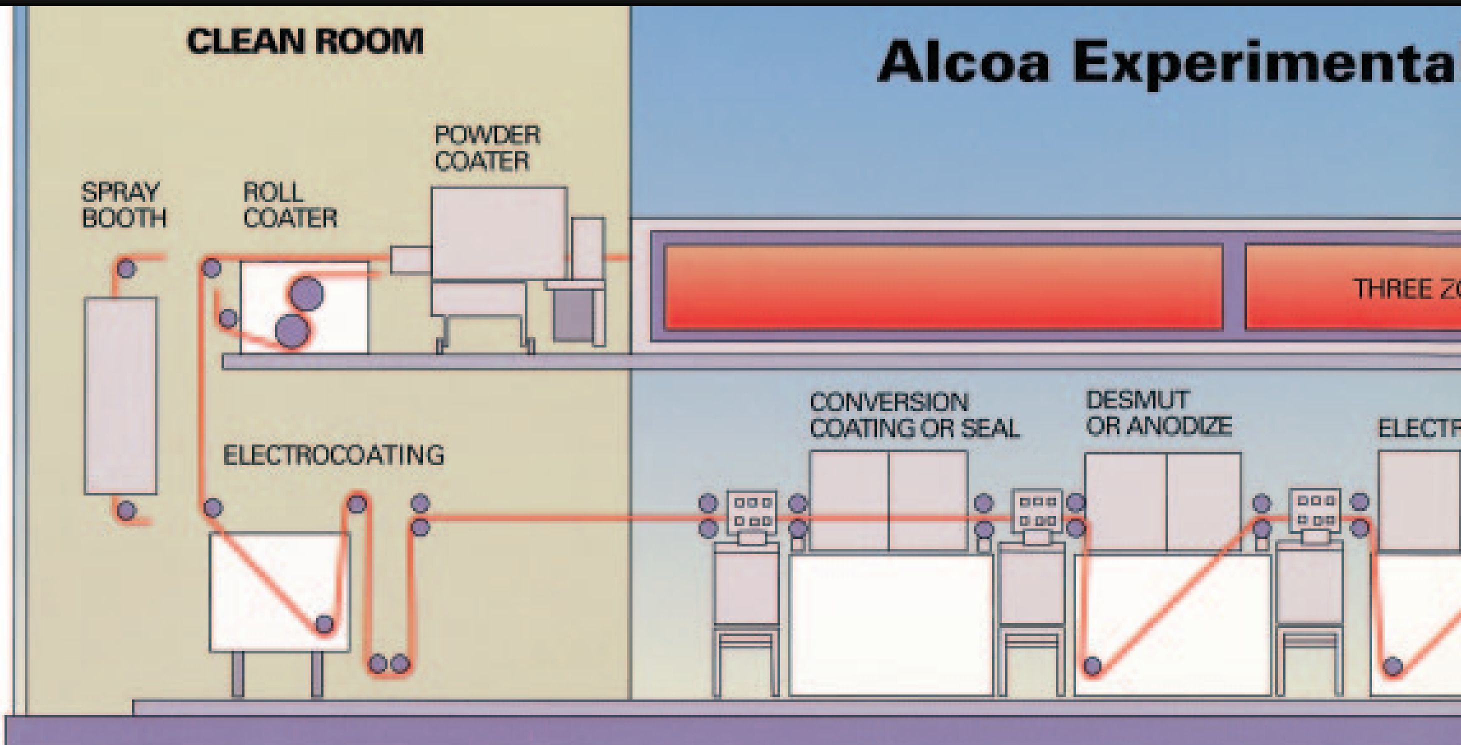


Continuous Coil Metal Finishing:

By Paul B. Schultz, CEF

Metal finishing processes are performed on a daily basis by immersing discrete pre-formed parts or assemblies into process tanks, or by spraying parts and assemblies on a continuous processing line. A less common approach to manufacturing, however, involves unwrapping a long coil of metal, finishing the surface in a series of continuous steps, and forming the parts or assemblies from the pre-finished metal. Such a finishing process has unique attributes.

Coil Finishing

In a typical coil finishing line, the metal is unwound from a large spool. The metal width may be under one inch or as much as 80 inches wide. Metal thickness ranges from foils of .001 inches to a quarter of an inch. Lengths depend somewhat on the metal thickness, but are typically thousands of feet. The metal is fed into the processing section at a constant rate, where the finishing operations occur. At any given time, there is a section of the metal in each processing step (see figure). A very wide variety of metal finishing operations may occur, including: Cleaning, etching, brightening, electropolishing, desmuting, anodizing, sealing, chromate conversion coating, chromium-free conversion coating, phosphating, electrocoating, electroplating (*e.g.*, electrogalvanized zinc), roll coating (standard coats and sol-gel), liquid spray coating, powder coating, and oven curing. These may be applied in nearly any combination or order desired, and by either spraying or immersion techniques. After finishing, the coil is rewound prior to transfer to a cutting and forming operation for manufacturing parts.

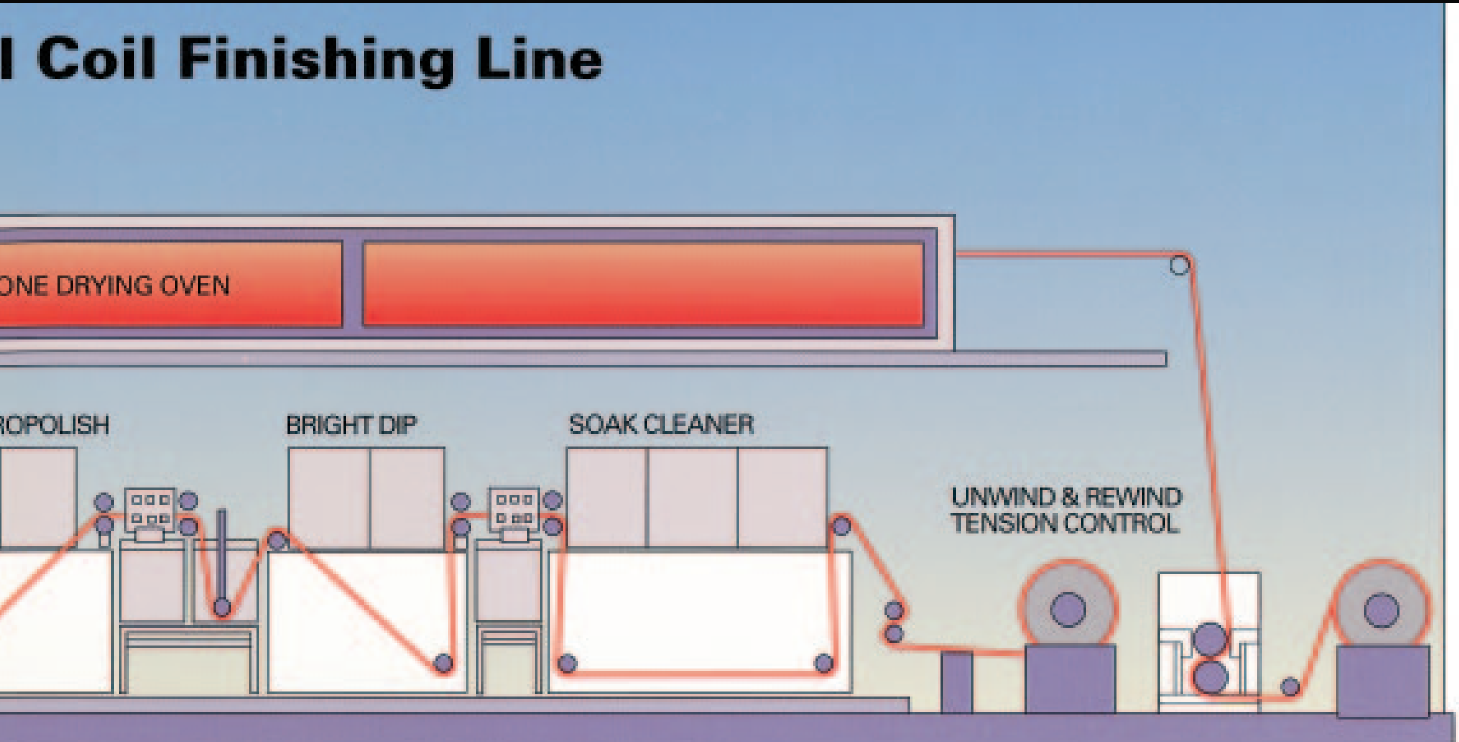
There is often an accumulator between the unwinding spool and the first tank that is a series of movable rolls taking up varying lengths of metal. When a coil has been fully unwound, metal is fed to the process line from the accumulator while another coil is being put on the unwind stand. This enables metal to be processed without stopping the coil in the process tanks. A second accumulator at the end of the line enables metal to continue coming off of the line while the rewind spool is being changed.

Reasons for Coil Finishing

Cost and volume throughput are the principal reasons coil finishing is used. Metal finishing by hand is a labor-intensive and costly operation. Racking and unracking parts is slow. Batch processing can lead to operator errors caused by repetitive and monotonous processes. Even with automated lines, a great deal of time can be spent on relatively few parts. With a continuous coil, the parameters are set up, the processing begins, and, if nothing goes wrong, the operators feed metal into one end, removing finished metal from the other, and monitor the process parameters. It is making sure that nothing goes wrong that can present some challenges.

In spite of the advantages of cost and throughput, there are some good

l Coil Finishing Line



Avoiding Problems Before They Start

reasons why coil finishing is not more widely practiced:

- A large capital expenditure is needed to set up operations, so a large volume of work is necessary.
- Parts must be fabricated from flat coil, so anything requiring casting, machining, or pre-shaped parts cannot be coil-finished.
- In order to wrap around the rollers at each bend and corner of the line, metal thickness is limited from 40 mils to one-quarter inch, depending on roll diameter, metal, and temper.
- Because the parts are cut from the coil after finishing, edges are not finished
- Because the coil is being constantly fed into the system, applications must be completed within a few seconds to 3–5 minutes to keep processing tanks and stations at a reasonable size.

These factors can eliminate many possibilities, such as 45-min plating times or two-mil anodizing thicknesses. There are many useful applications, such as lighting sheet, lithographic sheet, V-blinds, automotive trim, and appliance trim, which can be anodized, cleaned, or coated.

Problems and Solutions

Time

In batch processing, it is possible to have a one-min pretreatment followed by a 45-min coating step. In coil processing, the fact that the coil must enter and exit each step continuously demands that process times be relatively short. Coil duration time in each step is achieved by lengthening the coil path through each tank. Large tanks may be needed, or in some types of operations the coil may be back-tracked between rollers through the solutions. Although the coil may be accelerated or slowed down to change process times, this lowers or raises the residence time in all processes simultaneously and proportionately (*e.g.*, all doubled or all halved). With a back-tracking roller setup, the coil can be re-threaded to bypass some rolls, but this is time-consuming, and can only reduce process time in that step.

One solution to this problem has been the dipper arm concept. The roll forcing the coil down into the solution is mounted on a long arm that swings from above into the tank. Depending on the level to which the arm is lowered, immersion times of a few seconds to a few minutes can be obtained without re-threading the line, removing rollers, or even without stopping production. A processing step may even be skipped altogether—with nearly no changeover time—by raising the dipper arm to its full height. This concept has been proven in prototype lines and should be feasible in production. The transfer time between a process tank and the following rinse is fixed by the line speed and distance from the solution level to the beginning of the rinse. In batch operations, this can be as quick as the operator can get from the process tank to a rinse tank. In coil operations, transfer could take as long as 15–20 seconds, and because of the equipment configuration, this time generally cannot be shortened. Some solutions will begin to evaporate from the metal surface during this time, thus concentrating the solute and causing transfer etch. Air exposure of the wet coil may enable excessive oxygen to dissolve in the thin liquid film, also contributing to etching. Some solutions can have a corrosion inhibitor added to prevent this, but others cannot. In these cases, there are two possible remedies:

1. Spray the coil as it travels between the tank and the rinse with some solution from the tank that the coil is leaving. This prevents the solution from drying onto the coil and subsequent etch.
2. Another possible remedy works only when simply cooling the solution is needed. An air blowoff knife can be placed between the solution and the rinse station in such a way that a jet of air impinges on the coil as it leaves the solution. It is often an inexpensive way to prevent transfer etch with minimal equipment modification.

A spray water rinse, which may seem obvious at first, will eventually dilute and overflow the tank that it is draining into. Generally, it should not be used.

In powder coating operations, there can be a conflict of interest between line speed, deposition rate and oven length. Electrostatic guns must deposit powder at a fast rate for uniform powder distribution, so line speeds of 50–100 ft/min are needed to keep the coating thickness in a range of .5 to 1 mil. At these line speeds, however, a long oven is needed to achieve adequate curing time (50–100 ft of oven length per min of cure time in the above example). This is very costly.

There are two approaches to this problem. Tribostatic powder guns can uniformly deposit powder at slower rates. This enables line speed to be slowed down, and oven lengths can then be shortened for a given cure time. A second aid is the use of infrared (IR) ovens instead of normal convection ovens. The infrared energy is delivered more efficiently than convection heat. The infrared is principally absorbed by the organic coating, and the metal is largely heated by the surrounding air and organic matter. A greater part of the energy, therefore, is being delivered to the coating, and less to heating the metal substrate. The entire coating is being exposed to IR simultaneously, instead of the subsurface being heated conductively, so curing is faster. This shortens the required oven cure time, and the length of oven needed.

Rolls

At a high rate of speed, the coil can drag out large amounts of solution. The standard remedy for this is a set of squeegee rolls, much like the wringers on an old fashioned washing machine. By pulling the sheet between these two rolling pin-like rolls that are closely held together, excessive solution loss is avoided.

The location of the electrical contact rolls must be carefully considered before the coil line is constructed. The coatings applied are frequently poor electrical conductors. Electrical contact to the coil, therefore, must precede these application operations. One potential trap lies in electropolishing or anodizing. Electropolishing can leave thin, passive oxide layers on the coil surface after processing. These appear to conduct electricity when tested with a battery-operated conductivity meter. Thin anodic coatings (*e.g.* .08 mils) can also be conductive in small test circuits. These films, however, can be substantial barriers to the high current densities that must pass through the rolls and coil for processing. Arcing results, causing deep pitting in both the coil and the contact roll. It is vital to make sure that the coil surface is not only conductive at the point of electrical contact, but sufficiently conductive to carry the large currents that may be required. Liquid contact cells, in which a tank full of conductive liquid transmits current to the coil, can both cool the contact and spread it over a large surface area. This can enable electrical contacts to be made at marginally conductive areas of the coil.

The cleanliness of the rolls over which the metal is wrapped can be critical to quality finishes. An absorbed grease spot can impart a stain that repeats itself at every roll revolution, or a particle of sand imbedded in the rolls can dent the coil with every turn. It is important that rolls be cleaned before each start-up. Never run uncleaned metal through the line. Even for simple threading of the metal or running out a tail of metal, immersion of every part of the coil in heated cleaner, followed by rinsing, is important to retain roll cleanliness.

Finding the roll that has caused a repeating mark so it can be cleaned can be more challenging than one might expect: Access to each roll can be encumbered; many rolls are immersed in the tanks; viewing the coil at an appropriate angle during processing to see where the mark first appears may be impossible; and the coil may be moving very quickly. If this problem is anticipated in the construction stages, a simple solution can be designed in.

If each roll or roll set is constructed with a different circumference, measurement of the distance between defects on the completed sheet will reveal the roll or roll set that caused the problem. The disadvantage is that if spare rolls are kept, a larger inventory is needed to be prepared for all failures.

The cleaner solution itself may have small particles from a powdered concentrate, or particles may accumulate from cleaning the metal. These particles can be dragged out on the coil, imbed in a roll, and cause denting. Filtration of at least the cleaner tank is best to avoid this problem. Draperies or other barriers to prevent migration of particles from nearby construction work is also necessary.

Particles can be found in coil lines as a result of hard water deposits breaking away and embedding in rolls. The use of deionized water can prevent this, or periodic removal of lime scale may be required.

Making the rolls easier to clean and maintain will pay off in the long run. Some roll cover polymers work well in ideal conditions, but are difficult to clean off grease and dirt. Fluoropolymer rolls can be several times as expensive, but are more resistant to nitric acid and are much easier to wipe free of dirt, oils and particles.

Electrical Process Interactions

In some cases, it may be desirable to simultaneously electrofinish two different parts of the coil with different voltages and currents. An example might be electropolishing in one tank followed by anodizing in a second tank. Concern has been voiced that the currents or voltages may somehow get "mixed up," straying from one path to the other. It has been demonstrated that, if there are no unintended paths, such as grounding through electrically non-isolated heating coils, etc., simultaneous electrofinishing operations can be practical. The basic principle is that whatever current is produced at the positive pole of the rectifier, the same must return at the negative pole. This ensures that when no unintended complete circuit is available, the sheet can and does keep the two currents and voltages separate. A similar situation exists with AC power supplies, which may be used in some types of anodizing, etc.

Dissimilar processes can also interfere with each other. Electropolishing followed by solvent-based roll coating is an example. Although the great majority of the current is confined to the loop intended for it in the electropolishing step, a voltage remains applied through the length of the coil. An accidental grounding at the roll coater, combined with a small grounding elsewhere in the line, could cause a spark that might ignite a solvent fire. Meticulous care to eliminate unwanted electrical paths is necessary, combined with insulating panels at any metallic points in the roll coater where the coil might touch. Another possibility is to intentionally ground the negative pole of the rectifier and also ground the coil itself. This confines non-ground voltage to the anode and its wiring, thus placing the coil at the same ground potential as the roll coating apparatus. With coil and coater both at zero volts, a spark is less likely. With these and other reasonable precautions, it has proven feasible to electrofinish and organic-coat on the same line without incident. Explosion-proof wiring of the roll coater circuits is also advisable.

Stray currents can cause other problems, even if incompatibles such as electricity and solvents are not present. Stray currents can cause improper current or voltage in the process itself, even if the meters at the rectifier are indicating the correct conditions. Arcing can occur at undesirable areas, such as gas ovens, or simply pit the coil where the arc occurs. Precautions to take include insulation of the steam coils with insulated steam fittings in a non-metallic tank. The steam coil, temperature probes, water pipes below the solution level, etc., can create new electrical paths and so must be electrically isolated. When contact rolls are used, copper-impregnated graphite brushes will cause less voltage drop than standard graphite brushes in getting the current onto the coil, and will increase the effectiveness of insulating attempts at the unwanted current paths. Contact cells, in which a dilute conductive solution transfers the current to the coil instead of a metal roll, are more effective at reducing problems, but require more area in the line and are more expensive. Non-conductive bearings and sprockets are available in ultra-high molecular weight polyethylene or nylon for eliminating conductive paths. Metal oven rolls can be coated with a thin layer of non-conducting ceramic.

Broad Line Design

In designing a new line, a small inspection station incorporated at one or two critical points can be very beneficial. This may constitute only a narrow two- or three-ft section in which there is no equipment, allowing access to view the partially finished coil. This will enable easier tracking of the origin of defects, monitoring of the process prior to final operations, and cost only a small amount of additional floor space.

If roll coating, spray coating, or powder coating is involved, and curing ovens are used, it may be desirable to cool the oven-cured metal before it reaches the rewind stand. The oven cure is likely to be the final operation, but if the coated metal is rewound hot, problems can occur. The applied coating may be tacky if still hot, and blemish or roughen when pressed against the next wrap on the rewound coil. Further, when the coil cools and contracts, it will shrink and gradually force each wrap to slip against the next layer, causing slip scratches. The solution to this is to allow space after the ovens to insert a short water spray station, followed by an air blow off gun to dry the sheet. Little cooling is needed to reach room temperature, especially with thin sheet, but surface marring can be prevented.

Coil Lines are Efficient

Coil lines are well-suited for the proper types and volumes of parts. Their operation can result in a much lower cost of finishing parts and a faster throughput of work.

The capital set-up cost for coil lines is relatively high, so only high volumes and high speeds are practical. It can be very difficult to change some parameters once the line is built, especially adding process steps in the middle of the line. Many unique problems must be carefully considered before any design is finalized.

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About the Author

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