Abrasive Filament Brush Deburring of Powdered Metal Components

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The deburring of PM parts is commonly performed in a batch process. This typically involves loading a quantity of parts into a vibratory bowl filled with abrasive media. The vibration of the bowl causes the abrasive media, and parts, to “flow”. This interaction between the media and parts gradually abrades all surfaces of the part. Drawbacks to this process include part impingement upon one another, waste generation, lodging of media into the part, deburring of unnecessary areas on the part and the inherent vibration and noise created by the operation of these systems.

This paper discusses an abrasive filament medium which is ideal for deburring and edge radiusing PM parts. When formatted into a brushing tool, it can be applied on machine based systems for semiautomated or fully automated deburring of PM components. Through proper application, it is possible to gain the advantages of productivity, quality, and economics without the negatives associated with alternative methods.

FIBER ABRASIVES

The term “fiber abrasive” is used to describe an abrasive nylon filament. Developed approximately 25 years ago, they are commonly employed in brush form for a variety of industrial applications. These generally involve deburring, edge radiusing and general surface finishing.

The filament is composed of nylon, which has been coextruded with an abrasive grain. The resulting monofilament is a homogeneous structure of nylon and abrasive. Nylon is an ideal material for a brush filament. Compared to other polymers, it excels not only in its durability, but also in its resistance to moisture, abrasion and chemicals (1). Nylon types used in the production of fiber abrasives are Type 6, Type 66 and Type 612. Type 612 is preferred in industrial applications. It offers the greatest heat resistance and least amount of moisture absorbency.

The grain, or grit, is impregnated throughout the filament as well as exposed on the external surfaces. A magnified example of this filament is shown in figure 1.

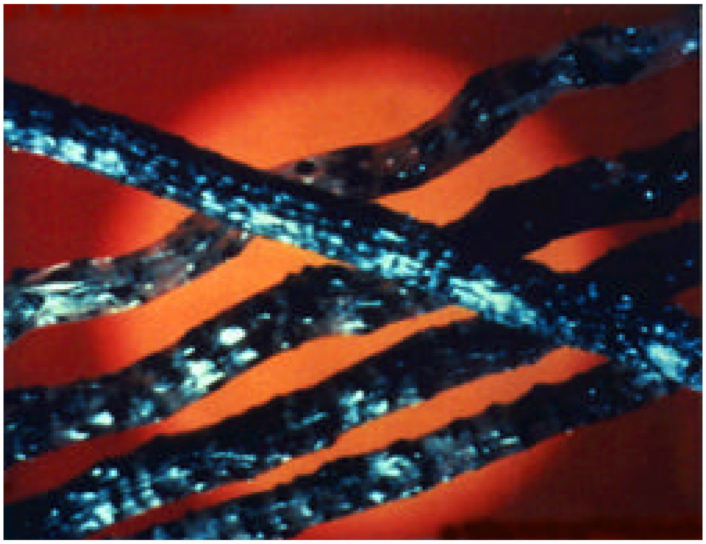

Figure 1: Enlarged View of Nylon Filaments

Abrasive action occurs on both the tip and the sides of the filament. As the filament is applied to the workpiece and begins to wear, new abrasive grit is exposed. The filament is, in effect, self sharpening. The filament is typically applied at slower speeds in order to allow it to strike and wipe against the workpiece surface. It acts much like a flexible file. This feature makes it ideal for finishing irregularly shaped surfaces.

Abrasive options are, for the most part, limited to silicon carbide and aluminum oxide. Other, more exotic abrasives are available. Diamond abrasives are available, but their expense limits their use to very specific applications. Grit sizes range from 600 through 46 (mesh number used in abrasive separation). Smaller grit numbers relate to larger grit particle size, larger grit numbers relate to finer (smaller) grit particle size. Filament diameters range from .012" - .060". As seen in Table 1, filament diameter increases as grit size increases. This relationship is necessary in order to effectively bind the abrasive. By weight, abrasive loading of the filament ranges from 20% to 40%.

Table 1.

Filament Dia. Inches (mm)	.012 (.30)	.018 (.46)	.022 (.56)	.030 (.76)	.035 (.089)	.040 (1.02)	.060 (1.52)
Grit Size	600	500 600	120 320	240	180	80 120	46

Silicon carbide is the most widely applied abrasive in fiber abrasive brushing tools. Silicon carbide combines cost effectiveness with excellent hardness and sharpness, making it ideal for deburring applications. Aluminum oxide is less likely to fracture and is not as "sharp" as silicon carbide. These characteristics create a filament that is generally applied to improve surface finishes.

Regardless of grit size or type, the fiber abrasive is not a heavy material removal tool. Although a large grit size can be applied (up to 46 mesh), the flexibility of the filament limits its cutting action. The fiber abrasive does remove some material, but at a minimal rate. With this feature, burrs and sharp edges are preferentially abraded away. This enables the tool to deburr without negatively affecting the size and dimensional tolerances of the part.

BRUSHING TOOL FORMATS

Fiber abrasives are typically formatted into brushing tools using conventional brush making machinery. Abrasive brushing tool formats include: disc, wheel, cup, end and tube as seen in Figure 2. Brushes of this type are applied with portable pneumatic and electric hand tools, manual stationary equipment (drill press, pedestal grinder, buffing lathe), semiautomated (CNC, NC, robotics) and fully automated, dedicated finishing systems.

Figure 2: Common brushing tool formats

PM PART DEBURRING

For deburring PM parts, two brush formats are commonly used; the radial wheel and/or the disc.

1. Radial Wheel

The radial wheel, as the name implies, employs fibers extending radially from a hub. The brush is mounted on a shaft and rotated in a direction that causes the fibers to strike the part perpendicular to the surface to be deburred. With a radial wheel, the brushing action is unidirectional as shown in figure 3.

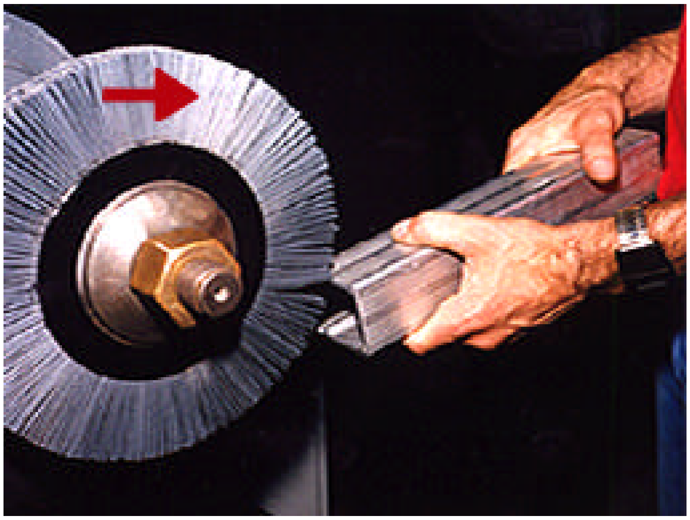

Figure 3: A radial wheel offers unidirectional brushing action

Deburring with a radial wheel brush can be either an off-hand process or machine based. Limitations of off-hand deburring include low productivity, irregular quality and potential for operator injury. Due to these factors, off-hand deburring of PM parts is rarely, if ever, employed.

Machine based deburring systems employing radial wheel brushes are designed to accommodate their unidirectional brushing action. This inevitably involves rotating the part to present the targeted surface at a 90 degree angle to the striking action of the filaments. Radial brushes, and the machinery to drive them, are often employed on parts which have multiple surfaces, on varying planes, to be deburred. An example would be a gear with a protruding hub where both the gear teeth and the hub face require deburring. Radial wheels are produced in diameters ranging from 1 inch through 21 inches.

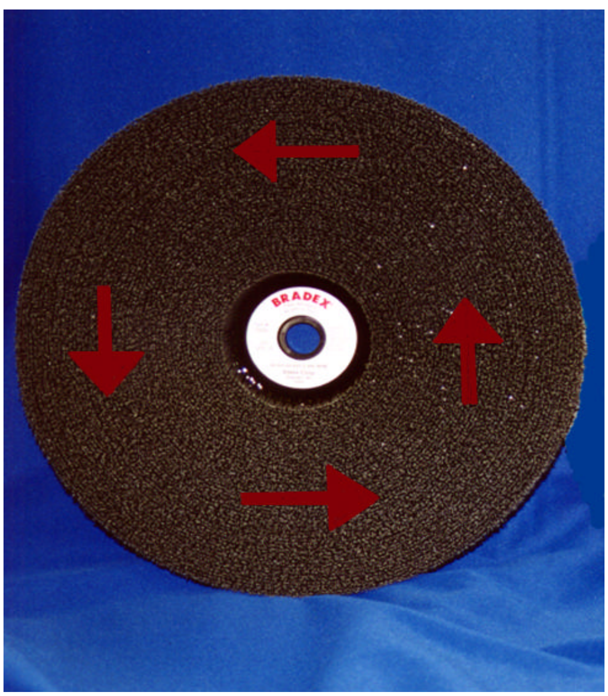

Figure 4: Disc format offers multidirectional brushing action

2. Disc

The disc is constructed of a backing into which the filaments are embedded. The fibers extend perpendicularly from the backing. Unlike the unidirectional brushing action of the radial wheel, the disc offers multidirectional brushing action as illustrated in figure 4. As a part traverses across the face of the disc, several surfaces are deburred. Because of this multidirectional brushing action, the disc brush tends to be a more efficient format for deburring PM parts. Disc brushes can be employed when the surface to be deburred is flat with little or no changes in elevation. Disc brushes are available from 2 through 48 inches in diameter.

BRUSH CONSTRUCTION

Variables in brush construction affect their performance in this application. The quality of the process is dependent upon optimizing each of these variables in relationship to each other. These variables are:

- Density
- Trim Length
- Filament Diameter
- Grit Size

1. Density

Density refers to the number of individual filaments in the brush. In either format, radial or disc, maximum density could be achieved by packing the filaments against one another, offering an almost solid face. This would not be practical in this application.

The individual filaments need to flex in order to provide a wiping action that will follow the contours of the part. Heat dissipation is also critical in order to avoid a condition referred to as “nylon smear”. The melting point of the nylon used in the filament is 410° F. Extreme density can contribute to heat generation sufficient to approach or exceed this melting point. When this occurs, the melted nylon is transferred onto the part where it cools and bonds. This process occurs almost instantaneously. This “nylon smear” appears slightly translucent on the part and can be difficult to remove.

Using a brushing tool with too little density may require prolonged dwell time in order to effectively deburr. Individual filaments are now required to work harder with less support. This leads to premature filament breakage and reduced brush life.

The optimal brush density is shown in figure 5. The filaments are distributed evenly across the face of the brush. Filaments are close enough to support one another yet spaced to allow flex and heat dissipation.

2. Trim Length

The trim length is the length of the visible filament, or the distance from the tip of the filament to its base. Trim length affects how aggressive the brushing action is. Generally, with all other variables fixed, the brush becomes more aggressive as the trim length is shortened. Assuming proper density, the increase in aggression as the brushing tool wears is generally not detrimental in this application. Longer trim lengths, however, will reduce aggressiveness. To compensate, longer dwell times are needed. There also is the tendency to increase part penetration into the brush face. This is counter productive as cycle times increase and brush life decreases. The ideal trim length is that which offers adequate aggression and maximizes brush life.

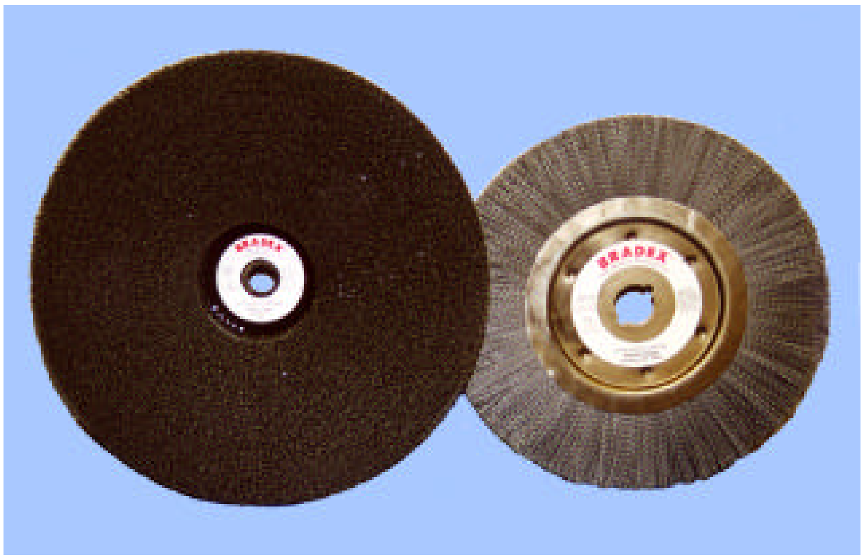

Figure 5: Optimal brush density

3. Filament Diameter and Grit Size

In many applications, it is often most effective to use a smaller diameter filament. This is true for PM part deburring. The filament is more flexible and, in a given density, more abrasive surface area can be exposed to the part. Larger diameter filaments may have a tendency to hit and bounce off the part (1). Larger diameter filaments also lack in flexibility. They are more apt to fracture and break off instead of wearing consistently, leading to accelerated brush wear. As was seen in Table 1, grit size and filament diameter are related. The most commonly applied disc brush for deburring PM parts employs a filament diameter of .022" and a grit size of 120. Radial wheels, with generally longer trim lengths, typically employ filament diameters ranging from .030" to .040" and grit sizes of 240 to 120.

BRUSH SPEED

Rotational speed of the brushing tool is also a critical factor in this process. The rule of thumb for the application of fiber abrasives is for brush speed not to exceed approximately 3500 surface feet per minute. Optimal speed, however, is determined by considering the brush construction variables and the parts to be deburred. With abrasive filaments, increased speeds result in more aggressive cutting action. Slower speeds allow the filaments to work on all intended surfaces and contributes to extended brush life. The ideal speed is that which minimizes cycle time and maximizes brush life. Machine builders, experienced in deburring PM parts, design their equipment to operate at the most efficient speeds.

EQUIPMENT

As mentioned earlier, both radial and disc brushes are typically applied on a machine based system. Either brush is capable of deburring the part. The challenge is to present the part to the brush, or the brush to the part, in a manner which maximizes:

- Productivity
- Quality
- Economics
- Safety

Several machine designs exist to realize these benefits.

1. Rotary Tables

A rotary table is generally designed to apply radial wheel style brushes. The basics of the system involve an indexing rotary platform with spindles tooled to accept a part or a closely related family of parts. Parts are typically loaded, deburred and brought back to the starting point for unloading. The system operates like a merry-go-round. Brushing heads are positioned around the table to interface with specific surfaces of the part. The number of heads, or stations, is dictated by the number of surfaces on the part to be deburred. Generally each station is dedicated to one specific edge plane on the part.

Since unidirectional rotating radial wheels are used, it is necessary to rotate the part while brushing. As the table indexes to present the part to the brushing station, the spindles rotate the part. At each station, the parts dwell under the brushing head for a prescribed length of time or number of rotations. The table then indexes, moving the part to the subsequent station for further deburring, part turnover or loading/unloading.

These systems can be either run "wet" with coolant, or dry. The effect of coolant on the brushing action reduces the potential for nylon smear. It also acts as a lubricant, reducing the cutting action of the abrasive. Systems tend to be designed according to the preference of the customer. They are successfully applied either wet or dry.

Rotary tables can be designed as manual, semiautomatic, or fully automatic deburring systems.

A. Manual - Manual rotary tables require an operator to load a part onto the spindle fixture and activate the indexing sequence. He may also be responsible for turning the part over and unloading, and monitoring and adjusting the heads to compensate for brush wear.

B. Semiautomatic - This system may still require an operator, however, tasks such as part turnover and brush wear compensation may be handled automatically. The operator may be limited to loading/unloading and monitoring the overall system.

C. Automatic - Automatic systems are typically incorporated into a production process, accepting parts conveyed from a prior process. Robotics and/or pick and place mechanisms are used to load the part, turn the part over, and unload the part onto an exiting conveyor. Brush wear compensation is done automatically.

A typical rotary table system is shown in Figures 6 & 7.

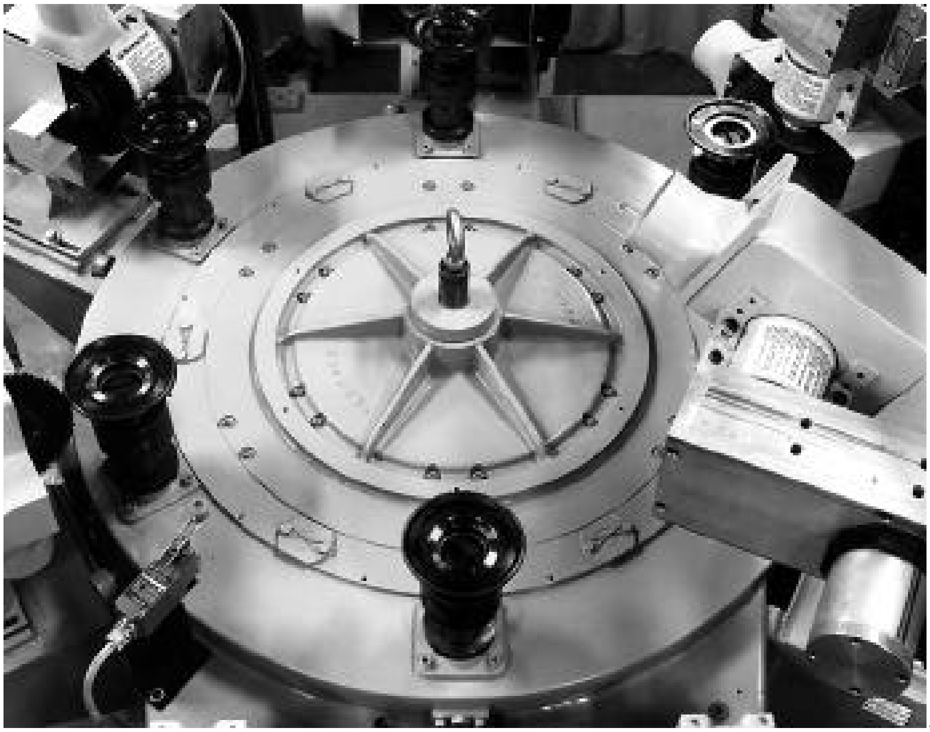

Figure 6: Rotary table deburring system

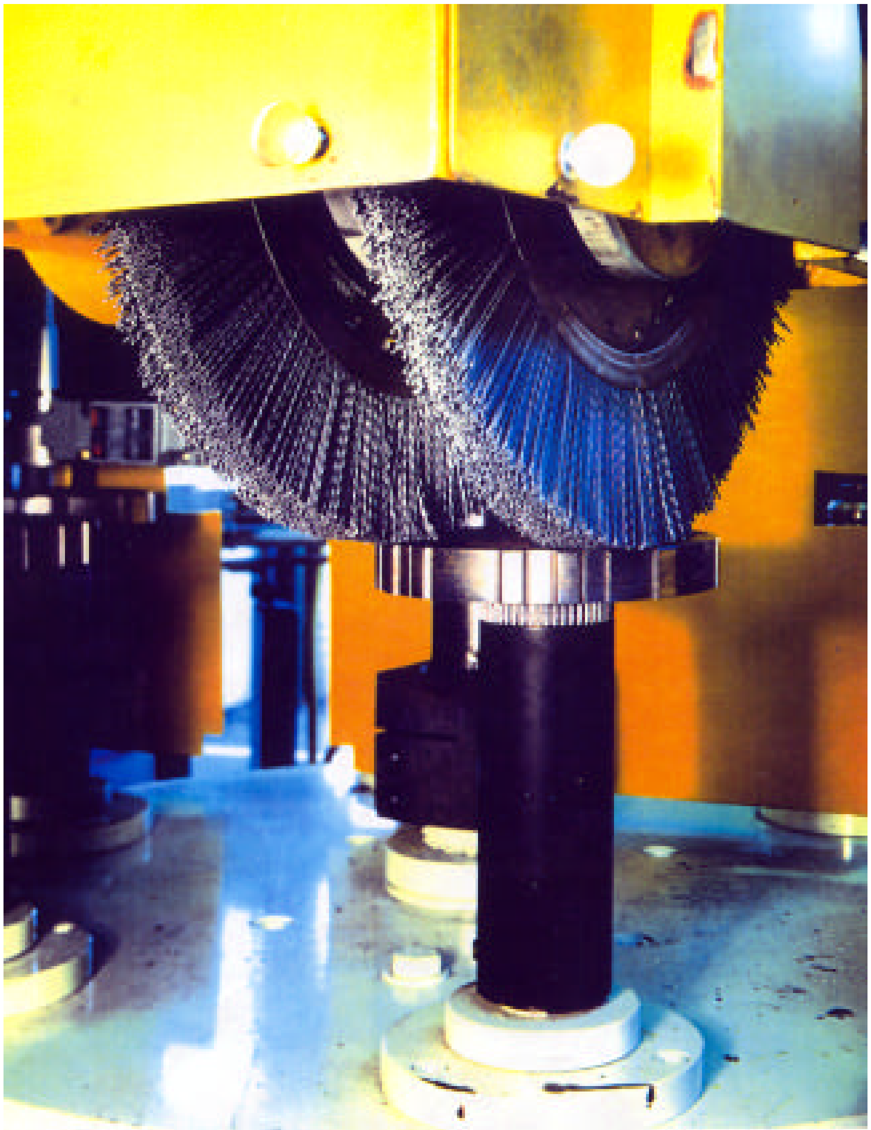

Figure 7: Close-up view of rotary table station

2. Disc Brush Systems

Disc brushing systems tend to be the most versatile and productive. By taking advantage of the multidirectional brushing action of the disc, it is not necessary to rotate the part during brushing. Part transfer is usually accomplished by means of a magnetic conveyor system. This elimination of tooling for part fixturing expands the use of the system to handle a variety of part shapes and sizes with minimal set up between part changes.

Disc brushing systems are designed to present each side of the part to a minimum of two brushing heads. In passing a part slightly off of the centerline of the disc brush, the part receives brush work on 270 degrees of its surface. Subjecting it to a second disc, rotating counter to the first, will deburr the balance of the surface. A third brush can be employed to ensure complete and thorough deburring.

An alternative method can be employed which involves several brushes on a single head which operates in a planetary motion. Each brush rotates independently while the entire head revolves. This provides random brushing action and subjects all surfaces of the part to fiber contact.

Disc brushing systems lend themselves to full automation. Typically, parts are conveyed to an accumulator which then drops them onto the magnetic conveyor of the deburring system. Parts are conveyed under the disc brushing heads, flipped over, then under another set of disc brushing heads. As the parts exit the system, they are demagnetized and conveyed onto the next process. These systems typically include automatic brush wear compensation and are fully programmable for automated set up according to part numbers. They can be designed to run wet or dry, with the same effect on brushing as the rotary table systems. Typical disc brush systems are illustrated in Figures 8 and 9.

Figure 8: Automated disc brush deburring system

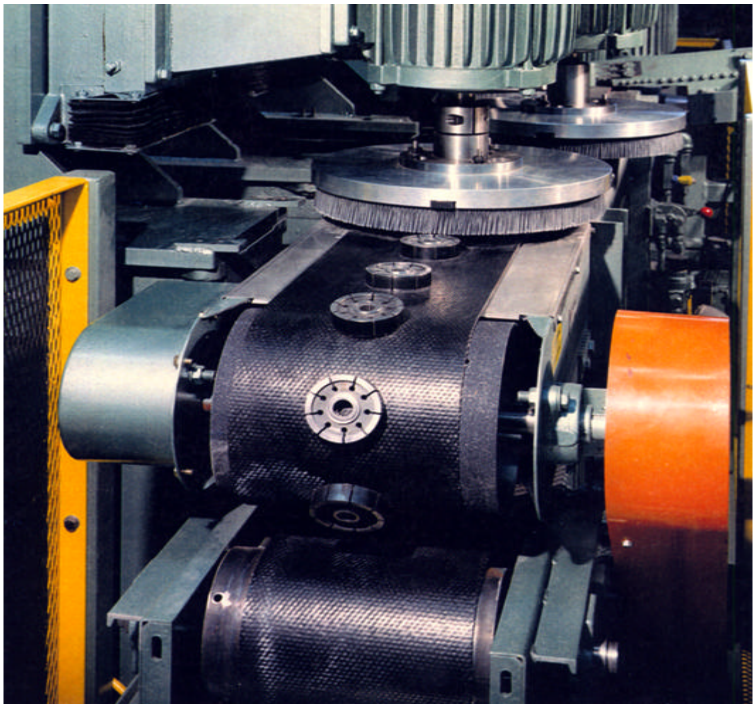

Figure 9: Close-up of disc brush deburring system

QUALITY, PRODUCTIVITY, ECONOMICS

Quality

Brush deburring of PM parts offers the advantage of only abrading the intended surface of the part. Unlike vibratory systems where the entire part is abraded, abrasive action can be concentrated on a specific surface. The light material removal feature of the fiber abrasive means that sharp edges are radiused with negligible impact on overall part size. The degree of edge radius can be controlled by brush variables (filament dia./grit size, trim length, density), and/or system set-up (dwell time under brush, brush speed). With the proper brush and system, a consistent edge break on all intended surfaces will be attained. This can be maintained over the life of the brush.

Another quality consideration is surface finish. Again, brush and machine variables will dictate surface finish. Generally, the right combination will achieve the desired edge break and maintain or improve surface finish.

Productivity

Productivity is largely dependent on machine design and level of automation. Rotary tables can range from 150 parts deburred per hour to 600 parts deburred per hour for fully automated systems. Fully automated disc brush machines attain deburring rates up to 2000 parts per hour.

Economics

For the purposes of this presentation, cost per part is evaluated strictly from the standpoint of brush consumption. Brush life is affected by many variables. Severity of burr, degree of edge radius desired, and brush characteristics play a large role in determining brush life. Contributing equally, if not more, is the design and operation of the deburring system. All of these variables have the potential to significantly affect brush longevity, either positively or negatively.

With this in mind, we have attempted to offer an “average” cost for brushes consumed per part deburred. This cost is based on a disc brush system deburring 2000 parts per hour (4000 sides). The average cost is $.02 per part, or $.01 per side.

CONCLUSION

Fiber abrasives are an effective and viable media for deburring PM parts. When formatted into radial wheel and disc brushing tools, they can be applied on a machine based system. These systems are designed to present the part to the brush(es) in a controlled and precise manner. Fiber abrasive brushes, on a machine based deburring system, provide a productive, high quality and cost effective means for deburring PM parts.

References:

(1.) Watts, J.H., “Abrasive Monofilaments - Factors that Affect Brush Tool Performance”, SME Deburring and Surface Conditioning Conference, MR89-112, San Diego, CA, February 13-16, 1989