Practical Applications & Considerations of Electro-Chemical Deburring

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Deburring is an ever increasing and important consideration relating to metal cutting and metal removal operations. The Electro-Chemical Deburring process has proven to be an excellent process in accomplishing reliable and consistent burr removal on a wide variety of applications. Electro-Chemical deburring can be used on all electrically conductive engineering materials. The process can easily be adapted to deburring simple, as well as complex and delicate close-tolerance parts. Described are practical applications of the Electro-Chemical Deburring process, including tooling considerations, benefits and limitations.

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Introduction

As mechanical, electrical, and fluid power systems become more technologically advanced, the potential problems resulting from system contamination become an ever-increasing concern. As individual mechanical components of such systems become more precise with tighter manufacturing tolerances, they become more sensitive to burrs that can adversely affect form, fit and function.

Today there are dozens of deburring alternatives available that range from using sophisticated hand deburring tools, to fast and efficient mass finishing systems. Electro-Chemical Deburring (ECD) falls near the "fast and efficient mass finishing" end of the spectrum of deburring processes. ECD has been used as a production deburring process for many years, and is used routinely by nearly every metal cutting industry. Figure 1 shows a variety of workpieces deburred using the ECD process.

Figure 1. Assorted workpieces deburred using ECD.

ECD Basics

ECD, as the name implies, uses electrical energy to accomplish the work of deburring. The action of the process is very localized and the affected area can be accurately sized and precisely located. Using carefully designed fixtures, the process easily removes the burr while leaving all other areas of the workpiece virtually unaffected. Aside from hand deburring, the ECD process is the only deburring process that can pinpoint selected locations to deburr. Because the process operates at near room temperatures, there is no danger of changes in the characteristics of the workpiece material. The fixture clamping forces are relatively small and workpiece distortion is rarely a concern.

The ECD process is accomplished by placing a metallic electrode close to the burr. The electrode is shaped to conform to the perimeter of the area where the burr is attached. With the electrode in place, an electrolyte solution is flowed through a small gap between the workpiece and the electrode. Then, a low-voltage/high- current is passed through the electrolyte solution between the workpiece and the electrode. This action results in what might be called a reverse plating operation, which causes the burr exposed to the electrode to essentially be dissolved. Figure 2 is a schematic diagram of the basics of the ECD process.

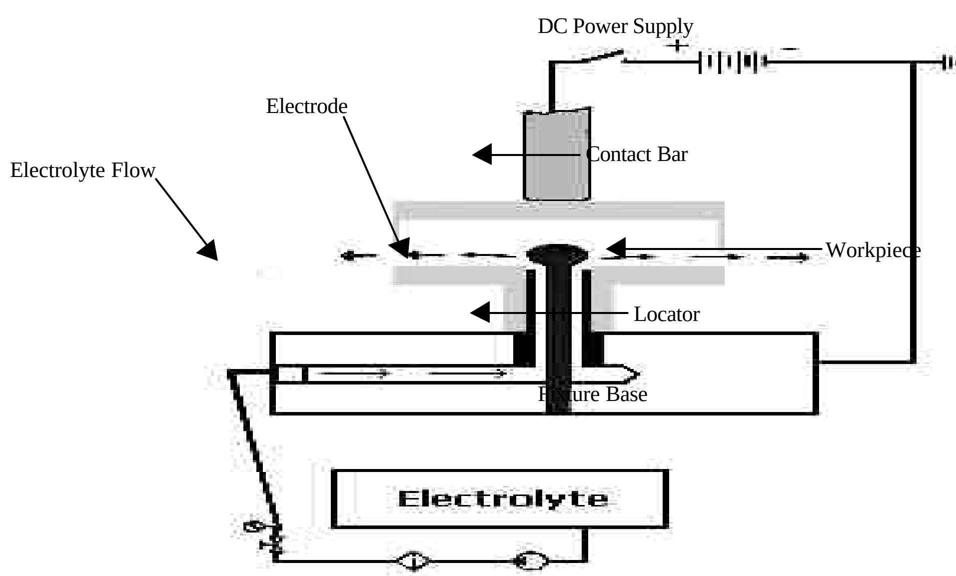

Figure 2. Schematic diagram of ECD basics.

A fixture is used to locate the workpiece so that the burrs are carefully positioned and oriented relative to the electrode. Most applications of the ECD process use stationary fixtures with permanently mounted locators and electrodes. Other applications employ stationary fixtures with moveable locators and/or electrodes. The moveable locators and/or electrodes permit access to burrs in difficult locations that cannot be reached by simply slipping the workpiece on and off a fixed locator/electrode. Workpieces processed on stationary fixtures may range in size from the size of a pencil eraser to many pounds.

As opposed to the fixed locators/electrodes, the ECD process can consist of a locator/electrode combination that is held in the hand and manually placed at the area to be deburred. The workpiece could be small and held in the hand and deburred with the hand held locator/electrode. Furthermore, the workpiece could be unlimited in size, or even immovable for that matter, and the hand held locator/electrode moved to any burr location on the workpiece for processing.

Burrs located on the external surfaces of a workpiece are often readily accessible and can be economically removed by mass finishing processes or "quick" hand deburr methods. For this reason, most applications of the ECD process are for deburring internal areas that do not lend themselves to mass finishing processes. However, if a workpiece has delicate or critical features that might be damaged by mass finishing, such a workpiece can be ECD'd on the external surfaces as easily as it is deburred internally. Figure 3 shows examples of external deburring applications that are not good candidates for mass finishing because of the external threads.

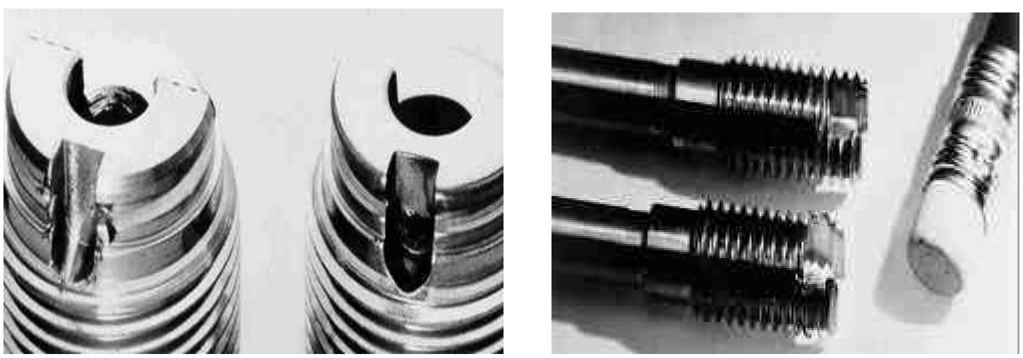

Figure 3. Good applications for ECD on external burrs.

The primary components of the ECD process consists of the workpiece; fixtures with locators, electrodes and clamps; electrolyte and electrolyte plumbing, including metering valves, coolers and filters; the electrics, including power supply, timers, and voltage controls; and the post cleaning processes.

In addition to the fixtures, locators and electrodes, the variable elements of the process are: cycle time, electrolyte, electrolyte flow, electrolyte concentration, electrolyte temperature, and voltage. These elements can be changed individually or in various combinations to cause subtle to dramatic differences in the ECD results.

The ECD process is often confused with EDM and Electropolishing, but they are all quite different. Electropolishing employs a low-voltage/high-current flow to remove material on all exposed surfaces of a workpiece immersed into an acidic electrolyte solution. The EDM process employs a high-voltage/low-current flow that arcs through a dielectric liquid to accomplish the metal removal process.

Fixtures

ECD fixtures are usually composed of a two-piece fixture base, nonconductive locators, metallic electrodes, metallic contact bars, electrical terminals, and fittings to attach electrolyte piping. The two-piece fixture base is comprised of a metallic sub-plate and a nonconductive top-plate. Figure 4 shows a basic ECD fixture and a more complex fixture.

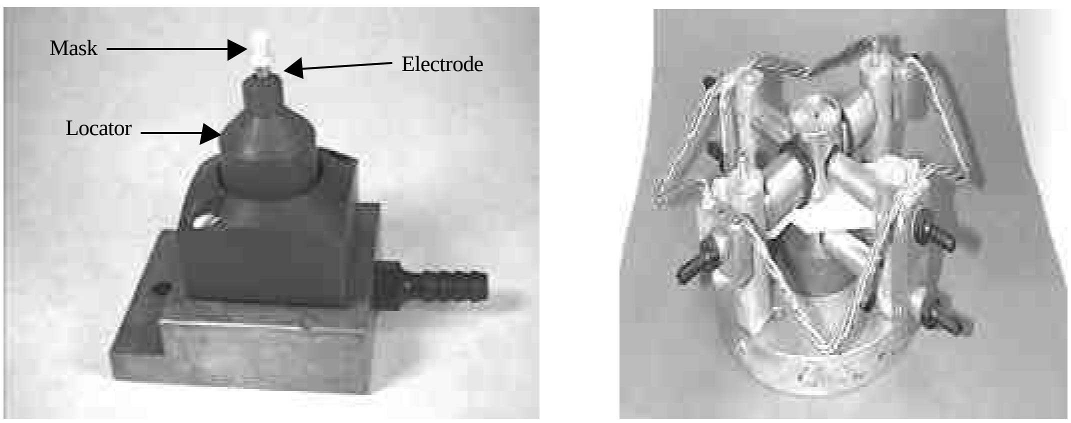

Figure 4. Basic (left) and complex (right) ECD fixtures.

The sub-plate provides for the rigid mounting of the electrodes and for making electrical continuity with the electrodes. The sub-plate is plumbed and ported to direct the electrolyte flow into and/or around the locators and/or the electrodes. The sub-plate can be made from most any conductive material.

The primary function of the top-plate is to firmly connect and clamp the locators to the sub-plate. It also positions the locators relative to the electrodes, which in turn locates the workpiece to the electrodes. Other locating elements may be attached to the top-plate to aid in locating the workpiece. The top-plate may be ported to assist in directing the electrolyte flow. The top-plate can be made from many nonconductive plastic materials.

The contact bar provides electrical continuity with the workpiece, and transmits the clamping forces to the workpiece to insure the workpiece remains stationary during the ECD cycle. Contact bars are made of conductive materials and are generally attached to the clamping mechanism of the ECD machine.

Locators

Locators perform several functions. They are used to locate the workpiece relative to the electrode, which in turn locates the electrode relative to the burr. The locator serves as an electrical insulator between the workpiece and the electrode, and provides plumbing circuits to direct the electrolyte flow. Locators can be made of many nonconductive plastic materials.

The condition of the locators must be carefully monitored during production runs. Cracks in and/or scratches on the locators can allow current or electrolyte leakage that can cause ECD action in unwanted areas of the workpiece.

Electrodes

The design, shape, and location of the electrode are critical to achieving successful ECD results. The electrode can be manufactured from a variety of conductive materials. They can be manufactured from solid bar stock, bent into shapes from wire, or fabricated into shapes from thin sheet stock. Because of the limitless variations of burr locations, burr size, workpiece tolerances, etc., the electrodes require ingenuity in design and manufacturing to achieve a final shape that insures the desired results. The electrical conductivity of the electrode material can influence the rate of deburring and the overall power consumption of the process.

A critical requirement of the ECD process is insuring that the electrode never makes contact with the workpiece to create a direct short. A short may occur when a workpiece is not made to print specifications. For example, the diameter of a hole may be too small or not drilled deep enough. In addition, electrodes may become bent or chips may get into the gap.

A short causes a current spike that can cause an arc that damages the workpiece and the electrode. Damage to the workpiece is usually the result of excessive and/or erratic material being removed at a critical location, and which could necessitate scrapping the workpiece. In this case, the fixture can be repaired, and only a single workpiece is lost.

A subtle situation may occur when an electrode is unknowingly damaged by an arc that leaves some workpiece material “welded” onto the electrode. Furthermore, arcing can cause pits or voids in the electrode. Any of these conditions may cause erratic results that may go undetected until many workpieces have been processed, and possibly scrapped.

The ECD machine should include an option to detect a short and shut the system down when one occurs. It is important to carefully inspect the electrodes and locators after a short, or suspected short has occurred.

Masking

Masking consists of covering, insulating or otherwise shielding a portion of the electrode in order to protect specific areas of the workpiece from the ECD action, while still allowing the process to do its work on the burr. Masking is an important element in the process of configuring the electrode to match the shape of the burr location.

Masking may be accomplished by placing the electrode inside of the locator, and permitting only a small section of the electrode to be exposed to the workpiece. A close fit between the workpiece and the locator will restrict electrolyte flow and mask the ECD action at the area of close fit. Effective masking can also be accomplished with the use of O-Rings, rubber bands, tape, glue, and epoxy materials. The ECD action on the workpiece is inversely proportional to the square of the distance to the electrode. Therefore, distance can serve as a form of masking, and some workpiece areas that are not near the electrode may not need to be masked.

Pattern Shapes

As previously mentioned, the shape of the electrode can be made to match the shape of the area to be deburred. The shape of the electrode can be limitless. Figure 5 shows a Control Lever with kidney shaped slots that are easily ECD'd using irregular shaped electrodes.

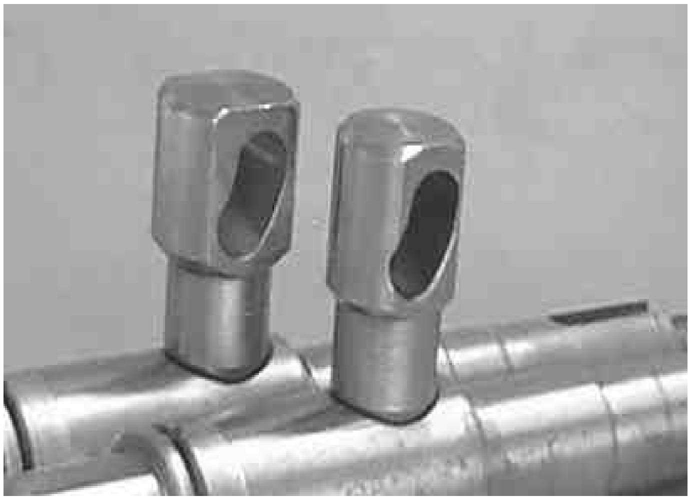

Figure 5. Irregular shaped ECD pattern.

When designing the ECD pattern, it is important to consider how close the pattern should match the burr area. Generally, the pattern should be larger than the burr area in order to insure thorough deburring and that the desired edge condition is achieved. Consideration must be given to the allowable tolerances on the workpiece, clearances between the workpiece and the locator/electrode, and fixture tolerances. These tolerances can stack-up and permit the ECD pattern to shift relative to the burr area, and when this happens, a portion of the burr can be "missed" by the process. Consequently, the ECD pattern must be sufficiently large to accommodate the allowable variations and still ensure proper burr removal and final edge condition.

The Flange in Figure 6 shows a pattern that is elongated horizontally. The crosshole is visually located relative to the electrode and the elongated pattern allows for slight errors in alignment. Because the vertical location of the hole is controlled by the fixture components, the vertical spread of the pattern can be much less.

Figure 6. Flange with elongated ECD pattern.

It is important to evaluate whether each burr location on a workpiece should be ECD'd individually, using multiple electrodes to produce individual spots, or if several burr locations could be ECD'd at one time, using one large electrode to produce a band. The Sleeve shown in Figure 7 was ECD'd using 6 electrodes to produce 6 separate bands for deburring the ID. The same Sleeve, shown in Figure 8 was processed using 144 individual electrodes to produce 144 separate spots for deburring the ID. Loading the workpiece onto the fixture in Figure 7 is much quicker because the Sleeve does not have to be accurately positioned to insure the electrodes are aligned with the holes. In addition, the fixture in Figure 7 is more robust and requires less maintenance.

Figure 7. ID deburred with 6 electrodes.

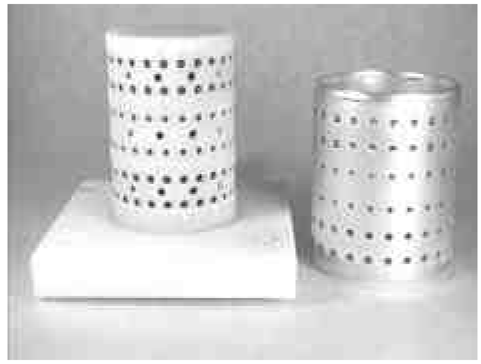

Figure 8. ID deburred with 144 electrodes.

The form, fit and function of the workpiece may dictate the use of the spot approach vs. the band approach. This could happen where the slight amount of material removed between adjacent holes could act as a fluid leak path between the holes. For any given workpiece, the individual spot approach uses less power and introduces less contamination into the electrolyte system. However, the design and construction of fixtures utilizing the individual spots is considerably more complex than fixtures utilizing the band pattern. If the band pattern can be used, the cycle time can often be improved because less attention is required in locating the workpiece on the fixture.

Electrolyte

Numerous chemicals, or chemical combinations, can be mixed with water to produce an electrolyte solution. The most common solutions are Sodium Chloride or Sodium Nitrate, with Sodium Chloride being the most popular. The parameters of the electrolyte that are controlled are: chemical analysis, concentration, flow rate, temperature, and cleanliness.

The role of the electrolyte solution is much more than to simply provide a path for current flow. The workpiece is not merely immersed into the electrolyte, but the electrolyte is carefully flowed between and around the burr and the electrode in a prescribed manner in order to accomplish specific results. The flow is a function of the fixture and its integral electrolyte plumbing passages. In addition, as the burr is being "deplated," the material that is being removed must be moved away from the electrode, by the electrolyte stream, so that it is not plated onto the electrode.

As the burr is being removed, it is possible that a section of the burr could be dissolved which might allow a piece of the burr to become detached and carried downstream with the electrolyte flow. If this happens, and the gap is located downstream, a piece of the burr could become lodged between the workpiece and the electrode and create a short. For this reason, always design the electrolyte flow to carry these pieces away from the gap.

The electrolyte flow can be plumbed through the locator and/or electrode and directed toward the workpiece, or, the flow can be plumbed through the workpiece and directed toward the locator and/or electrode. These options will produce different results. The choice of the direction of flow may be dictated by the constraints of the workpiece size, shape, etc. In addition, the electrolyte can be plumbed and directed to create a flow that is laminar, turbulent, or spiral in motion. These options will produce different results.

The material that is being removed from the burrs, and other areas of the pattern, is introduced into the electrolyte system, and is referred to as "sludge." To keep the electrolyte fresh, and extend its life, a filtering process is used to remove the sludge. Depending on the material of the workpiece, the sludge may contain heavy metals such as chrome, nickel, etc. Because of EPA constraints, these materials can be difficult and expensive to dispose of.

Electrical

The ECD power supply provides a low-voltage/high-current DC output for the process. The output can be a constant voltage for a steady current flow, or can be pulsed for a fluctuating current flow. As the burr is removed, the distance between the electrode and the workpiece increases which results in a progressively lower current flow. Some systems can compensate for this, which results in more uniform deburring, and quicker cycle time. These options can produce different results for any given material.

"Current density" is a term frequently used in discussions of Electro-Chemical Deburring. It is the ratio of current to unit area. Current, or current density, is a function of the length of the burr edge being deburred, or the size of the ECD pattern. The burr removal rate is a function of the voltage applied.

Cycle Time

The cycle time for processing a given workpiece is governed by the amount of material to be removed, which is determined by the length and thickness of the burr. The variables influencing the actual cycle time are: voltage, electrolyte temperature and gap width. Generally, increasing the voltage, warming the electrolyte, narrowing the gap, or a combination of these will reduce the deburring cycle time.

Qualifying

As mentioned earlier, the presence of loose chips, lodged chips, or large burrs can result in a short circuit that will usually damage the electrode, workpiece, or both. Because of the potential for arcing and damage, the workpiece may require "qualifying" before ECD processing.

Qualifying is the process of removing chips, hanging burrs or excessively large burrs to provide unrestricted access for the locator/electrode. A hanging burr might be similar to an attached drill cap; sometimes called a toilet seat burr or hubcap burr. Large burrs are long or tall, and are created by dull tools and/or high feed rates. In either case, these conditions may cause arcing and must be eliminated before ECD processing.

Figure 9 illustrates a Hub that requires qualifying for ECD. The locator/electrode must enter into the crosshole shown, and obviously would become entangled with the large and loose burrs. Qualifying may be accomplished by reaming, drilling, brushing, bead blasting, mass finishing, Thermal Deburring or hand methods.

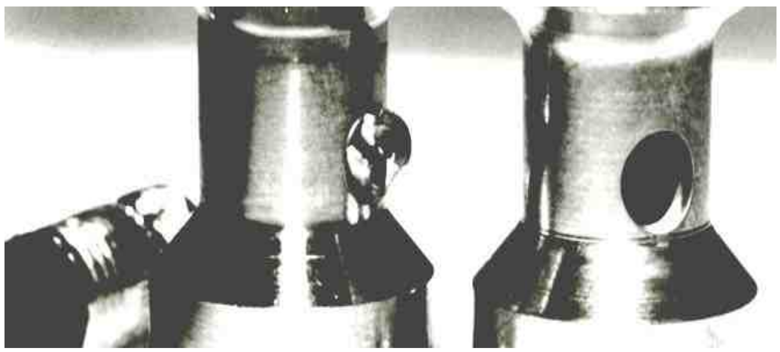

Figure 9. Hub requires qualifying before ECD.

Degreasing

The cleanliness of the workpiece before the ECD processing is an important consideration. As already discussed, chips and other forms of metallic contamination will usually result in a short. Contamination from nonmetallic particles can restrict electrolyte flow. Additionally, many cutting fluids, preservatives, rust inhibitors, and chemicals are dielectrics. Even small traces of these materials can appear as random “masks” to the process and cause erratic results. This is particularly true on workpieces with close tolerances, and where uniform results are important. All of these contaminants will deteriorate the condition of the electrolyte solution and shorten its life.

Post-ECD Cleaning

Special cleaning of the workpiece is usually required following the ECD process. The area where the burr is removed, and immediately adjacent to it, is often discolored and darker in appearance. The deposit of hydroxides or oxides, roughness of the surface, or a combination of these are thought to be causes of the discoloration. The discoloration is referred to as “smut” and is generally removed by mechanical means or chemical cleaning. Simply washing the workpiece will not remove the smut. Sometimes the smut can remain on the workpiece, and simply rinsing off the electrolyte solution in order to avoid corrosion, may be all that is necessary. Figure 10 shows a Nut with smut before and after cleaning.

Figure 10. Nut with smut before (left) and after (right) cleaning.

Hand brushing, power brushing, buffing, polishing, bead blasting, etc can mechanically remove smut. Smut can be removed chemically by a number of cleaning processes. Different workpiece materials, as well as different alloys, usually require different chemical cleaning processes.

If the workpiece is heat treated, plated, passivated, or painted following the ECD process, these processes can often remove the smut and eliminate the need for post-ECD cleaning. In these cases, a quick rinse to remove the electrolyte solution, and the application of a rust inhibitor in the case of steel workpieces, may be all that is necessary to achieve an acceptable condition.

Workpiece

Virtually any metallic engineering material can be deburred using the ECD process, however, some materials respond better than others. The best candidates are aluminum and stainless steel alloys. These materials usually exhibit smooth, consistent, and bright edge breaks. Titanium is marginally acceptable for the process.

ECD is routinely used to deburr workpieces made by every forming and/or machining process. Workpieces made from forgings, die castings, sand castings, extrusions, powdered metal, investment castings, heading, drawing, etc. lend themselves to ECD processing. Workpieces made by turning, milling, drilling, stamping, piercing, broaching, shaping, etc. are routinely ECD'd.

Workpiece Design

The design of a workpiece can have a significant impact on the ease and success of achieving the expected deburring requirements. Creativity in the initial design of the workpiece can even eliminate the need to remove some burrs. For example, a strategically placed relief, undercut, chamfer, etc. can provide a nonfunctional, out of the way, place for a burr to “hide.” Doing this can often simplify the ECD processing.

Manufacturing Processes

The sequence of the manufacturing processes determines where the burr will end up and what direction it is pointing. The order of the operations can be designed to insure that the burr ends up in a location where it is more readily accessible for deburring. This can make it easier to qualify, permit quicker deburring cycles, and/or allow for less critical deburring requirements.

The Swivel Body shown in Figure 11 illustrates the impact the sequence of operations can have on the choices for deburring. The bore shown is a critical, close tolerance bore. The critical bore on the Body on the left was machined after a threaded crosshole was machined. This sequence pushed the burr into the threaded hole, which allows a locator/electrode and mask to enter the critical bore to precisely ECD only the intersection. The Body on the right was threaded after the critical bore was finished, leaving burrs protruding into the bore. This prohibits a locator/electrode and mask from entering the critical bore without being qualified. However, the locator/electrode could be place into the threaded hole and successfully deburr the intersection, but this would allow electrolyte to flow onto the surface of the critical bore with possible adverse affects.

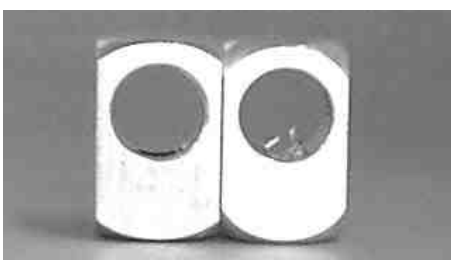

Figure 11. Sequence of machining.

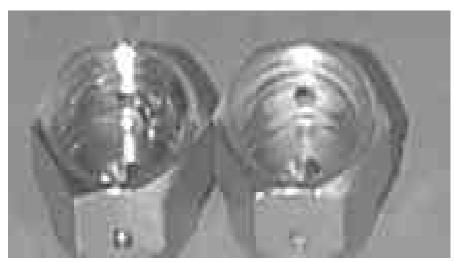

Figure 12. Sequence of ECD’ing.

Figure 12 shows a small diameter crosshole breaking into the large threaded diameter. In this case, it would not be practical to place a thin and fragile locator/electrode into the small diameter crosshole to accomplish the deburring. If the small hole was drilled first, then the thread was machined, the burrs would be pushed into the small hole. This would allow a large, robust locator/electrode to be placed into the threaded hole without qualify first. If the crosshole were drilled last, the thread would probably have to be qualified before performing the ECD process.

Burrs

"How much burr can be removed with the ECD process?" is a frequently asked question. The answer is, given sufficient cycle time and current flow; a burr of any size can be removed. However, this is not a practical solution to burr removal.

A universally accepted definition of a burr does not exist, and some aspects of burrs and deburring continue to remain vague and nebulous. Consequently, it is important for engineering, production, and quality personnel to have a good understanding of burrs for the ECD process to be successful. Some industries, professional societies and companies have developed their own definitions and standards that are very helpful.

Usually, close design tolerances dictate using carefully controlled machining operations, better tooling, better tool maintenance, etc. in order to maintain the required tolerances. This usually results in smaller, thinner, and more manageable burrs. The better burr condition allows for a smaller and more accurately placed ECD pattern, along with smaller gaps between the workpiece and electrode. This improves the overall success of ECD applications.

Safety

The ECD process is generally considered very safe. Other than the normal cautions exercised when working around 220-volt appliances, or machinery and water, the relatively low voltage employed by the actual deburring action poses little potential for electrical shock. The clamping forces of the contact bars are generally low and can rarely do serious harm if a careless mistake occurs.

The most common electrolyte, Sodium Chloride, requires no more caution than handling table salt in the kitchen. Sodium Nitrate should be given special attention because it is flammable under certain conditions. In solution, Sodium Nitrate is quite safe. However, when it becomes dried onto porous materials, like paper or cloth, it can become flammable, and should be handled with care and disposed of properly.

Benefits

The results of the ECD process are extremely uniform and predictable. The process gets into inaccessible areas that are not possible for mechanical deburring processes. Fragile workpieces are natural candidates for the ECD process.

The initial costs to purchase the ECD process, and tool-up, are considered reasonable. The consumable material for the ECD process, the electrolyte, is considered very inexpensive compared to medias used in other processes. The ECD electrolyte is easily removed from the workpiece, and there is no gritty residue to clean or stuck media to dislodge.

ECD is quicker than hand deburring, particularly when several areas of a workpiece are deburred. An ECD operator can be trained to set-up and run several part numbers quicker than a person can be trained with the requisite "craftsmanship" skills to competently hand deburr a single part number. The results of the ECD process are uniform and reliable; if the part goes on the fixture, the process does not forget to do a hole. Often the ECD pattern can be a "signature" to visually and quickly determine if a workpiece is deburred.

Limitations

Aside from the marginal success with Titanium, the major limitation is that plastics and other nonconductive materials cannot be deburred using the ECD process. Sometimes, considerable experimentation is necessary to optimize the electrolyte options for any given material. This can be particularly challenging when several materials are processed on the same machine.

Summary

The ECD process is widely accepted and successfully used in many industries including: aircraft, automotive, aerospace, nuclear, medical, semiconductor, fluid power, screw machine, Swiss machining, CNC machining, job shops, etc.

The days are long gone when deburring operations were performed by someone tucked away in a dim corner of a manufacturing plant and using a specially shaped blade of a pocket knife, or a sharpened hook on the end of a piece of welding rod. This might work for a few prototype samples, but as manufacturing engineers see the potential for increasing backlogs and larger scrap barrels in the deburring departments, the ECD process should not be ignored.