Thinking outside the bucket with non-drip electrochemical processing

Jean-Pierre Chaix, Dalistick France
Alan Rose, Keith Legg
Corrdesa LLC, USA
770–328–1346, arose@corrdesa.com
847–219–9868, klegg@corrdesa.com

Adapted from talk given by KOL at NASF SURFIN 2013
Electrochemical Processing

- Electrolytic processes are widely used for surface finishing
  - Electroplating
  - Anodizing
  - Electrolytic stripping and cleaning
  - Electropolishing
  - Non-electrolytic sealing, passivation
  - Chem milling
- Work very well
  - What about rework and repair?
Brush plating

- Hard to control and messy
  - Dip (quill pen) method
  - Pump (fountain pen) method
  - Catch and reuse electrolyte
Brush plating

Advantages
- Portable, plate anywhere
- Minimal volume, so minimal fumes
  - Avoids need for extensive air handling, scrubbing
- Avoids strip and replate
  - Reduced cost
- Avoids need for removal or disassembly

Downsides
- Messy – can drip and splatter
- Uncontrolled plating conditions
  - How handle QA and QC?
  - No records except what the operator writes down
- Have to be really careful about plating in place
  - How do you catch 100% of the run-off, prevent damage and contamination to adjacent components?
  - Especially in tight spaces, aircraft bays
There’s a reason it is called “Brush Plating”

- Because it does not use a brush – uses a pad
- You can use it to plate
  - Cd
  - Ni
  - Hard chrome
  - ZnNi
  - No-bake Cd (LHE Cd)
  - No-bake ZnNi (LHE ZnNi)
  - Silver
  - Or anything else your heart desires, provided it comes from aqueous solution
So, would anyone replace this with this?

Not really, no!
Think about what we have

- We have an anode, a power supply and an electrolyte
  - So we have the basics of an “electrochemistry set”
- Therefore we can do most of the “Electrolytic methods widely used for surface finishing”:
  - Electroplating
  - Anodizing
  - Electrolytic stripping and cleaning
  - Electropolishing
  - Non-electrolytic sealing, passivation
- Chemical milling
- And we can do them almost anywhere
But it is

✓ **STILL** messy
✓ It **STILL** has no QA/QC
✓ **STILL** just plating
✓ It can **STILL** only be used for small areas

RIGHT?...........WRONG!
First let’s get rid of “brush plating”

Change the **plus** to **minus**

and the **minus** to **plus**

Now what we have is **brush electrofinishing**
Second, let’s get rid of the chemical mess

- Non-drip stylus continuously recirculates electrolyte from holding tank through the head
  - Cleaning, anodizing and plating in any orientation, including overhead
  - Eliminates drips and splashes
  - Eliminates most of the fumes
  - Now you can treat in-place
Third, let’s give it some QA/QC

- We could use a robot
  - Maybe not – it rather destroys the concept of a nice, simple plating process

“I’m sooo depressed Brain the size of a planet and all you want me to do is brush plate”
Third, let’s give it some QA/QC

Computer control
- Automatically uses standard processes for QC
- Forces operator to follow procedure
- Data logging to capture run conditions, voltages, currents, times for QA

![Image of computer control setup with labels](image-url)

- Temp regulated/cooled tank
- Unique non-drip tool
- Computer control
- Printer
- Rectifier with computer control
- Process control and pump
Finally, let’s get rid of only plating small stuff

Production brush Ni + ZnNi on slat leading edge

Not every brush process is compatible with large scale, but it can be done
Anodizing engine cowl
Brush anodizing
Hard anodizing

- Chromic and sulfuric acid anodizing
- Thickness up to 90 microns
- Hardness up to 370 VHN
- Essentially same as bath anodize layer
For each alloy, a specific anodizing time determines layer thickness.

When anodize, rule of thumb is that half the material diffuses in and half builds out. Therefore anodizing can be used for limited build-up of Al components.
Production rework of oversize holes

Note: Proper attention must be paid to fatigue concerns if holes are likely to experience high stress.
Hard anodizing in bores for rework, corrosion, wear resistance

Qualified anodize restoration of bore diameter in floor beam with hard SAA anodized layer 70 to 90 µm thick

Note: This repair uses a flow-through brush tool, but a non-drip head could be specially designed for bore repair
Small area repair
With tank plating need a way to **rework** and **repair**

- Cold spray Al and brush plated no-bake ZnNi qualified by Boeing
  - Brush plating easier and widely available
  - Qualified to BAC5664 as no-bake brush ZnNi
    - No need for hydrogen bake to prevent embrittlement
ZnNi electroplate for Cd repair

If necessary ZnNi can be plated over Cd plate provided Cd plate adhesion is satisfactory, so Cd remnants not a problem.

Cu overplate for sectioning

ZnNi

Original Cd

Steel substrate
Repair and local plating/anodizing on large parts

Areas to be anodized

Anodizing areas of aircraft wing
Color-match repair – sulfuric acid anodized hydraulic cylinder

It is possible to come close to an “invisible” repair by careful matching of surface roughness, anodize thickness and sealer.
Anodized housing repair

Grind damage

Repair

Contacts: arose@corrdesa.com 770.328.1346; klegg@corrdesa.com 847.219.9868
Large area repair
Brush plating as a large scale process

French Navy uses for sea surveillance
Wing flap leading edge exposed to sand and salt

Dassault Guardian/Falcon
Problem – pitted slat leading edge

This is a far bigger area than people would usually brush plate
Problem with Ni to repair Al

- Sulfamate Ni is an excellent material to fill in protect
- But Ni is highly cathodic to Al
  - If plate Ni on Al the Al will galvanically corrode
- Therefore overcoat with ZnNi
  - Galvanically compatible with Al
  - Hard enough to resist damage

Non-drip brush plating to repair flap
ZnNi can be polished

- Slat surface tested as-deposited and polished
  - Looks very nice, but mirror finish lost with one or two low-level flights over ocean
  - Therefore usually used as-deposited for this application
2219 Al with pits up to 0.01” deep

Approved repair procedure:
• Grind out corrosion
• Fill with sulfamate Ni (350 VHN) up to 0.012” thick
• Hand grind with profile tool to original profile spec
• Since Ni would galvanically corrode Al, overcoat with 0.0005” LHE ZnNi (300 VHN)

Flight testing:
• Paint quickly gets damaged again
• ZnNi shows no further damage or corrosion
• Therefore final finish is ZnNi, without passivate or paint
• Now in production
Pulling it all together:
A complete electrochemical repair
Demonstration of electrochemical repair

- Under AFRL/CTC program Dalistick developed process for corrosion repair of steel components in confined space – proof of concept
  - Problem – initial components Cd plated/chromated
  - Chemical dissolution used to avoid contact with Cd
  - Then replace with “green” alternative
- Approach
  - Electrochemically remove Cd using non-drip system to avoid Cd dust and operated contact with Cd
  - Remove corrosion and activate surfaces electrochemically
  - Replace Cd plating with LHE ZnNi plating
Testing of processes

Initial status with no corrosion

Activator XF

Activator ST2

Initial status corroded

Cadmium

Zinc-Nickel

Contacts: arose@corrdesa.com 770.328.1346; klegg@corrdesa.com 847.219.9868
Electrochemical cleaning, removal of rust and Cd

Cd and rust electrochemically stripped with acid activator
Removes rust, but leaves residual corrosion pits, which can be removed mechanically or by electropolishing
Getting rid of the emissions mess

- Emissions testing carried out over a period of two hours with no air extraction.
- Personal exposure monitors to capture emissions
- Emissions well below allowable US OSHA exposure limits

<table>
<thead>
<tr>
<th>Process</th>
<th>Substance</th>
<th>Measured</th>
<th>OSHA PEL (8 hr TWA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd plating</td>
<td>Cd</td>
<td>0.0001 mg m$^{-3}$</td>
<td>0.005 mg m$^{-3}$</td>
</tr>
<tr>
<td>CAA</td>
<td>CrO$_3$</td>
<td>0.0005 mg m$^{-3}$</td>
<td>0.005 mg m$^{-3}$</td>
</tr>
<tr>
<td>ZnNi plating</td>
<td>Ni sulfate</td>
<td>0.0008 mg m$^{-3}$</td>
<td>1 mg m$^{-3}$</td>
</tr>
</tbody>
</table>
Conclusions

- We can use computerized non-drip brush electrochemical processing to carry out complete repairs with far less environmental impact and cost while still maintaining process control, QC and record keeping
  - Minimize ESOH issues for workers and workspaces (EPA and OSHA limits)
  - Recirculation and chemical containment
  - Reduced air emissions, environmental and health risks
    - Even when plating with Cd or chromates
  - Ability to replace toxic materials with clean alternatives
  - Ability to repair in-place with minimal risk of contamination or damage to nearby equipment