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DEBURRING CAPABILITIES FOR MINIATURE PRECISION PARTS

PDO 6984405, Topical Report

L. K. Gillespie, Project Leader

Project Team:
E. F. Felkner
L. Luebbert
B. J. Neal

Published September 1976

Prepared for the United States Energy Research and Development Administration Under Contract Number E(29-1)-613 USERDA

Bendix Kansas City Division

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Technical Communications Bendix Kansas City Division

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Prepared by L. K. Gillespie, D/822, under PDO 6984405

A study of 24 major deburring processes was made to determine those that are applicable to the production of miniature precision metal parts. In addition to the basic process capabilities and limitations, burr sizes that can be removed by each process are defined in terms of maintaining specific part-edge radii, dimensional tolerances, and surface finish requirements. Burrs having a major dimension of less than 25.4 μm (0.001 inch) are shown to be removable by almost any process without adverse effects on part dimensions or surface finish.

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SUMMARY

This study was initiated to determine which of 24 major deburring processes are applicable to the production of miniature precision metal components. Component parts of small precision mechanisms typically require near-sharp edges to assure reliable operation. A burr-free condition also is needed to minimize the possibility of the mechanism jamming in the event that burrs should break loose during operation. In the past, the reliable removal of machining burrs and the protection of the near-sharp part edges have dictated that deburring be performed only by hand. This method is inherently time-consuming and operator-variable.

Specifically, this study sought to determine the manner in which the burr size affects the operating parameters of each deburring process, and the extent to which part size, surface finish, and edge radii are influenced by the various processes. Tests were performed at Bendix Kansas City on 13 of the more promising processes. Of these, 6 were studied extensively, and reports on the individual investigations were published.

This report summarizes the data that were obtained from tests at Bendix which involved 30,000 measurements, a study of published literature, and discussions with hundreds of vendors and users of deburring equipment. The data presented describe the mechanism by which each process operates, define its uses and limitations, and provide the best possible estimate of its quantitative effects. This information can be used in the selection of a deburring process to meet specific part requirements.

As a result of this investigation, the conclusion was reached that burrs having a major dimension of less than 25.4 μm (0.001 inch) can be removed by almost any process without adverse effects on part dimensions or surface finish.

DISCUSSION

SCOPE AND PURPOSE

This study was made to determine the effectiveness of all the major deburring processes for the deburring of miniature precision parts. Specifically, each process was evaluated for its deburring efficiency and its effect on dimensions, surface finishes, and edge radii.

PRIOR WORK

Previous studies of vibratory deburring have been made by Bendix Kansas City personnel.[1,2,3] Other studies have explored the effectiveness of thermal shock deburring[4] and the deburring processes applicable to plastic workpieces.[5] Some of the results presented in this study have recently been or will be reported in greater depth than is here shown.[6-14] A very brief preliminary version of this report also has been published.[15]

In addition to the studies on deburring, several studies concerning the properties of burrs from machining operations have been published as a part of this project.[16-23] Theories of burr formation have been developed,[24-27] and the problems of burr measurement, prevention, and minimization have been documented.[28-31] Two bibliographies covering publications in eleven languages have been published,[32,33] as have two overviews of international research and trends in the field of burr technology.[34,35]

ACTIVITY

The information contained in this report is a distillation of analytical and experimental tests performed by or for Bendix Kansas City, and of information published in 1900 reference sources on deburring. Insofar as possible, the data presented relates the size of the removed burr to a given dimensional change, surface finish, and allowable edge radius. Because of the complexity of these interrelationships, this brief state-of-the-art summary provides only a realistic order-of-magnitude estimate of the effects which can be expected to occur with actual parts. Despite this limitation, the data presented will help to identify the processes having a high potential for success under a given set of conditions. References are made to sources which provide the additional details required to implement each process.

This study was initiated when component requirements such as those shown in the following list of typical constraints began to appear on part drawings:

- Burr-free under 8X to 30X magnification;

- Toleranced edge breaks [Example: 50.8/127.0 μm (0.002/0.005 inch) or 50.8 μm (0.002 inch) maximum];

- Surface finish of 0.2 μm (8 microinches); and

- Precision workpiece dimensions (having a total tolerance from 5.08 to 12.70 μm or 0.0002 to 0.0005 inch).

Although manual deburring with knives, files, abrasives, and miniature brushes could meet many of these requirements, it was expensive and provided no guarantee of the required repeatability. As was found in subsequent tests, conventional hand-deburring approaches are not reliable for producing edge radii smaller than 101.6 μm (0.004 inch). While smaller radii can be produced by manual deburring, they require that burrs be carefully abraded and not removed with knives. The extreme care necessitated by this approach can easily require 10 minutes to deburr each hole or edge. Although many controls on parts are not as critical as the constraints indicated in the preceding list, it is important to know how a deburring process will affect all part characteristics.

The data presented in this report is the result of over 30,000 measurements made on parts having a major dimension of 25.4 mm (1 inch), or less. Most of the studies were performed on parts having a volume less than 2.04 cm^3 (0.125 $inch^3$). The materials studied on experimental and production parts included beryllium-copper, 303Se stainless steel, 17-4PH stainless steel, 1018 steel, 6061-T6 aluminum, Alloy 6 brass, Kovar, Paliney, gold alloys, ceramics, and thermosetting and thermoplastic plastics. Only a small amount of effort was devoted to nonmetallic parts.

Throughout the studies, the fact that the successful deburring of miniature precision parts is dependent upon the presence of *small* burrs became increasingly apparent. Once the burrs exceed a triangular shape of roughly 76.2 by 76.2 μm (0.003 by 0.003 inch), their removal becomes practically impossible without exceeding at least one of the previously listed constraints. While some processes may cause out-of-tolerance conditions for approximately only 254 to 1270 μm (0.010 to 0.050 inch) around the deburred feature, this amount is too great when the part is only 1.524 mm (0.060 inch) in diameter or thickness. For these reasons, preventing and minimizing the size of burrs is very important, particularly when the burrs are located in hard-to-reach areas.

A companion report describes practical techniques for assuring the minimization of burrs and provides typical cost trade-offs between burr prevention, burr minimization, and deburring.[36]

Report Format

This report describes the operating characteristics of each deburring process. Each description contains a list of numbered references that will be found at the end of the report. Following these descriptions, tables are offered which provide comparative data concerning the various processes. Additional tables then describe processes that typically are used to deburr specific types of features. The information in the latter tables is recorded as a function of the allowable edge radius and stock loss.

Because of safety considerations or the fact that they are relatively new, some of the processes described in this report are not yet used in industry. However, for completeness, all major techniques for the removal of burrs are described. Those that are more commonly used are presented first. The relationships among the principal deburring processes and mechanisms are illustrated by Figure 1.

The data shown in the tables are based on typical deburring practice and on the best information available at the present time. In many cases, the data presented could be improved upon with the expenditure of considerable additional effort. Further advances in materials and research undoubtedly will improve the capabilities of many of these processes.

Vibratory Deburring

Process Mechanics

Parts are inserted into a vibrating tub or bowl with abrasive media, fine abrasive compounds, and water (Figure 2). The abrasive compound, which consists of soaplike ingredients and minute abrasive particles, is continually rubbed against workpiece edges by the stonelike media. This gradual abrasion eventually hones away the burrs and sharp edges. Any abrasive materials can be used as media, although aluminum oxide and plastics or ceramics impregnated with abrasive particles are the more common. An estimated 500 combinations of media size, shape, and material have been used in this process. References: 1-3, 6, 13, 37-44.

Typical Applications

Workpiece Size. Most vibratory deburring machines will accommodate workpieces that are hand-size or smaller. A typical unit has a capacity for 0.085 m^3 (3 $feet^3$) of media and workpieces; however, machines have been built to accommodate 12.2-m-long (40-foot) wing spars. Very small parts (3.175-mm or 0.125-inch cubes, for example) receive little action as compared to that received by larger parts.

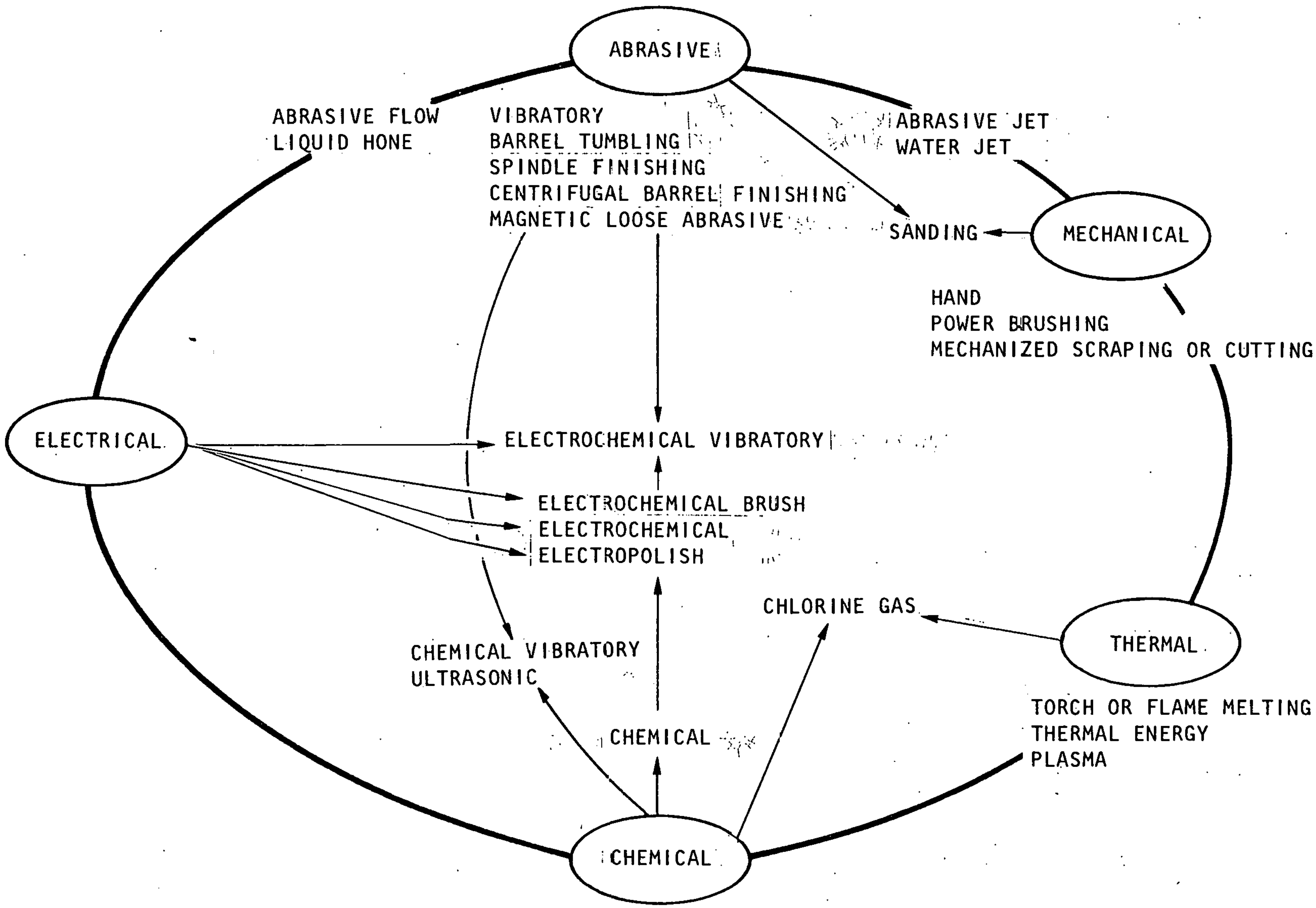


Figure 1. Principal Deburring Processes and Mechanisms

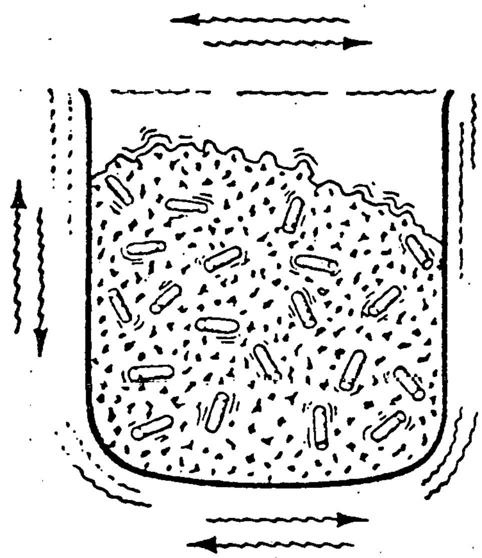


Figure 2. Vibratory Deburring

Workpiece Shapes. This process is used primarily to remove burrs from external edges of parts. Since a wide variety of media shapes and sizes are available, it can deburr parts having almost any contour. If the media can pass through holes in the part, it will radius the hole edges. Because of a piling-up of the media, the process generally is not effective on the edges of blind features; the media must be able to flow over the part edges.

Cycle Time. In a machine having a capacity of 0.085 m^3 (3 $feet^3$), a typical deburring operation requires 2 hours. Larger machines require shorter times, partly because there is more media to exert a force on the workpieces. As a general rule, from 30 to 50 percent of the machine's contents may consist of workpieces. The higher the percentage of workpieces, the more often part-on-part impingement will occur.

Limitations

Heavy burrs will not be removed from very small parts without a noticeable change in the part dimensions. This process removes stock from all external surfaces and edges. As previously mentioned, it does not perform well on internal features of small workpieces.

The process also impregnates minute particles of the media and abrasive into the workpiece surfaces. This can result in poor brazed, soldered, or welded joints, and it increases the probability of plating-adhesion failures. In general, the use of dolamite or silicon carbide will prevent these problems.

When a workpiece contains a number of different-size holes, effective media that do not lodge in some of the holes may be impossible to obtain.

Typical Effects on Dimensions and Tolerances

Size Change. A 5.1-μm (0.0002 inch) stock loss results from the removal of a 76.2-μm-thick (0.003 inch) burr from stainless steel.

Size-Change Repeatability. The repeatability of the change in size is a function of the part geometry, but the size generally will be repeatable within ±5.1 μm (±0.0002 inch).

Edge Radius. On most workpieces, the consistent production of a radius smaller than 76.2 μm (0.003 inch) is impossible. Few stainless-steel parts will exceed a radius of 0.25 mm (0.010 inch) in a deburring cycle. Aluminum workpieces will have up to twice the stock loss and edge radius of stainless steel.

Edge-Radius Repeatability. With consistent burr size, edge radii will have a repeatability of ±25.4 μm (±0.001 inch).

Surface Finish. Although vibratory finishing can produce surface finishes as fine as 0.2 μm (8 microinches) in a deburring cycle, finishes of 1.0 μm (40 microinches) are more common.

Comments

Typically, this process is the lowest-cost and most-easily-modified operation available for deburring parts. Large parts can be fixtured in vibratory units for rapid deburring with no part-on-part impingement.

Barrel Tumbling

Process Mechanics

Parts are inserted into a closed rotating tub with abrasive compound, media, and water (Figure 3). As in vibratory deburring, the continual rubbing of abrasive over the part edges slowly abrades the burrs. The nonabrasive portion of the compound provides a sudsing action which keeps the fine abrasive particles suspended between the media and the workpieces. The parts undergo a gradual sliding action as opposed to the shaking action of vibratory deburring. References: 6, 13, 37, 39-51.

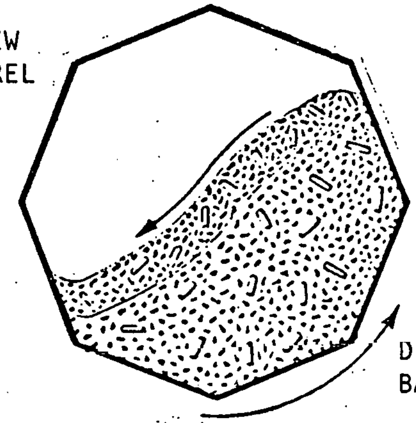


Figure 3. Barrel Tumbling

Typical Applications

Workpiece Size. Similar to the workpiece sizes used in vibratory deburring--hand-size or smaller.

Workpiece Shapes. Similar to those used in vibratory deburring.

Cycle Time. A typical deburring cycle is approximately 8 hours. Because many parts can be processed in the same barrel, the cost per part is low. One person can operate as many as 50 barrels, since little attention is required.

Limitations

This loose-abrasive process has the same limitations as those noted for vibratory deburring.

Typical Effects on Dimensions and Tolerances

Size Change. Typically, 5.1 μm (0.0002 inch) of stock loss occurs to remove the described burr. Aluminum usually will have twice the edge radii and stock loss that occurs from stainless steel.

Edge-Radius Repeatability. For consistent burr size, edge radii should be repeatable within ±25.4 μm (±0.001 inch).

Surface Finish. Typically, from 0.2 to 0.8 μm (8 to 32 microinches), although in burnishing cycles, 0.05 μm (2 microinches) can be obtained.

Comments

In many cases, this process may be noticeably more economical than vibratory deburring. Used extensively for deburring small electrical contact pins, it is one of the processes which will not bend or damage thin or fragile parts. It is a slower, more gentle process than vibratory deburring. Barrel tumbling produces compressive surface stresses up to 1.24 GPa (180,000 psi), which improves fatigue life dramatically.

Spindle Finishing

Process Mechanics

Parts are colleted on the end of a rotating spindle, one to a spindle, and inserted in a tub of abrasive media, abrasive compound, and water (Figure 4). The tub of media is rotated at a speed of 7.62 m/s (1500 sfpm) in the direction opposite to that of the spindle rotation. The continual flow of abrasive particles over the external edges of the parts quickly abrades the burrs and generates radii. The abrasive media and compounds are the same as those used for barrel tumbling and vibratory deburring. References: 40, 52.

Typical Applications

Workpiece Size. The majority of parts for which this process is used are of hand-size or larger, although any size of workpiece that can be held by one end can be used.

Workpiece Shapes. This process is used primarily on rotating parts such as gears, crankshafts, compressor rotors, and machined cylindrical components.

Cycle Time. In a typical application of a two-spindle machine, one part is completed each minute.

Limitations

As in all loose-abrasive processes, heavy roll-over burrs often will be beaten over rather than removed, and impregnation of the part with abrasive compound will occur. External edges will receive much more action than small cutouts or holes.

Typical Effects on Dimensions and Tolerances

Size Change. With stainless steel, a stock loss of 5.1 μm (0.0002 inch) probably will occur from external surfaces while 76.2-μm-thick (0.003 inch) burrs are removed. Die cast parts may experience a size change of 12.7 to 25.4 μm (0.0005 to 0.001 inch) in a one-minute cycle.

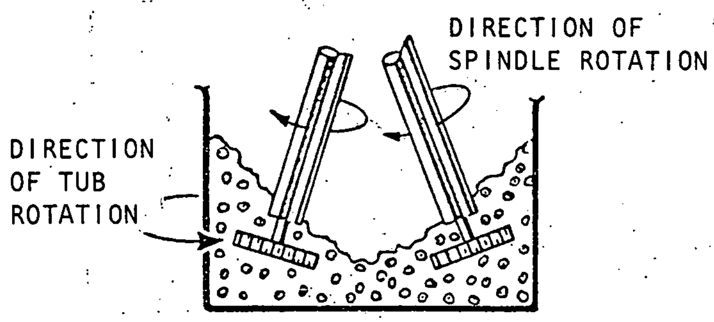


Figure 4. Spindle Finishing

Size-Change Repeatability. A reasonable assumption is that size-change repeatability will be within ±5.1 μm (±0.0002 inch), although no actual data has been reported. Workpiece geometry will greatly affect the results.

Edge Radius. As a general rule, edges develop radii quickly in this process. Radii of 76.2 to 508.0 μm (0.003 to 0.020 inch) have been reported for stainless steel workpieces.

Edge-Radius Repeatability. Reportedly, within ±2.54 μm (±0.0001 inch) for some edges. A more realistic repeatability for most parts would be ±38.1 μm (±0.0015 inch).

Surface Finish. Finishes of 0.4 to 1.0 μm (16 to 40 microinches) can be produced in a deburring cycle.

Comments

Parts often can be stacked on the spindle in such a manner that several parts are deburred at one time. Production rates of 500 parts per hour have been achieved with some workpieces. Because parts are fixtured, no part-on-part impingement can occur.

Centrifugal Barrel Finishing

Process Mechanics

Parts are immersed in a barrel of media, abrasive compound, and water, and the barrel is rotated (Figure 5). The turret on which the barrel sets is then rotated in the opposite direction. Because each barrel is positioned at some distance from the centerline of the turret, a centrifugal force is developed which increases the force between the media and the workpieces. Typically, the forces developed are in the order of 10 to 25 g.

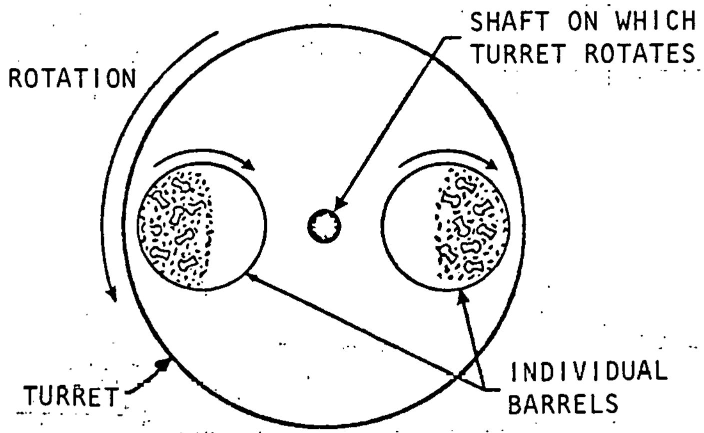


Figure 5. Centrifugal Barrel Finishing

As with all loose-abrasive processes, the basic mechanism of burr removal is abrasion. References: 6, 11, 37, 38, 40, 43-45, 50, 53.

Typical Applications

Workpiece Size. The principal utilization of this process is for hand-size or smaller parts (1.5 mm or 0.060 inch, for example). Large parts can be deburred individually in large barrels.

Workpiece Shapes. This process primarily removes burrs from external edges. Any configuration can be deburred, provided that the media are small enough. It generally does not do well on blind features because of media pile-up.

Cycle Time. Typically, deburring times vary from 5 to 20 minutes per load. With a small machine, as many as 2000 pins, each 0.5 mm (0.020 inch) in diameter, may be deburred simultaneously. As a general rule, 30 percent of the contents of a barrel can consist of workpieces. With six machines, 300,000 watch components can be deburred in a day.

Limitations

Heavy burrs will not be removed from very small parts without a noticeable change in part dimensions. This stock loss will occur over all external edges. The process can deburr small holes and slots, but it generally is not as effective as on fully exposed edges. As with vibratory deburring, media impregnation of the parts will occur unless soft media are used. When a workpiece contains a number of different-size holes, effective media that do not lodge in some of the holes may be impossible to obtain. Large parts can be deburred, but a large machine usually is required to accommodate them.

Typical Effects on Dimensions and Tolerances

Size Change. Stock loss is a function of the part size. Large parts will lose more material than small parts in the same cycle. While a stock loss of 5.1 μm (0.0002 inch) is common when 76.2-μm-thick (0.003 inch) burrs are removed, losses of only 1.02 μm (0.00004 inch) can be maintained for smaller burrs.

Size-Change Repeatability. For many parts, the repeatability of this process is in the order of ±1.52 μm (±0.00006 inch). This loss corresponds to ±3 standard deviations. Because of the previously described effect of part size, a group of parts may be more uniform in size after centrifugal barrel finishing than they were before.

Edge Radius. While 50.4-μm (0.002 inch) radii possibly may be produced, a 76.2-μm (0.003 inch) radius is the smallest that should be attempted with typical burrs. Radii up to 0.5 mm (0.020 inch) have been produced from stainless steel using large media in a two-hour cycle.

Edge-Radius Repeatability. For consistent burr sizes on the part edges, radii will be repeatable within ±25.4 μm (±0.001 inch).

Surface Finish. Typical surface finishes of 0.81 μm (32 microinches) are found on stainless steel after a deburring cycle, but finishes of 0.05 μm (2 microinches) have been produced on ball bearings as well as on soft metals.

Comments

This is one of the few processes that works well on very small parts. It also is one of the most flexible of the available processes. Separation of nonmagnetic parts from media of similar size can be a problem in some job-shop applications. As with barrel tumbling, this process can produce very high compressive stresses in surfaces and thus improve fatigue life.

Abrasive-Jet Deburring

Process Mechanics

A stream of high-velocity abrasive particles is directed at burrs until they become eroded or beaten over (Figure 6). The abrasive particles may consist of miniature glass beads, crushed steel shot, aluminum oxide, silicon carbide, plastic pellets, crushed

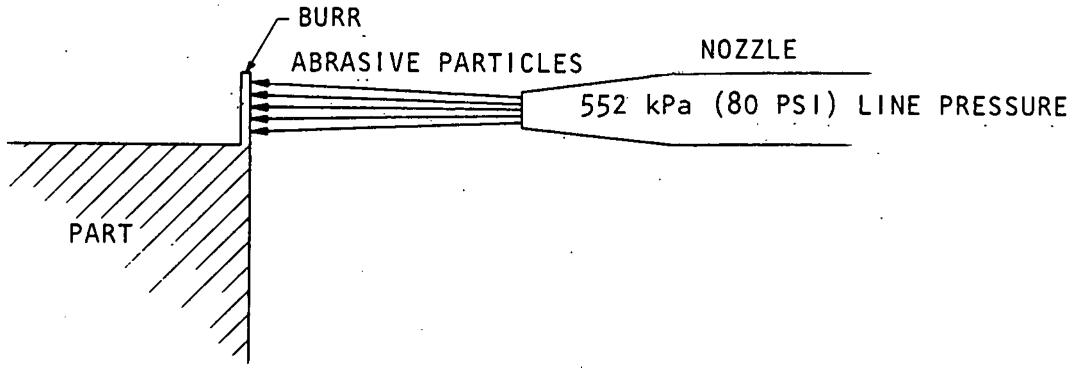


Figure 6. Abrasive-Jet Deburring

fruit or nut shells, or a variety of other materials. Although the abrasive generally is propelled by air, some machines utilize a slurry of water and abrasive. References: 37, 54-59.

Typical Applications

Workpiece Size. Machines have been produced which accommodate parts that must be held by tweezers as well as parts weighing up to 400 pounds. A typical unit will accept a 609.6-mm-diameter (2-foot) part for deburring. One manufacturer specializes in equipment for hand-size or smaller parts.

Workpiece Shapes. This process is used primarily for exposed edges, although burrs at hole intersections and under ledges also may be reached. It is insensitive to part shape unless the shape masks the burrs. Although its use for deburring blind features is somewhat limited, it is more efficient than the tumbling processes.

Cycle Time. In a typical application, from 1 to 2 minutes is sufficient to remove burrs and all loose particles. Floor-to-floor time will vary with the loading and unloading conditions, but automated lines can handle 400 parts per hour.

Limitations

Heavy burrs will not be removed without noticeable dimensional changes. The process is best suited to materials that produce thin, brittle burrs. It often is used when only loose and sharp fragments must be removed. As with all loose-abrasive processes, it impregnates minute amounts of abrasive into the workpiece surface; however, the use of dolamite, a soft limestone, will overcome this problem. The complete removal of abrasive particles from recessed areas may require special effort.

Typical Effects on Dimensions and Tolerances

Size Change. Because the process roughens a surface, an exposure of short duration will *increase* the part-diameter or thickness readings as much as 2.54 μm (0.0001 inch); with additional blasting, *decreases* in diameter up to 12.7 μm (0.0005 inch) are possible. The change in size often is expressed as the weight of material removed per minute, with 32 mg/minute being a common upper limit. Part size is affected only in the blasted area.

Size-Change Repeatability. Within the blasted area, the part size is consistent within ±10.2 μm (±0.0004 inch). For many wet-blasted parts, a repeatability of ±1.27 μm (±0.00005 inch) can be maintained.

Edge Radius. The edges produced by this process can be rounded and relatively uniform, or they can be chamfered, depending upon the conditions under which the process is used. With the exception of the miniature machines which utilize small nozzle openings, most machines will produce radii larger than 76.2 μm (0.003 inch) but smaller than 254 μm (0.010 inch). The miniature units and the wet-blast units will produce radii in the order of 76.2 μm.

Edge-Radius Repeatability. As in most deburring processes, edge-radius repeatability is a function of the burr-size repeatability. For typical production situations involving 76.2-μm-thick (0.003 inch) burrs, the typical edge-radius repeatability is ±76.2 μm.

Surface Finish. In typical applications, abrasive-jet deburring will roughen machined surfaces, sometimes up to 7.62 μm (300 microinches). A typical stainless steel surface will have a finish in the order of 1.63 μm (64 microinches), or better.

Comments

The cost of this process can be very low if the burrs are small or brittle. Burrs which are 25.4 μm (0.001 inch) in thickness, or less, are good candidates for the process. Because of its aggressiveness, it is not well suited to such soft metals as brass or aluminum, although it can be used. Some impregnation of the blasting media into the workpiece surfaces can affect welding and cutting-tool life. Because the process produces high compressive surface stresses, thin sections can be warped by blasting. This is one of the few processes that can be easily adapted to great differences in the size, geometry, material, and quantity of the parts.

Sanding

Process Mechanics

Parts are inserted into a machine in which sandpaper is used to abrade the burrs (Figure 7). References: 60, 61.

Typical Applications

Workpiece Size. Sanding machines are available to accommodate flat parts having a length from 12.7 mm (0.5 inch) to 0.914 m (36 inches). Typically, 12.7-mm-thick steel plate is the thickest material inserted into a machine, and 1.52-mm (0.060 inch) steel plate is the thinnest. If the workpiece is 25.4 mm (1.0 inch) or larger on a side, 0.178-mm-thick (0.007 inch) material can be deburred.

Workpiece Shapes. Machine sanding is limited to flat workpieces, although special innovations such as inflatable sanding drums, narrow-belt sanders, and flap wheels can be used manually or with mechanized equipment to deburr complex shapes.

Cycle Time. Flat sanding can be performed at a rate of 200 to 400 parts per hour, depending on the size of the part. Typical conveyors built into the sanding machine have a velocity of 102 mm/s (20 fpm).

Limitations

Flat sanding will remove heavy burrs without noticeably affecting the part size. With proper application, all sanding action will be concentrated at the edges of the part. Flat sanding produces a small burr of its own which has to be removed from miniature precision parts and from parts subject to fatigue loading. These small burrs are easily removed by most other deburring processes.

Typical Effects on Dimensions and Tolerances

Size Change. Complete burr removal can be accomplished while removing no more than 12.7 μm (0.0005 inch) of stock from flat surfaces. With appropriate rollers on a machine, no stock will be removed except at the part edges.

Size-Change Repeatability. While no data has been published on size repeatability, a reasonable assumption is that sanding an entire surface should result in a repeatability of ±25.4 μm (±0.001 inch). Of course, variations in the initial thickness will influence these results.

Edge Radius. With most workpieces, a burr, rather than a radius, is produced by sanding. By selecting an appropriate roller or using

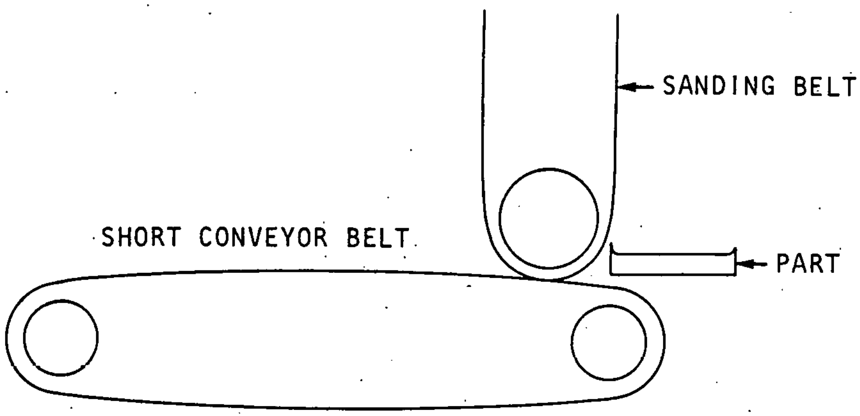


Figure 7. Sanding

a "Scotchbrite" type wheel, as opposed to conventional sandpaper, radii up to 254 μm (0.010 inch) can be produced. Loose belt sanders which conform to the part-edge geometry can produce practically any required radius.

Edge-Radius Repeatability. When radii are produced, their repeatability probably is within ±76.2 μm (±0.003 inch).

Surface Finish. With 320-grit abrasive paper, which would be used to remove small 25.4- by 25.4-μm (0.001 by 0.001 inch) burrs, a surface finish between 0.8 and 1.6 μm (32 and 64 microinches) can be maintained. If the abrasive contacts only the part edges, the surface finish is not affected.

Comments

Unlike the loose-abrasive processes, sanding does not impregnate abrasives into the workpiece. An estimated 400 different combinations of sanding materials, grit types, and grit sizes are available. Many of these products are designed for manually sanding holes, slots, contours, and other nonflat shapes.

Brushing

Process Mechanics

Rotating fibers cut and abrade burrs from the parent metal (Figure 8). Typically, the brush is oscillated over only the edge of the part, rather than over the entire surface. Steel, stainless steel, brass, tampico, and nylon constitute the most frequently used bristle materials. Many of the nylon brushes are impregnated with a fine abrasive to accelerate abrasion. A deburring abrasive compound normally is used with tampico

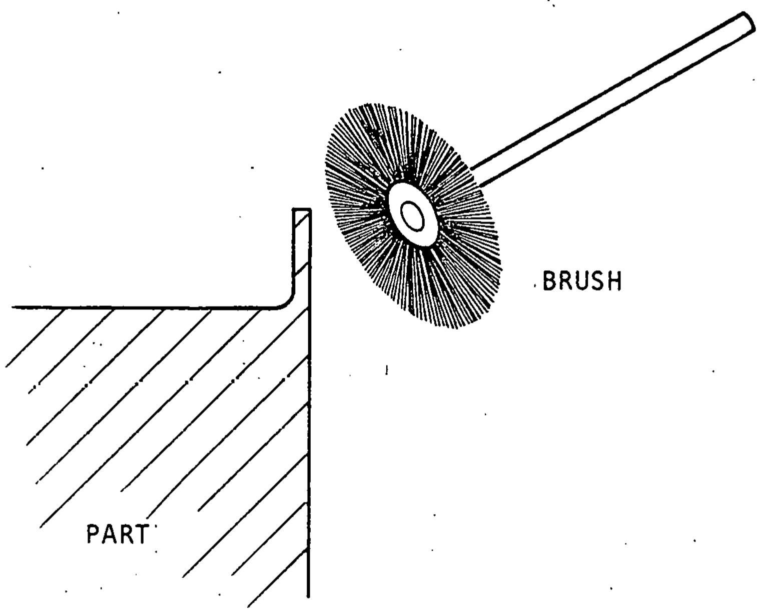


Figure 8. Brushing

brushes. Nonwoven nylon also is processed into a matted material and impregnated with resin and abrasive to provide a stiff brush which will not damage surfaces. References: 7, 8, 39, 62-65.

Typical Applications

<u>Workpiece Size</u>. Parts which are less than 12.7 mm (0.5 inch) in length cannot be readily brushed because of handling difficulties. Most bristles are in the order of 127 μm (0.005 inch) in diameter, so uniform burr removal and radiusing is difficult when slots are small (such as 0.51 mm or 0.020 inch in width).

<u>Workpiece Shapes</u>. If the bristles of the brush can rotate over an edge, the burrs will be removed. Any shape which will not allow the bristles near the edge of interest will not be deburred. Although brushes to remove burrs from intersecting 0.81-mm (0.032 inch) holes are available, they can remove only small burrs. Heavy burrs require aggressive brushes which cannot be produced in very small sizes.

<u>Cycle Time</u>. A 25.4-mm-long (1.0 inch) edge on a small part can be deburred in 1 minute by the use of a 25.4-mm-diameter brush. Larger and stiffer brushes can remove burrs faster, but they often will produce a chamfer rather than a radius.

Limitations

Heavy burrs will not be removed from very small parts. Typically, a 50.8-μm-thick (0.002 inch) burr is the largest that can be effectively removed from a precision stainless steel part.

Because brushing action is concentrated at the edges of the part, no size change occurs on the surfaces. Significant changes do occur, however, in the surface finish and hardness of the surface layer below the brushed area.

Typical Effects on Dimensions and Tolerances

Size Change. The only change in size is at the edge of the part. If the entire surface is brushed, a reduction in size up to 76.2 μm (0.003 inch) may occur.

Size-Change Repeatability. On brushed surfaces, the repeatability probably is ±12.7 μm (±0.0005 inch).

Edge Radius. Edge radii of 101.6 μm (0.004 inch) or less can be produced while removing thin (25.4-μm or 0.001-inch) burrs from stainless steel. On hard materials with very small burrs, radii of 50.8 μm (0.002 inch) or less can be produced.

Edge-Radius Repeatability. For 303Se stainless steel, the repeatability of brush-deburred edges was ±25.4 μm (±0.001 inch) when small brushes were used to remove small burrs. For other materials, the repeatability was ±76.2 μm (±0.003 inch), or better.

Surface Finish. With appropriate brushes, a 0.41-μm (16-microinch) surface finish can be maintained.

Comments

Brushing is one of the most underutilized, yet most adaptable deburring processes that is available. An estimated 300 combinations of brush sizes, materials, and designs are available.

Hand Deburring

Process Mechanics

Hand or manual deburring includes any deburring technique in which the part or the deburring tool is hand-held (Figure 9). Typically, the burrs are removed with knives or some other form of cutting tool. Drills, reamers, and countersinks also are used. Power-driven brushes, abrasive paper, abrasive stones, and abrasive-laden rubber products usually are used to polish the edges of the parts after the burrs have been removed. References: 12, 66.

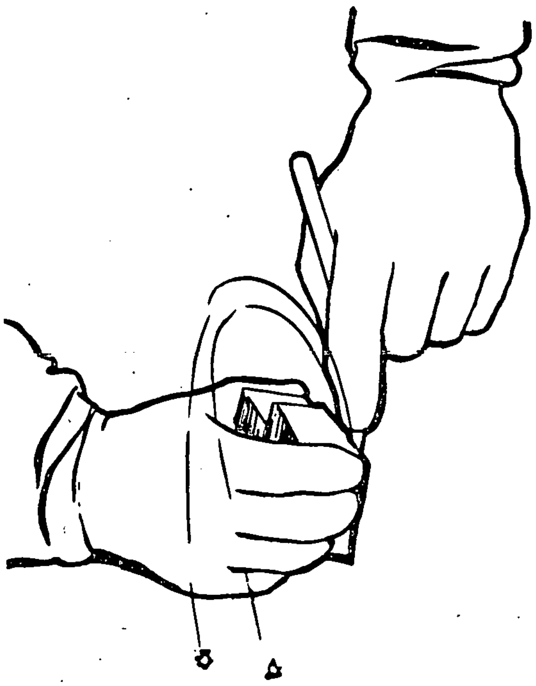


Figure 9. Hand Deburring

Typical Applications

Workpiece Size. Because parts that are smaller than 3.175 mm (0.125 inch) are difficult to hold, they cannot be readily deburred.

Workpiece Shapes. Hand deburring typically is used on parts having shapes that make deburring by other processes difficult or impossible.

Cycle Time. Five minutes is the average time required for deburring miniature precision parts. The time required is determined by the burr size, the workpiece material, the accessibility of the burrs, and the number of edges to be deburred.

Limitations

Heavy burrs greatly increase the time required for deburring. Because of individual differences in the personnel performing hand-deburring operations, the final results are operator-dependent and subject to operator fatigue.

Typical Effects on Dimensions and Tolerances

Size Change. Because the operators concentrate their efforts on the part edges, the size of the part will not change unless the part is distorted by holding pressure.

Size-Change Repeatability. No size change.

Edge Radius. Although edges having a radius of 50.8 μm (0.002 inch) or less can be produced, conventional practice utilizing knives can assure radii of only 101.6 μm (0.004 inch), or less. Smaller edge radii can be produced if all cutting or sanding forces are maintained parallel to the surfaces until the final blending pass.

Edge-Radius Repeatability. The typical edge produced on miniature precision components at Bendix Kansas City has a radius repeatability of ±50.8 μm (±0.002 inch).

Surface Finish. Hand deburring normally does not affect the surface finish of the part. A slip of a knife, however, often will produce a scratch.

Comments

Hand deburring should be used when burrs are not accessible to other processes, when an unusually heavy burr must be removed prior to deburring the whole part in a mechanized process, and when the required surface finish is 0.41 μm (16 microinches), or better.

Abrasive-Flow Deburring

Process Mechanics

An abrasive-laden, putty-like material is forced over burr-laden part edges (Figure 10). The abrasive gently abrades the burrs and provides a smooth radius. Abrasives from Number 120 to 16 typically are used with larger particles to provide a more aggressive abrading action. By varying the properties of the putty-like carrier, a wide variety of part materials and configurations can be deburred. References: 10, 67-69.

Typical Applications

Workpiece Size. Most machines will accommodate parts having a volume of 0.028 m^3 (1 ft^3), or less. Typical parts are hand-size, or smaller. Holes as small as 0.25 mm (0.010 inch) in diameter have been successfully deburred by this process.

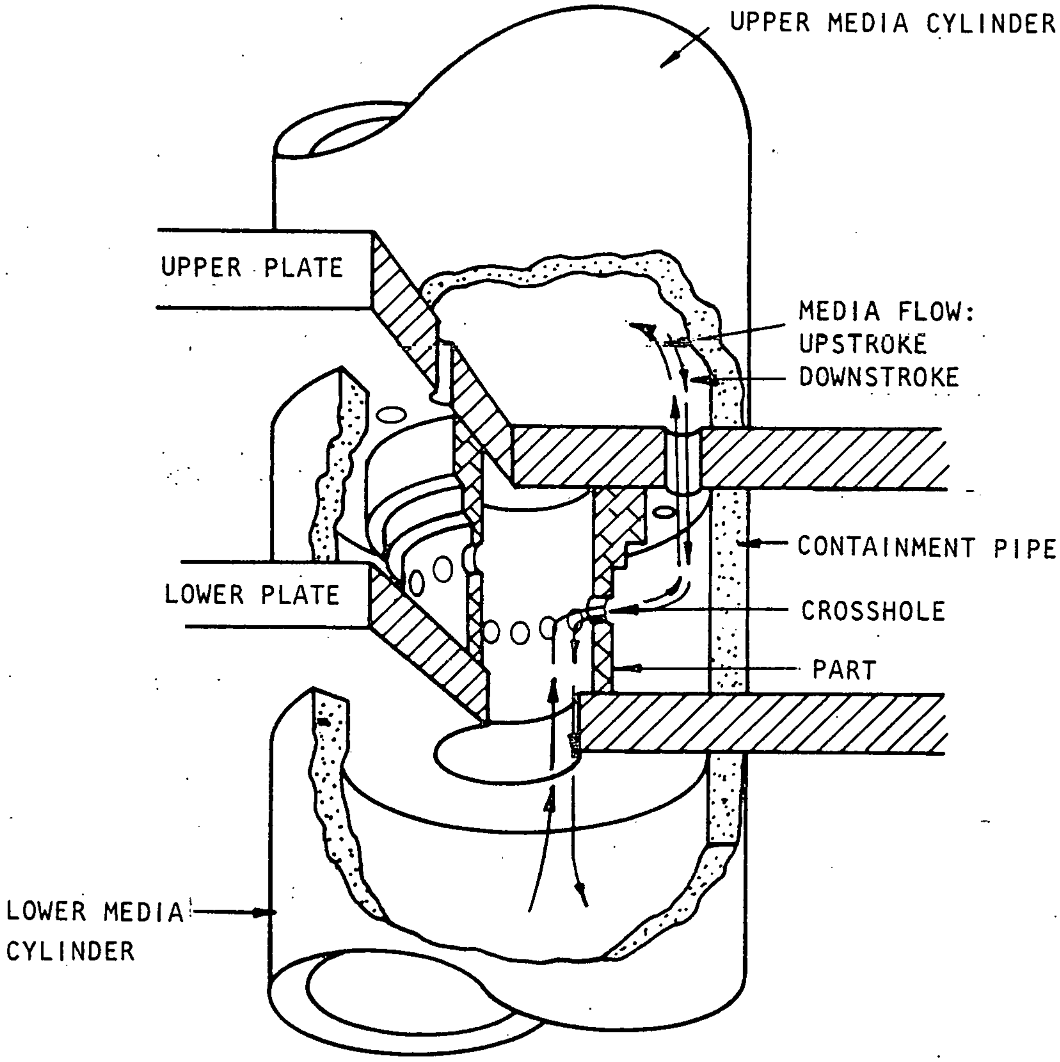


Figure 10. Abrasive-Flow Deburring

<u>Workpiece Shapes</u>. This process is applicable to all shapes of parts, although its principal application has been for deburring intersecting holes. If tooling can be designed to direct the media flow over the edge of interest, the edge can be deburred. In most cases, blind features cannot be readily deburred.

<u>Cycle Time</u>. Abrasive-flow deburring requires from 1 to 5 minutes per part for a complete cycle. The actual deburring normally requires 1 minute, or less. Loading and unloading the parts require more time than deburring. Typically, a single part is processed at a time, although multiple parts could be accommodated.

Limitations

Unless tooling is employed to concentrate the abrading action at the edges of the part, heavy burrs cannot be removed without the removal of similar amounts of stock from the adjoining surfaces. An occasional particle of loose abrasive may be left in complex passageways; however, complete removal of the particles can be assured in most situations. Parts require subsequent cleaning in either hot, soapy water or a solvent such as chlorethane.

Typical Effects on Dimensions and Tolerances

Size Change. Typically, a stock loss of 76.2 μm (0.003 inch) accompanies the removal of a 76.2-μm-thick burr. The use of tooling restrictors to concentrate the abrading action at the part edges will reduce the stock loss at a cost of the more complex tooling that is required.

Size-Change Repeatability. The repeatability of the change in the hole size, using extrude-hone X-base media, is ±38.1 μm (±0.0015 inch) or better, depending upon the size of and number of holes deburred at one time.

Edge Radius. For most workpieces, producing radii smaller than 76.2 μm (0.003 inch) while removing a 76.2-μm-thick burr is impossible. The use of tooling which causes the media to hone the holes without radiusing the edges is possible, but not typical.

Edge-Radius Repeatability. For consistent burr size, edge radii will have a repeatability of ±38.1 μm (±0.0015 inch), or better. On burr-free sharp edges, the radii consistency is probably half of this value.

Surface Finish. This process can produce finishes as fine as 0.05 μm (2 microinches), although a 0.4-μm (16-microinch) finish is more realistic for a deburring cycle.

Comments

This is another deburring process which can be easily modified for a particular application. Its greatest disadvantage is its need for tooling and the consequent loading and unloading of parts. Its surface-finishing capabilities, the smooth edges it produces, and its ability to deburr hard-to-reach areas are its principal assets.

Mechanized Mechanical Deburring

Process Mechanics

A wide variety of mechanical cutting operations have been mechanized to perform deburring activities (Figure 11). The use of countersink tools to remove burrs from holes is one example. Small grinding wheels or special cutters often are used to remove burrs from large production lots of gears. Machines are available for removing burrs from the edges of sheet metal by grinding or cutting a chamfer, or by physically pressing the burr back into the parent metal. While brushing, sanding, and hand deburring actually are cutting processes, they are described in separate sections of this report. Although electrical discharge machining (EDM) is not a mechanical cutting process, it too has been used to remove heavy burrs. Deflashing presses also fall into the category of mechanical deburring processes. References: 32, 33, 70, 71.

Typical Applications

Workpiece Size. Most of the machines that are available for the mechanical removal of burrs are used for hand-size or larger parts. Special-purpose machines can be easily built to deburr parts of almost any size.

Workpiece Shapes. Most mechanical deburring equipment is for use on external edges. The two largest groups of such equipment are for deburring sheet-metal parts and gears.

Cycle Time. Gears can be deburred with standard machines at rates up to 120 parts per hour. Sheet-metal edges are usually deburred at rates in the order of 15.24 mm/s (3 fpm), although faster rates are possible. In sheet-metal rolling plants, the edges of the metal are deburred as the stock emerges from the mill.

Limitations

The greatest disadvantage of mechanized mechanical deburring is that it produces new burrs while removing existing burrs. Typically, however, the burrs that are produced are smaller than the burrs removed. The new burrs then are removed by brushing or other deburring processes. Processes which roll the burr back into the edge of the parent material may not produce burrs, but the edge may develop a material buildup.

The second limitation to the use of mechanized mechanical deburring is accuracy. If a small edge break is required, a precision machine must be used, thus increasing the equipment

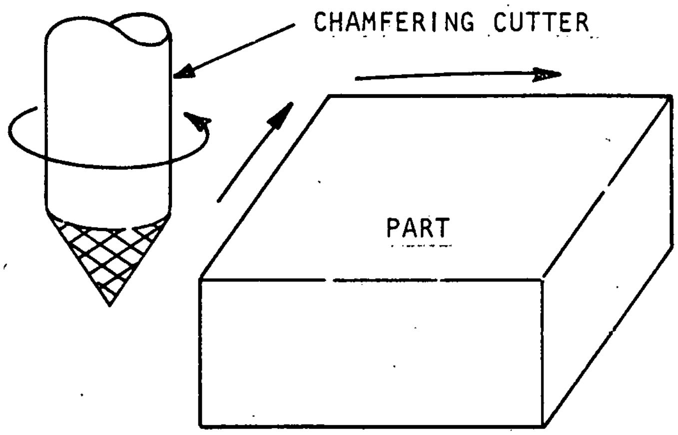


Figure 11. Mechanized Mechanical Deburring

cost. For very small, complex part geometries, cutters that will reach into small crevices may be impossible to obtain.

Typical Effects on Dimensions and Tolerances

Size Change. Because all deburring action is concentrated at the edges of the parts, no change occurs in the thickness dimensions.

Size-Change Repeatability. No change in thickness dimensions.

Edge Radius. Most of the available equipment produces chamfers rather than radii. While 50.8 by 50.8-μm (0.002 by 0.002 inch) chamfers are possible, 127.0-μm (0.005 inch) chamfers are more common.

Edge-Radius Repeatability. Probably ±50.8 μm (±0.002 inch) on chamfers.

Surface Finish. This process does not affect surface finish.

Comments

For some miniature parts, this technique may be faster and more repeatable than hand deburring if precision equipment is available to do the work. Eventually, miniature programmable robots with portable spindles may be available for such work.

Thermal-Energy Deburring

Process Mechanics

Natural gas and oxygen are ignited in a closed chamber filled with parts (Figure 12). The very brief high-temperature shock wave which accompanies the combustion burns away much of the burr. Within a few microseconds, the burr again ignites briefly as a result of high heat buildup in the burr. Reference: 72.

Typical Applications

Workpiece Size. The largest available standard chamber is 254.0 mm (10 inches) in diameter and 152.4 mm (6 inches) high. Parts therefore must be capable of being fitted into this size of chamber.

Workpiece Shapes. This process will work as well for intersecting holes as for external edges. If the fuel gases can surround the burr, the burr can be removed.

Cycle Time. A typical thermal-energy deburring cycle requires 20 seconds. Small parts can be treated in batch lots since the fuel gas completely surrounds all parts.

Limitations

While thick burrs can be removed by this process, thin flanges also may be consumed at the same time. The rule-of-thumb that is used for determining the maximum allowable burr size is that the burr thickness must not exceed 1/15 the thickness of the thinnest feature on the part. Delicate parts may have to be located on pins to keep them from being buffeted by the combustion shock.

Because an oxide is deposited on the surfaces of the parts during this process, a subsequent part-cleaning operation is required. Because some of the metal below the burr becomes liquid during combustion, a thin recast layer is produced at the part edge. This may cause cracks in previously hardened steels.

Typical Effects on Dimensions and Tolerances

Size Change. Approximately 2.54 μm (0.0001 inch).

Size-Change Repeatability. Probably less than ±2.54 μm (±0.0001 inch).

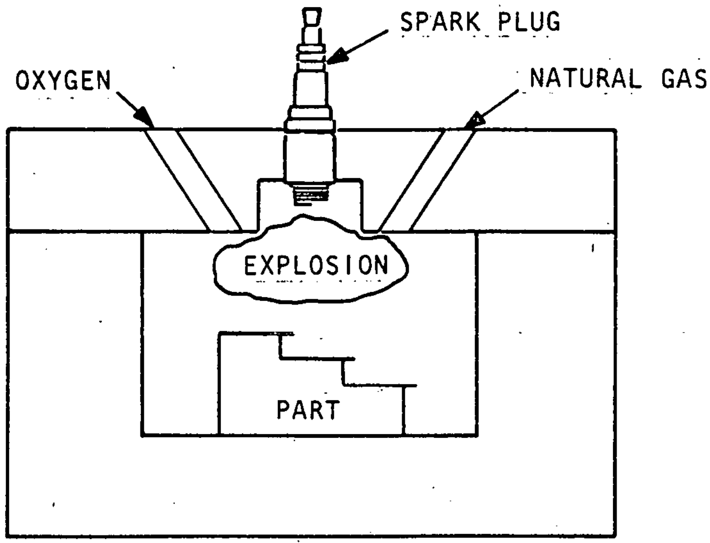


Figure 12. Thermal-Energy Deburring

Edge Radius. From 0.508 to 1.52 mm (0.002 to 0.060 inch) on steel; 50.8 to 254 μm (0.002 to 0.010 inch) on aluminum.

Edge-Radius Repeatability. Probably ±50.8 μm (±0.002 inch), although the repeatability of the burr size will determine the repeatability of the radius.

Surface Finish. Coarse surface finishes may be improved slightly, but finishes finer than 0.81 μm (32 microinches) may be degraded with a consequent loss in reflectivity.

Comments

The equipment required for this deburring method costs from $60,000 to $200,000. As a result, this process generally is economical only for high-volume production. Because of the thick burrs usually found on aluminum and 300-series stainless steel parts, and because of the configuration and radius limitations of many miniature precision parts, this process is not applicable to most of the miniature precision parts that are produced at Bendix Kansas City. The process is widely used for cast iron, brass, and zinc components, and for materials having low strain-hardening exponents.

Chemical Deburring

Process Mechanics

Parts are inserted into a tank of specially formulated acids which etch away the burrs and some of the parent metal (Figure 13). Because of the stock loss, this process generally is used only for parts having thin burrs. Honing and grinding burrs are removed by this process, as are the burrs produced on electrical connectors by screw machines. In large batch operations, parts sometimes are tumbled in the solution to assure a uniform stock removal. Reference: 73.

Typical Applications

Workpiece Size. Most of the parts that are chemically deburred are very small, although the only limitation is the size of the tank.

Workpiece Shapes. This process is not affected by the shape of the workpiece. It attacks all edges and surfaces uniformly, provided that gas bubbles do not build up on a portion of the part surface and shield that area from further attack.

Cycle Time. In general, a batch of parts will require from 5 to 30 minutes for deburring. Obviously, the time required is a function of the burr size.

Limitations

Heavy burrs will not be removed without a similar change in the part size. With some materials, chemical deburring may be able to "soften" long burrs so that they can be easily removed by vibratory deburring.

Typical Effects on Dimensions and Tolerances

Size Change. Typically, the change is equal to the thickness of the removed burr (from 12.7 to 76.2 μm or 0.0005 to 0.003 inch).

Size-Change Repeatability. The repeatability of the size change has not been documented. By nature, however, it should be repeatable within ±25.4 μm (±0.001 inch).

Edge Radius. Published data indicate that edge breaks will be 2 to 3 times greater than the amount of stock removed.

Edge-Radius Repeatability. Probably ±25.4 μm (±0.001 inch).

Surface Finish. Finishes as fine as 0.15 to 0.20 μm (6 to 8 microinches) can be maintained. Roughness exceeding 0.8 μm (32 microinches) will show some improvement.

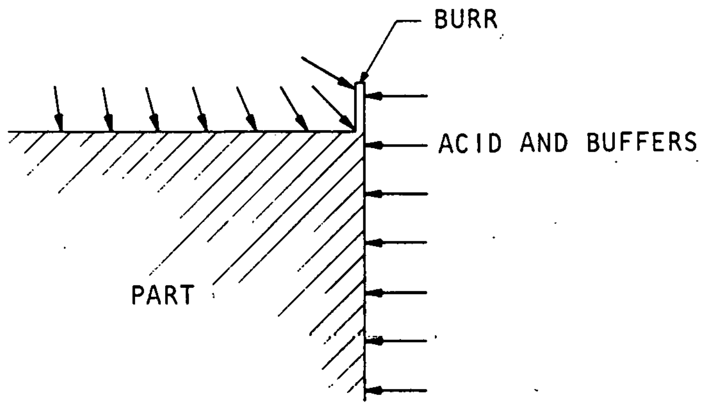


Figure 13. Chemical Deburring

Comments

This is a very low-cost process, but it requires careful monitoring. It has been used successfully on carbon-steel alloys, 300-series stainless steel, aluminum, and copper-base alloys. It removes surface oxides, but the parts must be free of oil prior to deburring. Although little data on the solutions for chemical deburring have been published, many chemical companies supply deburring solutions.

Electrochemical Deburring

Process Mechanics

Electrochemical deburring (ECD) utilizes a dc electrical current and a chemical bath to remove metal from selected areas of a part (Figure 14). With two exceptions, the process is similar to that used for electroplating. First, in an electroplating cell, the entire sacrificial anode is consumed and is plated onto the cathodic workpiece; in ECD, the workpiece constitutes the anode, and only the burr is removed. Second, under normal circumstances, no metal deposition occurs on the cathode (the tool) during ECD. Unlike the procedures used for electrochemical plating processes, the cathode must be placed within a few thousandths of an inch of the area to be deburred.

To prevent stock removal from other locations on the part, the electrically conductive tool is covered with a nonconductive coating except for the area which will be adjacent to the burr. To remove waste products, the salt-solution electrolyte is continuously forced through the gap between the tool and the burr. Once the power has been turned on, the cathodic electrode

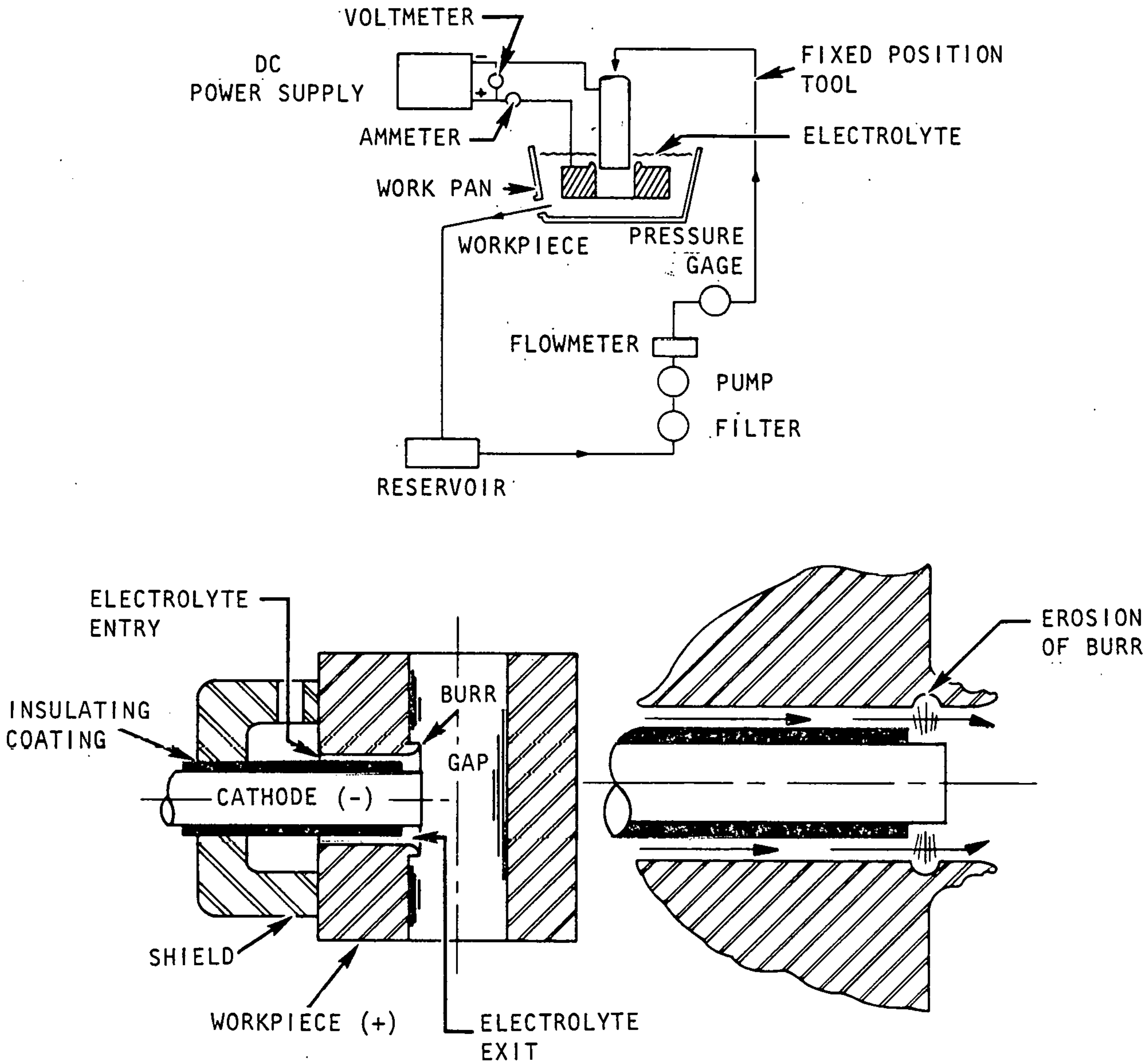


Figure 14. Electrochemical Deburring

is not moved. Fixturing is required to accurately position the workpiece, and the electrodes must be machined to conform to the feature that is to be deburred. References: 74-76.

Typical Applications

Workpiece Size. The features that are deburred by this process range in size from parts having a diameter of 914.4 mm (3 feet) to small cylinders with holes having a diameter of 0.5 mm (0.020 inch).

Workpiece Shapes. Provided that the electrode can be positioned close to the burrs to be removed, the process is not noticeably affected by the configuration of the workpiece.

Cycle Time. Deburring often can be completed in 20 seconds, although the total cycle time is approximately 3 minutes for nonautomated applications. Typically, only one part is deburred at a time; however, multiple parts could be easily deburred in a single cycle.

Limitations

This process is relatively unaffected by the thickness of the burrs to be removed. It is very sensitive to excessively long burrs, however, since they may cause a short in the electrical system. Because the electrolyte typically consists of a solution of table salt, corrosion may occur on all parts passing through the process. Stray pitting or etching also should be expected. This process can be used only on electrically conductive workpieces.

Typical Effects on Dimensions and Tolerances

Size Change. No size change occurs except in the immediate vicinity of the burr.

Size-Change Repeatability. Size is not affected.

Edge Radius. Typical radii produced by this process range from 127 to 254 μm (0.005 to 0.010 inch). Smaller radii can be produced if burrs are small.

Edge-Radius Repeatability. For a consistent burr size, the edge radii will be repeatable within ±50.8 μm (±0.002 inch).

Surface Finish. With the exception of some stray etching, the process does not affect surface finish. In the immediate vicinity of the burr, a finish of 0.406 μm (16 microinches) can be produced.

Comments

This is one of the few processes that are applicable to the deburring of intersecting holes. Precision tools are required for precision parts. A black residue usually is left on the surface of ferrous parts, and a white residue is left on aluminum parts. These residues can be removed by brushing or by loose-abrasive finishing processes. This process produces a corrosive salt mist which may corrode other nearby machines. The process is particularly well-suited for use on 300-series stainless steel.

Electropolish Deburring

Process Mechanics

Parts are electrically connected to a power source and then immersed in a buffered acid solution (Figure 15). When a dc current is applied to the anodic part, metal from the surfaces of the part goes into solution in a manner similar to that of an electrochemical plating bath. Unlike electrochemical deburring, material is removed from all part surfaces unless they are covered with a protective coating. For proper action, most solutions must be heated to 65°C (150°F), and either the parts or the solution must be agitated. References: 77-80.

Typical Applications

Workpiece Size. Electropolish deburring is commonly used on small watch-component-size parts, although 1.83-m-diameter (6-foot) tanks have been deburred by immersing only a small portion of the part at a time. The size limitation is determined by the capacity of the power supply. Deburring typically is performed at current densities from 0.46 to 2.31 A/cm^2 (3 to 15 $A/in.^2$) of part surface.

Workpiece Shapes. Workpiece configuration does not influence deburring action, provided that gas bubbles do not become trapped and shield an area of the part from further attack. Internal features often are attacked at a slower rate than external features.

Cycle Time. In most situations, burrs will be removed within a range of 0.5 to 10 minutes. The process can be performed on single parts, or a group of parts can be deburred simultaneously.

Limitations

Because this process removes material from all part surfaces, it usually is limited to the removal of small burrs. Thick burrs can be removed if a stock removal of 76.2 to 127.0 μm (0.003 to 0.005 inch) is permissible. The process is limited to electrically conductive workpieces.

Typical Effects on Dimensions and Tolerances

Size Change. Although burrs are removed somewhat faster than metal from flat surfaces, a good rule-of-thumb is that the removal of 76.2-μm-thick (0.003 inch) burrs will remove 76.2 μm of stock from all part surfaces.

Size-Change Repeatability. With long deburring cycles, some taper of the parts will be visible. In general, the size at a particular location on the part should be repeatable within ±25.4 μm (±0.001 inch). Closer tolerances are possible.

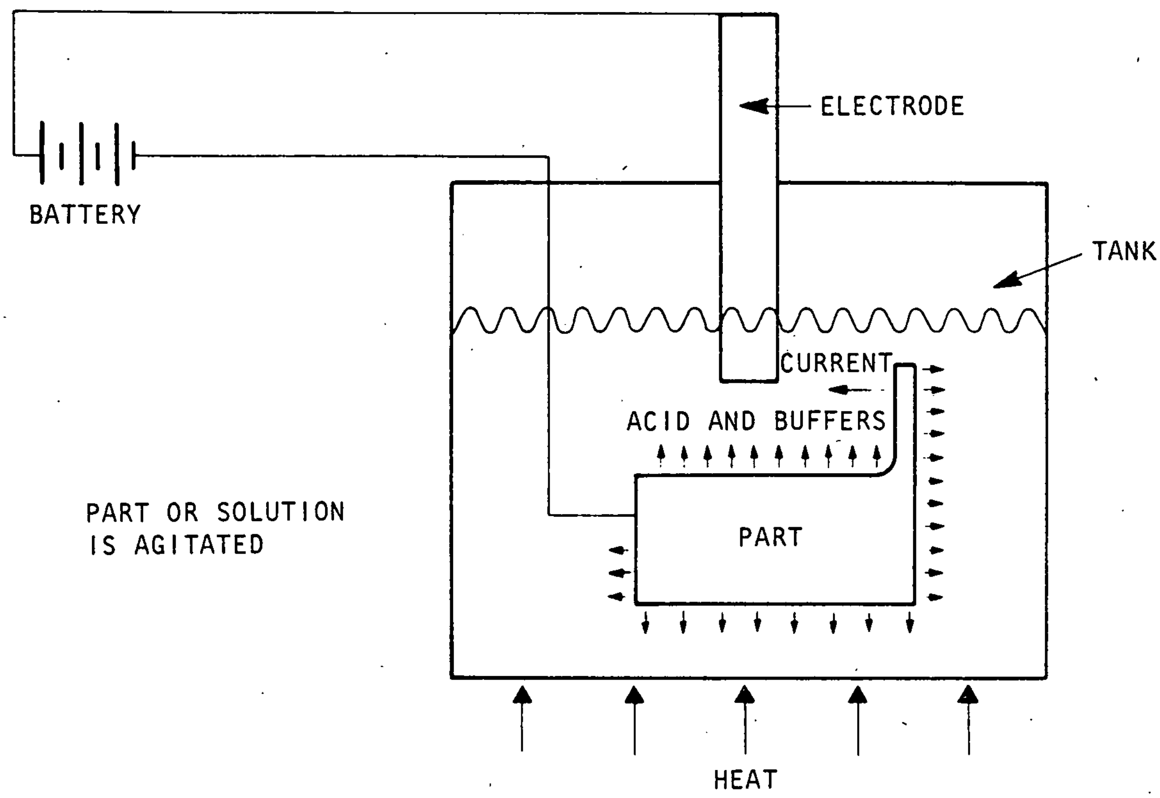


Figure 15. Electropolish Deburring

Edge Radius. Radii develop slowly with the use of this process. Typically, for miniature precision parts, the radii will be in the order of 76.2 μm (0.003 inch).

Edge-Radius Repeatability. If the burr size is consistent, the final edge radius should be consistent within ±25.4 μm (±0.001 inch).

Surface Finish. Surface finishes of 0.05 μm (2 microinches) can be produced with this process. In a deburring cycle, finishes can be developed or maintained in the order of 0.4 μm (16 microinches), or better.

Comments

Typically, this process is used on very small burrs such as those produced by lapping, honing, or grinding. In addition to producing fine finishes, it removes contaminating elements from the workpiece and relieves the high residual stresses often found on machined surfaces. In Europe, it is widely used for deburring watch-size parts. Electropolish deburring is particularly well suited to use on stainless steels and copper-base alloys if the burrs are small.

Ultrasonic Deburring

Process Mechanics

Ultrasonic deburring utilizes ultrasonic cavitation and a specially compounded acid slurry (Figure 16). The slurry consists of a comparatively weak etching solution and a small quantity of abrasive particles. Ultrasound provides high-energy shock waves which cause the abrasives to remain suspended and to constantly bombard the workpiece edges. The ultrasound also increases the etching action. The combination of etchant, ultrasound, and abrasives apparently attacks the edges of the parts more than the surfaces because of microstructure changes in the area of the burr. The burrs are strain-hardened material, and strain-hardening produces microstructure changes.

Although ultrasonic deburring was introduced in 1953, little information has been published regarding the process. The constituents of the slurry appear to be a closely guarded secret, although a recent Soviet publication indicates that 30- to 70-μm (0.0012 to 0.0079 inch) abrasive particles are used with glycerin, stearic acid, sulphuric acid, and other ingredients. References: 14, 81-83.

Typical Applications

Workpiece Size. Most components that have been successfully deburred by the use of ultrasound are of watch-component size. Large parts require large tanks and powerful ultrasonic transducers.

Workpiece Shapes. The process is most applicable for use on burrs on external part edges, although the part configuration is not critical since the operating medium consists of a fluid.

Cycle Time. Time requirements are directly proportional to the burr size. Very thin burrs can be removed in 10 minutes or less, while normal machining burrs require 25 minutes or longer. Parts have been deburred at a rate of 20,000 parts per day, but this rate appears to be an exception to the rule.

Limitations

This process is used only on thin burrs (those having a thickness of approximately 12.7 μm or 0.0005 inch). Typical applications consist of honing burrs or small burrs on stamped electronic components. The process has been used on a number of different materials.

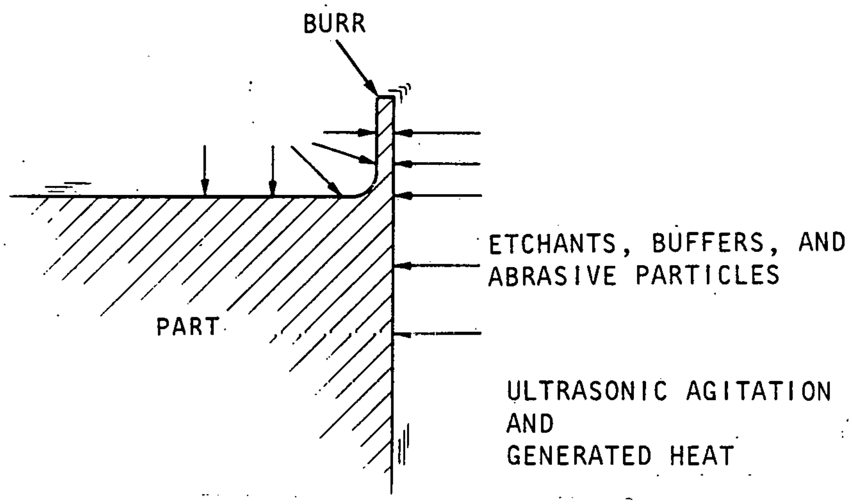


Figure 16. Ultrasonic Deburring

Typical Effects on Dimensions and Tolerances

Size Change. Based on published data, the typical stock loss is 50.8 to 76.2 μm (0.0002 to 0.0003 inch). The removal of thick burrs would produce a greater stock loss.

Size-Change Repeatability. Approximately ±2.54 μm (±0.0001 inch).

Edge Radius. Edge radii of 50.8 to 127.0 μm (0.002 to 0.005 inch) have been produced, although the lower limit appears more characteristic of the process.

Edge-Radius Repeatability. A repeatability of ±2.54 μm (±0.0001 inch) has been quoted for edge radiusing.

Surface Finish. A 0.406-μm (16-microinch) surface finish has been reduced to 0.203 μm (8 microinches) for 416 stainless steel.

Comments

This relatively obscure process is being utilized by at least two facilities in the United States. Its success appears to require careful control of all parameters.

Torch or Flame-Melting Deburring

Process Mechanics

Oxyacetylene or similar torches are used to melt the burr and the edge of the part (Figure 17). Reference: 84.

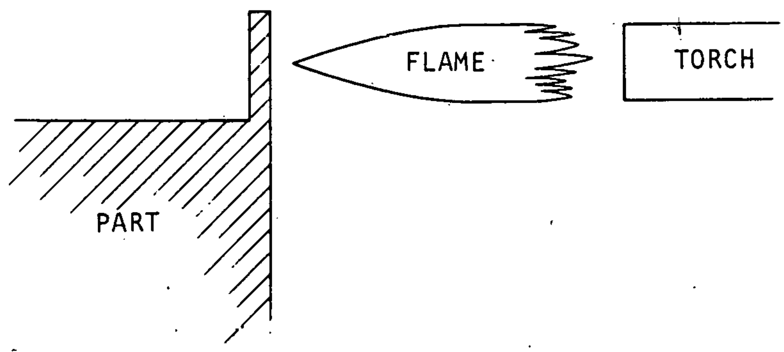


Figure 17. Torch or Flame-Melting Deburring

Typical Applications

Workpiece Size. Because the heat melts surrounding surfaces, this process apparently is used only on very large castings.

Workpiece Shapes. Although the process is applicable to any shape of part, the flame must be able to reach the burr.

Cycle Time. The deburring time per part requires approximately the same time as a welding operation. Very small burrs can be removed at a rate of 0.83 to 1.66 mm/s (20 to 40 ipm).

Limitations

A heat-affected zone is left around edges that have been deburred by this technique. On some parts, resolidified droplets may be left attached to the part.

Typical Effects on Dimensions and Tolerances

Size Change. Piece part dimensions should not be affected.

Size-Change Repeatability. The repeatability of the part size is not affected unless the part has thin sections.

Edge Radius. Although smaller radii are possible, most edges should have radii of 127 μm (0.005 inch) or larger after being exposed to this process.

Edge-Radius Repeatability. Probably in the order of ±127 μm (±0.005 inch).

Surface Finish. This process should not affect surface finishes.

Comments

Torch or flame-melting deburring appears to be most applicable to the removal of sprues, gates, and flash from man-size parts. Very little information has been published to indicate the applications in which it is best used. Although miniature torches are available, the process does not appear applicable to the complete removal of burrs from miniature precision parts.

Water-Jet Deburring

Process Mechanics

A very fine stream of high-pressure water cuts the burrs from the part edges (Figure 18). The water stream is in the order of 127 to 508 μm (0.005 to 0.020 inch) in diameter, and the pressures utilized range up to 689 MPa (100,000 psi). With some units designed for deburring aluminum transmission-valve bodies, pressures of only 334 MPa (5000 psi) are used. For this application, a wider stream of water is employed to reach all part surfaces. Parts can be positioned under a moving nozzle or transported under fixed nozzles. References: 85, 86.

Typical Applications

Workpiece Size. Most applications have been for components 305 mm (1 foot) in size, or larger; much smaller parts can be deburred, however.

Workpiece Shapes. The process can be used for any shape of part at which a fine stream of water can be directed.

Cycle Time. Nonmetal parts have been deflashed at lineal rates up to 254 mm/s (600 ipm). Aluminum transmission housings have been deburred at rates up to 350 pieces per hour.

Limitations

This process will not remove heavy burrs efficiently. At a pressure of 33.4 MPa (5000 psi), the maximum thickness of an aluminum burr that can be removed is 101.6 μm (0.004 inch).

Typical Effects on Dimensions and Tolerances

Size Change. This process does not affect part size.

Size-Change Repeatability. Size repeatability is not affected.

Edge Radius. No published data are available concerning the edge radius that is produced. A reasonable assumption is that radii will be in the order of 50.8 to 254 μm (0.002 to 0.010 inch).

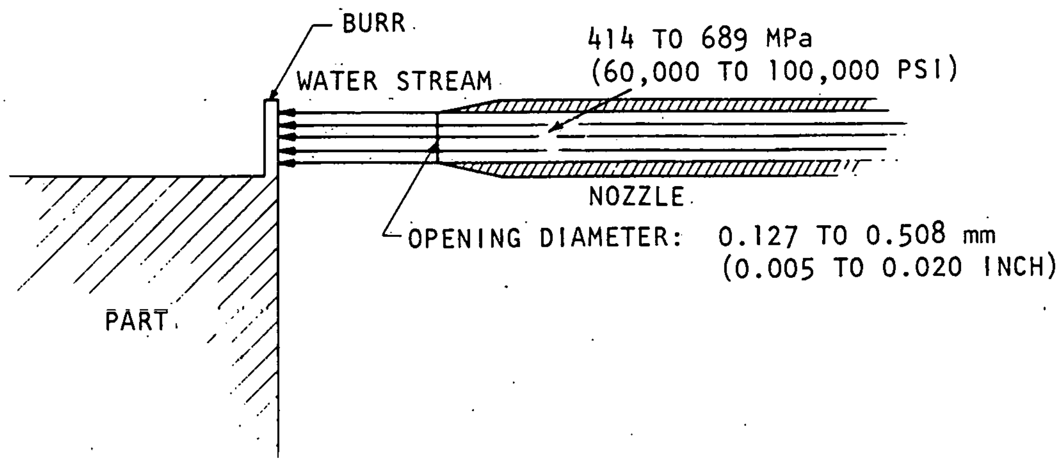


Figure 18. Water-Jet Deburring

Edge-Radius Repeatability. Probably within ±50.8 μm (±0.002 inch).

Surface Finish. Surface finishes should not be affected except at the immediate edge of the part.

Comments

This process has been used commercially on plastics, wood, aluminum, and other materials which require low cutting forces. Although it can cut thin sheets of metal (up to 254 μm or 0.010 inch in thickness), it apparently is not fast enough to use for deburring steels. The process has an advantage over abrasive-jet deburring in that no foreign material is introduced to part surfaces or hard-to-reach areas. In addition, the water removes most of the dirt and loose chips.

Electrochemical Vibratory Deburring

Process Mechanics

Parts are placed in an electrically insulated drum filled with electrolyte and graphite spheres (Figure 19). Electrodes are connected to an external power source and placed in the drum. When the drum is vibrated, the abrasive graphite spheres, which take the place of conventional deburring media, act as local extensions of the electrodes and, as in electrochemical deburring, remove the burr electrolytically. They also abrade the passivating surface oxides on the work and expose fresh surfaces to the electrolytic action. The result of this process is a reported reduction in operating time by a factor of 10 to 30.

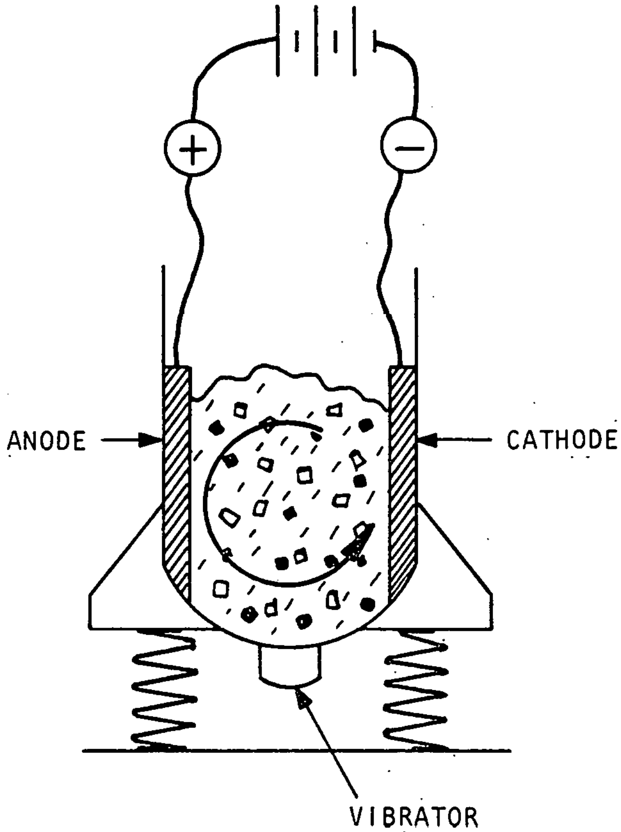


Figure 19. Electrochemical Vibratory Deburring

Two British patents, filed in 1968, indicate that phosphoric acid is used as the electrolyte in this process, and that either silicon carbide or copper-coated aluminum oxide can be used as the deburring media.

In a related development, one researcher connected parts to the positive side of a power supply and followed a similar process. In his study, however, a physical coupling with the workpiece apparently was used, whereas in the other cases, the electrolyte and graphite provided the coupling. One researcher's results indicated that the process was from 3 to 9 times faster than conventional vibratory finishing. References: 14, 87, 88.

Typical Applications

Workpiece Size. Most of the parts described in the available literature have been hand-size or smaller. The parts must be able to fit in a vibratory deburring machine.

Workpiece Shapes. As in vibratory deburring, the edges to be deburred must be exposed to the tumbling media. This mainly limits the process to use on external edges, although some internal features can be deburred.

Cycle Time. Based on the most recently published information, a typical cycle requires 30 minutes, although earlier publications indicated that a drilled brass wristwatch housing having a 50.8-μm-thick (0.002 inch) burr was deburred in 35 seconds.

Limitations

This process is limited to use on materials which conduct electricity. Only one production installation is known to exist in the United States; it reportedly uses the process on millions of small precision components every week. As with the loose-abrasive deburring processes, material is removed from all exposed surfaces.

Typical Effects on Dimensions and Tolerances

Size Change. Although little data have been published, basic size changes for most cycles should be in the same order of magnitude as for the standard loose-abrasive processes: from 2.54 to 101.6 μm (0.0001 to 0.004 inch).

Size-Change Repeatability. Based on one published example, the size is uniform within ±50.8 μm (±0.002 inch).

Edge Radius. The edge radius produced probably is similar to that produced in vibratory deburring: 76.2 μm to 508 μm (0.003 to 0.020 inch).

Edge-Radius Repeatability. Probably within ±50.8 μm (±0.002 inch).

Surface Finish. One recent publication indicates that a surface finish of 2.03 μm (80 microinches) is the best typical finish that can be produced.

Comments

This process still is in its infancy, even though it has been commercially available for more than ten years. It appears to be most applicable to nonprecision, high-volume parts. Electrochemical barrel finishing and electrochemical spindle finishing are offshoots of this process.

Electrochemical Brush Deburring

Process Mechanics

Parts are positioned in fixtures and sprayed with an electrolyte while an electrically charged rotating brush is passed over their burr-laden edges (Figure 20). The combination of electrolytic action and the mechanical cutting by the bristles of the brush remove the burr. The belt-driven brush spindle is connected to the negative side of the power supply. As in conventional brush deburring, a variety of brush styles can be used. Although little data are given in the only article published to date on this process, a 3000-percent increase in productivity is quoted. Reference: 89.

Typical Applications

Workpiece Size. This process is most applicable to hand-size or larger parts although, theoretically, small parts present no obstacle.

Workpiece Shapes. The process is designed primarily to remove burrs from external edges of parts. If the brush utilized is small enough, internal features also can be deburred.

Cycle Time. This process should be faster than brush deburring. Theoretically, it could be as fast as electrochemical deburring which requires a deburring cycle of 20 seconds, or longer. Electrochemical brush deburring could be easily applied to continuously moving stock, while electrochemical deburring typically is limited to a stationary type of operation.

Limitations

The use of electrochemical brush deburring is limited to workpieces which conduct electricity. At the present time, no commercial equipment is available for this process, although electrochemical grinders could be used. As in electrochemical deburring, some stray etching of the parts may occur.

Typical Effects on Dimensions and Tolerances

Size Change. Some change in the part size probably will occur because of the electrolyte, although most of the action will be in the area of the brush-workpiece interface. In most cases, the size change probably is 2.54 μm (0.0001 inch), or less.

Size-Change Repeatability. The repeatability of the size change, if it occurs, probably is in the order of 2.54 μm (0.0001 inch).

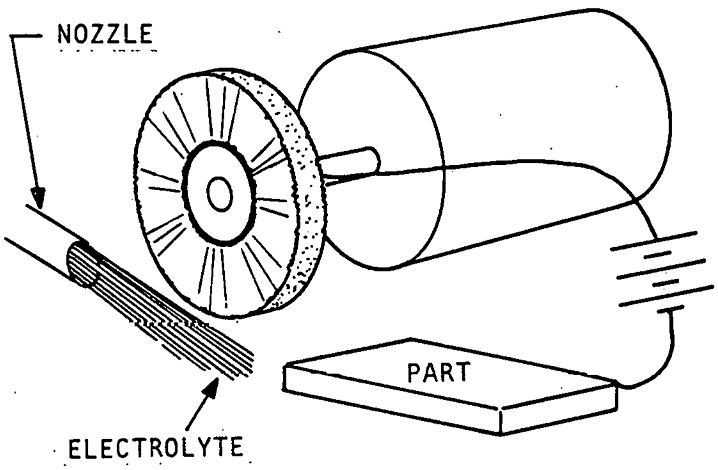


Figure 20. Electrochemical Brush Deburring

Edge Radius. As with brush deburring and electrochemical deburring, the edge radius produced probably is between 50.8 and 508 μm (0.002 and 0.020 inch).

Edge-Radius Repeatability. Based upon electrochemical grinding, a repeatability of ±25.4 μm (±0.001 inch) is a reasonable assumption.

Surface Finish. Although surface finish basically is not affected by the process, some stray etching may occur and degrade the finish in small areas of the part.

Comments

This process still is in the developmental phase.

Chemical Vibratory Deburring

Process Mechanics

Parts are immersed in a vibrating tub of abrasive media and chemicals (Figure 21). The chemicals react with metal parts to remove metal. The vibrating media wipe away any passivating films which occur, and they provide additional mechanical cutting and burnishing action. Conventional vibratory finishing media and tubs can be used, although rubber linings may be affected by the chemical solutions. References: 14, 90-94.

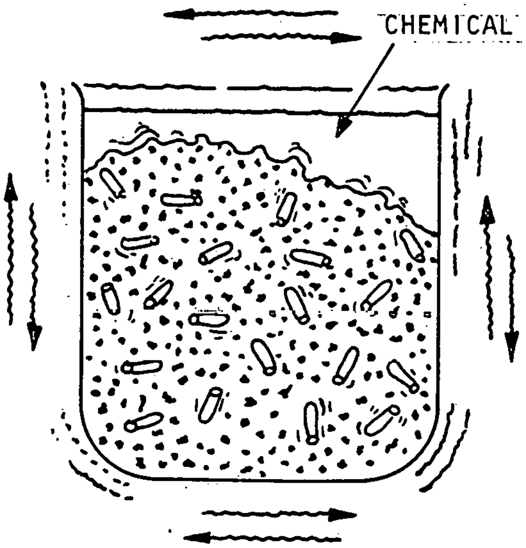


Figure 21. Chemical Vibratory Deburring

Typical Applications

Workpiece Size. The only size limitation in the use of this process is the capacity of the vibratory machine. As a general rule, hand-size and larger parts would be used.

Workpiece Shapes. The vibrating media must contact the burr. In general, internal features will not receive significant deburring action.

Cycle Time. When the removal of heavy stock is required, the process reportedly is up to 10 times faster than conventional vibratory deburring. Deburring times therefore would range from 20 minutes to 1 hour per load.

Limitations

This process reportedly will remove 0.5-mm-thick (0.020 inch) flash from zinc die castings if the process is allowed to operate for some length of time. Although the basic process has been used on steel and brass parts, it is currently used in the United States primarily on zinc die castings. All the limitations of conventional vibratory deburring apply. Because of the chemicals used, the process currently is limited to use on metals.

Typical Effects on Dimensions and Tolerances

Size Change. Zinc die castings typically will experience a stock removal of 76.2 to 152.4 μm/hr (0.003 to 0.006 in./hr). This of course will vary with the media and chemicals used. Steel parts probably will experience a similar stock loss.

Size-Change Repeatability. The repeatability of this process probably is within ±12.7 μm (±0.0005 inch). Early research indicated that cylinders that were barrel-tumbled, as opposed to those that were vibratory-deburred, tended to lose their shape as well as their size.

Edge Radius. Edge radii up to 0.5 mm (0.020 inch) apparently can be produced. The lower limit to the edge radius would be in the order of 76.2 μm (0.003 inch).

Edge-Radius Repeatability. Edge radii probably are repeatable within ±50.8 μm (±0.002 inch), provided that the burrs are repeatable.

Surface Finish. Finishes of 0.10 μm (4 microinches) have been produced on zinc die castings in a 45-minute cycle. With steel, a more likely representative finish in a deburring cycle would be in the order of 0.51 μm (20 microinches).

Comments

This process originally was developed in 1956 for tumbling barrels. The basic concept could be extended to centrifugal barrel finishing and spindle finishing, as well as vibratory deburring.

Liquid Hone Deburring

Process Mechanics

Fine abrasive particles, suspended in water, are forced over burr-laden part edges (Figure 22). The steady flow abrades the burrs and generates small radii. Typically, a 120-grit, or finer, abrasive consisting of silicon carbide or aluminum oxide is used in a stream of water at a pressure of 345 kPa (50 psi).

The process is similar to, yet distinctly different from, both abrasive-jet deburring and abrasive-flow deburring. The liquid hone process does not operate through the impact of a high-velocity, concentrated stream, as does the abrasive-jet process; instead, the media are forced *over* the edge of the part rather than *at* the edge. In most applications, tooling contains and directs the water flow.

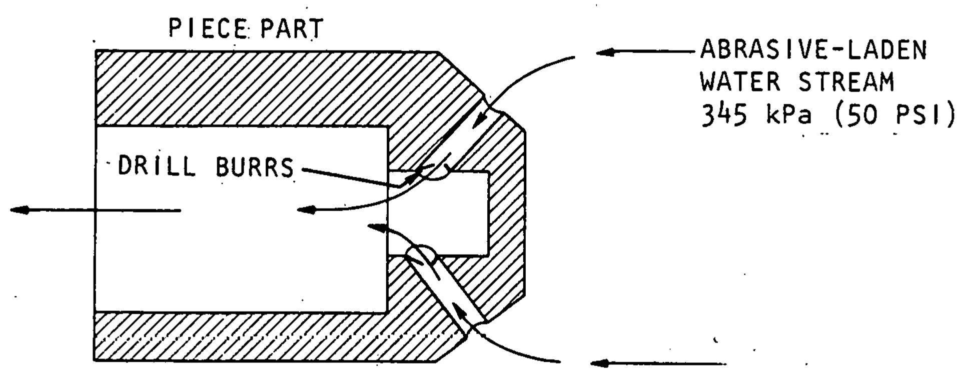


Figure 22. Liquid Hone Deburring

While liquid hone deburring uses water to carry the abrasive particles, the water provides little force to support the particles. In abrasive-flow deburring, the unique properties of the silicone rubber and other carriers provide a soft "backing" for the abrasive as it performs its work. In addition, with this type of carrier, the work is concentrated at the points at which the liquid flow is constricted. Reference: 14.

Typical Applications

Workpiece Size. The only applications that have been reported involve holes having a diameter of 1.57 mm (0.062 inch), or less. Larger features would require noticeably longer deburring times since the deburring action is a function of the amount of media passing over the part edges. With large holes, most of the media would be in the center of the hole rather than at the edges.

Workpiece Shapes. Although holes constitute the only reported application, slots and other features can be deburred by this process.

Cycle Time. Typically, the removal of very small burrs requires a 1- to 3-minute cycle. A hole pattern can be deburred during the cycle as easily as a single hole.

Limitations

The greatest limitation to the use of this process is the size of the burr that can be removed. Effective removal occurs only when the burr is 12.7 μm (0.0005 inch) or less in thickness and up to 25.4 μm (0.001 inch) in height. Typical machining burrs are approximately five times larger than this maximum. The use of free abrasive particles can result in the lodging of particles in parts having small cutouts. The process will not deburr blind features.

Typical Effects on Dimensions and Tolerances

Size Change. Approximately 2.54 μm (0.0001 inch) of stock might be removed during deburring.

Size-Change Repeatability. Probably within ±2.54 μm (±0.0001 inch).

Edge Radius. Edge radii larger than 127.0 μm (0.005 inch) are impossible to produce in most situations. Radii of less than 2.54 μm (0.0001 inch) have been produced while removing minute burrs.

Edge-Radius Repeatability. Edge radii should be repeatable within ±2.54 μm (±0.0001 inch).

Surface Finish. Surface finishes of 0.41 μm (16 microinches) on steel parts would not be degraded by this process.

Comments

Printed circuit boards are frequently "defuzzed" by this process. In this application, the abrasive removes the thin burr left from sanding the copper-clad surface and removes the loose glass fibers from the holes.

This process is not specifically connected with equipment bearing the same name. Commercial wet-abrasive blasting can be used with suitable tooling. Small tubing pumps also can be used with a suitable holding and mixing chamber.

Chlorine-Gas Deburring

Process Mechanics

The exterior of steel workpieces is heated to 315°C (600°F), or higher, and then exposed to a chlorine atmosphere (Figure 23). The chlorine combines with the iron to produce iron chloride which vaporizes below 315°C. Because of the thin cross section and the high surface-area-to-mass ratio of the burrs, they become hotter than the parent material and therefore are removed faster than material from the part surfaces. Burr removal is proportional to the burr temperature. References: 14, 95, 96.

Typical Applications

Workpiece Size. Because a closed chamber is required to contain the chlorine gas, this process normally would not be selected for the deburring of large parts. Small parts which fit in the palm of one hand have been conveniently deburred.

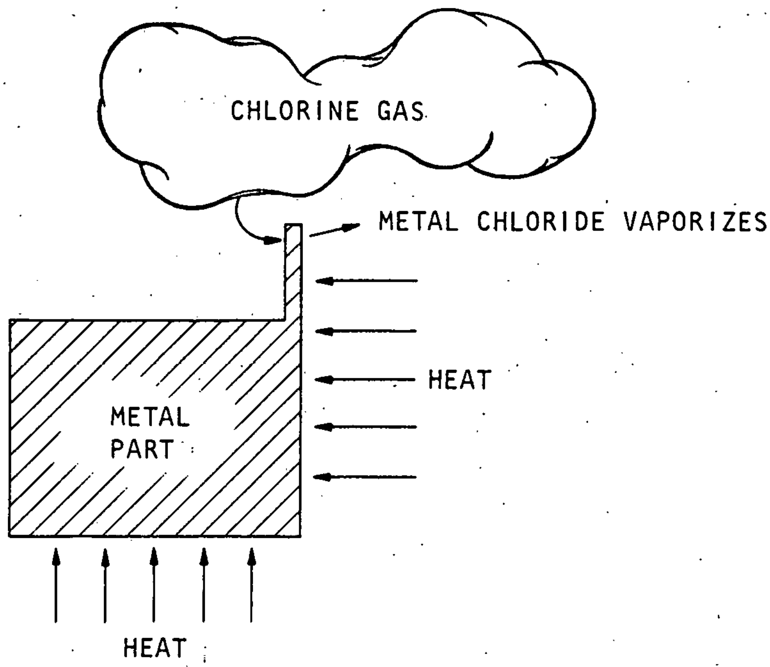


Figure 23. Chlorine-Gas Deburring

Workpiece Shapes. Because the deburring medium is a gas, it will reach all areas of a part. However, internal burrs probably will not reach as high a temperature as external burrs.

Cycle Time. The complete removal of drilling burrs and abrasive-saw cut-off burrs can be obtained in 20 to 60 seconds. If the chamber size permits, several parts can be deburred simultaneously.

Limitations

This process changes the dimensions of the part. It is effective only on iron-base alloys, since other metal chlorides do not sublime at such low temperatures. Because of the toxicity of chlorine, special safety precautions are required. No commercial units are being marketed, apparently because of safety considerations.

Typical Effects on Dimensions and Tolerances

Size Change. A 1-minute cycle will remove 10.2 to 254 μm (0.0004 to 0.0100 inch) of stock from the part surfaces, depending upon the temperature. A 76.2-μm-thick (0.003 inch) burr probably could be removed with a stock loss of only 38.1 μm (0.0015 inch).

Size-Change Repeatability. The repeatability of the size change probably is in the order of ±12.7 μm (±0.0005 inch).

Edge Radius. Edge radii have not been described in the literature pertaining to this process, but a reasonable assumption is that the radii would not exceed the burr thickness.

Edge-Radius Repeatability. With consistent burrs, edge radii should be consistent within ±25.4 μm (±0.001 inch).

Surface Finish. Very rough finishes will be improved. A 90-second treatment of a part having a 33.5-μm (1320-microinch) roughness improved the finish to 0.17 μm (66 microinches).

Comments

At the present time, this process is a laboratory curiosity; no commercial units are known to exist. The process has several advantages: no tooling is required; no secondary burr is produced; workpiece complexity is not a problem; and no residual stresses are produced.

Magnetic Loose-Abrasive Deburring

Process Mechanics

Parts are inserted in a container of magnetic, loose-abrasive media (Figure 24). An oscillating magnetic field then is set in motion to vibrate the media over burr-laden parts. While the workpieces can be stationary, effective deburring of all exterior edges can be accomplished only by tumbling or otherwise moving the parts. When media such as barium ferrite are used, the parts must be nonmagnetic in order to obtain relative motion between the media and the parts. It is conceivable that a magnetic field would oscillate miniature magnetic parts through conventional media. Most iron-base components will not react well to high-frequency changes in a magnetic field. Magnetic media can be coated with ceramics or other metals to minimize contamination of the workpieces. References: 97, 98.

Typical Applications

Workpiece Size. This process has been used on small parts. Large parts present impingement problems and thus limit the number of parts that can be deburred in a single load.

Workpiece Shapes. This process has the capability of deburring inside cavities and blind features. While part shape therefore is not a major limitation, external features are easier to deburr.

Cycle Time. The removal of 25.4-μm-thick by 25.4-μm-high (0.001 by 0.001 inch) burrs from 303Se stainless steel can be accomplished in a 30-minute cycle. Nonferrous materials, including

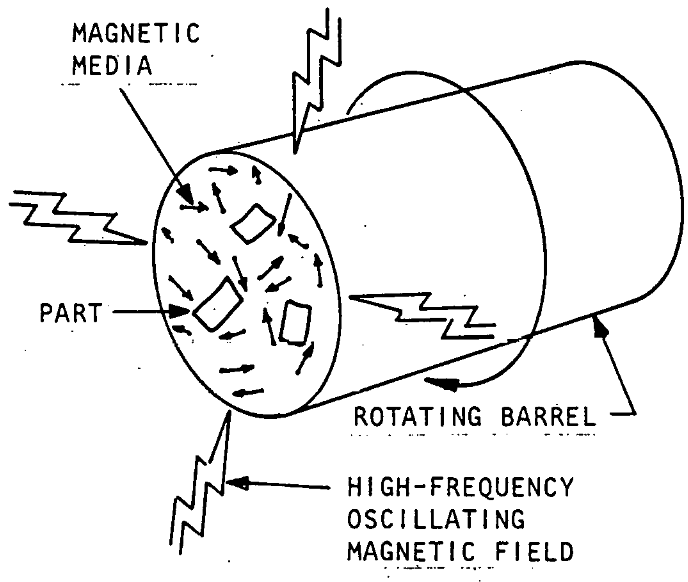


Figure 24. Magnetic Loose-Abrasive Deburring

plastics, could be deburred in a shorter time. As with all loose-abrasive processes, the media size and the intensity of the media impact determine the deburring time.

Limitations

Although this process is best suited to the removal of small burrs from small components, heavy burrs can be removed by the use of a powerful magnetic field. A residue is left on the workpieces and must be subsequently removed. While the basic process is limited to use on nonmagnetic parts, it is conceivable that magnetic parts could be deburred in nonmagnetic media by inverting the process. However, this approach is only a possibility; it does not constitute a known, feasible method.

Typical Effects on Dimensions and Tolerances

Size Change. Because this process is basically the same as other loose-abrasive processes, the stock loss will be similar: a stock loss of approximately 5.1 μm (0.0002 inch) to remove 76.2-μm-thick (0.003 inch) burrs from 303Se stainless steel.

Size-Change Repeatability. The size-change repeatability should be within ±5.1 μm (±0.0002 inch).

Edge Radius. From 50.8 to 254.0 μm (0.002 to 0.010 inch).

Edge-Radius Repeatability. For consistent burr size, edge radii should be repeatable within ±25.4 μm (±0.001 inch).

Surface Finish. Although the process can improve surface finishes, the final finish in a deburring cycle typically would be in the order of 0.76 to 1.00 μm (30 to 40 microinches).

Comments

This process is still in its infancy, although some units have been tested commercially. Several Soviet publications describe adaptations of the basic process. However, no detailed data have been published, and the process may not be introduced commercially for several years. Deburring media apparently are readily available.

Plasma Deburring

Process Mechanics

Parts with burr-laden edges are placed in a plasma flame (Figure 25). The greater electrical field strength which occurs at the corners and sharp edges of the parts concentrates the thermal energy in these locations. The plasma, which has a temperature of 5000 K or higher, quickly melts the burrs. Reference: 99.

Typical Applications

Workpiece Size. This process can work on any size of part, although small parts can be greatly affected by the concentrated heat.

Workpiece Shapes. Except for large parts, the use of the process is basically limited to the removal of external burrs. For the process to operate, the gas nozzles and controlling electrical field must be near the burr.

Cycle Time. Although no data have been published on this process, a reasonable assumption is that it is faster than plasma-arc machining. Conceivably, deburring therefore could be performed at a lineal rate of 95 mm/s (200 ipm). The process is limited to the deburring of one part at a time.

Limitations

Use of this process is limited to electrically conductive materials. By the nature of the process, one would assume that small and thin precision parts would become distorted. There also is a question about the quality of the edge produced.

Typical Effects on Dimensions and Tolerances

Size Change. Although data are not available, the basic size of large parts should not be affected.

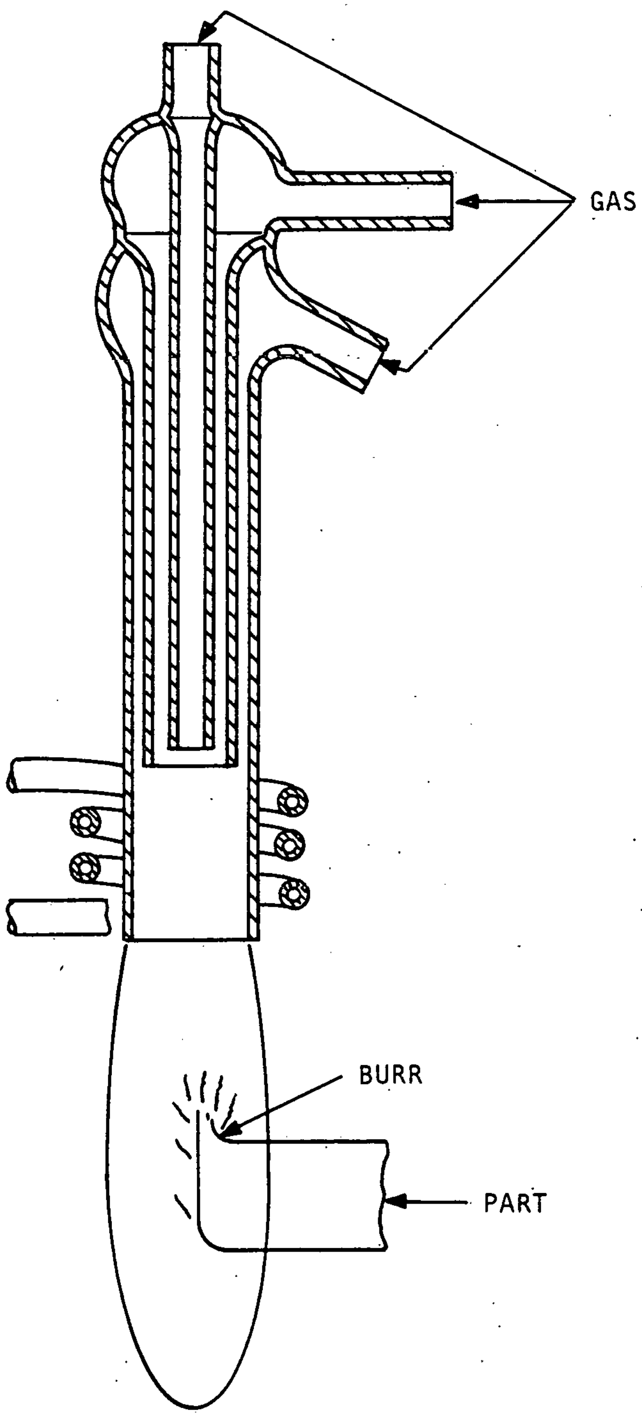


Figure 25. Plasma Deburring

Size-Change Repeatability. Data not available.

Edge Radius. Data not available.

Edge-Radius Repeatability. Data not available.

Surface Finish. The surface finish of large parts should not be damaged except at the edges. Rough surfaces would be somewhat improved.

Comments

Apparently, this process has not been used as a production method.

Comparisons Between Deburring Processes

Tables 1 through 7 provide a basis for comparing the various deburring processes. These comparisons represent the best estimates available, and they are specifically applicable to miniature precision parts made from aluminum, beryllium-copper, and stainless steel.

Table 1 compares the process materials and the deburring mechanisms used, and it offers brief comments that may prove helpful in selecting a deburring process for a specific application. Table 2 lists process side effects, process cycle times for both lots and individual parts, and specifies any required secondary operations. Table 3 shows the approximate life of the materials used, and lists any required health and safety considerations. Ranges in costs for tooling, equipment, and materials used are provided in Table 4.

Table 5 lists the applicable workpiece materials for each deburring process, any applicable limitations as to part geometry, and provides pertinent comments on the use of the processes. Table 6 defines the typical sizes of burrs that can be removed and the edge radii produced. The effects of the processes on adjacent surfaces and on part size are provided along with the edge-radius repeatability in Table 7.

Specific Deburring Process Capabilities

The remaining tables in this report provide more specific details on the capabilities of the various deburring processes. The information in these tables is based on the fact that deburring cannot be realistically performed without knowledge of all of the following factors.

- Burr properties--thickness, height, and hardness in relation to the part hardness;

Text continued on page 78.

Table 1. Comparison of Deburring Process Materials and Mechanisms, With Comments

Deburring Process	Materials Used	Deburring Mechanism	Comments*
Abrasive Flow	Silicone Putty SiC, Al_2O_3	Erosion	Used on hard-to-reach burrs.
Abrasive Jet	Al_2O_3	Abrasion	Used on hard metals.
Barrel Tumbling	Al_2O_3, SiC Plastics	Abrasion and Fatigue	Widely used, typically least expensive of all processes.
Brushing	Nylon Fibers, Al_2O_3, Steel Fibers	Abrasion or Cutting	Used on all burrs and accessible edges.
Centrifugal Barrel Finishing	Al_2O_3	Abrasion	Used on small parts.
Chemical	Buffered Acids	Chemical Attack	Used for thin burrs.
Chemical Vibratory	$CuSO_4$, Al_2O_3	Chemical Reaction and Abrasion	Used for rapid stock removal.
Chlorine Gas	Chlorine Gas	Chemical Attack	Laboratory method only.
Electrochemical	Any Salt Solutions	Electrolytic Deplating	Used on hard-to-reach burrs.
Electrochemical Brush	Metal Brush	Electrolytic Deplating	
Electrochemical Vibratory	Caustic or Phosphoric Acid, Graphite	Electrolytic Deplating and Abrasion	Only one installation in United States.

Table 1 Continued. Comparison of Deburring Process Materials and Mechanisms, With Comments

Deburring Process	Materials Used	Deburring Mechanism	Comments*
Electropolish	Buffered Acids	Electrolytic Action	Used for thin burrs.
Hand	Steel Knives, Al_2O_3 or SiC Points, Nylon Brushes	Cutting or Abrasion	Used for precision or on hard-to-reach areas.
Liquid Hone	Water and SiC	Erosion	Used on thin, short burrs.
Magnetic Loose-Abrasive	Magnetic Media	Abrasion, Impact, and Fatigue	
Mechanized Mechanical	Cutters or Dies	Shearing or Cutting	
Plasma	Ionized Gases	Melting	
Sanding	Sandpaper Al_2O_3, SiC	Abrasion	Used on flat parts and external edges.
Spindle Finishing	Al_2O_3	Abrasion	Used on cylindrical parts like gears and turbines.
Thermal Energy	H_2, O_2	Melting and Shock	Used on thin burrs on zinc and some steel alloys.
Torch or Flame	H_2 and O_2, Acetylene	Melting	Typically used only on large castings.
Ultrasonic	Acids, Buffers, and Al_2O_3	Chemical Attack	Used for very thin burrs.

Table 1 Continued. Comparison of Deburring Process Materials and Mechanisms, With Comments

Deburring Process	Materials Used	Deburring Mechanism	Comments*
Vibratory	Al_2O_3, SiC Plastics	Abrasion and Fatigue	Typically most commonly used and least expensive of all processes.
Water Jet	Water	Erosion and Cavitation	Used only on thin or brittle burrs.

*Information provided represents typical results from steel piece parts (unless otherwise noted), based on a burr thickness of 50.8 μm (0.002 inch), a part volume of 16.387 cm^3 (1 $in.^3$) or less, and a batch size of 100 parts per lot.

Table 2. Comparison of Deburring Process Side Effects, Cycle Times, and Required Secondary Operations

Deburring Process*	Side Effects	Cycle Time Part (Min.)	Cycle Time Lot (Min.)	Required Secondary Operations
Abrasive Flow	Polishing	2		Air and Ultrasonic Cleaning
Abrasive Jet	Matte Finish	1 to 5		Cleaning
Barrel Tumbling	Residual Stress Changes and Some Material Impregnation		120 to 480	Cleaning
Brushing	Polishing	1 to 5		Cleaning
Centrifugal Barrel Finishing	Produces Large Residual Compressive Stresses		5 to 20	Cleaning
Chemical	Polishing, Brightening		5 to 30	Precleaning
Chemical Vibratory			10 to 20	Cleaning
Chlorine Gas	Polishing			Cleaning
Electrochemical	Stray Etching	1		Film Removal
Electrochemical Brush				
Electrochemical Vibratory			1 to 60	Cleaning
Electropolish	Possible Pitting and Streaking		1 to 10	Precleaning
Hand		1 to 20		None
Liquid Hone		1 to 5		Cleaning

Table 2 Continued. Comparison of Deburring Process Side Effects, Cycle Times, and Required Secondary Operations

Deburring Process*	Side Effects	Cycle Time: Part (Min.)	Cycle Time: Lot (Min.)	Required Secondary Operations
Magnetic Loose-Abrasive	Covers Part with Film of Media		30 to 120	Cleaning
Mechanized Mechanical		1		Radiusing
Plasma				
Sanding		1 to 5		Cleaning
Spindle Finishing		1 to 5		Cleaning
Thermal Energy	Covers Part with Oxide Film		0.1 to 1	Cleaning
Torch or Flame				Cleaning
Ultrasonic	Polishing, Brightening		5 to 10	None
Vibratory	Residual Stress Changes and Some Material Impregnation		120	Cleaning
Water Jet	None	1		None

*Information provided represents typical results from steel piece parts (unless otherwise noted), based on a burr thickness of 50.8 μm (0.002 inch), a part volume of 16.387 cm^3 (1 $in.^3$) or less, and a batch size of 100 parts per lot.

Table 3. Comparison of Deburring Process Life of Materials and Health and Safety Considerations

Deburring Process*	Life of Materials**	Health and Safety Considerations
Abrasive Flow	18.14 kg Each 1000 Parts	None, with adequate hydraulic press considerations.
Abrasive Jet	1.81 kg Per Hour	Control of airborne dust.
Barrel Tumbling	90.72 kg Media or Compound Each 10,000 Parts	None, with proper chemicals.
Brushing	1 Brush Each 10 to 1000 Parts	Only a regard for rotating wheels.
Centrifugal Barrel Finishing	90.72 kg Each 5000 Parts	None
Chemical		Typical precautions for chemicals and fumes.
Chemical Vibratory		None
Chlorine Gas		Chlorine may require strict safety procedures.
Electrochemical	0.38 m^3 Each 500 Parts	Typical electrical, chemical, and gaseous precautions.
Electrochemical Brush	-	
Electrochemical Vibratory		
Electropolish		Typical electrical, chemical, and gaseous requirements.
Hand		None
Liquid Hone		None

Table 3 Continued. Comparison of Deburring Process Life of Materials and Health and Safety Considerations

Deburring Process*	Life of Materials**	Health and Safety Considerations
Magnetic Loose-Abrasive		None
Mechanized Mechanical		Precautions for keeping hands free of press and rotating cutters.
Plasma		
Sanding		None
Spindle Finishing	90.72 kg Each 5000 Parts	None
Thermal Energy		Typical control of combustible gases and consideration for controlled detonations.
Torch or Flame		Combustible gases.
Ultrasonic		Typical precautions for chemicals and fumes.
Vibratory	90.72 kg Media or Compound Each 10,000 Parts	None
Water Jet		None

*Information provided represents typical results from steel piece parts (unless otherwise noted), based on a burr thickness of 50.8 μm (0.002 inch), a part volume of 16.387 cm^3 (1 $in.^3$) or less, and a batch size of 100 parts per lot.
**1 kg = 2.20 lb.; 1 m^3 = 264.17 gallons.

Table 4. Comparison of Deburring Process Costs of Tooling, Equipment, and Materials

	Cost		
Deburring Process*	Tooling ($)	Equipment ($)	Materials ($)
Abrasive Flow	100 to 500	20,000 to 30,000	10 to 30 Per Pound**
Abrasive Jet	100	2,500 to 40,000	1.50 Per Pound
Barrel Tumbling	0	200 to 5,000	0.80 Per Pound
Brushing	0 to 200	50 to 15,000	
Centrifugal Barrel Finishing	0	5,000 to 40,000	0.80 Per Pound
Chemical	0	1,500 to 20,000	
Chemical Vibratory	0	100 to 8,000	
Chlorine Gas	100 to 300	Not Available	
Electrochemical	150 to 500	8,000 to 35,000	0.05 Per Gallon***
Electrochemical Brush			
Electrochemical Vibratory	0	11,000	
Electropolish	200 to 500	1,500 to 25,000	
Hand	5 to 50	0 to 100	
Liquid Hone	100 to 500	500 to 20,000	0.80 Per Pound
Magnetic Loose-Abrasive			
Mechanized Mechanical	5 to 500	50 to 10,000	
Plasma			

Table 4 Continued. Comparison of Deburring Process Costs of Tooling, Equipment, and Materials

	Cost		
Deburring Process*	Tooling ($)	Equipment ($)	Materials ($)
Sanding	0	100 to 2,000	
Spindle Finishing	0	7,500 to 11,000	0.80 Per Pound
Thermal Energy	250 to 500	60,000 to 150,000	0.01 to 0.05 Per Part
Torch or Flame	0	150 to 1,500	
Ultrasonic	0	1,500 to 5,000	
Vibratory	0	100 to 30,000	0.80 Per Pound
Water Jet	0 to 100	50,000 to 100,000	

*Information provided represents typical results from steel piece parts (unless otherwise noted), based on a burr thickness of 50.8 μm (0.002 inch), a part volume of 16.387 cm^3 (1 $in.^3$) or less, and a batch size of 100 parts per lot.
**1 lb = 0.45 kg.
***1 gallon = 3.785 dm^3.

Table 5. Comparison of Deburring Process Workpiece Materials and Part Geometry Limitations, With Comments

Deburring Process	Applicable Workpiece Materials	Part Geometry Limitations	Comments
Abrasive Flow	All Metals, Machined Plastics, Ceramics	Blind features will not be deburred.	Used on hard-to-reach intersections and for good finishes.
Abrasive Jet	Metals, Plastics	Burr must be accessible to abrasive stream.	
Barrel Tumbling	All Metals and Plastics	Edges must be readily exposed to deburr.	Use appropriate media and compound if welding or plating follows deburring.
Brushing	Metals, Plastics	Most miniature applications limited to external burrs.	
Centrifugal Barrel Finishing	Metals, Plastics	Same as for barrel tumbling.	Same as for barrel tumbling.
Chemical	Iron, Steels, Stainless Steels, Copper Alloys, Brass, Bronze, Aluminum		Parts must be clean prior to deburring.
Chemical Vibratory	Steel Alloys, Zinc Alloys	Same as for barrel tumbling.	Same as for barrel tumbling.

Table 5 Continued. Comparison of Deburring Process Workpiece Materials and Part Geometry Limitations, With Comments

Deburring Process	Applicable Workpiece Materials	Part Geometry Limitations	Comments
Chlorine Gas	Metals		Laboratory process only at this time.
Electrochemical	All Metals		Not well suited to aluminum because of oxide film deposit.
Electrochemical Brush	Metals		
Electrochemical Vibratory	Metals	Burr must be accessible to graphite spheres.	Holes 3.175 mm in diameter are enlarged 5.08 μm in one 10-minute cycle.*
Electropolish	Stainless Steels, High-Temperature Metals, Aluminum, Beryllium		
Hand	All Materials	Burr must be accessible.	Can be used to reduce burr size before commercial process.
Liquid Hone	Metals, Plastics	Blind features will not be deburred.	
Magnetic Loose-Abrasive	Metals, Plastics	Same as for barrel tumbling.	

Table 5 Continued. Comparison of Deburring Process Workpiece Materials and Part Geometry Limitations, With Comments

Deburring Process	Applicable Workpiece Materials	Part Geometry Limitations	Comments
Mechanized Mechanical	Metals, Plastics	Same as for barrel tumbling.	
Plasma	Metals		
Sanding	Metals	Usually limited to flat parts.	Can be used for preliminary deburring.
Spindle Finishing	Metals, Plastics	Same as for barrel tumbling.	Same as for barrel tumbling.
Thermal Energy	Metals, Plastics	Deburrs blind features.** Burr area must be free from oil and water.	Not well suited to heavy burrs on thin part sections.
Torch or Flame	Metals, Plastics		
Ultrasonic	Copper Alloys, Brass, Zinc, Aluminum	Some limitations on round parts.	
Vibratory	All Metals and Plastics	Same as for barrel tumbling.	Same as for barrel tumbling.
Water Jet	Molded Asbestos/ Sisal, Aluminum Alloys	Limited to external burrs/ flash.	Used by automotive industry.

*1 mm = 0.03937 inch.
**Provided that fixturing does not shield features from gases.

Table 6. Comparison of Deburring Process Burr Sizes Removed and Edge Radii Produced

Deburring Process**	Typical Sizes of Burrs Removed (μm)	Edge Radii Typically Produced in Indicated Material		
		SST and Steel (μm)	BeCu (μm)	Al (μm)
Abrasive Flow	5.02 to 76.2 Thick	25.4 to 127		50.8 to 127
Abrasive Jet	12.7 to 127 Thick	76.2 to 254		
Barrel Tumbling	2.54 to 76.2 Thick	76.2 to 254	101.6 to 254	152.4 to 762
Brushing	5.08 to 76.2 Thick	50.8 to 254	50.8 to 254	76.2 to 381
Centrifugal Barrel Finishing	5.08 to 76.2 Thick	76.2 to 508	76.2 to 508	127 to 762
Chemical	2.54 to 12.7 Thick			
Chemical Vibratory				
Chlorine Gas	5.08 to 101.6 Thick	127 to 508		
Electrochemical	7.62 to 127 Thick; 25.4 to 508 Long	50.8 to 254	50.8 to 254	152.4 to 762
Electrochemical Brush				

Table 6 Continued. Comparison of Deburring Process Burr Sizes Removed and Edge Radii Produced

Deburring Process**	Typical Sizes of Burrs Removed (μm)	Edge Radii Typically Produced in Indicated Material		
		SST and Steel (μm)	BeCu (μm)	Al (μm)
Electrochemical Vibratory	50.8 to 127 Thick	127 Maximum		
Electropolish	2.54 to 25.4 Thick	25.4 to 127	25.4 to 127	
Hand	5.08 to 76.2 Thick	50.8 to 254	50.8 to 254	76.2 to 381
Liquid Hone	5.08 to 25.4 Thick	127 Maximum		
Magnetic Loose-Abrasive	0 to 25.4 Thick	25.4 to 76.2	25.4 to 76.2	
Mechanized Mechanical	0 to 254 Thick	None	None	None
Plasma				
Sanding	5.08 to 76.2 Thick			
Spindle Finishing	5.08 to 76.2 Thick	25.4 to 508	76.2 to 508	127 to 762
Thermal Energy	5.08 to 50.8 Thick	50.8 to 406.4		50.8 to 1524
Torch or Flame				
Ultrasonic	2.54 to 12.7 Thick	25.4 to 76.2	25.4 to 76.2	

Table 6 Continued. Comparison of Deburring Process Burr Sizes Removed and Edge Radii Produced

Deburring Process**	Typical Sizes of Burrs Removed (μm)	Edge Radii Typically Produced in Indicated Material		
		SST and Steel (μm)	BeCu (μm)	Al (μm)
Vibratory*	2.54 to 76.2 Thick	76.2 to 254	101.6 to 254	152.4 to 762
Water Jet	0 to 38.1 Thick Flash			

*In a 2-hour deburring cycle.
**All values shown represent information applicable to small and miniature precision components; 1 μm = 39.37 microinches.

Table 7. Comparison of Deburring Process Effects on Adjacent Surfaces, Effects on Part Size, and Repeatability of Edge Radiusing

Deburring Process*	Effect on Adjacent Surfaces (μm)	Effect on Part Size** (μm)	Apparent Best Repeatability of Edge Radiusing		
			SST (μm)	BeCu (μm)	Al (μm)
Abrasive Flow	Polishes; 0 to 101.6 Stock Loss	None except near burrs.	±25.4	±25.4	±50.8
Abrasive Jet	Matte Finish; 0 to 25.4 Stock Loss	None			
Barrel Tumbling	Surface Finish and Size Change	0 to 12.7 Size Change	±38.1	±63.5	±63.5
Brushing	Polishes	None	±50.8	±50.8	±76.2
Centrifugal Barrel Finishing	Surface Finish and Size Change	0 to 12.7 Size Change			
Chemical	1.27/Minute Etch Rate on High-Carbon Steel	1.27/Minute Etch Rate on High-Carbon Steel			
Chemical Vibratory		1.27 to 127 Size Change			
Chlorine Gas	10.16 to 254 Stock Loss	10.16 to 250 Stock Loss, Each Side			

Table 7 Continued. Comparison of Deburring Process Effects on Adjacent Surfaces, Effects on Part Size, and Repeatability of Edge Radiusing

Deburring Process*	Effect on Adjacent Surfaces (μm)	Effect on Part Size** (μm)	Apparent Best Repeatability of Edge Radiusing SST (μm)	BeCu (μm)	Al (μm)
Electrochemical	Slight Etch; 0 to 254 Local Stock Loss	Possible Stray Etching	±50.8		±101.6
Electrochemical Brush					
Electrochemical Vibratory	Some Etching Possible	5.08 to 76.2 Typical Size Change	±50.8		
Electropolish	Polishes; Up to 12.7 Stock Loss Per Side	Up to 12.7 Stock Loss Per Side	±1.27		
Hand	None	None	±50.8	±50.8	±76.2
Liquid Hone		None			
Magnetic Loose-Abrasive	Surface Finish and Size Change	0 to 12.7 Size Change			
Mechanized Mechanical	None	None			
Plasma					

Table 7 Continued. Comparison of Deburring Process Effects on Adjacent Surfaces, Effects on Part Size, and Repeatability of Edge Radiusing

Deburring Process*	Effect on Adjacent Surfaces (μm)	Effect on Part Size** (μm)	Apparent Best Repeatability of Edge Radiusing		
			SST (μm)	BeCu (μm)	Al (μm)
Sanding	Surface Finish Changes	2.54 to 50.8 Stock Loss			
Spindle Finishing	Surface Finish and Size Change	0 to 12.7 Size Change			
Thermal Energy	Surfaces are Covered With an Oxide	0 to 2.54 Size Change; Surfaces are Covered With an Oxide	±76.2	±76.2	±127
Torch or Flame					
Ultrasonic					
Vibratory	None	0 to 12.7 Size Change	±38.1	±63.5	±63.5
Water Jet	Cleans	None			

*All values shown represent information applicable to small and miniature precision components; 1 μm = 39.37 microinches.
**These values are conservative for hand-size or larger parts. Data in this column apply to all surfaces exposed to the deburring media, and not just those adjacent to the burr-laden edge.

- Allowable dimensional changes in the part resulting from the deburring operation;

- Required edge radius; and

- Required final surface finish as well as the surface finish of the part before deburring.

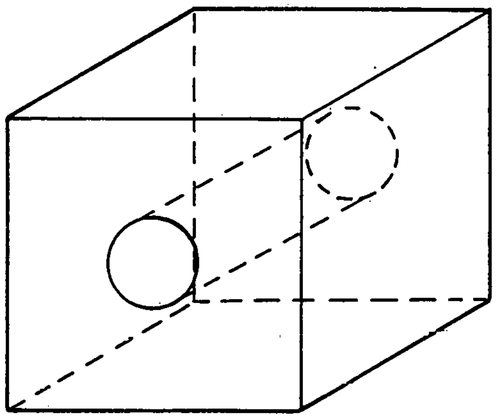
While such conditions as burr location, part geometry, and part material are important, a knowledge of the preceding factors is essential for the preliminary selection of deburring processes for precision parts. The simple cube shown in Figure 26 illustrates these basic requirements. For an accurate selection of a deburring process, the approximate hole size, the amount of stock loss from the hole that will result from deburring, the repeatability of the stock loss, the initial surface finish, the required final surface finish, and the required edge radius at the entrance and exit of the hole must all be known.

The size of the hole is important because some processes will not work well on miniature holes while others will not work well on large holes. When precision holes are involved, both the average stock loss and the repeatability of the stock loss must be ascertained. Although the holes can be drilled smaller to accommodate the stock loss from deburring, this action is of little help if the stock removal is not repeatable.

Similar data pertaining to the external edges of the part also are needed. The selection of deburring processes for a complex part involving many edges, surfaces, and burr sizes may require considerable thought. Although the availability of actual data is highly desirable, previous experience frequently will intuitively provide the facts needed to select the appropriate process. When the allowable stock loss must be kept below 2.54 μm (0.0001 inch), however, there is little margin for error.

Table 8 lists the deburring processes described in this report and assigns a code letter to each process. These code letters are used in Tables 9 through 14 to identify the applicable deburring processes.

Table 9 indicates the processes that can be used to deburr external edges while maintaining a maximum allowable edge break, an allowable stock loss, and a given stock-loss repeatability. The data in this table is only valid for a 76.2-μm-thick by 76.2-μm-high (0.003 by 0.003 inch) burr on a stainless steel workpiece requiring a surface finish of 0.81 μm (32 microinches), or better. An initial surface finish of 0.81 μm is assumed, although some deburring processes would improve a rougher finish.



HOLE
DIAMETER
ALLOWABLE STOCK LOSS
ALLOWABLE STANDARD DEVIATION OF HOLE SIZE FROM DEBURRING PROCESS
SURFACE FINISH
ALLOWABLE EDGE RADIUS
EXTERIOR SURFACE
DIMENSIONS
ALLOWABLE STOCK LOSS
ALLOWABLE STANDARD DEVIATION OF EXTERNAL DIMENSIONS
SURFACE FINISH
ALLOWABLE EDGE RADIUS
BURR SIZE
HEIGHT
THICKNESS
WORKPIECE MATERIAL

Figure 26. Workpiece With Hole Illustrating the Considerations for Selecting a Deburring Process

As shown in Table 9, when the deburring process is allowed to remove only 1.27 μm (0.00005 inch) of stock, and when it is required to produce an edge radius of 50.8 μm (0.002 inch) or less for the given burr size, no single process will produce the desired result. Either more stock loss or a larger edge break must be allowed. The only other choice available is to reduce the burr size before employing the deburring process. Sanding, for example, will remove this type of burr from a flat surface, but it will generate a smaller burr. The smaller burr then can be removed by a number of processes, as indicated later. Although two sanding operations can be used, a single sanding will not suffice since the removal of the heavy burr requires sanding parallel to the part surfaces in order not to break the edge. A second arrangement in which the sanding belt is held like a shoeshine cloth will remove the first sanding burr and radius the edge if the angle between the belt and the part surface is small enough. This operation requires much lower pressures or forces than the first sanding operation.

When the standard deviation of the stock loss must be maintained to 0.51 μm (0.00002 inch) or less, and when 50.8-μm (0.002 inch) edge breaks are required, only electrochemical deburring will meet these requirements. Note that in the tables provided, the repeatability of the stock loss is independent of the average stock loss. In Table 9, Process M (electrochemical deburring) is shown to be capable of maintaining 50.8-μm edge breaks if the part surfaces can change 2.54 μm (0.0001 inch), and if a standard deviation of 0.508 μm (0.00002 inch) for this loss is acceptable.

Table 8. Codes Used in Tables 9 Through 14 for Deburring Processes

Code	Deburring Process
A	Vibratory
B	Barrel Tumbling
C	Spindle Finishing
D	Centrifugal Barrel Finishing (Harperizing and Others)
E	Abrasive Jet
F	Sanding
G	Brushing
H	Hand
I	Abrasive Flow (Extrude Hone and Dynetics)
J	Mechanized Mechanical
K	Thermal Energy (Surf/Tran)
L	Chemical
M	Electrochemical
N	Electropolish
O	Ultrasonic
P	Torch or Flame Melting
Q	Water Jet
R	Electrochemical Vibratory
S	Electrochemical Brush
T	Chemical Vibratory
U	Liquid Hone
V	Chlorine Gas
W	Magnetic Loose Abrasive
X	Plasma

Table 9. Typical Processes for the Precision Deburring of External Edges

Maximum Edge Break (µm)**	Allowable Size Change* Thickness Change on External Surfaces (µm)				Thickness-Change-Repeatability Standard Deviation (µm)		
	1.27	2.54	25.4	127	0.508	5.08	50.8
2.54	--***	--	--	I	--	I	I
25.4	--	--	I	I	--	I	I
50.8	--	F,J,M	F,I,J, M	F,I,J, M	M	F,I,J, M	F,I,J, M
127	F-H,J, M	F-H,J, M	A-K,M, R,S	Most	F-H,J, M	A,B,D, F-K, M-O,S	Most
254	F-H,J, M	F-H,J, M	A-K,M, R,S	All	F-H,J, M	A,B,D, F-K, M-O,S	All

*Refer to Table 8 for definitions of deburring-process code letters. Information in this table pertains to stainless steel workpieces having a surface-finish requirement of 0.81 µm (32 microinches) or better; it is based on the complete removal of burrs having an initial thickness of 76.2 µm (0.003 inch) and an initial height of 76.2 µm. (Milling and many turning operations produce a burr of this size.)

**1 µm = 39.37 microinches.

***Dashes indicate that no process will produce the desired result for the specified burr size, surface finish, and material. (In this case, the burr must be sanded or machined until a much smaller burr is left for removal by one of these processes.)

The reason that electrochemical deburring can be used while other processes cannot is that it does not affect adjacent surfaces, except for a small amount of stray etching; it concentrates the stock losses at the part edges. While electrochemical deburring can produce large edge radii, it also can maintain low edge breaks. However, experimentation may be required to determine proper power settings and tool design.

As previously indicated, the information shown in the tables is based on the best data that are available at the present time. Additional research may necessitate changes and rearrangement in some of the tabular material.

When two holes intersect, the angles between the hole surfaces vary considerably around the intersection. Because many, if not all, deburring processes are affected by the edge angle, deburring tolerances also are affected. As shown in Table 10, no process will maintain a 50.8-μm (0.002 inch) radius for the burr size and surface finish shown because of the varying angles.

When the burr size is reduced to a thickness and a height of 25.4 μm (0.001 inch), several processes can be used to produce the desired results (Table 11). Precision parts from the automatic screw machines at Bendix Kansas City typically have burrs of this size. As a result, they too generally can be deburred by most processes without excessive loss in stock or radii (Table 12). As parts become smaller, however, some processes such as centrifugal barrel finishing begin to lose their effectiveness. For example, a 0.5-mm (0.20 inch) pin, 3.18 mm (0.125 inch) long, may require twice the time to remove the same size burr as that on a 3.18-mm pin of the same length.

Plastic molding flash also can be removed rather easily from many materials if it is not too thick (Table 13). Recast metal from EDM and allied processes can be removed from most materials without excessive stock losses (Table 14).

Threaded features represent a problem to many deburring processes when the thread features are small and have close tolerances. Table 15 shows the processes that can be used advantageously on threads.

Each of the tables presented in this report is based on typical usage of the deburring processes. While special fixtures or special approaches may be employed to concentrate more action at the edges and less action at the surfaces of the parts, and while a process may be improvised in such a manner that it will meet the requirements of a particular part, these measures increase the operating cost and slow down the deburring process.

Text continued on page 88.

Table 10. Typical Processes for the Precision Deburring of Intersecting Holes

Maximum Edge Break (μm)**	Allowable Diameter Change*						
	Hole Diameter Change (μm)				Diameter-Change Standard Deviation (μm)		
	1.27	2.54	25.4	254	0.508	5.08	50.8
2.54	--***	--	--	--	--	--	--
25.4	--	--	--	--	--	--	--
50.8	--	--	--	--	--	--	--
127	M	H,J,M	H-K,M	D,H-N, T,V-X	M	H,J,M	Most
254	H,M	H,J,M	H-K,M	D,H-N, T,V-X	H,M	D,H-O	Most

*Refer to Table 8 for definitions of deburring-process code letters. Information in this table pertains to stainless steel workpieces having a surface-finish requirement of 0.81 μm (32 microinches) or better, and holes 12.7 mm (0.5 inch) in diameter, or smaller; it is based on the complete removal of burrs having an initial thickness of 76.2 μm (0.003 inch) and an initial height of 76.2 μm.

**1 μm = 39.37 microinches.

***Dashes indicate that no process will produce the desired result for the specified burr size, surface finish, and material.

Table 11. Typical Processes for the Precision Deburring of Exposed Hole Edges

Maximum Edge Break (μm)**	Allowable Diameter Change*						
	Hole Diameter Change (μm)				Diameter-Change Standard Deviation (μm)		
	1.27	2.54	25.4	254	0.508	5.08	50.8
2.54	--***	U	I,U	I,U	--	U	I,U
25.4	J,U	J,U	J,L,U	Most	--	I,J,U	I,J,U
50.8	J,U	D,J,U	D,I-L, N,O,U	Most	D,J,M, N	D,I-O	D,I-O
127	D,H,J, M,U	D,H,J, M	Most	All	D,H,J, M,N	D,H-O	D,H-O
254	D,H,J, M,U	D,H,J, M	Most	All	D,H,J, M,N	D,H-O	D,H-O

*Refer to Table 8 for definitions of deburring-process code letters. Information in this table pertains to stainless steel workpieces having a surface-finish requirement of 0.81 μm (32 microinches) or better, and holes 12.7 mm (0.5 inch) in diameter, or smaller; it is based on the complete removal of burrs having an initial thickness of 25.4 μm (0.001 inch) and an initial height of 25.4 μm. (A burr of this size would result after sanding or lightly chamfering the hole after drilling; a typical burr produced by drilling is 76.2 μm or 0.003 inch thick.) Some stock loss will occur on the external workpiece surfaces.

**1 μm = 39.37 microinches

***Dashes indicate that no process will produce the desired result. (In this case, burrs noticeably smaller than those described above must be produced.)

Table 12. Typical Processes for the Precision Deburring of Miniature Screw Machine Parts

Maximum Edge Break (μm)**	Allowable Size Change*: Diameter Change (μm)				Diameter-Change-Repeatability Standard Deviation (μm)		
	1.27	2.54	25.4	127	0.508	5.08	50.8
2.54	--***	--	--	--	--	--	--
25.4	--	--	--	I	--	I	I
50.8	--	D,J,K, M	D,F, I-N	D,F, I-O,V	D,F,J, K,M	D,F, I-O	D,F,I-O, V,W
127	F,H,J, M	A-D,F, H,J,K, M	Most	All	D,F,H, J,K,M	A-D,F, H-O	Most
254	F,H,J, M	A-D,F, H,J,K, M	Most	All	D,F,H, J,K,M	A-D,F, H-O	All

*Refer to Table 8 for definitions of deburring-process code letters. Information in this table pertains to stainless steel workpieces 4.75 mm (0.1875 inch) in diameter, or smaller, and having a surface-finish requirement of 0.81 μm (32 microinches) or better; it is based on the complete removal of burrs having an initial thickness of 25.4 μm (0.001 inch) and an initial height of 25.4 μm.

**1 μm = 39.37 microinches.

***Dashes indicate that no process will produce the desired result for the specified burr size, surface finish, and material.

Table 13. Typical Processes for the Precision Deburring and Deflashing of Thermosetting Parts

Maximum Edge Break (μm)**	Allowable Size Change*: Thickness Change on External Surfaces (μm)				Thickness-Change-Repeatability Standard Deviation (μm)		
	1.27	2.54	25.4	127	0.508	5.08	50.8
2.54	--***	--	--	--	--	--	--
25.4	E	E	E	E	E	E	E
50.8	E,G,J, K	E,G,J,	E,G, I-K	E,G, I-K	E,G,J	E,G, I-K	E,G, I-K
127	E-H,J, K	E-H,J, K,Q	A-K,Q	A-K,Q	E,G,H, J	D-K	A-K,Q
254	E-H,J, K	E-H,J, K,Q	A-K,Q	A-K,Q	E,G,H, J	D-K	A-K,Q

*Refer to Table 8 for definitions of deburring-process code letters. Information in this table is based on the complete removal of flash having an initial thickness of 25.4 μm (0.001 inch).

**1 μm = 39.37 microinches.

***Dashes indicate that no process will produce the desired result.

Table 14. Typical Processes for the Precision Removal of Recast Material From the Edges of Small Parts

Maximum Edge Break (μm)**	Allowable Size Change*: Thickness or Diameter Change (μm)				Thickness- or Diameter-Change-Repeatability Standard Deviation (μm)		
	1.27	2.54	25.4	127	0.508	5.08	50.8
2.54	--***	--	--	I	--	I	I
25.4	--	--	I	I	--	I	I
50.8	F,J,M	D,F,J, M	A-D,F, I,J,M	A-D,F, I,J-M	F,J,M	D,F,I, J,M	D,F,I, J,M
127	F-H,J, M	D,F-H, J,M	A-K,M, R,S	Most	F-H,J, M	A,B,D, F-K, M-O,S	Most
254	F-H,J, M	D,F-H, J,M	A-K,M, R,S	All	F-H,J, M	A,B,D, F-K, M-O,S	All

*Refer to Table 8 for definitions of deburring-process code letters. Information in this table pertains to stainless steel workpieces; it is based on the complete removal of recast material having an initial thickness of 25.4 μm (0.001 inch) and an initial height of 25.4 μm.

**1 μm = 39.37 microinches.

***Dashes indicate that no process will produce the desired result.

Table 15. Processes That Can be Used for Deburring Small Threaded Features Without Special Effort

Deburring Process	External Threads	Internal Threads
Abrasive Jet	X	
Brushing	X	X
Centrifugal Barrel Finishing	X	
Chemical	X	X
Chemical Vibratory	X	
Chlorine Gas	X	X
Electrochemical		X
Electropolish	X	X
Hand	X	X
Magnetic Loose Abrasive	X	
Thermal Energy	X	X

*Information in this table pertains to stainless steel workpieces with threads having a basic diameter of 9.52 mm (0.3750 inch) or smaller; it is based on the complete removal of all burrs and chips except the thin fin which occurs on the lead-in or lead-out portion of the thread.

Each year, new advances are made in deburring processes and more explicit guidelines are developed. The thermal energy deburring method is one such example: in seven years, equipment innovations and process improvements have at least doubled the number of situations to which it is applicable. Tool materials for abrasive-flow deburring now are often made from rubbery plastics rather than from steel. Each of these developments will slightly change the capabilities described in this report.

Despite the limitations noted, this report provides a rational approach to the selection of feasible deburring processes. Although it is specifically directed toward the production of miniature precision parts, it also is applicable to many other types of parts. As consistently indicated throughout the report, any process can remove burrs without adversely affecting part tolerances if the burrs are kept small.

ACCOMPLISHMENTS

The basic mechanism of burr removal has been identified for each of the 24 major commercial and laboratory deburring processes. The limitations and capabilities of these processes, as they are typically used, have been defined in both general and specific terms relating to the production of miniature precision metal parts. Detailed studies of several of the processes have been made to determine their effect on stock loss, edge radius, and surface finish. These studies have been described in previous reports. Deburring capabilities have been expressed in terms of stock loss, edge radius, surface finish, and burr size.

FUTURE WORK

While no additional work in the field of deburring is planned, a great amount of research is required to develop easy-to-use yet accurate techniques for identifying beforehand the most effective deburring process for a given circumstance. However, the material developed to date offers a reasonable methodology and data base with which to make decisions regarding the selection of a deburring process.

REFERENCES

[1]G. V. Robbins, *Radius Generation in Vibratory Deburring* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-85, September, 1966 (Available from NTIS).

[2]G. V. Robbins, *Radius Generation in Vibratory Finishing* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-090, October, 1966 (Available from NTIS).

[3]L. K. Gillespie, *Vibratory Deburring* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-735 (Rev.), March, 1974 (Available from NTIS).

[4]J. H. Kuehnle, *Thermal Shock Deburring* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-642 (Rev.), July, 1972 (Available from NTIS).

[5]R. J. Hishaw, *Mechanical Deburring of Plastics* (Final Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-988 (Rev.), March, 1974 (Available from NTIS).

[6]L. K. Gillespie, *The Effect of Edge Angle on the Radius Produced by Vibratory Finishing* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1279, February, 1975.

[7]L. K. Gillespie, *Brush Deburring* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1056 (Rev.), October, 1974 (Available from NTIS).

[8]L. K. Gillespie, *Brush Deburring of Precision Miniature Parts*, SME Paper MR 74-994, 1974.

[9]L. H. Luebbert, Jr. and L. K. Gillespie, *Extrude Hone Deburring* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-948, August, 1973 (Available from NTIS).

[10]L. K. Gillespie, *Extrude Hone Deburring With X-Base Media* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1546, March, 1976.

[11]L. K. Gillespie, *Deburring by Centrifugal Barrel Tumbling* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1559, June, 1976.

[12]L. K. Gillespie, *Hand Deburring of Precision Miniature Parts* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1443, November, 1975 (Available from NTIS).

[13]L. K. Gillespie, *A Quantitative Approach to Vibratory Deburring Effectiveness*, SME Paper MRR 75-11, 1975.

[14]L. K. Gillespie, *Comments on the Capabilities of Some Little Known Deburring Process*, SME Paper MR 75-841, 1975.

[15]N. S. Ajlouny and L. K. Gillespie, *State of the Art of General Deburring*, SME Paper MR 74-116, 1974.

[16]L. K. Gillespie, *The Effects of Reaming Variables on Burr Properties* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1083 (Rev.), September, 1974 (Available from NTIS).

[17]L. K. Gillespie, *Properties of Burrs Produced by Ball Broaching* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1084 (Rev.), April, 1975 (Available from NTIS).

[18]L. K. Gillespie, *Burrs Produced by Drilling* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1248, December, 1975.

[19]L. K. Gillespie, *Burrs Produced by Side-Milling Cutters* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1303 (Rev.), November, 1975 (Available from NTIS).

[20]L. K. Gillespie, *Burrs Produced by Grinding* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1372, February, 1976.

[21]L. K. Gillespie, *Burrs Produced by End Milling* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1503, April, 1976.

[22]L. K. Gillespie, *Effects of Drilling Variables on Burr Properties* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1502, March, 1976.

[23]L. K. Gillespie, *Burrs Produced in Turning Operations* (Topical Report). UNCLASSIFIED. Bendix Kansas City: To be published.

[24]L. K. Gillespie, *The Formation and Properties of Machining Burrs*, MS Thesis, Utah State University, Logan, Utah, 1973.

[25]L. K. Gillespie and P. T. Blotter, *The Formation and Properties of Machining Burrs*, ASME Paper 75-PROD-J, 1975.

[26]L. K. Gillespie, *The Formation and Properties of Burrs*, SME Paper MRR 75-03, April, 1975.

[27]L. K. Gillespie, *The Effect of Cutting Edge Radius on Poisson Burr Properties*, SME Paper MR 74-990, 1974.

[28]L. K. Gillespie, *The Measurement of Burrs*, SME Paper MR 74-993, 1974.

[29]L. K. Gillespie, *Effects of Measurement Technique and Experimental Design in the Analysis of Burrs*, SME Paper MR 75-985, 1975.

[30]L. K. Gillespie, *The Burr--Manufacturing's Perennial Thorn*, SME Paper MR 74-992, 1974.

[31]L. K. Gillespie, *Towards a Rational Approach to Deburring*, SME Paper MR 74-996, 1974.

[32]L. K. Gillespie, *Deburring--An Annotated Bibliography*, SME Bibliography Series, 1974.

[33]L. K. Gillespie, *Deburring--An Annotated Bibliography, Volume II*, SME Paper MRR 75-04, 1974.

[34]L. K. Gillespie, *An Overview of International Activities in Burr Prevention and Removal*, SME Paper MRR 75-02, 1975.

[35]L. K. Gillespie, *Recent Trends in Burr Technology*, SME Paper 75-833, 1975.

[36]L. K. Gillespie, *Economic Tradeoffs in Deburring* (Topical Report). UNCLASSIFIED. Bendix Kansas City: BDX-613-1620, June, 1976.

[37]L. K. Gillespie and others, *Impregnation and Contamination From Abrasive Deburring Processes* (Final Report). UNCLASSIFIED. Bendix Kansas City: To be published.

[38]L. K. Gillespie and Fred Clay, "Deburring Influences on Plating Adhesion," *Finishing Highlights*, September/October, 1975, pp 26-27.

[39]James A. Murphy, *Surface Preparation and Finishes for Metals*. New York: McGraw-Hill, 1971, pp 62-87.

[40]J. N. Brandt, "Fundamentals of Media Selection," *Abrasive Engineering*, November/December, 1973, pp 19-21.

[41]*Precision Vibratory Finishing*, Lorco Division of Wheelabrator Corporation, 1969.

[42]William E. Brandt, "Selection and Use of Chemical Compounds for Vibratory Finishing," *Tool and Manufacturing Engineer*, March, 1966, pp 26-30.

[43]Masahisa Matsunaga and Yoshiaki Hagiuda, *Researches on Barrel Finishing*, Report of the Institute of Industrial Science, The University of Tokyo, Japan, Volume 17, Number 4 (Serial Number 111), February, 1967.

[44]Ralph Enyedy, *Handbook of Barrel Finishing*. New York: Reinhold Publishing Company, 1955.

[45]H. R. Letner, "Stress Effects of Abrasive Tumbling," *Transactions of the ASM*, Volume 51, 1959, pp 402-420.

[46]L. P. Tarasov, "Barrel Finishing: What It Does To Service Lift," *American Machinist*, February 9, 1959, pp 98-100.

[47]Donald Mosher and others, "Barrel Finishing With Specific-Shape Abrasive Media," *Tool Engineer*, February, 1959, pp 81-84.

[48]Hubert M. Goldman, "Barrel Finishing Methods," *Electroplating Engineering Handbook*, (Kenneth Graham, editor), Second Edition, 1962, pp 83-106.

[49]Brian Blundell, *Industrial Finishing Equipment*. London: Pergamon Press, 1965, pp 1-62.

[50]P. K. Clarke, "Determining Finishing Costs Accurately," *Metal Finishing Journal*, November, 1969, pp 396-398.

[51]H. A. Van Derck Frechette, editor, *Applied Mineralogy*. New York: Springer-Verlag, 1971, pp 55-166.

[52]J. N. Brandt, *Spindle Finishing--Capabilities and Limitations*, SME Paper MR 75-832, 1975.

[53]J. Bernard Hignett, *Capabilities and Limitations of Centrifugal Barrel Finishing*, SME Paper MR 75-834, 1975.

[54]John R. Jones and Michael N. Gardos, "An Investigation of Abrasive Blasting," *Journal of the American Society of Lubrication Engineers*, November, 1971, pp 393-400.

[55]"Fastest in the West," *Tooling and Production*, 1968, pp 74-75.

[56]C. E. Smeltzer and others, "Mechanism of Metal Removal by Impacting Dust Particles," *Transactions of the ASME*, September, 1970, pp 639-654.

[57]Lester F. Spencer, "Abrasive Blasting," *Metal Finishing Guidebook Directory*, 1971, pp 140-149.

[58]Raymond Harbin, *Surface Finishing by Wet Abrasive Blasting*, SME Paper MR 75-828, 1975.

[59]H. J. Plaster, *Blast Cleaning and Allied Processes*, Volumes I and II. Letchworth, Hertfordshire, England: Garden City Press, Ltd., 1972.

[60]E. H. Ganz, "Sanding Machine Deburrs Bush Faces," *American Machinist*, Volume 89, Number 26, December 20, 1945.

[61]"Belt Deburring," *Tooling*, Volume 23, Number 11, 1969, p 25.

[62]James E. Bateman, *Capabilities and Limitations of Brush Deburring*, SME Paper MR 75-826, 1975.

[63]Richard West, *Deburring With Power Brushes*, SME Paper MR 75-476, 1975.

[64]"Power Brush Cleaning and Finishing," *Metals Handbook*, Volume 2, 1964, pp 405-408.

[65]"Can Power Brushing Help You in Finishing," *Products Finishing*, Volume 24, Number 7, April, 1960, pp 36-45.

[66]Bernard S. Miller, "Control Deburring Quality," *Metalworking*, November, 1965, pp 40-42, 56-58.

[67]John Stackhouse, *Deburring by Dynaflow*, SME Paper MR 75-484, 1975.

[68]Winfield Perry, *Properties and Capabilities of Low Pressure Abrasive Flow Medias*, SME Paper MR 75-831, 1975.

[69]Lawrence J. Rhoades and David E. Siwert, *Extrude Hone Deburring: Theory and Application of Abrasive Finishing*, SME Paper MR 75-842, 1975.

[70]*Guide to Deburring of Machined Components, Part IV--Power Tools*. Melton Mowbray, England: Production Engineering Research Association of Great Britain, Report Number 45, September, 1956.

[71]"Semi-Automatic Gear Deburring Reduces Operation to Seconds," *Grinding and Finishing*, Volume 5, August, 1959, pp 31-32.

[72]A. C. Montag, *Deburring With TEM*, SME Paper MR 75-835, 1975.

[73]Gerald H. Poll, Jr., "Chemical Deburring Solves Problem for A.C. Spark Plug," *Products Finishing*, Volume 24, Number 2, November, 1959, pp 44-47.

[74]*Chemform Electrochemical Deburring Tool Design Manual*. Pompano Beach, Florida: Chemform Corporation, 1971.

[75]Gordon Michaels, "Precision Deburring by ECD," *Products Finishing*, Volume 33, Number 4, January, 1969, pp 48-54.

[76]*ECM, ECD, ECG Simplified*. Pompano Beach, Florida: Chemform Corporation, April, 1970.

[77]"Controlled Electrolytic Deburring Replaces Costlier Hand Methods," *Iron Age*, Volume 174, October 28, 1954, p 94.

[78]Charles L. Faust, "Electropolishing," *Electroplating Engineering Handbook, Second Edition*, (A. Kenneth Graham, editor). New York: Reinhold Publishing Corporation, 1962.

[79]Bruno R. Siegel, *How to Deburr 1,000,000 Drill Holes Within 15 Minutes*, SME Paper MR 75-486, 1975.

[80]John F. Jumer, "Electropolishing," *Metal Finishing Guidebook*, 38th Edition, 1970, pp 519-530.

[81]John P. Wright, "Ultrasonic Deburring," *American Machinist*, Volume 101, February 11, 1957, pp 129-136.

[82]"Sound Waves Strip Off Burrs," *Iron Age*, August 5, 1965, pp 62-63.

[83]B. S. Korshunov, "Ultrasonic Flash--Removal From Small Components," *Russian Engineering Journal*, Volume 49, Number 12, 1969, pp 45-46.

[84]B. G. Ivanov, and Yu, I. Zhuravitsky, "Firecutting in the Trimming and Cleaning of Castings," *Litelioe Prozv*, Number 12, December, 1967, pp 9-11.

[85]William D. Campbell, *Capabilities and Limitations of Water Jet Deburring*, SME Paper MR 75-827, 1975.

[86]M. C. Kurko and R. F. Chadwick, "High Pressure Jet Machining," Paper presented at the National Conference on Fluid Power, 27th annual meeting, Chicago, Illinois, October, 1971 (Copies available from Bendix Research Laboratories, Southfield, Michigan).

[87]Akihko Shimizv, *Electrochemical Barrel Finishing*, SME Paper MR 75-837, 1975.

[88]George DeGroat, "ECM Deburring with Graphite," *American Machinist*, December 1, 1969, pp 78-79.

[89]Hans Wicht and Peter Kurze, "Deburring Still a Difficult Problem?" *ZIS Mitt.*, Volume 15, Number 8, August, 1973, pp 930-935 (In German).

[90]K. Sachs and M. Edgers, "Smoothing of Mild Steel by Barrel Treatment in Oxalic Acid-Hydrogen Peroxide Solution," *Transactions Institute of Metal Finishing*, Volume 33, 1956, pp 245-269.

[91]M. E. Shainskii and others, "The Vibratory Cleaning and Polishing of Parts," *Russian Engineering Journal*, Volume 45, Issue Number 9, 1965, pp 66-70.

[92]E. S. Blagodeteleva, "Aqueous Solution for Vibrational Deburring of Sharp Edges," Soviet Patent 236,183, Filed June 6, 1967.

[93]A. P. Babichev and others, "Accelerating the Vibratory Cleaning Process," *Russian Engineering Journal*, Volume 47, Number 12, 1967, pp 43-45.

[94]W. H. Safranek and H. R. Miller, "Vibratory Finishing With Chemical Accelerators," *Plating*, Volume 59, January, 1972, pp 38-40.

[95]"New Field Opened by Chlorine Deburring," *Steel*, November 4, 1963, pp 115-116.

[96]"What's New in Materials," *Materials in Design Engineering*, Volume 59, January, 1964, pp 111-113.

[97]Boris Makedonski, "Magnetic-Abrasive Grinding of Parts," *Mashinostroene*, Volume 23, Number 4, April, 1974, pp 59-60 (In Bulgarian).

[98]V. A. Morozov, "Changes in the Physic Mechanical Properties of Component Surfaces in Magnetic-Vibratory Machining," *Vibrats, Obrabotka* detalei mashin i priborov (vibratory machining of machine and instrument components), Rostov-On-Don, 1972, pp 23-29 (In Russian).

[99]Rolls Royce, Ltd. (London, England), West German Patent Application 2401969, 1974.

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