A Personal View of the History of Twin-jet Electropolisher

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Way back in 1966, when I first started my industrial career at U.S. Steel's Edgar C. Bain Laboratory for Fundamental Research (which is what it was called before it became a grease spot *in Corporate America)* Gene Fischione and Dick Glenn were engaged in a "moon race" of sorts to bring out some of the earliest electrolytic jet polishers. Remy Schoone helped Gene build his model; and Bob Sober helped Dick make the competition. I haven't used either one of these fine instruments in nearly thirty years, so the only connection is historical and the good feelings I have about the four nice guys who made them.

There are apparently two basic reasons for the jet polisher's success: one principle is that adjusting the flow rate changes the polishing conditions in much the same way as changing the voltage across the cell. One first goes through a linear increase in polishing current (with increasing flow rate), then a local maximum, then a decreasing current, and lastly a rapidly increasing current. The regime between the maximum and the minimum is where the best polishing takes place. Go past the minimum, and gas evolution begins, accompanied by pitting. The second reason is that the turbulence of the jet impinging on the workpiece reinforces the boundary layer (called the anilyte layer by the jet set) at the interface between the workpiece and the electrolyte. Even without a suitable electrolyte (one that *naturally forms* an anilyte layer in the absence of any flow), the jet polisher forces there to be an artificial anilyte layer because of the boundary layer inherent in turbulent fluid flow. In other words, the jet flow tricks the electrolyte.

The first principle allows the cell to be easily adjusted to obtain polishing conditions for the particular geometrical and chemical parameters for each specimen. Just start from a low flow rate (*i.e.*, pump speed) and gradually increase until one gets into the reverse characteristic between the maximum and the minimum. *This technique was infallible for me -- I never got a poor surface.*

The second principle allows the use of just about any electrolyte to polish what would at first seem impossible. My favorite was an iron-gold alloy whose phase diagram suggested that I could heat treat to get approximately 50% face-centered cubic and 50% body-centered cubic phases - pure gold and pure iron intimately mixed. Hah, I made very nice thin foils from that stuff, regardless of its phase composition, with ordinary sodium chromate (the use of which is probably a felony these days ...) and with about the same conditions as for ordinary iron. Another small success was the making of copper thin foils with an electrolyte, which worked best in the (quite vigorous) gas-evolution regime. The reference to that electrolyte is buried in one of my old papers; I forget it right now. The copper was easy in the face of adversity because the boundary layer resulting from just the fluid flow functioned as an affective anilyte layer, I guess.

Another virtue of the jets was that the geometry could be adjusted to compensate for poor (or just plain difficult) specimen preparation. Many of the tiny disks that I made from my iron wires (necessarily all different diameters, ranging from about 1/4 inch down to 1/64 inch) were distinctly wedge-shaped, so the thin area didn't want to be in the center. I would simply place the specimen holder way off axis in the space between the jets so as to compensate. This worked fine, with few failures.

The twin-jet polishers made the old window technique obsolete, because the specimen was simply centered on the line between the jets and close attention was paid to the polishing current (in the use of Dick Glenn's plain-Jane apparatus) or waited for the bells & whistles to go off (in Gene Fischione's gussied-up apparatus). One got a small hole, but all around the perimeter of that hole were acres and acres of thin area—usually.

I had no trouble making good thin foils from the 1/64th inch diameter disks, but it would take Dick the rest of the afternoon to get the foil suitably mounted between the grids because it was so small & shaped like a quarter-moon. Therefore, later on, Dick developed the technique of nickel plating the thinner (0.003 inch diameter) wires, again in the jet polisher (I think). Dick then cut disks with a wire-electrode EDM (Electrical Discharge Machining), and proceeded to make a thin foil. His first try was astoundingly successful, as he quickly noticed that the compressive residual stresses acting on the iron core made it pop up into a dome shape. The more the dome bulged, the thinner the specimen was becoming. It helped a lot that the iron polished faster than the nickel. The first disk was electron-transparent across the entire 0.003 inch diameter cross section of the wire, and Dick made a TEM picture of that entire cross section just for the record. The first one.

You might guess from this that I was partial to Dick's simpler apparatus; that was because of my variable-size (and, later, variable shape) specimens and because I was applying the techniques to strange alloys. I could see what I was doing better with Dick's prototype twin-jet polisher, and the much simpler specimen holder (an alligator clip soldered to a brass rod) accommodated my specimens much more flexibly.

Gene Fischione's twin-jet polisher was best applied to specimens of a uniform diameter. For those, it was easier to use because one did not have to go through the labor of applying stop lacquer around the specimen holder and around the perimeter of the specimen. Try that on a 1/64th inch diameter disk. Actually I didn't, I gave up using the stop lacquer on disks smaller than 0.020 inch. Gene's lollypop holder was a real labor saver if one could make everything into 1/8th inch disks.

The twin-jet electrolytic thin-foil machines therefore worked even better than ordinary electropolishing because the boundary layer inherent to turbulent flow accomplished the same end as the anilyte layer in the best electrolytes. Marginal materials or marginal electrolyte could be used. The current-flow rate characteristic of a jet polisher looks just like the current-voltage characteristic of an ordinary electropolishing cell, so the practical adjustments are easy and a period of trial and error is not needed to find the right conditions.

That's my history of the post-invention development of the twin-jet electropolisher. There's not much more that I can say. ■