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HAND DEBURRING GUIDE

By L. K. Gillespie

Published July 1979

MASTER

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**Kansas City
Division**

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HAND DEBURRING GUIDE

BDX-613-2089R (Rev.), Manual, Published July 1979

Prepared by L. K. Gillespie

Appropriate hand deburring techniques have always been difficult to define because of the infinite variety of part shapes, sizes, materials, and burr conditions. This guide, however, has been prepared to assist those responsible for hand deburring. The purpose of the guide is to define Bendix Kansas City burr specifications and inspection practices; to define the results of practical tests on hand deburring; to define some typical in-house practices; and to define the in-house tools available for this work.

WPC-TR/16

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SUMMARY

Hand deburring has always been treated by industry as if it were a subject impossible or useless to describe or prescribe on paper. Many have felt a need to provide some insight and training on hand deburring, but such efforts have never appeared in print. This guide was prepared to offer production workers new to deburring some permanent guidance in addition to their formal training. Also, it was written to provide shop supervisors and manufacturing engineers with a sourcebook on hand deburring.

The material presented includes background on typical in-house standards on burrs and their removal, a brief description of the capabilities and limitations of machine deburring, a description of the expected performance of production workers doing deburring and the guidance required by process engineers, an explanation of typical hand tools used at Bendix Kansas City, results of studies on hand deburring, and some typical approaches used on specific features.

An attempt has been made to make this guide as definitive as possible, but it is impossible to provide all the information on this subject. Similarly, the approaches described are typical but not the only way to perform hand deburring efficiently. Workers have their own techniques that work best for them. This guide is based on the input of more than 100 production workers, supervisors, methods engineers, and process engineers.

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DISCUSSION

SCOPE AND PURPOSE

This effort was concerned with developing facts about typical deburring practice used on precision miniature parts at Bendix Kansas City and documenting approaches commonly used. An attempt was made to cover all pertinent aspects of deburring and inspecting of burrs.

PRIOR WORK

At Bendix, deburring has continuously been studied since 1967. These studies are documented in more than 50 publications, 47 of which have been listed.¹ These reports cover many processes, but three are specifically related to hand deburring.^{2,3,4} The material reported in this guide is in addition to the work published earlier, although some overlap does exist.

ACTIVITY

Eight major aspects of deburring were observed in the preparation of this guide.

- Inspection requirements and techniques used were evaluated.
- Hand deburring techniques in use on production parts were evaluated.
- Capabilities of mechanized processes were evaluated.
- Brief studies of hand tool effectiveness were performed.
- Production factors which influence hand deburring were considered.
- Commercially available hand tools were evaluated.
- Hand tools available in-house were evaluated.
- Needs were discussed with several hundred vendors and users of deburring tools.

Although the guide does not provide answers to all the questions faced in hand deburring, it does provide discussions of the basic considerations in deburring precision or miniature parts to Bendix standards.

Why Hand Deburr Parts?

Bendix has used 12 processes to remove burrs (Figure 1). Nine of these are currently used on a production basis to remove burrs. Although a total of 37 deburring processes are used in industry, only those mentioned are capable of meeting the majority of Bendix's needs on small parts.

The mechanized processes are limited. They affect part dimensions or finishes. They impregnate contaminants which cannot be removed. They are not as repeatable as required. They will not work in hard-to-reach areas. They generate too large or too small edge radii. And they nick or bend the parts.

In practice, the limitations often are a combination of several of these items. And the varying size of burrs produced on a single part precludes consistent results. In a few cases, hand deburring is actually faster than mechanized deburring, but this is by far the exception.

Many parts receive both hand deburring and mechanized deburring because the combination of the two results in the most effective process.

What is Hand Deburring?

Hand deburring consists of any operation in which a hand held deburring tool is used or in which a hand held part is placed against a fixtured tool. Hand deburring includes cutters and motorized tools (Table 1). Although this list is not complete, it is representative. The actual number of tools used is essentially endless because of variations in geometry, size, and techniques used.

Bendix Kansas City Burr Related Specifications and Practices

Many part drawings contain requirements regarding burrs and sharp edges. Most requirements for miniature parts are described in Bendix requirements for typical parts and for miniature mechanisms. Specific requirements that pertain to burrs and edges are reprinted below.

Figure 1. Principal Deburring Processes and Mechanisms Used at Bendix Kansas City

Table 1. Items Used for Hand Deburring

Cutters		Motorized Tools
Bur tools	Nonwoven Nylon products	Minisanding belts
Knives	Drills	Reciprocating sanders
Scrapers	Reamers	Jitterbug sanders
Files	Mounted points	Reciprocating files
Abrasive filled rubber	Rotary files	Motorized spindles
Sandpaper	Mini-brushes	
Picks	Countersinks	
Abrasive stones		

Specified Requirements for Typical Parts

Discussion

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.

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. 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.

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.

Appearance. All threads shall be free from burrs, nicks, and rough or chattered surfaces, that are visible without magnification.

The intent of the requirements is relatively obvious, but some aspects require some additional interpretation.

The section on Removing Burrs and Sharp Edges 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 though this material is not a fragment (Figure 2). 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 for typical parts.

Three specific assemblies at Bendix require somewhat more stringent edge requirements than those listed. These units specify that edges must meet the requirements for miniature mechanisms.

Specified Requirements for Miniature Mechanisms

In any areas covered both by this specification and the specification for typical parts, this specification takes precedence.

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:

Figure 2. Raised Metal or Smooth Bumps at Edges Not Allowed on Most Precision Miniature Parts

- A. No surface shall be more than $\frac{1}{2}$ 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.

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.

Appearance. All threaded parts must be free from burrs.

Visual Inspection. Normal inspection 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 2) 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 μ m). Even if the part measured 0.049 (1.245 mm), the requirement would be 0.005 inch (127.0 μ m) because the nominal 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 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 typical part edge conditions, the inspection traveler states, "Workmanship/..., 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 and 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 it does in fact very well indicate when significant numbers of parts fail to meet the burr-free requirement.

Inspection does not measure edge breaks unless they appear to exceed allowable limits. (The requirement for miniature mechanisms does not take exception to this portion of the requirement for typical parts.)

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.

Table 2. Edge Break Requirements as a Function of Part Dimensions (See Figure 3 for Examples of Usage)

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	$\frac{1}{2}$ length of edge*	<0.500	$\frac{1}{2}$ 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.

*The requirement for miniature mechanisms 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.

A Bendix Internal Procedure states, "... Inspection supervision judgement may be exercised to... use a power higher than specified to resolve uncertainties or to assure compliance with applicable requirements. ... In all cases the selection and use of magnification equipment is to be based on sound, informed judgement with the object of making a realistic determination of product condition in relation to applicable requirements and quality standards." This procedure allows inspection to use 30X magnification if necessary. However, inspection seldom exceeds 10X magnification.

One of the requirements of any inspection department is that it not be forced to accept discrepant parts in such a manner that others are led to believe that they do in fact meet requirements. As a result, in most companies throughout the world, inspection departments are entirely independent of production pressures. Inspectors can take as long as required to verify edge quality. They do not have to meet a standard hour rate. Their purpose is to ascertain if the parts meet the specification.

When assembly inspection departments indicate that burrs still exist on certain locations of certain parts submitted to stores, inspection supervision informally asks inspectors to pay special

ALL VALUES SHOWN
ARE IN INCHES

3d

Figure 3. Edge Breaks Allowed on Miniature Mechanisms (See Table 2 for Allowable Values)

attention to these areas. The same is true of parts and features which recently have been rejected by any department. The inspection departments can recall any parts in stores or next assembly to verify burr free status.

The assembly inspection department can reject assembled units if burrs that would be or could be detrimental to the unit are found.

The product engineer can ask inspection to be particularly critical of specific areas or to ignore "small" burrs on noncritical areas. Whenever possible, however, Engineering is required to define explicitly on the drawings and the travelers exactly what edge requirements are needed.

Inspection monitors some edges closely because past experience with assembly departments rejecting parts for burrs makes it desirable to look closely at the edges.

When miniature threaded holes are gaged, the thread gage can raise a burr. Inspection can reject the parts for this burr, but in most cases manufacturing supervision has agreed to remove any such burrs generated by inspection. In such situations inspection does not initiate a "reject" citation since the parts were acceptable as received.

Inspection looks particularly closely at threaded features because they are easily overlooked and are a frequent source of concern in next assembly.

As previously indicated, inspection will reject parts for burrs even though fragments are not visible. For example, if a smooth mound of material is present, that is sufficient reason to reject a part for burrs.

For parts which require miniature mechanism edge conditions, the inspection traveler states, "Workmanship/..., 100 percent inspect, visual inspect at 7-10X magnification." Thus every part calling out this specification is checked for burrs on all edges.

Because of the large number of edges involved and the time and difficulty required to measure edge radii, the inspection department only measures those edge breaks which appear to exceed the allowable limits.

The inspection department's general philosophy is that if an edge is critical it is indicated specifically on the drawing and the inspection traveler. For example, a 0.003 inch [76.2 μ m] maximum break would be called out on the drawing.

Basic Capabilities of Machine Deburring

At this point, it is important to take a closer look at the practical limits of machine deburring. The centrifugal barrel tumbler for example, can remove any size burr from any part, provided changes in part size are not important, surface finish is not critical, and edge radii of 0.003 to 0.030 inch (76.2 to 762.0 μm) are allowable. When size changes must be controlled to 0.0001 inch (2.5 μm) or less, then burr size is the major limitation to the use of this process.

The time required to remove the burr by centrifugal barrel tumbling is affected by burr thickness (Figure 4a). For the conditions used, a 0.003 inch (76.2 μm) thick burr would be removed after 30 minutes. Figure 4b shows that 30 minutes at these conditions also will leave a 0.003 inch radius on all edges. The surface finish after 30 minutes would be slightly less than 30 microinches (0.7 μm), provided it was no worse than 50 microinches (1.2 μm) initially. If the burr were thicker, it would have required longer to remove, and this in turn would have produced a radius greater than 0.003 inch. It also would have changed the size of the part more. More aggressive media will remove the burr faster, and also will produce a radius faster and change dimensions faster (Figure 5). Thus, regardless of how the part is tumbled, the initial burr size determines how much radius and size change occurs.

When the burrs are very long and flexible, the tumbling processes beats them flush against the part rather than removing them.

Such requirements as 0.003 inch (76.2 μm) maximum edge break in "tumbling" type processes can be maintained only by beginning with small burrs because the final edge break is at the smallest equal to the initial burr thickness. With larger burrs or burrs inaccessible to the media, only hand deburring can meet all the critical requirements of some parts.

Chemical, electropolish, and electrochemical deburring face similar limitations. In chemical and electropolish deburring, for example, the part diameter or thickness must be changed by 0.003 inch to remove a 0.003 inch thick burr. In electrochemical deburring, deburring does not affect part size, but a large burr thickness typically results in a large radius.

In addition to all these effects, the mechanized processes can discolor, bend, gouge or, nick parts. The processes can beat undesirable abrasives into the part so that they cannot be removed, and in many cases, the process is not as repeatable as desired because the burr is not as repeatable as desired.

Figure 4. Effect of Time in Machine on Burr Removal, Edge Break, Finish, and Size

Figure 5. Effect of Media Size, Burr Size, and Time in Machine on Burr Removal, Edge Break, Finish, and Size

Expected Results

Several characteristics are expected of those individuals who are involved in some facet of deburring.

Engineers

Product engineers responsible for piece part drawings and specifications are expected to define on the drawing(s) what the desired edge conditions are. When burrs are allowable, the product engineers are expected to indicate this on the drawing. On items that require some interpretation as to acceptability, the product engineer is responsible for making these judgements.

Process engineers are responsible for indicating on the production traveler what type of deburring is required (manual or machine) and what the edge requirements are. Unless otherwise indicated, any instructions to hand deburr any feature assumes that a 0.010 inch (0.25 mm) maximum break or radius is allowable. To eliminate wasted effort if only certain edges are to be deburred at a specific operation, these edges will be indicated on the production traveler. Process engineers are also responsible for obtaining adequate tools or products for deburring. When burr or edge related drawing changes are in order, it is generally the responsible process engineer's function to suggest these to the product engineer.

Quality process engineers are responsible for indicating inspection requirements on the inspection traveler and for providing necessary inspection tooling.

Quality control engineers are responsible for identifying when specific quality problems exist and for assuring that adequate solutions are provided. For example, if a part has a history of rejects for burrs, the quality control engineer brings this history to the attention of all those involved and pursues the problem until adequate corrections are initiated.

Machine Operators

Machine operators and all individuals involved in machining parts are expected to meet four burr-related requirements as specified in the Bendix General Process Instructions.

- To prevent gross burrs,
- To remove burrs during machine cycle time,
- To place the burr for easiest removal, and
- To identify problem areas.

Extremely large or gross burrs should never occur. They can easily be prevented by changing the cutter, adjusting the spindle speed or the feedrate or otherwise adjusting the process. There are three keys to determining if a burr is too gross to constitute good workmanship:

- If the burr cannot be readily removed with a burr knife, it is too big,
- If the burr or surrounding area is burnt or discolored, it is not acceptable, and
- If material is obviously bulged in the vicinity of the burr, it is not acceptable.

In most departments, machine operators are expected to deburr the workpiece edges they machine if time is available to do so while the machine is cycling on the next part. An operator should do as much deburring as possible even if it is not possible to completely deburr all parts or all areas of any part. On some parts the cycle time is too short to allow the operator to gauge, prepare for loading, and deburr during the cycle. On most parts produced on semi-automatic or numerically controlled equipment, however, there is time to do some deburring.

In the precision miniature machining department, because of the many close tolerances on edge breaks, machine operators are not expected to break part edges unless specifically indicated on the traveler or required for in-process gaging.

The emphasis on deburring during the machine cycle should be on removing the obvious "heavy" burr. If time permits, the smaller burrs, which can be felt but not readily seen, should then be removed. Edges which are specifically identified as edges to be deburred should be deburred first. The remaining edges should be deburred as completely as possible without affecting cycle time.

Whenever possible, burrs should be produced on an edge from which they can most easily be removed. On some parts, the operator can control this by the direction of feed (Figures 6, 7, 8). When two intersecting holes are produced in the same operation, the burr should occur on the edge from which it is most easily removed. As an example, a small hole would typically be drilled into a larger hole to allow room for a burr tool to remove the burr.

Whenever good practices result in an abnormally large burr, the supervisor should be notified. The supervisor should also be notified whenever some doubt exists as to best burr location or which areas should be deburred during machine cycle. Two areas of particular interest are identifying tools which make excessive burrs and identifying tools which have very short tool life.

PREFERRED METHOD

THIS PUTS LARGE BURR ON FLAT FACE OF LAST PART.

POOR APPROACH

THIS THEORETICALLY ELIMINATES LARGE EXIT BURR SINCE CUTTER CUTS AGAINST BACKUP. FROM A PRACTICAL STANDPOINT THIS OFTEN DOES NOT OCCUR BECAUSE OF VARIATIONS IN SPACER AND WORKPIECE THICKNESS AND FLATNESS ALLOW GAPS BETWEEN BACKUP AND WORKPIECE. ALSO SOFT SPACERS WILL ALLOW A BURR TO FORM EVEN IF GAPS DO NOT EXIST.

Figure 6. Effects of Hob Rotation/Feed

EXIT BURR HERE REQUIRES EXTENSIVE
HAND DEBURRING ON LOW VOLUME,
HIGH PRECISION PART.

EXIT BURR ON FLAT FACE IS EASILY
SANDED OFF. THEN EDGE IS RADIUSSED
BY VIB DEBURR.

Figure 7. Effects of Hob Feed/Rotation Direction

POOR CHOICE OF EXIT BURR LOCATION

BETTER CHOICE OF EXIT BURR LOCATION

Figure 8. Effects of Cutter Feed Direction

The production traveler shall indicate those few instances when exceptions are to be taken to the practices listed here. On some materials, a very long burr will be produced. A long burr is often a sign of poor workmanship. If, however, this burr can be readily flexed by a fingernail, toothpick, or similar technique, the burr is acceptable despite its length.

Individuals Performing Hand Deburring

Each person doing hand deburring is expected to perform the following operations:

- To remove all burrs to the extent that they meet the requirements for typical parts or other identified requirements;
- To leave no sharp edges, secondary burrs, or humps of material at edges;
- To maintain the indicated edge breaks;
- Not to mark, scratch, or change dimensions of the part;
- To select the best method for the particular part and individual;
- To verify his or her own work;
- To identify burr conditions which if not corrected would result in scrap, rejects, or other problems;
- To identify to the manufacturing supervisor specific needs for deburring tools; and
- To initial the appropriate Bendix form when all the parts in a lot have been completed.

Although these requirements appear to be straightforward, this is not always the case. For example, on parts which are large and weigh several pounds, burr or edge conditions are not normally checked using microscopes. Typically, burr free implies burr free without magnification. On close tolerance miniature parts requiring the same workmanship specifications, the parts may be checked at 20X magnification to verify burr-free levels.

On some parts, preliminary deburring on machine cycle has been specified on the production traveler but for one of many reasons was never actually performed. On some parts, the final deburr operation specified that specific edges were to be deburred and that others were not because they should already have been finished. When such situations arise, it is important that the production

supervisor be advised that burrs still exist on the part. Parts should not be signed off on a final deburr operation unless they are completely burr free or the supervisor has been notified of the burrs.

It is also expected that each person will read the traveler operation for the deburring operation to assure that he or she understands what edge requirements are necessary.

Inspectors

Inspectors are responsible for verifying that parts are burr free and meet the edge break requirements defined in the inspection traveler. Following standard procedure, this verification of burr-free conditions is to be performed before dimensional inspections are made. To facilitate any rework, the inspector is expected to indicate by adhesive-backed arrows on the part or by words on the appropriate Bendix form the general location of any burrs found on a part.

Typical Problem Areas

Experience has shown that several problems occur frequently. Sixteen of these are shown in Table 3 and discussed in subsequent paragraphs.

Threads

Threads frequently appear to be only partially deburred. There are four areas of threads that require special attention. A burr is left on the crests of all threads whether produced by tapping or cold forming (Figures 9, 10). On external threads, these fine burrs can easily be removed from most parts by sanding, tumbling, or brushing (Figure 11). Although internal threads are more difficult, they too can appear as burr free as these threads, particularly in the larger thread sizes (Figure 12). On the smaller threads, such as the 1.0, 0.8, and 0.6 mm threads, it is important to assure that retapping or using thread gages to "clean" threads does not affect thread size.

When viewed with the naked eye, the crest burrs cannot be seen on a 0-80 UNF thread. They are only obvious when viewed at 10-20X magnification. One must wonder if such small burrs actually create problems in assembly. The answer is not clearcut, but it is important to realize that a small metal fragment, such as one of these hairlike thread crest burrs, can keep an electrical contact from closing and thus cause a failure. Larger metal fragments or burrs can cause the close fitting components to jam. Although the probability of such events is small; considering the many times that some parts are assembled, disassembled, and tested, the actual possibility is real for many situations.

Table 3. Common Burr Problems on Miniature Parts

Problem	Solution
Burrs on internal thread crests	Brush, ream, and/or tap to clean up.
Burrs on external thread crests.	Brush, sand, or tumble to clean up.
Lead in/lead out thread damaged.	Cut out flexible portion of lead in/lead out thread.
Raised metal around tapped hole.	C'sink prior to tapping, after tapping use c'sink, abrasive paper discs, or mounted points.
Burrs in bottom of blind tapped holes.	Examine all blind holes carefully, cut burrs out with knives, bottoming taps, or sharp probes. Use vacuum probe to remove particles.
Minute burrs on gear teeth.	Examine at 10-20X magnification very carefully before submitting as complete.
Dirt on parts hides burrs.	Clean until no dirt particles are evident.
Burr rolled over on face of screw machine parts.	Examine with shadow-casting lighting at 10-20X magnification.
Burrs beat flush against diameters.	Notify engineer to eliminate or change tumbling operation.
Too much edge break.	Change deburring method, use edge break break standards.
Missed half of all features on entire lot.	Scrutinize all parts 100 percent prior to submitting to next operation.
Missed one or more parts completely in a lot.	Scrutinize all parts 100 percent prior to submitting to next operation.

Table 3 Continued. Common Burr Problems on Miniature Parts

Problem	Solution
Varying level of quality in a lot.	Allow only one person to deburr all parts within a lot in order to assure consistency. (Remove the problem of allowing several persons to deburr a portion of parts in a lot.)
Small secondary burrs left on part.	Polish all edges with cratex or brushes to eliminate burrs/sharp edges produced by knives. Scrutinize at 10-20X prior to submitting to next operation.
Indenting or "marking" part.	Use soft jaw collets (brass), put tape on chuck jaws, get special design holders.
Leaving burrs or sharp edges in hard-to-reach areas.	Ask engineer to provide tools for difficult areas.

35 Figure 9. Burrs Produced by Conventional Cutting Taps

Figure 10. Burrs and Crest Configuration Produced by Cold Forming Taps

Figure 11. External Threads After Tumbling
(0-80 UNF Thread) 50X

On the 0-80 UNF and smaller threads, it is generally not possible to achieve the same levels of internal burr-free crests as for larger sizes. Consequently, inspection departments are less demanding on these minute features. The mating external threads can be "clean" (Figure 11) and are expected to be so. The fact that one of the two threaded components has entirely burr-free crests, that gages have been threaded into the internal threads, and that an honest attempt has been made to remove all loose particles significantly reduces the possibility of burr-related problems.

Figure 12. Burr Free Crests on Internal Threads (2-56 UNF Thread)

It is more difficult to remove burrs from cold formed threads and threads in aluminum. Typical part requirements allow cold formed threads to have a crest (Figure 13). The same is allowed in the requirements for miniature mechanisms. Unfortunately, in the miniature threads the actual cross-sectional shape looks more like that shown in Figures 10, 14. As seen there, the two sides of the crests are folded over so that they almost close. As shown in Figure 14, they do in fact meet, and only a small black spot indicates that a cavern exists below the crest of each thread. In addition, Figure 14 illustrates the rough appearance of the actual crest after being produced. In threads as rough as these, it is important to use cross hole deburring brushes to remove all loose particles.

COLD FORMING THREAD TAPS MAY BE USED IN LIEU OF METAL CUTTING TAPS. A SLIGHT GROOVE MAY APPEAR ALONG THE THREAD CREST AS A RESULT OF THE METAL FLOWING ACTION OF THESE TAPS.

Figure 13. Condition Allowed on Typical Parts and Miniature Mechanisms

In fact, all internal threads should be brushed to remove loose particles.

General inspection practice is to inspect almost all threaded features produced in the miniature machining department under 7X magnification. Similarly, parts having very close tolerances (± 0.0002 inch [1.0 mm]) or whose features are very small (0.040 inch [1.0 mm]) are typically inspected under magnification for burrs. Conversely, threads whose diameter is 3 or 4 inches (75 or 100 mm) will seldom be inspected under microscopes unless a specific concern is raised. Such a policy on use of scopes may seem inconsistent, but it should be noted that minute crest burrs represent a larger problem to the small precision parts than to larger or less critical parts.

Neither requirements for typical parts nor requirements for miniature mechanisms require that the lead in or lead out thread (referred to as the "incomplete thread" or "blunt start" in national thread standards) be partially removed, except for Acme style threads. In practice, it is essential to remove enough of these thread ends to assure that this thin thread portion cannot be bent over or otherwise damaged. Inspection practice is to reject any threads in which this thin fin is bent or in any way damaged (Figure 15). Both specifications, however, require leading edges of external threads to be chamfered, which minimizes some of this "fin."

Requirements for typical parts and for miniature mechanisms are that all threaded holes be chamfered. If they are not chamfered, a small swell of metal occurs at the hole entrance and exit. Those performing the drilling and tapping are responsible for chamfering the holes.

Figure 14. Actual Cross Section of Cold Formed Thread

Although those performing deburring may have to occasionally perform such chamfering, the absence of such chamfers should be noted to supervision.

Blind tapped holes frequently have hard to reach burrs or chips at the end of the bottom thread (Figure 16). As difficult as they are to remove, these chips should be removed since mating screws can dislodge them in the next assemblies. These screws are inserted and removed frequently during assembly.

Gears

It is possible on many of the 96 diametral pitch gears to find very minute burrs rolled into the teeth by sandpaper, knives, or brushes. At 20X or 30X magnification, burrs as small as 0.0002 inch (5 μ m) can be seen. Each miniature gear should be scrutinized

Figure 15. Damaged Lead Out Thread

at these magnifications to assure that no burr exists. In some cases, the use of Redliner gear inspection equipment may be desirable to pinpoint parts still having burrs.

Figure 16. Chip in Bottom of Blind Hole

Dirt and Burrs

On gears and threads, any dirt or particle will hide some of the very small burrs. Sometimes, it is just a case of confused identity: it looks like dirt but actually is an attached particle. Before parts are submitted to inspection they should be thoroughly cleaned and then scrutinized. Similarly, for the most effective deburring, parts should be clean and should be recleaned frequently as required during deburring. In many cases, an ultrasonic rinse in warm soapy water is required. Some of the magnetic parts, specifically solenoid components, cannot be immersed in water, however.

Screw Machine Parts

Five common problems occur on screw machine or lathe turned parts.

- Burrs are rolled over onto shoulders,
- Burrs are beat flush against diameters,
- Edge breaks are excessive,
- Parts have indentation marks in them, or
- Diameters become tapered.

On pinion type parts that rub on part shoulders, it is critical that no burrs exist on the shoulders because they will affect the operating torque of the next assembly. In the past, it has been easy to miss the minute burrs that get bent out of the way onto these surfaces (Figure 17). These burrs are frequently best detected using long focal length microscopes and lighting which casts harsh shadows.

Some parts which are tumbled have burrs beat flush with the part diameter (Figure 18). These burrs can only be detected under 7X to 20X magnification. When these conditions exist, the tumbling process must be changed.

Maintaining 0.003 inch (76.2 μm) edge breaks on small parts is extremely difficult. Unfortunately, many of the parts requiring this level of precision are the miniature screw machine parts. Edge standards are available, however, to allow deburring workers to assess the edge condition produced.

When the miniature parts are held in vise jaws, steel collets, or pin vises, it is very easy to leave indentations in the part. Many of these marks are unallowable. To prevent such occurrences, one can use brass jaws or collets, put masking tape over jaws, or very carefully control the amount of closure pressure applied.

Many of the small screw machine parts have diameter tolerances of ± 0.0002 inch ($\pm 5 \mu\text{m}$). When abrasive paper is used to remove the burrs from edges, these short diameters can be easily tapered by 0.0003 inch (7.6 μm) in only 2 or 3 seconds with 600 grit paper.

Burrs Produced by Deburring

Any time a cutting tool is used to remove burrs, it produces burrs itself. Chamfering tools, for example, typically leave two small burrs while removing one large burr. For miniature precision parts, even these miniature burrs should be removed. On some

Figure 17. Burrs on Shoulders of Turned Parts

parts, a sharp chamfer will act as a cutting tool when a mating pin is pressed in. An assembly-produced chip or burr, which is highly undesirable (Figure 19), results.

Burrs Left in Hard-to-Reach Areas

A few shapes exist in which burrs are almost impossible to reach. There is a natural tendency to leave them because of their difficulty. These conditions should be brought to the attention of the process engineer so that adequate tooling can be provided to give a truly burr-free part.

Systematic Deburring Techniques

Many burr rejects are the result of not developing a systematic approach of handling each part. For example, some features on a part may not be deburred because they were inadvertently overlooked. The practice of allowing two different people to deburr parts from the same lot causes similar differences in quality.

The solutions to these situations are a consistent approach on every part and an in-depth review of finished part quality.

Figure 18. Burrs Beat Flush Against the Diameter (0.020 Inch/
0.5 mm Diameter Pin at 50X

For example, all parts not totally deburred are placed on the left side of the bench. Finished parts are placed in a container on the right side. After deburring, a final check is made on part quality using higher magnification than for deburring, if necessary.

On some parts, it may be convenient to make a checklist and mark each feature off when it is completed. On some parts, all holes may be deburred first, followed by other edges. Each part should be treated in the same sequence as all other parts. To facilitate deburring, the following checklist should be used:

Figure 19. Chip or Burr Produced by Press Fitting

- Are traveler instructions clear and specific?
- Are special tools required?
- Are special tools supplied or are they specified on the traveler?
- Would a special brush, tool, or airmotor help?
- Are the microscopes being used adequate for the task?
- Is the appropriate lighting available?
- Are all parts in a lot being deburred by the same individual?

- Are any burrs excessive?
- Can burrs be placed in a more easily removed location?
- Can the part be totally or partially deburred by machine faster or easier?
- Is a systematic approach used to deburr the parts?
- Have all parts been cleaned prior to a final verification of burr-free conditions?

Deburring Not Specified for Some Features

On a few parts, drawing notes or production travelers allow burrs to exist on specific edges. In some cases, previous workers do not complete their deburring. The last operation, however, assumes that this previous work has been completed. The production department is responsible for shipping all parts burr-free into inspection. When parts obviously have burrs after final deburring instructions have been followed, supervision should be notified.

When a traveler states only "final deburr" or "deburr complete" it means that, unless otherwise indicated, 0.010 inch (0.25 mm) edge breaks are allowable and that every edge is to be deburred.

When the words "deburr indicated edges" are used in conjunction with a production traveler operation "ABCD" code, only the edges shown or described are to be deburred. Unless otherwise indicated, a 0.010 inch (0.25 mm) edge break is allowable. These edges should be completely deburred to a level acceptable by inspection.

When "deburr on machine cycle" is specified, the machinist should remove all burrs.

- Visible to the naked eye,
- Detectable by touch,
- Which would influence subsequent part location, and
- Which would influence in-process gaging.

Usually, a subsequent hand deburr will be needed to touch up and to eliminate minute burrs and sharp edges. The "rough" deburring will be performed while the next part is being machined.

When "deburr on machine" is indicated, burrs visible to the naked eye or touch should be removed while the part is still in the machine. Usually deburring will be done after the machining cycle is complete and will add time to the operation.

In tumbling processes, the process engineering specification (PES) governing the machine indicates that after the tumbling operation is complete those operating the equipment are expected to look at 10 percent of all the parts to verify that all burrs have been removed. If the burrs have not been removed, the supervisor and process engineer should be notified.

Other Problem Areas

On many parts, workers tend to produce the smallest possible break on all edges. Although this tendency helps ensure that excessive breaks never occur, it also greatly increases deburring time and, in fact, increases the probability that some burrs are left on parts. The most economical and the intended practice is to use techniques which meet the requirements without unnecessarily "creeping up on the burr."

Some of the purchased parts, such as screws, bearings, and retaining rings, arrive at Bendix with larger burrs than those allowed on most of our parts. Larger burrs are allowable on some parts because these items are purchased to military specifications rather than to normal Bendix standards. These usually are also less critical parts than those made in the production department. Although an obvious difference in quality expectations exists on some of these parts, the majority of purchased parts are expected to meet the same quality levels as those produced in-house.

Basic Description of Bendix Deburring Tools

Table 1 (page 12) indicates some of the items commonly used for hand deburring. These tools are described in more detail elsewhere. Illustrative photos are shown here. Deburring tools fall into 16 basic categories (Table 4).

Knives

Triangular knives are typically used to cut or scrape burrs from straight edges. (Figure 20). Oval knives are normally used for hole edges or hard to reach areas. Special shaped knives were designed for burrs on a specific part but are often useful in other situations. Scalpel blades are used for trimming flash from plastic. They are rarely successful, however, for metal burrs because of the metal's hardness.

Table 4. Categories of Deburring Tools Used
at Bendix

	Shown in Figure
Knives	
Triangular	20
Oval	20
Special Shapes	20
Scalpel Blades	20
Files	
Large	21
Miniature	21
Round (rattail)	21
Half Round	21
Triangular	21
Curved or Bent	21
Bur Balls, Burs, Rotary Files	
Bur Balls	22
Burs	22
Rotary Files	22
Scrapers	23
Countersink Tools	24
Brushes	
Wheel	25
Cross Hole Deburring	25
End and Cup	25
Abrasive Filled Rubber Products	
Bullets	26
Cylinders	26
Flat Bars	26
Discs	26
Cups	26
Dental Bullets	26
Abrasive Paper Products	
Discs	27
Rolls	27
Sheets	27
Cord	27

Table 4 Continued. Categories of Deburring
Tools Used at Bendix

	Shown in Figure
Felt Bobs	
Discs	28
Bullets	28
Cylinders	28
Lapping Compounds	28
Mounted Points	
Balls	29
Discs	29
Cylinders	29
Cones	29
Special Shapes	29
Abrasive Stones	
Bars	30
Triangles	30
Cones	30
Points	30
Mandrels for Tools	31
Pin Vises	
Dog Nose	32
Collet	32
Motorized Tools	
Bench Motors	33
Air Motors	33
Dental Tools	33
Jitterbug Sanders	33
Belt Sanders	33
Reciprocating Files	33
Miscellaneous Tools	
Swivel Blade Tools	34
Back Side Cutters	34
Special Design Tools	34
Vacuum Probes	34

Figure 20. Typical Deburr Knives Used at Bendix

Files

More than 300 different files in a variety of sizes can be purchased commercially. Swiss escapement, parallel machine, needle, riffler, diemaker riffler, and die sinker riffler files can be found in a variety of miniature sizes. The files are rectangular, triangular, round, curved, or bent (Figure 21). Some are made from high speed steel; others are made from carbide or diamond particles plated onto a steel shank. Each of these can be used on any part, although it is easy to exceed 0.003 inch (76.2 μ m) edge breaks when using these tools. Although the needle files come to almost a sharp point (0.030 inch/0.75 mm), the narrowest rectangular file used at Bendix is 0.015 inch (0.38 mm) thick. Some triangular files, however, come to a knife-edge-like corner which is thinner than 0.015 inch.

Burs

Bur balls and related tools (Figure 22) also can be purchased in a variety of diameters, shapes, tooth coarseness, and materials (Figure 35). One company alone lists 1028 different burs and rotary files in its catalog. Although bur balls are the most used type of these tools, pointed cones and flame-like shapes also are in frequent use (Figure 35). For most miniature part usage, these tools are placed in pin vises and rotated by hand. All of these tools can be inserted in bench motors, air motors, or dental motors to provide faster action. These tools tend, however, to chatter or cut too deep unless very fine teeth are used. The smallest of these tools is a 0.004 inch (0.1 mm) ball. The smallest standard ball diameter is 0.020 inch (0.5 mm). Several of these shapes will deburr the backside of holes which may be inaccessible by other means. These tools can be used on numerically controlled machines or other machines as well as manually.

Scrapers

Several scrapers are available commercially for removing burrs. A "Red Devil" (Figure 23) is used on larger parts but is not generally small enough to use on small parts. In addition, maintaining small edge breaks is difficult with these tools.

Countersink Tools

The Bendix coded tool catalog lists more than 100 countersink tools (Figure 24). Most drills and reamers also are often used to remove burrs in the same manner as countersink tools. These tools also are typically rotated by hand to prevent excessive edge break.

Figure 21. Typical Files Used at Bendix

Figure 22. Typical Bur Balls and Related Burs Used at Bendix

Figure 23. Scrapers Used for Deburring at Bendix

Figure 24. Typical Countersink Tools Used for Deburring at Bendix

Brushes

Fifteen miniature brushes are in common use on miniature parts. These brushes include the small diameter wheel-like brushes, end brushes, cup brushes, and the cross hole deburring brushes (Figure 25). Brass fiber brushes will discolor steel parts, and all brushes can eventually pick up enough oil or grease to leave black marks on stainless steel parts. At speeds of 20,000 rpm, nylon brushes will melt and leave a nylon film on parts. Few small diameter brushes can be purchased as standard items, but most brush manufacturers will build any brush that a company wishes. End brushes are useful for removing splattered metal drops left by electrical discharge machining or welding processes.

Abrasive Filled Rubber Products

For deburring small parts, bullet-shaped rubber tools (Figure 26) are widely used. They can be purchased in four different levels of aggressiveness. The degree of aggressiveness is determined by the size and number of silicon carbide particles molded into the rubber. To facilitate identification, the degree of aggressiveness is indicated by color. One manufacturer uses brown to indicate a medium aggressiveness, dark green for coarse, red for fine, and light green for extra fine. A few products used at Bendix but produced by other manufacturers have different color codes.

If these products are used on lathes or mills, the particles that are worn off may score or scratch machine ways. If blown into chuck jaws or collets, these particles will indent subsequent parts which then must be scrapped.

A special miniature dental rubber cone has no abrasives in it.

Abrasive Paper Products

A variety of sandpaper-like products are used on the miniature parts (Figure 27). The miniature discs have adhesive backsides for holding them to mandrels. As previously indicated, even 600 paper can quickly remove 0.0003 inch (7.6 μ m) stock from small diameters. The smallest commercially available disc size is 0.5 inch diameter. Smaller sizes have been punched out with dies made at Bendix.

Felt Bobs

Occasionally, specially formed felt shapes (Figure 28) are used with a diamond lapping compound to remove burrs. Usually, the abrasive-filled rubber products will deburr faster without generating too large a radius.

Figure 25. Typical Brushes Used at Bendix for Deburring

Figure 26. Typical Abrasive Filled Rubber Products Used for Deburring at Bendix

Figure 27. Typical Abrasive Paper Products Used for Deburring at Bendix

Figure 28. Typical Felt Bobs and Lapping Compound Used for Deburring and Polishing at Bendix

Mounted Points

Miniature grinding wheels, known as mounted points (Figure 29), are used for edge finishing in many companies, but these tools are too abrasive for many miniature part applications. Mounted points, too, come in a seemingly endless quantity of sizes, shapes, and materials. The diamond coated tools used in the dental industry quickly break edges in hard-to-reach areas without chatter.

Abrasive Stones

A wide variety of abrasive stones also are in use for removing burrs and improving finishes (Figure 30).

Mandrels

Many of the tools shown in Figures 20 through 28 require a special mandrel (Figure 31) to hold them.

Pin Vises

A variety of pin vises (Figure 32) are used to hold parts and tools for deburring. Some of these have brass collets or jaws to prevent "marking" of the part while it is grasped. In addition to those that locate on the outside diameter of parts, four are available for grasping inner diameters. When necessary, these can be machined to hold smaller diameters or special shapes.

Motorized Tools

More than 100 motorized tools for deburring can be purchased. For example, one company offers 15 different dental tool motors. Motors, powered with belt drives, integral electric motors, flexible shaft drives, or air can be obtained. Some operate at 2000 rpm and others operate at 400,000 rpm. An estimated 50 different designs of these tools are used at Bendix (Figure 33). Although each of these products can be used successfully with no training, it is necessary to lubricate some of the dental tools several times a day. In most applications, the motors that operate at 20,000 rpm or higher are designed to remove burrs by applying a measurable force to the part.

Miscellaneous Tools

For noncritical parts, several swivel bladed tools are available (Figure 34). Some tools are designed to remove burrs from the bottom side of holes when that side is inaccessible by normal means. Roughly 20 tools have been designed to deburr a special

Figure 29. Typical Miniature Mounted Points Used for Deburring at Bendix

Figure 30. Typical Abrasive Stones Used for Deburring at Bendix

Figure 31. Mandrels Used to Hold Miniature Tools at Bendix

Figure 32. Pin Vises Used at Bendix

Figure 33. Motorized Deburring Tools Used at Bendix

Figure 34. Miscellaneous Deburring and Allied Tools Used at Bendix

feature on a specific part. Whenever conventional tools will not remove a burr, the process engineer should be requested to design a special tool or to purchase some of the non-standard bur tools (Figure 35).

On a few parts, chips and loosely attached burrs are difficult to remove because of their location (in deep holes, for example). Sometimes a vacuum probe and vacuum producing motor will remove these particles.

Results of Studies on Hand Deburring

Several brief studies which provide significant facts about hand deburring have been made.

Deburring Repeatability

In one study, experienced deburring personnel were asked to deburr samples (Figure 36a). A 0.005 inch (127 μ m) maximum break was the goal on these parts. Extensive measurements indicated that 95 percent of the edges met the 0.005 inch maximum break. Fifty percent of the edges had radii of 0.002 inch (50.8 μ m) or less. These samples were made of 303 Se stainless steel and had normal burrs on them.²

In the second study, the sample (Figure 36b) was deburred again in an attempt to maintain 0.005 inch maximum break. In this case, the actual edge break that was produced varied depending on which edge was involved. Edge Number 2, for example, consistently had breaks which exceeded 0.005 inch. In reality, the average radius on most edges was between 0.002 and 0.004 inch (50.8 and 101.6 μ m). Part requirements at Bendix, however, are that every point on an edge be less than the indicated maximum break. Typically, if the average break was 0.004 inch then half the breaks varied from 0.004 to 0.0066 inch (101.6 to 167.6 μ m). This is not a large variation, but it is large enough that every part in this study would have been rejected for excessive edge break.

At this point, the question arises "Are requirements like 0.003 or 0.005 inch maximum (76.2 or 127.0 μ m) really needed on miniature parts?" In some cases, they are not, but in the majority of cases, there is a real need for small breaks. Sometimes, a small break is required to provide an adequate bearing surface for small diameter journals (Figure 37). If a larger radius existed on the example shown, the hole diameter would quickly enlarge and allow the shaft to change its precision location. Sometimes, the available space for press fitting pins into holes is so limited that a large chamfer on the hole or pin would not provide enough area to hold the pin in the hole (Figure 38).

Figure 35. Common Shapes of Burs

36a

36b

Figure 36. Specimen Geometry Used to Assess Edge Break Repeatability

Figure 37. Effect of Edge Break on Bearing Surface

Figure 38. Effect of Edge Break on Press Fit Engagement

Close edge breaks are generally required at Bendix to assure a complete and sound weld. Large breaks require higher laser weld power which heats surrounding metal, burns thin sections, and blows more weld beads onto surrounding surfaces (Figure 39).

One other reason for close edge breaks which is not widely appreciated is that on miniature magnetic solenoid or rotors the edge radius affects the magnetic flux lines and either slows or increases the rate or location at which a rotor develops its maximum torque (Figure 40). Miniature solenoids are very sensitive to these changes in available torque or power.

In regard to breaks produced on the slotted sample, close and exact edge breaks are significant. Figure 41 is a graph of edge breaks on Edge Number 2 of Figure 36b. The graph shows that 3 percent of the edge had a break of 0.002 inch (50.8 μ m) or less; 44 percent of the edge had a radius of 0.004 inch (101.6 μ m) or less; and 75 percent had a radius of 0.005 inch (127.0 μ m). Thus, 25 percent of the edge had an edge break greater than the specification. This fairly large range of results also indicates some of the difficulty of maintaining edge breaks of 0.003 inch (76.2 μ m) or less or toleranced edges, such as 0.002/0.005 inch (50.8/127.0 μ m).

In the third study, operators were asked to deburr the part illustrated in Figure 36b and at the same time to maintain a 0.002 inch (50.8 μ m) maximum edge break. Three hundred thirty edges were measured. On stainless steel samples, only 18 percent of the edges actually had a 0.002 inch or smaller break across the entire edge. Figure 42 illustrates the typical results obtained in this study. Although a large percentage of edges had some portions with 0.002 inch break or less, it is significant that, because of so many edges on a part, not a single part had all edges within the required 0.002 inch. Essentially, one would have had to allow 0.004 inch (101.6 μ m) to accept 95 percent of the parts.

Although it may be true that some individuals can do better than indicated in Figures 41, 42, this work was performed by several well-qualified people. The results point out that, with normal practices using knives, abrasive paper, and brushes, it is almost impossible to produce 0.002 or 0.003 inch (50.8 or 76.2 μ m) maximum breaks on all portions of every edge of an intricate part.

In subsequent tests, individuals with only two months' training on deburring were told they were not capable of maintaining 0.003 inch maximum breaks but that they were to try to do it anyway using any technique they desired. They were given the parts shown in Figure 43. These parts had normal to small burrs (0.003 inch [76.2 μ m] thick or less) and were made from 303 Se stainless steel. In this study, 24 of 25 people maintained edge breaks of

Figure 39. Effect of Edge Break on Laser Welds

Figure 40. Effects of Edge Break on Solenoid Performance

Figure 41. Percent of Edge Number 2 Having an Edge Break Smaller Than a Specified Value

Figure 42. Percent of Edges Having an Edge Break Smaller Than a Specified Value

Figure 43. Test Specimen Used to Determine Smallest Edge Break Individuals Could Maintain

less than 0.0025 inch (63.5 μ m) on all edges and at least 25 percent of the individuals maintained edge breaks less than 0.001 inch (25.4 μ m).

In analyzing the results, several items stand out. These "rookies" were told it was almost impossible to meet the requirement. As a result, they took great care in deburring the parts. In a normal situation, they would be trying to meet a production rate of close to 2 minutes a part. In this study, they had as much time as they wanted--and most took 20 minutes a part to meet the requirement.

Second, they knew that their work was going to be measured and that everyone else would know how "good" or "bad" their performance was.

Third, to meet the requirement, they realized that for most of them it would be impossible to use knives or brushes. Most resorted to 600 grit abrasive paper, sanded parallel to edges, and used comparators to check their own work. Some used the backside of abrasive paper to limit the abrasive action.

Finally, the parts used had easily accessible edges and only one-fourth to one-half the total length of edge on a part as used in the initial studies. As a result, the level of burr removal difficulty was much lower than the specimen shown in Figure 36b.

They did far better than most might have expected, but used nonstandard methods and took up to 10 times longer than individuals using conventional approaches.

Figure 44 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 group of 25 maintained 0.003 inch (76.2 μm) breaks or less on 92 percent of the edges of the simple parts shown in Figure 43. 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 μm) or smaller.

A possible reason for the presence of burrs on the samples was that some workers prejudged the time normally expected for their work and therefore allowed expected production rates to override the goal of optimum quality. Although this explanation is conjecture, each individual knew his or her time and capability were going to be listed by his or her name. These individuals utilized an average of 10 minutes per part, which was half the time of inexperienced workers.

Effect of Burr Size on Deburring Time

Figure 45 illustrates how burr thickness influences removal time. Washer-like parts with 0.005 inch (127.0 μm) thick burrs took four times longer to remove than burrs 0.0015 inch (38.1 μm) thick. Obviously, thinner burrs require considerably less deburring time.

Figure 44. Percent of Edges Having an Edge Break Smaller Than a Specified Value (Produced by Experienced Deburring Workers)

Figure 45. Effect of Burr Thickness on Deburring Time

Effect of Hole Size on Deburring Time

Smaller holes frequently require more time to deburr than larger holes (Figure 46). More time is spent scrutinizing under a microscope the result of deburring small holes than larger holes. In addition, most deburring tools are designed for 0.125 inch (3.175 mm) diameter holes rather than smaller sizes. Ten percent of the allowed time is spent looking for burrs on simple parts rather than deburring. On small gears, 50 percent of the rated time may be spent just looking for minute burr fragments.

Effect of Burr Location on Deburring Time

Figure 47 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

Figure 46. Effect of Hole Size on Deburring Time

hole was 0.5 inch (12.7 mm) in diameter, a 6061-T6 aluminum part (Figure 48) required less than 3 minutes to deburr. When the 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. Processes such as abrasive flow deburring and electrochemical deburring can, however, provide smooth blending on any of these hard to reach intersections.

Figure 49 illustrates the time required for deburring slotted parts. As slot width decreases, deburring times rise exponentially when hand deburring is required.

Capabilities of Deburring Tools

The limits that each hand deburring tool and technique are capable of have not been defined. For example the questions might be asked, "Can an abrasive filled rubber bullet remove a burr and produce no more than a 0.001 inch (25.4 μ m) edge break? If it

Figure 47. Geometry of Intersecting Hole Specimen

can, how long does it require, and what technique must be used to achieve it?" Although extensive detailed information is not available some recent results provide some background information.

Figure 50 shows results obtained by a variety of tools. For example, one individual using only a miniature file was able to remove burrs and leave an edge break of only 0.001 inch (25.4 μ m). Another person could not produce a break smaller than 0.002 inch (50.8 μ m). By aggressive action, a 0.010 inch (0.25 mm) break can be produced with miniature files.

Figure 48. Effect of Cross-Hole Diameter on Deburring Time

Figure 49. Effect of Slot Width on Hand-Deburring Time

Figure 50. Basic Edge Break Capabilities Using Specific Tools to Remove 0.003 Inch Thick by 0.003 Inch High (76.2 by 76.2 μ m) Burrs from 303 Se Stainless Steel

A deburring knife or a one-inch (25.4 mm) diameter abrasive-impregnated nylon brush also can maintain 0.001 inch break provided the user is very skillful and careful (Figure 50). Typically, knives produced a 0.003 to 0.005 inch (76.2 to 127.0 μ m) break.

Some useful guidance on the aggressiveness of various tools, is available from this study. However, every individual will generate somewhat different results even under identical conditions. Part geometry and burr size also will influence the results.

Figure 51 illustrates the effect that grit size has on surface finish when various abrasive papers are used. The finish is subject to considerable variation. Worn abrasive paper and wet sanding typically produce the best finishes. Table 5 describes the finishes produced by a variety of deburring products on a sample having an initial finish of 4 to 10 microinches AA. Figure 52 illustrates the impact that some of these items have on part dimensions.

Basic Approaches to Hand Deburring

In this section, some general approaches to deburring such features as holes, slots, contoured edges, gears, and so forth are presented for general information. If other approaches are found that are easier, faster, or provide needed higher quality, they should be used.

Large Metal Parts

On most large metal parts the use of scrapers and files is adequate. For example, a 12 inch (304.8 mm) diameter threaded ring is not typically susceptible to problems from microscopic burrs. Because of its size, chamfers of 0.010 inch (0.25 mm) will not affect performance or assembly. Consequently, deburring under a microscope is not necessary.

Most inspection departments, however, expect that threaded holes will be clean and free from obvious burrs, chips, or bent entrance threads.

There is no formal policy on allowable edge conditions as a function of part size or tolerance. But a basic concept of the level of quality which is really expected or required as a function of these aspects is provided in Figure 53.

Small Metal Parts

On hand size and smaller parts, the use of microscopes for inspection and deburring is assumed; although many of the noncritical parts will not receive the 100 percent in-depth examination that others do. Miniature parts should be thoroughly cleaned prior to deburring.

Figure 51. Surface Finish Produced as a Function of Grit Size Used

Table 5. Effect of Various Deburring Products on Surface Finish

Product	Surface Finish Produced
Abrasive Filled Rubber Products	
Extra fine (gray) bullet	
Fine (brown) bullet	9
Fine disc	11
Extra fine disc	7
Coarse stick	13
Medium stick	8
Green dental bullet	12
Green dental bullet + lapping compound	20
Brown dental bullet	8
Abrasive Paper*	
150 grit	20
400 grit	6
600 grit dry	2
4/0 polishing paper	6
Crocus cloth	4
Stones	
Abrasive filled rubber tablet	9
Diamond hone	11
320 grit stone	7
Hard Arkansas	12
Fine India	
Brushes	
Steel bristle	8
Steel bristle	5
Steel bristle	10
Steel bristle	21
Brass bristle	5
Abrasive filled nylon (white)	11
Abrasive filled nylon (black)	4
Nonwoven nylon abrasive filled wheel	13

Table 5 Continued. Effect of Various Deburring Products on Surface Finish

Product	Surface Finish Produced
Hand Polishing Products	
Green unwoven nylon pad	7
Purple unwoven nylon pad	11
Purple unwoven nylon pad in butterfly brown	28

*Figure 53

The initial finish on the 302 stainless steel test coupons was 4 to 10 microinches AA.

EFFECT OF DEBURRING TOOL AND DEBURRING TIME ON PART SIZE

Figure 52. Effect of Deburring Product and Time on Part Dimensions

Figure 53. Conceptual Model of Magnification at Which Burrs Should Not Be Visible

Flat Parts. The quickest way to deburr most flat parts is to lay them on abrasive paper and wipe them in a figure-eight pattern. Typically, 320 to 600 grit paper will remove machining or blanking burrs in a minute or less.

If the parts are small (0.25 inch [6.32 mm] largest dimension for example), lapping may be faster, since 200 parts this size can be lapped in a two-minute cycle. In practice, 200 such parts would require about 30 minutes to load, run, unload, and clean.

Bur balls, brushes, and abrasive paper are typically used to remove the burrs from the flat sanding operation. Usually, however, they can be removed more economically by vibratory deburring or centrifugal barrel tumbling.

Round Parts. Most round parts are held in pin vises and deburred with knives and abrasive paper. Collecting parts in a bench motor also provides a consistent orientation below the microscope. The collets should not be tightened so hard that indentations are left on the parts.

Contours. When parts have cam-like or profiled contours, most individuals follow the contours with a knife, then use abrasive paper, and finally a brush. Where configuration allows, the abrasive filled rubber bullets or miniature dental abrasive-filled rubber products also are used.

Features in General. The following paragraphs describe typical approaches to part details that can occur on any part.

Holes. If holes are larger than 0.040 inch (1.0 mm), heavy burrs normally are removed by a bur ball. If the part has critical edge breaks a knife is typically used first, followed by the careful use of a bur ball. An abrasive filled rubber bullet or abrasive paper is used to provide a radius.

If the burr is very light, frequently a knife held parallel to the hole axis is used, followed by paper or bullet. If the production traveler does not indicate the allowable amount of edge break, it is assumed to be 0.010 inch. Requirements for typical parts, however, actually allow holes to have a bell-mouthed condition which is greater or less than 0.010 inch. As shown in Figure 54 and Table 6 the allowable bell-mouth condition could be as little as 0.004 inch (0.1 mm) on a thin part to as much as 0.020 inch (0.5 mm) on a deeper hole. This condition is allowed, but the full amount should not be used for chamfering.

On holes less than 0.040 inch (1.0 mm) diameter, the use of knives is almost impossible because of size or location. Bur balls followed by a specially "sculptured" bullet can be used.

Figure 54. Bell-Mouth Condition Allowed on Typical Parts

The miniature dental bullets allow radiusing of much smaller holes than previously was possible. Wooden toothpicks also can be successfully used to remove miniature burrs in holes. The smallest commercially available bur ball is 0.020 inch diameter, but manufacturers reportedly have made some shapes as small as 0.004 inch diameter.

Slots. Most slots are deburred with a knife or thin file, then radiused with abrasive paper. If the slot is 0.030 inch (0.75 mm) wide or larger, the dental rubber points can be used. In some cases, a miniature blasting machine also can be used to remove fine burrs from hard-to-reach areas.

Gears. A typical deburring sequence for deburring flat face gears is shown in the following sequence:

- Clean parts,
- Wipe faces on 400 to 600 grit paper,
- Deburr center hole with knife and rubber bullet,

Table 6. Amount of Bell-Mouth
Allowed on Typical
Parts (See Figure 4)

Length of Hole "T"	Maximum Allowable Length of Bell-Mouth
0.020	0.004
0.040	0.008
0.050	0.010
0.100	0.020

- Place 10 to 20 gears on a mandrel,
- Align gear teeth,
- Brush teeth with abrasive filled nylon brushes,
- Lightly sand outer diameter of teeth,
- Ultrasonically clean gears,
- Scrutinize for burrs,
- Use knife or brush to remove any remaining burrs,
- Ultrasonically clean gears, and
- Scrutinize all gears again to verify burr free condition.

In practice, some operators will swish parts in freon or other cleaning solutions stored on their benches. This operation helps clean but will not remove all particles down in the teeth. Only ultrasonic cleaning will remove all loose particles, assuring that no burrs remain.

When heavy burrs are present or when gears have a shaft rather than a center hole, they must be handled one at a time. Typically, a knife rather than a brush must be used, although brushing can be used to radius edges.

Because of the function of most gears, it is extremely important that they be free of even the slightest burr, fragment, or raised metal. From a deburring standpoint, many gears must actually be burr free at 30X magnification even though drawings may not specify such high magnification.

Tapped Holes. The following typical approach is used to deburr miniature blind tapped holes:

- Ultrasonically clean parts,
- Stone top surface to remove raised metal,
- Chamfer with bur ball,
- Remove flexible portion of first thread with knife,
- Clean crests with cross hole deburr brush,
- Blow clean,
- Chisel out chips in bottom of hole,
- Form cone with abrasive paper and radius top edge,
- Brush top surface with 1 inch nylon brush,
- Blow out,
- Ultrasonically clean,
- Blow out,
- Inspect hole, and
- Repeat steps from "Remove flexible. . ." as required.

Sometimes, abrasive paper is used instead of a stone to remove raised metal around the hole. Reamers will remove the heavy burr on the crests of threads. Using a tap to clean out burrs may be necessary, but both taps and reamers can cut threads oversize.

To remove chips from blind holes and blind tapped holes, the following tools or methods frequently are used:

- Miniature cross hole deburring brush,
- Toothpick,
- Hypodermic syringe and needle filled with solvent,

- Magnetized miniature knife or probe,
- Vacuum probe,
- Drill point,
- Simple shaking upside down,
- Air jet, and
- Ultrasonic cleaning.

Plastic Parts. Because of the flexibility of most burrs and flash on plastic parts, only a few tools are successful. Sharp scalpel blades normally are successful. Weldon style countersink tools also work well for holes in nylon and Teflon-like materials. On fiberglass products, toothpicks have been used, as has laser cleaning of edges and low temperature tumbling. Sharp cutting edges are essential.

Miscellaneous Observations

- Toothpicks and writing paper have worked well for deburring gold parts, which are very susceptible to damage. Toothpicks and writing paper also have been used to polish beryllium copper hole edges and to defuzz holes in plastic parts.
- A "Red Devil" scraper is used for small burrs on long (6 inches or more) straight edges, particularly on aluminum. For bigger burrs files or sanders are used.
- Jitterbug sanders concentrate the action on the outside edges and may not do anything to holes in the middle of a part.
- It frequently is cheaper to machine heavy burrs off than to hand deburr.
- If a tool is used to push the burr into a more favorable location, deburring time may be reduced.
- A toothpick can be used to hold some small parts while deburring without damaging them.
- A laser has been used to remove the fuzzy glass reinforcing fiber ends on some plastic parts.

Basic Concepts in Inspecting for Burrs

Many burrs, particularly minute ones, are difficult to see. Ability to see burrs improves with experience. Looking in the best direction, using the correct lighting, probing, and using gages to detect burrs may help to make burrs more visible.

Concept of the Best Direction

Looking at the correct edge but in the wrong direction makes many burrs almost impossible to see. For example, burrs on holes may not be visible if viewed from the bottom of the hole. Many of these burrs can be found by looking through the hole to the bottom surface. (Figure 55). To verify that all burrs are removed, the operator should look at the bottom side as well as through the hole. This same concept applies to all edges, not just holes. Specifically in the case of precision gears, one must look through the teeth to see all the burrs on the opposite side.

Optimum Lighting

Seven basic lighting techniques are used with microscopes. Each offers certain advantages for deburring and inspecting for burrs:

- Tensor lights off the microscope,
- Ring lights (fluorescent tube around lens),
- Nicholas illuminators off the microscope,
- Nicholas illuminators through the microscope,
- Fluorescent illuminators off the microscope,
- General purpose illuminators off the microscope,
- Coaxial illuminators (through the microscope),
- Back lighting, and
- Polarizing accessories.

Tensor Lights. Tensor lights located off the microscope provide high intensity light making viewing easier in many cases. That Tensor lights create shadows is an advantage in inspecting for burrs because any burr will cast a visible shadow. This lighting is recommended for inspecting for minute burrs. Typically, two opposing lights are used during deburring. Disadvantages of these lights are that they consume needed space in the working area and will burn hands if accidentally touched (Figure 56).

BURR MAY NOT BE
VISIBLE WHEN VIEWED
FROM SIDE ONLY.

LOOKING DOWN THROUGH THE
HOLE WILL REVEAL BURRS
ROLLED INTO THE HOLE.

Figure 55. Finding Burrs on Opposite
Side by Looking Through
Holes

Figure 56. Tensor Lights Used for Deburring

Ring Lights. Fluorescent ring lights provide uniform lighting across the entire workpiece. The light quality is similar to daylight and is shadowless (Figure 57). Less eye strain for many individuals results. Mounted around the microscope lens, fluorescent ring lights reduce the allowable working height, and burr tools can easily break the bulbs.

Nicholas Illuminators. Nicholas illuminators (Figure 57) provide a directional concentrated beam of relatively high intensity light. A single power setting is available on some lights; three levels of light intensity are offered on others. These lights can be placed at the side of the microscope, or they can be inserted in some microscope stands to provide nearly vertical lighting.

General Purpose Illuminators. General purpose lights are available. They provide an intense spot of light concentrated in a relatively small field and focusable from 3 inches to infinity. These lights also have adjustable intensity levels and can be mounted on or off the microscope. With the addition of an iris diaphragm, the size of light spot can be adjusted (Figure 57).

Nicholas Illuminator

Fluorescent
Ring Light

Figure 57. Types of Lighting for Microscope Use

Fiber Optic
Illuminator

General Purpose
Illuminator

Figure 57 Continued. Types of Lighting for Microscope Use

Fluorescent Illuminators. When surfaces are highly reflective, an off-microscope fluorescent light is helpful. All fluorescent lighting is much cooler than conventional bulb lighting.

Fiber Optic Illuminators. Fiber optic strands encased in a flexible sheath allow low to intense lighting to be directed anywhere it is needed (Figure 57).

Coaxial Illuminators. For peering into relatively deep holes or looking at flat reflecting surfaces, coaxial illuminators are highly desirable. These lights direct all light down the line of sight (Figure 58). Because the light is straight down on the workpiece, shadows are eliminated unless the part is tipped at an angle to the line of sight.

Back Lighting. Many microscopes have a mirror in the bottom of the stand or base. This mirror reflects some light upward toward the bottom of the workpiece. On some microscopes a light can be installed in the base to provide upward illumination.

Polarized Light. Polarizing attachments added to some lighting systems can reduce the glare emanating from highly reflective surfaces.

Tactile Inspection

Although most burr-related specifications at Bendix indicate that only visual means shall be used to verify absence of burrs, in practice the touch sense also is used. For example, most individuals can detect a burr only 0.0005 inch high by drawing a fingernail over the burr-laden edge. Similarly, by using a wooden toothpick or similar probe one can often verify that a suspected burr exists or does not exist. Because of a shadow effect generated by radii, determining if a black line is a burr or a radius often is difficult.

Frequently, holes will be checked for burrs by using a "go" plug gage. If it hangs up at hole entrance or exit, a burr probably is present. A special design gage has occasionally been provided to indicate the amount of burr allowable on a part.

Improving Hand Deburring

Despite extensive efforts to make hand deburring easier, faster, and more consistent, significant improvements always can be made. On many parts, operations can be improved by

- Designing special deburring hand tools,
- Purchasing standard deburring hand tools,

Figure 58. Coaxial Illumination for Microscopes
(Photo Courtesy of Bausch & Lomb, Inc.)

- Identifying workpieces which can be deburred in part by mechanized processes, and
- Identifying particularly difficult deburring requirements.

Frequently, the solution to difficult or time-consuming deburring is to make special deburring tools (Figure 59, 60) or to use a back-up material to support edges. Engineering is responsible for providing adequate tools, but those individuals performing the work can often best identify the need. Similarly, when the capabilities of the mechanized deburring processes, such as vibratory, centrifugal barrel tumbling, electrochemical deburring, and others, are recognized it will be obvious that some portion of hand deburring can best be done by one of these other methods. Although every part has different burr sizes or shapes, Table 7 lists some average production rates for several common Bendix deburring processes. These data, however, are only a basic guideline.

Whenever a problem exists on hand or mechanized deburring, the production supervisor should be notified so that timely solutions can be provided. Employees are further encouraged to suggest improvements through the Bendix Cost Reduction Proposal system and in normal informal discussions with supervision and Engineering.

A considerable amount of research on deburring has been done at Bendix. It is documented in more than 60 reports, articles, and books. The reference section lists those specifically concerning hand deburring. A complete listing of all deburring reports is available.

FUTURE WORK

Deburring is currently undergoing its own industrial revolution, and to keep abreast of new technology as well as to implement new approaches, additional research efforts on hand deburring and electrochemical deburring are in work.

Figure 59. Special Design Hand Deburr Tools

Figure 59 Continued. Special Design Hand Deburring Tools

Figure 59 Continued. Special Design Hand Deburring Tools

Figure 60. Sanding Block for Gears With Hubs

Table 7. Typical Standard Hour Run Times for Deburring

Process	Standard Hours/ 100 Parts	Parts/Hour
Vibratory Deburring	1.33	75
Centrifugal barrel finishing	1.26	80
Lap	0.5	200
Hand Sand	2.5	40
Miniature Abrasive jet	2.00	50
Vapor Blast or Glass Bead	3.00	33
Barrel Tumble	1.5	67
E.C.D.	3.0	33
Chemical Deburring	0.03	3000

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REFERENCES

¹L. K. Gillespie, Precision Deburring of Miniature Parts (Final Report). Bendix Kansas City: BDX-613-1697, August, 1977 (Available From NTIS).

²L. K. Gillespie, Hand Deburring of Precision Miniature Parts (Topical Report). Bendix Kansas City: BDX-613-1443, (Rev.) November, 1975 (Available From NTIS).

³L. K. Gillespie, Plantwide Control of Deburring Costs. SME Paper MR77-05, March, 1977.

⁴L. K. Gillespie and others, Hand Deburring: A Necessity That Can Be Improved. SME Paper MRR78-03, 1978.

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BIBLIOGRAPHY

- Gillespie, L. K. Hand Deburring of Precision Miniature Parts (Topical Report). Bendix Kansas City: BDX-613-1443 (Rev.), November, 1975 (Available From NTIS). (Same available as SME Paper MRR77-08, 1977.)
- Gillespie, L. K. A Guide to Deburring, Deflashing, and Trimming Equipment, Supplies and Services. SME Bibliography Series Report (no number), 1976.
- Gillespie, L. K., editor. Deburring Capabilities and Limitations. SME, 1976.
- Gillespie, L. K. Precision Deburring of Miniature Parts (Final Report). Bendix Kansas City: BDX-613-1697, August, 1977 (Available From NTIS).
- Gillespie, L. K. Plantwide Control of Deburring Costs. SME Paper MR77-05, March, 1977.
- Gillespie, L. K., editor. Advances in Deburring. SME, 1978.
- Gillespie, L. K., and others. Hand Deburring: A Necessity That Can Be Improved. SME Paper MRR78-03, 1978.
- Miller, B. S., "Control Deburring Quality." Metalworking, Volume 21, Number 11, November, 1965, pp 40-48.

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