Brush Plating of Nickel-Tungsten Alloy for Engineering Application

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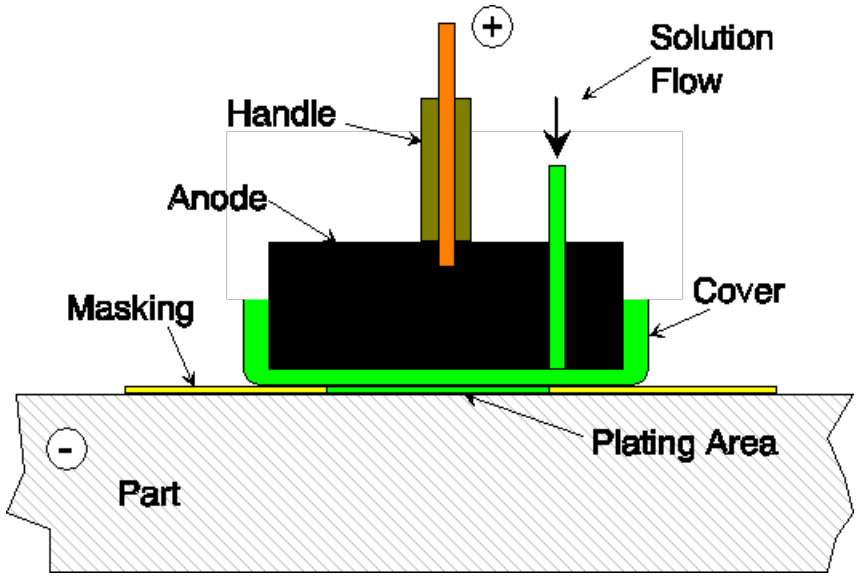
Engineering (functional) applications

- 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

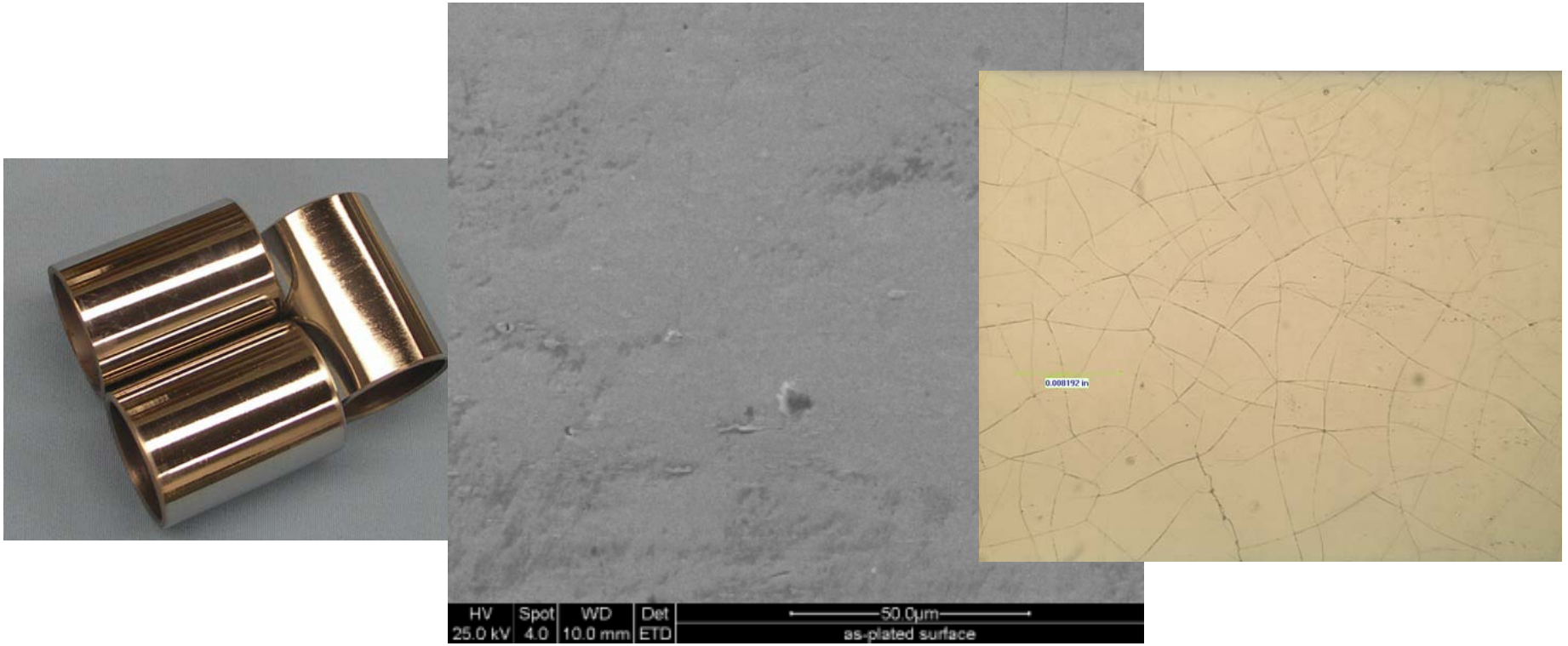
Brush plating of Ni-W

- 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

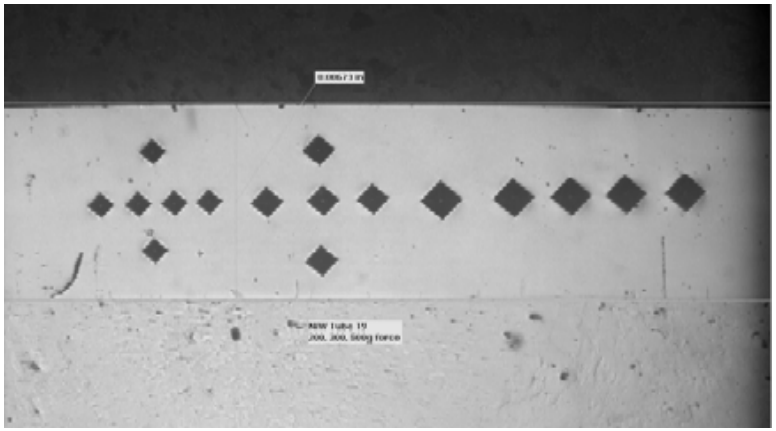
Ni^{+2} (g/l)	35 ± 2
W^{+6} (g/l)	35 ± 2
pH	7.8 ~ 8.1
Temp (°C)	55 (49 ~ 59)
Current density	1 ASI (0.16 A/cm^2)
Plating rate	3.1 mil/hr (80 µm/hr)
Current efficiency	55 ~ 60 %

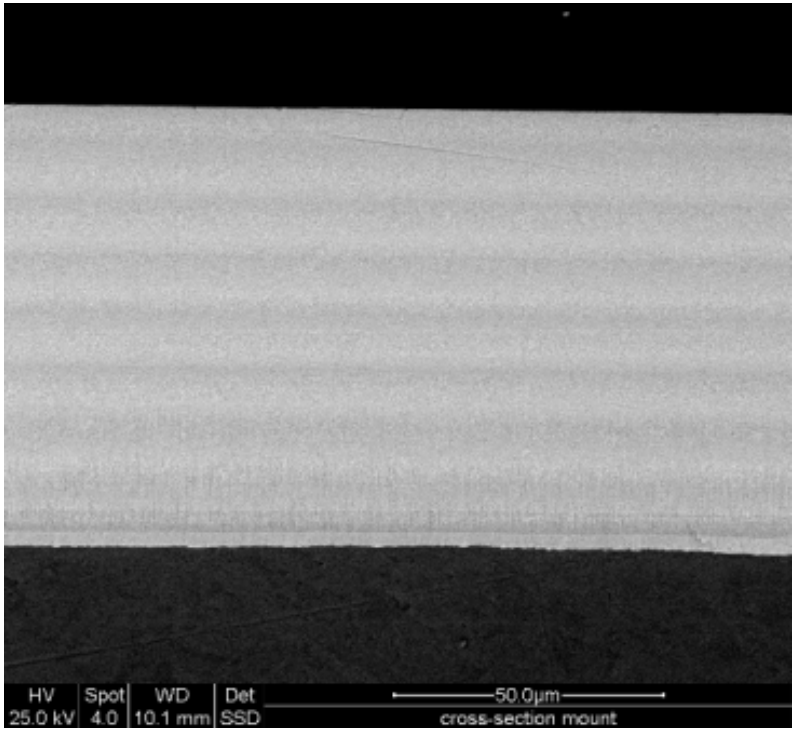
Surface morphology



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

Deposit structure in cross-section



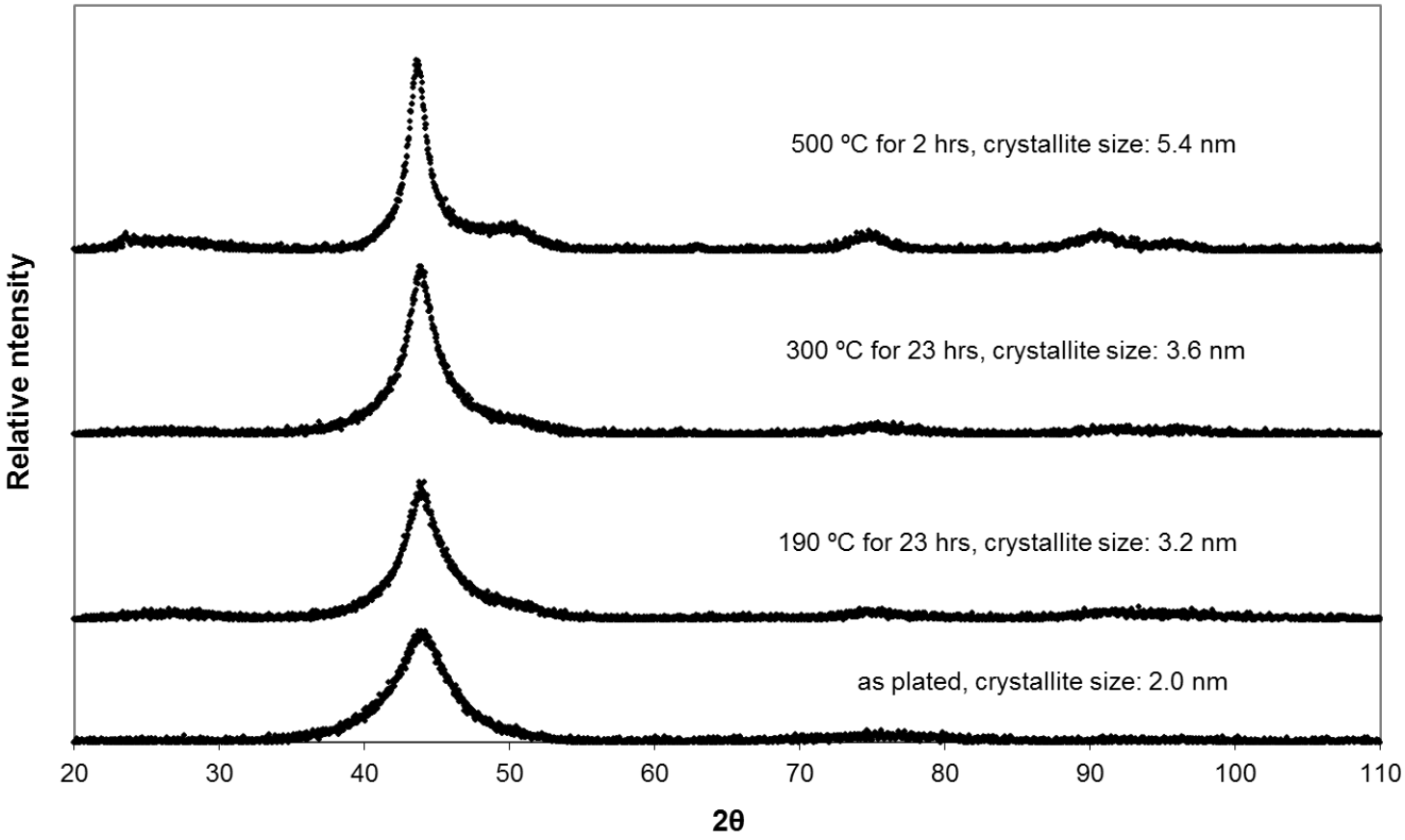


Banding to direction of growth, no compositional variation detected by EDX

Nickel-Tungsten deposit properties

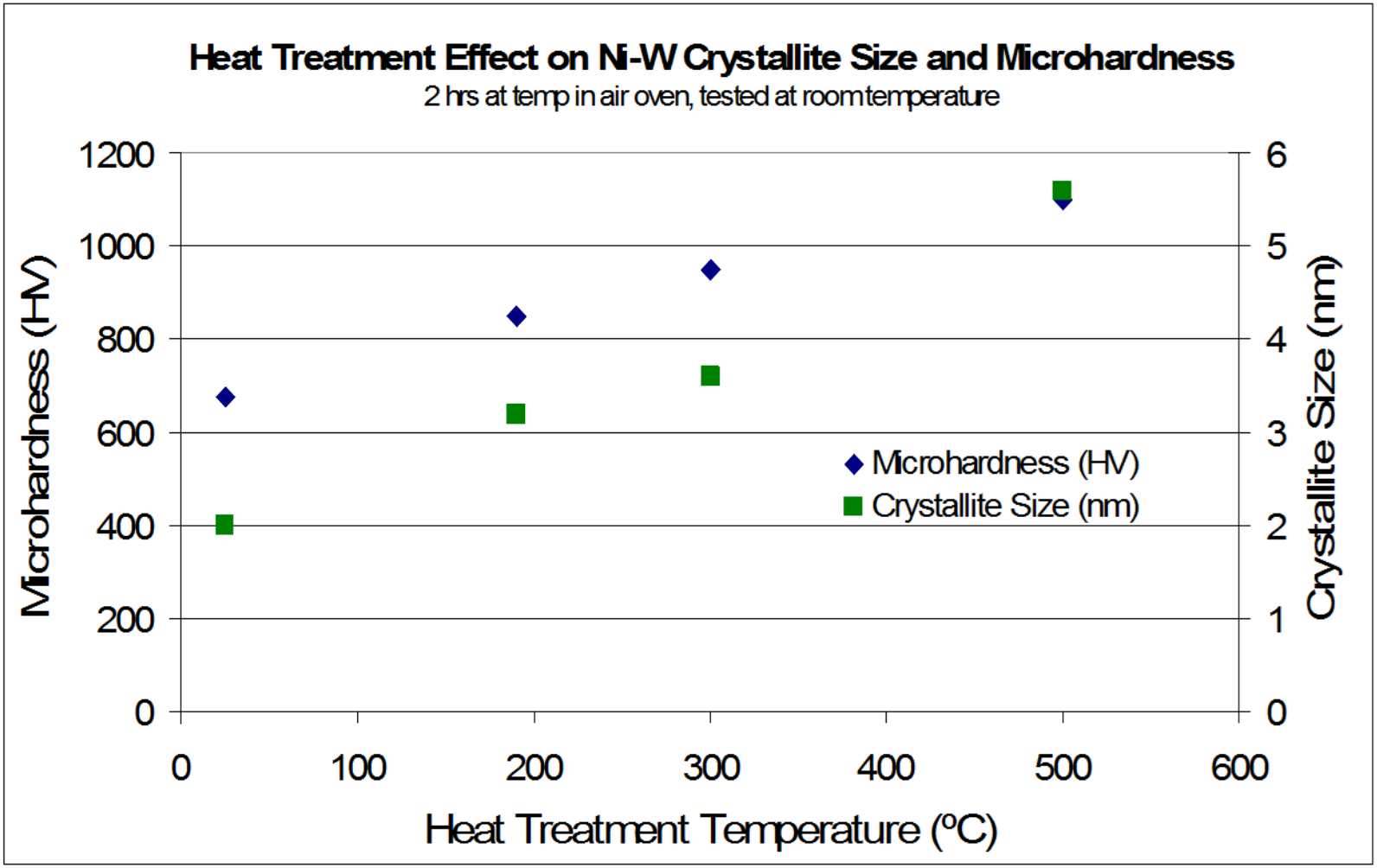
Property	Test method	Result
Microstructure	XRD	Nanocrystalline
Structure	Microscopy	Micro-cracked
Composition	Chemical Analysis	Ni 60 wt.%: W 40 wt.%
Residual Stress	Bent strip	12 ~ 16 kpsi tensile
Hardness	Microhardness (Vickers)	660 ~ 690 HV
Hydrogen embrittlement	ASTM F519 1a.1 notched bar	Pass without 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

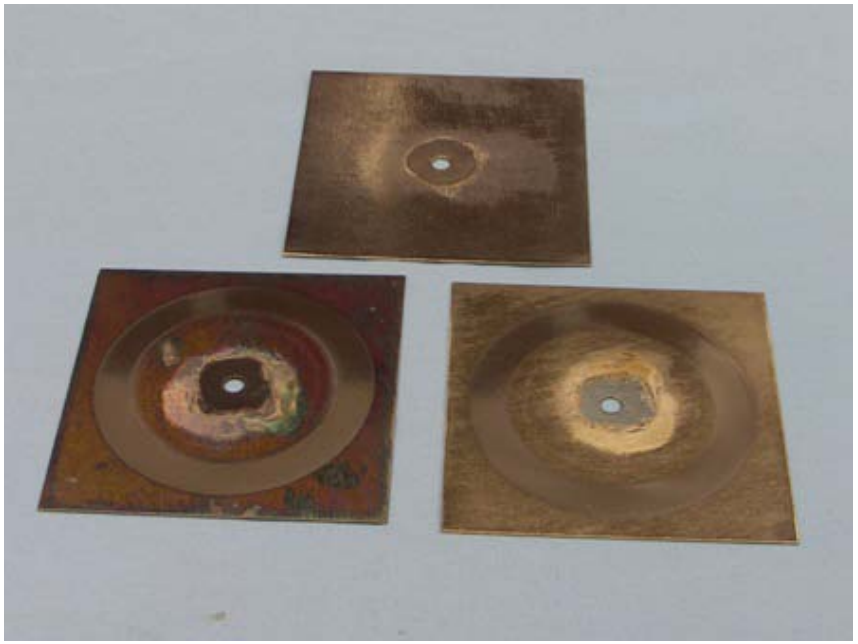
Sliding wear: pin on disk (ASTM G 99)

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

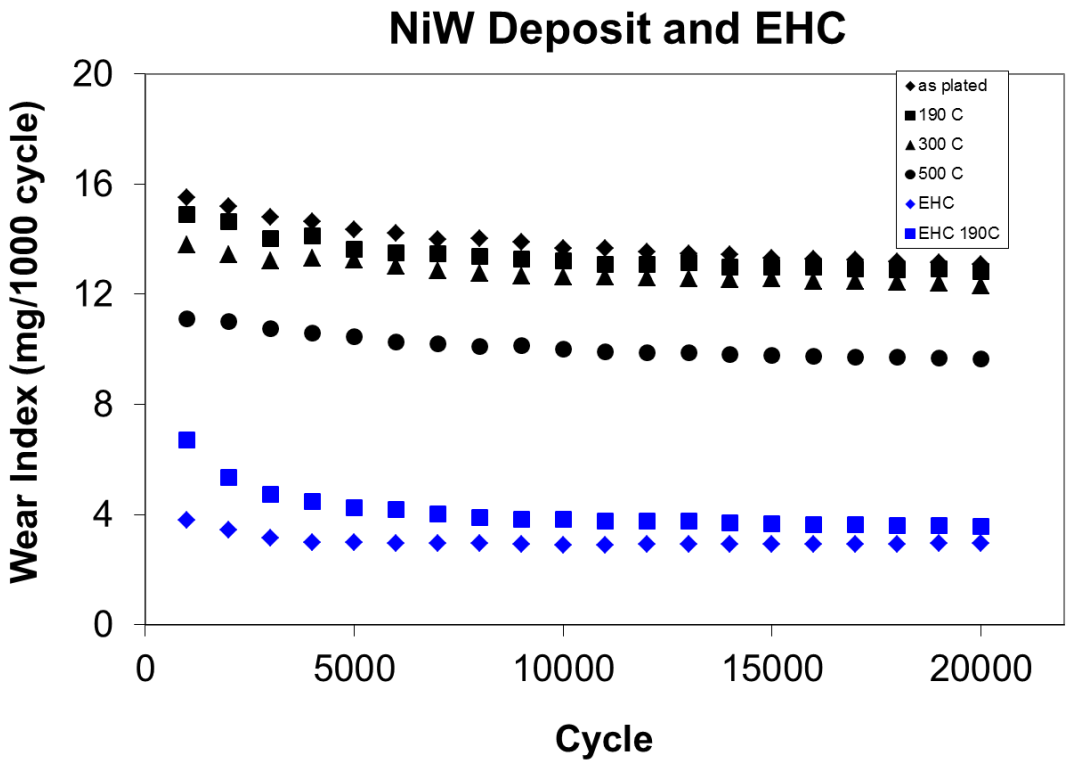
Taber wear (ASTM D 4060)

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



Abrasive Wear: Taber wear test

Wear Index ~ weight loss



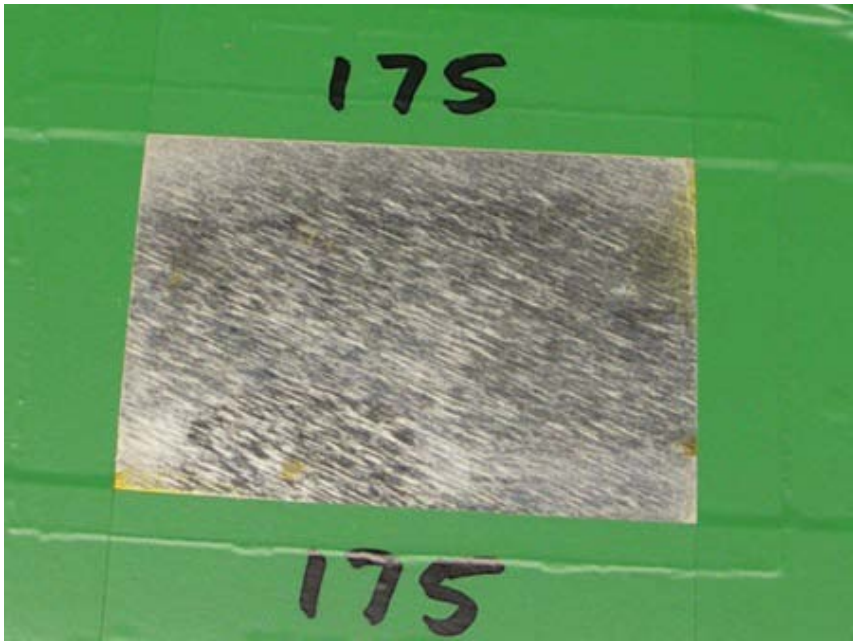
Wear rate (nm/cycle) ~ volume loss

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

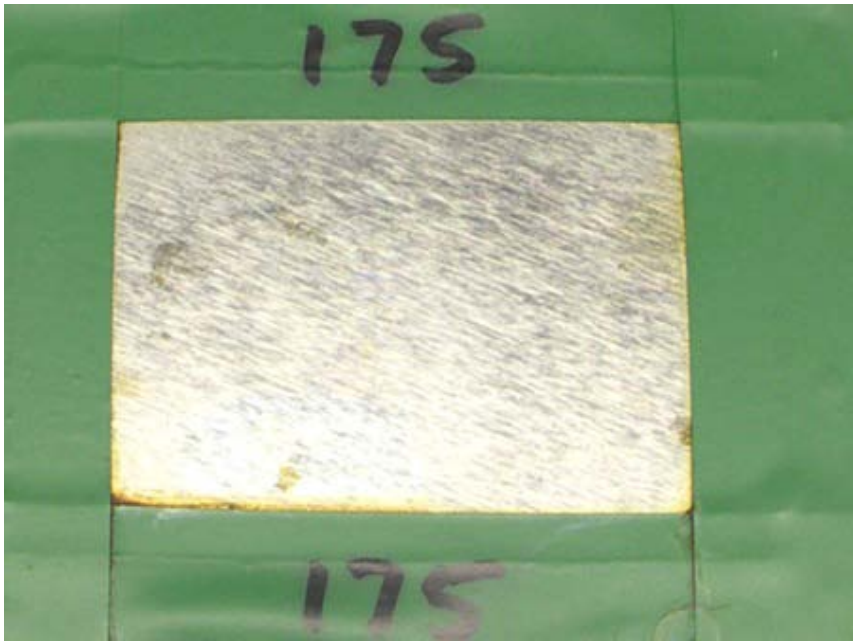
Salt spray corrosion (ASTM B117 test)

- 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

- H_2S containing environments in oil & gas production
- Ambient pressure, H_2S 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/(m^2·hour)
  Ni foil 0.046 g/(m^2•hour)

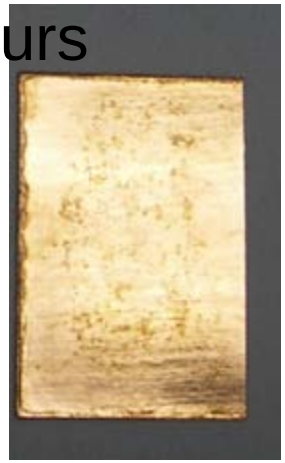
before test

Nickel 200 foil

Ni-W deposit

100 hours

Nickel 200 foil

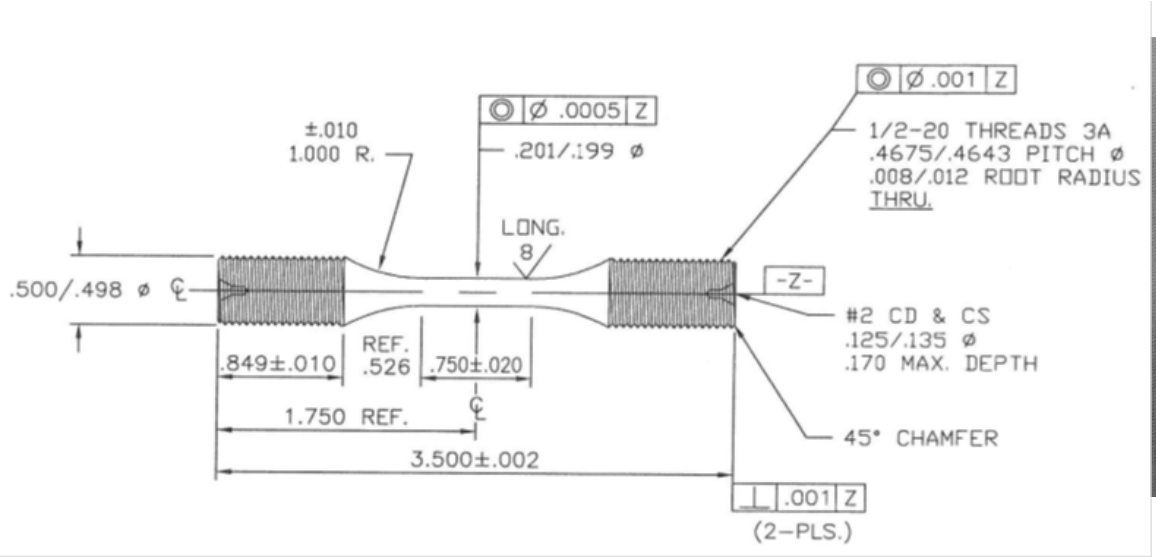


Ni-W deposit

Axial fatigue test (ASTM E 466)

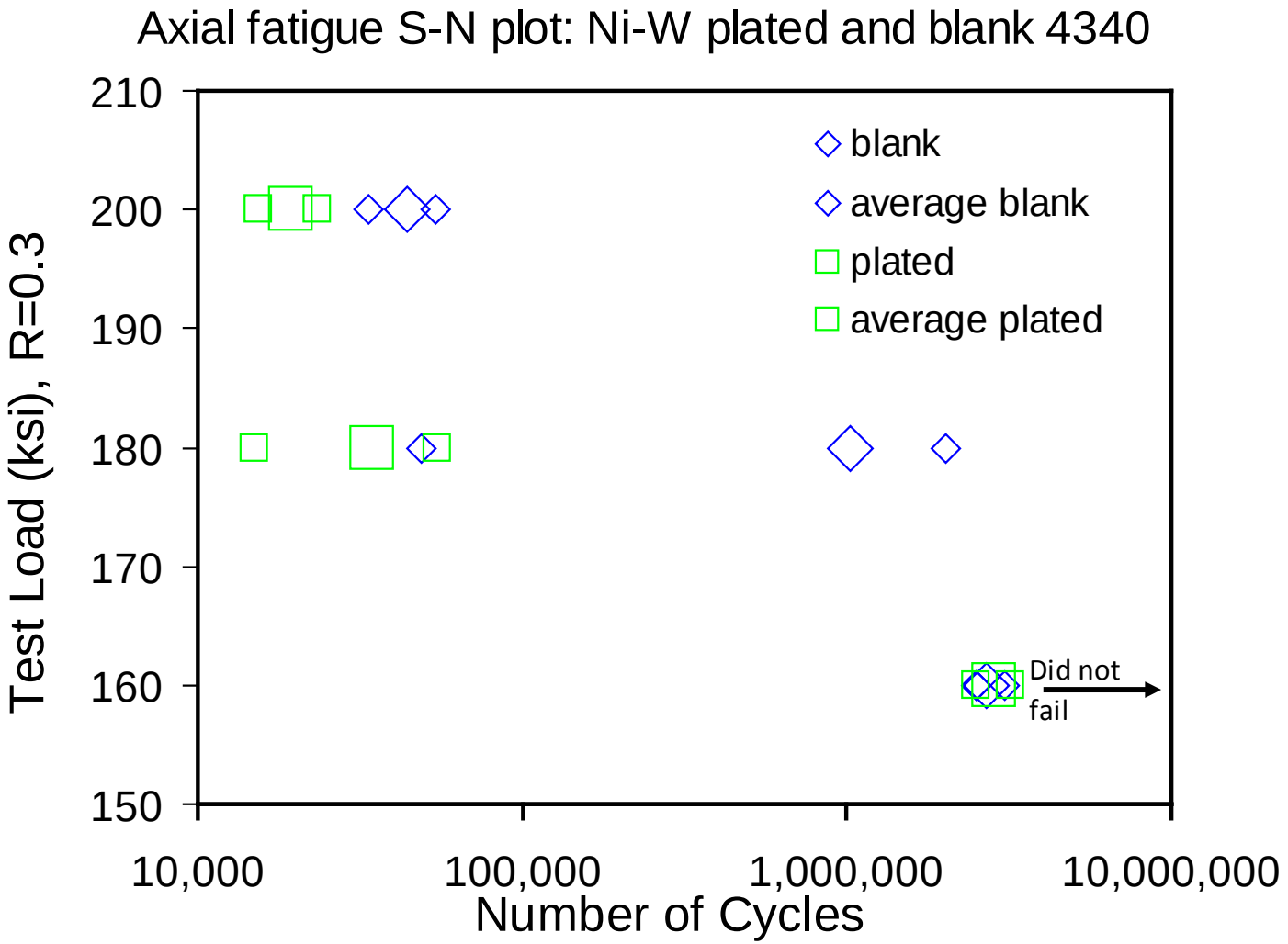
- AISI E4340 steel heat treated per AMS H 6875 (50 ~ 53 HRC). Tensile strength tested (267 ksi).
- Specimens fabricated per ASTM E 466
- Blank and plated specimen tests at 3 stress levels

Fatigue specimens & test condition

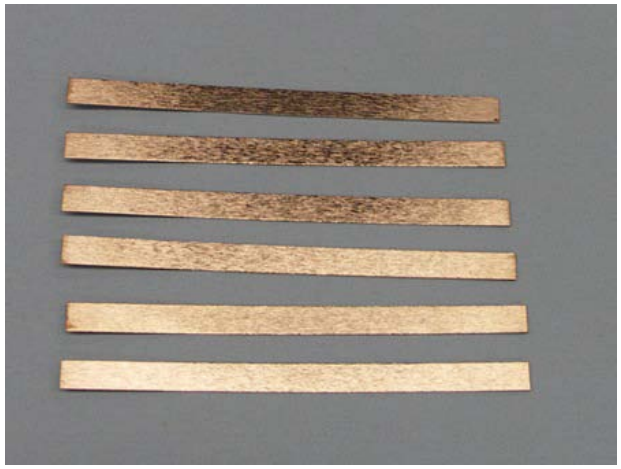


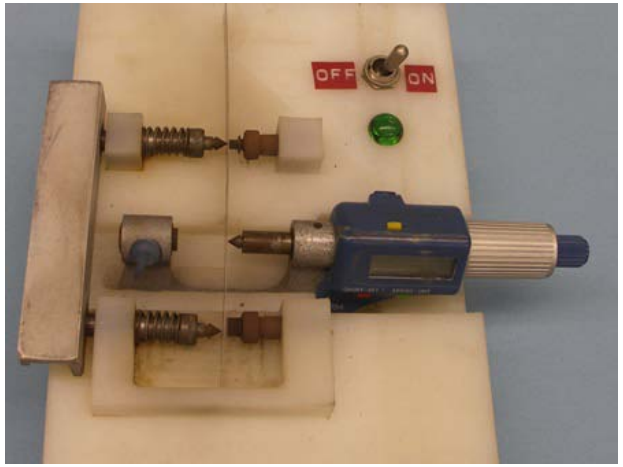
Low-stress machining	Stress load (ksi) R = −0.3 160	180	200
Blank 4340	3	3	3
Ni-W plated	3	3	3

Fatigue test results



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 375º 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

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