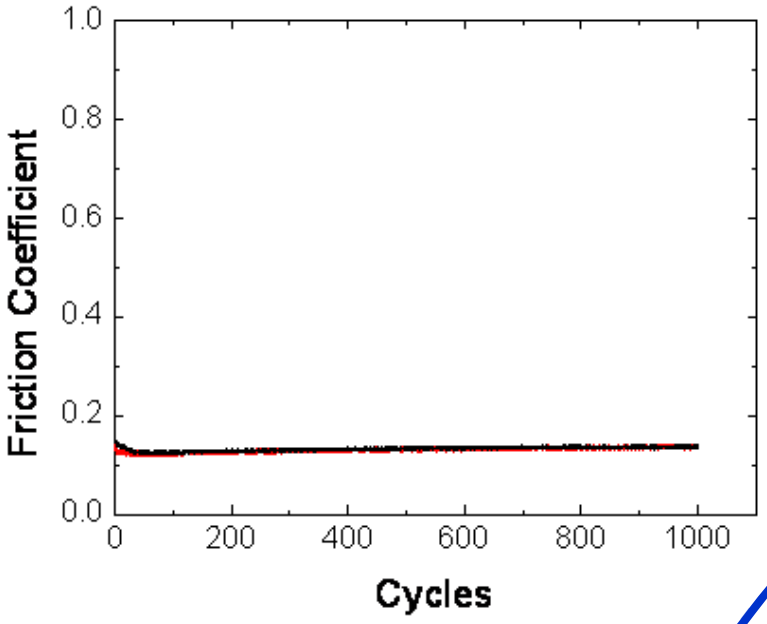


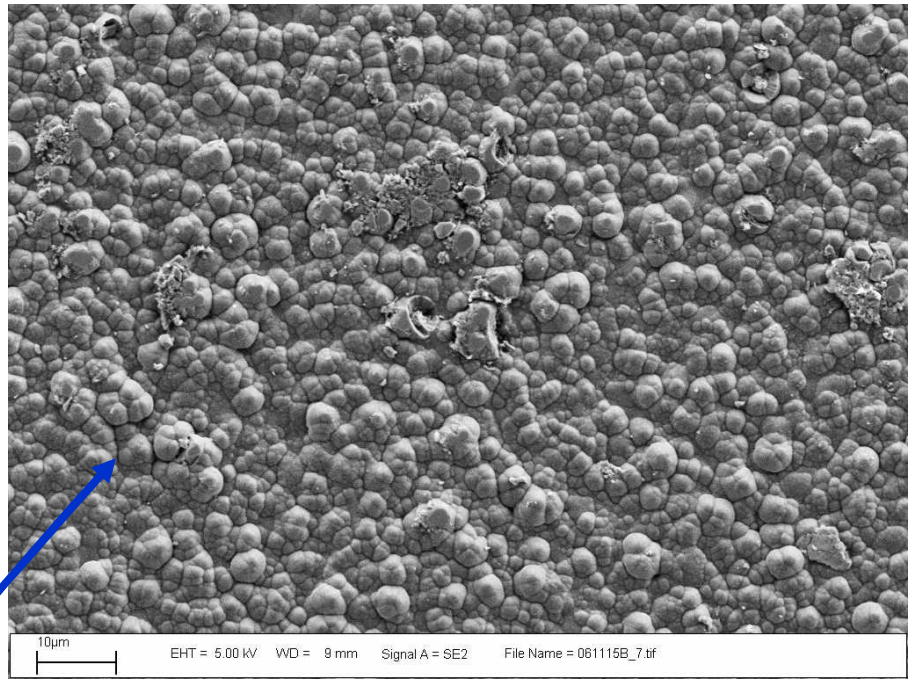
Wear Track

(3.125 mm diameter Si_3N_4 ball, 50% RH)



Friction & Wear Behavior of a DLN Coated Recast Layer Surface



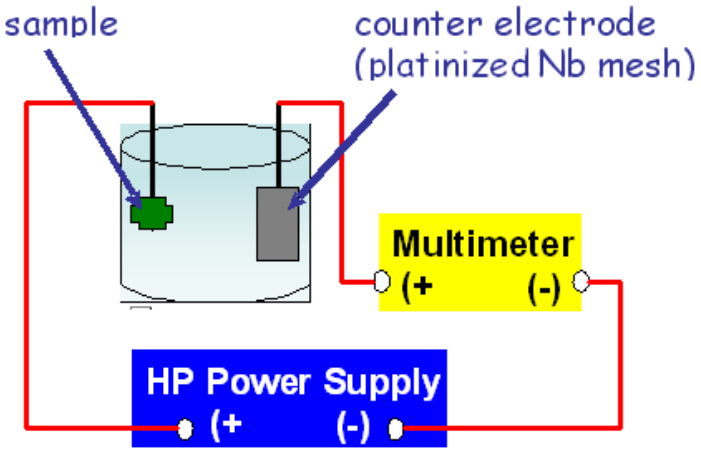


- 1.0 micron thick Diamond-Like Nanocomposite Hard Coating on Titanium Layer on Recast Layer on 21-6-9 SS
- DLN Process: Plasma Enhanced Chemical Vapor Deposition

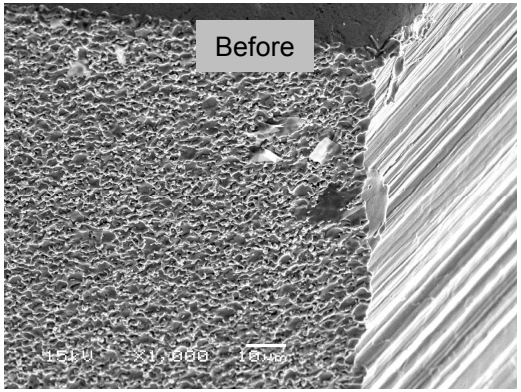
Many Stress Raisers will affect Fatigue Life

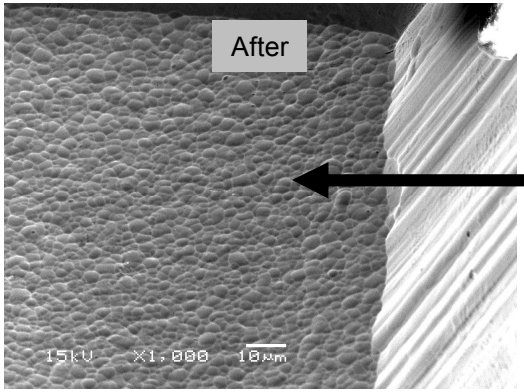
EDM Recast Layer Removal Development

- Mechanical Polishing
- Laser Ablating/Glazing
- Micro-Abrasion
- Electro-Polishing



Adjusting Electro-Polishing Parameters

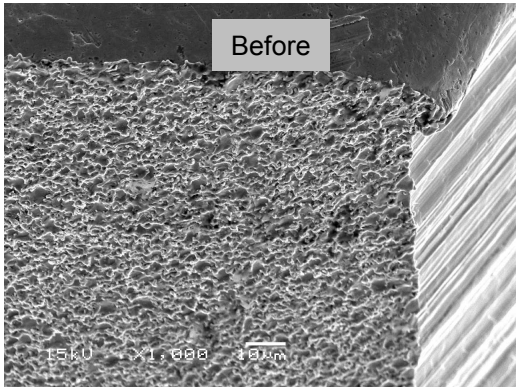


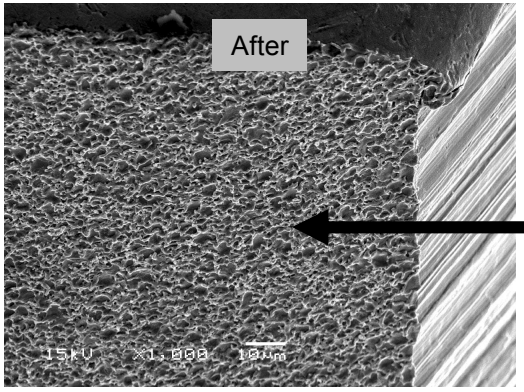


Too Much Current

Recast Layer Removed with Scalloped Stainless Steel Surface Exposed

Surface Morphology of Clock Plate 1 as EDM Trimmed with Recast Layer and after Electro-Polishing (1940 mA, 366 mA/cm², 2 minutes)





Not Enough Current

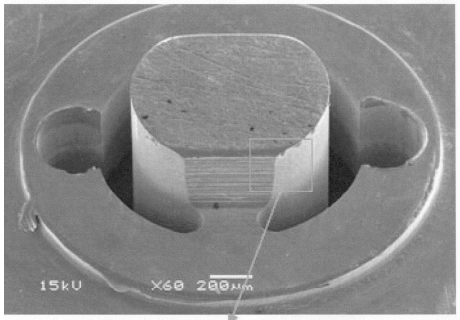
Recast Layer Remains

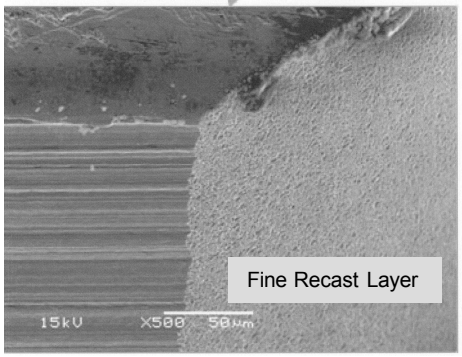
Surface Morphology of Clock Plate 2 as EDM Trimmed with Recast Layer and after Electro-Polishing (1065 mA, 200 mA/cm², 2 minutes)

Electro-Polishing Prototype Pins

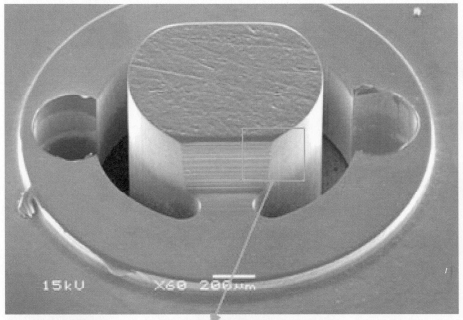
Pivot Pin

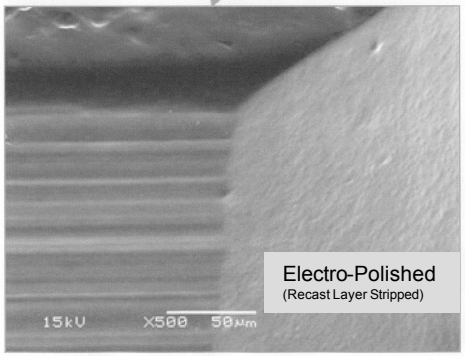
Before





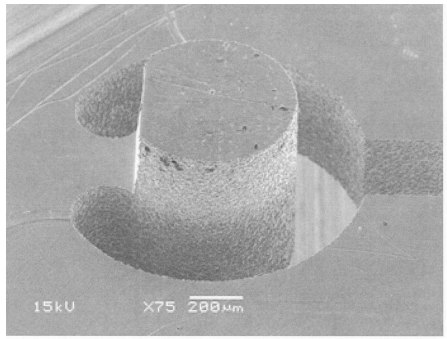
After

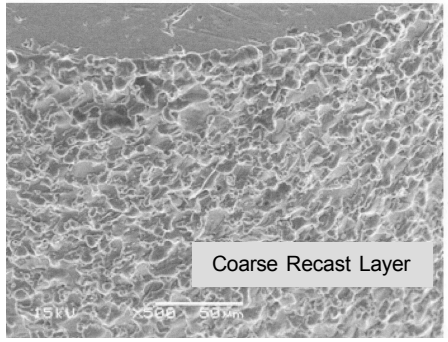




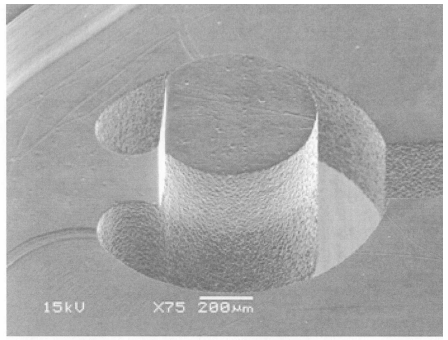
Registration Pin

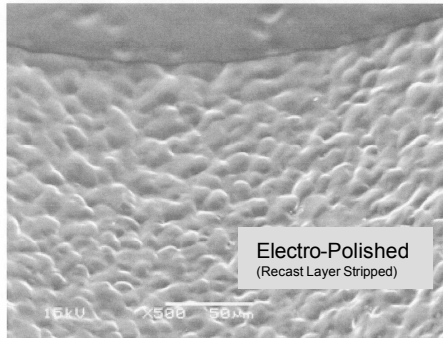
Before



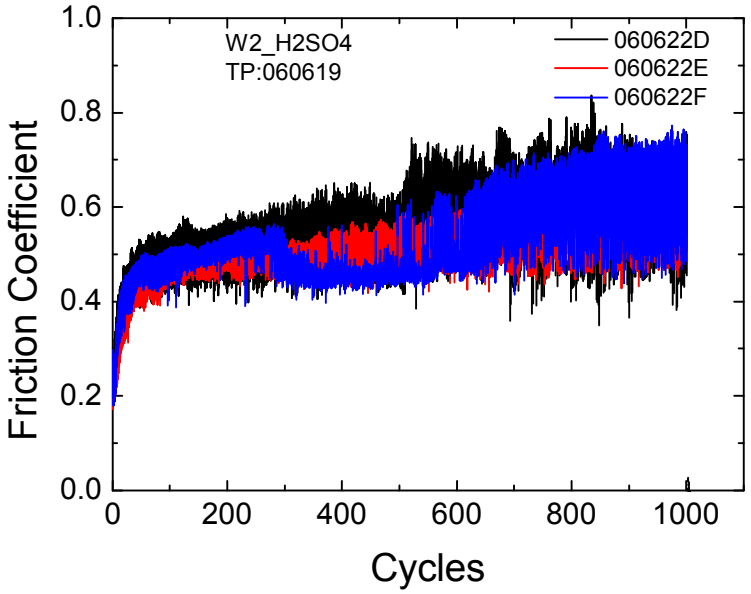


After

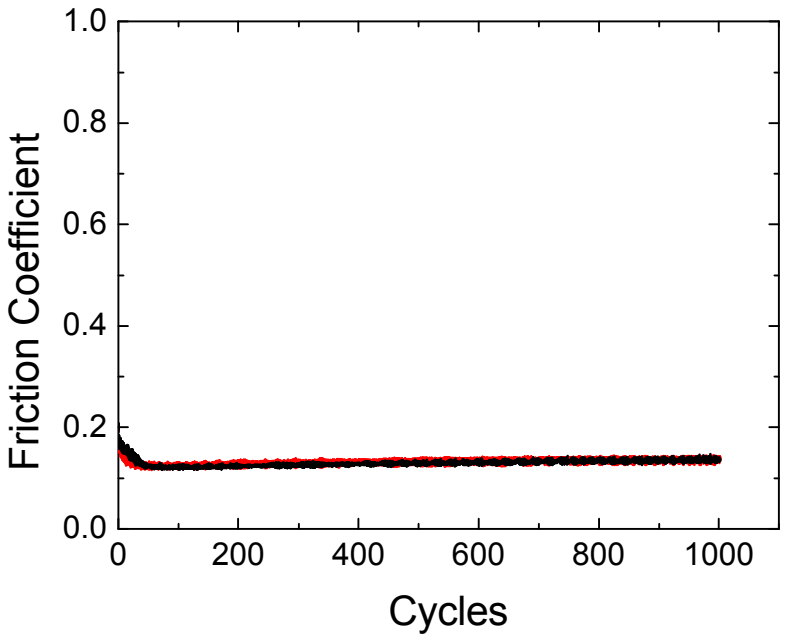


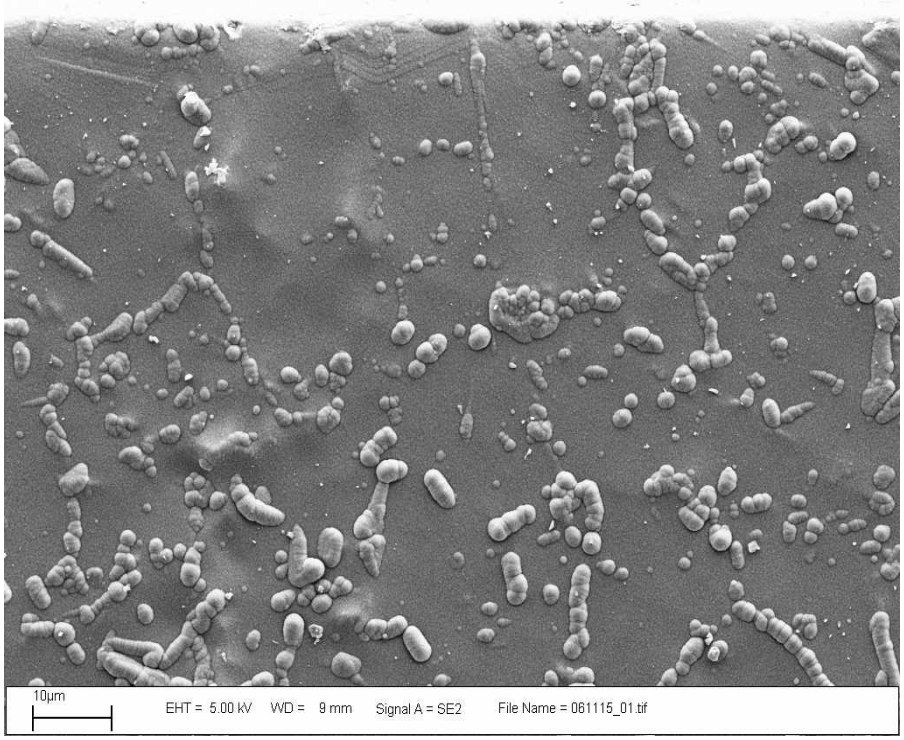


Friction & Wear Behavior of an Electro-Polished Stainless Steel Surface (Recast Layer Stripped)



Friction & Wear Behavior of a DLN Coated Electro-Polished Stainless Steel Surface (Recast Layer Stripped)



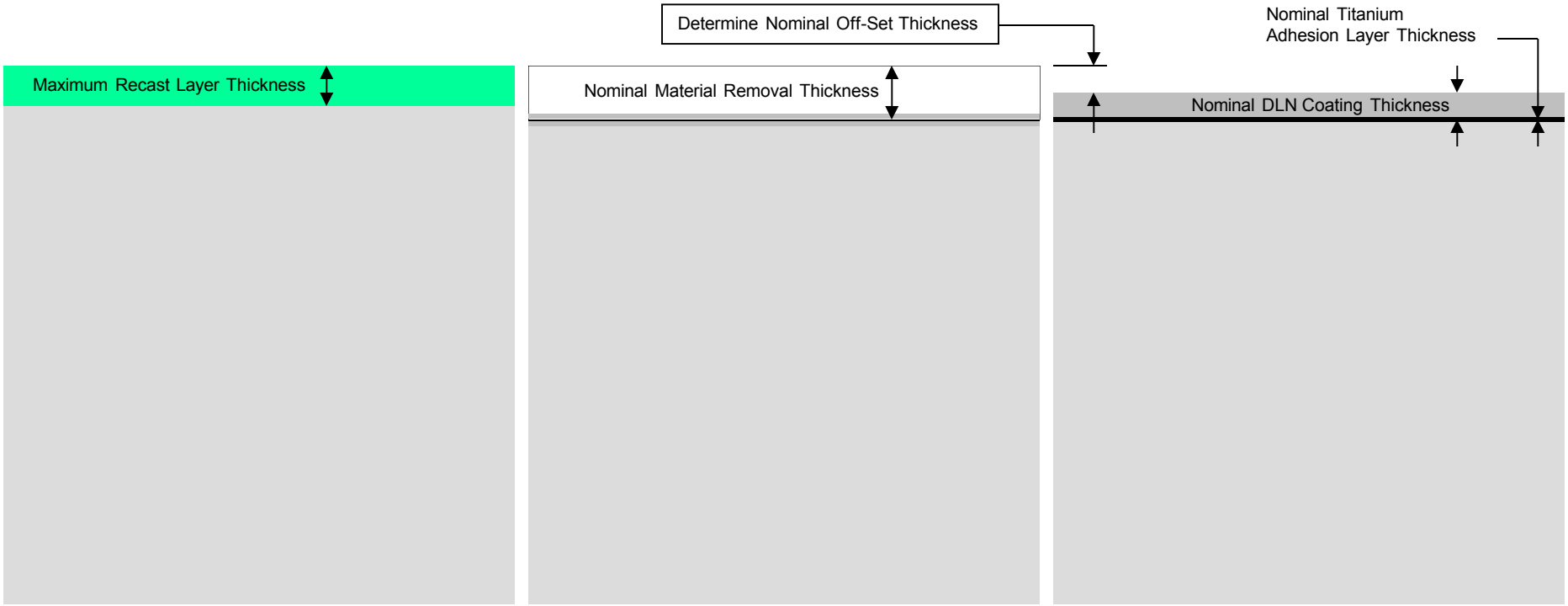


- 1.0 micron thick Diamond-Like Nanocomposite Hard Coating on Titanium Layer on 21-6-9 SS (Recast Layer Stripped)
- DLN Process: Plasma Enhanced Chemical Vapor Deposition

Proposed Future Work

Repeatable Process Parameter and Dimensional Off-Set Study

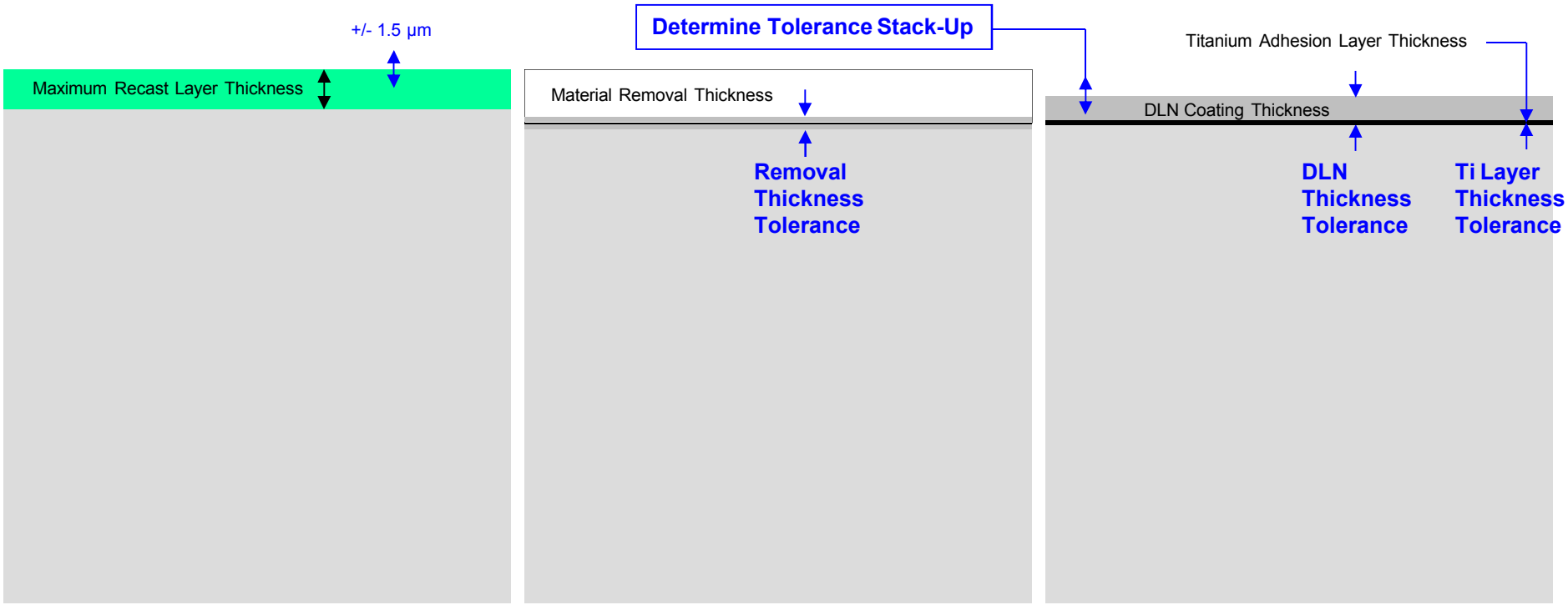
Micro-Wire Electro-Discharge Machining	Recast Layer Stripping by Electro-Polishing	Diamond-Like Nanocomposite Hard Coating



Proposed Future Work

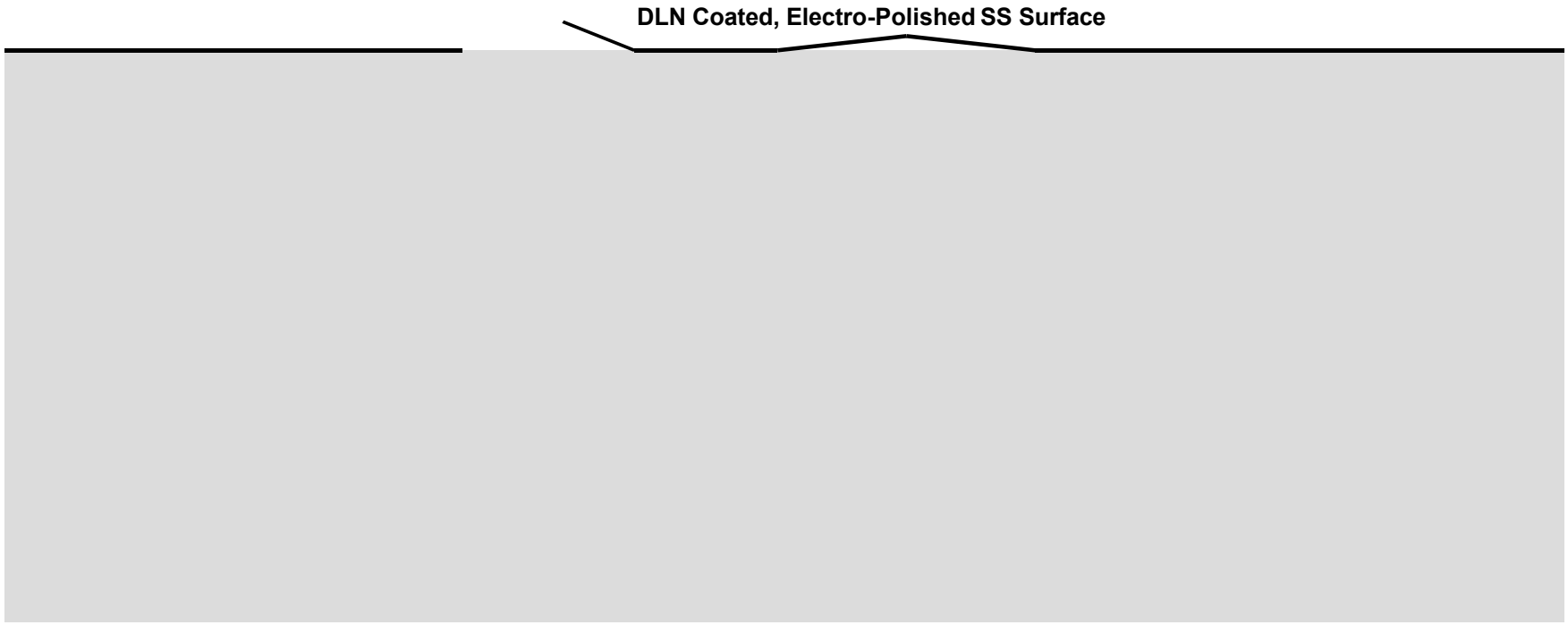
Dimensional Variation Study

Micro-Wire Electro-Discharge Machining	Recast Layer Stripping by Electro-Polishing	Diamond-Like Nanocomposite Hard Coating



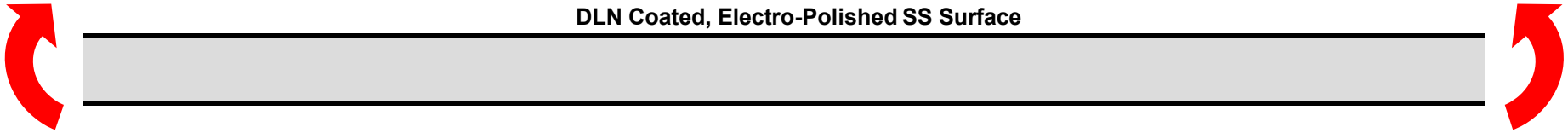
Proposed Future Work

Impact Loading Wear, & Adhesion Study for DLN Coating



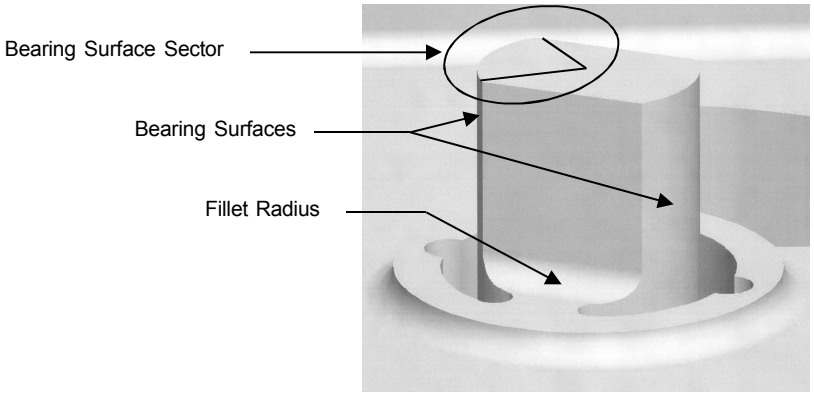
Proposed Future Work

Flexure Fatigue Life Study



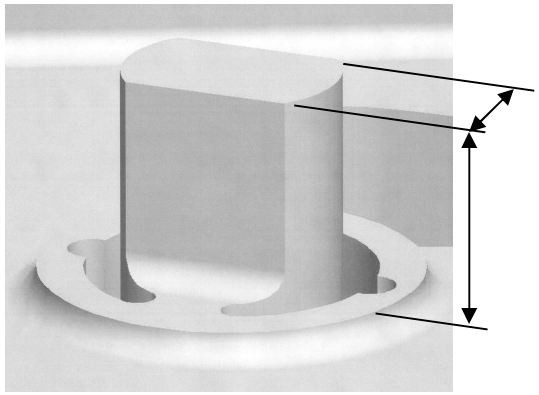
Proposed Future Work

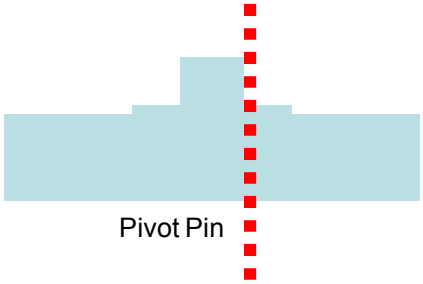
Fillet Radius, Stress, & Bearing Surface Sector Angle Study

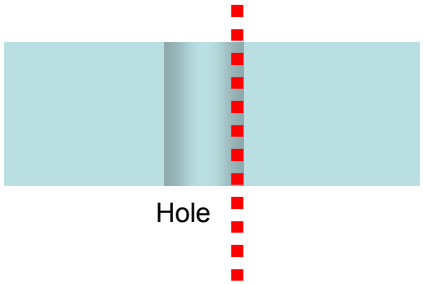


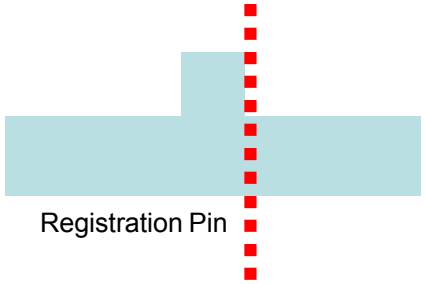
Proposed Future Work

Pin Aspect Ratio & Precision Milling Study









Meso-Scale Clock Plate Summary

The two-step machined clock plates met their dimensional tolerance specifications and demonstrated the practicality of meso-scale clock plates having integrated pivot pins, pass-through pivot pins, registration pins, front-to-back registration pins, motion stop surfaces, holes, and precision-fit component pockets.