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**Deburring: Technical Capabilities
and Cost-Effective Approaches
Lessons 9 and 10**

By L. K. Gillespie

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DEBURRING: TECHNICAL CAPABILITIES AND COST-EFFECTIVE APPROACHES,
LESSONS 9 AND 10

BDX-613-2421, Published June 1980

Prepared by L. K. Gillespie

This ten lesson text on deburring is designed to provide engineers and production supervisors with an overall understanding of deburring economics and current capabilities. The material included describes economics, side effects, process selection techniques, product design influences, standards, plantwide approaches, burr formation, and prevention. Deburring methods described include barrel, centrifugal barrel, vibratory, spindle, manual, electrochemical, electropolish, brush, abrasive jet, abrasive flow, water jet, thermal energy, and mechanized mechanical. Lessons 9 and 10 describe abrasive jet, water jet, abrasive flow deburring, and other common deburring processes with an overview of capabilities.

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Deburring: Technical Capabilities and Cost-Effective Approaches

By
LaRoux K. Gillespie

LESSON 9 Abrasive Jet, Water Jet, and Abrasive Flow Deburring

SUMMARY

Abrasive jet, water jet, and abrasive flow deburring are not panaceas for the world's deburring problems. They do, however, solve many of the problems where burrs are either difficult to reach or amenable to automation. As seen in this lesson, they can deburr miniature parts as well as large parts. In almost every case; however, one will note that accessibility of the burr is the key to the success of these processes.

Volumes have been published on the effects of abrasive jet parameters. The reader is encouraged to pursue some of the citations in the Source of Additional Information for further quantitative information. Similarly, data on abrasive flow deburring is also available. Little data, however, has been published on water jet deburring.

LESSON 9

ABRASIVE JET, WATER JET, AND ABRASIVE FLOW DEBURRING

Blasting parts with abrasive particles is another of the widely used deburring and finishing processes. It is also possible to remove some burrs with a high velocity stream of plain water. The use of abrasive filled 'putty' is another of the rapidly growing techniques for removing burrs in hard-to-reach areas. This lesson describes the basic capabilities of these processes.

ABRASIVE BLAST DEBURRING

One of the simplest processes for deburring which is widely used commercially is known as abrasive blast or abrasive jet deburring. This process is very similar to sandblasting in that one directs the stream of high velocity abrasive particles at the workpiece edges. Millions of tiny particles cut and abrade the burrs from the surface.

Capabilities of Blasting

Figure 1 illustrates a type of basic blasting application for small and hand size parts. As seen there the blasting operation is carried out in an enclosed box. In most instances the operators work with rubber gloves and blast the entire surface of the workpiece. On commercial parts this is frequently adequate for deburring and providing non-sharp edges. In addition the process cleans and in some cases adds a desirable matte finish. This process is frequently not suitable for precision parts because the forces involved in totally removing all burrs and providing uniform radii also would greatly peen the work surface.

In addition to deburring, the abrasive blasting operation is used to provide a uniform matte surface to some parts that will receive subsequent dry film lubricants or which must be bonded into assemblies. The dry blasting operation is also used frequently for deburring individual or groups of plastic parts. In this application either an air driven crushed nut shell is used for the deflashing operation, or an abrasive mixed with water is used to roughen surfaces.

A refined version of the blasting operation is used on miniature parts. In this instance a miniature blasting unit is used in which the abrasive stream is only a few thousandths of an inch in diameter. Figure 2 for example, illustrates an operator using one such unit. As seen there the nozzle on this part is extremely small. Nozzles can be obtained that are only

Figure 1. Abrasive Blasting in an Enclosed Machine

Figure 2. Abrasive Blasting With a Miniature Blaster

0.003 inches (76.2 μm) in diameter. With such miniature nozzles one is of course forced to use miniature abrasives; this in turn confines the abrasive action to edges or to a very localized area. As a result this process can be used to deburr otherwise inaccessible small areas. Figure 3 for example illustrates a miniature part and a paper clip. This part can be deburred by using the miniature blaster.

Types of Blasting Machines

Several types of abrasive blasting machines are used commercially. These include:

- Air carried dry blast jet;
- Air carried dry miniature jet;
- Mechanically wide pattern;
- Liquid carried abrasive jet;
- Liquid abrasive wide pattern; and
- Cryogenic blasting.

Figure 3. Miniature Part Blasted to Remove Discoloration and Burrs in Hard to Reach Areas

The machines that perform each of these blasting operations vary in size from roughly the size of an office desk drawer to those which stand two stories tall. In general most machines are 6 to 8 feet (1.8 to 2.4 m) tall and have enough room so that one or two people could crawl inside if necessary. As implied by the above list, there are basically three ways of throwing the media

i.e. high pressure air, mechanically slinging the media, and high pressure liquid. In these cases the liquid or air pressures involved would involve 40 to 150 pounds per square inch (0.27 to 1.03 MPa). Figure 4 illustrates the complete miniature machine shown in Figure 2.

Variables in Blasting

The parameters that one can change to increase or decrease the aggressiveness of blasting process include:

- Size of abrasive particle;
- Type of abrasive particle;
- Sharpness of abrasive particle;
- Friability of abrasive particle;
- Pressure used;
- Cushioning agent used;
- Angle of the abrasive jet;
- Size of the abrasive jet; and
- Distance from the workpiece.

As seen from the above list, one has a number of variables to change as necessary to increase the aggressiveness or soften the action of this process. On a microminiature blaster for example, one can increase the pressure up to 150 pounds per square inch. At these high pressures, cutting works very quickly. Many machines are normally operated at 80 pounds per square inch. By doubling the pressure one increases the cutting action by a factor of 4. Thus one can essentially do the same amount of deburring in 1/4 the time by using these high pressures.

Larger particles also result in faster cutting as does holding the end of the nozzle closer to the workpiece. The use of water to carry the media results in a very soft action compared to the air driven particles. Some of the minerals are man-made and can be tailored to provide media which fractures very easily or media which is very tough. This may affect the aggressiveness of the action, but in many cases one does not have the capability to change these properties. One will typically use what he has on hand to do this deburring.

Materials Used for Blasting

The materials used for blast deburring include:

Figure 4. Miniature Blasting Machine

- Aluminum oxide;
- Silicon carbide;
- Glass beads;
- Metal shot;
- Plastic particles; and
- Ground nut shells.

A variety of other materials are also used in other applications, but the above list is representative of those used on most metal and plastic parts. The minerals such as aluminum oxide and silicon carbide actually cut the edges at which they impact. For this reason they are generally used for the deburring applications. Miniature hollow glass beads are frequently used for cleaning surfaces and removing brittle burrs. These hollow glass beads develop a high force and will physically knock off or peen off brittle burrs. They do not normally cut and are not normally very successful in removing very thick burrs.

In some instances metal shot or crushed metal particles are used to provide the desired surface texture properties. These items

can also be used for deburring. Some companies use small plastic pellets to deburr small plastic parts. This eliminates some of the undesirable impregnation or surface contamination which other products will cause. Many of the plastic parts which have flash on them are deburred with the use of ground nut shells or apricot pits.

Specific Examples of Use

It must be emphasized that while the blasting machines will remove burrs, under normal circumstances they are used only on relatively small burrs. While one can use them to physically cut a piece of metal in half, it generally requires too long a time and is not as controllable as desired on precision parts. If one has to use this process for cutting off thick burrs, a gouge or irregular edge or surface will generally be left.

Economics of Blasting

Under normal circumstances blasting operations will be used for only 1 or 2 minutes on a part. If the deburring requires more time there may be more economical approaches. As in the case of many deburring processes this is also used only on hard-to-reach areas, very small areas or specific types of edge problems. As an example it is one of the processes used to remove small "recast balls" or resolidified nuggets from the edges of parts produced by EDM. The process is particularly beneficial when one has a very hard material to work on. It is not generally successful on such soft materials as aluminum.

Potential Problem Areas

The blasting processes have several side effects which must be considered when they are used. These include:

- The process impregnates particles into the work surface;
- The process may roughen surfaces;
- The process may change dimensions on certain areas of the part;
- The process may beat burrs over;
- The process can make new burrs; and
- The process may leave blasting media in holes and pockets.

The fact that the process inherently beats media into the work-piece is detrimental for many parts. For this reason alone it

may not be possible to use this process. In other cases the fact that it roughens the surface and provides an adherent bonding surface is a distinct advantage. Blasting processes are not normally used on surfaces which require high surface finishes because they may worsen such precision surface finishes.

While this process will not normally change dimensions, it will if one dwells at one specific location at the part. Just as a fast running river cuts a new or wider course for itself, the abrasive jet will carve out a niche in the workpiece.

In many cases the media will become hidden in small pockets or deep holes and may not be totally removed. For this reason it is important to always have a cleaning operation after the blasting operation is performed to verify that all particles have been removed. If the part is wet or damp or has an oily film before the blasting begins, abrasive particles will be more apt to stay entrapped in these hard-to-reach areas.

WATER JET DEBURRING

Water jet deburring is a high production process used extensively in the automotive industry to remove machining burrs and thin die casting flash from nonferrous automatic transmission control mechanism components. The process was first used in production in 1971 and has since been adopted by most major automatic transmission manufacturers. The process consists of ultra high velocity, high pressure (5000 psi--34.5 MPa) fan-shaped blades or conical streams of water impinging on the surface of the workpiece and cutting, eroding, breaking or otherwise disintegrating the burrs from the parent metal and removing the metal residue with the used water (Figure 5).

Water jet deburring has replaced primarily expensive hand deburring and abrasive blasting with walnut shells. The use of walnut shells had inherent disadvantages that were overcome with the use of water jet:

- Corner deformation of close tolerance bore. Heavier than normal burrs (caused by dull cutting tools) would tend to be deformed by the walnut shells back into the original bore causing a reduction in diameter near the end of the bore. Water jet deburring leaves square corners.
- Abrasive residue. Any walnut shells left in the workpiece could result in the same type of operational problems as the presence of the burrs they were intended to remove and would cause assembly problems if not removed from blind threaded holes. No foreign material of any sort remains on the surfaces with water jet.

Figure 5. Fan Shaped Blades of Water Used for Deburring

Description of the Process

A water jet deburring machine consists of a conveyor belt that conveys workpieces in front of a series of jets through each of which is flowing a high velocity stream or fan-shaped blade of water powered by a pressure head of approximately 5000 psi (34.5 MPa). As the workpiece moves in a controlled path past these jets, the water impinging on the surface of the material disintegrates the most fragile and brittle portions of the workpiece, the burr. The longer the exposure to the jet, the greater the erosion or disintegration, and consequently the greater the size of the burr that can be removed. Typical automotive application exposure times are determined by test of actual workpieces that have typical sharp cutting tool burrs. The machines are not designed to remove burrs caused by dull cutting tools, laminations in die castings, or heavy die casting flash as these types of burrs are not apt to come loose in part service life anyhow.

Complete removal of all burrs could be accomplished only with very long exposure times that would negate the economic justification for the machine, and would result in erosion and damage of surfaces other than desired surfaces.

Economic Factors of Water Jet Deburring

- Deburring of die cast aluminum with typical machining burrs formed by sharp cutting tools is accomplished at a rate of 350 pieces/hour. Nozzle to part distance varies from 1 to 4 inches (25.4 to 101.6 μm).
- Anodized aluminum burrs are somewhat harder and easier to disintegrate than non-anodized material. They can be removed at pressures down to 4000 psi (27.6 MPa).
- Manual deburring and/or abrasive media removal can be omitted, although most components will still be visually inspected for gross types of defects. Visual inspection requires much less labor content than manual deburr and/or media removal.
- Jet replacements in a properly maintained machine should not be needed until after approximately 5000 operating hours (1,750,000 parts at 350 parts/hour).
- Floor space required approximates 1000 sq ft (93 sq m) per machine.
- Electrical power requirements are approximately 300 kw depending on the size of the machine. Annual electrical costs in one industrial region for this power consumption exceed \$30,000.
- Water can be recirculated, filtered, and chilled for minimal water consumption.
- Use of one to three percent water soluble oil is usually employed to prevent rust in the system and improve wear life of the hydraulic high pressure pumps.

Capabilities of Water Jet Deburring

- This process can remove burrs and flash from aluminum, cast iron, steel molded asbestos, and phenolic moldings.
- This process can remove burrs through narrow openings (1/16 inch--1.6 mm).
- This process can remove internal burrs in direct line with an external opening.
- This process does not affect accuracy or surface finish of adjacent machined surfaces when removing thin burrs on aluminum parts.

- This process can accommodate a large variety of anticipated burr locations in various workpieces, including round workpieces that are rotated while exposed to the jet.

Limitations of Water Jet Deburring

- Removal of thicker than designed-for aluminum burrs, cast iron burrs, and steel burrs must be accomplished with either higher pressure (machines with pressures up to 100,000 psi (698 MPa) are available) or extended exposure time.
- This process cannot deburr where there is no direct access to an external opening perpendicular to the burr.
- This process requires accurate positioning of the workpiece relative to the jets and the jets relative to the anticipated burr locations on the workpiece.
- Access by the water jets to the workpiece is limited to three sides in one machine.
- Machines must be individually designed for each workpiece and cannot be conveniently changed over.

Operating Details

While the transmission industry is using fans of 5000 psi (34.5 MPa) water, other industries use a very narrow stream under 60,000 psi (408.1 MPa) or greater pressure. In these applications nozzle diameters of 0.012 to 0.060 inch (0.30 to 1.50 mm) are used with these pressures. Under these conditions with nozzles 2 inches (51 mm) or less from part edges, feedrates of 3 inches per second (75 mm/sec) are possible on 1020 steel (R_B 74).

Similar small milling burrs on 316 stainless steel (R_B 105) can be removed under similar conditions at 2 inches per second (50 mm/sec). Figure 6 illustrates the effect of nozzle diameter on feed rate for 1020 steel.

From this figure, it is evident that the larger the diameter, the better the nozzle is for deburring. Some reasons for this improvement in performance are that larger jets exert more force on the burr and maintain a cohesive region capable of removing burrs longer.

Pressure Requirements

In order to achieve cutting rates that are high enough to be suitable for jet machining, a high pressure pumping source must be available. A good estimate is the required pressures can be

Figure 6. The Effect of Nozzle Diameter (mm) on High Pressure Jet Deburring

obtained by neglecting the frictional losses through the nozzle, thereby obtaining a theoretical relationship between the nozzle pressure and the nozzle exit velocity.

$$V_j = (2g_c p_n / \rho)^{1/2}$$

where:

g_c = gravitational constant;

p_n = nozzle pressure;

ρ = fluid density; and

V_j = jet velocity.

This equation is plotted in Figure 7 for water and the calculation is based on an average density change because of compressibility. Actual velocities will be somewhat less than

Figure 7. Jet Pressure Requirements

those indicated because of nozzle friction. Accurate values for frictional velocity coefficients are almost non-existent in this range of velocities because of the difficulty of measuring actual exit velocities with available instrumentation.

Flow Parameters

Volumetric flow requirements for a given nozzle and jet velocity can be obtained by calculation with the continuity equation. A plot of theoretical flow rates is given in Figure 8 for a realistic range of jet velocity and nozzle size. The term D_n in this Figure denotes nozzle diameter. The values given are theoretical in that no discharge coefficient has been included in the calculation. The strong dependence of flow required on nozzle diameter shown in the graph indicates the desirability of using as small a nozzle as can be obtained for cutting work. Large nozzles not only require greater flow and the attendant power, but result in more material waste. Furthermore, large volume pumps increase the capital cost of the jet cutting system.

Figure 8. Flow Rate Dependence on Velocity and Diameter

Power requirements for any jet cutting system are critical because of their effect on the total economics of the system. The theoretical power required by a single jet is given by:

$$P = (\rho/2g_c) A_n V_j^3$$

where:

P = power; and

A_n = nozzle area.

This equation is plotted in Figure 9 for several practical nozzle sizes. It is clear that with a cubic dependence on velocity, the power required will be strongly affected by the choice of jet velocity for a given application. It must be remembered that the greater the power in the jet, the faster material can be removed and the higher the allowable surface travel speed.

Figure 9. Power in Cutting Jet

Nozzles

The selection of nozzles for jet cutting is a matter of great importance. Both the geometric design and the material used to fabricate the nozzle have an effect on the quality of the emerging jet. A large number of designs have been tried by various investigators. The most commonly used geometry is simply a conical entry of small included angle and a straight cylindrical exit of about two to three exit diameters in length.

Because of the high pressures and velocities, nozzles are subject to stress failure and erosion. Material selection to avoid failures has led designers to use a wide variety of substances from steel and tungsten carbide on the one hand, to diamond and sapphire on the other. When jewel materials are used for their hardness and erosion resistance, they must be afforded some supporting strength.

Target Reactions

When a high velocity jet is applied to a piece of stock, the forces applied to the stock are of interest to the process designer. The target forces can be calculated from momentum considerations:

$$F = (\rho/g_c) A_n V_j^2$$

where:

F = Reaction Force.

Target forces calculated for a range of nozzle velocities and nozzle diameters are plotted in Figure 10. Forces calculated using equation 3 have been shown to agree well with experimentally determined target forces. It should be noted from Figure 10 that when nozzles less than 0.010 inch (0.254 mm) are used, forces on the target (workpiece) can be expected to be less than 10 pounds (44.5N). Forces of this magnitude are easily accommodated by support or clamping devices.

Not all materials can be cut satisfactorily with high velocity jets. Some materials are too strong for the available pumping pressures. Some are too brittle and result in fractured stock and very ragged edges. Some laminated materials cut well but others develop separated laminations when cut with a liquid jet. The cutability question is an empirical one and if some doubt exists, the best procedure is to try it. A number of materials exhibit a wavy surface after exposure to jet cutting. The cause of these striated surfaces is not understood and is the subject of further study.

ABRASIVE FLOW DEBURRING

The abrasive flow deburring process is a method of abrading surfaces by extruding a viscous, semisolid abrasive laden media across areas or surfaces. In order to contain and direct the flow of media, the workpiece is confined within a fixture between the two vertically opposed media chambers (or cylinders) of the machine (Figure 11). Under hydraulic pressure, the media is extruded from one media chamber through the fixtured workpiece and into the opposite media chamber. In most applications, the media is then extruded back through the part into the original media chamber. The amount of abrasion that is accomplished with a given media formulation and process pressure is directly related to the quantity of media flow. Depending upon the application, adequate flow quantities range from 10 to 1000 cubic inches (16 to 1600 cm³).

Figure 10. Target Reaction Forces

The process can be thought of as a flowable file with capabilities ranging from a light buff to coarse stock removal. By using various compound formulations, machine adjustments, and fixture designs, selective deburring can be performed on many types of components.

A basic principle of this process is the media's ability to be significantly abrasive only at the point of greatest restriction in its flow path.

Abrasive flow systems consist of machine, media, and fixtures.

Basic Machine Configuration

Abrasive flow machines are designed to control media flow over a wide range of process parameters. All units are designed to extrude the semisolid media through a fixtured workpiece at a selected pressure and velocity. Automatic and manual operation machines are available.

Figure 11. The Media in Abrasive Flow Deburring Passes Through the Lower Fixture Plate, Holes in the Part, Through the Upper Fixture Plate, Then the Cycle is Reversed

The pressure range used to flow these compounds vary from 100 to 1600 psi (7 to 112.5 Kg/sq cm). This relatively low range enables delicate and complex components to be processed as well as large sturdy parts. Fixturing to contain these hydraulic pressures need not be massive. Nylon, aluminum, and 1018 steel are common fixture materials.

Part cleaning after abrasive flow deburring consists of blowing the media out of the part with an air gun. Most of the compound will be removed from the part in this manner even from blind and threaded features. Final cleaning is performed with a commercial solvent (trichlorethane for example) or detergent cleaning systems. Ultrasonic agitation is necessary for total removal of abrasive particles in many small parts.

Basic Media Considerations

The rheological characteristics of the media are important in the successful application of the process. Media formulations provide the following characteristics:

- Wide range of flowability;
- Uniform suspension of abrasive grain;

- Stability--long life without breakdown or separation;
- Nontoxic for operator safety;
- Noncorrosive to parts;
- Maximum aggressiveness to minimize process cycle times; and
- Cohesiveness--to improve handling and cleanliness of operation.

The basic media consists of abrasive grain uniformly suspended in a semisolid/semifluid extrudable matrix such as silicone rubber. The matrix is formulated to obtain special rheological characteristics. Proprietary additives are used to obtain the desired consistency, stability, and cohesion. Various sizes, types, and ratios of abrasive grain are used in media formulations depending upon the given application. Aluminum oxide, silicon carbide, boron carbide, and diamond grain are used in the process.

Silicon carbide is the preferred grain for deburring applications. Size ranges from #8 to #600 grit with larger sizes selected for faster stock removal and larger radii and smaller sizes selected for finer surface finishes. Typical sizes used for deburring are 36 and 60 grit.

Basic Fixture Considerations

Fixtures are used in abrasive flow deburring to:

- Hold the workpiece in position between the media cylinders of the machine;
- Direct media flow to selected holes and/or part surfaces requiring finishing;
- Meter media flow;
- Protect critical edges and surfaces; and
- Assist in loading, unloading, and cleaning operations.

Fixturing can be either very simple and inexpensive or complex and comparatively expensive depending upon the specific part requiring deburring, the manufacturer's deburring standards, and the production rate required. Each part requires its own fixture.

Urethane and/or nylon is often used on fixture surfaces in contact with the workpieces. This is done to prevent impinging

the workpieces with loose abrasive grain during clamping. Steel and aluminum are normally selected for major fixture details because of their low cost and good machinability. Wear inserts of abrasive resistant tool steel are used in wear prone areas of the fixtures.

Fixtures have been designed, built, and used in production for workpieces as small as a precision gear with a pitch diameter of 0.100 inch (2.54 mm) and as large as 47 inches (119 cm) diameter turbine hub. Production rates on small parts of up to 1000 parts/hour have been obtained through proper fixturing techniques.

Cutting Action

As an example of the ability to produce large edge radii with this process, consider Table 1. This test data was taken by forcing media back and forth through holes in the workpiece. In all cases 10 complete cycles of back-and-forth flow was used and the sample was cold rolled steel having a single 0.125 inch (3.18 mm) hole 0.250 inch (6.35 mm) long. The particular media selected was stiff (viscous) and consisted of 38 percent of 36 grit abrasive and 6 percent 700 grit abrasive. The fine grit helps provide a better matrix for the larger grit but does not influence the cutting.

As seen in Table 1, a 75 percent increase in pressure reduced cycle time by a factor of 10. In addition, the higher pressure resulted in more hole size change and a larger radius.

The test data in Table 1 demonstrates large hole size changes. It is possible; however, using different parameters to control size change to 0.008 inch (0.2 mm) or less. Rectangular holes as small as 0.010 inch (0.25 mm) wide have been finished with this process.

Deburring Characteristics, Advantages

As a relatively new deburring process, abrasive flow deburring has gained a wide acceptance by manufacturers because it offers several advantages for deburring applications. These include:

- Ability to deburr all media;
- System flexibility;
- Automatic controlled process;
- Selective deburring capability;

Table 1. Results From the Ten Cycle Tests

Pressure (PSI)	Total Time (Minutes)	Initial Diameter (Inch)	Final Diameter (Inch)	Diameter Increase (Inch)	Radius Produced (Inch)	Stock Removed (Milligrams)
Aluminum Oxide Media						
300	18.0	0.127	0.141	0.014	0.020	118
400	3.8	0.127	0.145	0.018	0.020	176
500	1.8	0.127	0.153	0.026	0.040	293
Silicon Carbide Media						
300	22.7	0.126	0.144	0.018	0.020	168
400	4.2	0.127	0.149	0.022	0.025	239
500	2.0	0.127	0.153	0.026	0.030	293
Boron Carbide Media						
300	19.3	0.126	0.160	0.034	0.020	328
400	3.8	0.125	0.164	0.039	0.020	344
500	1.6	0.126	0.173	0.047	0.040	540

- o Ability to deburr a wide range of part sizes;
- o Easy changeover from one part to another;
- o Multipart processing capability per cycle;
- o Short process cycles;
- o Minimal fixture costs;
- o Improved surface finish; and
- o Ability to deburr areas not accessible to normal deburring techniques.

Metal hardness has no significant effect on the process. This process can be used for both soft and hard materials with little or no change in media formulation and process parameters.

Easy changeover from one part to another is especially important to the manufacturer with low volume runs on several different parts. The complete changeover of media and fixtures and the resetting of process parameters can normally be accomplished in minutes.

Multipart processing capability--depending upon the size of the part and the machine, many parts can be loaded into a fixture and deburred simultaneously. Thus high production rates can be achieved and per part cost minimized.

Short process cycles are a characteristic of abrasive flow deburring. Actual process cycle times are dependent upon work-piece condition and manufacturers' deburring requirements. Cycles of less than one minute meet most deburring requirements.

Improved surface finish and high surface integrity are other significant side benefits of the process. The process produces a "stress free" surface with a very fine finish. Surface finishes down to 2 microinch ($0.05 \mu\text{m}$) have been produced on steel work-pieces. In most deburring operations finishes of 16 microinches ($0.41 \mu\text{m}$) will not be degraded when this process is used.

Limitations

All deburring processes have limitations and this process is no exception. The process is automatic and will produce uniform repeatable results only if the burr conditions presented to the process are relatively consistent. The process is flexible and can accommodate changes in burr conditions but the operator must then make decisions about process parameters.

As in all deburring processes, there is a limitation as to the size of burr that can be removed without affecting part dimensions significantly. Process parameters can be adjusted to minimize this factor and on close tolerance parts, allowance can be made for stock loss which accompanies deburring. The process can remove any size burr as long as part tolerances and process time available permit.

Blind holes and cavities are difficult and often impossible applications for the process since it is based on the controlled flow of media, and blind holes prevent conventional flow.

The machine, fixtures, and media normally are more expensive than vibratory or tumbling equipment and, therefore, if satisfactory deburring can be obtained using these mass finishing processes, it is more economical to do so.

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Deburring: Technical Capabilities and Cost-Effective Approaches

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LESSON 10 Other Common Deburring Processes and an Overview of Capabilities

LESSON 10

OTHER COMMON DEBURRING PROCESSES AND AN OVERVIEW OF CAPABILITIES

There are four deburring processes which are in reasonably common use in addition to the processes discussed in earlier lessons. These are the Thermal Energy Method, Chemical, Orboresonant, and Manual Deburring. In addition, some variations of the processes already described are noteworthy. To reduce deburring costs, four cardinal rules must be followed.

THERMAL ENERGY METHOD

The Thermal Energy Method (TEM) of deburring was introduced to industry in 1971. Since that time it has found acceptance in several diverse industries. The Thermal Energy Method is probably the fastest of all the known methods of deburring. The actual time to remove even the largest burrs is generally less than 20 milliseconds.

The Thermal Energy Method starts by placing a manufactured part with burrs into a chamber, closing the chamber, and then pressurizing the chamber with a fuel gas and oxygen mixture. When a spark from a spark plug ignites the mixture, a fire is started. This causes the combustible mixture to ignite (Figure 1). Unlike automobile engines where the ignition causes a piston to move, all of the energy of the fuel must be converted into heat. The heat hits everything in sight. It hits the walls of the water cooled chamber where it is carried away. It hits the main body of the part itself tending to warm it. It hits the burrs themselves regardless of their location. The heat hitting both sides of the burr soon meets itself in the middle and seeks a way to conduct itself into the main body of the part. The only way out for the heat is through the root of the burr into the part itself. The route through the root of the burr is relatively narrow--restricting the flow of heat. This restriction causes the heat to build up within the burr until it reaches its ignition temperature.

After the first fire using the fuel gas and oxygen goes out because all of the fuel gas is consumed, a second fire starts using the head of the initial detonation, excess oxygen and for fuel, the material from which the component is made. This second fire, the burning of the burrs, will continue until one of the three essential elements of a fire is lost. This will obviously never be the fuel unless the entire part is consumed, and as stated before, an excess of oxygen exists in the chamber

Figure 1. Thermal Energy Method of Deburring

by design. The second fire goes out only after it reaches the corner or surface of the part itself by the root of the burr. At this point, the heat is no longer restricted by the narrowness of the burr but suddenly has a wide path in which to flow. It rushes into the component itself lowering the temperature of the flame and the flame goes out.

In each case the metal combines with oxygen to form the oxide of the metal that is present. This oxide then settles on the surface of the part. The oxides can be removed by means of a liquid

solvent if desired. In the case of steels that are later heat treated, cleaning can be omitted; in the cases of zinc which is dichromated, aluminum which is anodized, or brass which is brite dipped, extra cleaning is not necessary; and in the case of inexpensive components sometimes the oxides are simply left on the parts.

The burr is not removed by vibration, wear, or the shock wave which accompanies ignition. The burr is actually burned off.

Capabilities

TEM can work on all combustible materials including ferrous and nonferrous metals, thermoplastics and rubber. One would have difficulty in doing a thermosetting plastic which would not burn but simply get harder as heat is applied. The process requires more energy to deburr corrosion resistant metals than unalloyed metals. The fact that the second fire goes out because of heat flowing into the component would logically mean that materials which are better heat conductors would have the fire go out prior to poor conductors. Thus it is easier to obtain an edge break or radius on a poor conductor such as steel as opposed to brass which is a relatively good conductor.

The TEM process has instantly removed fingernail size burrs as thick as 0.020 inch (0.5 μ m) under ideal conditions. Ideal means that the remainder of the component has no sections thinner than 15 times the thickness of the largest burr and that it is capable of sustaining the detonation without damage. Most production burrs are 0.005 inch to 0.010 inch (0.127 to 0.25 μ m) in thickness. Burr length is not a factor in TEM. It is the thickness of the burr root that is critical.

The TEM process has put radii on steel from 0.002 to 0.060 inch (0.05 to 1.5 mm), and on aluminum from 0.002 to 0.010 inch (0.05 to 0.25 mm). The size of the radius can be only partially influenced by the controls available to the process. The major determinants are the workpiece material and the size of the burrs. In thermal deburring the radius achieved is directly related to the size of the burrs. One will get larger radii where there are burrs on various edges and virtually no radius on edges where there was virtually no burr. This is the opposite of what one might expect; however, it is explainable if one considers the burrs as kindling to start a fire. The radii achieved will be consistent within ± 0.002 inch (± 0.05 mm) for a given material with the same size burr. In general, a sufficient radius will be put on all edges to prevent hand cuts from the typical ragged edges left on untreated parts. A part which is properly placed in a TEM chamber can, both inside and outside, meet that elusive specification "remove all burrs--break all sharp edges."

Thermal deburring generally averages about 20 seconds in total cycle time for each load of parts with factory units operating as low as nine seconds and the slowest as high as 30 seconds. In the average 20 seconds, although one can only deburr one large cast iron pump body, one could deburr four ordinary sized aluminum carburetors, about 30 to 40 brass elbow fittings, or several hundred zinc lock cylinders. Thus rather than measuring part times in minutes, when one gets above 200 parts per load, cycle time per part is in tenths of seconds per part.

The distinguishing feature of all the parts just mentioned is that the deburring problem area is internal. TEM is the fast method of removing burrs which are inside a part, possibly located in a blind hole, an inaccessible groove, or even in locations which are not readily visible. Certainly any pump, valve, metering device, fitting, etc., through which air, water, gas, oil, or any liquid must flow is an ideal candidate for the TEM process. TEM is an excellent way of eliminating the loose debris often found internally in such components. TEM for example is now used by virtually every major carburetor manufacturer in the world as the method of providing consistent quality to meet environmental standards. It is also gaining in popularity among hydraulic and pneumatic component manufacturers.

The limitations to the process generally result from the effects of the shock and heat waves connected with the detonations to fragile or thin parts. There is a stress relieving characteristic equivalent to dropping the parts from a height of over one foot. This is especially noticeable on highly stressed parts such as formed or stamped sheet metal parts. Air hardening steels which have thin sections can be troublesome if it is impossible to shield or heat sink the thin sections and if the part is not to be heat treated later. On rare occasions, engineers will not accept the recast layer under a removed burr. The process is also not recommended for materials which have been previously hardened because the surfaces occasionally develop heat check cracks.

Depending on size and amount of automation, units such as these can cost between \$60,000 and \$250,000. Users with large rectangular parts with internal burrs use no tooling at all and they simply pay for the fuel costs which, including rental of the tanks from a supplier, average between \$.01 and \$.015 per detonation.

Users with many small parts do have to contain them in some sort of basket to prevent them from spilling over the sides and these stainless steel baskets generally cost below \$100 each. Users with parts which have external burrs which are to be removed simultaneously with the internal burrs must raise the parts up in

a manner so that the external burrs are "in the gas." This requires some form of pin, post, or nest which, although it must be made of stainless steel, does not require the precision of an ECM electrode, the form fitting of the abrasive putty machines, or the complexity of the holders on spindle finishing machines. Some customers for a few thousand dollars have made standard sub-plates and pin sets capable of handling several parts of varying sizes and shapes.

Just as all the deburring methods using an abrasive wear out various components, various seals for TEM are subjected to wear by the process and must be changed regularly. The chamber and mixing valve seals can be compared to cutting tools on a lathe or milling machine when stressing the need for regular, scheduled changes. Rather than having this changing time classified as downtime, it should be classified as setup time as it is on normal machine tools.

It is difficult to give an average value for the cost of seals, spark plugs, thermocouple tips, etc., for the process because their use is directly proportional to the energy level which is used. For example, a zinc manufacturer would use relatively low energy levels in which a set of such components could last well over 30,000 detonations which, in turn depending on size, could mean 120,000 to 240,000 carburetors. This could be about two cents per detonation or mils per part. On the other hand, a customer deburring a stainless steel part one at a time in a special fixture at a very high energy level could require new seals before 5000 detonations requiring costs in excess of \$.05 per workpiece.

Guidelines for Usage

Three rules must be followed for successful Thermal Deburring, and these rules further highlight process limitations.

Rule 1: KEEP THE BURRS IN THE GAS. That sounds simple enough but it is easy to violate the rule. For example, if you have external burrs on the corners of the parts and set the part into the chamber with the burrs touching the chamber, these burrs will be heat sunk by the chamber--not brought up to auto-ignition temperature and therefore not eliminated. In the case of bulk loaded parts which may be run several hundred at a time such as brass fittings, tees, elbows, etc., the burrs are all internal and there are no problems in getting the burrs "in the gas." As soon as the component has some external burrs, however, bulk loading presents the probability that an external burr will touch a mating part and be heat-sunk. Although rerunning the components twice, having stirred them between thermal shots, can improve the odds, there will always be some external burrs remaining. Blind or intersecting holes which are filled with

cutting oil, coolant, or packed with chips will obviously not allow the gas to surround a burr located at the bottom of such a hole. If only a thin layer of coolant is present, one will be able to use the unique capability of this process to eliminate burrs in blind, inaccessible locations. Just as burrs which are folded over can be hammered into the part by a vibratory system, a tightly hammered-in burr will heatsink itself in the thermal process. Users who wanted to tumble large external burrs and use the thermal method for small internal ones complained when the thermal process could not correct the occasional misses of the tumbling system. Obviously the processing should be reversed and the Thermal Deburring be done first.

Rule 2: MAKE SURE THAT WHAT YOU WANT TO KEEP IS DESIGNED TEN TIMES THICKER THAN WHAT YOU WANT TO GET RID OF.

One should not produce burrs with a root of 1 mm thickness if on the same part one has a threaded hole whose thread has a root of 0.5 mm thickness. Actually threads withstand the thermal process quite well in that they have a shape resembling flash which allows the heat to flow back into the part. However, when the energy level is set to eliminate massive burrs, a fine thread must go.

Rule 3: RESTRAIN THE PART IF REQUIRED. Picture the detonation as the release of energy in all portions of the chamber at once with vectors and ricocheting forces beating on the part on all sides. It is quite natural for components to want to move in the direction of least resistance. If the part is unequally shaped, it will tend to move in one direction or another gaining velocity the further it moves. Use a nest on individual parts to stop them after about an eighth inch or so of movement so they do not damage themselves by hitting the sides of the chamber. In the case of bulk loading into a basket, one part tends to support another and no particular fixturing is necessary providing the parts do not have external burrs. On many parts one needs no tooling to deburr. Gas conforms to all components without help being required. Occasionally nests are required to prevent the part from moving or some heatsinks for thin sections designed by a product engineer not familiar with the process.

Most manufacturers of valves, manifolds, and other rectangular pieces of "swiss cheese" type parts use no fixture at all. Manufacturers of irregular parts such as small die castings or brass fittings use a stainless steel basket costing about \$100 which holds many parts.

Unlike EDM and ECM, the surface of the deburred part where the burr used to be is affected by the thermal process. Obviously if one were burning the metal, it was in a gaseous form and it had to be in a liquid form before vaporizing, there is a very slight

recast layer generally about 0.00008 inch (2.03 μm) thick; but sometimes as thick as 0.001 inch (25.4 μm) which has had its metallurgical properties changed. Generally the layer is so thin that this does not bother anyone and one prominent manufacturer indicates that the layer did not affect the hobbing tools which were shaving gears deburred thermally.

Guidelines for consideration of the process are as follows:

- If one can use a satisfactory automated bulk method--stick to it. TEM is still less economical than these methods at this time.
- The investment required means that one must have three or four people hand deburring in order to justify the investment if only the economics and not added quality are taken into consideration.
- The largest advantage is the universality and ability to change from one component to another in minutes without tooling. It is only on the first half dozen or so shots that trial and error methods are used to establish the energy level; thereafter, the parameters are noted and one can get consistency.
- Do not expect TEM to treat wide surfaces as done by practically all other deburring methods. Most wear down the surfaces in some manner leaving a smaller remaining part but one which has improved surface finish. Although TEM may alter the shape of some fragile parts because of stress relieving, it definitely does not remove metal on flat surfaces.

CHEMICAL DEBURRING

Buffered acids have been used for many years to remove burrs. In this process, parts are inserted into a tank of specially formulated acids which etch away the burrs and some of the parent metal (Figure 2). 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 burrs produced on electrical connectors by screw machines. In large batch operations, parts sometimes are tumbled in the solution to assure uniform stock removal.

Most of the parts that are chemically deburred are very small, although the only limitation is the size of the tank. This process is not affected by the shape of the workpiece. It attacks all edges and surfaces uniformly, provided that bubbles do not build up on a portion of the part surface and shield the

Figure 2. Chemical Deburring

area from further attack. In general, a batch of parts will require from 5 to 30 minutes for deburring. Obviously, the time required is a function of burr size. Heavy burrs will not be removed without a similar change in the part size. With some materials, chemical deburring may be able to "soften" burrs so that they can be easily removed by vibratory deburring.

The repeatability of the size change has not been documented. By nature; however, it should be repeatable within $\pm 25.4 \mu\text{m}$ (± 0.001 inch). Published data indicate that edge breaks will be two times greater than the amount of stock removed, and the repeatability of this is probably $\pm 25.4 \mu\text{m}$ (± 0.001 inch).

While a few solutions are designed for actual deburring, most are known as bright dip solutions which are used more for adding luster to parts than deburring. Finishes as fine as 6 to 8 $\mu\text{in.}$ (0.15 to 0.20 μm) can be maintained. Roughness exceeding 32 $\mu\text{in.}$ (0.8 μm) will show some improvement.

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.

The only publicized case history of cost indicates that a 10 inch (254 mm) steel rod cost 28 cents to deburr on the basis of a yearly run of 128,000 parts. Since many of these solutions only cost 4 dollars per gallon, it is possible to do smaller parts at a much less expensive rate. Costs of 1 to 2 cents per part are possible with this process.

ORBORESONANT DEBURRING

In the Orboresonant process parts are attached to fixtures at the ends of a long beam (Figure 3). The beam is oscillated at its resonant frequency and a tank of loose abrasive media beneath the fixture is elevated until parts are in the media. The 75 to 100 Hz vibration of the parts against the abrasive media radiuses edges. When the part is finished the media tank is lowered and the parts allowed to vibrate for a short time to shake out any media setting in hard to reach areas. The process is typically run wet with a cleaning solution in order to remove machining oils while deburring and finishing.

The process is typically used to deburr parts weighing up to 40 pounds (18 kg). Several parts can be deburred at one time if their weight does not exceed this limit. It is best used on external edges, although large castings for valve and pump bodies or other hydraulic components have been successfully finished by this process. Typical cycle times range from 3 to 15 minutes.

As in most loose abrasive processes, removing heavy burrs will require longer cycle times and will result in more stock removed from the workpiece. Stock will be removed from all surfaces exposed to the media. The process does not work well on deep, hard to reach edges but it can be effective on short blind features. The abrasive particles which the process impregnates into the workpiece can affect welding, soldering, brazing, and plating.

If workpieces contain a large number of different-size holes and cutouts, it may be impossible to find an effective media which does not lodge in some holes.

No data has been published on stock loss from this process, but it is reasonable to assume that it is similar to that of other loose abrasive processes. Removing a 0.003 inch (76.2 μm) burr from stainless steel would therefore probably remove 0.0002 inch (5.1 μm) stock from the workpiece.

Similarly it is reasonable to assume that the stock loss repeatability is comparable to other loose abrasive processes which have an repeatability in the order of ± 0.0002 inch (± 5.1 μm).

It is difficult in any loose abrasive process to produce edge radii smaller than 0.003 inch (76.2 μm) when the initial burr is of similar thickness. Radii of 0.010 inch (0.25 mm) should be possible with this process. Aluminum and other soft metals will have twice the radius that most steels will have. With a consistent burr size one should expect edge radii to be repeatable with ± 0.001 inch (± 25.6 μm).

Figure 3. Schematic of Orboresonant Process

Although surface finishes are not described in the literature, it is again reasonable to assume that finishes are comparable to those produced in other processes. One should therefore expect to see finishes of 10 to 30 microinch (0.25 to 0.75 μm) with appropriate media, cycle time, and initial surface finish.

The biggest apparent advantage for this process is that it will deburr relatively large parts without part-on-part impingement. In addition, it will concentrate the action on one surface. The fact that the media does not continuously rub against itself as in the case of vibratory deburring should result in significant media wear savings.

MANUAL DEBURRING

Despite the widespread use of manual or hand deburring, there is little data in the literature describing its capabilities or economics. It is, of course, more subject to work capabilities and interest than the other deburring processes. It is also relatively expensive. It does, however, have some unique advantages:

- It doesn't tie up equipment;
- It can concentrate all action at edge;
- It does not require tooling, N/C tape, or machine available lead time (short turn around time for small quantities);
- It does not normally require expensive holding fixtures;
- It can quickly re-orient parts with respect to tools since no fixtures are involved (an N/C or mechanized approach may require 5 axis);

- It adapts to all edge conditions (versus machine pre-programmed motion); and
- It can accommodate tool shortages by substituting tools or techniques.

Manual or hand deburring involves many approaches and an estimated 10,000 tools are commercially available to assist in this process. As discussed elsewhere, there are 19 basic types of hand deburring tools and 60 sub-categories (Table 1). This variety of choices inevitably manifests itself in a similar variety of approaches by those performing the deburring. Each worker develops his or her own technique and favorite tools. As a result, prescribing detailed step-by-step approaches may not be feasible nor the most economical approach.

Figure 4 illustrates the ability of experienced hand deburring workers, each using his or her own approach to produce a burr-free edge with the minimum possible edge break. The groups of 25 workers maintained 0.003 inch (76.2 μ m) breaks or less on 92 percent of the edges of the simple parts in question. Unfortunately, of the 50 samples measured, 12 still had a small burr on them. Thus roughly 25 percent of the samples from the most experienced workers would not have been acceptable to inspection. Although the burrs left were minute and were found only on one small portion of an edge, they were present and could have caused problems in the mechanism of an assembled part.

Of the parts produced by the nine individuals generating the smallest edge breaks and leaving no burrs, essentially 100 percent of the edges had 0.003 inch breaks or less. The most skillful individual observed in this study had 97.7 percent of all his edges 0.001 inch (25.4 μ m) or smaller.

Figure 5 illustrates how burr thickness influences removal time. Washer-like parts with 0.005 inch (127.0 μ m) thick burrs took four times longer to remove than burrs 0.0015 inch (38.1 μ m) thick. Obviously, thinner burrs require considerably less deburring time.

Smaller holes frequently require more time to deburr than larger holes (Figure 6). More time is spent scrutinizing under a microscope when deburring small holes. In addition, most deburring tools are designed for 0.125 inch (3.175 mm) diameter holes rather than smaller sizes.

Figure 7 illustrates a part having four small holes breaking into a larger one. The time required to deburr the intersections depends on the diameter of the large cross hole. When the large hole was 0.5 inch (12.7 mm) in diameter, a 6061-T6 aluminum part (Figure 8) required less than 3 minutes to deburr. When the

Table 1. Categories of Hand Deburring Tools

Categories	Tools
Abrasive Filled Rubber Products	Bullets Cups Cylinders Dental Bullets Discs Flat Bars
Abrasive Paper Products	Cord Discs Rolls Sheets
Abrasive Stones	Bars Cones Points Triangles
Brushes	Cross Hole Deburring End and Cup Wheel
Bur Balls, Burs, Rotary Files	Bur Balls Burs Rotary Files
Countersink Tools	Aircraft Piloted Deburr Tools Conventional Countersinks
Felt Bobs	Bullets Cylinders Discs
Files	Curved or Bent Half Round Large Miniature Round (rattail) Triangular
Knives	Oval Scalpel Blades Special Shapes Triangular
Lapping Compounds	
Mandrels for Tools	

Table 1 Continued. Categories of Hand Deburring Tools

Categories	Tools
Miscellaneous Tools	Back Side Cutters Special Design Tools Swivel Blade Tools Vacuum Probes
Motorized Tools	Air Motors Belt Sanders Bench Motors Dental Tools Jitterbug Sanders Reciprocating Files
Mounted Points	Balls Cones Cylinders Discs Special Shapes
Pin Vises	Collet Dog Nose
Scrapers	

horizontal hole was 0.062 inch (1.57 mm) deburring took 11 minutes. Unfortunately, with a very small cross hole, providing a nice smooth blend at hole intersections by hand deburring is not possible. As a result, more time on such difficult features is required and also deburring quality worsens.

Despite the many limitations of manual or hand deburring, it frequently is the most economical process or at least could be if appropriate tools were available and edge requirements were well defined. As in the case of all deburring processes, effective use of this process requires a careful evaluation of economics and individual deburring steps.

OTHER DEBURRING PROCESSES

This series of lessons has briefly described the characteristics of the 14 most widely used deburring processes. Many other processes and variations of these processes exist. As seen in Figure 9, thirty-seven processes have been used. Some of these involve the addition of chemicals or electrolytic action to standard processes. Several work well in a very narrow range of

Figure 4. Percent of Edges Having an Edge Break Smaller Than a Specified Value

Figure 5. Effect of Burr Thickness on Hand Deburring Time

applications. Some are so new that their true capabilities are not yet known.

It is important in most manufacturing environments to know that the best process has been selected before it has been installed. Because of this the reader is encouraged to review Deburring Capabilities and Limitations and Advances in Deburring for background material on these lesser used processes.

Lesson 1 provided several tables of comparative performance of the deburring processes. Table 2 and 3 of this chapter provide two additional views of comparative performance. Table 2 defines the general applications that the major processes can accommodate. Table 3 summarizes some of the process side effects and typical cycle times.

Figure 6. Effect of Hole Size on Deburring Time

APPROACHES TO MINIMIZING DEBURRING COSTS

Throughout these 10 lessons the emphasis has been that deburring is only part of the problem of reducing or maintaining deburring costs. The reduction of deburring costs involves several techniques, for example:

- Preventing burrs from forming;
- Minimizing the size of burrs;
- Putting burrs in easier to remove locations;
- Designing parts to facilitate deburring;
- Minimizing cost by approaching burr problems on a plant-wide basis; and
- Finding more appropriate deburring processes or equipment.

In this approach in addition it is necessary to:

Figure 7. Geometry of Intersecting Hole Specimen

- Develop in-house standards on burrs;
- Develop in-house standards on deburring processes;
- Educate the people within the plant on burr-related facts;
- Experiment to verify that the published approaches do in fact minimize the problems; and
- Document observations.

In reviewing the ten lesson titles in this manual it is apparent that half of the lessons are concerned with the basic problems of the burr as opposed to the removal of the burr. The reason for this is that THE BURR IS THE PROBLEM, NOT DEBURRING.

Figure 8. Effect of Cross-Hole Diameter on Deburring Time

In analyzing specific situations one has to analyze why deburring is required and determine whether or not the existing reasons are valid. One will have to consider whether or not a job shop deburring facility can remove burrs cheaper than an in-house facility. One must consider whether or not changes in feedrates and speeds will make smaller, more easily removed burrs.

Figure 9. Principal Deburring Processes and Mechanisms

The basic approaches to minimizing burr-related costs all have one common facet--they require careful consideration of facts and actual requirements. In addition they require following the four cardinal rules:

- If you don't make a burr, you don't have to remove it.
- Every conventional machining operation produces some burr.
- If you don't have to remove the burr, don't.
- The machining conditions affect the deburring costs.

Table 2. General Comparison Between Deburring Processes

Process	Generally Applicable To						
	External Edges	Intersecting Holes	Large Parts	Hand Size Parts	Miniature Parts	Hard-to-Reach Areas	Low Cost Parts
Barrel	x	-	s	x	x	-	x
Centrifugal Barrel	x	-	s	x	x	-	x
Vibratory	x	-	s	x	s	-	x
Spindle Finishing	x	-	-	x	-	-	s
Orboresonant	x	-	x	x	-	-	-
Electropolish	x	x	x	x	x	x	x
Electrochemical	x	x	x	x	x	x	-
Mechanized Mechanical	x	s	x	x	-	-	-
Abrasive Jet	x	s	x	x	x	s	s
Abrasive Flow	x	x	s	x	s	s	-
Water Jet	x	-	x	x	-	-	-
TEM	x	x	-	x	x	x	x
Chemical	x	x	x	x	x	x	x
Ultrasonic	x	-	-	x	x	-	-
Manual	x	x	x	x	x	x	-

x = applicable

- = not generally applicable

s = applicable in some cases

Table 3. Comparison of Deburring Process Side Effects and Cycle Times

Deburring Process*	Side Effects	Cycle Time	
		Per Part (Min.)	Per Lot (Min.)
Abrasive Flow	Polishing	2	
Abrasive Jet	Matte Finish	1 to 5	
Barrel Tumbling	Residual Stress Changes and Some Material Impregnation		120 to 480
Brushing	Polishing	1 to 5	
Centrifugal Barrel Finishing	Produces Large Residual Compressive Stresses		5 to 20
Chemical	Polishing, Brightening		5 to 30
Chemical Vibratory			10 to 20
Chlorine Gas	Polishing		
Electrochemical	Stray Etching	1	
Electrochemical Brush			
Electrochemical Vibratory			1 to 60
Electropolish	Possible Pitting and Streaking		1 to 10
Hand		1 to 20	
Liquid Hone		1 to 5	
Magnetic Loose-Abrasive	Covers Part with Film of Media		30 to 120
Mechanized Mechanical		1	
Plasma			
Sanding		1 to 5	
Spindle Finishing		1 to 5	
Thermal Energy	Covers Part with Oxide Film		0.1 to 1
Torch or Flame			

Table 3 Continued. Comparison of Deburring Process Side Effects and Cycle Times

Deburring Process*	Side Effects	Cycle Time	
		Per Part (Min.)	Per Lot (Min.)
Ultrasonic	Polishing, Brightening		5 to 10
Vibratory	Residual Stress Changes and Some Material Impregnation		120
Water Jet	None	1	

*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.

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DEBURRING: TECHNICAL CAPABILITIES AND COST-EFFECTIVE APPROACHES, LESSONS 9 AND 10, L. K. Gillespie, June 1980.

This ten lesson text on deburring is designed to provide engineers and production supervisors with an overall understanding of deburring economics and current capabilities. The material included describes economics, side effects, process selection techniques, product design influences, standards, plant-wide approaches, burr formation, and prevention. Deburring methods described include barrel, centrifugal barrel, vibratory, spindle, manual, electrochemical, electropolish,

SPECIAL PROJECTS: Deburring

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