
Brush Plating of Nickel-Tungsten Alloy for Engineering Application

Zhimin Zhong & Sid Clouser

Report Documentation Page

Form Approved
OMB No. 0704-0188

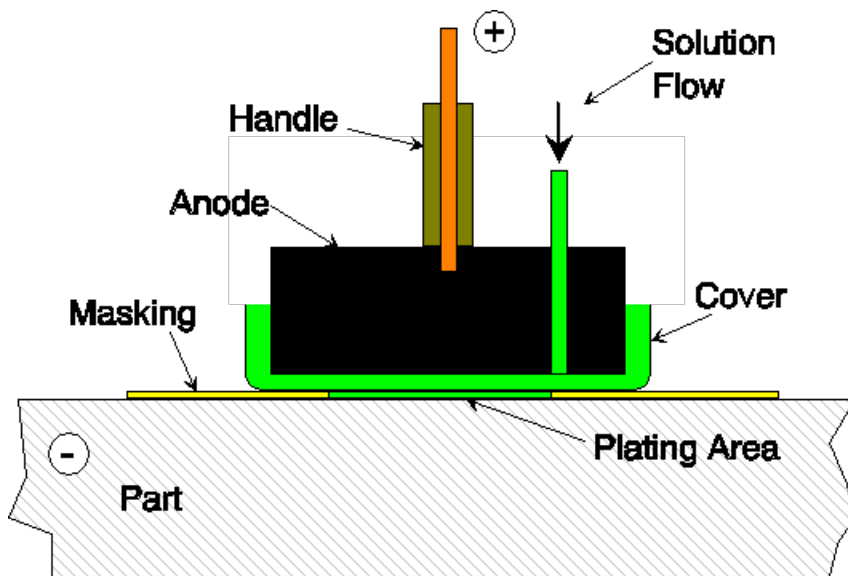
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1. REPORT DATE AUG 2012	2. REPORT TYPE	3. DATES COVERED 00-00-2012 to 00-00-2012	
4. TITLE AND SUBTITLE Brush Plating of Nickel-Tungsten Alloy for Engineering Application		5a. CONTRACT NUMBER	
		5b. GRANT NUMBER	
		5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)		5d. PROJECT NUMBER	
		5e. TASK NUMBER	
		5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) SIFCO Applied Surface Concepts, 5708 E. Schaaf Road, Independence, OH, 44131		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)	
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited			
13. SUPPLEMENTARY NOTES ASETSDefense 2012: Sustainable Surface Engineering for Aerospace and Defense Workshop, August 27-30, 2012, San Diego, CA. Sponsored by SERDP/ESTCP.			
14. ABSTRACT			
15. SUBJECT TERMS			
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified	
			18. NUMBER OF PAGES 24
			19a. NAME OF RESPONSIBLE PERSON

Engineering (functional) applications

- Hardness, wear resistance, & corrosion protection for substrate
- Electrodeposited Hard Chrome (EHC)
- Ni, Ni-P, Co-P, metal - carbide composites by electroplating, HVOF, thermal spray, etc.
- OEM or repair (restore)
- Automotive, aerospace, military, oil & gas, etc.

Brush plating



- Applied to localized area
- OEM and repair
- Line of sight, & non-line of sight plating, OD & ID
- Small amount of solution, ~ 4L
- High current density & high plating rate

Brush plating of Ni-W

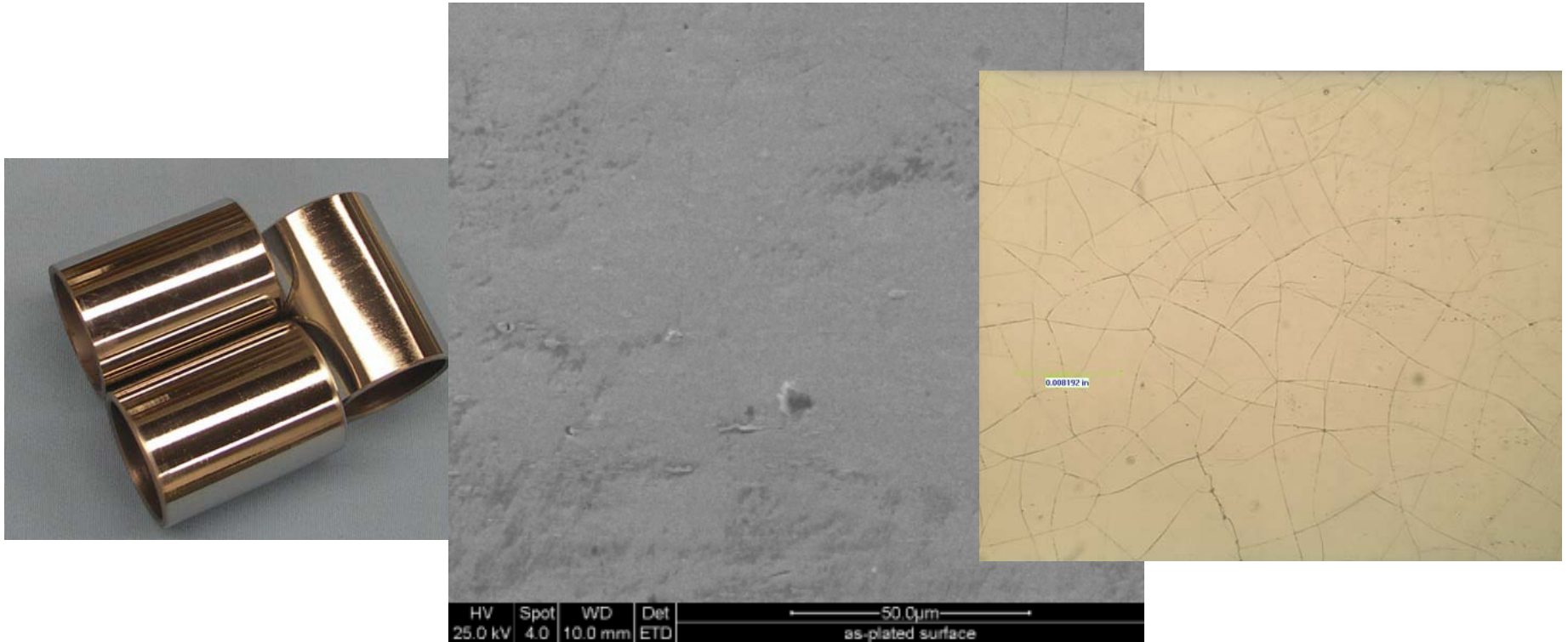
- Began development with bath plating in 1 L beaker
- Optimizing solution formula, plating temperature, and deposit properties
- Brush plating with SIFCO AeroNikl Flow System (Model 75, 4L)
- Reducing plating temperature
- Adjusting Ni to W ratio in solution close to that of deposit
- Formulation contains sulfate, sulfamate, sodium citrate, borate, and ammonium fluoroborate anions

Brush plating parameters

Ni ⁺² (g/l)	35 ± 2
W ⁺⁶ (g/l)	35 ± 2
pH	7.8 ~ 8.1
Temp (°C)	55 (49 ~ 59)
Current density	1 ASI (0.16 A/cm ²)
Plating rate	3.1 mil/hr (80 μm/hr)
Current efficiency	55 ~ 60 %

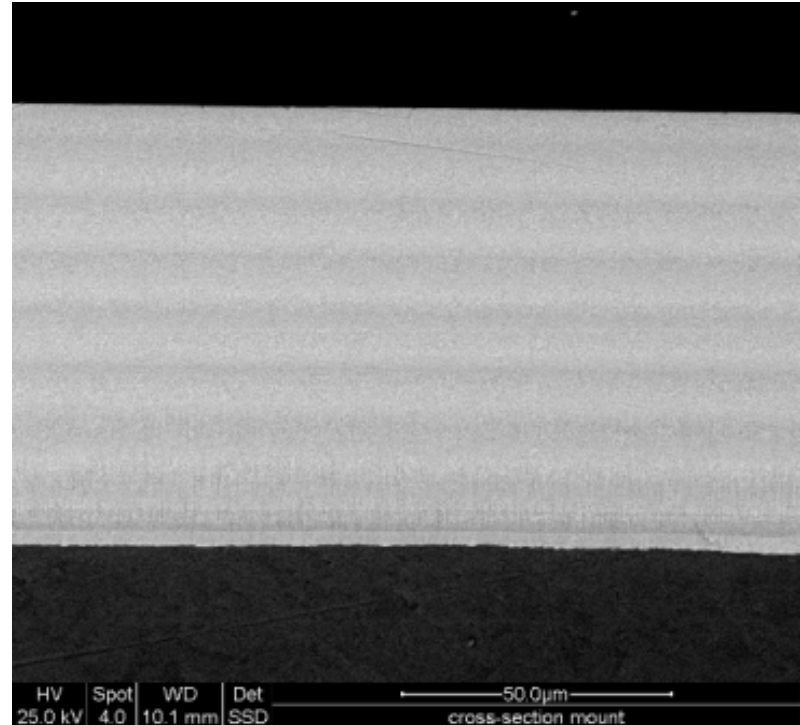


Surface morphology



Visual appearance, scanning electron and optical microscope images. Smooth, fine grained, micro-cracked surface morphology

Deposit structure in cross-section

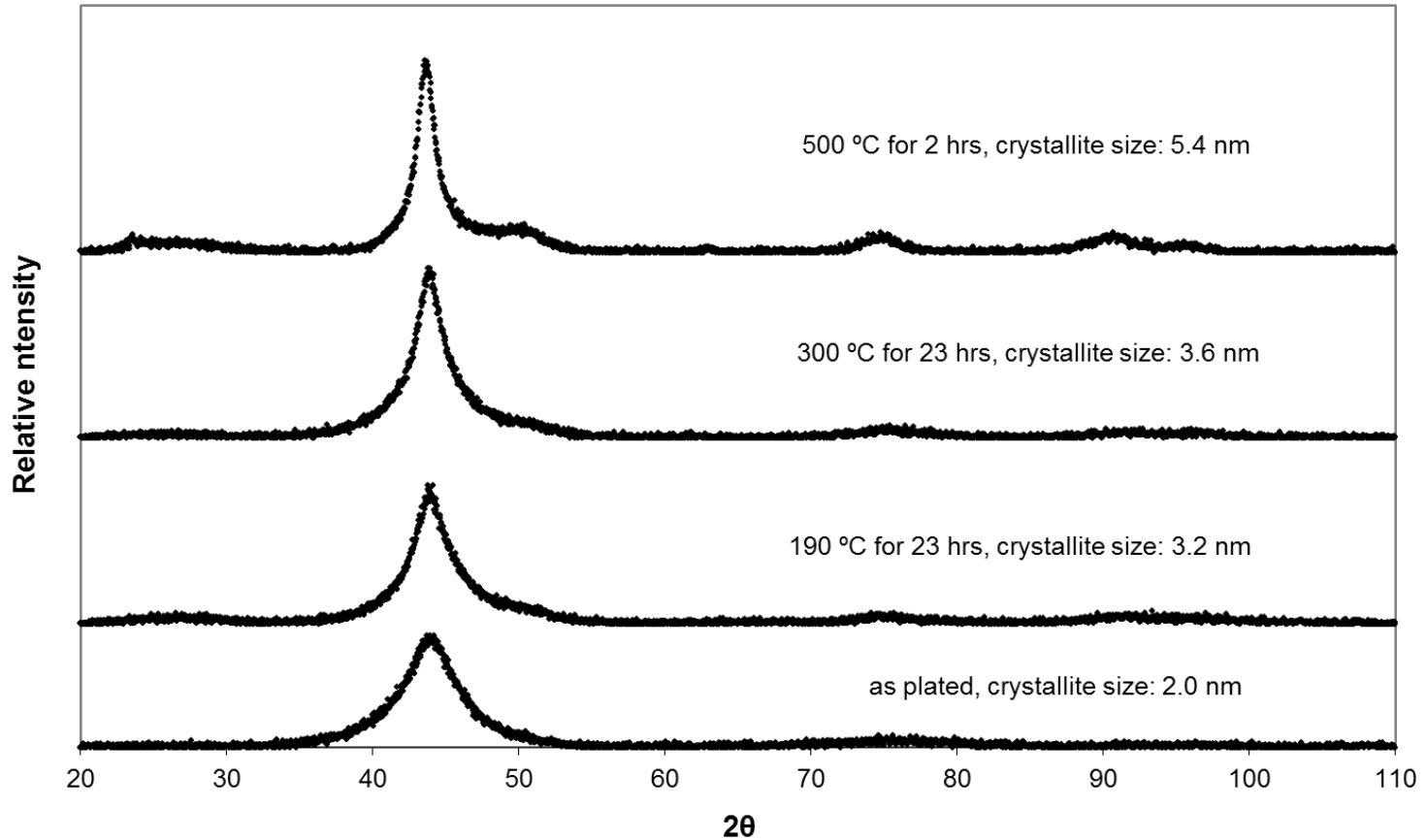


Banding to direction of growth, no compositional variation detected by EDX

Nickel-Tungsten deposit properties

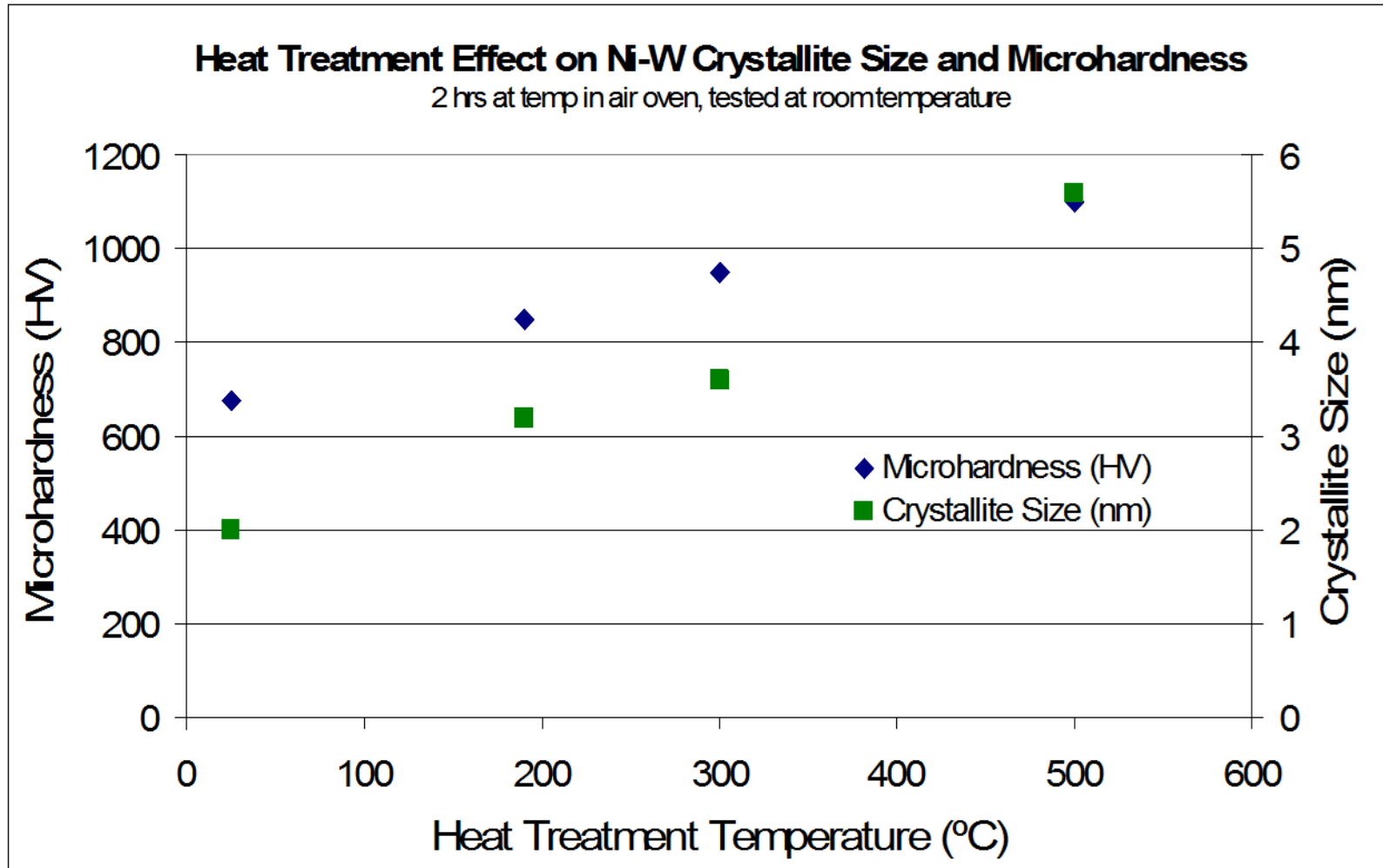
Property	Test method	Result
Microstructure	XRD	Nanocrystalline
Structure	Microscopy	Micro-cracked
Composition	Chemical Analysis	Ni 60 wt.%: W 40 wt.%
Residual Stress	Bent strip	12 ~ 16 kpsi tensile
Hardness	Microhardness (Vickers)	660 ~ 690 HV
Hydrogen embrittlement	ASTM F519 1a.1 notched bar	Pass without bake
Ductility	Bend test	1.6%
Abrasive wear	Taber	14 mg/1000 cycle
Friction coefficient	Pin on disk	0.35 ~ 0.55
Corrosion	Salt spray, NACE	Preplate to protect substrate
Fatigue	Axial fatigue	Debit

Crystallite size by x-ray diffraction



Heat: grain size growth ~ grain boundary relaxation

Heat treatment of nickel-tungsten



Hydrogen embrittlement (ASTM F 519)



Ni-W deposit on ASTM F519 Type 1a.1 notched bars (AISI E4340)

- Ni-W plated directly onto notched bars & tested to verify the process is non-embrittling
- Tested per ASTM F 519 passing the 200 hour sustained load test
- No post-plating relief bake is required

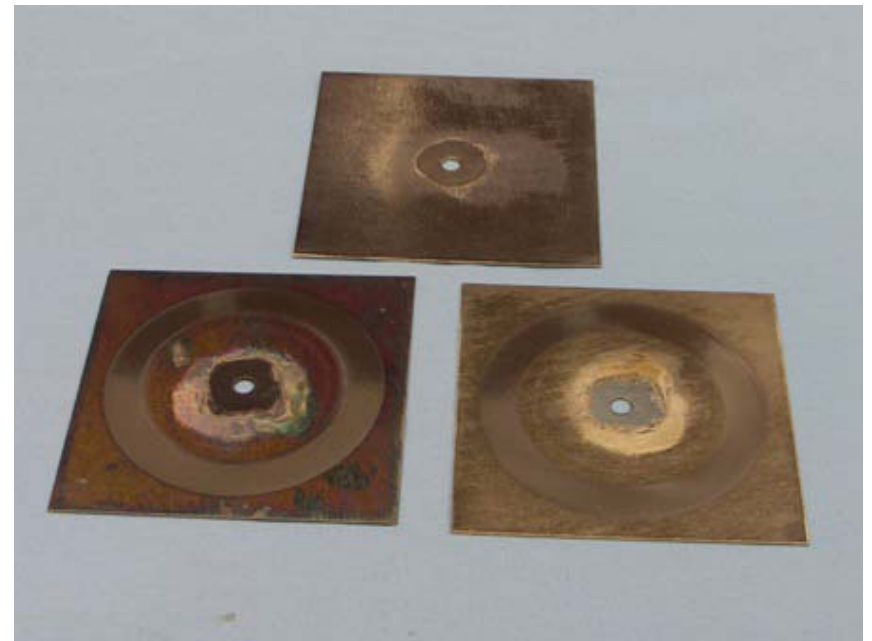
Sliding wear: pin on disk (ASTM G 99)

- Surface polished to R_a 0.1 μm for sliding wear test. As-plated surface is too rough, R_a 1.0 μm
- Extra sliding distance (>2,700 m vs. 500 m)
- Lower volume wear rate and friction coefficient

	Volume wear rate ($\text{mm}^3/\text{N}/\text{m}$)	Friction coefficient	Pin wear
Ni-W	0.5×10^{-6}	0.45	mild
EHC	10×10^{-6}	0.7	severe

Taber wear (ASTM D 4060)

- CS-17 wheel & 1000 g load
- 2 mil deposit on Taber wear panel

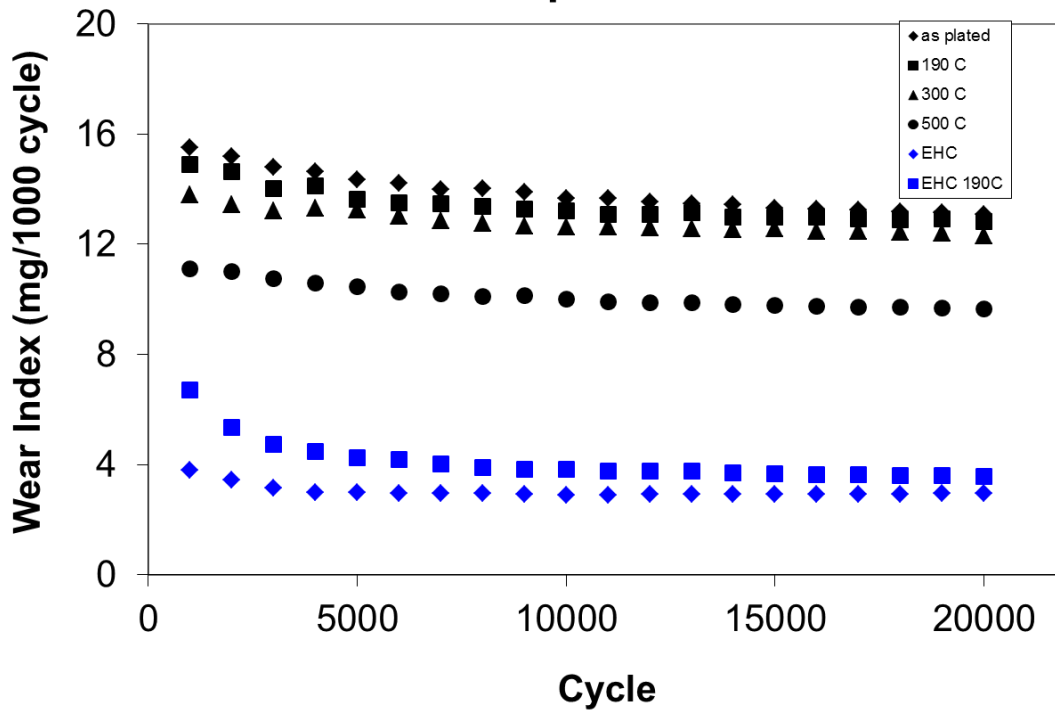


Abrasive Wear: Taber wear test

Wear Index ~ weight loss

Wear rate (nm/cycle) ~ volume loss

NiW Deposit and EHC

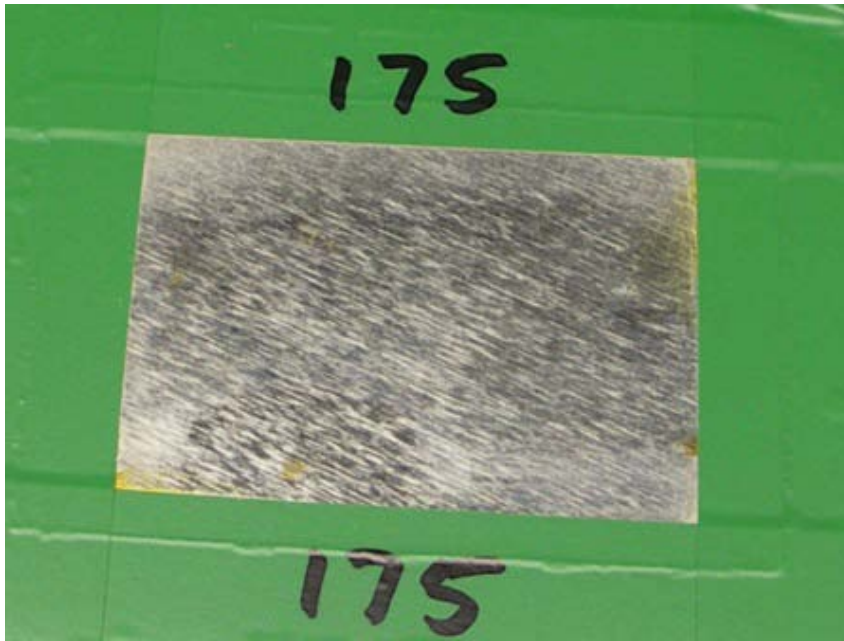


Heat treatment	nm/cycle
As plated	0.34
190 °C	0.33
300 °C	0.31
500 °C	0.25
EHC	0.13
EHC 190 °C	0.18

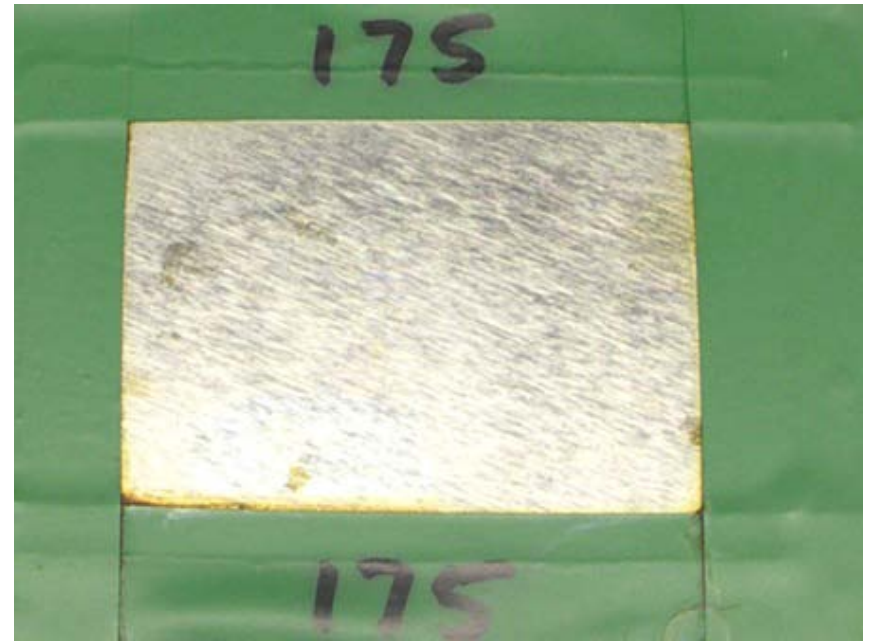
Salt spray corrosion (ASTM B117 test)

- Micro-cracked deposit is not impermeable, does not protect steel substrate during salt spray
- A Cu preplate (0.2 mil) to protect steel substrate

136 hours

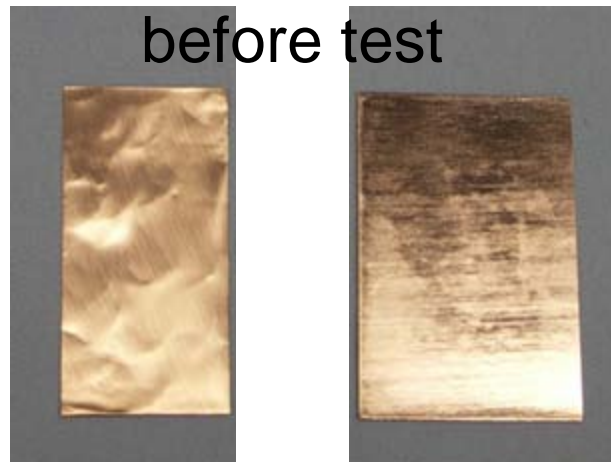


500 hours



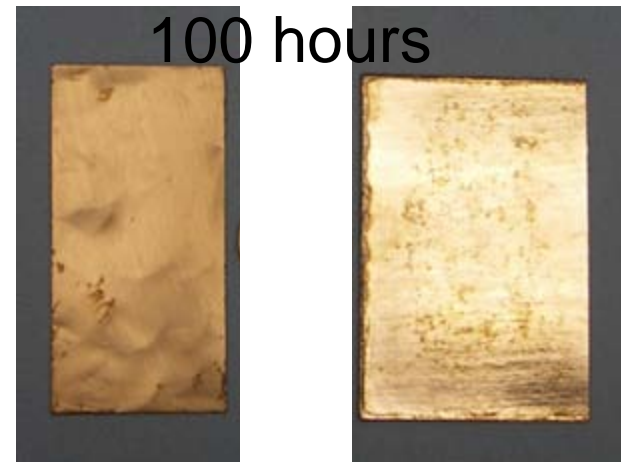
NACE (National Association of Corrosion Engineers) corrosion test

- H₂S containing environments in oil & gas production
- Ambient pressure, H₂S saturated (0.5 g/l), with NaCl (5 g/l), and acetic acid (adjust pH to 3.5 ~ 4.0)
- Corrosion rate ASTM G 31: Ni-W 0.072 g/(m²·hour)
Ni foil 0.046 g/(m²·hour)



Nickel 200 foil

Ni-W deposit



Nickel 200 foil

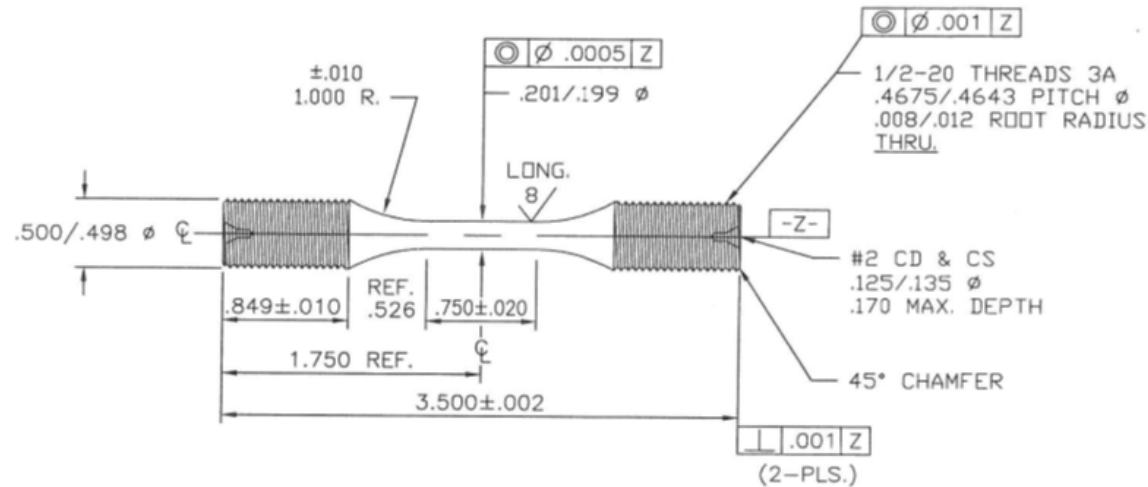
Ni-W deposit

Axial fatigue test (ASTM E 466)

- AISI E4340 steel heat treated per AMS H 6875 (50 ~ 53 HRC). Tensile strength tested (267 ksi).
- Specimens fabricated per ASTM E 466
- Blank and plated specimen tests at 3 stress levels



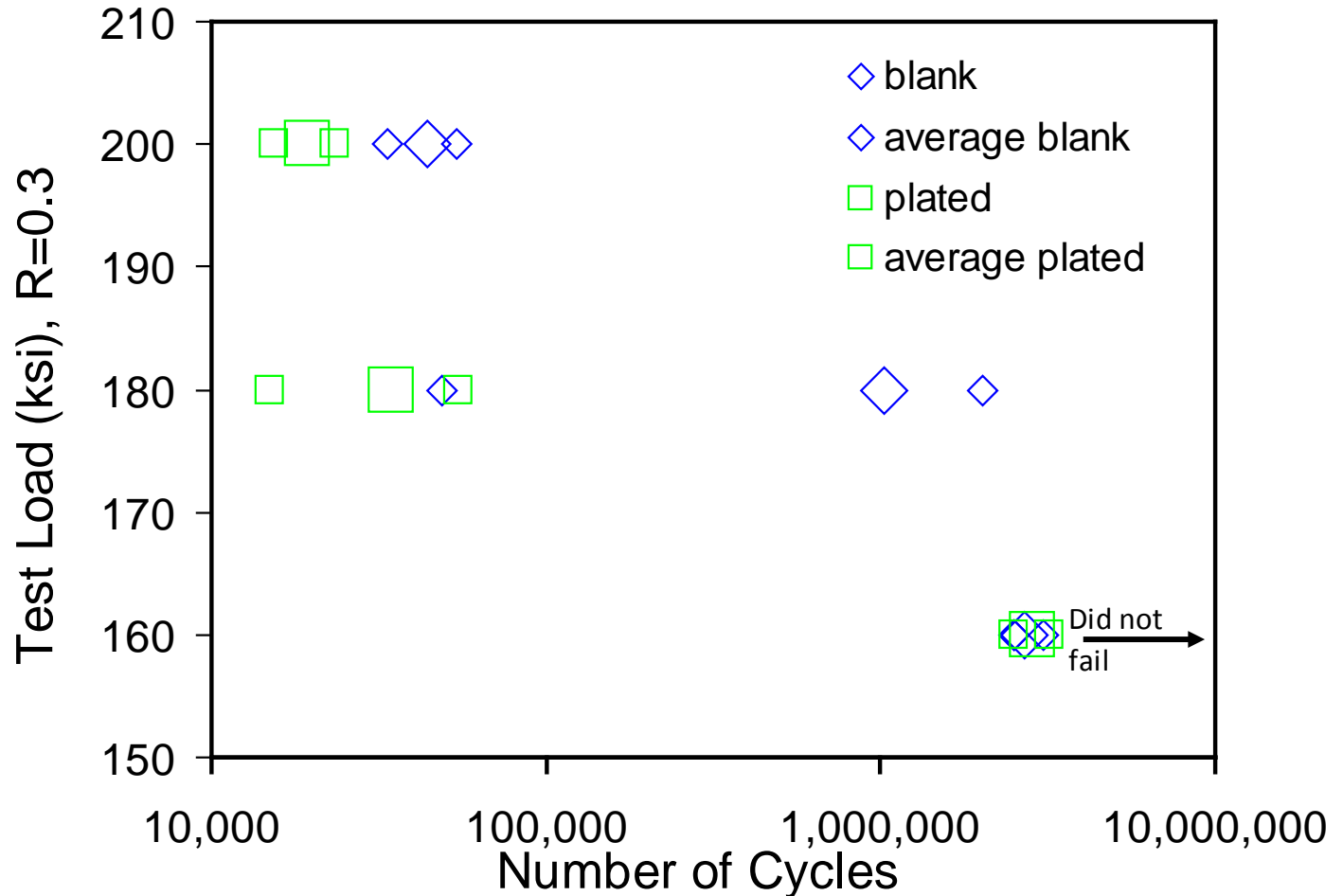
Fatigue specimens & test condition



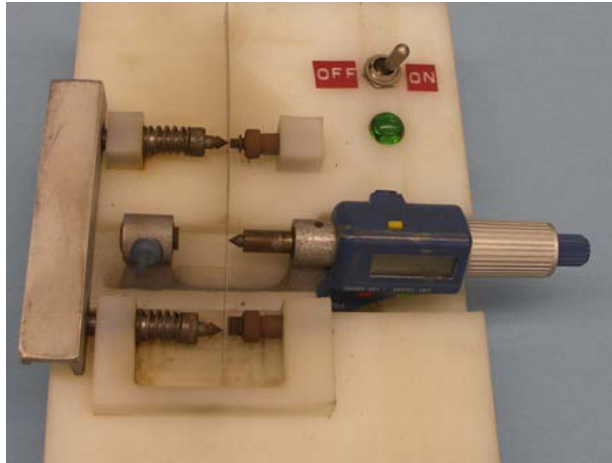
Low-stress machining	Stress load (ksi) R = -0.3		
	160	180	200
Blank 4340	3	3	3
Ni-W plated	3	3	3

Fatigue test results

Axial fatigue S-N plot: Ni-W plated and blank 4340



Other tests



- Composition: XRF, verified with ICP-OES
- Ductility: 6" long strips, bent around mandrels, per ASTM B 489
- Internal stress: difference of deflection of strip prior and post plating
- Chemical stripping (~0.1 mil/hour)

Properties comparison, Ni-W and EHC

		Ni-W	EHC
Structure		Micro-cracked	Micro-cracked
Ductility		<1.6%	<1%
Hardness HV	As-deposited	660 – 690	800 – 1200
	Heat treat 375° F 23 hr	830	790
Sliding wear (pin on disk)	Wear loss	5×10^{-7} mm ³ /N/m	10×10^{-6} mm ³ /N/m
	Friction coef.	0.45	0.70
Taber wear		14	3 – 6
Hydrogen embrittlement		Pass without bake	Pass with bake
Axial fatigue		Debit	Debit

Summary

- Ni-W alloy brush plated with high tungsten content
- Good hardness, improves with heat treatment
- Excellent wear properties
- Lower friction coefficient vs. EHC
- Better pin wear (counter part) vs. EHC
- Plating faster than EHC
- Ni-W plated directly on high strength steel meets hydrogen embrittlement requirement without bake

Future work

- Rotating beam fatigue
- Hydrogen embrittlement test with heavy build-up
- Application specific testing (other fatigue specimen, other wear, other corrosion, etc.)
- Plating on chrome, and other chrome replacements

Thank you!

Contact us

SIFCO Applied Surface Concepts

Phone: (216) 524-0099

**Email: info@sifcoasc.com,
sclouser@sifcoasc.com**

Website: www.sifcoasc.com