The "then and now" of electropolishing
by John Swain, Anopol Ltd

Introduction

Electropolishing is certainly not new to the field of Metal Finishing. Through the ages it has encouraged several descriptions, including electro-brightening, electrochemical polishing, reverse plating and even de-plating. Little did the earlier pioneers of the process imagine that their efforts would one day sustain companies wholly engaged in electropolishing. Naturally, the treatment parameters have been stretched over the years, but not by research in any university’s laboratories. The improvements and advancements, both in the chemistry and the methods employed, can be attributed to those working in the industry; those with practical industrial experience.

Where did it all start? According to the Russians Fedot’ev and Grilikhes in their book of 1957, the very first work on the use of electrolytic processes was carried out in Russia. On 19 January 1911, I I Shpital skiy, working at the University of Moscow, was granted a patent for ‘A Process of Producing a Polished and Bright Finish on the surface of Metals and Electrodepolished Coatings of Metals’. Unfortunately, we are not acquainted for sure with the type or types of metal involved, but one of them was almost certainly aluminium.

In the 1930s a Frenchman, Dr Jacquet, started experimenting with electropolishing of copper and this was probably the forerunner to the industrialisation of the process. But it did not stop with copper. In Tegar’s book, ‘The Electrolytic and Chemical Polishing of Metals’, published in 1959 a W Bos in Melbourne is quoted as follows: ‘In 1937 Pierre Jacquet showed me a specimen of high purity aluminium which he had polished by a new method involving neither rubbing nor abrasives.’

In the 1950s, a German company, Elektrolyse-Gesellschaft mbH was extremely successful in marketing plant, chemicals and know-how for electropolishing components in copper and its alloys. Typical customers manufactured and polished pressings for handbag frames and powder compact, as well as brass castings for chandeliers.

In the 1960s, the employment of stainless steel, in all its forms, was showing a significant increase and various concoctions for electropolishing these metals had appeared. One particularly successful solution for stainless steel was patented and marketed by Albright & Wilson in the West Midlands under their ‘Electropol’ brand. The finish was described as an industrial sheen and the fairly low cost electrolyte was to survive for many years. However, the solution contained cyanide, which was later declared a carcinogenic, and the chemical fell into disuse.

In the meantime, two companies in the UK had established a presence for sub-contract electropolishing of stainless steels. The Brightside Electropolishing Company operated in Birmingham and the Electropol Processing Company had its base in Farnham, Surrey; the latter paying a licence fee to Albright & Wilson for using its name and electrolyte.

Similar activities were in operation on the Continent. The French favoured using a particularly volatile electrolyte containing perchloric acid. Contact with organic materials could result in an explosive power greater than TNT and incidents of factories losing their roofs were rumoured. Operators were supposedly employed for their swiftness of foot.

Development of safer and more effective electrolytes continued during the 1970s and 1980s, resulting in chemical solutions which polished at lower temperatures than previously. This increased their throwing power with the added advantage of achieving highly reflective, bright polished surfaces.

An electrolyte solution, that has universal characteristics, is now being used in numerous electropolishing installations. Its main attribute is that it is suitable for polishing a wide range of stainless steel grades, where previously, different electrolytes needed to be employed.

The other metals

Electropolishing of various stainless steel grades probably accounts for over 95% of metals being processed today. There are, however, a large range of other materials which can be treated to great advantage. Aluminium does not appear to be one of them. A highly reflective mirror finish can be achieved electrochemically on the purer grades of aluminium. Sadly there has never been a serious requirement for this finish and this may be down to the cost of the aluminium relative to the costs involved for electropolishing. The cheaper alternative of chemical brightening, which involves simple immersion and no electrical input, has proved to be the preferred treatment, certainly in the UK.

There is a requirement for processing exotic metals, such as titanium and nitinol, but these appear to be mainly restricted to the medical industries. Medical companies, manufacturing in such metals, generally prefer to keep the polishing operations under their control and therefore process in-house.

With the influx of cheaper imports, electropolishing of copper and its alloys has diminished to such a degree, that no one is interested in mixing the flammable electrolytes in the UK.

The requirement for treating carbon steels by electropolishing also appears to have diminished significantly; probably assisted by the introduction of chemical smoothing and deburring processes involving simple immersion. Electropolishing carbon and tool steels involves the use of an electrolyte containing chromic acid, that has fallen out of favour due to health and safety considerations.

Industrialisation of electropolishing today

There are companies worldwide offering sub-contract services for electropolishing stainless steel. Stainless steel is the universal name given to a number of different steels, used primarily for their anti-corrosive characteristics. Stainless steels are essentially ferrous alloys, comprising mainly of iron, but with at least 10.5% chromium content.

Other elements are used in the manufacture of stainless steel, the most common one being nickel. Corrosion resistance, welding and Machining properties can be improved by the addition of elements such as molybdenum, manganese, sulphur, etc.

Stainless steel’s resistance to corrosion is due to the metal’s capacity to passivate in a sufficiently oxidative environment (such as air) by forming an invisible chrome oxide film. When this condition exists, stainless steel surfaces are said to be in a passive state. Electropolishing is known to form a stable passive layer on the surface of all grades of stainless steel. All stainless steels are recyclable, regardless of the type and grade.

There are several manufacturers who carry out electropolishing treatments in-house. However, in the UK, these are outnumbered by companies carrying out subcontract services, predominantly for stainless steels, up and down the country.

Electrochemistry of electropolishing

Electropolishing takes place as a result of the electrochemical removal of a surface layer and the principles of electropolishing are similar to those for electroplating. The major difference concerns the polarity of the work-piece being treated. When electropolishing, the workpiece is positively charged, which is achieved by electrically connecting the item being processed to a source of direct current whilst immersed in a chemical solution.

Continued on page 32.
The “then and now” of electropolishing
Continued from page 30.

This solution, usually acid based, is referred to as an electrolyte and its composition will depend on the metal being treated. The electrochemical circuit is completed by metal cathodes (negative), which are also immersed in the electrolyte solution.

A rectifier, which converts alternating current (ac) into direct current (dc), is the usual means of providing the anodic and cathodic currents.

Process effects of electropolishing

When operated correctly, electropolishing progressively removes a surface layer in a very special way. In the process of electropolishing, the higher current density areas receive a heavier deposit than other surfaces. The opposite effect applies to electropolished surfaces, where metal is removed preferentially from high current density areas. Typical high current density areas are the edges of components or any high spots or peaks on the surface. A relatively small amount of metal is removed, generally 10 to 40 micrometres. The process will not, therefore, remove scratches or heavy scuff marks.

The overall effect of electropolishing is the formation of a micro-smooth, contaminant-free surface and this occurs without producing any thermal or physical distortion, often a side effect of abrasive mechanical treatments.

The electropolished surface has a number of beneficial characteristics:

- Decoratively attractive, highly reflective surface, also on complex shapes.
- Preparation of surfaces with critical cleanliness requirements by removal of surface contamination.
- Rendering working surfaces easier to clean and maintain.
- Improved passive oxide layer, thereby increasing corrosion resistance.
- Fine deburring of precision components.
- Reduction of bacterial growth on micro-smooth surfaces.
- Removal of occluded gases in the metal’s surfaces.
- Reduction of friction for contact surfaces by levelling micro-roughness.
- Controlled removal of metal around holes, slots, etc for the purpose of increasing hole size.
- Controlled metal removal on complicated shaped components for the attainment of precision fits.
- Material control by detection of micro-cracks, porosity etc.
- Reduction of radiation ingress due to sealed, micro-smooth surface finish.

As the process of electropolishing generates oxygen at the metal surface, there is no risk of hydrogen embrittlement.

Schematic layout of electropolishing system.

Specifying an electropolished surface finish

The most satisfactory and reliable method of establishing the desired surface finish is by means of sample treatment. It is, of course, important that the pre-electropolished finish on the item to be treated reflects accurately that of the sample. Problems can be avoided if the electropolishing contractor retains before and after treatment samples.

It is not uncommon for the final finish to be specified as a surface roughness measurement. The most common parameter for surface texture is Ra or Roughness Average, also known as CLA (Centre Line Average). Ra is calculated by an algorithm that measures the average length between the peaks and the valleys and the deviation from the mean line on the entire surface within the sampling length.

Ra averages all peaks and valleys of the roughness profile and therefore neutralises the few outlying points so that the extreme points have no significant impact on the final results. It is a simple and effective method for monitoring surface texture and ensuring consistency in the measurements of predominantly multiple mechanically finished surfaces.

The characteristics of a surface produced on stainless steel by electropolishing vary significantly to those of a surface achieved by mechanical means. The metal is electrochemically eroded rather than abraded, so that no mechanical forces are involved. Peaks are preferentially removed, resulting in a micro-smooth reflective finish.

The macro-topology is barely affected - the process has been likened to removing the trees and the boulders from the landscape, but leaving the hills and valleys intact. In the majority of cases, a reduction of Ra is achievable by electropolishing.

Conventional surface measuring instruments rely upon a precision stylus traversing over a small sampling length. In the case of a micro-smooth electropolished finish, the stylus can travel unimpeded up hills and down valleys. On occasion, this has produced a higher Ra reading than that of the surface prior to electropolishing. The implication is that electropolishing has roughened the surface detrimentally. Scanning electron microscope images, however, show the electropolished surface to be infinitely smoother than the previous ground finish (see images on page 34).
The “then and now” of electropolishing  Continued from page 32

Sectors employing electropolishing today

The use of the electropolished surface finish can be found in a wide range of applications, whether for aesthetic, decorative or functional purposes, and the list below is by no means exhaustive.

Automotive

Several stainless steel items are regularly electropolished for the Automobile Industry. Typical components are exhaust pipes, radiator grilles, loud speaker bezels, bull-bars and car trim in general. Both the bright decorative and corrosion resistant functional characteristics are enhanced by the treatment.

Pharmaceutical

Electropolishing is used extensively for finishing sterile equipment employed in the production of products for pharmaceutical use. In addition to powders and gels, the electropolished finish has proved invaluable for the insides of pure water storage tanks and vessels. The resulting finish ensures that the chance of the product sticking to the processing equipment is significantly reduced, as is also the risk of bacterial growth on the product contact surfaces and in crevices. Storage tanks and pipe-work for purified water are subject to “mugging”. Whilst electropolishing will not prevent “mugging” eventually occurring, it will slow down the accumulation.

Process equipment

Complex process equipment, pumps, vessels, valves, pipeline, etc. coming into contact with adhesive products, such as latex and plastic polymers, benefit from the electropolished finish. The interaction of product with occluded gases in the metal’s surface structure is virtually eliminated and the resulting micro-smooth finish ensures effortless detachment of product materials.

Medical

A wide range of medical devices are routinely electropolished, either for internal or external use. Surgical instruments, including dental appliances, sterile handling equipment, hypodermic needles and body implants are most frequently treated. The resulting surface is sterile, micro-smooth, particle-free and reduces the risk of pathogen and pyrogen growth. Fine edges are deburred and the items exhibit a bright aesthetic finish with improved corrosion resistance. In addition, they are easily deamed and can be repeatedly sterilised without fear of corrosion occurring.

Food and beverages

The hygienic, anti-stick characteristics of an electropolished surface make it ideal for food and drink preparation and storage. Hot water tanks for vending machines are treated internally to prevent lime scale build-up and externally for aesthetic reasons. The internal surfaces of food mixing vessels are another suitable application, as is also the mixer shaft and blades. Containers for storing acidic drinks, such as colas, benefit from electropolishing by extending their life cycle.

Pulp and paper

A build-up of pulp fibres, during the manufacture of paper, can lead to “snowballing”, resulting in costly and time consuming break-downs when the pulp mass is released. To prevent this build-up, critical components, such as the head box, are micro-smoothed by electropolishing. Holes and slots in screen cylinders can be enlarged with precision to accommodate the grade of paper being produced and simultaneously prevent clogging.

Semiconductor

Gases, employed in the production of micro-chips, are usually transported through a maze of small-bore pipe-work and fittings. Even the minutest trace of contamination in these gases will disrupt production. For this reason, all internal surfaces coming into contact with the gases are electropolished to give a clean and particle-free finish.
The “then and now” of electropolishing

Continued from page 34.

Architectural

With the increasing use of stainless steel in buildings, the bright electropolished finish offers the architects a real option to the less corrosion resistant brushed satin finish. Decoratively attractive, it also has the advantage of minimal cleaning, requiring only sponging with clean water or washing down with a high-pressure water jet. Complex patterned gates, doors and street furniture, durbars plate flooring, handrailing, etc all have been subject to electropolishing to improve finish and durability in service.

Sculptures

Sculptors recognise electropolishing as a finish that gives great flexibility. No matter how complex the creation, a uniform bright finish is possible at a cost well below that of a labour-intensive hand-polished finish. An added bonus is the reassurance that out-of-doors sculptures will retain their corrosion-free appearance.

Leisure

It is a well known fact that stainless steel does not like chlorine, whether as a liquid or in its airborne state. Swimming pools contain some chlorine, both directly in the water and indirectly in the atmosphere. Untreated stainless steel will rapidly fall prey to the effects of chlorine, exhibiting unsightly corrosion stained surfaces. Electropolished surfaces will withstand chlorine attack for an extended period of time when compared to other mechanical surface finishes. Items like tubular ladders and equipment storage cabinets are routinely treated for this purpose. Tubular pulleys, ladders and boat fittings in general are routinely electropolished to better withstand marine environments by increasing corrosion resistance.

Textiles

In certain textile processing machines, snagging of synthetic materials can cause serious damage to the fabric. Micro-smoothing the contact surfaces with the fabric can alleviate this problem significantly. In addition, dyeing vats have considerably shorter changeover times between different coloured dye batches.

High vacuum and nuclear

Occuised gases occurring in the surface of stainless steel used to fabricate high vacuum equipment will slow down the process of achieving the desired vacuum conditions. Electropolishing effectively removes the bulk of these gases allowing pumping times to achieve high vacuum to be achieved in much shorter times. One research establishment claims that high vacuum was reached in one fifth of the time following electropolishing.

Electropolished surfaces are known to absorb a lesser amount of radioactivity than mechancially finished surfaces. In addition, the micro-smooth finish is more readily receptive to decontamination. Electropolishing plants in secure facilities have been employed for decontaminating radio-active tools and components.

Conclusion

Like the majority of metal finishing treatments, electropolishing is an “art”, or as some have falsely suggested, a “black art”. Any company that has honed its skills over several years is always going to have advantages over “the new boys on the block”.

And this is true for electropolishing because it is not simply a question of dangling a piece of metal into a tank of liquid. In addition to the chemistry required, there is a skill in how the work-piece is positioned on a fixture or jig prior to immersion. For some items, auxiliary cathodes will be essential to achieve an even, uniform polish. The design and manufacture of jigs and cathodes require the mental and physical agility of a craftsman.

Polishing the same components day in and day out makes for an easy life. The sub-contract electropolisher, however, will often be confronted with the challenge of treating a range of different size and shaped items over the course of a week. This can vary from small stainless steel wire-work components up to the internal surfaces of a 3.5 metre diameter, 40 tonnes processing vessel. The astute electropolishing company will also have the ability and equipment to carry out the process at the customer’s premises where size and weight dictate.

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About the author . . .

John Swain is managing director of Anopol Ltd, a company specialising in specific finishes on stainless steels. He is past president of the British Jewellery, Giftware and Finishing Federation and past chairman of the Metal Finishing Association and the Stainless Steel Fabricators’ Association.

After serving an indentured apprenticeship as a structural engineer, he joined the Report Department of Girling Brakes, a subsidiary of the Joseph Lucas organisation. On returning to the UK after five years with Girling in Germany, he established a subsidiary for a German company and became involved with surface finishes. He led a successful MBO during the eighties, which resulted in a company name-change and the formation of Anopol.

John Swain has had numerous articles published on chemical and electrochemical treatments for stainless steels. He has also appeared in national newspapers and on radio, criticising over-zealous UK legislation that is detrimentally effecting metal finishing and manufacturing in general.

He currently sits on the Council of the British Stainless Steel Association and the National Committee of the Surface Engineering Association. He is also a fellow of the Institute of Metal Finishing.

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