The NICE [3]-Whyco Technologies Partnership: Saving Energy, Dollars, and the Environment in the Metal Plating Industry

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ABSTRACT

In partnership with the U.S. Department of Energy's Office of Industrial Technology, Whyco Technologies, Inc., has developed an innovative perforated plating barrel used in the plating of metal parts. This new technology employs a thin-walled construction, differing from the traditional thick-wall design required to provide adequate structural integrity. The thicker walls lowered the efficiency of transferring plating solution into and out of the barrel and diminished the electrical current pushed through the holes and onto the parts being plated. By machining pockets out of the traditional thick-walled perforated structure, Whyco produced a "honeycomb" of staggered cells, allowing for the greatest number of holes per open area while maintaining structural integrity. Hydrodynamic pumping occurs during barrel rotation to create greater solution transfer than in traditional barrels. The Whyco barrel has higher current density plating, which leads to faster plating cycles, reduced bath concentration, and better plating of difficult chemistries such as in alloys. This new technology has helped the company reduce energy use by 16%, eliminate more than 480 tons/year of solid waste, and reduce wastewater by more than 17,000 gallons/day. The resulting cost savings total more than $500,000 annually. The company has manufactured and sold more than 275 of these barrels to other electroplating companies that are reporting up to a 40% increase in plating productivity and similar energy and environmental impacts.

Introduction

Electroplating is the process of applying a thin layer of metal to an object by means of electrolytic deposition. While the exact method may vary in detail, virtually all electroplating processes are identical. The objects to be plated are suspended (either on a rack, in a barrel, or by wire fixture) in an electrolytic solution; these objects become the cathode (negative electrode) in the electrolytic deposition process. The anode (positive electrode) is introduced and is typically a plate of the metal to be deposited. A low-voltage direct current applied to the system induces metallic ions to migrate to the cathode (the object to be plated) where they are deposited. Electroplating is done to either metal or plastic to provide corrosion or wear resistance, to improve the object's appearance, or to increase the object's dimension.

Objects to be plated are placed in plating barrels or on racks and lowered into and out of plating and rinsing tanks. The specific type of plating required determines the types and numbers of plating and rinsing cycles necessary.

The electroplating process is both energy- and environmentally-intensive due to the electricity required in the process and the metal-latent electrolytic solutions used. It was these two constraints that drove the research for a less energy-intensive and more environmentally friendly process; this was the focus of the partnership between the National Industrial Competitiveness through Energy, Environment, and Economics program (NICE^3), a program sponsored by the U.S. Department of Energy's Office of Industrial Technologies, and Whyco Technologies, Inc..

An electroplating firm located in Thomaston, CT, Whyco had developed and tested an innovative plating barrel. Through in-house testing and use, Whyco realized it had a product that could be used by the entire electroplating industry. To acquire additional funding to demonstrate the use of this barrel, Whyco teamed with the State of Connecticut and received a $390,000 grant from the U.S. Department of Energy's NICE^3 Program. The federal government's show of support also increased their product's visibility with potential customers. The addition of the NICE^3 grant to Whyco's own investment of over $690,000 provided the additional boost needed to diversify beyond electroplating to barrel production.

Background

In electroplating using a barrel (barrel plating), parts are placed in a perforated polypropylene barrel as they are moved through the plating process. Barrel plating is the preferred technology when plating small parts that could not economically be placed on a rack or fixture.

In traditional barrel plating, the plating barrel has a wall thickness ranging from 0.75 to 1.0 inch, with thousands of holes drilled into the walls to allow electrical current and plating solution into the vessel. The wall thickness is required to provide adequate structural integrity. However, this thickness also lowers the efficiency of transferring plating solution (electrolyte) into and out of the barrel and diminishes the electrical current that is pushed through the barrel's holes to the parts being plated. In essence, these mass transfer limitations require long plating cycles to allow for complete plating. Figure 1 shows a traditional plating barrel.

Such mass transfer difficulties also create unique problems during high tech alloy plating, a process in which combinations of metals are simultaneously plated onto the parts and the ratios of metals in solution must be carefully controlled. In traditional barrel plating, certain ions are selectively depleted in the barrel, disturbing the required electrolyte ratio and creating undesirable effects, including a lower-quality final plating. This depletion requires excessive amounts of chemicals to be added to the plating bath in order to maintain sufficient levels of all the constituents. This practice is both costly and wasteful.

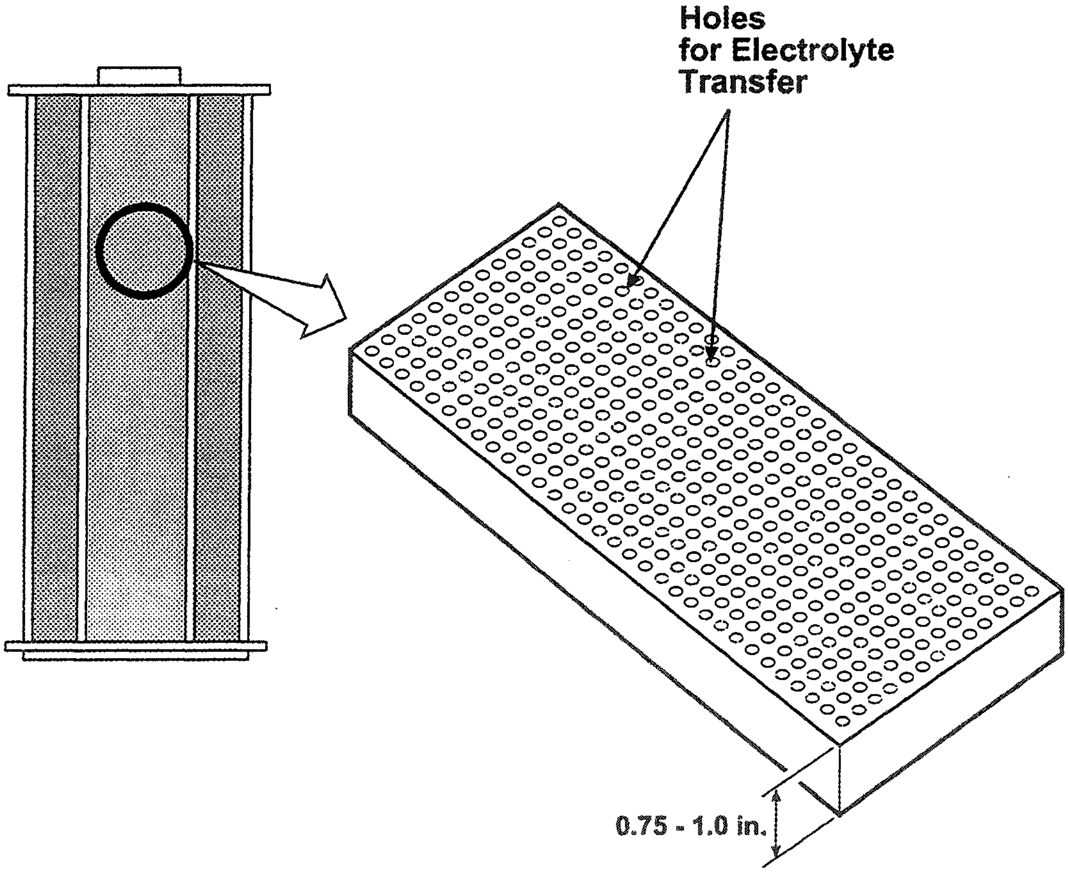

Figure 1. Traditional Plating Barrel

After parts are plated, they must be rinsed of electrolyte to avoid damage to the newly deposited metal finish. When the traditional barrels are removed from the plating tank, a great deal of plating solution remains in the barrel holes, held there by capillary action. The plating solution held over in this way, called drag-out, is then carried over to the rinse tank. The more drag-out carried over to the rinse tanks, the more rinse water is required to clean the parts. This rinse water must undergo costly chemical treatment that produces a hazardous metal-hydroxide sludge. The resulting excessive water usage and the disposal of this sludge are major expenses for the industry.

Resource-Efficient Plating Barrel

The resource-efficient plating barrel is constructed by machining a staggered pattern of rectangular-shaped pockets into the traditional thick-walled polypropylene

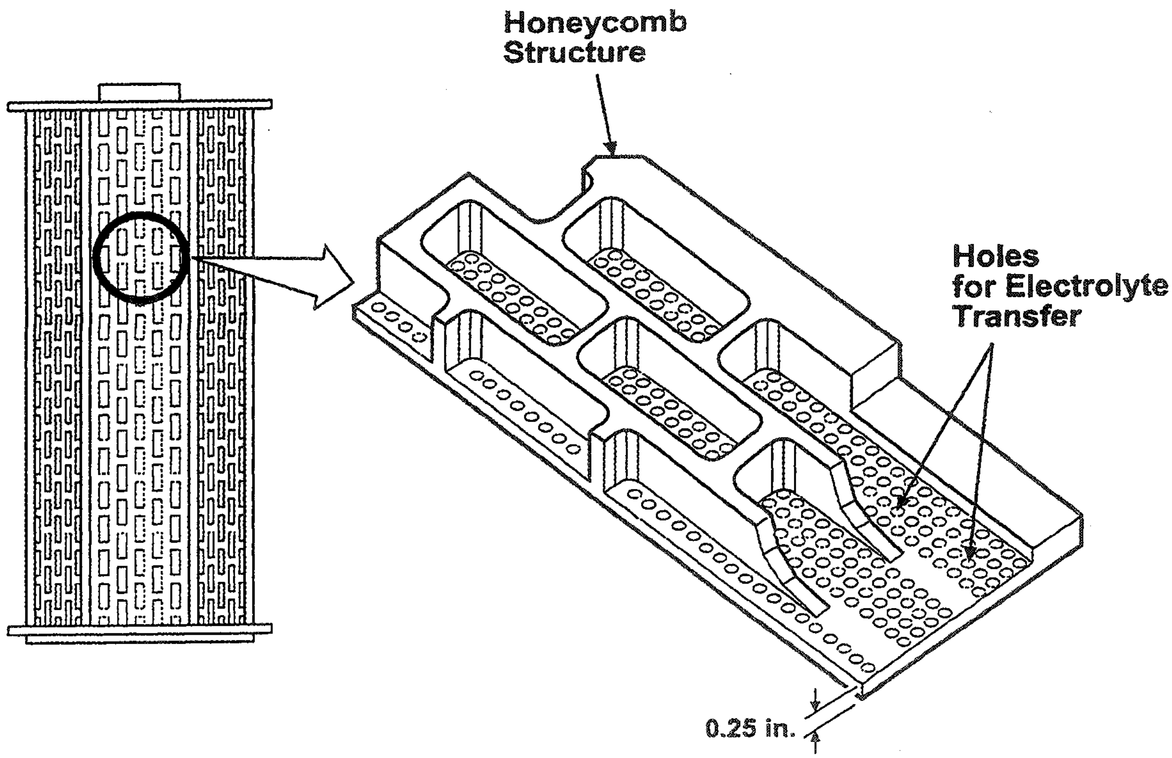

Figure 2. Resource-Efficient Plating Barrel

barrel. After machining, the barrel's structure resembles a honeycomb formation in which thousands of small, now shorter, holes have been drilled. In the traditional barrel, the holes through which the electrolyte flows are between 0.75 to 1.0 inch thick. In the resource-efficient barrel, holes are reduced to about 0.25 inch. This patented staggered-cell design, shown in Figure 2, allows for the greatest number of holes per open area while maintaining the barrel's structural integrity.

Benefits

There are a number of major technical benefits to the resource-efficient plating barrel:

- greater solution transfer into and out of the barrel - Because the resource-efficient barrel has a shorter distance (i.e., thinner walls) through which the electrolyte has to pass, these barrels experience a higher mass transfer (electrolyte transfer) into and out of the barrel. In addition, when the barrel is rotated during normal plating operation, the honeycomb structure creates a hydrodynamic pumping action that induces even greater electrolyte transfer.

- higher current density leading to faster plating cycles - With thinner walls through which the electrolyte has to pass, there is a net increase in current density (a measure of plating efficiency), which leads to faster plating cycles. While a higher current density may slightly increase instantaneous process power use, the increased plating speed more than makes up for the increased current draw.

- reduced bath concentrations due to higher mass transfer rates - As mass transfer rates increase, the necessary plating solution concentrations can be reduced to accomplish the same quality of plating as with the traditional barrels. This reduction impacts not only the up-front cost of the solution, but also the cost of treating rinse water with reduced electrolyte concentrations.

- better plating of difficult alloy plating - Alloy plating is difficult because of the need to closely control ratios of different metals in solution. The resource-efficient plating barrel makes this type of plating easier because of the increased transfer rates and because of the lower and more predictable solution concentrations.

- reduced drag-out - The most significant environmental benefit to this technology is the reduced drag-out resulting from the improved design. With shorter holes, the resource-efficient barrel has a smaller volume for the plating solution to occupy (held by capillary action) as the barrel is moved from the plating tank to a series of rinse tanks. A reduction in electrolyte transfer from plating tank to rinse tank means a reduction in rinse water use and treatment, as well as a reduction in hazardous metal hydroxide sludge generation and ultimate disposal.

Results: Productivity, Resource, and Environmental Impacts

Productivity savings for the resource-efficient plating barrel result from increased process efficiency, reduced materials use, and reduced waste generation. Resource savings will vary with the size and type of parts plated as well as the facility's production capacity. The productivity benefits are due to reduced cycle-time resulting from greater plating solution transfer and higher current densities.

Table 1 details the results of the testing done at Whyco. The tests were conducted on similar parts and with the same plating type; in one case, parts were plated in the traditional plating barrel, with others plated in the resource-efficient plating barrel. The table lists the finishing type (the type of plating applied), the part plated, the thickness of the plating, and the productivity improvement. The productivity in this case refers to the decrease in plating process cycle-time, given as a percentage, for the parts listed. It is interesting to note that the range of productivity improvement is between 10 and 50%, with an average of about 28% for the parts listed.

The resource and environmental impacts of this plating barrel were also measured at Whyco. The savings are based on a 50-plating-barrel operation (considered a mid-sized plating operation), operating 65,000 plating cycles per year. Table 2 presents the energy-related savings of the resource-efficient plating barrel. These savings result from reduced general plant operations due to productivity improvements (heating, lights, etc.), reduced process-related energy use (pumps, motors, etc.), and reduced use of the waste treatment facility.

Table 1. Plating Process Productivity Improvements Using the Resource-Efficient Plating Barrel

Finish Type	Part Plated	Thickness (mils)	Productivity Improvement
Bright Nickel	Tube	0.39	10%
Bright Nickel	Fastener	0.24	25%
Bright Nickel	Lipstick Tube	0.32	38%
Bright Nickel	Valve Cap	0.26	20%
Bright Nickel	Ball-bearing	0.26	44%
Semi-Bright Nickel	Fastener	0.20	50%
CnCu	Fastener	0.27	20%
CnCu	Ball-bearing	0.40	40%
Alkaline Zinc	Fastener	0.32	25%
Alkaline Zinc	Fastener	0.52	24%
Acid Zinc/Nickel	Fastener	0.52	23%
Acid Zinc/Nickel	Ball-bearing	0.30	25%

Table 2. Plating Process Energy Savings Using the Resource-Efficient Plating Barrel, Based on 50-Barrel Operation (65,000 plating cycles/year)

Fuel	Category	Savings (billion Btu/year)	Percent Savings
Electricity	Reduced general plant operations Reduced pumping operations Reduced treatment operations	16.5	20%
Natural Gas	Reduced general plant operations Reduced makeup water heating Reduced waste dehydration	7.4	12%
Total Savings:		23.9	16%

The total annual savings for a 50-plating-barrel operation are estimated to be 23.9-billion Btu; these savings represent about a 16% reduction in energy use. Additional savings resulting from reduced transportation of fuels (raw material and process waste delivery, employee travel, etc.) were not included in this analysis.

Table 3 presents other resource and emissions savings for this technology for the same 50-plating-barrel operation. The resulting emissions savings vary between 17 and 20% for CO_2, SO_2, and NO_X. A significant saving in metal-hydroxide sludge, 40% over the baseline use, was noted. This sludge, considered a hazardous waste, has a reported disposal cost of $372 per ton; thus, the annual savings in disposal cost in this case would be more than $170,000.

Table 3. Plating Process Emissions and Waste Savings Using the Resource-Efficient Plating Barrel, Based on 50-Barrel Operation (65,000 plating cycles/year)

Emissions/Resource	Category	Annual Savings	Percent Savings
CO_2	Reduced electricity and natural gas use	1,523 tons	17%
SO_2	Reduce electricity use	11 tons	20%
NO_X	Reduced electricity and natural gas use	5.5 tons	18%
Metal-hydroxide Sludge	Reduced drag-out	486 tons	40%

Conclusions

The resource-efficient plating developed through the NICE^3-Whyco partnership is a great success. To date, more than 395 of these plating barrels are being used throughout the country, with an estimated annual savings of more than 150-billion Btu. Assuming 50% of the estimated 100,000 plating barrels currently in use are replaced by the year 2010, the projected energy savings would be over 19-trillion Btu/year.