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Progress in the Battle With the Burr

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PROGRESS IN THE BATTLE WITH THE BURR

BURRS

DEBURRING

STANDARDS

BURR MEASUREMENT

BURR PREVENTION

BURR FORMATION

INSPECTION

TRAINING

by

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ABSTRACT

Although U.S. industry still spends more for removing burrs than it needs to, significant improvements in deburring are developing. Standards for burrs are now in reasonably common use at many companies. The mechanisms by which burrs form and by which one can predict their properties have been documented, and some de-deburring economics have been described. Advances in a number of processes have emerged within the past two years, and the entire subject of deburring has been receiving greater emphasis in most high-technology countries than before.

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ABSTRACT

Although U.S. industry still spends more for removing burrs than it needs to, significant improvements in deburring are developing. Standards for burrs are now in reasonably common use at many companies. The mechanisms by which burrs form and by which one can predict their properties have been documented, and some de-deburring economics have been described. Advances in a number of processes have emerged within the past two years, and the entire subject of deburring has been receiving greater emphasis in most high-technology countries than before.

INTRODUCTION

In 1974 the Society of Manufacturing Engineers held its first international conference on deburring. That meeting represented the first major attempt to focus international attention on this long-overlooked subject. Since that time, largely as a result of the effort of the Society of Manufacturing Engineers, deburring has become a common topic in many magazines, conferences, and meetings. Although the subject lacks full documentation, the public at least has acknowledged that deburring is an appropriate topic at almost any conference that considers manufacturability improvement. As a result of, or with the assistance of SME, projects have begun or continued in Japan, Germany, Denmark, India, and Canada. The widespread emphasis in this country has paralleled similar efforts by individuals in Japan and West Germany.

Burrs and their removal encompass several related but frequently overlooked areas. These include

- Edge finishing;
- Corner finishing;
- Surface finishing;
- Cleaning;
- Product design:
- Product standards;
- Inspection;
- Machining;
- Casting;
- Welding;
- Plating;
- Economics;
- Training; and
- Management.

The list is not complete, but is at least representative of the interrelationships to be considered in improving deburring and edge finishing processes. The original SME task force on deburring entitled "The Burr Technology Division of SME," increased awareness that other closely allied areas had not received appropriate attention. This awareness brought about creation of a more comprehensive scope, and this group is now entitled "SME Burr, Edge and Surface Condition Technology Division."

Product Design as It Relates to Burrs and Deburring

As many practicing engineers have observed, the mere shape of a part in many instances makes a dramatic effect on burr size and difficulty of removal. As indicated in Advances in Deburring,[1] it is possible in some situations to alter slightly the design of the workpiece to capitalize on some of these geometry effects. Although some of these effects have been documented for several years, the design areas of industry have shown little recognition that they are aware of these possibilities. In many instances, by using these approaches, it is possible to reduce deburring costs by as much as 50 percent of the costs of conventional approaches.

Burr-Related Standards

A problem in establishing industry-wide standards for burrs or deburring is the tremendously wide variety of part usage and design. However, some industries have common edge requirements. These include

- Automotive glass;
- Technical ceramic;
- Cutting tools;
- Ceramic wafers (for integrated circuits);
- Printed circuit boards;
- Hydraulics;
- Pneumatics;
- Aircraft frame components; and
- Aircraft engine components.

In discussing standards it is important to recognize the reasons that burrs must be removed or that certain edge qualities must be provided. Some of these reasons are to

- Prevent cut hands;
- Prevent mechanisms from jamming;
- Prevent interference of mating parts;
- Prevent scoring of mating parts;
- Minimize friction;
- Reduce wear on mating parts;
- Prevent electrical short circuits from loose burrs;

- Prevent cut wires from sharp burrs;
- Minimize possibility of high voltage breakdown of dielectrics;
- Provide uniform electrical/magnetic fields;
- Minimize the detuning of microwave vacuum tubes;
- Prevent metal contamination in aerospace assemblies;
- Prevent miniature filters from being blockes by loose burrs;
- Help assure that rubber seals are not cut;
- Eliminate stress concentrations;
- Prevent plating buildup on edges;

Standards encompass national standards, industry standards, in-plant standards, interplant standards, and standards on individual products and on nomenclature. As indicated elsewhere, several national standards relate to such deburring products as blasting or tumbling media.[1] In addition to those mentioned in those publications, the United States Department of Commerce Handbook H28, which defines screw standards, contains some isolated comments about the burr or shape of the first threads on threaded features.[2] A long burr is formed at some of these thread starts and must be removed for any thread to operate properly. ASTM Standard D2967 represents a national standard for which to evaluate edge coverage of coating powders.[3]

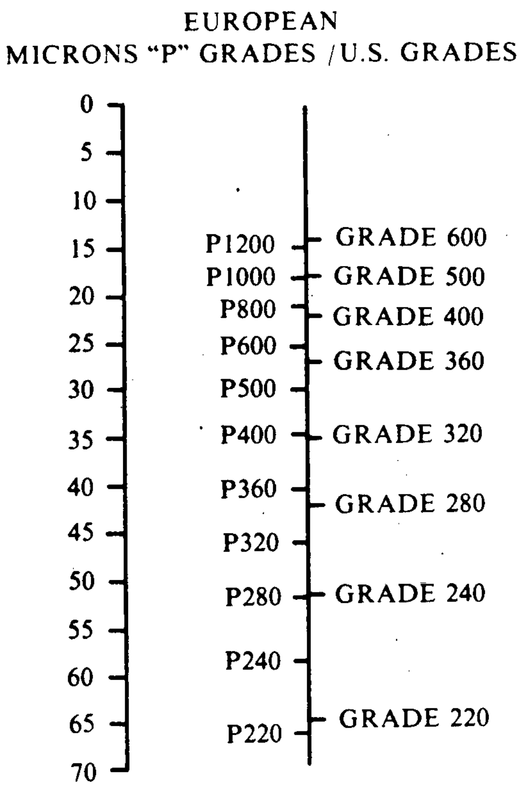
The American Metal Stamping Association has published standards about burr size or burr conditions on stamped products.[4-6] The Washer Division of the American Metal Stamping Association has its own standard for burrs and edge conditions on washers.[6]

Standards for the screw machine industry have been previously discussed.[1] Underwriter's Laboratories and the Consumer Product Safety Commission have issued several industry standards or related reports on edge requirements for safety.[7-10]

The subject of national standards or industry-wide standards frequently challenges the necessity of having such standards. A recent newspaper article, however, has shown that a need exists in such inconspicuous items as heating register covers and children's toys. The Consumer Product Safety Commission began an investigation in 1978 of heat register louvers. They found that the burrs left on these louvers in many cases were sharp and made such severe cuts that reconstructive or plastic surgery was required on children's fingers, toes, and feet.[11] As a result, such products most likely will have to be mandatorily free of burrs and sharp edges in the future.

With the growing emphasis on metric classification and increased trade with metric countries, recognizing that European abrasive media size standards do not match U.S. size standards is important. As shown in Table 1, abrasives coarser than 220 grit may differ significantly from U.S.-produced materials.[12]

Table 1. Comparison of Median Particle Sizes*



*Reproduced courtesy of Machine and Tool Blue Book.

In-plant Standards

The need for in-plant standards for burrs and edge quality is based upon recognition that statements such as "parts shall be free from burrs" are not adequate to define the actual part requirement. Not only are these statements inadequate, but they are economically undesirable.

Currently, every company has its own approach to this problem. In some cases, a single standard is sufficient; in others, several standards are required within a single plant to give adequate coverage. The following general approach may be adequate for some plants, but the general approach overlooks the need for more thorough discussions of threads, hole intersections, raised metal, and other attributes. As indicated, separate documents define exactly what is required, not only of edges but of surface appearance in general.

> "A burr is defined as plasticly deformed material produced by a chip-producing process. It can be a sharp ragged projection, it can be firmly adhered or loose-hanging projections, or it can be a small swell of raised material.
>
> None of the above conditions is allowable. If workmanship specification 9900000 is a drawing requirement, these conditions must not be visible under 4X magnification. If workmanship specification SS 331834 is specified, these conditions must not be visible under 10X magnification. If workmanship specification SS 290029 is specified, these conditions must not be visible under 20X magnification. Individual parts may have specific drawing notes, illustrating magnifications other than indicated here. The drawing notes take precedence.
>
> Sharp edges are not permitted. For reference purposes, a radius of 0.0005 inch or less shall be considered sharp."

Standards representing general requirements for the plant or specific requirements for a family of parts are in themselves also, frequently not the <u>total</u> answer. In some instances, product drawings need specific deburring notes for clarity. As an example, this note may be appropriate for the part in Figure 1:

> Firmly adhered or swelled metal is permissible in the area of the milled flats mismatch, provided it does not extend outside the major diameter of the part. Adherence of metal is to be verified by a 0.020 to 0.022 inch-diameter wire with a free length of 0.75 to 1.00 inch. If this probe does not produce a metal fragment, the burrs shall be considered firmly adhered.

A dearth of published information exists for in-plant deburring standards. Five specific standards used by individual companies are in the Appendix to this report, and the reader is encouraged to obtain References 13, 14, and 15 for additional examples.

The one aspect missing from each of these standards is that written words do not contain actual examples of quality desired. Although such examples are difficult at times to depict photographically, they are at least definable by some form of graphic representation. Visual standards have been used in a variety of

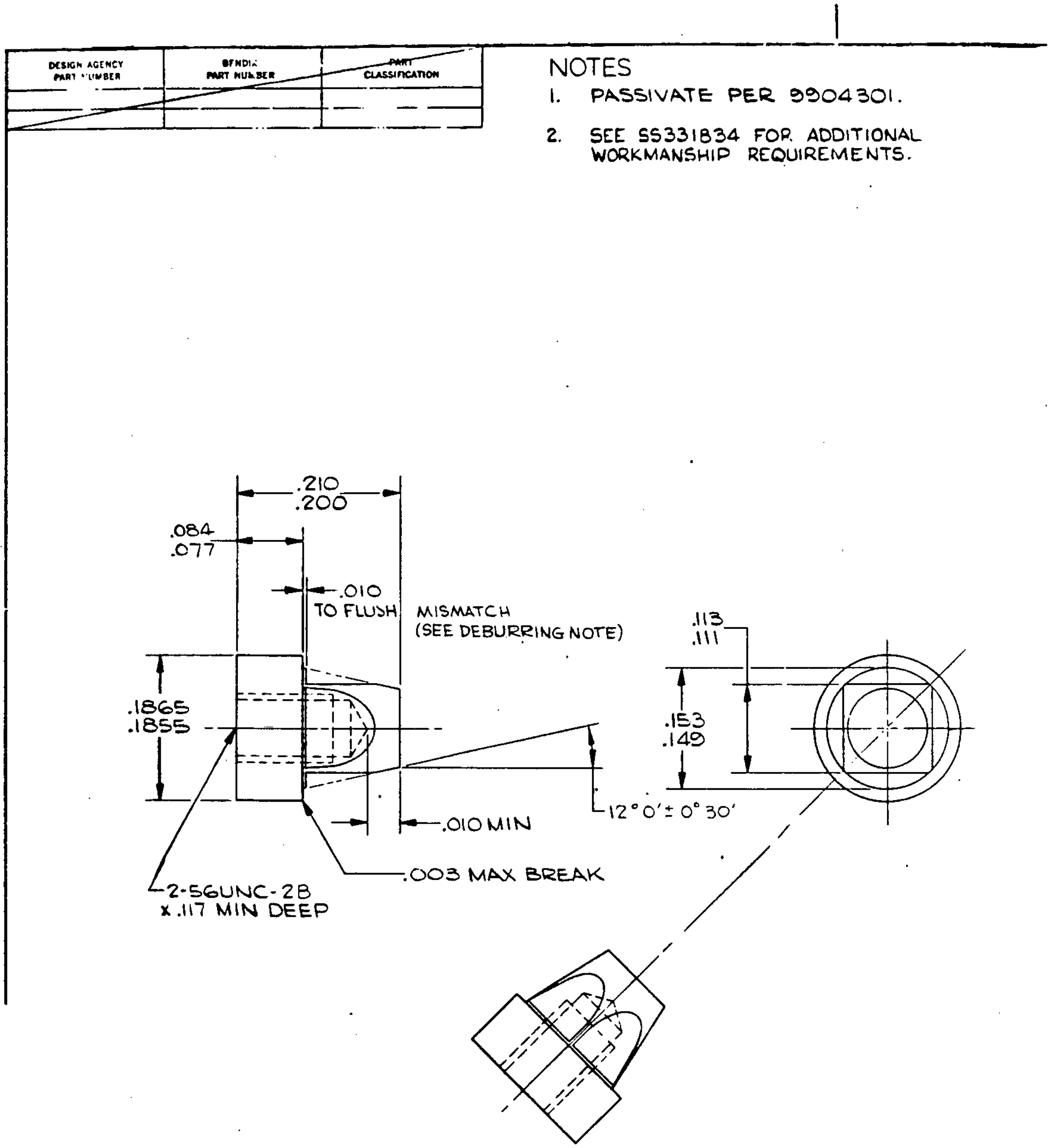


Figure 1. Part Requiring Special Burr Note

industries for other purposes, such as defining acceptable quality for soldering, drilled holes in laminated plastics, welding, sealants, or swaged terminals. Treatment of visual standards can be found in Machine Design.[16]

One reason that deburring quality is sometimes overspecified is that designers, or those is charge of manufacturing, do not recognize the options available to define various levels of quality. For example, for deburring threads, at least six factors are involved in delineating allowable deburring quality on threads, and a variety of levels are within each of these factors (Figure 2). A small booklet in which to show product engineers and others involved exactly the required levels of "burr-free" or smoothing is helpful. Use of such illustrations, combined with tabled time standards, allows ready identification of the economic benefit of choosing a less-demanding edge quality.

Maintaining work measurement standards with the variety of conditions obtainable in deburring is sometimes difficult. However, by using a formal computerized standard system, overnight generation of new time standards as a result of varying burr conditions is possible.[17]

Standards for Intercompany Use

In many instances, communication problems happen more often among companies than within an individual company. Small job shops in particular suffer from these problems when they manufacture parts for different companies. Especially useful in such situations is a printed piece that defines that company's policy, or the joint policy of the two companies, in establishing their related quality levels. The handout shown in Figures 3 and 4 provides the discussion focal point that both parties can use. Sometimes the vendor or subcontractor need only circle the alphanumeric entities appropriate to individual parts or groups of parts. As demonstrated in these Figures, required are

- Statement of edge quality requirements;
- Definition of what burrs are; and
- Definition of what constitutes sharpness.

Exceptions to these general standards would be defined on individual drawings. An alternative is to publish a booklet describing in detail burr-related expectations.[18,19]

To indicate ways to deburr parts in-plant, brief notes are useful, such as those in Figure 5, or more detailed information that includes illustrations like those in Figure 6. Other approaches are in the two Society of Manufacturing Engineers deburring texts.[1,20]

One company's very simple approach for deburring commercial parts entails painting entire scrap parts white and then color-coding each feature to be deburred. A different color code indicates a different type of deburring tool. As an example, in Figure 7, the first step would be to flat-sand the surface around hole number 1 and then use an MX wheel in an air motor. The color-code sequence also indicates the work sequence. The color band closest to the edge indicates the first operation to be done, and that farthest from the edge indicates the last operation. This

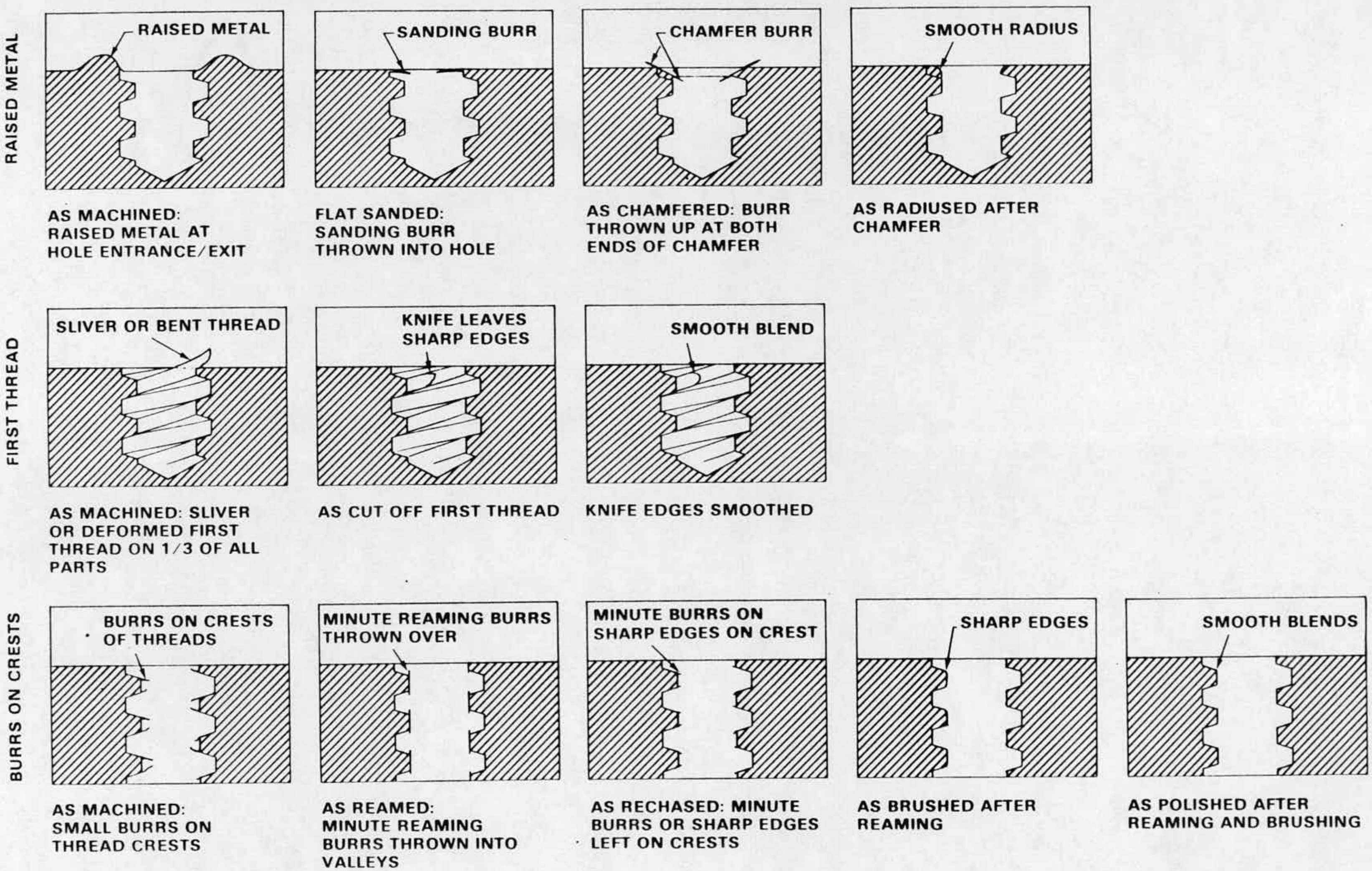


Figure 2. Various Levels of Possible Thread Quality

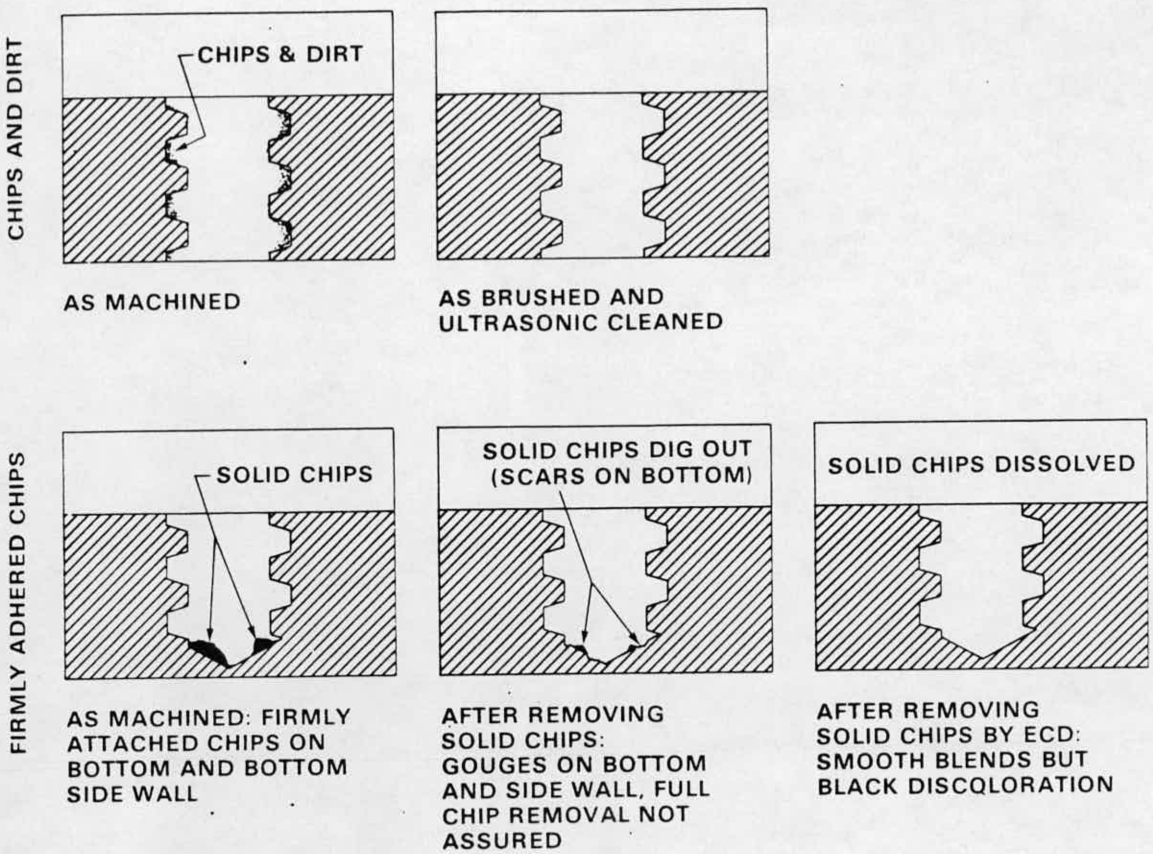


Figure 2 Continued. Levels of Possible Thread Quality

technique does not indicate the required edge break, or the exact tool to use, but it represents a color-coded scheme to which a new worker can quickly refer when he has doubts. This approach is advantageous because it requires no paperwork, but it does require a storage facility to store all the sample parts.

STANDARD NOMENCLATURE

Though industry still has no standard nomenclature for burrs, at least an extensive series of recommendations has been listed in Advances in Deburring and elsewhere.[1,21] Noteworthy, however, is that use of the word "burr", because it still implies different objects to many individuals. To some individuals to burr means the sharp metal edge typically ascribed to it. To others, the word defines the tool used to remove this sharp edge. To still others, burr defines a washer; to others, it defines a threaded nut. One company in the ceramic industry uses the word "burr" to

Standard Definition of One Company's Allowable Edge Conditions

Category Number	
1	Deburring not required
2	Remove all loose particles
3	Dull all edges for handling safety
4	Burrs and raised material are allowable, provided they do not extend past part tolerance limits
5	Raised material is allowable, if it does not extend past tolerance limits and is not sharp
6	Burrs visible to the naked eye are not allowable, except as noted
7	Burrs not detected by a sharp No. 2 wooden pencil are allowable
8	Burrs or raised material visible at 4X magnification are not allowable, except as noted
9	Burrs or raised material visible at 7-10X magnification are not allowable, except as noted
10	Burrs or raised material visible at 20X magnification are not allowable, except as noted

Figure 3. Sample Handout to Designate General Level of Deburring Quality Required

indicate a bump in an otherwise smooth surface, as opposed to material left at an edge (Figure 8). Some definitions not defined in Advances in Deburring are listed in the Appendix of this report.

Within the dental industry, use of miniature carbide cutters is contained in standards designating them as a "bur." Many metal-working producers of such tools, in fact, use the same nomenclature to define these metal removal tools. Several companies, however, have not drawn such a distinction, and their literature uses the word "burr" to define a tool used to remove a burr. In many instances, the distinction is not significant, but in others it is confusing, especially in Communications with other companies to describe the necessary activities to remove the burr. It is appropriate that the metalworking industry at least consider standardizing the meaning of the word "bur" to represent a metal tool used to remove burrs and to blend surfaces.

Burrs are defined as

A. Any plastically deformed material at an edge generated by a chip-producing process. This includes non-sharp raised material.

B. Any loose or semi-loose material left on edges by a chip-producing process.

C. Any sharp raised material at an edge produced by a chip-producing process.

Sharpness is defined as

+ the ability to cut hands in normal handling.

- failures to pass the Underwriters' Laboratories sharp edge tester's test.

* edge breaks smaller than 0.01 inch.

--edge breaks smaller than 1/10th of the thickness of the part--i.e.; on a 0.005 inch-thick part, a sharp edge is any edge having a radius or chamfer smaller than 0.0005 inch.

EXAMPLE FOR USE OF THESE CODES

On part number 299971, the allowable edge conditions are your code number 5A, 0.015 inch maximum break. This defines for both you and your customer what he wants, what burrs and sharpness are defined to be, and what the maximum allowable edge break is. Exceptions to these allowable conditions would be stated by special callouts on the customer's part drawings.

Figure 4. Continuation of General Quality Level Handout

Inspecting for Burrs

Determining the presence of burrs is, in many cases, a relatively easy technique. Several pages have been published already on this subject.[1,20] In other cases, the presence of burrs is not so readily determinable because the relationships between burrs and existing standards are not explicit enough to provide adequate information. One approach to solving this is to establish an inspection standard, in contrast to a design or workmanship standard, such as this one:

> The following technique shall be used to verify that loose burrs are not present on edges:
>
> After ultrasonic cleaning to remove any loose chips or burrs, wipe a small diameter wire over burr-laden edges. If the wire breaks any metal from the burr without scratching the workpiece, loose burrs are present. If no metal particles are broken free, the burrs shall be judged as firmly adhered.

PRODUCTION TRAVELER

GUIDE, LONG RETAINER BAR

M. ACKMANN

93

262169-101
9A
8-27-74

Opr.	Dept.	Type of Opr.	Hrs/Part
50	93	Z902	3.175

Remove heavy burr in square hole and (2) counterbored holes in preparation for vibratory deburring. Brush polishing is not required.

REQUIREMENTS LIST:

Kit 48002259

Figure 5. Sample of Basic Production Routing Sheet Instructions to Those Who Do Deburring

> The wire used in this inspection shall consist of 0.022 inch-diameter steel spring wire (piano wire), projecting 3/4 to 1 inch from a holder. The end of this wire shall be approximately spherical to prevent scratching. The wire shall be drawn across the edge instead of pushed into the edge.

When sharp edges are not acceptable, use of a sharp edge tester developed by Underwriters' Laboratories now commercially available is possible.[22-25] This simple tool uses only adhesive-backed foam and teflon tape to detemine if part edges are sharp enough to cut hands. More than 2500 of these tools are currently in use.

A special micrometer has been used for measuring burr height in Germany for several years but is currently not available in the United States.[1,20,26,27] At least one company now manufactures an acoustical die monitor that detects wear on dies and can determine the noise generated when excessively large burrs are produced.[28] This is one of the few instruments available that detects burr sizes at the instant they are produced.

One company depends on water flow to determine burr existence on an edge. In this case, precision holes, which must be absolutely

Dept. 1360	SETUP AND WORKSHEET	Part: 6807
Date:	Sheet 1 of 2	No. of Seq.: 65, 30, 50, 70, 75, 80

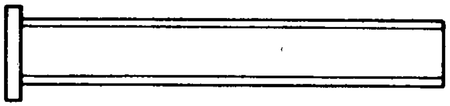
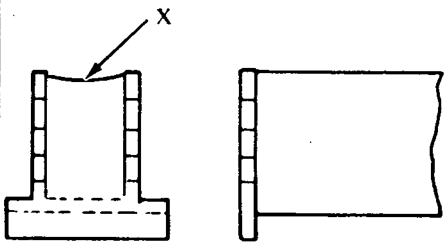
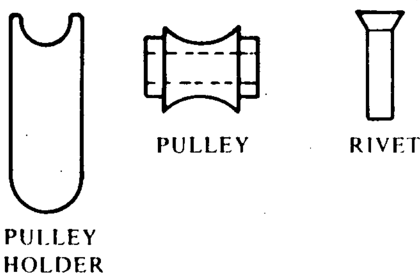
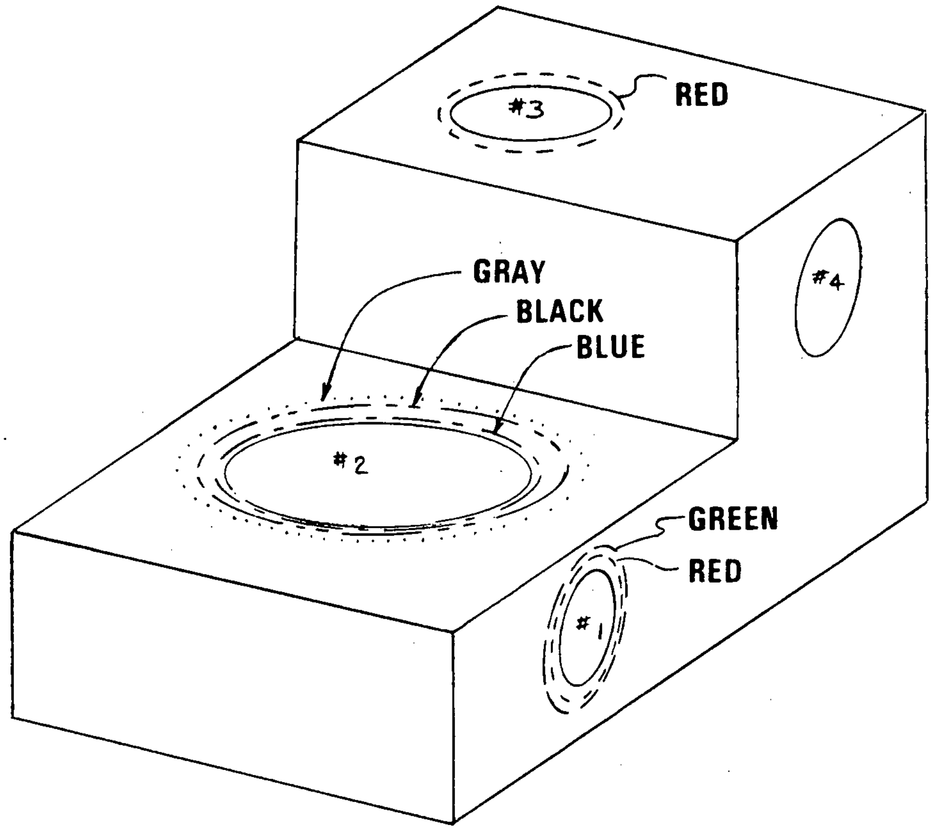
	Seq.	Work & Setup Description	Stat.	Tool and Tool No.	S. U.	Pcs./Hr.
	30	Apply whatever designated tool needed to straighten parts, if necessary. When using an arbor press, insert fiber strip into the channel. Shearblock has to be square to channel with ±0.003.	3-1	Spreaders. Fiber-strip mallet, arbor press.		30
	50	Remove all shearblock burrs on wire wheel. Hold edge to be deburred at a 45°-angle to wire wheel, and move part entire burr side. Attention: Do not put radius on shearblock area marked "X."	11-1	No tooling required.		120
	70	Put Pulley 6647 into channel with pulley holder (handmade). Drop rivet (#6648) into hole. Repeat same with second hole. Lay this assembly into fixture (I-4188), peen-end of rivet facing you and rivet flush with channel.	21-10	Riveting fixture I-4188. Riveting punch I-4188-1.		

Figure 6. Sample of Detailed Deburring Instructions

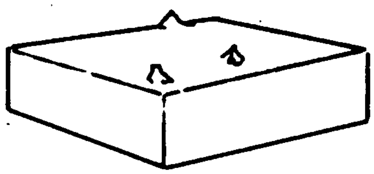


HOLE NO.	COLOR BAND	HAND DEBURRING APPROACH
1	RED	FLAT SAND
1	GREEN	MX WHEEL IN AIR MOTOR
2	BLUE	SWIVEL BLADE KNIFE
2	BLACK	TRIANGULAR KNIFE
2	GRAY	ABRASIVE-FILLED RUBBER IN MOTOR
3	RED	FLAT SAND
4	NONE	NONE

Figure 7. Example of Color-Coded Deburring Guide

burr-free, are mounted into a container and water is forced through those holes. Any burr on the hole will disrupt the fluid flow on the backside (Figure 9). Visual monitoring of the water path indicates whether burrs exist on the hole.

A related product is commercially available, and is used to determine coverage of shop peening.[29] In this situation, prior to shop peening, a sample part coated with a fluorescent tracer



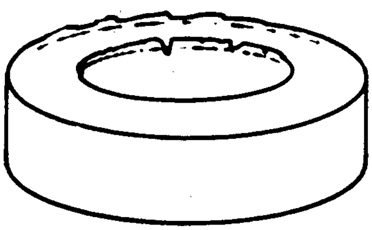


Figure 8. One Company's Definition of a Burr and Flash

die is removed by peening when 100 percent peening occurs. A part not totally contacted by blasting media will show small bits of white visible under an ultraviolet light. This may be of benefit, not only for inspection of a complete deburring coverage, but also for verification of surface quality. The approach also may be beneficial to determine the effectiveness of loose-abrasive finishing.

A recent reference indicates that General Motors uses automated laser inspection to check for burrs on threaded nuts.[30] Other references indicate that hypodermic needles are routinely inspected by laser beams to determine whether edge quality is adequate.[31-33] In this instance, the needle defracts the laser light in relation to the sharpness of the needle tip. Hooked or blunt tips or those with burrs are quickly detected. This system is reportedly capable of performing eight inspections a second. Studies are currently underway to determine whether such an approach would be able to measure the sharpness of razor blades or similarly sharp-edged components.[34] Measuring the sharpness of such components is at least a slow operation in high-speed productions and almost impossible in a number of parts because of geometry. References 35 and 36 describe some approaches to

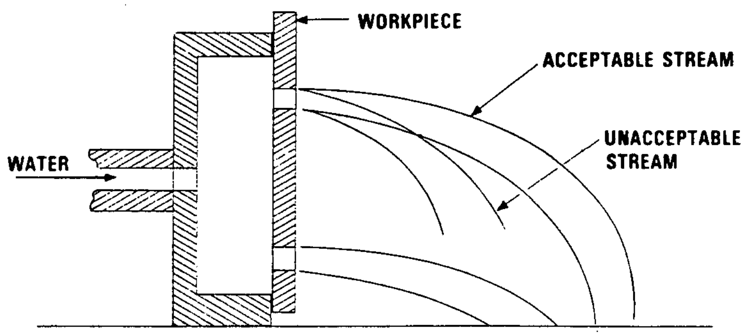


Figure 9. Burr on Hole Disrupts Fluid Flow

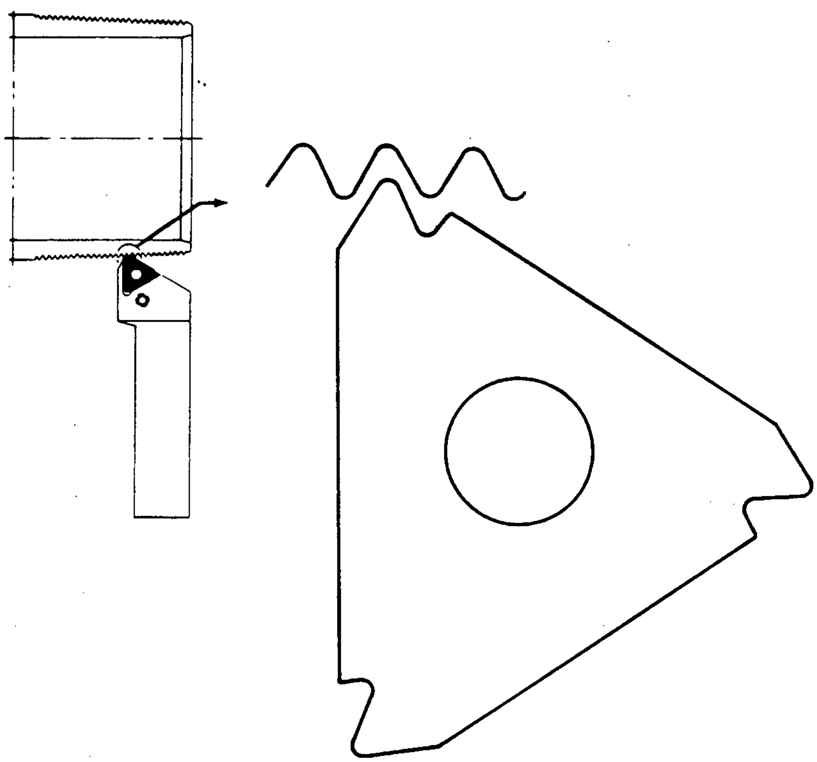


Figure 10. Threading Tool Wipes Off Burrs

measuring very small edge breaks and small radii. These references are appropriate for those who must maintain small breaks on precision parts.

As indicated elsewhere,[1] the testing and reporting of loose-abrasive finishing media wear are performed in different ways by media producers. The considerations in developing a significant standard for such tests have recently been reported.[37]

Burr Formation and Prevention

Within the past two years, few publications have discussed subjects of burr properties or techniques for predicting these properties. One exception is a paper on predicting the size of lathe operation cutoff burrs.[38] The paper presents two equations that can be used to predict the approximate size of the cutoff burr.

Other studies have included burrs produced in turning operations,[39,40] drilling,[41-44] and profile milling.[45] Phillip's 1000-page study provides burr-related information about such variables as type of material, feed, speed, drill, type, reamer type, torque, and thrust.[41] In addition, this is one of few reports that directly ties fatigue life to burrs and deburring procedures. The subject of burrs in drilling operations has been documented with over 20,000 measurements. Although studies of side milling and end milling burrs have been published previously,[46,47] Schafer's study is one of the most useful.[45]

Recent publications have dealt with ways to minimize the burr through tool design or some form of process control. The use of numerical control machining to remove burrs during a machining cycle is being explored by at least two companies. One of them indicated that retracing threaded configurations saved deburring time of 9 to 10 minutes for each part.[48]

In a related approach, some petroleum thread forms require a finished radius or otherwise topped thread crests. These are produced with A.P.I. carbide thread inserts, (form tool) which wipe off any burrs on the crest as they are formed (Figure 10).

Another author notes that the direction of grind on ceramic insert tools plays a major role in determining the life of such tools.[49] By implication, one also would assume that burr formation is more adequately controlled when one grinds the surface of these tools as shown in Figure 11. Yet another author has indicated that the use of black oxide on drills versus the as-ground drill surfaces can result in great reductions in thrust forces,[50] in some cases, four-to-one reductions. The high thrust force is often the reason for large drill exit burrs. Therefore,

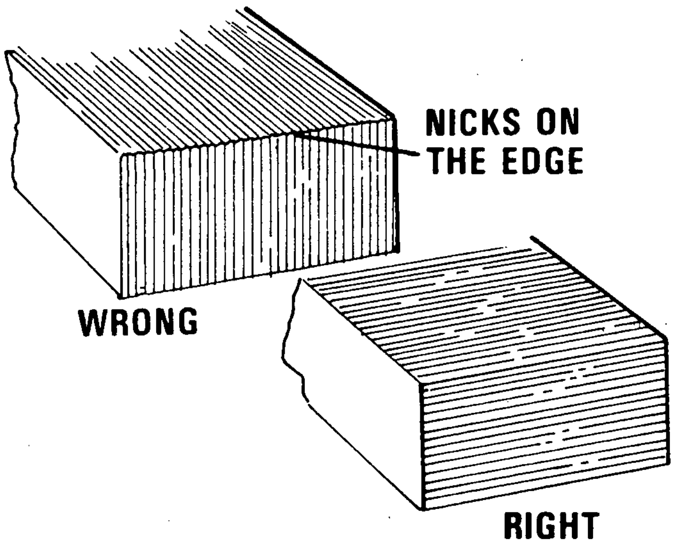


Figure 11. Grind Direction Affects Life of Cutting Tools

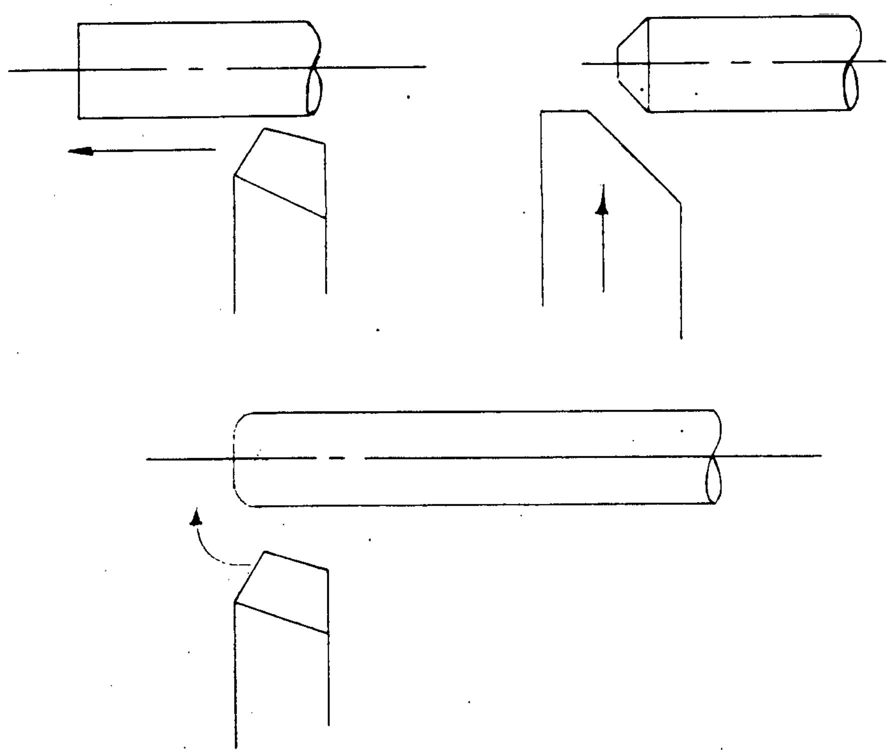


Figure 12. Programming Automatic Screw Machines to Generate Edge Breaks Rather Than Use Plunge Chamfer Tool

if black-oxided drills do, in fact, reduce thrust, the size of burrs produced should be significantly smaller than those produced with conventional as-ground tools.

Another author has illustrated his use of a piggy-back tool setup to chamfer tubes in the same operation in which they are cut off.[51] Although machines or tooling adapters are available to do this work, this person made a very simple adaption to an existing tool and achieved a significant savings.

Burr Prevention and Minimization

As indicated on the list, a variety of ways exist to minimize burrs, some more difficult to implement than others. As an example, many parts can be automatically deburred on an automatic screw machine if enough positions are available to provide a light chamfer on each edge. The alternative is for the screw machine tool to generate an edge break instead of a chamfer (Figure 12).

Approaches that minimize burrs are changes in

- Part shape;
- Tool geometry;
- Feedrates;
- Cutting velocities;
- Machining stiffness;
- Type of machining operation;
- Workpiece materials;
- Workpiece properties;
- Direction of cut; and
- Burr location.

Other approaches consist of minimizing cutting forces and the use of backup material and better fixturing.

One author indicates that burrs produced by flat broaching are very minimal on the exit side of the cut, provided the cut is above the center line of the diameter (Figure 13).[52] This, of course, is true of any machining operation. If the cut is performed above center line, the exit angle is larger than 90°. As the exit angle increases, burr size must decrease.[1] This is a geometry effect and not a process effect. Milling likely would similarly provide a minimal burr, if the principal cutting forces were directed along the same vector.

One manufacturer claims that the combination of a vibrating spindle and wheel oscillation on an automatic cutoff saw is responsible for the much smaller burrs produced in this machine than would be the case with conventional saws. Data in literature, however, are lacking on this subject.

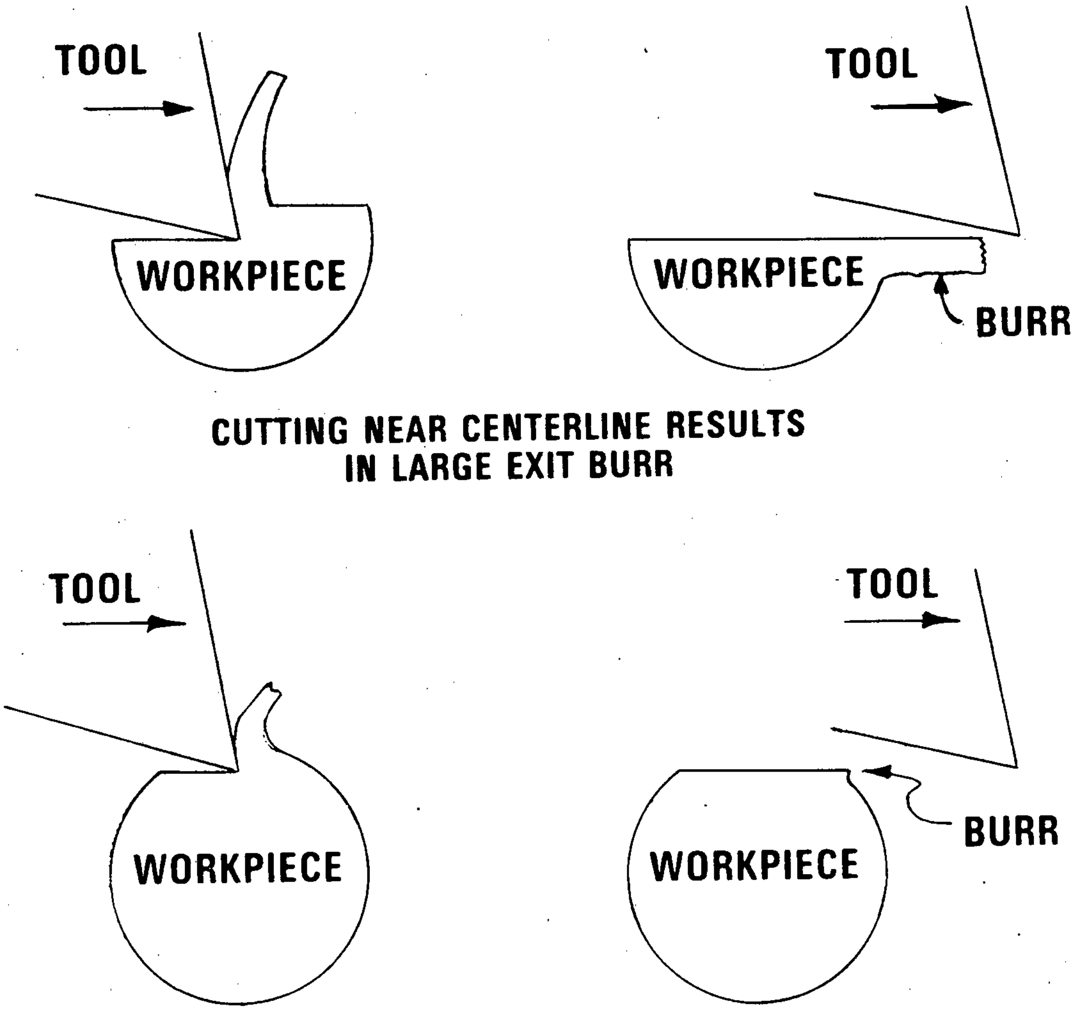


Figure 13. Exit Burr is Minimal, Provided the Cut Occurs Above Centerline

A basic contributor to the size of burrs is the ductility of the material in which they are produced. A very brittle material under normal conditions will not produce a large burr. Heat-treating all materials to control ductility is possible, but often is not feasible because of strength and machinability requirements.

Several innovations within the past few years, however, may offer a solution to this problem. In one instance, use of a mercury coating has hardened metal chips and made them easier to remove.[53,54] If in chip formation, the workpiece surface also is hardened, thereby reducing ductility, then use of this 'coolant' could be expected to reduce burr sizes.

In another instance, it has been shown that it is possible to heat-treat stripes in the metal by using high-frequency current.[55] These stripes can be as narrow as 0.060 inch and as short as one-half inch. Stripe depths of 0.016 inch to 0.024 inch have been produced in less than one-third of a second. This technique allows hardening in only a portion of the area in which the cutter will pass. If the portion at which the edge would be formed is in the middle of the stripe, only a small burr would likely result, because again ductility would be lower here (Figure 14). Salt bath nitriding is used for hardening workpiece surfaces.[56] Like many such hardening processes, by performing this operation after the burr forms on the part, it is possible to harden the burr so that many processes can easily remove it.

One author has noted that diamond-compacted cutting tools have at least one advantage to conventional steel or carbide tools. Aluminum frequently will weld to carbide inserts as they become dull. This produces burrs larger than, would be, if welding did not occur. Diamond tools tend to minimize this welding because of their fine surface finish and different material properties. To minimize burr formation, it is important on many materials to chamfer the exiting edge of the workpiece, approximately 45°, <u>before</u> the finished path is produced (Figure 15). This again provides the large exit angle, which minimizes burrs.[57]

Very high end mill velocities in aluminum have been reported to minimize the size of the burrs produced. However, other researchers have indicated that high speed <u>alone</u> does not necessarily reduce burr size, at least for the ranges studied to date.

Research on burr-free slitting and punching is being done in Japan and Germany.[58-63] Material is partially punched in one direction, the punch is retracted and the slug is pushed out in the opposite direction. As shown in Figure 16, this minimizes the size of burrs produced. Although this work has been reported in various stages for several years, the equipment to accomplish the work has existed for a short time and is not available throughout the world.

Battelle-Geneva researchers are attempting to develop a cutting tool whose wear pattern is such that as the tool wears, it still presents a sharp cutting edge.[64]

As researchers have previously indicated,[1,20] processes such as electrochemical grinding can leave burr-free edges. These edges not only have no burrs but in this case have a small edge radius, as indicated in Table 2 and Figure 17.

Currently, control systems are being developed for die casting use that control the speed and impact pressure of the initial

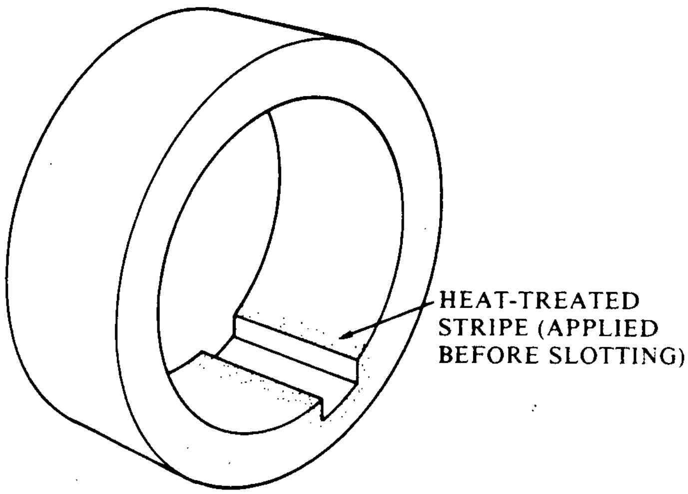


Figure 14. Heat-Treated Stripe Placement Relative to Subsequent Slotting Operation

charge. Use of such systems reportedly dramatically reduces the flash on the workpiece so produced.[65] Several other articles also describe advances in die casting or forging.[66-70]

The presence of burrs is not always an undesirable factor. The U.S. Navy, for example, recently needed perforated deck material for a non-skid surface and drainage holes. In this instance, punched 3/4 inch diameter holes with burrs left on them projected 1/16 of an inch above the surface of the part.[71] On some miniature parts, burrs are desirable, if they are formed in the proper direction, because they act as fill metal.

Deburring Processes

With few exceptions, few publications in the past two years describe capabilities and limitations of any major deburring process.

Electropolishing

An in-depth analysis of electropolish action and electropolish deburring was published in 1978, based on work performed at the University of Stuttgart Institute for Production and Automation.[72] This report represents an extensive analysis of action in the electrolytic tank and its effects on part shapes and burr size.

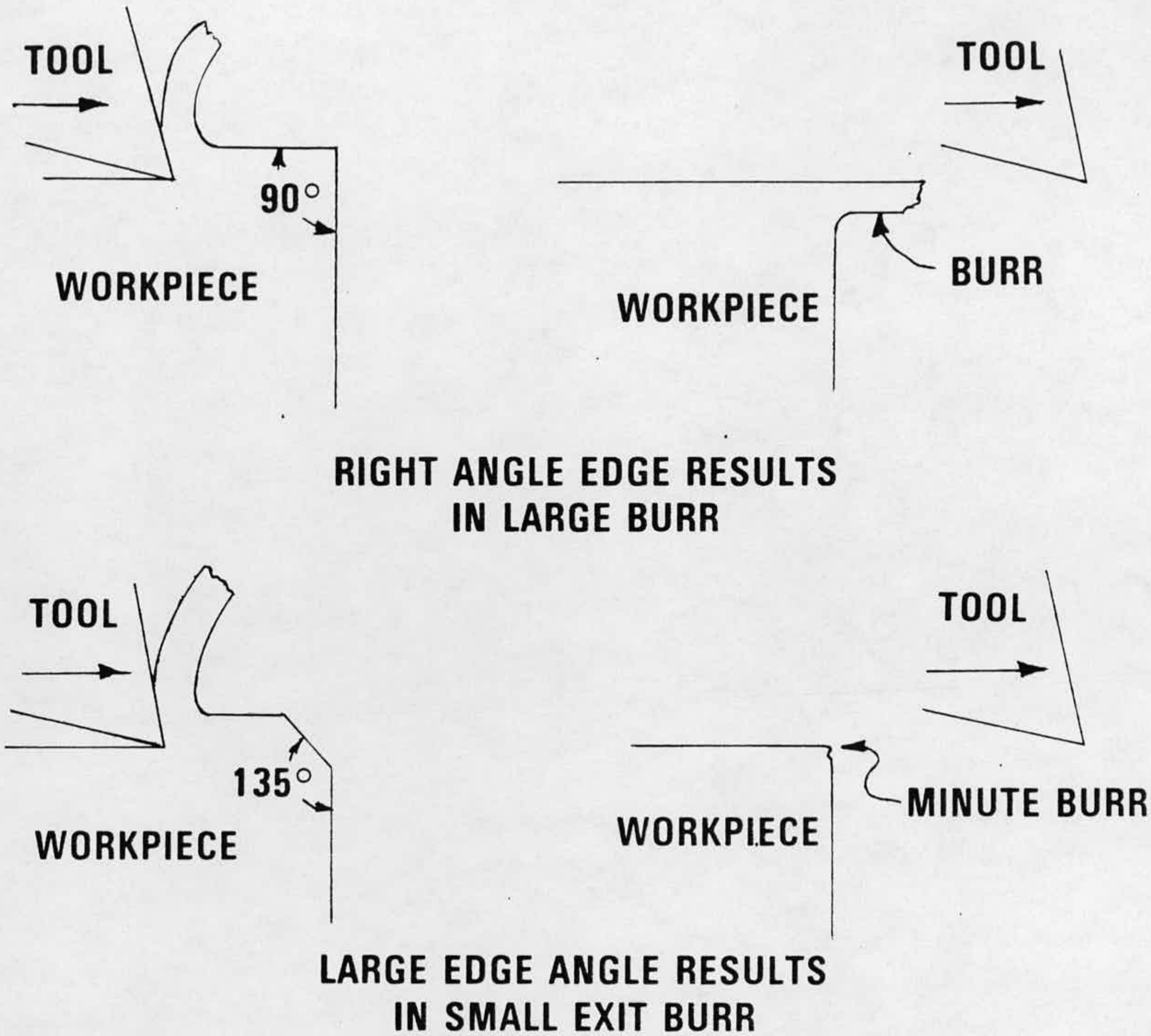


Figure 15. Chamfer Before Cutting Minimizes Burr Size

Magnetic Abrasive Finishing

Another exception to the lack of published information about deburring processes is publication of several references on magnetic abrasive finishing.[73-76] Most of this research has been published in Russia, and some German work is also available.

Robots

Within the last five years, the use of robots in metal-finishing applications has increased throughout the world. Robots now assist with the deflashing of die-cast parts, and they are beginning to do the chamfering of noncritical large components.[77-81]

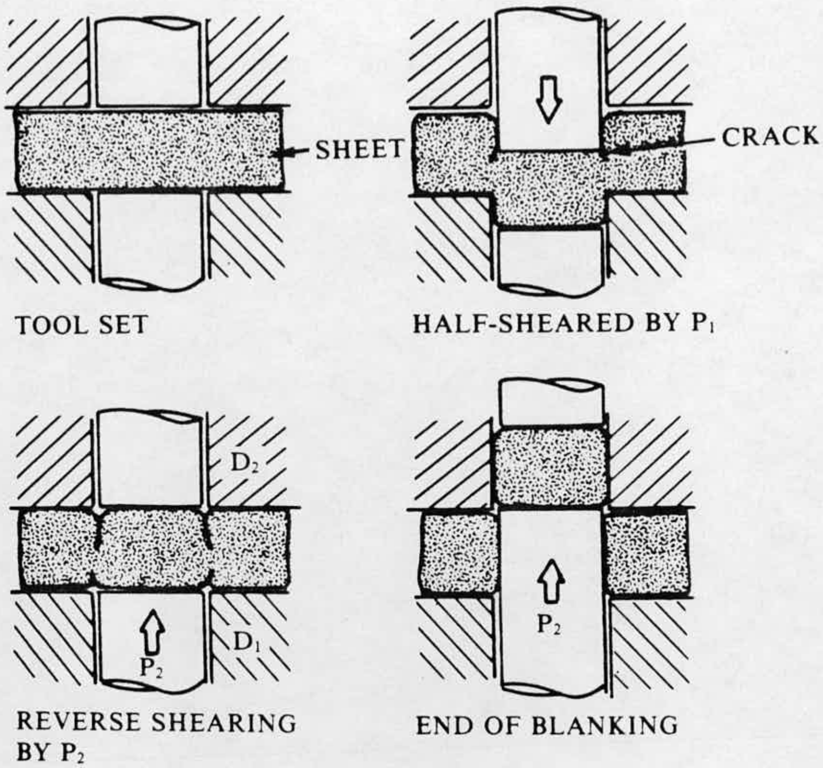


Figure 16. Burr-free Punching of Materials

Current literature indicates that the accuracy of robot actions can be as precise as +0.002 inch, although most cannot hold an accuracy greater than 0.008 inch.

Miscellaneous Processes

One author notes that ballizing can be an effective deburring process to remove burrs from a single hole drilled from opposite ends (Figure 18).[82]

The thermal energy method of deburring has increased its number of applications and is frequently cited in the literature.[83-87] Similarly, the use of certain non-woven abrasive products has received recognition for deburring capabilities in literature.[88-90]

Notable reports also have appeared recently on abrasive jet deburring,[91-92] abrasive flow deburring,[93-94] and loose-abrasive deburring processes.[35,95-104]

Equipment

Of many equipment innovations cited in literature, one of the most interesting is a portable low-cost vibratory deburring

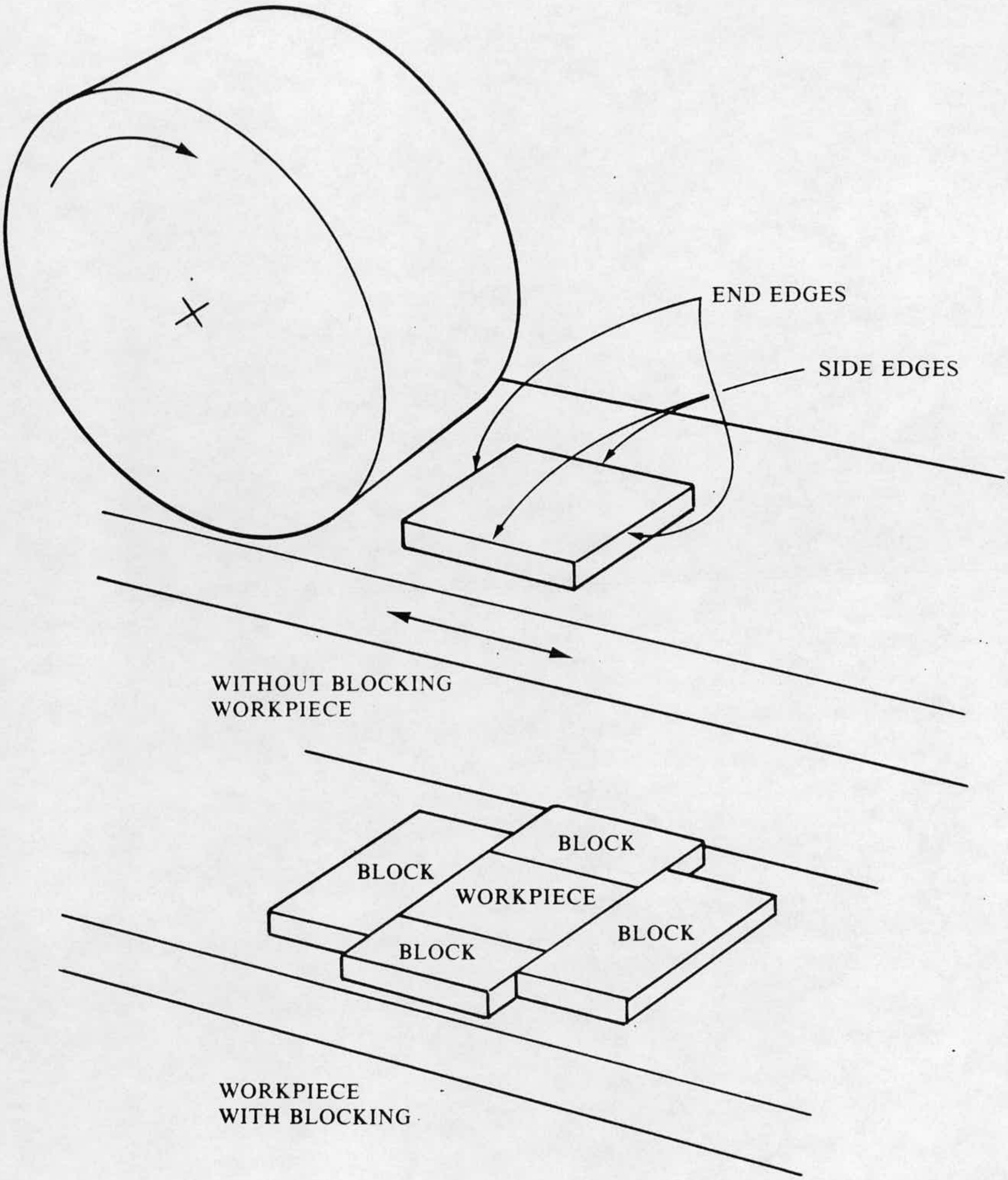


Figure 17. Edge Break From Electrochemical Grinding

Table 2. Edge Conditions Produced on Electrochemically Ground Specimen From Figure 17

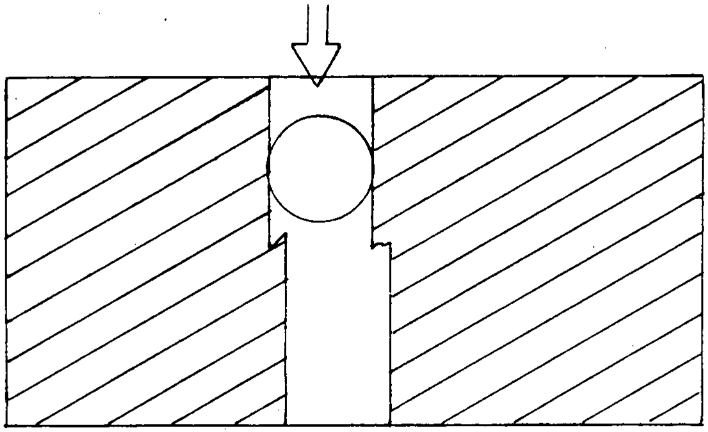
Material	Side Edge Radius (In.)	Ends
Aluminum	0.003, 0.004	0.003, 0.004
Aluminum	0.004, 0.004	0.002, 0.003
Aluminum	0.002, 0.003	0.002, 0.002
BeCu	0.004, 0.005	0.002, 0.002
BeCu	0.003, 0.004	0.002, 0.002
BeCu	0.004, 0.005	0.002, 0.002
17-4 ph SST (H900)	0.003, 0.003	0.002, 0.002
17-4 ph SST (H900)	0.002, 0.003	0.002, 0.002

Edge radii were measured from room temperature vulcanized molds of the specimen. These molds typically measure 0.0013 smaller than actual measurements of edges that have been cross sectioned and mounted in metallurgical mounts. The radii on the sides probably could be kept smaller by blocking the speciman with other specimens. The specimens in this study were 6 inches long and 1 in. wide. The grinding wheel was 2 inches wide.

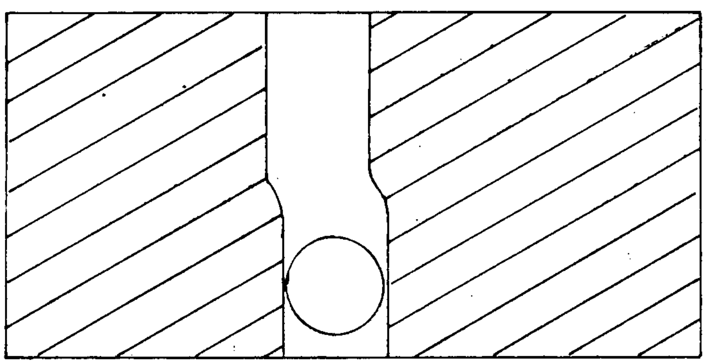
machine. This small machine can be physically rolled to any place in the plant to do deburring. Another new machine combines vibratory and centrifical action in a machine not totally unlike a conventional vibratory machine.[99] This device reportedly is up to 30 times faster than conventional vibratory machines. Another company has introduced an orbiting unit which reportedly reduced deburring time below vibratory levels.[105] Another small machine automatically removes cutoff burrs left in lathe operations.[106] This machine reportedly can remove up to 1500 cutoff burrs an hour.

Another manufacturer has a portable metal finishing machine which will chamfer outside edges, faces and deburr many small parts of heavy or light steel or cast iron.[107] This machine basically consists of a sander but is actually a workbench designed for finishing a small part.

An important trend recently is an increase in the number of companies manufacturing or representing new vibratory deburring machines. At one time, 17 such companies could be counted; at



BURRS AT HOLE MIDPOINT CAUSED BY DRILLING FROM BOTH ENDS



HOLE AFTER BALLIZING IS FREE OF BURRS AND LOOSE METAL

Figure 18. Ballizing to Deburr Mismatched Hole Intersections

the present time at least 20 different companies are known to manufacture or to be national distributors of vibratory deburring equipment.

A second observed trend is the many foreign-design machines currently sold within the U.S. These include gear-tooth chamfering machines, miniature automatic sanders for very small flat parts, loose-abrasive finishing machines, electrochemical deburring machines, and hand-held air motors. This trend has become very evident within the last two years and appears to continue.

Job shops offering sophisticated high-technology deburring processes are now appearing. In many cases, this technology eliminates the need for small companies to incur high equipment costs or to provide appropriately trained operators.

Among the hand tools introduced within the past two years are diamond and cubic boron nitride-coated abrasive strips and discs, diamond-plated files or rotary burrs, and a variety of similar miniature hand-held or motorized tools. Ultraminiature blasting machines are also available to use on fine cleaning, deburring and oxide removal. These are hand-held units selling for less than $100. One manufacturer of tool room lathes produces a standard burring chuck to deburr cylindrical parts on the lathe.

To further encourage purchase of deburring equipment, some companies have initiated an equipment leasing program.

Within the past year, a number of advertisements have appeared from companies to extend the life of metal files. It is interesting to note that techniques describing how to reclaim worn files published 20 years ago appear as applicable now as they were then.[108]

Trends

One of the current trends which is, in some instances, misleading are advertisements that indicate that a specific process machine or tool will produce burr-free parts. Some of these advertisements imply the following capabilities:

- Ream thin materials burr-free;
- Provide burr-free ends on tube cutting machine; or
- Cut burr-free on cutoff saw.

In discussions with vendors who employ such advertisements, most have said that their equipment produced a part that was more burr-free than by other, yet-undefined techniques. In many instances, manufacturers indicate they are implying "commercially burr-free" rather than "actually burr-free." Because no uniformly accepted definition exists of what a burr is, it is difficult to argue the point.

Economics

A perennial shortcoming in deburring literature is a lack of economic data regarding individual processes and comparisons among processes. Within the past two or three years, however, a few reports have appeared that give some mathematical treatment of the economics of individual and comparative processes.[1,89,98,104,109] This is certainly one of the areas, however, that merits additional treatment by knowledgeable authors.

Although the U.S. industry spends an estimated $2 billion a year for burrs, some surveys have been made that have not yet been reported. Significantly, however, Production estimates that 6.2 percent of the capital equipment dollars spent by American industry will be allocated to finishing equipment.[110] This percentage represented a projected $50 million expenditure in 1979. Similar studies indicate that expenditures for 1980 will amount to about 6.2 percent of capital equipment expenditures.[111]

Surveys of the die casting industry show that most plants have an average of two vibratory or barrel tumbling machines in a plant. Studies show a planned increase of almost 5 percent in new equipment in this industry by the end of 1979.[112]

Though a significant amount of American effort during the past few years has been devoted to analyzing energy costs, this author has found only one report that describes the energy requirements consumed in any type of deburring process.[113] This particular study indicated that energy costs for several deburring processes could vary from 0.007 to 0.029 KW hours on a part in comparisons of powder metal parts to machined or forged parts. At a rate of 5 cents/KW hr. this would amount to slightly more than one-tenth of one cent per part for deburring energy. For the truck parts in this analysis, the energy required for deburring typically represented one-half of one percent of the total energy consumed in manufacturing these parts, whether by powder metal, machining, or forging.

AN ASSESSMENT OF THE USE OF EXISTING KNOWLEDGE

Although many advances in deburring have evolved within the past two to three years, major advances have taken place in knowledge of appropriate deburring solutions within the last five or six years. Despite these advances, however, some basic problems exist in applying what is already known. Today 36,000 pages of available information discuss burrs, deburring, deburring equipment, processes, burr prevention, and related facts. Despite this tremendous amount of readily available knowledge, many of its potential users are either not aware that it exists or are unable to implement the suggested solutions.

Many of these information sources have been described in Chapter 20 of Advances in Deburring. That publication contains information sources that can be categorized into the following subdivisions:

- Books
- Magazines
- Manufacturers' brochures
- Manufacturers' newsletters
- Films
- Videotapes
- Seminars
- Conferences
- Workshops
- Technical Reports
- One-on-one discussions
- Formal training programs

Books

The following books offer concentrated information on the subject of deburring. They represent some of the finest examples of in-depth, usable information.

	Reference
• Machine Techniques - Data File	114
• Mass Finishing	115
• Deburring Capabilities and Limitations	20
• Advances in Deburring	1
• Guide to Deburring, Deflashing, and Trimming Equipment, Supplies, and Services	116
• Blast Cleaning and Allied Processes	117
• Vibrational Machining of Components with a Free Abrasive	118
• Vibratory Finishing of Machines and Instruments	119
• Entgraten	120
• Surface Preparation and Finishes for Metal	121
• An Introduction to Industrial Finishing Equipment	122
• Magnetic Abrasive Polishing of Components	74

Technical Reports of Major Significance

Some of the world's best technical reports that often can be considered in many respects to be books rather than reports include these:

Magazine Publications of Particular Note

Although a relatively large number of magazine articles are worthy of special commendation, these are suggested because of the in-depth material presented within a single issue or through several issues.

Monthly Publications Covering Deburring

Films

The only movie directly connected to deburring which the author has seen is Pratt and Whitney's "Clean Engines." Several video tapes, however, have been prepared on deburring. For example, the Society of Manufacturing Engineers has completed a video tape covering several deburring processes. Similarly, manufacturers, for use in promotion of their processes, have made brief tapes about specific processes. In-house video tapes have also been prepared for training use or for orientation on deburring requirements within a specific company.

Seminars, Conferences, and Workshops

Within the past three years, 16 major deburring conferences and workshops have been held in the U.S., Canada, and Japan (Table 3). Undoubtedly, other ones have been held elsewhere and simply have not been widely publicized. Since 1973, an individual who attended all the major deburring conferences known to exist would have spent more than 45 days in conference settings. In addition to these, of course, special groups such as technical societies have provided one- or two-hour programs at monthly meetings for their members. More than 900 individuals attended a single deburring conference and exhibition in Japan in 1978.

As a result of all these information sources, there is little justification for an individual to indicate that information is not available on the deburring subject in which he is interested. All of that 36,000 pages of information is available and most of it in very convenient, digestable form. It is appropriate, though, to explore further why more of this information is not used. The following list provides some known and suspected reasons that the existing written technology has not been assimilated as best it could.

- Personnel at engineering levels responsible for deburring are constantly changing.
- There is little specialized in-depth training for deburring.
- An implied assumption exists that deburring does not require high levels of intelligence to do or to solve such problems.
- Users expect ready-made answers to be available in literature.
- Published literature is written for a general audience rather than for technical personnel.
- Published literature often is lacking specific facts. (It talks in concepts rather than details.)
- Unbiased deburring information is difficult to obtain.

Table 3. Recent Burr-Related Conferences

Sponsoring Group or Company	Date	Location	Title or Theme	Duration (days)
AIAC	Oct. 1977	Montreal	Annihilating the Burr	1
SME Local	Oct. 1977	Indianapolis	Deburring	1/2
I. Prod. E.	1977	Gloucestor, England	Deburring	1
SME	May 1978	Philadelphia	Deburring Symposium	1
---	May 1978	East Hartford, Connecticut	Deburring	1 1/2
SME Local	May 1978	Chicago	Deburring	1
SME	May 1978	Detroit	Deburring Costs	1/2
SME	April 1978	Niagara Falls	Deburring Symposium	1/2
SME	Nov. 1978	Seattle	Deburring Symposium	1
Japan SCFCT	Dec. 1978	Tokyo		?
SME	May 1979	Detroit	Automotive Deburring	1
SME	Sept. 1979	Hartford		1
SME	Oct. 1979	Cleveland	3rd Int, Conference	3
SME	Jan. 1980	Charlotte	Mass Finishing	3
SME	May 1980	Kansas City	Hand Deburring	3
SME	May 1980	Cleveland	Deburring	1

- The management of many companies has no long-term commitment to improve deburring.

- The most suitable approaches for solving deburring problems are not always applied.

- Technical personnel often is not willing to have translations made of foreign literature.

- Technical personnel does not think it has the time to become knowledgeable about deburring.

Although it is true that there are no training textbooks on any facet of deburring, several training aids are in work. These training aids include course material for universities, home study textbooks, and multi-volume training guides for in-plant use. Within the next year, all of these types of products are expected to be in use in American industry.

To become truly proficient at solving deburring problems in a medium- or large-sized company requires several years of study and daily experience. Transferring individuals in and out of such responsibility on a six-month or yearly basis will not furnish the necessary training and experience to solve deburring problems quickly or completely.

A frequent question is "What kind of training is best for solving deburring problems?" Of course, no single solution or answer exists to that question because every company has different needs and capabilities. Only a handful of individuals has received doctor of philosophy degrees in some facet of burrs or deburring, but more are expected in the future. The formation of burrs and removal by many processes is a mathematically highly complex subject.

High levels of study, however, are not necessary to solve practical on-the-shop floor problems for specific parts. These problems require a commitment, a knowledge of existing in-house facilities, and capabilities outside a given plant. In addition, problem solving requires an ability to categorize facts and assimilate them for later retrieval.

It is frustrating to purchase text materials or attend conferences to try to find the solution for a specific problem and end up with no obvious solution, but few readymade answers lie in any book for any real problems. Although material on deburring may not provide a solution for many individuals, it at least serves as a framework for sorting out potentially viable approaches or considerations. And yet, within each reader is the hope that somewhere within a book or presentation is the spark needed to start off in the right direction to solve a specific problem.

Those who attend the many engineering conferences generally return with at least three ideas that will more than pay for the time and money expended attending the conference, but these ideas may not be on the immediate topic of interest. Acquiring the ideas may require alertness on the part of the attendee, but the potential is there in almost every conference. As an example, one exhibition at a combined conference and exhibition displayed some miniature deburring tools inconspicuously. The engineer who saw those minute tools in a mammoth exhibition hall full of $40 million of other tools solved many of his problems. At the same time, the exhibitor didn't realize that his display of hand tools increased his income by more than $10,000.

For some reason, it is common experience to expect an individual to solve a deburring problem quickly or to select the appropriate process quickly that will work. On the other hand, before manufacturing a part, it is not unreasonable to expect to wait days before developing an in-depth manufacturing process to produce the basic shape. All too often, constraints have been placed arbitrarily upon deburring problems that require immediate short-term fixes. What is needed to be done is to develop rationale for solving deburring problems so that they can be prevented, not only months but years before they occur.

Technologists have not done this very well, although researchers in Germany are making notable strides in this direction in the area of deburring.

As an example of a rational approach to solving deburring problems, the reader is encouraged to review a recent article on the subject of parts feeding.[140] This article summarizes some geometry observations made on a variety of parts to help standardize feeding approaches to automatic assembly and transfer of parts. In that particular presentation (shown in Figures 19 and 20), the geometry and dimensions of the part are used to categorize families of parts so that solutions can be made for families of parts very quickly and readily. This same approach, generally classified as 'group technology', is necessary in deburring before many deburring problems can be minimized and the utilization of known facts can be maximized.

The Future

Making predictions about what is expected in the future for any field of endeavor is easy. Such predictions do not have to become reality, nor do they have to be realistic to be accepted. Within the next five years, however, based on events in the past five years, obviously, major strides have been made. Needs were identified five years ago, and to a very large extent, once they were identified solutions began coming forth.

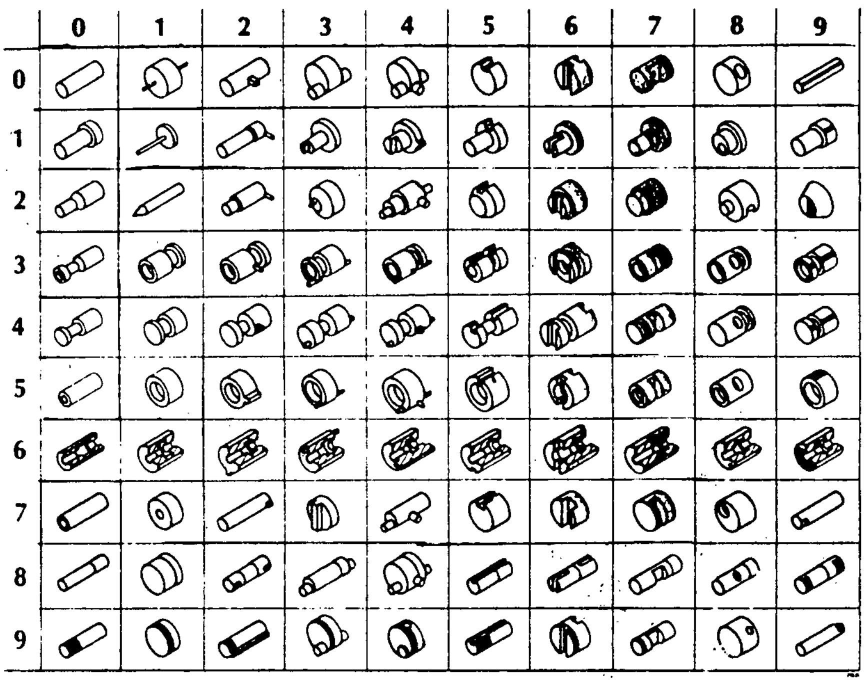


Figure 19. Classification of Parts by Shape

In the future, of course, a much wider acceptance and utilization of the written standards on allowable burrs and deburring techniques will prevail. A larger number of publications will be devoted to the subjects of calculating, predicting, or at least assessing the economics of various deburring processes that are yet to be developed. Manufacturers undoubtedly will find uses for many processes, that researchers will begin documenting the true capabilities and limitations of some of these processes. For example, loose fiber ends raised from machining glass fiber-reinforced products are now being removed (deburred) by laser. Within the next five years, literature describing the effectiveness of this approach should begin appearing.

In assessing these needs to document processes, at least two universities in the United States and Canada are seeking research project funds on burr-related projects. However, the universities have not been able to catch the attention of companies or foundations willing to support such effort. In the press of daily business it is difficult for those in industry to devote the time, even when the need is known. It will be important for engineers and other technological personnel to work more closely with the universities, not only in the field of deburring but in all the finishing processes.

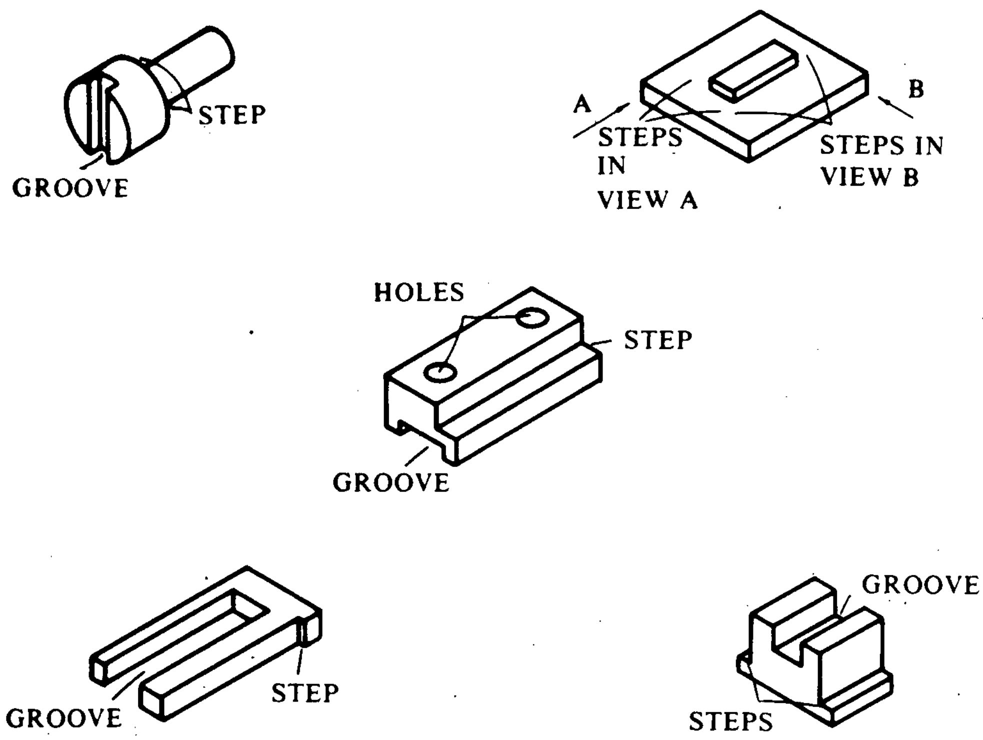


Figure 20. Characteristics of Parts Requiring Consideration in Deburring and Group Technology

Yet to be found within the literature is a significant number of case histories on deburring to help researchers, other companies, or students better understand the thought processes that went into selecting various deburring processes. For the advancement of deburring it is important to have many case histories to illustrate in-depth the decisions made. Case histories are not easy to write and they can never be fully complete. Nevertheless, an effort must be made.

Few authors have documented the burr characteristics they wish to solve. Though Japanese and German researchers evaluate deburring as a function of burr dimensions, most U.S. investigators ignore this, one of the most important facets in deburring. This must change if research is to be readily transferrable to other situations.

For many years deburring has had a stigma within the manufacturing industry as a task which anyone could do with no skill or training required. That, in part, may be why industry now faces so many deburring problems. Technological personnel has not done a good job of recognizing or acknowledging the benefits and ideas of those who have contributed within their own companies or industry. Deburring is a field few individuals understand well, a field with which many would prefer not to have to associate. It is a field requiring high technology as well as broad daily experiences. Deburring is a field in which many have developed a philosophy of not trying or not caring to answer the challenge of finding a better way.

At the end of this paper is a three-page survey that may help many companies assess their attitude toward deburring. After completing the answers to these questions and analyzing them, it should be obvious whether a company or industry in general really has determined that deburring is a problem. Technology has made major strides in the battle with the burr. Unfortunately, the war is not over.

Acknowledgements

The following sources have provided or authorized some of the material presented in this report:

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Standards Engineering

Machine Design

Production Engineering

Society of Manufacturing Engineers

Bendix Corporation

Bailey Meter Company

DuoFast Corporation

Foxboro Company

Varian

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Appendix A. Standards

STANDARDS FOR DEBURRING: COMPANY A

1. SCOPE

This standard establishes several classifications limiting the size of allowable burrs (raised edges or tears caused by tools during the fabrication of parts and finished products). Any burr not designated on the engineering drawing will be subject to the limits of a Class I Burr Condition per Section 2.1.

Before any burr can be considered for acceptability, the part, excluding the burr, must be within the specified dimensional tolerances.

Exceptions to the designated burr conditions can be found in Section 3.

2. DESIGNATIONS

2.1 Class I Burr Condition

A burr is acceptable in this classification if it is within the dimensional tolerances of the part as specified on the engineering drawing and is no larger than the maximum allowable burr size specified in Table A1.

2.2 Class II Burr Condition

A burr is acceptable in this classification if it meets the requirements of Section 2.1 and is not visible when viewed from a distance of 18 in. (450 mm) by an observer with normal or corrected to normal vision.

2.3 Class III Burr Conditions

A burr is acceptable in this classification if it meets the requirements of Section 2.1 and is not visible when viewed at a specified magnification of 3X, 10X, 30X, or 60X.

2.4 Remove Burr

Older drawings with this designation will be interpreted to mean that a burr is acceptable if it meets a Class II Burr Condition (refer to Section 2.2).

Table A-1. Maximum Allowable Burrs

Material Diameter (in.)	Thickness, Etc. (mm)	General Application (in.)	(mm)	Sheet (or strip) and Round (in.)	Stock (mm)
Up to 0.062	Up to 1.58	0.004	0.10	0.003	0.08
0.062 to 0.125	1.58 to 3.18	0.006	0.15	0.004	0.10
0.125 to 0.250	3.18 to 6.35	0.008	0.20	0.005	0.13
0.250 to 0.500	6.35 to 12.70	0.011	0.28	0.007	0.18
0.500 to 0.750	12.70 to 19.05	0.015	0.38	0.008	0.20
0.750 to 1.250	19.05 to 31.75	0.020	0.51	0.010	0.25
1.250 and up	31.75 and up	0.020	0.51	0.012	0.30

*Sheet (or strip) is rectangular stock with a thickness of 0.250 in. (6.35 mm) or less.

2.5 Maximum Allowable Burr = Size

This designation should be used to specify an allowable burr condition beyond the limits of the previous classification. In determining the maximum allowable burr to be specified, the engineer should consider its affect on the function and aesthetics of the part as well as assuring that it will not constitute a safety hazard during handling.

3. EXCEPTIONS

3.1 Thread Burrs

Unless otherwise specified, threaded parts will have no burrs that prevent acceptance by standard gaging methods.

3.2 Screw Head and Slotting Burrs

Unless otherwise specified, burrs on screw heads and slots will be acceptable when within the limits of Table A2.

3.3 Length of Cutoff Burr (Teat)

Unless otherwise specified, the length of the cutoff burr on screw machine parts will be acceptable when within the limits of Table A2.

Table A-2. Cutoff Burr Limitations

Material Diameter (in.)	(mm)	Max. Allowable Burr (in.)	(mm)
Up to 0.125	Up to 3.18	0.010	0.25
0.125 to 0.438	3.18 to 11.13	0.015	0.38
0.438 to 0.625	11.13 to 15.88	0.020	0.51
0.625 and up	15.88 and up	0.030	0.76

3.4 Countersink Burrs

Unless otherwise specified, burrs due to countersinking are acceptable when within the limits of Table A2.

3.4 Chamfer Burrs on Hexagonal Rod

Unless otherwise specified, chamfer burrs on hexagonal rod will be acceptable when within the limits of Table A3.

Table A-3. Chamfer Burr Limitations

Material Diameter (in.)	(mm)	Max. Allowable Burr (in.)	(mm)
Up to 0.125	Up to 3.18	0.005	0.13
0.125 to 0.375	3.18 to 9.53	0.010	0.25
0.375 to 0.750	9.53 to 19.05	0.015	0.38
0.750 and up	19.05 and up	0.020	0.51

STANDARDS FOR DEBURRING: COMPANY B

A Definition: A burr is the extruded material that extends beyond two intersecting surfaces of a part, except in the case of a cutoff burr.

B Categories: Burrs will always fall into one of two categories.

B-1 Loose burrs: Any burr that may become dislodged and hinder the assembly of the part or the function of the device in operation.

B-2 Tight burrs: A burr that is securely attached to the parent surface and will not become dislodged in part assembly or device operation.

C Routine Burr Removal Without Note on Drawing

C-1 Loose burrs must always be removed.

C-2 Holes with 0.005 in. tolerance, or less, on the diameter must be burr-free.

C-3 Holes which are to be tapped coarser than 28 pitch must be burred by countersinking before tapping.

C-4 The corners of any area of a part which has a decimal tolerance specified on the drawing shall be burr-free.

C-5 The corners of all micro-inch finished surfaces shall be burr-free, using 1/64 x 45° maximum chamfer or 1/64 maximum radius.

D Burrs Removed by Note on Drawing

D-1 If the burr on a hole which is to be tapped 28 pitch or finer must be removed, a note should be included on the drawing. Shop should request such a note be added if tapping difficulty occurs.

D-2 Corners of screw machine parts are to be chamfered approximately 1/64 x 45°, if this does not entail a second operation. Inspection of such broken corners is to be visual only. If, despite the need for a second operation, a corner must be chamfered, a note is required on the drawing.

D-3 All stampings such as cams, which require deburring, must include a note on the drawing: "Must be burr-free."

D-4 Where loose or tight burrs exist, and a sharp corner is required for functional purposes, the drawing must state: "Sharp Corner Required."

D-5 Where the commercial burr, permitted by the A.D.C.I. (see A16 675, page 1.22) is excessive for functional purposes, its removal must be indicated by a note on the drawing.

E Burrs Permissible

E-1 If the burr will be removed from the O.D. or I.D. of a part on a subsequent machining or assembling operation on another drawing, a note should be included on the first drawing stating: "Burrs are permissible--will be eliminated on subsequent operations."

E-2 The cutoff tip burr on screw machine parts is permissible, unless the drawing states otherwise.

E-3 On screw machine parts on which a second operation is required to remove the burr, the burr will be permissible, unless otherwise noted on the drawing.

F Inspection

F-1 A burr is the extruded material that extends beyond two intersecting surfaces of a workpiece, except in the case of a cutoff burr.

F-2 Such extruded material or cutoff tip material may not be considered as part of the workpiece being measured.

F-3 Measurement should be made across the true surface of the workpiece, avoiding burrs.

F-4 If no accessible burr-free surface exists on the part, one must be created by carefully removing the extruded material so that measurement may be made at the true surface.

STANDARDS FOR DEBURRING: COMPANY C

2.0 BURRS

2.0.1 Definition. A burr is an undesired displacement of metal at the intersection of surfaces.

2.1 Classification (Good Workmanship)

The absence of specific burr symbols or notes implies that burrs consistent with good workmanship are acceptable, based on the following:

2.1.1 Punch Press Parts

Stock Thickness	Maximum Burr Height
0.004 and under	0.001
Over 0.004 to 0.014 incl.	0.0015
Over 0.014 to 0.039 incl.	0.002
Over 0.039 to 0.124 incl.	0.003
Over 0.124 to 0.186 incl.	0.004
Over 0.186 to 0.311 incl.	0.005
Over 0.311	0.010

2.1.2 Machine Operations - all stock sizes and materials.

Maximum Burr Height Allowed for Specified Finish

Operation	32 and Under	64	125 and Over
Grinding	0.002	0.003	0.003
Drilling	0.003	0.003	0.003
Turning	0.001	0.003	0.006
Milling	0.001	0.006	0.012

2.2 Burrs on Screws and Screw Threads

2.2.1 Male or female threaded parts shall have no burrs which prevent acceptance by normal gaging methods. Threads on tuning screws shall have no loose burrs or flawed portions that will impair the smooth engagement of a thread plug or ring gage over entire thread length.

2.2.2 Burrs on commercial screw heads and slots shall be acceptable; however, folded-over or curled burrs shall be removed by Company C if necessary.

2.3 General Limitations

2.3.1 All degrees of folded over, curled or embedded burrs are rejectable, except as applied to commercial screw-heads and slots, par. 2.2.1.

2.3.2 Burrs in holes and slots shall not decrease the minimum specified diameter or size thereof.

2.3.3 Burrs on cut lengths of wire and ribbon, including flattening caused by shearing pressure, shall not exceed 10 percent of the diameter or thickness thereof, unless otherwise specified.

2.4 Burr Symbols and Drawing Callouts

2.4.1 Burr requirements closer than good practice (par. 2.1.1, 2.1.2) shall be specified as follows:

a. "NO BURRS PERMITTED"
b. ".00(X) MAX BURR OK"

2.4.2 Drawings shall specify the direction in which burrs may occur by means of an arrowhead and the capital letter "B" superimposed on the dimension line, on the side where the burr is permissible (Figure 1). No burr is permissible on the intersecting surface at the edge, unless otherwise specified. If the direction of the burr is optional, the letter "B" shall appear on dimension lines extending from both sides of the part (Figure 2).

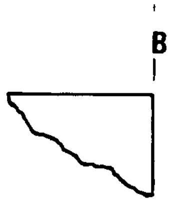


Figure 1

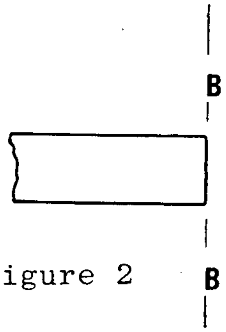


Figure 2

2.4.3 The maximum size of permissible burr also shall be specified as part of the burr symbol (Figures 3 and 4).

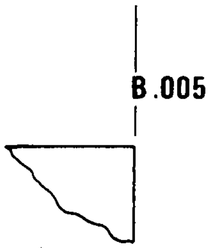


Figure 3

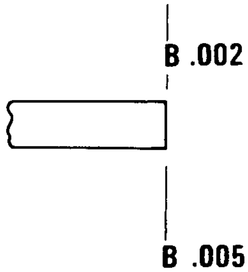


Figure 4

2.4.4 Figure 4 also illustrates the case for parts where it may be desirable to specify different degrees of allowable burrs on opposing edges; viz: a 0.002 burr may be the maximum allowed on one edge, but on a more liberal 0.005 burr may be acceptable on its opposing edge.

2.4.5 For punch press operations, the burr symbol (Figure 5) may also indicate the direction of shear. If the radius on the opposite side of the part (where the punch first engages the metal) is critical, the maximum radius shall be specified on the drawing (Figure 5).

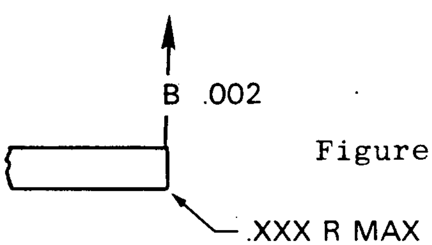


Figure 5

2.4.6 For certain critical parts or areas, the drawing may specify "NO BURRS PERMITTED." (Refer to 2.5.2).

2.4.7 For certain noncritical parts or areas, the drawing may specify "BURRS NOT CRITICAL", in which case any degree of burrs is acceptable.

2.5 Burr Removal

2.5.1 Vendors shall remove burrs from the parts fabricated by punch press operations as directed by Purchase Order or drawing, except as noted in 2.1 above.

2.5.2 Vendor will be responsible for the removal of burrs from machined parts, unless otherwise directed by Purchase Order. If the drawing specifies "NO BURRS PERMITTED", the edges shall be deburred and normally will be broken slightly as a result. The broken surface shall have the same finish as the adjacent surfaces. Unless otherwise specified, the size of the edge radius or chamfer shall be noted.

2.5.3 Deburring methods which do not introduce contamination, foreign particles, or produce unacceptable surface conditions may be used, provided the method and its application are approved by the cognizant Engineering Department.

2.5.4 Parts drawings having the following callouts may be either hand- or machine-deburred at the option of the vendor:

"MACHINE DEBURR OPTIONAL"
"MACHINE BURNISH OPTIONAL"
"MACHINE RADIUS OPTIONAL"

DEFINITIONS

Machine deburring and machine burnishing include the use of a barrel and vibratory machines, wet and dry abrasive blasting, and slurry roto-blasting methods.

Hand deburring includes the use of hand-held tools such as files, rasps, knives, abrasive cloth, stones; use of small hand power tools such as stand grinders, buffers, speed lathes, and belt sanders.

2.6 Inspection

2.6.1 Burr inspection shall be conducted by any convenient means, except magnification shall not be more than 10 power.

2.6.2 In no case shall the dimensional tolerances of finished parts be exceeded as a result of the burrs.

STANDARDS FOR DEBURRING: COMPANY D

General Parts - Specification 9900000

Para. No.	Discussion
5.5.1	Hole Quality. The walls of holes shall be clean-cut and shall present a good machined surface. Hole edges shall be free from burrs and shall not be ragged, chipped, or torn. These requirements are subject to visual inspection only and are to be evaluated in terms consistent with the characteristics of the material and with the method used to produce the hole.
5.6	Removing Burrs and Sharp Edges. All burrs and sharp edges shall be removed to the extent that material fragments are not visible and sharpness cannot be felt. Either a 0.3 mm (0.010 inch) maximum x 0.3 mm (0.010 inch) maximum chamfer or 0.3 mm (0.010 inch) maximum radius is satisfactory treatment in breaking edges and deburring. Only those edges that appear to exceed these limits upon visual inspection need be measured for conformance to these dimensions. If it is necessary to break sharp edges or to deburr after application of chemical surface treatment, the bared metal shall be touched up as required by paragraph 5.10.3. Flash on molded plastic parts that does not cause the part to exceed maximum dimensional limits need not be removed. These requirements do not apply to rough and semi-finished metal castings and forgings.
5.12	Flaws. Flaws include scratches, cuts, dents, cracks, checks, pits, blow holes, bumps, ridges, and similar marks and imperfections. Acceptance of parts having surface flaws shall be at the discretion of the buyer and shall be based upon the function of the part.
6.1.2	Appearance. All threads shall be free from burrs, nicks, and rough or chattered surfaces, which are visible without magnification.

The intent of specification 9900000 is obvious, but some aspects require some additional interpretation.

Paragraph 5.6 indicates that burrs must be removed to the extent that fragments are not present. On most miniature parts even a smooth bump or smooth area of raised metal is not allowed, even through this material is not a fragment (Figure 1). In essence, any material extending past the theoretical intersection of the two surfaces creating the edge will be rejected as unacceptable.

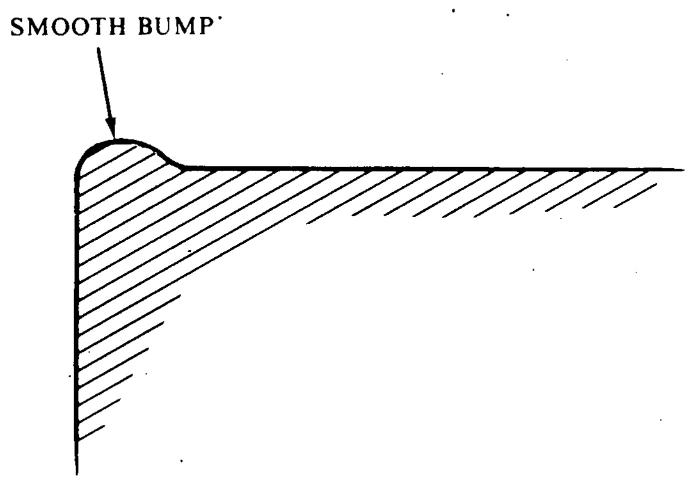
If, however, notes on the part drawing allow burrs at specific locations, then the previous comments do not apply at those locations.

Unless otherwise indicated, the burr and edge requirements on all parts are expected to meet the requirements of Specification 9900000.

Miniature Precision Parts - Specification SS331834

1.2.1 In any areas covered both by this specification and 9900000, this specification takes precedence.

5.1 Intersections of Surfaces. Surfaces intersecting to form internal corners shall not have an undercut. All burrs, raised metal, and sharp edges must be removed from external corners. The maximum size of chamfers or radii, generated by machining or deburring, is limited by the adjacent surfaces as follows:



A. No surface shall be more than 1/2 used in chamfers or radii.

B. Any surface 0.050 inch or less in length may lose up to 0.005 inch at both ends to chamfers or radii.

C. Longer surfaces may lose up to 0.010 inch at both ends to chamfers or radii.

5.3 Surface Flaws. Flaws are surface irregularities and imperfections that occur at one place, or at relatively infrequent intervals, in contrast to the normal irregularities produced by the surface finishing operations. Flaws include surface conditions such as scratches, cuts, dents, steps, cracks, checks, pits, blow holes, bumps, ridges, and similar mars and imperfections. Stains, discolorations and foreign material shall be considered surface flaws. Surface flaws are acceptable if the product function is not impaired.

6.1.2 Appearance. All threaded parts must be free from burrs.

7.2 Visual Inspection. Normal inspection for Section 5, Section 5, Manufacturing Requirements, and 6.1.2, Appearance, shall be visual using seven to ten magnification. The use of other powers or techniques is acceptable. When variations which might impair the product function are found, the production agency product engineer shall determine if the part is still functional.

These paragraphs require some interpretation. First, if the drawing dimension of the short side (Table 1) was 0.049/0.051 inch (1.245/1.295 mm), then the nominal size would be 0.050 inch (1.270 mm) and the consequent allowed edge break would be 0.005 inch (127.0 μm). Even if the part measured 0.049 inch (1.245 mm), the requirement would be 0.005 inch (127.0 μm) because the nominal drawing requirement was 0.050 inch (1.270 mm).

Second, since deburring operations do not typically show part dimensions, it is the engineering division's responsibility to provide instructions on the required edge radius whenever this specification or drawing is required.

Inspection Practice

The inspection departments are responsible for assuring that all parts made meet the requirements of one of these drawing specifications as well as the part drawing. Although some minor differences exist among inspection departments (as a result of the particular types of products being inspected), the following inspection guidelines are used universally.

For parts which require Drawing 9900000 edge conditions, the inspection traveler states, "Workmanship/9900000, standard sampling plan, visual inspect at 5-8X magnification." The standard sampling plan essentially says to pull a group of 15 parts from the parts submitted for inspection, inspect them for burrs; if any part has burrs, the entire lot is rejected and returned to production for completion of deburring. A 15-piece sample may not seem to represent the entire lot, but experience has shown that the sample very well indicates when significant numbers of parts fail to meet the burr-free requirement.

Inspection supervision does not use high magnification unless some doubt exists as to part quality. For example, parts are not automatically checked at 30X just to reject them. Some part drawings do specify, however, that 20 to 30X magnification be used.

*Drawing SS331834 says that no more than half of a surface can be used in edge break. The values shown here assume that this quantity is equally split between the two edges. In actual practice, this may not be the case.

PARTS SUBJECTED TO HARD ANODIZING

Outside Corners. The hard anodizing process does not produce a coating on sharp edges and corners. Rounded edges and outside corners having the following radii should be specified:

Coating Thickness (Inch)	Minimum Radius (Inch)
0.001	0.032
0.002	0.062
0.003	0.125

EDGE BREAKS ALLOWED BY DRAWING SS331834
(SEE TABLE 2 FOR ALLOWABLE VALUES)

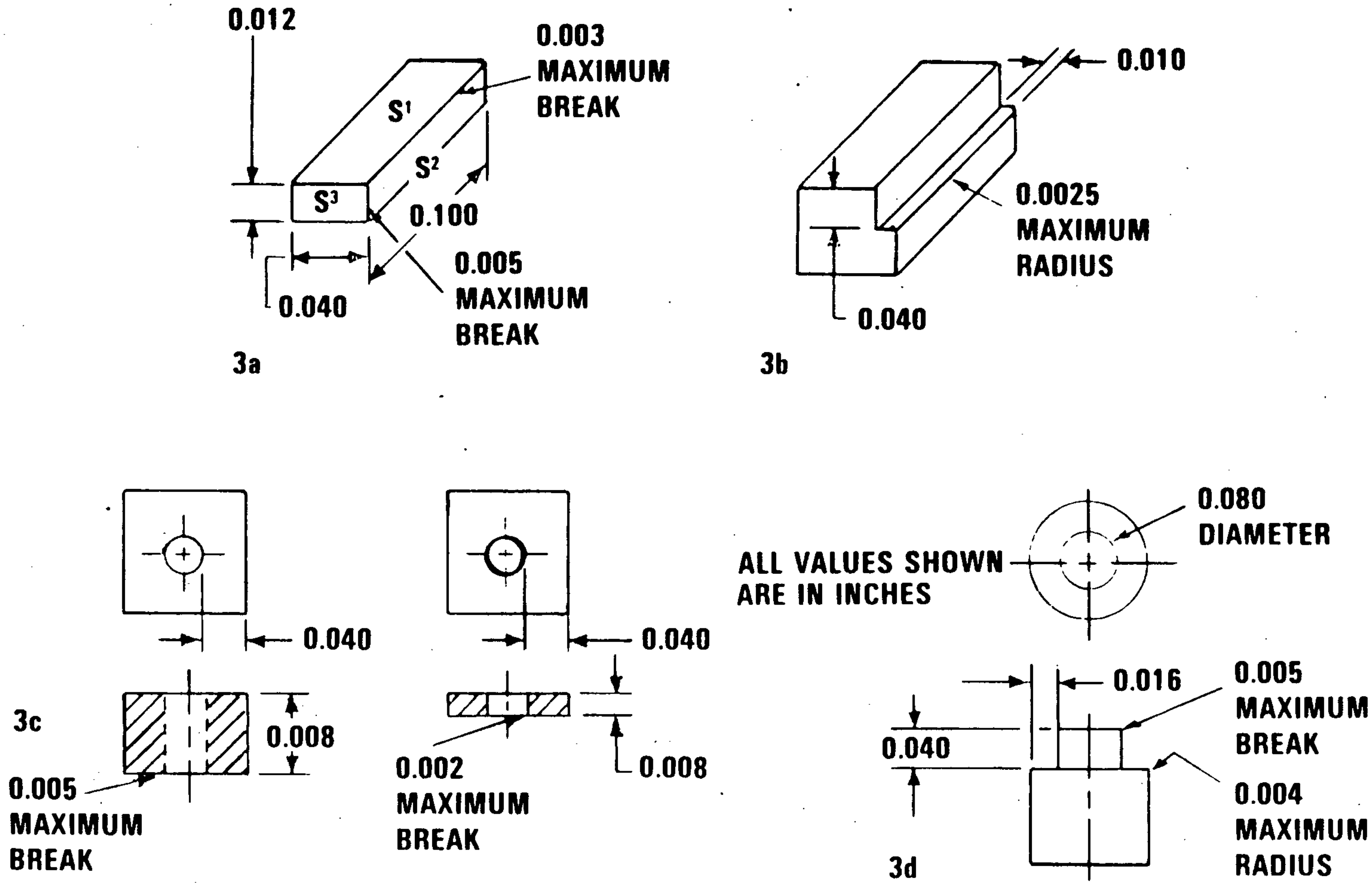


Table A-2. Edge Break Requirements as a Function of Part Dimensions

English Units		Metric Units	
Short Side Dimension of Part (inch)	Maximum Permissible Edge Break/Radius (inch)	Short Side Dimension of Part (mm)	Maximum Permissible Edge Break/Radius (μm)
<0.020	1/4 length of edge*	<0.500	1/4 length of edge*
<0.050	0.005	<1.270	127.0
>0.050	0.010	>1.270	254.0

<0.020 indicates that the part dimension is less than 0.020.
>0.050 indicates that the part dimension is greater than 0.050.

Appendix B: Burr-Related Definitions in Published References

Deburring	The removal of the sharp flash or burr of metal left at the bottom of a shearing cut or saw cut.[141]
Burr	The sharp ridge of metal nearly always remaining at the end of a sawing operation. Also, the ridge remaining on the bottom side of a drilled hole.[143]
Flash	The excess metal attached to a part after a forming operation.[142]
Fin	The excess metal attached to a part after a forming operation.[142]
Burring	A common term for deburring or smoothing the rough-cut edges of metal.[142]
Burr side	The side of a punched blank represents a rough edge around its periphery or a hole or opening in it. In blanking operations, it is the face or side of the blank that comes in direct contact with the punch. In piercing or perforating operations, it is the face or side of the blank that comes in direct contact with the die.[142]
Deburring	Removing burrs.[142]
Burrs	A burr is an undesired displacement of metal at the intersection of surfaces.[15]
Burr	A rough or sharp edge left on metal by a cutting tool.
Burr	Metal displaced beyond the plane of the surface by slitting or shearing (Reference Standard A682, A-1).[145]
Burr	Fragment of excess material or foreign particle adhering to the surface.[145]
Burr	Jagged edge around a punched hole, caused when the punch goes through the mica. These jagged edges appear on the bottom side as punched (Reference Standard F 12, F-1).[145]

Burr	Metal displaced byond the plane of the surface by slitting or shearing (Reference Standard A 623, A-1).[145]
Burr	Thin, wing-like ridge protruding from side or edge of point or underside or top of head; defect formed during pointing or heading process and intended to be removed during manufacturing process (Reference Standard D 2478, D-7).[145]
Burrs	Raised edges caused by a faulty die (Reference Standard D 2965, D-9).[145]

Appendix C: Questions Which Might Be Asked On A National Or An In-Plant Survey

1. Would better casting quality reduce your deflashing costs?

2. Are your deburring processes selected by engineers or by those performing the deburring?

3. What is the ratio of deburr labor to metal cutting labor in your plant?

4. What training do your manual deburring operators receive?

   ___ through in-plant training
   ___ through outside agencies
   ___ hrs/year/person
   ___ none

5. Does engineering provide detailed instructions on deburring processes?

6. Has your plant ever performed formal research on burrs or deburring?

7. Is one individual responsible for all burr or deburring approaches in your plant?

8. Does your plant have a written definition of what burrs are?

9. Do your inspection departments have written standards defining exactly what burr/edge requirements are allowable?

10. A. Should deburring require the same planning and development as plating, machining and other processes?

    B. Does it receive this level of consideration in your plant?

11. What burr or deburring areas need further research or development?

12. How does your company stay current on deburring developments?

    ___ Trade magazines
    ___ Technical Society conferences
    ___ Technical Society papers
    ___ Vendor literature
    ___ Participating in national burr technology groups or associations
    ___ We don't
    ___ In-plant training sessions

13. A. Have you ever used job shop deburring facilities?

B. Was this an effective approach?

C. Why?

14. Do vendors of deburring equipment or supplies provide enough technical information to fill your needs?

15. Do the 100 to 150 annual publications on burrs fill your needs for

A. Applied information?

B. General process understanding?

C. Directions for needed in-house development?

16. A. Do you have a computerized technique for selecting deburring processes?

B. Do you believe this is a realistic possibility?

17. A. Do you scrap parts because of improper deburring?

B. What percentage of your scrap is caused by improper deburring?

18. Do you have to deburr?

A. ___ all parts, or only ___ percent

19. Do you specify on some parts

A. Which direction you want the burr to face?

B. The maximum allowable burr size?

20. Do layoffs of personnel affect your deburring quality?

21. What labor rates do most deburr personnel receive?

A. Hand deburring _____

B. Vibratory and barrel process operations _____

C. More "sophisticated" process operations _____

22. Are you aware of any industry standards on burrs or edges?

23. Does deburring create any significant problems other than expense?

Occasionally ______
Frequently ______
Everyday ______

24. What kind of problems does deburring cause you?

25. Which of the following describe your plant?

A. High production

B. Medium production

C. Job shop production

D. High precision parts

E. Low precision parts

26. A. Has your plant purchased any deburring equipment in the past year?

B. What type?

1. Vibratory
2. Other loose abrasive process
3. Blasting
4. Electrochemical
5. Abrasive flow ("putty" process)
6. Thermal energy
7. Brushing
8. Sanding
9. Mechanized edge chamfer/finishes

27. Do your designers and engineers design parts to minimize burrs?

28. Does your plant have any written guidelines for designing to minimize burr problems?

29. Does your plant have any written procedures for selecting or using in-plant deburring processes?

30. Has your plant developed in-house equipment for deburring?