MASTER

BRUSH DEBURRING - STILL A DRIVING FORCE IN DEBURRING

by

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Power driven brushes are used in practically every major metal industry. They deburr, clean, descale, polish, edge blend, and texturize parts. Despite their widespread use however they appear to be utilized considerably below their potential.

WIDELY USED BUT NOT TO THEIR FULL POTENTIAL

Brush deburring has many advantages which make it one of the most widely used deburring processes (Table 1). The fact that it uses a rotary action is a major advantage because it allows a tremendous variety of driving motors and fixturing to be utilized. The tremendous flexibility available by choosing a slightly different bristle material, diameter or length further broadens its industrial usefulness. The fact that it is safe and simple to use are two additional major advantages to industry.

One of the factors which have prevented its obtaining its deserved share of the deburring market is the fact that many potential users are unaware of the variety of non-traditional brushes which are now available. When one thinks of brushes it is normal to think of something which has straight fibers projecting from a hub. Today's brushes include a variety of materials which do not fit this concept. As an example consider the items shown in Figure 1. In the top half from left to right are:

miniature flapwheel, elastomer filled radial brush, abrasive

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Table 1. ADVANTAGES OF BRUSHING

1. It is fast.
2. It is relatively inexpensive.
3. A wide range of brushes are available.
4. It can be a non-contaminating process.
5. It will radius edges.
6. It can improve surface finish.
7. It can clean parts.
8. It is readily adaptable to manual or automatic equipment.

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FIGURE 1. NONCONVENTIONAL BRUSHES

FIGURE 2. STANDARD BRUSH STYLES

filled nonwoven synthetic wheel, abrasive filled nonwoven nylon sideaction brush, felt bob, and abrasive filled muslin wheel. In the lower half of Figure 1 is a Flex-Hone (an abrasive tipped nylon filament tube-brush-like tool).

These are not the configurations which generally come to mind when the word brush is mentioned. It is these types of deburring tools which are not widely recognized in smaller shops and which have tremendous promise for rapid burr removal. In many cases one can achieve better surface finishes as well as faster cutting than with traditional brushes.

If we classify rotary powered deburring tools by their generic names we find that there are basically eight families of tools (Table 2). While polishing buffs are recognized by most as a distinct family, many users frequently consider them as a part of the brush family. Flapwheels are a combination of both brush and sanding product. The nonwoven or matted products are to some degree a buff and to some degree a sanding product. Industry has not yet decided how to categorize all of these tools, and some manufacturers do not want their product characterized as a brush. Despite these classification problems many industry users have or will consider soft rotating wheels as a pseudo-brush.

Some of the other reasons for underutilization are listed in Table 3. The fact that selecting brushes is somewhat of a "black" art for users has to be one of the major reasons for underutilization. Users want an easy to use system that classifies brushes by their burr removal ability as well as the brushes' effect on surface finish. When faced with at least 2000 conventional commercially available deburring brushes to pick from the

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Table 2. TYPES OF ROTARY POWERED DEBURRING TOOLS

Brushes

Polishing buffs

Abrasive filled rubber products

Sanding products

Mounted points

Rotary burs

Countersinks

Special motorized deburring scrapers

small shop has a major problem knowing which product is best and which is cheapest for its need. Typically the need is immediate and there is little time to search for or experiment on potential brushes.

While the American Brush Manufacturers' Association promotes wider usage of brushes and issues some educational materials on brush availability and use, there is no single source of brush information which provides comparative data on brush performance. While each brush manufacturer has a staff which assists users in brush selection there is no visible independent source of comparative information.

As shown in Table 3 there are a variety of additional reasons brushes are not more widely used. Many of these are related to the fact that in today's world we just do not have time to evaluate all the suggestions or personally delve into specific areas. As a result we arbitrarily rule out even trying some potentially useful solutions. Rightly or wrongly we are in fact looking for panaceas and expect to find them (or have them thrust upon us) with only an initial effort.

Industry is constantly changing people from one position to another. As a result every year we must educate thousands of engineers, foremen, setup men, buyers, salesmen, and other workers on even the older time proven brushes. Figure 2 and Table 4 for example illustrate some of the variety of traditional commercially available brushes. While many experienced users are familiar with these, thousands have never seen or considered all of them. Similarly many are not aware that while in-depth recommendations are not available basic considerations in selection and use have been described in several readily available publications (see references).

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elements of good practice in deburring is that one should not bend the filaments as shown in Figure 3. That particular admonition however was based on maintaining long life in metal filled brushes and abrasive laden ~~brushes~~. Abrasive filled nylon brushes appear to be an exception to the rule when one desires smooth radii.

A second economic rule in brushing is to throw away brushes when the filaments are obviously worn out. In a recent situation one engineer tried to get workers who were using miniature abrasive filled nylon wheels to throw them away when the filaments were obviously worn out. The workers however noted that these dog-eared brushes were now ideal to use on precision ultraminiature gears. A close investigation revealed that the 0.014 inch diameter nylon filaments had tapered to 0.006 inch. These fine filaments now would reach to the bottom of gear teeth on 96 diametral pitch gears. In addition the brush was much more flexible than before and as such could maintain an edge radius of 0.005 inch maximum which was required.

While detailed brush recommendations are not available some basic concepts of selection are. Figure 4, ~~Figure 4~~, defines the first step required in selecting a brush. As indicated, when surface requirements require less than 30 microinches roughness one uses the left side of the chart section. For aggressive deburring one selects conditions in the middle of the chart. This chart in conjunction with one or more manufacturers' catalogs and a discussion with a local vendor or a brush manufacturer's staff will result in at least a reasonable first choice.

Once the initial brush choice has been tested one needs to refer to

Table 3. REASONS FOR UNDERUTILIZATION OF BRUSH DEBURRING

1. New nontraditional brushes are not well known for deburring.
2. No standard chart is available defining burr removal/surface finish capabilities.
3. No single comprehensive source of brush information is available.
4. Local vendor representatives may not be knowledgeable about products or buyers' technical deburring needs.
5. Bad experience with previous use biases customer attitude.
6. Wide range in user need implies a large variety of brushes is needed.
7. Sizes available are not well publicized.
8. Ready availability of special made brushes is not known.
9. Continual turnover in industrial manpower results in loss of brush knowledge.
10. Industry looks to new processes and forgets the old ones.

Table 4. STANDARD DEBURRING BRUSH CONFIGURATIONS

Radial brush

End brush

Cup brush

Cross hole or tube brush

Side action brush

Sibot or square brush

Flare brush

Each year the brush industry introduces several new brush sizes, shapes, or material combinations. A recent survey of 9 brush manufacturers' catalogs revealed that a much wider range in brush sizes is available than is found in any one manufacturer's catalog alone (Table 5). The actual range in sizes available is even larger than shown because some manufacturers make special brushes for individual customers. As an example cross hole deburring brushes only 0.024 inch in diameter are being purchased by one user in quantities of only 200 - 400 per order. As indicated in Table 3 many users have overlooked the potential of relatively low cost specially fabricated brushes.

AGGRESSIVENESS OF BRUSHES

There are 10 factors which influence the burr removal ability of brushes (Table 6). For maximum aggressiveness one wants a brush with large diameter, short filaments closely packed together. Knotted or crimped filaments add stiffness as does a wider wheel. Where the diameter of the filaments performs the deburring (rather than the ends) a rough filament surface provides greater abrasion. Typically one desires to cut with the ends of the filaments although with abrasive filled nylon brushes a sliding of filaments over an edge adds to the radiusing action. Faster velocities increase the effective stiffness of brushes.

One typically thinks of brush filaments as having a uniform diameter since they normally begin that way. After use however the brush ends may not be uniform. As an example when one bends the filament of nylon brushes during deburring (Figure 3) the ends become tapered. Because they are tapered they are less stiff and consequently cut less. One of the common

Table 5. SIZE RANGES OF COMMERCIALY AVAILABLE STANDARD BRUSHES

<u>Brush Type</u>	<u>Filler Material</u>	<u>Size Range Available (inch)</u>
Radial	Stainless Steel	3/4 - 15
	Brass	3/4 - 6
	Nylon	3/4 - 2
	Abrasive filled nylon	1 3/8 - 14
	Nonwoven abrasive filled nylon	2-6
	Tampico	2-16
	Cord filled	1-16
	Abrasive tipped	1/2 - 2
	Elastomer filled	1 1/4 - 12
	Flapwheel	1 - 16
	Felt bob	1/4 - 3
	Abrasive filled muslin	3/16 - 1
Cup	Stainless Steel	3/4 - 6 1/4
	Brass	3/4 - 3/4
	Elastomer filled	4 - 6
End	Stainless Steel	1/4 - 1
	Elastomer filled	1/2 - 1
Cross Hole or Tube	Stainless Steel	1/32 - 3
	Brass	1/4 - 2
	Nylon	1/4 - 2
	Elastomer filled	1/2 - 1
Side Action or Sibot	Stainless Steel	1/4 - 1 1/4
	Brass	1/4 - 7/8
	Nylon	1/4 - 7/8
	Abrasive filled nonwoven nylon	1/2 - 3
Flare	Steel	1 1/2 - 4

Table 6. FACTORS AFFECTING BRUSH AGGRESSIVENESS
(Conventional Brushes)

Diameter of filaments

Free length of filaments

Filament material

Filament configuration

Density of filaments

Texture of filaments

Velocity of wheel

Width of wheel

Type of contact with part

Configuration of filament end

FIGURE 3. BENDING FILAMENTS SHORTEN THE LIFE OF METAL BRUSHES BUT PROVIDES SMOOTH RADII WHEN ABRASIVE FILLED NYLON FILAMENTS ARE USED.

CHART NO. 1

FIGURE 4

Chart No.II (Figure 5) to help determine improved brush properties.

Again discussions with a brush manufacturer's representative and close examination of catalogs are required to obtain the best result in the shortest time.

As a general rule researchers have failed to record the relationships between initial burr size, resulting edge radius and brushing time. As a result there is little quantitative information about brush deburring. As a brief exception however tests have shown that when the intent is to remove a 0.0005 inch thick grinding burr and produce a minimum radius miniature brushes can easily do this at a feed rate of 1 to 2 inches per minute and a speed of 1800 SFPM. Table 7 illustrates some comparative results. As seen there the nylon brushes maintained significantly smaller edge breaks than the stainless brush which had much smaller filaments.

Edge breaks as small as 0.003 inch have been maintained on both ferrous and aluminum parts while removing burrs. As in all deburring processes however maintaining small edge breaks requires that the initial burrs also be small. Smaller burrs also allow one to use softer wheels which can hold finishes as low as 4 microinches.

Because of the need for verifiable comparative information on brushes many large companies have to perform their own testing. Unfortunately many rule out products before they are tested. As an example one manufacturer typically removed large burrs on miniature parts with special designed knives then brushed with the nylon brushes described in Table 7. This produced edge radii of the desired size and finish. Previous efforts to use brushes only failed because of too much edge breakdown. When a

CHART NO. II

FIGURES

OBSERVED RESULTS

BRUSH WORKS TOO SLOWLY	BRUSH WORKS TOO FAST	FINER OR LOWER MICRO INCH SURFACE REQUIRED	SURFACE FINISH IS TOO SMOOTH AND LUSTROUS	BRUSHING ACTION NOT SUFFICIENTLY UNIFORM	ACTION OF BRUSH PEENS BURR TO ADJACENT SURFACE
<ul style="list-style-type: none"> • INCREASE BRUSH OUTSIDE DIAMETER • INCREASE BRUSH SPEED • DECREASE TRIM LENGTH THEREBY INCREASING THE BRUSH FILL DENSITY • INCREASE FILAMENT DIAMETER • CHANGE BRUSH TO HEAVIER DUTY TYPE 	<ul style="list-style-type: none"> • REDUCE TRIM LENGTH • DECREASE FILAMENT DIAMETER • REDUCE BRUSH OUTSIDE DIAMETER • REDUCE BRUSH SPEED • SELECT BRUSH TYPES HAVING LOWER BRUSHING ACTION STRENGTH 	<ul style="list-style-type: none"> • DECREASE TRIM LENGTH THEREBY INCREASING BRUSH FILL DENSITY • DECREASE FILAMENT DIAMETER • SELECT BRUSH CAPABLE OF PRODUCING LOWER MICRO INCH SURFACE FINISHES • USE AUXILIARY ABRASIVE COMPOUNDS OR OIL BASE LUBRICANTS WITH BRUSH • INCREASE BRUSH SPEED 	<ul style="list-style-type: none"> • INCREASE TRIM LENGTH • INCREASE FILAMENT DIAMETER • SELECT A BRUSH TYPE CAPABLE OF PRODUCING COARSER FINISHES • REDUCE BRUSH SPEED 	<ul style="list-style-type: none"> • INCREASE TRIM LENGTH • CHANGE BRUSH TYPE FROM SECTIONAL TO HELICAL CONSTRUCTION • SELECT SUITABLE BRUSHING MACHINERY • OSCILLATE BRUSH TO AVOID "TRACKING" 	<ul style="list-style-type: none"> • DECREASE TRIM LENGTH • SELECT HIGH DENSITY CRIMPED WIRE WHEEL • FOR DUCTILE METALS CHANGE FROM WIRE FILLED BRUSH TO NON-METALLIC FILLED BRUSHES
BRUSH FACE LOADS WITH MATERIAL BEING REMOVED	BRUSH DEVELOPS EXCESSIVE HEAT	BETTER CONTROL OF BRUSHING PRESSURE	BRUSH WIRE FILAMENT ENDS BECOME DULL	IMPROVE BRUSH DYNAMIC BALANCE CONDITION	BRUSH FACE WEAR UNEVEN OR GROOVING
<ul style="list-style-type: none"> • INCREASE BRUSH TRIM LENGTH • INCREASE BRUSH FILAMENT DIAMETER • IF WET APPLICATION APPLY SOLUTION THROUGH BRUSH ARBOR AND DISPERSE OUTWARD THROUGH BRUSH FACE • WHERE CLEANING SOLUTIONS ARE USED WITH BRUSH MODIFY CLEANER FOR BETTER SOLUBILITY • CHANGE BRUSH FILL SPECIFICATIONS 	<ul style="list-style-type: none"> • USE INTERNAL COOLING OF BRUSH AND BRUSH ARBOR • REDUCE BRUSHING PRESSURE • SELECT HEAVIER DUTY BRUSH • INCREASE BRUSH TRIM LENGTH • REDUCE BRUSH PERIPHERAL SPEED • USE EXTERNAL COOLING OF BRUSH 	<ul style="list-style-type: none"> • INCREASE BRUSH TRIM LENGTH • INSTALL METERS TO MEASURE BRUSHING LOADS • WHEN PART SIZE VARIES DESIGN PRESSURE RELIEF IN PART HOLDING FIXTURE • WITH AUTOMATIC BRUSHING EQUIPMENT ALLOW BRUSH TO FLOAT OR PROVIDE AUTOMATIC PRESSURE SENSING AND PRESSURE ADJUSTING 	<ul style="list-style-type: none"> • REVERSE ROTATIONAL DIRECTION OF BRUSH TO AUTOMATICALLY RECONDITION • DRESS THE BRUSH FACE WITH AN ABRASIVE STONE (WITH THE BRUSH OPERATING IN A DIRECTION REVERSE OF NORMAL USE) • SELECT A HEAVIER DUTY BRUSH • KEEP BRUSHING HEAT AS LOW AS PRACTICAL 	<ul style="list-style-type: none"> • WHEN WIDE FACED BRUSH UNITS ARE MADE UP OF THIN SECTIONS, STATIC BALANCE EACH SECTION AND STAGGER HEAVY SIDES • CHANGE FROM SECTIONAL BRUSH ASSEMBLY TO A HELICALLY FORMED BRUSH • DYNAMICAL BALANCE BRUSH ARBOR AND BRUSH ASSEMBLY • REDUCE BRUSH SPEED • CHECK ENTIRE BRUSH DRIVE TRAIN FOR IMBALANCE 	<ul style="list-style-type: none"> • IF POSSIBLE HAVE PART CONTACT BRUSH SO THAT THE FULL FACE OF BRUSH IS ON THE PART • CONSIDER OSCILLATING BRUSH OR PART • PROVIDE A MEANS FOR PERIODICALLY DRESSING THE BRUSH FACE • AVOID EXCESSIVE BRUSHING PRESSURE • CHANGE FROM SECTIONAL BRUSH ASSEMBLY TO A HELICALLY FORMED BRUSH PART

Table 7. COMPARATIVE RESULTS OF MINIATURE BRUSHES

<u>Brush Description</u>	<u>Workpiece Material and Brinell Hardness</u>			
	303Se Stainless Steel (226)	Beryllium Copper (187)	7075-T6 Aluminum (150)	6061-T6 Aluminum (95)
Resulting Edge Radii (inch)				
Stainless Steel Brush .003 Filaments	0.0064	0.0085	0.0174	0.0186
.014 Diameter Nylon Filaments with 600 Grit Silicon Carbide	0.0064	0.0053	0.0070	0.0082
.018 Diameter Nylon Filaments with 500 Grit Aluminum Oxide	0.0058	0.0079	0.0062	0.0066

wider, denser brush was obtained with .024 inch diameter bristle and a trim length of .250 inch instead of .375 inch it was obvious to all concerned (engineers and workers alike) that the brush was considerably too stiff. The brushes laid in a box for several weeks until an individual tired of knife work tried them. That brush, which obviously wouldn't work, did and saved several thousand hours.

A similar incident occurred with the muslin filled wheel shown in Figure 1. It obviously wasn't aggressive enough. When it was tested however it worked excellently. The fact that it was small, readily available, and could be shaped with a file or knife made it an excellent choice for miniature as well as hand size parts.

BRUSHING SIDE EFFECTS

Brushing can create a number of side effects (Table 8) which can be beneficial or detrimental depending upon the application. The degree to which some of these items occur depend in part upon whether brushing involves entire surfaces or merely edges.

The fact that brushes can produce finishes as fine as 4 microinches is a distinct advantage for most companies. Others take advantage of the fact that brushes can leave a decorative texture on surfaces. Turbine and air-frame manufacturers employ brushes in part because they smooth out tool marks which are points of high stress concentration. Jet engine manufacturers for example have found that half the failures in their parts can be traced to stress concentrations and progressive fractures such as scratches, sharp edges, or burrs. The elimination of these stress concentrations greatly extend fatigue life.

Table 8. BRUSHING SIDE EFFECTS

- Surface finish changes
- Surface texture changes
- Removal of stress raiser tool marks
- Residual stress changes
- Surface Hardening
- Fatigue life changes
- Contamination of part surfaces
- Dusty environment
- Part size change
- Generation of new burrs
- Color changes

Wire filled brushes can greatly affect the residual surface stresses (and as a result harden a surface). Research over the past 100 years indicates that as a result of chemical, thermal, and mechanical interactions during surface brushing surface residual stresses can increase dramatically. As an example one researcher noted that hardness near the part's surface was 5 times larger than in the center of the part.

Others have shown that work hardening as opposed to brushing can only double the hardness. If one assumes that hardness is proportional to yield strength then the residual stresses near the surface would be five times larger than the bulk stresses. Those high stresses occur in a layer only a few thousandths of an inch thick. While these typically greatly help increase fatigue life they can decrease life in thin materials or in materials whose inner core has high tensile residual stresses. In addition on thin nonsymmetrical parts part distortion can easily occur.

Surfaces whose texture is similar to that of orange peels are apparently one additional side effect of these stresses. This particular condition however can be easily seen and corrected by reducing the frictional heat generated by the brush.

Any time a foreign material contacts a part the part is contaminated. Thus when one brushes stainless steel with a carbon steel brush carbon steel is deposited on the part. This will allow rust spots to occur on a normally "rust proof" surface. Brass brushes used on steel will leave a yellow brass coated part. Nylon if used at high speeds will melt on parts leaving black splotches and probably a thin invisible layer of nylon. Tampico wheels when used with grease base "burring" compounds leave obvious muddy like deposits on the part which in some cases is harder to

remove than the burrs. Diamond lapping compounds can similarly be almost impossible to remove from hard to reach recesses. In the case of some aluminums anodizing will not be complete if foreign particles are embedded in the surface. Similarly if large amounts of aluminum oxide are embedded in steel parts, welding, soldering, and brazing can be impossible to perform satisfactorily. At the present time however abrasive impregnated nylon or synthetic brushes do not appear to impregnate abrasives into the workpiece in quantities sufficient to cause problems for the majority of industry. In contrast tumbling or blasting processes produce gross surface contamination. In some situations the color of a part will change slightly as a result of brushing. This can improve or diminish the aesthetics of a part.

Contamination can be carried over from one part to another. As an example if a nylon brush is used on aluminum parts then on stainless steel, the stainless steel part will have traces of aluminum on it. Similarly nylon brushes in particular will pick up oil, grease, or other coatings from one part and deposit them on the next. This can be a source of concern when hand deburring parts which require high levels of cleanliness.

The use of "burring" compounds with tampico wheels, metal filled wheels, buffing wheels, or felt bobs results in a large quantity of particles and clumps of compound thrown into the atmosphere and the work area. Because the process is inherently dirty, safety regulations must be followed.

By the nature of the process one changes the dimensions of the part

every time a brush is used. It is after all a metal removal tool or it couldn't improve surface finishes. Generally the amount of size change is small (0.000050 inch for example) except at edges where burrs are to be removed. It is possible, however, to make significant size changes. If for example one holds an abrasive filled muslin wheel such as shown in Figure 1 on the same spot for 1 minute at 10,000 rpm the part will have a gouge in it 0.010 inch deep.

Brushes have an advantage over other products that they will brush down into a hole while the surface is being brushed. This removes some of the burrs frequently left by flat belt sanding. If, however, one selects an incorrect wire brush or speed the brush can generate burrs on edges which were initially burr free.

BRUSH DEBURRING EQUIPMENT

At least 10 manufacturers produce standard or special design machines for brush deburring. A number of other manufacturers also manufacture bench motors, pedestal grinders and single and two spindle polishing lathes. The fact that simple machines are so inexpensive and readily available makes it easy to initiate brush deburring and to experiment without affecting production needs.

Many companies, however, have overlooked the fact that brushing parts on the machine which produces the part can be more economical than using a secondary brushing operation. Even screw machines can have brushing cycles designed into cams and tooling. Putting a five spindle and brush in a lathe turret for example can allow one to brush I.D. or O.D. without additional handling. It also has the advantage that if the brush doesn't

remove the burr the operator knows immediately that sharper tools or different machining techniques are required. In this case the operator controls both the burr and its removal. This eliminates the unreasonably large burrs one can find when these responsibilities are separated.

The abundance of N/C equipment and industrial robots provide great flexibility in on-machine deburring. N/C milling machines for example can machine the part, deburr it and inspect it in a single set up. It does not appear, however, that many have taken advantage of the possibility of the fast and thorough brushing possibilities offered by their N/C equipment. At least one manufacturer however is documenting the tradeoffs in this approach.

DEBURRING ECONOMICS

The time required for brush deburring can vary from 5 seconds per part to 15 minutes depending upon the degree of automation used and part complexity. Most commercial semi-automatic machines, however, can finish parts in 60 seconds or less. As an example one gear brushing machine requires 32 seconds per side for a 61 tooth gear 10 inches in diameter. Hydraulic servo valves are being deburred with abrasive filled nonwoven nylon pads as a rate of 245 per hour. Fully automated lines produce 600 to 2000 parts per hour.

The following equation defines the major cost factors in brush deburring.

$$C = \frac{C_D + C_M + WC_P}{N} + \frac{C_B}{N_p} + \left[\frac{C_L}{N} + \frac{C_A}{N_c} + \frac{C_L t_s}{n} \right] \left[1 + D_o \right] + \frac{A(F + H + L_i + I + G)}{H_y N}$$

Where:

C = Deburring cost per part

C_D = Depreciation cost per hour machine cost/operating hours

C_M = Maintenance cost per hour of operation

C_L = Labor cost per hour to run machine

C_P = Cost of power used (\$/kilowatt hr)

C_A = Cost of cleaning per hour after deburring (labor & material)

C_B = Cost of brush

D_O = Overhead as percentage of labor rate

N = Number of parts run per hour

N_p = Life of brush (number of parts run)

N_c = Number of parts cleaned per hour

n = Number of parts per setup

t_s = Setup time (hour)

W = Power used, kilowatts (1 hp = 0.75 kw)

F = Yearly floor space costs (\$/sq ft/yr)

H = Yearly heating costs for deburring area (\$/sq ft/yr)

L_i = Yearly cost of lighting for deburring area (\$/sq ft/yr)

I = Yearly insurance costs for deburring area (\$/sq ft/yr)

G = Any other yearly general overhead costs (\$/sq ft/yr)

H_Y = Hours per year the deburring area is used

A = Floor area of operation (sq ft)

Assume that the brushing operation is in a job shop which has to make and deburr a wide variety of parts in a given week. Two hundred parts are being run. A \$2500, 1HP pedestal grinder will be used and its life is 5,000 hours. The deburring which will require hand holding the part against the wheel will require two minutes per part. The 8 inch abrasive filled nylon brush used costs \$20 and will last for 1500 parts. In this case no subsequent

cleaning is required and the floor space needs are small. Further assume the other costs shown in table 9 are applicable.

With these assumptions the cost per part is 28 cents. When one evaluates each of the four terms in this equation it is obvious that labor is the most expensive item in this list. In this case labor constituted 83 percent of the deburring cost. Even if one assumed that the \$20 brush had a life of only 150 parts labor would represent 59 percent of the deburring cost.

Consider now a fully automated machine which produces 240 parts per hour and costs \$25,000. Its life is projected to be 10 years at 2000 hours per year. Maintenance costs are expected to be 20 percent of the yearly depreciation costs. Labor is \$6 per hour and overhead costs are 50 percent of direct labor costs. Assume a total of \$80 of brushes is required and these must be replaced every 1000 parts. Setup time is 2 hours and 3000 parts will be finished on this setup.

With these assumptions the cost per part is 13.2 cents. In this case labor represents only one third of the deburring costs. The brush cost is responsible for almost two thirds of the cost.

Assume now a fully automated line which produces 1200 parts per hour and costs \$80,000. Its life is expected to be 10 years at 4000 hours per year. Maintenance and labor costs are as shown in Table 9 and overhead is 25 percent of direct labor costs. Assume that brushes will last 3000 parts and cost \$80 total. Setup time is 4 hours and 80,000 parts will be finished on this setup. Further assume that some subsequent cleaning is required because of the brushing compounds. The cleaning

Table 9. EXAMPLES OF UNIT DEBURRING COSTS

Cost Item	Example No. 1 Short run	Example No. 2 Automated Machine	Example No. 3 Automated Machine	Example No. 4 Hand Operation
C _D	0.50	1.25	2.00	.01
C _M	0.05	.25	.40	0
C _L	5.00	6.00	6.00	5.00
C _P	0.04	0.04	0.04	0.04
C _A	5.00	6.00	6.00	6.00
C _B	20.00	80.00	80.00	1.25
D _o	0.30	0.50	0.25	0.20
N	30	240	1200	120
N _P	1500	1000	3000	200
N _C	--	--	1200	--
n	200	3000	80,000	100
t _s	0.05	2.00	4.00	0.03
W	0.75	0.75	3.00	0.75
F	5.00	5.00	5.00	5.00
H	1.40	1.40	1.40	1.40
L _i	0.50	0.50	0.50	0.50
I	0.10	0.10	0.10	0.10
G	1.00	1.00	1.00	1.00
H _Y	500	2000	4000	2000
A	36	200	600	5
Calculated C	\$0.281	\$0.132	\$0.042	\$0.059

production rate is the same as brushing. (We ignore the cost of cleaning equipment in this example but it should be considered in many instances). The equipment used in this instance requires 4HP.

For this situation the brushing cost per part is slightly over 4 cents per part. In actual practice on simple parts brushing costs as low as 1 cent per part should be attainable. The key to low cost in automation is long brush life per dollar of brush cost and high production rate. From a technical standpoint small burrs are a necessity to make these two economic factors possible.

As a final example assume a hand deburring operation requires only a small bench motor and utilizes a 1 1/2 inch nylon brush which costs \$1.25 and has a life of 200 parts. Brushing can be done at a rate of 120 parts per hour and the lot size if 100 parts. Setup time is 2 minutes. Further assume that the example 4 data in Table 9 is applicable. A \$300 motor will last 15 years at 2000 hours per year.

As seen in Table 9 the cost per part is only 6 cents for brushing. Again the success of low cost brush deburring requires burrs which are small enough to be removed satisfactorily at the indicated rate.

CONCLUSION

Brushes are a particularly economical deburring method for small shops which do not have high production nor the space to install special machines. While the cost of brushing doesn't compete with the cost of barrel tumbling or vibratory finishing it does not require as much room nor is it as likely to damage critical parts. The fact that it cleans and polishes and is as adaptable as it is will continue to keep it in its position as one of the most widely used deburring processes.

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CAPTIONS FOR FIGURES

Figure 1. Nonconventional brushes

Figure 2. Standard brush configurations (courtesy Weiler Brush Co.)

Figure 3. Bending filaments shorten the life of metal brushes but provides smooth radii when abrasive filled nylon filaments are used.

Figure 4. Chart No. II. Making the initial brush selection (reproduced courtesy Anderson Brush Co.)

Figure 5. Chart No. II. Optimizing the choice of a brush (reproduced courtesy Anderson Brush Co.)

**Kansas City
Division**

P.O. Box 1159
Kansas City, Mo 64141
The Bendix Corporation

Lucille Heater
Weiler Brush Company, Inc.
Cresco, Pennsylvania 18326

December 20, 1978

Dear Ms. Heater:

I request permission to use the illustration on page 21 in your catalog number 777 in an article to be published by Machine and Tool Blue Book. The article will be entitled "Brush Deburring - Still a Driving Force in Deburring". This article is scheduled to be published in the March, 1979, issue. For this article the source of the illustration will be cited below the illustration as "(courtesy of Weiler Brush Co.)".

I appreciate the materials which you have sent to me and while your verbal approval is acceptable for immediate needs, written permission is required before the article is published. Your prompt consideration of this request will be greatly appreciated. A release form is given below for your convenience. The duplicate is for your file.

Yours truly,

LaRoux K. Gillespie
Electromechanical Products
Department 822, 2A36

LKG/vlm

I (we) hereby grant permission for the use of the material requested above.

(signed) _____

Date: _____

(Publisher)

**Kansas City
Division**

P.O. Box 1159
Kansas City, Mo 64141
The Bendix Corporation

Bob Sasena
Anderson Corporation
1040 South Bridge St.
Worcester, Massachusetts 01610

December 20, 1978

Dear Mr. Sasena:

As I indicated on the telephone yesterday I would like to have your written permission to use the Anderson "two step chart" for selecting appropriate brushes for deburring. This chart will be broken down into two illustrations for an article entitled "Brush Deburring - Still a Driving Force in Deburring" which will be published in the March, 1979, issue of Machine and Tool Blue Book.

An acknowledgement of the source of chart will be made in the figure legend as "(reproduced courtesy of the Anderson Brush Co.)".

While your verbal approval is acceptable for the immediate needs, for our records it is essential that we have written permission. A release form is given below for your convenience. The duplicate is for your file. I sincerely appreciate your prompt consideration of this request.

Yours very truly,

LaRoux K. Gillespie
Electromechanical Products
Department 822, 2A36

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I (we) hereby grant permission for the use of the material requested above.

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